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DETERMINATION OF THE MALTING AND MILLING PERFORMANCE OF SORGHUM CULTIVARS

BY

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KEYWORDS

Sorghum, malting, physical properties, tangential abrasive dehulling device, roller milling, diastatic power, germination, abrasion/ dehulling, break mills, milling losses, viscosity.

LIST OF ABBREVIATIONS

ML	-	Malting loss
WA	-	Water absorption
FAN	-	Free amino nitrogen
DP	-	Diastatic power
GV	-	Germinative vigour
GE	-	Germinative energy
SF	-	Sieve fractions
SFS	-	Sieve fraction small
SFM	-	Sieve fraction medium
SFL	-	Sieve fraction large
MF	-	Meal fractions
MFS	-	Meal fraction small
MFM	-	Meal fraction medium
MFL	-	Meal fraction large
HKW	-	Hundred-kernel weight
MC	-	Moisture content
TADD	-	Tangential Abrasive Dehulling Device
B1B	-	Break 1 bran
B1M	-	Break 1 meal
B2B	-	Break 2 bran
B2M	-	Break 2 meal
B2G	-	Break 2 grits
TL	-	Total loss
S1	-	Sieve 1
S2	-	Sieve 2
TH	-	Through
HE	-	Hard endosperm
SE	-	Soft endosperm
AHI	-	Abrasive hardness index
DI	-	Dehulling index
CVA	-	Canonical variate analysis
CV	-	Canonical variate

ANOVA	-	Analysis of variance
CP	-	Centipose
Green	-	Greenlands
Potch	-	Potchefstroom Dryland
Plat	-	Platrand

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CHAPTER 1

LITERATURE REVIEW

1.1 INTRODUCTION

Sorghum is produced on a large scale in many parts of the world (Maestri *et al.*, 1996; Munck, *et al.*, 1982). India and Africa are especially important in sorghum cultivation for human consumption (Wankhede *et al.*, 1989), as sorghum is an important source of protein and calories for a large segment of the human population (Maestri *et al.*, 1996). Sorghum crops are mainly grown in the semi-arid tropical regions of the world (Zipf *et al.*, 1950; Dixon Philips *et al.*, 1989; Maestri *et al.*, 1996;) and are able to withstand conditions that cause other crops to fail (Zipf *et al.*, 1950).

Grain sorghum is often considered to be of inferior quality for food, feed and industrial utilization when compared to maize (Subrahmanyam & Hoseney, 1995), when in fact sorghum and maize have similar compositions, kernel structures, starch properties and methods of starch isolation (Yang & Seib, 1996). This incorrect perception about sorghum caused it to be used mainly as feed, even in countries that used it as food since the earliest days (Munck *et al.*, 1982). However, the quality of the same sorghum cultivar is highly variable with locality (Pretorius *et al.*, 1996) and season (Pretorius *et al.*, 1996; Shepherd, 1982), but also in terms of colour, size and defects, sorghum is of a less consistent quality than maize (Yang & Seib, 1996). This drawback makes the selection of sorghum cultivars in terms of quality characteristics, much more difficult than with some other grains. Table 1.1 indicate the rainfall conditions and soil type found at the different localities and seasons applicable in the present study. Pretorius (2001) observed that drier conditions improve malting performances of sorghum cultivars, as these cultivars are generally softer. High rainfall conditions will improve the milling performances of sorghum cultivars, as more hard endosperm will be produces under ideal conditions. Regarding physical properties, high rainfall conditions will decrease water absorption levels and increase the moisture content of sorghum cultivars. This data should be considered throughout the current study when environmental data are interpreted. Despite this negativity about sorghum utilization as a food, sorghum will remain the most productive crop in rainfed lands, e.g. India, where it has been cultivated for many years (Wankhede *et al.*, 1989).

TABLE 1.1

THE MONTHLY RAINFALL AND SOIL TYPES FOUND AT ENVIRONMENTS THAT COULD INFLUENCE THE QUALITY PROPERTIES OF SORGHUM CULTIVARS

LOCALITY	SEASON	SOIL TYPE	MONTHLY RAINFALL												
			TOTAL	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEBR	MARCH	APR	MAY	JUNE
Potchefstroom	1997/98	Hutton	499	2	11	44	22	86	53	75	136	59	13	0	0
	1998/99	Hutton	469	0	0	7	40	122	161	20	47	21	27	24	0
Greenlands	1997/98	Arcadia	510	12	5	10	27	76	63	83	107	121	0	6	0
	1998/99	Arcadia	158	0	0	5	69	0	0	0	0	53	12	19	0
Dover	1997/98	Clovelly	158	0	0	5	69	0	0	0	0	53	12	19	0
Plantrand	1998/99	Unknown	592	0	0	33	71	125	117	92	74	47	7	21	4

Many African and Asian people utilize sorghum as a staple food (Akingbala *et al.*, 1988; Singh & Singh, 1991) in the form of porridges (Akingbala *et al.*, 1988; Desikachar, 1982; Pushpamma & Vogel, 1982). These porridges can be classified according to the fineness of the meal, preparation method or the type of fermentation (Novellie, 1982). The two major groups of porridges manufactured from sorghum in India and Africa (Akingbala *et al.*, 1988), are *ogi* (Akingbala *et al.*, 1982; Akingbala *et al.*, 1988; Pushpamma & Vogel, 1982) and *tô* (Akingbala *et al.*, 1982; Akingbala al., 1988), the first being a thin fermented porridge and the latter a thick porridge (Akingbala *et al.*, 1988). Although the use of sorghum porridge as a staple food has declined, sour fermented sorghum porridges remain popular among the Tswana people of Botswana (Novellie, 1982; Sooliman, 1993). The most common use of sorghum in the food industry has been in the malted form for centuries (Beta *et al.*, 1995). Sorghum malt is used for the production of baby food and alcoholic and non-alcoholic beverages (Beta *et al.*, 1995), with sorghum beer (Pushpamma & Vogel, 1982) being a quite common product in African countries. These are the two most well known uses of sorghum in the food industry.

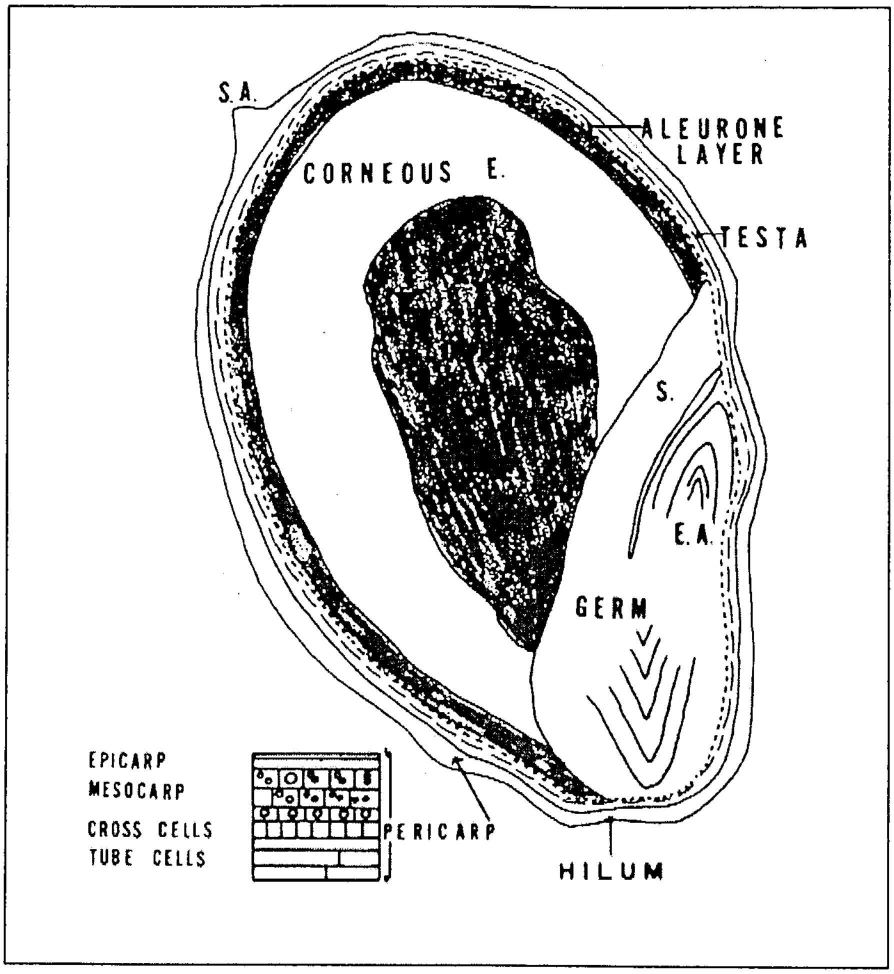
The role of sorghum as a food stretches beyond the limits of the porridge and malting industry. Sorghum-flour is cheaper than wheat flour (Torres *et al.*, 1994) and could be used in *tortilla* production (Akingbala *et al.*, 1982; Akingbala *et al.*, 1988; Torres *et al.*, 1994), which is of Latin American origin (Akingbala *et al.*, 1988), as an extender (Torres *et al.*, 1994) or replacement (Akingbala *et al.*, 1982; Akingbala *et al.*, 1988) of maize. Some snack foods like pancakes (Desikachar, 1982) and a ready-to-eat product such as *fura* (Pushpamma & Vogel, 1982) are made from sorghum. These products have to be manufactured from sorghum flour or grits, as sorghum is less successfully cooked as a whole grain than rice (Desikachar, 1982). The determination of milling quality is therefore important in determining product quality (De Francisco *et al.*, 1982). Sorghum also shows great potential for the manufacturing of starch on an industrial scale (Buffo *et al.*, 1998; Munck *et al.*, 1982; Subramanian *et al.*, 1994; Watson & Hirata, 1955) and since sorghum is generally cheaper than most other grains, developments in this regard could be expected in the near future.

Sorghum food products have an important role to play in some countries, but unfortunately sorghum is often seen as a food for the poor (Novellie, 1982; Sooliman, 1993; Wankhede *et al.*, 1989) by the urban elite. The tendency amongst these people is towards more refined food, with less fibre and coarseness in the product than sorghum products (Novellie, 1982). To assure a growing market for sorghum products, suppliers should be able to market these products according to their quality and unique attributes, instead of selling it as a price-sensitive substitute for maize products. This will require a thorough knowledge of the market at which the product is aimed, as well as of the desired product for the specific market (Sooliman, 1993). These factors gave rise to the idea that the milling characteristics of grain are important in determining milling quality (De Francisco *et al.*, 1982), but unfortunately the influence of sorghum grain quality on end product quality is relatively unknown (Cagampang & Kirleis, 1984). Another problem with sorghum in the food industry is the insufficient development in the milling technology to produce acceptable light-coloured flour (Munck *et al.*, 1982). Therefore the need exists for a thorough knowledge of both the malting and milling quality characteristics of sorghum, to assure that a product of acceptable quality is supplied to a specific market.

1.2 SORGHUM KERNEL STRUCTURE

The sorghum kernel consists mainly of four parts, namely the endosperm, germ, testa and pericarp (Dewar *et al.*, 1993) as is shown in Fig. 1.1. The germ tissue is attached to the endosperm by a thin layer, the so-called "cementing layer" (Hahn, 1969). Bran is the industrial term for the outer layers of sorghum, e.g. the pericarp, seed coat, etc. However, the terms are not easily definable regarding structural components, as each miller includes different structural components under his definition of the bran (Hahn, 1969). This relatively simple physical structure of the kernel is an important determinant in the efficiency of milling, i.e. flour yield, colour, chemical composition and acceptability (Munck *et al.*, 1982). Processing quality criteria of sorghum grain, namely ease of dehulling and grain hardness (Reichert *et al.*, 1982), are influenced by kernel structure, which are again influenced by cultivar and locality (Dewar *et al.*, 1993).

Two grain properties that play an important role in the determination of product quality are endosperm texture and endosperm type (Pushpamma & Vogel, 1982). Endosperm type refers to either a horny or floury endosperm (Dewar *et al.*, 1993), while endosperm texture is the proportion of horny (hard) to floury (soft) endosperm (Cagampang & Kirleis, 1984). Maxson *et al.* (1971) found endosperm texture to be highly correlated with milling performance. A strong positive correlation between endosperm texture and milling yield is known, as well as a strong negative correlation between endosperm texture and hardness, test weight and density (Maxson *et al.*, 1971). Grit yields from soft endosperm samples during grit-milling are low, indicating poor milling performance by floury endosperm varieties. This is due to the disintegration of soft kernels during abrasive milling action. For the same reason grain of intermediate endosperm texture shows variable milling yields (Maxson *et al.*, 1971).



SA=STYLAR AREA

E=ENDOSPERM

S=SCUTELLUM

E.A.=EMBRYONIC AXIS

FIG. 1.1

THE MORPHOLOGY OF A SORGHUM KERNEL (HOSENEY, 1994).

The sorghum endosperm's main constituent is starch (Cagampang *et al.*, 1985), indicating that the endosperm texture of sorghum is also related to the starch content of the kernel. The starch content of flour can be increased, due to an increase in floury endosperm by sifting; the protein content is decreased (Novellie, 1982). Starch properties have a major influence on the textural properties of cooked sorghum products, because of the presence of the starch containing endosperm in all products (Cagampang *et al.*, 1985).

Polyphenols (as condensed tannins) are present in the pericarp and/or testa of some varieties, with some detrimental nutritional effects on the product (Deshpande *et al.*, 1982b). The presence of tannins in sorghum also has an influence on the milling quality of the product. Bird-resistant (pigmented) breeding samples contain more pericarp and less endosperm than unpigmented samples, because the pigment containing testa is included in the pericarp fraction (Jambunathan & Mertz, 1973). This is the reason for white or light coloured sorghum varieties producing high flour yields, with a light colour and bland flavour (Torres *et al.*, 1994). Breeders should therefore pay attention to aspects such as the amount of soft endosperm and genetically controlled pigment production, in their genetic selection programs for sorghum of high milling and malting quality (Munck *et al.*, 1982).

1.3 CHEMICAL PROPERTIES

1.3.1 LIPID CONTENT

Lipids, which are a minor component in cereal grains, are mostly situated in the germ of sorghum. Thus, by means of decortication or degermination, a large part of the lipid fraction of sorghum is easily removed. The whole grain consists of three types of lipids. The most abundant group, the nonpolar lipids, consists mainly of triglycerides, which serve as reserve nutrients during germination. The other two smaller groups, i.e. the polar (e.g. phospholipids, glycolipids) and unsaponifiable lipids (e.g. phytosterols, carotenoids and tocopherols) have other important biochemical functions to fulfill (Serna-Saldivar & Rooney, 1995).

TABLE 1.2

THE FATTY ACID COMPOSITION OF SORGHUM COMPARED TO OTHER TYPES OF GRAIN (MORRISON, 1978)

CEREAL	FATTY ACID				
	C16:0	C18:0	C18:1	C18:2	C18:3
Maize	13	<4	35	50	<3
Sorghum	12	1	35	49	3
Pearl millet	20	5	25	48	3
Rice	22	<3	39	36	4
Oats	20	2	37	37	4
Rye	18	1	25	46	4
Barley	22	<2	12	57	5
Wheat	21	2	15	58	4

Table 1.2 gives an indication of the fatty acid composition of different types of grain. The fatty acid composition of sorghum is similar to that of maize and pearl millet, which contain higher levels of C18:1 fatty acids than for e.g. barley and wheat. (Hoseney, 1994). The rapid deterioration of the quality of pearl millet after milling can be attributed to the lipid components, but the problem cannot be accounted to classic oxidative rancidity and the mechanism of the deterioration is unknown (Hoseney, 1994). Although the fatty acid profile of sorghum (Table 1.2) indicates an even greater unsaturation than with pearl millet, the problem is apparently not significant in sorghum, since it is not mentioned in the literature.

The lipid content of sorghum ranges from 2.1 to 5.0 % (Hoseney, 1994). Different sorghum cultivars show some variation, but these variations are not as extreme as in the case of other chemical and physical properties of sorghum. A commercial red sorghum with a yellow endosperm was shown to have an ether extract of 3.0 % (McDonough *et al.*, 1998), while the Dekalb hybrid had a crude free fat content of 4.4 % (Buffo *et al.*, 1997). Beta *et al.* (1995) found that 16 different sorghum cultivars had an average fat content of 3.7± 0.6 %, while Yang & Seib (1995) found a lipid content range of 3.2 to 4.1 % for 9 sorghum samples. The latter is very close to the crude free fat range of 3.44 to 4.90 % that Buffo *et al.* (1998) found amongst 24 sorghum hybrids.

Milling plays an important role in the final lipid content of sorghum meal, because of the great part of the lipid fraction situated in the sorghum germ. Lipid content could also be used a means of quality control of meal, to indicate whether proper separation of kernel parts took place during milling. During a grit milling procedure, it was found that corneous (horney) endosperm sorghum varieties were of superb milling quality for grit milling, as the low fat content indicated proper separation of kernel components (Maxson *et al.*, 1971). This is proven by the significant negative correlation that exists between Vickers' hardness and fat content, as this relationship indicates that the harder a seed, the greater the precision separation of botanical parts of the seed during milling (Munck *et al.*, 1982).

1.3.2 ASH CONTENT

Sorghum is a rich source of minerals, as the pericarp, aleurone and germ have a high ash content. Sorghum foods that are more refined may develop low levels of some of these minerals as a consequence of the dehulling process. While sorghum is deficient in calcium, it contains phosphorus in great amounts. The availability of phosphorus as a nutrient is dependent on the amount bound by phytates (Serna-Saldivar & Rooney, 1995). A typical value for the ash content of sorghum is 1.1 % (Buffo *et al.*, 1997).

As a large proportion of the mineral content of sorghum is concentrated in the bran component, the ash content of milled sorghum products could also be indicative of the efficiency of the milling procedure in the separation of different kernel parts. During grit milling it was concluded that floury endosperm sorghum varieties are of inferior grit-milling quality, due to the high ash content of end products. When these soft varieties are milled, the kernel disintegrates, with the consequent insufficient separation of the endosperm and pericarp. The grits were found to have high bran content as indicated by the high ash content (Maxson *et al.*, 1971). The relationship between kernel hardness and ash content of the sorghum end product was proved by the significant negative correlation that exists between Vickers' hardness and the ash content of the dehulled products. This is an indication of the less precise separation of kernel morphological parts when the kernel is soft (Munck *et al.*, 1982).

1.3.3 CARBOHYDRATE CONTENT

The quality and quantity of carbohydrates present in sorghum are important quality characteristics of sorghum and could influence consumer acceptance of the end product (Pushpamma & Vogel, 1982). Starch is the most abundant carbohydrate in sorghum, while sugars and fibre exist in minor quantities (Serna-Saldivar & Rooney, 1995). Sugars, starch and fibre are discussed below, but for the purpose of this study only starch will be examined in more detail.

1.3.3.1 SUGAR CONTENT

Sugars are found in low quantities in sorghum (Serna-Saldivar & Rooney, 1995), but are of great importance during the yeast fermentation process of sorghum malt (Subramanian *et al.*, 1992). Subramanian *et al.* (1992) determined the total soluble sugar content of nine ungerminated sorghum cultivars. It varied between 29.6 to 78.1 mg per 100 grains, while Hoseney (1994) stated that the sugar content of sorghum varied between 1 and 6 %. The latter value is only found in cultivars especially grown for high sugar content and the sugars are mainly composed of sucrose, while the trisaccharide raffinose and tetrasaccharide stachyose are found in smaller amounts (Hoseney, 1994). The sugar content were found to increase after germination of 96 h (Subramanian *et al.*, 1992), as alpha- and beta-amylase activity increased, with the consequent formation of fermentable sugars (Taylor & Dewar, 1996).

1.3.3.2 STARCH CONTENT

Starch, the major carbohydrate in sorghum (Serna-Saldivar & Rooney, 1995), is mainly found in the endosperm of the kernel (Cagampang *et al.*, 1985) as mentioned before. This leads to the major role that starch properties play in the textural properties of cooked sorghum products (Cagampang *et al.*, 1985), as well as the provision of fermentable sugars for beer brewing during malting (Taylor & Dewar, 1996). Sorghum starches have off-colours that are dependent on the pericarp colour and the presence of a black pigment in the glumes or other portions of the plant. Those containing black pigments have pinkish colours and those lacking this pigment have yellowish off-colours, while colour intensity was influenced by the pericarp colour (Watson & Hirata, 1955). The reason for these off-colours is the leaching of pigments from the pericarp into the starch when sorghum grain is moistened (Subramanian *et al.*, 1994).

The starch content of different sorghum cultivars shows wide variation. Buffo *et al.* (1997) found a starch content of 72.1 % in the Dekalb hybrid, while Wankhede *et al.* (1989) found the CSH-1 hybrid to contain 64.5 % starch. The first-mentioned falls within the range of 69.11 to 76.48 % for the 24 sorghum hybrids used by Buffo *et al.* (1998).

Starch consists of amylose and amylopectin held together by hydrogen bonds in a highly orderly fashion (Serna-Saldivar & Rooney, 1995). The amylose component plays a significant role in the rheological and shelf life properties of sorghum foods such as porridge and *tortillas* (Ring *et al.*, 1982) and is significantly correlated to the vitreousness of sorghum (Cagampang & Kirleis, 1984).

Starch can be classified as waxy or non-waxy according to the amylose content. Waxy starch varieties contains nearly no amylose, while non-waxy varieties were found to contain amylose levels of up to 24 % (Ring *et al.*, 1982). A third group, the heterowaxy type, has a lower amylose content than non-waxy starches. The waxiness of sorghum starch influences its rheological properties. Gelatinization temperatures of non-waxy, heterowaxy and waxy sorghum varieties were found to increase with an increase in the number of waxy alleles (*wx*), with consequent higher gelatinization temperatures in starches containing less than 20 % amylose (Akingbala *et al.*, 1988). Despite lower gelatinization temperatures (Akingbala *et al.*, 1988), non-waxy sorghum varieties take longer to reach their maximum viscosities than the waxy ones, because amylose restricts its swelling (Cruzy Celis *et al.*, 1996). This is in agreement with the negative correlation that Akingbala *et al.* (1982) found between the amylose content and swelling power and the amylose content and solubility of starch. Starch swelling power and solubility is highly correlated (Akingbala *et al.*, 1982) and gelatinization is thus restricted by amylose's restriction against swelling and solubilization (Cruzy Celis *et al.*, 1996). Amylose is able to reorient itself during the cooling of sorghum pastes (setback) and causes a higher end-viscosity in non-waxy cultivars (Cruzy Celis *et al.*, 1996).

The starch content and composition of sorghum are influenced by several factors. Firstly the type of endosperm from which starch was extracted plays a significant role. Starch from the corneous endosperm of sorghum, exhibits a lower amylose content and higher gelatinization temperature, as well as a higher intrinsic viscosity than that from the floury endosperm (Campangang *et al.*, 1985). Environmental and genetic factors determine amylose levels in sorghum (Ring *et al.*, 1982), as was demonstrated with sorghum grown under supplementary irrigation and rainfed conditions. The starch of irrigated sorghum was shown to have significantly higher amylose contents than the rainfed ones (Taylor *et al.*, 1997). Environmental effects may affect the amylose content of starch more than genetic differences in the case of nonwaxy varieties (Ring *et al.*, 1982).

1.3.3.3 DIETARY FIBRE CONTENT

Cereals are an important source of fibre, which consist of cellulose, hemicellulose, lignin, pectin and gums. Fibre is indigestible by the monogastric stomach and upper gastrointestinal tract and is defined as soluble or insoluble. As fibre is mainly found in the pericarp and endosperm walls, its levels in the milled product are determined by the extent of milling (Serna-Saldivar & Rooney, 1995). The crude free fibre content of a Dekalb hybrid was 4.4 % (Buffo *et al.*, 1997).

The fibre content is one of the chemical characteristics of sorghum known to be of importance in sorghum product quality determination, as it is important for consumer acceptability of the product (Pushpamma & Vogel, 1982). Most of the fibre content of sorghum is insoluble, thus reducing transit time in the gastrointestinal tract and preventing gastrointestinal problems. Soluble fibre reduces blood cholesterol levels and arteriosclerosis. Unfortunately the soluble fibre content in sorghum grain compared to a cereal such as oats, is low (Serna-Saldivar & Rooney, 1995).

The cell walls of sorghum appear to be much thinner than that of wheat and rye. In the case of wheat flour in a slurry of water, the addition of an oxidizing agent can increase the viscosity of the slurry. The sorghum cell wall is constituted by less hydrophilic hemicellulose which does not participate in the formation of viscous, slimy mixtures as in the case of wheat and rye. Instead, the hemicellulose is composed of complicated mixtures of constituent sugars, namely arabinose xylose, and glucose (Hoseney, 1994). This could be of importance when the viscosity (1.8.2.2) of sorghum porridges is considered, as hemicellulose cannot contribute to an increase in viscosity in sorghum.

1.3.4 PROTEIN CONTENT

The protein content of sorghum is an important quality-attribute in terms of consumer acceptability (Pushpamma & Vogel, 1982), nutrition (Serna-Saldivar & Rooney, 1995) and malting (Taylor, 1998a). The protein content and composition of cereals vary according to genotype, water availability, soil fertility, temperatures and environmental conditions. The major group is the prolamins, which are mainly found in the protein bodies and protein matrix in the starch endosperm (Serna-Saldivar & Rooney, 1995).

From a nutritional view, sorghum is mainly utilized in developing countries where cereals are a staple food. This might cause nutritional problems, since sorghum and most other grains, when compared to the albumin, glutelin and globulin proteins, are deficient in essential amino acids, especially lysine. The breeding of high lysine sorghum varieties involves an increase in the levels of these three proteins, causing these varieties to contain approximately 50 % more lysine and better amino acid profiles than regular varieties (Serna-Saldivar & Rooney, 1995). From a milling quality perspective, a negative correlation between water-soluble proteins and hardness was found, while a positive one between kafirin proteins prolamins and vitreousness was identified (Cagampang & Kirleis, 1984).

Buffo *et al.* (1997) found a Dekalb hybrid to have a protein content of 9%, commercial red sorghum with a yellow endosperm contained 11.2 % protein (McDonough *et al.*, 1998) and 9 other sorghum samples also had protein contents of between 9 and 11 % (Yang & Seib, 1996). Therefore it seems as if the protein content of sorghum is generally between 9 and 11 %, but in contrast to this Beta *et al.* (1995) found the mean protein content of 16 sorghum cultivars to be 13.1±1.09 %. The protein content of sorghum declined during malting after 96 to 144 h of germination due to enzymatic activity (Subramanian *et al.*, 1992), as will be explained in 1.3.6.2. The cooking process of sorghum-flour could also decrease the protein content. Raw sorghum flour were founds to contain 10.4 % protein, while boiled and roasted flour to contain 9.2 and 9.5 % protein respectively (Singh & Singh, 1991).

1.3.5 TANNIN CONTENT

Birdproof (bird-resistant) sorghum varieties are those with a pigmented testa that produce condensed tannins from phenols (Serna-Saldivar & Rooney, 1995). These polyphenols (condensed tannins) are mainly situated in the pericarp and/or testa of pigmented sorghum varieties (Deshpande *et al.*, 1982b).

On the negative side tannins are anti-nutritional factors, as they bind proteins with consequent precipitation, which causes a lower nutritional value. Tannins also cause astringent tastes (Beta, 1998). The second problem lies in the colour acceptance of sorghum products. As mentioned earlier, the consumer discriminates against dark coloured sorghum products. White sorghum produces the most acceptable products to consumers in terms of colour (Serna-Saldivar & Rooney, 1995), which is a further problem with birdproof varieties. Another disadvantage of condensed tannins is the fact that they inactivate malt enzymes during brewing, if they are not inactivated before malting. One way of inactivation is by treatment with a very diluted formaldehyde solution during the steeping process (Taylor, 1998a).

Tannins offer advantages of supplying birdproof sorghum varieties with bird and mould-resistance. In Botswana and Zimbabwe high tannin sorghum varieties are used, because they provide sorghum with mould-resistance at malting temperatures of 25 to 30 °C and relative humidities of 95 to 100 % (Beta, 1998). The tannin content of sorghum might be reduced, although not totally eliminated, by dehulling the grains. This concept was found to be successful in beans (Deshpande *et al.*, 1982b).

According to their tannin content, sorghum is classified in South Africa as GM (malting class, no tannins present, high diastatic power), GL (feed class, no tannins present, low diastatic power) and GH (malting class, tannins present) (Beta, 1998). This classification is only valid for the malting industry and does not indicate the importance of tannins in the milling industry.

1.3.6 ENZYMES

1.3.6.1 AMYLASES

1.3.6.1.1 α-AMYLASE

α-Amylase in sorghum is secreted in the scutellum (Serna-Saldivar & Rooney, 1995). This endo-enzyme is responsible for the random breakage of α–1,4 glucosidic bonds. A reduction in the size of large starch molecules results (Hoseney, 1994) as starch is hydrolysed into short chains of glucose (Hardie *et al.*, 1976). For this reason, the action of the enzyme in a starch paste, leads to the rapid decrease in viscosity (Hoseney, 1994).

Levels of α-amylase are low in sound, intact grain, but increase several-fold during germination of the grain (Hoseney, 1994). This increase in enzyme activity through the process of malting is discussed in 1.9.2.

1.3.6.1.2 β -AMYLASE

β-Amylase is an exo-enzyme that attacks starch from the non-reducing ends, by breaking every second α-1,4 glucosidic bond. The end product of this enzyme's activity is maltose, but the "maltose value" previously used for an indication of β-amylase-activity is actually an indication of the combined action of α-and β-amylase (Hoseney, 1994).

β-Amylase is found at much higher levels in sound, intact grain than α-amylase and germination does not result in severe level increases as found in the case of α-amylase (Hoseney, 1994). Measurement of α– and β-amylase in sorghum are more difficult than in other grains, because of the insolubility of many of the enzymes (Hoseney, 1994). As condensed tannins tend to bind and precipitate proteins (Beta, 1998), the tannins in sorghum may contribute to the insolubility of the enzymes. Despite lower levels of amylase produced in sorghum, the purified amylase displayed similar activity levels than those in other grains (Hoseney, 1994). The increase in β-amylase activity due to germination is discussed in 1. 9.2.

1.3.6.2 PROTEASES

Proteases in sorghum grain are mainly found in the endosperm (Serna-Saldivar & Rooney, 1995) and consist of peptidases and proteinases. These enzymes are found in mature, sound cereals, but are of low activity (Hoseney, 1994). During malting and brewing these enzymes work together to hydrolyse protein into peptides and amino acids (Taylor, 1998a) as discussed in 1.9.3.

1.3.6.3 LIPASES

Lipase is an enzyme that hydrolyses triglycerides into fatty acids and its activity is present in all cereals at varying levels. The importance of lipase activity in grains lies in its formation of free fatty acids, which are more susceptible to oxidative rancidity (Hoseney, 1994).

The lipid content of sorghum was proven to decrease during malting, indicating lipase activity (Aucamp *et al.*, 1961). Taylor (1998a) also stated that lipase was present in sorghum malt, but of minor importance in beer brewing when compared to amylases and proteases.

1.3.6.4 OTHER ENZYMES

Lipoxygenase is the enzymes present in cereals which catalyses the peroxidation of polyunsaturated fats by oxygen. This enzyme is important in wheat (Hoseney, 1994) with high levels of C18:2 and C18:3 polyunsaturated fatty acids (Table 1.1). Although lipoxygenase is present in sorghum malt, its role in beer brewing is minor (Taylor, 1998a) as sorghum has lower levels of polyunsaturated fatty acids and higher levels of mono-unsaturated fatty acids (Table 1.1). Fibre degrading enzymes, namely beta-glucanases and pentosanases, present in sorghum malt, are also less important in beer brewing than amylases and proteases (Taylor, 1998a). Their minor role may be attributed to the difference in the composition of the hemicellulose present in sorghum, when compared to other grains (1.3.3.3).

1.4 MALT AND MALTING

Malting is the well-known process during which grains are germinated under controlled conditions of temperature and high relative humidity. During the process endogenous amylase enzymes are mobilized, which in turn hydrolyze starch into fermentable sugars (Beta *et al.*, 1995; Taylor & Dewar, 1996). The presence of fermentable sugars in malt is important for yeast utilization during brewing (Subramanian *et al.*, 1992). Alpha-amylase in malt hydrolyses glucosidic bonds randomly, while beta-amylase hydrolyses penultimate glucosidic bonds at the non-reducing end of starch. The end products of alpha-amylase action are therefore a wide range of dextrins and fermentable sugars, while that of beta-amylase is the fermentable sugar maltose (Hardie *et al.*, 1976). On commercial scale the pneumatic and floor-malting processes are commonly used in Southern Africa, but pneumatic malting offers the advantages of better control over malting conditions, i.e. time, temperature and humidity, as well as better quality malt in terms of uniformity (Beta *et al.*, 1995).

1.4.1 STEEPING AND GERMINATION

The malting process is initiated with a soaking process of the sorghum grain for 24 hours. This is called the steeping process and is followed by the actual germination process (Taylor & Dewar, 1996). An increase in steeping temperature and time, improves the quality of malt, with an optimum steeping temperature between 25 to 30 °C (Dewar *et al.*, 1997). Another indication of good malting is the amount of steep-out moisture (Taylor & Dewar, 1996; Dewar *et al.*, 1997). An increase in this leads to good quality malt (Dewar *et al.*, 1997).

Germination is the 5- to 6- day process following steeping (Taylor & Dewar, 1996), which leads to the modification of chemical compounds in grain, causing qualitative and quantitative changes (Subramanian *et al.*, 1992). The protein content of sorghum decreases during malting (Subramanian *et al.*, 1992), but of even greater importance are the changes in the starch fraction. The amylase enzyme produced during germination, increases in activity as the germination process proceeds, and acts on starch. Therefore a great amount of the starch present is converted to maltose and other sugars, but part of the starch content remains unaltered (Subramanian *et al.*, 1992). This is confirmed by a significant correlation between alpha-amylase activity and respiration (Beta *et al.*, 1995), as germination accelerates the metabolic activity of grain (Subramanian *et al.*, 1992).

While steep-out moisture acts as a preliminary test of final malt quality, the GE (germinative energy) and GV (germinative vigour) tests are tools to determine malting potential in advance. The GV measures germination uniformity and is indicative of the percentage of germinated kernels with a root at least as long the kernel itself. The GE measures potential germination during malting. A large difference between the GE and GV indicates poor grain quality, as the GE decreases with storage time of sorghum. Therefore malting of sorghum should be performed as soon as possible, before the GE declines (Taylor & Dewar, 1996). The GE was found to correlate with dry matter losses, which also correlates with respiration loss, root and shoot loss, alpha-amylase activity and diastatic power (Beta *et al.*, 1995).

The modification of starch to fermentable sugars varies widely with cultivars. This was observed with a variation in the reduction of the starch content, during a 96-h germination process from 33.0 to 58.34 % between cultivars. Despite this, all cultivars show a reduction in soluble sugars after 16 h of germination, but a sharp increase after 96 h of germination (Subramanian *et al.*, 1992).

1.4.2 DIASTATIC POWER

The diastatic power (DP) refers to the combined activity of alpha- and beta-amylase present (diastase) in sorghum malt (Taylor, 1998a) and is expressed as sorghum diastatic units (SDU per gram dry malt) (Subramanian *et al.*, 1992). The DP of sorghum malt is an important indicator of the final malt quality of sorghum (Taylor & Dewar, 1996) and a value of 28 SDU/g malt is classified as acceptable in the industrial beer-brewing industry (Taylor, 1998a).

Beta *et al.* (1995) found 11 sorghum cultivars in an assay of 16 cultivars, to have SDU values greater than 28 SDU/g. As germination time increases from 16 to 96 h, SDU values also increase. At 48 h of germination, SDU values varied between 36.3 and 191.4 and at 96 h, from 34.0 to 219.2. These values were extremely high, but the author did not use the SABS 235 standard method for DP determination. The opposite was found at 144 h of germination, where SDU values decreased compared to those at 96 h. Thus, an increase in germination time improves SDU values up to a certain point beyond which prolonged germination decreases amylase enzyme activity. These high SDU values, due to enzymatic activity after 48 h of malting, was confirmed by a decrease in starch levels at the same time, due to enzymatic degradation (Subramanian *et al.*, 1992). As mentioned earlier, steep-out moisture is a good indication of malt end product quality (Dewar & Taylor, 1996; Dewar *et al.*, 1997). Therefore the significant correlation found between steep-out moisture and DP is not unexpected (Dewar & Taylor, 1996), as both refer to malt quality.

1.4.3 FREE AMINO NITROGEN

The free amino nitrogen (FAN) refers to the technique by which the free amino nitrogen content of malt is assayed (Taylor, 1998a). The protein content in sorghum decreases during germination (Subramanian *et al.*, 1992) due to enzymatic breakdown. Two types of proteases are responsible for this. Proteinases hydrolyze proteins into peptides, while peptidases further hydrolyze these peptides into smaller peptides and amino acids, which are jointly known as free amino nitrogen. The presence of FAN in sorghum malt for beer brewing is important to ensure active yeast growth and complete alcoholic fermentation (Taylor, 1998a).

FAN is another quality criterion of final malt quality and as in the case of SDU correlates well with steep-out moisture (Taylor & Dewar, 1996). Therefore an increase in steeping time significantly improves FAN values of malt, as it improves malt quality (Dewar *et al.*, 1997).

1.5 THE PHYSICAL PROPERTIES OF SORGHUM GRAIN

1.5.1 HARDNESS AND ADHESIVENESS

Hardness of sorghum grain is an important quality criterion (Reichert *et al.*, 1982; Sooliman, 1993) in terms of processing. No single definition is found for sorghum hardness in the literature, but it is closely related to another quality criterion, namely ease of dehulling (Reichert *et al.*, 1982). The hardness of sorghum is determined by the endosperm texture (Kirleis & Crosby, 1982). Hardness of grains can be measured in terms of a pearling index (Reichert *et al.*, 1986), which McDonough *et al.* (1998) had indicated to be 14.4 % for a commercial red sorghum with a yellow endosperm.

In the milling industry, hardness of grain is of extreme importance, as it influences milling time, energy expenditure, as well as the end product's appearance (De Francisco *et al.*, 1982). Adhesiveness of the pericarp-testa is as important as hardness during abrasive milling, since it determines the ease with which the pericarp breaks from the endosperm and hardness of the endosperm is important in preventing endosperm breakage during the same type of milling (Munck *et al.*, 1982). Typical hard cultivars, such as PAN 8420 and PhB 8601 are suited for meal production, but soft cultivars, such as PAN 8501 and SNK 3975 are unsuited for meal production (Dewar *et al.*, 1993). Sorghum millers therefore require hard cultivars for meal production, although the influence of hardness on the porridge quality as such, is still a subject of uncertainty (Taylor *et al.*, 1997). The moisture content or uptake of grain also influences hardness. When moisture enters the endosperm, the protein-starch bonds that contribute to hardness, are broken or weakened (Hoseney, 1994).

The hardness of sorghum correlates with milling yield (Maxson *et al.*, 1971) and with kernel density (Reichert *et al.*, 1986; Beta *et al.*, 1995), particle size index, percentage vitreousness (Reichert *et al.*, 1986) and test weight (Beta *et al.*, 1995). Therefore hardness is not only an important quality characteristic of sorghum, but it also correlates well with other quality characteristics.

1.5.2 KERNEL SIZE AND SHAPE

Grain size is an important quality criterion of sorghum (Sooliman, 1993), with consequences on sorghum processing. During the wet milling of sorghum, small kernel sizes absorb water more quickly, with consequent quicker extraction of soluble substances than in the case of larger kernels (Watson & Hirata, 1955). Small kernels also offer some other advantages in the milling industry, as large kernels have the tendency to crack during milling if they are not hard enough (Munck *et al.*, 1982). This explains why Wills & Ali (1982) found an increase in milling yield as the grain size decreased. On the other hand, larger sorghum kernels have better pearling properties than smaller ones with the same hardness (Kirleis & Crosby, 1982). The importance of grain size in milling quality of sorghum therefore appears to be revealed only when differences in the hardness of kernels are present.

Kernel shape is a kernel characteristic which influences yield and the quality of the polished kernel during abrasive milling. During abrasive milling of sorghum a spherical polished product is obtained, with consequential greater losses with oval shaped kernels than with round kernels (Munck *et al.*, 1982).

1.5.3 THOUSAND-KERNEL WEIGHT AND HUNDRED-KERNEL WEIGHT

Two methods are commonly used to determine the density of sorghum grain kernels, namely the hundred-kernel weight (HKW) and the thousand-kernel weight (TKW). The HKW, which is the weight of 100 kernels, determines the density of kernels and is expressed in gram per 100 kernels ($g.100^{-1}$) (Gomez *et al.*, 1997). The TKW of sorghum grain, which is the weight of 1000 kernels, is another common method of determining kernel density, and is expressed as gram per 1000 kernels ($g.1000^{-1}$) (Dewar *et al.*, 1993). The TKW was in fact found to be a better indication of kernel size than kernel density (Kirleis & Crosby, 1982). Therefore the TKW is an indication of both kernel density and kernel size (Kirleis & Crosby, 1982). Hardness is correlated to TKW (Kirleis & Crosby, 1982; McDonough *et al.*, 1998) and kernel volume in exactly the same way and as the latter is largely determined by kernel size, the TKW is mostly determined by kernel size (Kirleis & Crosby, 1982). The HKW takes into account the variation in kernel size that exists within the same variety and is therefore an indication of the average kernel size within a variety (Gomez *et al.*, 1997). Accordingly, it could be concluded that both the TKW and the HKW indicate the density and kernel size of sorghum grain.

The TKW of a commercial red sorghum with a yellow endosperm was found to be 39.4g (McDonough *et al.*, 1998) and wide variations amongst different sorghum cultivars are found (Buffo *et al.*, 1998). Twenty-four commercial sorghum hybrids showed a mean value of 30.56±2.91 g, a minimum of 24.88 g and a maximum of 35.88 g (Buffo *et al.*, 1998). The HKW of nine cultivars was found to vary between 2.0 g and 3.9 g (Subramanian *et al.*, 1992). Although TKW is widely used as an indication of kernel density, Dewar *et al.* (1993) recommended that the TKW as well as the Hectoliter weight should be used as an indication of kernel density. This is on account of the fact that the TKW is difficult to determine if a sample consists of small grains with a heavier weight, or large grains with a small weight (Dewar *et al.*, 1993). This is probably the reason why the TKW is a better indicator of kernel size than density, as discussed above. Although the TKW and HKW both indicate kernel size and density and only the unit of expression differs, the HKW was selected in the present study as a means of determining kernel density, since it is quicker than the TKW where many cultivars have to be evaluated.

1.5.4 MOISTURE CONTENT

The moisture content of sorghum is an important quality characteristic in the sorghum processing industry. Both in the malting and milling industry, it is important to know the moisture content before processing, in order to ensure that the correct conditioning process is applied in roller milling and moisture content of malt is determined to determine the DP.

Twenty-four commercial sorghum hybrid samples displayed a mean moisture content of 13.95±0.33 % (Buffo *et al.*, 1998), while a commercial red sorghum with a yellow endosperm contained 11.0 % moisture (McDonough *et al.*, 1998). Raw sorghum-flour was determined to have a moisture content of 10.4 %, while the flour that was boiled in water and oven-dried had a moisture content of 9.2 (Singh & Singh, 1991). The moisture in grain is in equilibrium with the air surrounding the grain and thus, with the relative humidity of the air. As the moisture content of even the same type of grain varies depending on the surrounding air (Hoseney, 1994), it can be expected that the same cultivar planted at different localities would have different moisture contents, seeing that the relative humidities of the air varies. Therefore, no average moisture content for sorghum and sorghum meal can be stated, as there is too much variation between different samples, which emphasizes the importance of moisture determinations as part of quality control in the further processing of sorghum.

1.6 FOOD QUALITY CHARACTERISTICS

Some consumers do not positively accept the visual appearance, mouth-feel and flavour of sorghum foods. The dark colour, pronounced flavour, grittiness of the flour, tannin content and palatability are some of the negative aspects associated with sorghum products (Sooliman, 1993). Sifting of the flour during manufacturing can influence grittiness and palatability in the end product, as sifting leads to an increase in protein content and a decrease in starch content. In turn, this causes an increase in the ratio of bound starch (by protein) to free starch. This retards particle hydration, cooking time, viscosity and gelatinization. The grittiness in mouth feel is caused by a high horny endosperm content. The starch in the horny endosperm, with high protein content, swells less than the less tightly bound starch. Less swelling causes an underdeveloped jelly layer covering the particles, with a consequential harder and grittier mouth-feel (Novellie, 1982).

Many of the negative quality characteristics of sorghum products could be removed by implementing higher grain quality standards, appropriate processing technology or a combination of the two (Sooliman, 1993). The fibre content can be decreased by sifting, leaving the processor with a smoother, blander and lighter coloured product with less mouth-irritation. Bowel bulk and nutrient losses are reduced, as phytic acid, which binds trace elements, are removed with bran constituents (Novellie, 1982). A focus of the present study will be to compare the success of the Tangential Abrasive Dehulling Device (TADD) process with roller milling, in improving sorghum product quality and consumer acceptability and to identify possible physical characteristics that have an influence on malting and/or milling quality.

1.7 TADD ABRASIVE MILLING OF SORGHUM

1.7.1 PRINCIPLE

The Tangential Abrasive Dehulling Device is a laboratory scale device built to resemble the type of dehullers used on commercial scale (Reichert *et al.*, 1982). The TADD machine is able to process eight 5-g samples at a time (Oomah *et al.*, 1981). It consists of 8 tubes (compartments), each containing a column of grain as shown in Fig. 1.2(a). Each tube is positioned to just clear a rotating horizontal abrasive disk (Shepherd, 1979), as seen in Fig. 1.2(b). The TADD operates horizontally, but some vertically operating dehullers are also found (Reichert *et al.*, 1982). The abrasive material used may be carborudum stones (Reichert *et al.*, 1982; Reichert & Youngs, 1976) or emery-coated abrasive disks (Reichert *et al.*, 1982).

During the abrasive process the TADD only removes the outer layers of the grain, namely the pericarp, testa, part of the germ and part of the endosperm (Dewar *et al.*, 1993; Subramanian *et al.*, 1994). Some pigments present in the pericarp are also removed with the outer layers (Subramanian *et al.*, 1994). Most of the endosperm should be left unharmed for further milling into meal (Dewar *et al.*, 1993).

1.7.2 EFFECT OF DEHULLING ON THE SORGHUM KERNEL

Sorghum is more easily decorticated than pearl millet, because the sorghum pericarp is removed in large flakes from the starch-containing mesocarp (De Francisco *et al.*, 1982). The large decortication flakes of sorghum will not easily pass through a 1-mm round sieve hole without further attrition (Shepherd, 1979). Decortication of sorghum grain led to a pericarp-free sample and because of the removal of the outer portions of the grain, starch levels increased by 17 % in the dehulled sorghum kernel, while protein content was reduced by 8 % (Yang & Seib, 1996). With levels of 10 to 12 % dehulling the maximum grain recovery with the smallest nutrient losses were obtained (Desikachar, 1982).

As the pericarp is removed during dehulling, the meal obtained has lower bran content and a lighter colour (Pretorius *et al.*, 1996). The reason for the lighter colour is the removal of pigments in the pericarp by the dehulling process (Subramanian *et al.*, 1994).

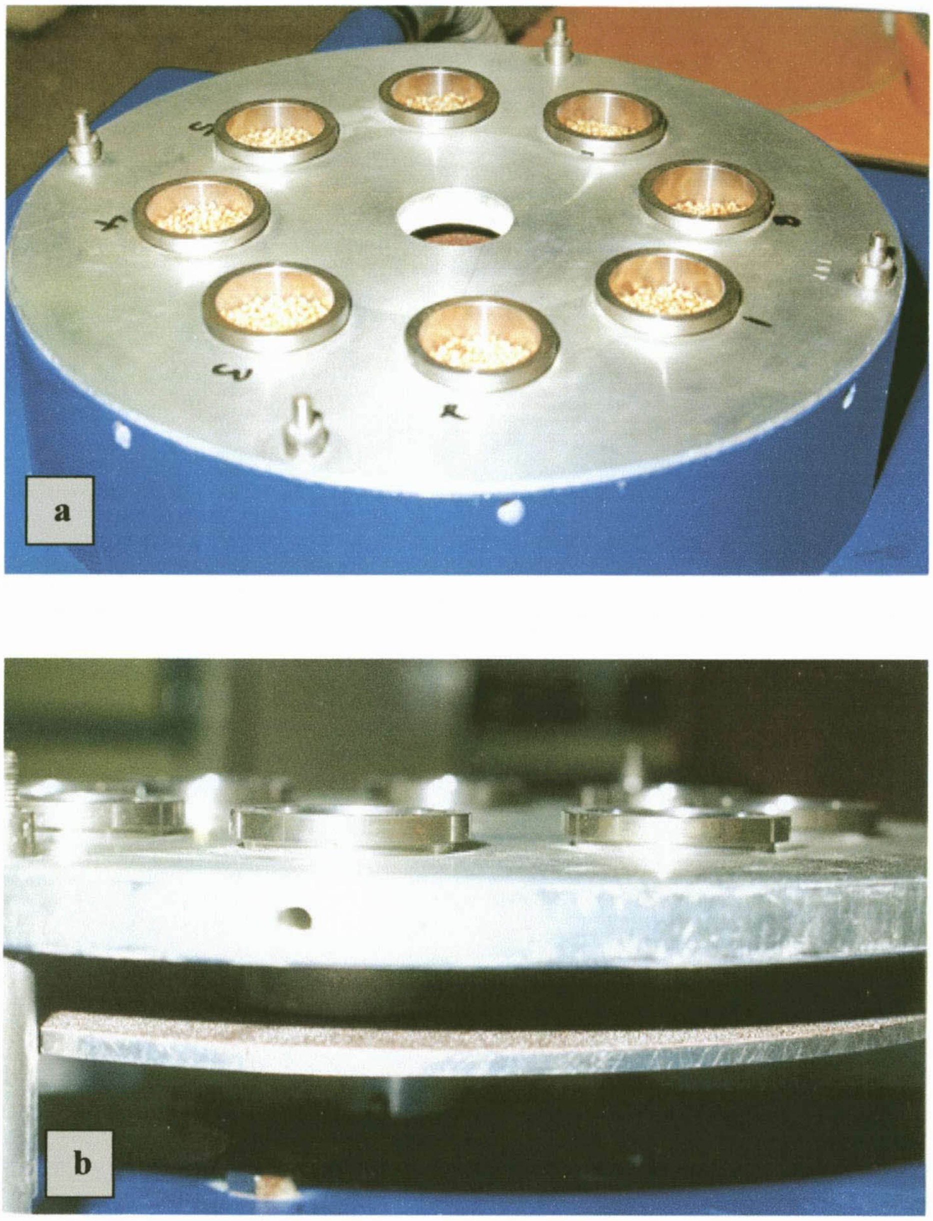


FIG. 1.2

A TANGENTIAL ABRASIVE DEHULLING DEVICE: (a) EIGHT SAMPLE CUPS FILLED WITH SORGHUM GRAIN (b) SIDE VIEW TO INDICATE SANDPAPER AND DISTANCE OF SAMPLE CUPS FROM ABRASIVE SURFACE

1.7.3 FACTORS AFFECTING DEHULLING YIELD AND EASE OF DEHULLING

The factors that cause variation in dehulling yield are not only related to the type of dehuller used, but also to the type and size of sorghum used (Sooliman, 1993). A very important property of the TADD itself, is the clearance between the bottom of the sample cups and the rotating decorticating surface. This gap size determines the particle size of the grains escaping from the cup and thus the bran yield of the sample. The reason for this is the linear relationship that exists between clearance size and bran yield (Reichert *et al.*, 1986).

In contrast to factors related to the type of machine used, there are several kernel characteristics affecting dehulling yield and the ease of dehulling. The hardness of the grain influences the yield and quality of the product (Munck *et al.*, 1982), as well as the ease of dehulling (Reichert *et al.*, 1982). Dehulling of hard endosperm sorghum cultivars displayed better results than the soft cultivars (Kirleis & Crosby, 1982), as a hard endosperm is less easily broken (Desikachar, 1982; Munck *et al.*, 1982) under the pressure of the abrasive surface (Reichert *et al.*, 1982). Therefore, hard varieties result in higher whole grain yields (Desikachar, 1982), while soft varieties cause the removal of fine material from the whole grain, instead of only the peripheral layers (Reichert *et al.*, 1982), which is much less valuable than the endosperm (Dewar *et al.*, 1993). The hardness of the grain may vary according to the moisture content of the grain, as discussed in 1.4.1.

Another factor affecting dehulling yield due to the loss of valuable kernel material, is the degree of adhesion between the unwanted bran layers and the useful endosperm (Reichert *et al.*, 1982). In the roller milling system, the conditioning process, through which the bran is toughened by the addition of water for easier removal (1.7.1), manipulates adhesion. No conditioning process is applied during the TADD abrasive milling process, though. The ease of dehulling and quality of the polished product are also dependent on the ease of breakage of the pericarp and testa from the endosperm during processing (Munck *et al.*, 1982). Milling yield also increases as the grain size decreases (Wills & Ali, 1982), since large kernels that are not hard enough, have the tendency to crack (Munck *et al.*, 1982). The fact that the abrasive principle produces spherically shaped kernels, leads to greater endosperm losses from oval shaped kernels than with round kernels. Therefore, not only the kernel size is important in determining dehulling yield, but also the kernel shape (Munck *et al.*, 1982).

Cultivar also has an influence on the dehulling yield. Pretorius *et al.* (1996) reported that one minute of dehulling yielded significant differences in mean AHI values among five sorghum cultivars ranging from about 9 to 14 5. Buffo *et al.* (1998) reported abraded percentages to vary from 49 to 74 % in 24 sorghum hybrids. In another study 24 sorghum hybrids had a mean percentage abraded of 52.31±5.93 % with a range of 49.07 to 73.93 % (Buffo *et al.*, 1998). As could be expected, the time of dehulling also plays an important role in the yield. This is because of the linear relationship between percentage of kernel removed and the retention time (Oomah *et al.*, 1981), as mentioned earlier. The percentage kernel removed increased from 8.26 to 35.37 % when the retention time was increased from 0.5 to 8 minutes (Oomah *et al.*, 1981). All these factors should therefore be considered when the results from the TADD are interpreted.

1.7.4 ADVANTAGES AND DISADVANTAGES OF AN ABRASIVE DECORTICATION PROCESS

The advantages offered by an abrasive decortication process could be divided into four main categories (Table 1.3), which are discussed in detail below, namely:

1. Those that improve the appearance.
2. Those that improve other sensory properties.
3. Those that improve the nutritional value of sorghum products.
4. Advantages offered by the TADD instrument self.

Firstly, the abrasive decortication process improves the appearance of sorghum products. This is brought about by the removal of the coloured bran, glumes (Desikachar, 1982) and the reduction of the tannin content (Deshpande *et al.*, 1982b) present in the pericarp, with a consequent lighter meal colour (Pretorius *et al.*, 1996). The visual appearance of sorghum starch is also improved by dehulling, as pigments from the pericarp, which may leach into the starch when the grain is moistened, are removed (Subramanian *et al.*, 1994).

TABLE 1.3
SUMMARY OF THE ADVANTAGES AND DISADVANGES OF AN ABRASIVE DECORTICATION PROCESS

	ADVANTAGES	DISADVANTAGES
1	**Appearance Improvement**	Ash and protein content decreased
	Improvement of meal colour	
	Improvement of colour of starch	
2	**Sensory properties Improvement**	Losses when kernels break in process
	Improvement of mouth feel	
	Improvement of palatability	
3	**Nutritional value improved**	
	Improvement of digestibility	
	Lipid content decreased	
	Tannin content decreased in high tannin cultivars	
4	**Advantages offered by TADD self**	
	Simplicity of operation	
	Little time consumption	
	Small sample size	
	Machine maintenance simple	

Secondly, the abrasive decortication process improves some of the other sensory properties of sorghum products. The reduction of the bran content (Pretorius *et al.*, 1996) of sorghum during abrasive decortication improves the mouth feel of sorghum products, as roughness and bitterness are eliminated (Desikachar, 1982). For the same reason the palatability of products are also improved (Reichert *et al.*, 1986).

Thirdly, the abrasive decortication process also offers some nutritional advantages to the consumer. The lower bran content improves the digestibility of the grain (Reichert *et al.*, 1986). The same can be expected with regard to abrasive decorticated sorghum meal. In 1.3.1 and 1.3.2 it was indicated that the sorghum lipid and ash content are mainly found in the germ, and as part of the germ is removed during abrasion, a relative decrease in these portions are expected. The same tendency could be expected for the proteins, which are mainly found in the endosperm (1.3.4), as the outer layers of the endosperm are also removed during dehulling. This was proven to be true for beans by Deshpande *et al.* (1982b), who found that, due to the removal of the outer layer of beans the relative protein, lipid and ash content of the flour is increased. As mentioned under the improvement of the appearance, dehulling reduces the tannin content in dry beans, although it is not totally eliminated (Deshpande *et al.*, 1982b). This is also expected to be the case with high tannin cultivars in sorghum. This offers nutritional benefits as tannins are anti-nutritional factors, as was explained in 1.3.5.

Fourthly, the greatest advantage of the abrasive decorticative method of dehulling assay is its simplicity (Reichert & Youngs, 1976; Ehiwe & Reichert, 1987). The little time needed for the assay and small sample size are further advantages of this method (Ehiwe & Reichert, 1987), while the machine itself has a convenient size and simple maintenance requirements when compared to other similar devices (Reichert & Youngs, 1976).

It is clear that the TADD offers some great advantages, but one disadvantage needs to be discussed. When kernel breakage occurs during abrasive milling, endosperm loss in the flour occurs, as it is removed with the bran fraction (Munck *et al.*, 1982). This is the reason for the importance of kernel hardness, as mentioned in 1.4.1. It therefore seems as if the use of the TADD abrasive method offers more advantages than disadvantages and that there are ways to overcome the disadvantages to a great extent.

1.8 ROLLER MILLING

1.8.1 PRINCIPLE

The roller milling of sorghum is a relatively unknown approach in sorghum processing. At first sorghum was milled with wheat roller mills (Hahn, 1969; Munck *et al.*, 1982). The aim of roller milling, as for other types of milling, is to separate different parts of the kernel, such as the pericarp, testa, aleurone, embryo and the endosperm. A roller mill functions on the principle of breaking, sieving, purification and reduction processes (Hahn, 1969). The reduction part of the process is only applied when to manufacture flour and not for sorghum meal. A small roller mill that was recently developed in South Africa consists of 2 or 3 pairs of rollers, as well as vibrating screens. The first and second pair of rollers is break rollers, with a coarsely fluted first pair and a finer second pair, which are used in sorghum (Taylor, 1998b).

The roller milling process starts with a conditioning process. Sufficient water is added to moisten the bran, which then becomes looser (Desikachar, 1982), tough and rubbery (Hahn, 1969) for easier separation from the endosperm (Desikachar, 1982), which in turn becomes soft and friable (Hahn, 1969). The bran is resistant to fine grinding, while the drier and more friable endosperm is milled fine (Desikachar, 1982). The germ is removed in large flat pieces, which, due to its oil content, is made "putty like" (Hahn, 1969). The first pair of rollers, of slightly different speeds, squeezes and abrades the kernel (Munck, 1995), which causes the kernel to break open and leave the endosperm exposed (Taylor, 1998b). In Fig. 1.3 sorghum grain entering the first break rollers of a roller mill are shown. The second pair of rollers produces meal by scraping off the exposed endosperm from the flattened seed (Munck, 1995). Reduction rollers may be added to the process to reduce the meal to flour by means of a crushing action (Taylor, 1998b). The screens separate meal or flour from the bran component (Taylor, 1998b) in each milling step to contribute to the total meal yield (Munck, 1995) and to change the bran content, as well as the ratio of peripheral to interior endosperm (Novellie, 1982).

FIG. 1.3

SORGHUM GRAIN ENTERING THE BREAK 1 ROLLERS OF A ROLLER MILL

1.8.2 FACTORS INFLUENCING THE EFFECTIVENESS OF ROLLER MILLING

As mentioned in 1.8.1, the roller milling of sorghum is not a well-known field. For this reason not many factors influencing the ease and effectiveness of roller milling is known. The only factor identified, is the conditioning process. Effective separation of kernel parts is dependent on conditioning by the addition of water (Hahn, 1969). Moderate conditioning to 16 % moisture before roller milling, resulted in sorghum meal with higher extractions and lower fat and ash contents than decorticated products (Gomez, 1993). Gomez (1993) also showed the possibility of identifying some other factors, such as locality of growth and cultivar.

1.8.3 ADVANTAGES AND DISADVANTAGES OF ROLLER MILLING

The major advantage of the roller milling of sorghum can be the use of reduction rollers, which enables the production of fine flour from sorghum with ease (Taylor, 1998b). Roller milling of sorghum produces a variety of products. A break flour yield of 10 to 15 % can be obtained, with a low protein content, but starch-like gelatinization characteristics. This product is useful in products requiring high viscosities and adhesive strength (Hahn, 1969) (e.g. sorghum porridges to be eaten by hand).

The disadvantages of roller milling lie in the lack of refinement and purity of products. This is because of the fact that sorghum is harder to mill than wheat, consequently resulting in coarser flours (Hahn, 1969). The break flour consists of many positive properties, but unfortunately its "specky" appearance limits its use to products in which appearance is of minor importance. This problem with appearance of flour could be solved by the use of lower extraction rates (Hahn, 1969). It may seem as if the disadvantages of the use of the roller mill for sorghum outweigh the advantages, but little is known on this aspect due to a lack of research. It can be expected that more advantages of roller milling will be revealed in the current study, when the process is compared to the abrasive decortication process.

1.9 SORGHUM IN THE PORRIDGE INDUSTRY

1.9.1 PROPERTIES OF SORGHUM PORRIDGE

The most important quality characteristic of sorghum porridge is the viscosity, which is discussed in section 1.9.2.2. The relationship between sorghum hardness and porridge-making quality is not clear. The porridge-making quality of sorghum is of extreme importance, as this property offers maize a competitive advantage over sorghum porridges. The problem with sorghum porridges lies in the lack of stiffness, which is important as these porridges are usually eaten by hand (Taylor *et al.*, 1997).

The physical properties (e.g. viscosity) of sorghum starches vary upon heating and cooling whenever moisture is present (Akingbala *et al.*, 1982). This could have some important consequences for the porridge-making properties of sorghum, as these porridges are eaten hot or cold (Taylor *et al.*, 1997). The starch present in sorghum flour or meal participates in starch-starch and/or starch-protein interactions during gelatinization (Singh & Singh, 1991) with different stages of gelatinization, which may be identified by specific temperatures. With dry solids levels of 18 % for sorghum starch and 22 % for sorghum flour, the onset gelatinization temperature was found to be 71.0±1.0 °C, the peak temperature 75.6±0.9 °C and the end temperature 81.1±1.1 °C (Akingbala *et al.*, 1988). These properties of sorghum porridges are influenced by several factors, as discussed in the next section.

1.9.2 FACTORS AFFECTING THE QUALITY CHARACTERISTICS OF SORGHUM PORRIDGES

1.9.2.1 COLOUR

Colour is one physical property of sorghum with a definite relationship to grain quality (Pushpamma & Vogel, 1982; Sooliman, 1993) and is a limiting factor in terms of consumer acceptability (Munck *et al*, 1982). The consumer prefers a light-coloured sorghum product (Pretorius *et al.*, 1996) and even off-colours in the starch fraction are rejected (Yang & Seib, 1995). The colour of sorghum grain can vary from reddish-brown to pale yellow or yellowish white (Subramanian *et al.*, 1994). The colour of sorghum-flour is determined by milling efficiency, which is in turn determined by the physical structure of the kernel (Munck *et al.*, 1982). Different cultivars and localities of growth significantly influence the colour characteristic of sorghum kernels (Dewar *et al.*, 1993). A very critical factor affecting the production of an acceptable light-coloured flour or meal from sorghum is the adequacy of milling technology implemented during processing (Munck *et al.*, 1982).

A popular method of determining colour of sorghum products on laboratory scale, is the Hunter L a b, where L indicates lightness (100) or darkness (0), +a redness, -a greenness, +b yellowness and –b blueness. For sorghum the "L" and "a" scales are used and the "b" scale, being difficult to interpret, is not used (Dewar *et al.*, 1993; Pretorius *et al.*, 1996). A strong negative correlation between the L and a scale exists, because the whiter the colour of flour, the less red it is (Dewar *et al.*, 1993). Sorghum meal from red cultivars are sometimes lighter than those from white cultivars, but in terms of the cooked porridge, white cultivars produce the whitest porridges (Pretorius *et al.*, 1996).

Breeders in the sorghum industry in South Africa have, in contrast to the maize industry, no guidelines in terms of colour selection. Breeders should therefore be informed to concentrate on pigment free varieties with an acceptable white colour to compensate for consumer prejudice (Sooliman, 1993). These breeding programs integrated with milling technology developed to produce the best coloured product, should be able to control rejection of sorghum products due to consumer resistance.

1.9.2.2 VISCOSITY

As mentioned earlier, sorghum porridge is one sorghum product that plays an important role in the diets of many African people. When measuring the viscosity of these products as a quality attribute, it is actually the resistance of these pasty foods to flow, which are determined (Diehl, 1982). The viscosity of these porridges is influenced by many factors e.g. intrinsic viscosity of the starch present (Abd Allah *et al.*, 1987), environmental conditions (Diehl, 1982), malting losses (Beta *et al.*, 1995), cultivar and locality (Dewar *et al.*, 1993), endosperm type (Cagampang *et al.*, 1985), starch type (Akingbala *et al.*, 1982) and bran content (Novellie, 1982).

Of all the sorghum meal compounds, starch has the greatest influence on the viscosity of sorghum porridge. Despite the fact that both starch and bran are able to absorb water and swell, bran does not play an important role in increasing the viscosity of sorghum porridges (Novellie, 1982). In fact, a higher bran content in sorghum meal decreases the starch content available during porridge making, with a consequent lower viscosity (Novellie, 1982). Starches of different sorghum cultivars were found to have pasting peak viscosities varying from 53.5 to 101.0 SNU (stirring number units) and the authors attributed differences in intrinsic viscosities of different sorghum starches to different sorghum cultivars and localities of growth (Dewar *et al.*, 1993). Except for the cultivar and locality of growth, the type of endosperm in which the starch is situated, also influences the intrinsic viscosities of different starches. Floury endosperm starches tend to have lower intrinsic viscosities than the starches from the corneous endosperm (Campangang *et al.*, 1985). This trend could be expected as cultivar and locality of growth has a great influence on kernel characteristics (Dewar *et al.*, 1993), which again influences viscosity of starches. Waxy starches have higher pasting viscosities than non-waxy starches in isolated sorghum starch, as the waxy starches lacks the linear fraction (amylose) to resist against swelling of the starch granules. On the other hand non-waxy sorghum starches can better withstand external pressure from the endosperm matrix in sorghum flour as it is less fragile, which results in higher pasting viscosities (Akingbala *et al.*, 1982). Therefore, it seems as if the sorghum starch type and factors influencing it, such as cultivar and locality, play a major role in the viscosity of sorghum porridges.

Environmental conditions (e.g. temperature) affect the viscosity of foods with a very high or low water or oil content (Diehl, 1982). In the case of sorghum starches, swelling and solubility increased, accompanied by a high viscosity at 75.5 °C. At 93 °C the viscosity decreases, due to fragmentation and solubilization of starch granules, but during cooling to 50 °C, retrogradation of amylose causes an increase to a maximum viscosity of the paste (Wankhede *et al.*, 1989). The peak paste viscosity of cooked sorghum porridge at 95 °C, were found to be lower than that of the raw paste (Sing & Sigh, 1991), but as explained, the viscosity reaches a maximum only after cooling to about 50 °C. Therefore, the temperature is of extreme importance during viscosity measurements, but especially in a product such as sorghum porridge, with such wide variation in viscosity at different temperatures.

Malting losses, in the form of dry matter losses, also cause the viscosities of sorghum starch pastes to decrease by an average of 4.4 SNU (Beta *et al.*, 1995). The reason for this is not known, but kernel densities decrease during malting (Beta *et al.*, 1995) which might play a role in this phenomenon.

1.9.2.3 OTHER FACTORS RELATED TO THE SORGHUM ITSELF AND THE PROCESSING INTO SORGHUM MEAL

Other factors than viscosity affecting the quality of sorghum porridges can be divided into two groups, namely those related to the sorghum grain and those related to the processing of the raw product into meal. The most apparent factor of sorghum grain itself is the influence of different cultivars. Different sorghum cultivars resulted in different paste peaking viscosities (PPV) during the porridge-making process (Taylor *et al.*, 1997). This is due to the fact that different sorghum varieties vary in waxy properties and could be classified as waxy, non-waxy or heterowaxy as mentioned in 1.3.3.2, where it was also indicated that the waxiness of sorghum, influences rheological properties. The PPV's of porridges also varied between those prepared from sorghum grown at rainfed and supplementary irrigation conditions. Those from the supplementary irrigation conditions had higher PPV's, as the grain was softer, with consequential greater facilitation for the expansion of starch during gelatinization (Taylor *et al.*, 1997). This influence of hardness of the endosperm on viscosity of sorghum porridges was also observed during a study where a significant correlation between percentage vitreousness and Brabender viscosity was found (Cagampang & Kirleis, 1984).

One very important chemical property of sorghum that influences porridge quality is its starch properties, as mentioned earlier. This is true because of the fact that starch is a major constituent of the sorghum endosperm (Cagampang *et al.*, 1985) and differences in its gelatinization temperature, specific heat and other thermal properties exist (Akingbala *et al.*, 1988). The amylose content of sorghum starches also has a major effect on the rheological properties of sorghum porridges (Ring *et al.*, 1982). Waxiness of starch also influences the porridge-making abilities of sorghum. Waxy sorghum varieties are not successfully used for sorghum porridge production, as they produce fragile gels that easily break down when subjected to shear forces (Dewar *et al.*, 1993). All these aspects of sorghum starch influences the viscosity and thus the thickness of the porridge, which are very important in the consumer acceptance of the product.

Processing of sorghum grain into meal could also influence sorghum porridge properties. Dehulling before manufacturing into meal increases the protein content of meal and removes the seed coat layer in dry beans (Deshpande *et al.*, 1982a). In sorghum 3 % protein are found in the pericarp (Serna-Saldivar & Rooney, 1995) and dehulling, which removes the pericarp, would thus decrease protein content. The higher protein content in dry beans increase the rate at which a continuous network is formed during gelation, therefore resulting in better gelling abilities in the porridge (Deshpande *et al.*, 1982a). In sorghum, on the other hand, higher kaffirin protein body levels were found to act as a barrier against starch gelitinization (Chandrashekar and Kirleis, 1988). Secondly, milling affects the cooking properties of sorghum meal during porridge making, resulting from the amount of damaged starch and endosperm particles during processing (Akingbala *et al.*, 1982). Thirdly, sifting influences the gelling properties of porridges, as the starch content, as well as the floury endosperm content is increased, while the protein content is decreased. Thus, the amount of free and weakly bound starch granules are increased compared to the bound, with a consequential speedier gelatinization and sharper increase in viscosity. The viscosity tends to decrease on long cooking or vigorous mechanical stirring (Novellie, 1982).

1.10 AIM OF STUDY

Sorghum as a food plays an important role in the diets of people in many parts of the world, whether it is in the malted form or in the form of sorghum meal. From the literature it is seen that the malting and milling industries of sorghum, are two important and well-researched fields. Despite this fact, it was observed that consumer complaints about sorghum product quality and acceptability still exist (Novellie, 1982), which emphasizes the fact that more research on sorghum malting and milling quality needs to be done.

Firstly, the importance of malting properties such as water absorption and malting losses in the determination of the malting quality of sorghum cultivars needs to be determined, as well as the way they compare to other malting quality parameters of sorghum cultivars, such as the DP, FAN, GV and GE. From the literature it is known that water absorption and malting losses of sorghum do play a role in malting quality, but its magnitude is relatively unknown.

Secondly, the focus of the present study will be to compare the success of the abrasive decortication process with roller milling, in improving sorghum product quality and consumer acceptability and to identify possible physical characteristics that have an influence on malting and/or milling quality of sorghum cultivars. While the use of the abrasive decorticative process is a well-known procedure for sorghum dehulling, the use of the roller mill for sorghum is a relatively unknown field with a lot of questions still unanswered. The current study may identify a suitable technique for sorghum roller milling and may also give an indication of the quality of this product, compared to the dehulled product.

Thirdly, the relationship between different physical properties and milling performance of sorghum needs to be investigated, as well as the influence of these properties in a roller milling system compared to the TADD system. The influence of roller milling compared to abrasion with the TADD on the quality of porridges, will be investigated.

In the past, the two fields of sorghum malting and milling were treated separately and recommendations on cultivar suitability were made on the basis of either the one or the other. Sorghum was either classified as good malting or milling sorghum. The need exists for the identification of sorghum cultivars and their properties that are suitable for use in both the malting and milling industry. The aim of this study is therefore to discriminate among sorghum cultivars according to milling and malting quality and to explain the differences in terms of physical and chemical qualities.

CHAPTER 2

THE MALTING QUALITY OF SORGHUM

2.1 INTRODUCTION

Sorghum malt has been used in the food industry for centuries (Beta *et al.*, 1995). The malt is used for the production of baby food and alcoholic and non-alcoholic beverages (Beta *et al.*, 1995), as well as sorghum beer (Pushpamma & Vogel, 1982). During the malting process endogenous amylases are mobilized to hydrolyze starch into fermentable sugars (Beta *et al.*, 1995; Taylor & Dewar, 1996) for yeast utilization during brewing (Subramanian *et al.*, 1992). The determination of the malting quality of sorghum is based on the measurement of the final malt quality, as well as measurements made at certain stages of the malt development.

The first step in the malting process to determine of the high tannin properties of the sorghum grain, intended for the process. All sorghums contain phenols and flavonoids, but only cultivars with a pigmented testa are birdproof (Serna-Saldivar & Rooney, 1995). Birdproof sorghum cultivars that produce condensed tannins from phenols (Serna-Saldivar & Rooney, 1995) should be identified, because tannins inactivate malting enzymes (Taylor, 1998a). The chlorox-bleaching test serves as a quick quantitative of a high tannin content. The chlorox reagent dissolves the outer pericarp of the grain in the presence of heat, thereby leaving the birdproof cultivars completely black, while the low tannin grains are left yellowish, yellowish brown or reddish brown (Dewar *et al.*, 1999). These cultivars should be treated with a very dilute formaldehyde solution before malting to inactivate tannins (Taylor, 1998a), or otherwise peptone should be used as extractant during DP determination as it prevents amylase inactivation by tannins (Dewar *et al.*, 1995). The determination of the total polyphenols can serve as a means of determining the condensed tannins in sorghum qualitatively and could serve as a tool for the determination of the tannin content in non-birdproof cultivars.

The malting process initiates with a daylong soaking or "steeping" process of the sorghum (Taylor & Dewar, 1996). As a faster water absorption rate of sorghum, secures the efficient release of protein and starch from the protein-binding matrix during the conditioning process for wet milling (Buffo *et al.*, 1998), the possibility exist that water absorption during steeping could assist in the release of enzymes during malting. Therefore, water absorption levels during steeping serve as a quality parameter and are determined in the current study.

Germination follows steeping (Taylor & Dewar, 1996), and modifies the chemical compounds in grain, causing qualitative and quantitative changes (Subramanian *et al.*, 1992). As good germination of the grain is essential for the development of good malt, germination can serve as a tool to determine malting potential in advance, by means of the GE and GV tests (Taylor & Dewar, 1996).

Malting loss is an important quality parameter of sorghum malt, but most importantly it is a significant economic consideration when selecting a sorghum cultivar for malt production. Malting loss is defined as the dry mass loss that occurs during malting, as a result of respiration losses in the form of dry matter loss through carbon dioxide production and water. This happens because of an accelerated respiration rate that develops during germination (Dewar *et al.*, 1999). Malting losses are measured in terms of dry mass after the oven drying of malt at the end of germination and serves as a measurement of quality. Malting loss should not be too high, but good germination increases losses and thus a balance between germination and losses should be found (Dewar *et al.*, 1999). In Fig. 2.1 a dried malt sample before milling for chemical analyses of DP and FAN, can be seen.

FIG. 2.1

A DRIED SORGHUM MALT SAMPLE WITH ROOTS AND SHOOTS BEFORE MILLING FOR DP AND FAN ASSAYS

The final assays in sorghum malting quality determination are the performances of the DP and FAN assays on the malt. The combined activity of alpha- and beta-amylase present in sorghum malt (Taylor, 1998a) at a value of 28 SDU/g malt, is classified as acceptable in the industrial beer-brewing industry (Taylor, 1998a). FAN refers to the technique by which the free amino nitrogen (Taylor, 1998a), which is formed by proteinases and peptidases from proteins and peptides (Taylor, 1998a), is assayed.

In South Africa the Agricultural Research Council – Grain Crops Institute, classifies sorghum for malting quality on the basis of the birdproof properties, DP, FAN and germination (GE and GV). Table 2.1 shows a summary of the grading system for sorghum. Hereby, sorghum can be classified as GM, GL, GH and other sorghum (Pretorius *et al.*, 1999). Table 2.2 indicates the classification of sorghum cultivars according to the above-mentioned system during the 1998/1999 season.

TABLE 2.1

GRADING SYSTEM OF SORGHUM (PRETORIUS *et al.*, 1999)

CLASS	DESCRIPTION	GRADE
GM	MALTING SORGHUM WITHOUT DARK LAYER UNDERNEETH PERICARP, THAT IS INCLUDED UNDER GM CLASS IN THE CULTIVAR LIST – MEET REQUIREMENTS SET FOR THE GRADE OF GM CLASS SORGHUM.	GRADE GM
GL	SORGHUM WITHOUT DARK LAYER UNDERNEETH PERICARP. IS A GM CULTIVAR, BUT CANNOT BE CLASSIFIED AS A GM CLASS OR IS A GL CULTIVAR IN THE CULTIVAR LIST – MEET REQUIREMENTS SET FOR THE GRADE OF GL CLASS SORGHUM.	GRADE GL1 GRADE GL2
GH	MALTING SORGHUM WITH A DARK LAYER UNDER PERICARP, THAT IS A GH CULTIVAR IN THE CULTIVAR LIST – MEET REQUIREMENTS SET FOR THE GRADE GH CLASS SORGHUM.	GRADE GH1 GRADE GH2
OTHER	SORGHUM THAT DOES NOT MEET REQUIREMENTS FOR CLASS GM, GL AND GH SORGHUM.	NONE

TABLE 2.2

CLASSIFICATION OF SORGHUM CULTIVARS ACCORDING TO THE NATIONAL SORGHUM CULTIVAR TRIALS IN THE 1998/99 SEASON

CULTIVAR	CLASS
ADV 5010	GL
APN 881	GM
NK 283	GM
NK 286	GM
NS 5511	GH
NS 5655	GM
PAN 8061	GM
PAN 8171	GL
PAN 8262	GM
PAN 8272	GL
PAN 8370	GL
PAN 8446	GM
PAN 8564	GM
PAN 8660	GM
SNK 3337	GM
SNK 3443	GM
SNK 3567	GM
SNK 3620	NONE
SNK 3663	GM
SNK 3860	GH
SNK 3863	GL
SNK 3883	GL
SNK 3939	GM
SNK 3975	GM

The objectives of this chapter are to:

1. Identify and determine the most important malting quality parameters of 24 sorghum cultivars over 2 seasons at 3 localities per season in order to see which are most suited in malting quality prediction.
2. Determine an interrelationship between some of the malting quality traits (Polyphenols, ML, WA, FAN, DP, GV and GE) of sorghum in order to develop a predictive model for sorghum malting quality.

2.2 MATERIALS AND METHODS

2.2.1 SORGHUM CULTIVARS

Sorghum cultivars from 3 localities per season over 2 seasons from the National Sorghum Cultivar Trials were used. A total of 24 cultivars from Dover, Greenlands (Green) and Potchefstroom Dryland (Rainfed) (Potch) were used from the 1997/1998 season. The same 24 cultivars from the 1998/1999 season were used from Platrand (Plat), Green and Potch. Plat is situated to the East of the country, where high rainfall conditions occur. All grain was twice passed through the air stream of a winnowing machine to remove light grains and impurities. No replications for assays were performed for assays, as were done by Purchase (1997). NK 283 was included to act as an internal standard (control) in each trial, since replications were not performed.

2.2.2 CHLOROX-BLEACHING TEST

The chlorox-bleaching test was done according to procedure described by Dewar *et al.* (1995), but a water-bath set at 70°C was used to heat samples instead of an oven. Sorghum samples (approximately 100 grains) were covered with the chlorox reagent, consisting of a 5 % (m/v) sodium hydroxide (analytical reagent) (NT) solution in a household bleach that contains a minimum of 3.5 % sodium hypochlorite (Jik) and heated for 20 min in the water-bath. The superfluous reagent was discarded after this period and the samples were evaluated on filter paper for the presence of black kernels. Black kernels indicate birdproof properties (pigmented testa), while sweet sorghum are known by their light yellowish colour. The percentage of birdproof kernels present in a sample was estimated.

2.2.3 POLYPHENOL CONTENT

The tannin content was determined according to the method described by Dewar *et al.* (1995) and was expressed as the % polyphenols present. Samples were milled with a 1093 Cyclotec Sample Mill equipped with a 2 mm screen. Sorghum meal (250 mg) samples were extracted in 5 ml of a 75 % dimethylformamide (DMF) (analytical excellence) (BDH) solution in centrifuge tubes by shaking it on a Labcon Shaking Platform for one hour, followed by centrifugation for 5 min at 4000 rpm. Pipetted into test tubes were the following: 5 ml distilled water, 1 ml of CMC-EDTA reagent consisting of 1% carboxymethylcellulose (general purpose reagent) (BDH) and 0.2 % disodium ethylene-diamine-tetra-acetate (guaranteed reagent) (Merck), 0.2 ml of a 1.75 % ammonium ferric (III) citrate green (general purpose reagent) (BDH) solution (16 % Fe), 0.2 ml DMF extract of working standards and 0.2 ml of an 28.8 % ethanolamine solution reagent was allowed to react with the sample supernatant for 10 min, before reading absorbance on a CECIL CE 1020 Spectrophotometer at 525 nm. The standards consisted of a 0, 1, 2 and 4 % tannic acid (chemically pure) (NT) solution. Standards were prepared by dissolving 50 mg tannic acid in 5 ml DMF diluent as stock solution. A further 2 ml of the stock solution was diluted to 10 ml with DMF extractant in a volumetric flask (4 % tannic acid). A 2 % standard was prepared by the addition of 2 ml DMF to 2 ml of the 4 % solution. A further 2 ml of the 2 % solution was diluted by the addition of 2 ml DMF to a 1 % standard. DMF extractant served as the 0 % tannic acid standard. A blank that contains 5 ml DMF instead of DMF extract and 0.2 ml distilled water instead of the ferric reagent, was also read. The % polyphenols present in samples is calculated from the regression line of the standards.

2.2.4 GERMINATIVE VIGOUR (GV) AND GERMINATIVE ENERGY (GE)

Germination of the samples was done according to the technique described by Dewar *et al.* (1995), but was modified to make germination counts after 24, 48 and 72 h, instead of only once at 48 h. The GV was determined after 48 h, while the GE was only determined after 72 h, instead of at 48 h. The determination for each sample was performed in triplicate. One hundred sorghum kernels were placed on two filter papers in a petri dish, after which the filter paper was moistened with distilled water and the kernels were spread evenly. Petri dishes were placed for 72 h in a Specht Scientific SG-330 Germinating Cabinet, with a temperature set at 25 °C and the relative humidity at 95 %. The number of germinated kernels was counted after 24, 48 and 72 h of germination. At 48 h, values were reported as the GV% and at 72 h, as the GE%, as mentioned above. At 72 h of germination the germinated, as well as the chitted kernels, were counted. The chitted kernels are those kernels that started to germinate, but with only the tip of the root visible through the pericarp.

2.2.5 WATER ABSORPTION AND MALTING LOSS DURING THE MALTING OF SORGHUM

Malting of the samples was done according to the technique described by Dewar *et al.* (1995), but modifications were made to wash samples before steeping in a solution of 25 ml Biocide IO_4 (IO Dophor based reagent) (SABS 1081) (Lever Industrial) in 16 liters of water and after steeping in 10 ml bleach (3.5 % hypochlorite m/v) in 16 l water (i.e. 0.16 % hypochlorite in final solution). Samples (50 g) of sorghum were weighed into nylon bags. Samples were washed in the Biocide IO_4 solution, by means of a 5 min scrubbing-10 min soaking process, followed by rinsing in clean water three times. After rinsing, samples were spinned for 3 min in a Miele WZ 259 Spinner. Steeping of the samples was done in a Labotec Model 101 Steeper at 25 °C for 24 h. The steeping cycle of 24 h consisted of 3 h intervals of soaking and a 1h period during which water flowed from the steeper, to allow aeration of the grain. The samples were washed in the bleach solution after steeping, but not scrubbed, followed by soaking, rinsing and spinning. Water absorption was determined after the steeping period, by weighing the grain after the washing was completed and was calculated as follows:

$$\%WA = \frac{\text{soaked mass of grain (g)} - \text{original mass (g)}}{\text{original mass (g)}} \times \frac{100}{1}$$

Germination was done in a Specht Scientific SG- 330 Germination Cabinet for 5 days, during which the samples were soaked in water (10 min) and spinned (3 min) twice daily. The germinated grain was dried in a Memmert UL 80 drying oven at 50 °C for 24 h. Samples were weighed after the drying process and the malting losses (ML) were determined as follows:

$$\%ML = \frac{\text{original mass of grain (g)} - \text{dried mass (g)}}{\text{original mass (g)}} \times \frac{100}{1}$$

After malting, the samples were milled by a Janke & Kunkel IKA sample mill for use in 2.2.6 and 2.2.7.

2.2.6 DIASTATIC POWER

The moisture content of malt was determined in a Memmert UL 80 drying oven set at 105 °C for 3 h according to the method described by Dewar *et al.*, (1995). The DP assay was performed on the samples according to the micro-method described by Gomez *et al.*, (1997) with peptone as extractant. A malt sample (prepared in 2.2.5) of 0.5 g was mixed with a peptone extract, by adding 10 ml of 2% peptone (bacteriological) (Biolab) solution and heating it for 2.5 hours at 30 °C, whilst covering the solution with parafilm and shaking it every 20 min. The samples were centrifuged at 3000 rpm for 2 min in a Heraeus Christ Labofuge Centrifuge. Supernatant (0.2 ml) from each sample was added to a buffered starch solution at 30 seconds intervals in a water-bath at 30 °C and after 30 min the reaction in the water-bath was stopped by the addition of 4 ml 0.5 N sodium hydroxide (0.5 N ampule) (Merck reagent no. AC001252.500). The starch solution was prepared by dissolving 20 g starch (guaranteed reagent) (Merck) in water over heat and adding 20 ml starch buffer before filling the solution up to the mark of a 1 000 ml volumetric flask. This solution should be kept at 30 °C and the starch buffer was prepared by diluting 68 g sodium acetate (guaranteed reagent) (Merck) and 1 N acetic acid (guaranteed reagent) (Merck) to 1 liter with distilled water. In the case of the blank, sodium hydroxide was added to the buffered starch solution before the addition of the malt extract. One blank was prepared for each sample. A volume of 4 ml 0.05N alkaline ferricyanide (guaranteed reagent) (Merck) was pipetted into Erlenmeyer flasks and 2 ml of the digested starch solution was added. The flasks were kept in a boiling water-bath for 20 min. After cooling the solution, 10 ml of 1 N acetic acid salt solution, prepared from glacial acetic acid (guaranteed reagent) (Merck), and 0.4 ml potassium iodide (guaranteed reagent) (Merck) solution were added before it was titrated against 0.05 N sodium thiosulphate (0.1 N ampule) (Merck). The potassium iodide indicator was prepared by the addition of two drops of concentrated sodium hydroxide solution to 50 g of potassium iodide dissolved in 60 ml distilled water and diluting the solution to 100 ml. The DP was determined as follows:

$$DP = \frac{TB-TA}{100-M} \quad X \quad \frac{VE \ X \ VD \ X \ 2000 \ X \ f}{W \ X \ AE \ X \ AD}$$

where TA= titre of thiosulphate used for the sample;

TB= titre of thiosulphate used for the blank;

AD= aliquot of digest for sugar determination, i.e. 2.0;

AE= aliquot of extract for sugar determination, i.e. 0.5;

f= normality of thiosulphate, i.e. 0.05

MC= % moisture content of malt

VD= volume of digest for sugar determination, i.e. 20.5;

VE= volume of extract for sugar determination, i.e. 0.5, and

W= weight of malt extracted

(Gomez *et al.*, 1997).

As seen, the DP was corrected to consider the moisture content of the malt and the titration volume of the blank was taken into consideration. The DP of the sample was measured in SDU/g malt.

2.2.7 FREE AMINO NITROGEN

The FAN assay of the samples was done according to the technique described by Dewar *et al.* (1995), but concentrated (99.7-100 %) ethanol (analytical excellence) (BDH) was used instead of 96 % ethanol. An extractant was prepared by dissolving 2 g potassium iodate (guaranteed reagent) (Merck), in 600 ml distilled water and adding 400 ml of concentrated ethanol. A volume of 40 ml extractant at 30 °C was added to 1 g malt samples (prepared in 2.2.5) and covered with parafilm after which it was extracted at 30 °C for 1h. The samples were shaken at 20 min intervals during this period. Extraction was followed by centrifugation for 10 min at 2000 rpm in a Heraeus Christ Labofuge Centrifuge. The supernatant (1 ml) was diluted to 25 ml in a volumetric flask. Volumes of 2 ml standard, 2ml distilled water and 2ml supernatant were added to respective test tubes in triplicate and 1 ml ninhydrin colour reagent was added and test tubes were covered with parafilm before boiling them for 25 min in a water-bath. The standard was prepared by dissolving 107.2 mg glycine (analytical excellence) (BDH) in 100 ml distilled water in a volumetric flask. A volume of 2 ml of this stock solution was diluted to 100 ml to serve as the standard. The ninhydrin colour reagent was prepared by dissolving 100 g of disodium hydrogen phosphate (guaranteed reagent) (Merck), 60 g potassium dihydrogen phosphate (guaranteed reagent) (Merck); 5 g ninhydrin (guaranteed reagent) (Merck); 3 g fructose (biochemical) (Merck) to 1 liter in distilled water. After cooling the samples for 20 min, 5 ml diluent was added and absorbancies of standards, blanks and samples were measured on a CECIL CE 1020 spectrophotometer at 570 nm. The absorbancies of the samples are corrected to take the moisture content of the malt into consideration and are read against the absorbance of the standard. The FAN content is expressed as mg FAN/100 g malt.

2.2.7 STATISTICAL ANALYSIS OF DATA

An Analysis of Variance (ANOVA) was done on each malting quality parameter to identify significant differences among cultivars, localities and seasons for each parameter, by the use of Costat (Cohort Version 3.02). A two-way randomized block ANOVA was used. The coefficients of variation (%CV) were determined from the ANOVA.

The linear correlation coefficients between different parameters were determined by Costat (Cohort Version 3.02).

Canonical variance analyses (CVA) were done using the GENSTAT 5 statistical analysis package (GENSTAT 5 Committee, 1978) for all malting quality parameters. CVA's were done to identify groupings between cultivars and environments (localities x seasons).

2.3 RESULTS AND DISCUSSION

2.3.1 CHLOROX-BLEACHING TEST AND POLYPHENOL CONTENT

Table 2.3 and Fig. 2.2 indicate the results of the chlorox-bleaching test. Only three cultivars were identified as birdproof cultivars, i.e. the presence of condensed tannins, namely NS 5511, SNK 3620 and SNK 3860. All the other cultivars were classified as being sweet cultivars with no condensed tannins underneath the pericarp. Therefore, only three cultivars may present problems during the malting process by binding malting enzymes to condensed tannins, in the absence of certain precautions that should be taken, as mentioned in 2.1.

Table 2.3 indicates the birdproof sorghum cultivars by means of the chlorox-bleaching test quantitively, as well as the actual % polyphenols of the 24 sorghum cultivars at the different localities and seasons.

TABLE 2.3

THE POLYPHENOL CONTENT AND BIRDPROOF PROPERTIES OF DIFFERENT SORGHUM CULTIVARS AT DIFFERENT LOCALITIES OVER 2 SEASONS

CULTIVAR	% POLYPHENOLS (TANNIC ACID EQUIVALENTS)										CHLOROX BLEACHING TEST
	DOVER	PLAT	GREEN		POTCH		MEAN		SD		
	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	
ADV 5010	0.35	0.28	0.36	0.40	0.29	0.13	0.33	0.27	0.04	0.13	SWEET
APN 881	0.33	0.31	0.70	0.23	0.29	0.23	0.44	0.26	0.22	0.04	SWEET
NK 283	0.25	0.24	0.26	0.17	0.09	0.29	0.20	0.23	0.10	0.06	SWEET
NK 286	0.22	0.23	0.33	0.24	0.09	0.14	0.21	0.21	0.12	0.05	SWEET
NS 5511	1.34	2.19	1.79	1.39	1.11	1.56	1.41	1.71	0.34	0.42	BIRDPROOF
NS 5655	0.09	0.11	0.27	0.33	0.21	0.00	0.19	0.15	0.09	0.17	SWEET
PAN 8061	0.26	0.43	0.42	0.00	0.10	0.09	0.26	0.17	0.16	0.23	SWEET
PAN 8171	0.30	0.36	0.53	0.35	0.45	0.10	0.43	0.27	0.11	0.15	SWEET
PAN 8262	0.26	0.27	0.52	0.34	0.18	0.26	0.32	0.29	0.18	0.04	SWEET
PAN 8272	0.00	0.44	0.33	0.53	0.19	0.34	0.17	0.44	0.17	0.09	SWEET
PAN 8370	0.48	0.29	0.73	0.42	0.26	0.31	0.49	0.34	0.24	0.07	SWEET
PAN 8446	0.36	0.39	0.38	0.25	0.27	0.19	0.34	0.27	0.06	0.10	SWEET
PAN 8564	0.29	0.36	0.28	0.17	0.10	0.17	0.22	0.23	0.11	0.11	SWEET
PAN 8660	0.22	0.10	0.48	0.39	0.24	0.08	0.31	0.19	0.15	0.17	SWEET
SNK 3337	0.29	0.38	0.44	0.26	0.06	0.25	0.26	0.29	0.19	0.07	SWEET
SNK 3443	0.34	0.24	0.69	0.31	0.34	0.20	0.46	0.25	0.20	0.06	SWEET
SNK 3567	0.37	0.22	0.43	0.22	0.23	0.19	0.34	0.21	0.11	0.02	SWEET
SNK 3620	1.56	2.41	2.15	1.83	1.75	1.00	1.82	1.74	0.30	0.71	BIRDPROOF
SNK 3663	0.40	0.30	0.60	0.00	0.26	0.20	0.42	0.17	0.17	0.15	SWEET
SNK 3860	1.46	2.23	1.82	1.85	1.34	1.49	1.54	1.86	0.25	0.37	BIRDPROOF
SNK 3863	0.24	0.24	0.39	0.03	0.31	0.15	0.31	0.14	0.07	0.11	SWEET
SNK 3883	0.21	0.00	0.32	0.06	0.12	0.00	0.21	0.02	0.10	0.03	SWEET
SNK 3939	0.40	0.28	0.27	0.17	0.00	0.04	0.23	0.16	0.20	0.12	SWEET
SNK 3975	0.35	0.23	0.85	0.18	0.32	0.22	0.51	0.21	0.30	0.03	SWEET
MEAN	0.43	0.52	0.64	0.42	0.36	0.32	0.48	0.42			
MIN	0.00	0.00	0.26	0.00	0.00	0.00	0.17	0.02			
MAX	1.56	2.41	2.15	1.85	1.75	1.56	1.82	1.86			
RANGE	1.56	2.41	1.89	1.85	1.74	1.56	1.65	1.84			
SD	0.41	0.69	0.52	0.51	0.43	0.42	0.45	0.53			

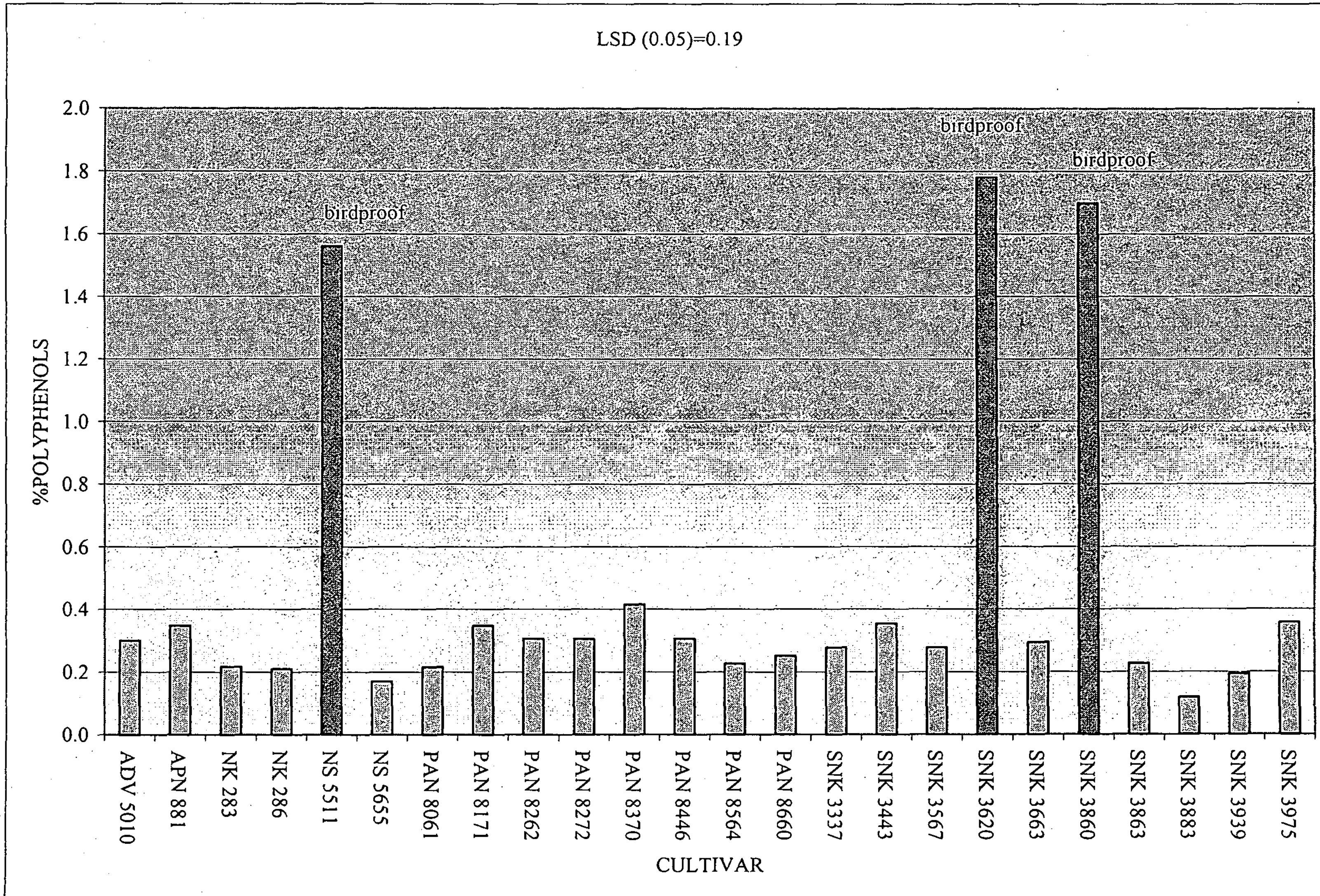


FIG. 2.2

THE SIGNIFICANT DIFFERENCES IN THE MEAN POLYPHENOL CONTENT OF DIFFERENT SORGHUM CULTIVARS

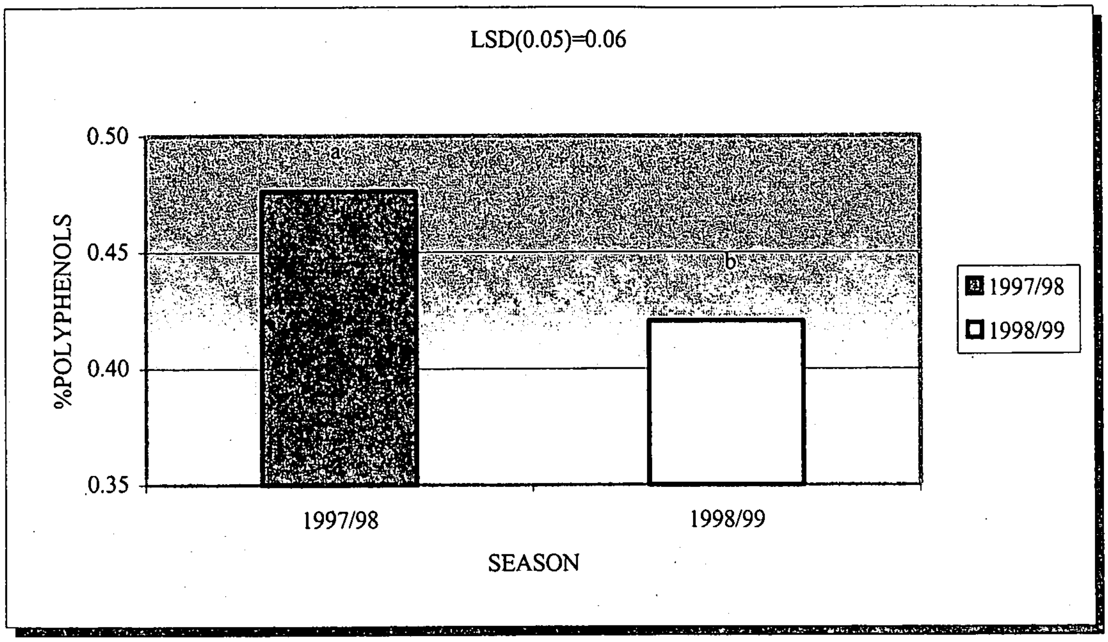


FIG. 2.3

THE SIGNIFICANT DIFFERENCES IN THE MEAN POLYPHENOL CONTENT OF SORGHUM CULTIVARS GROWN OVER DIFFERENT SEASONS

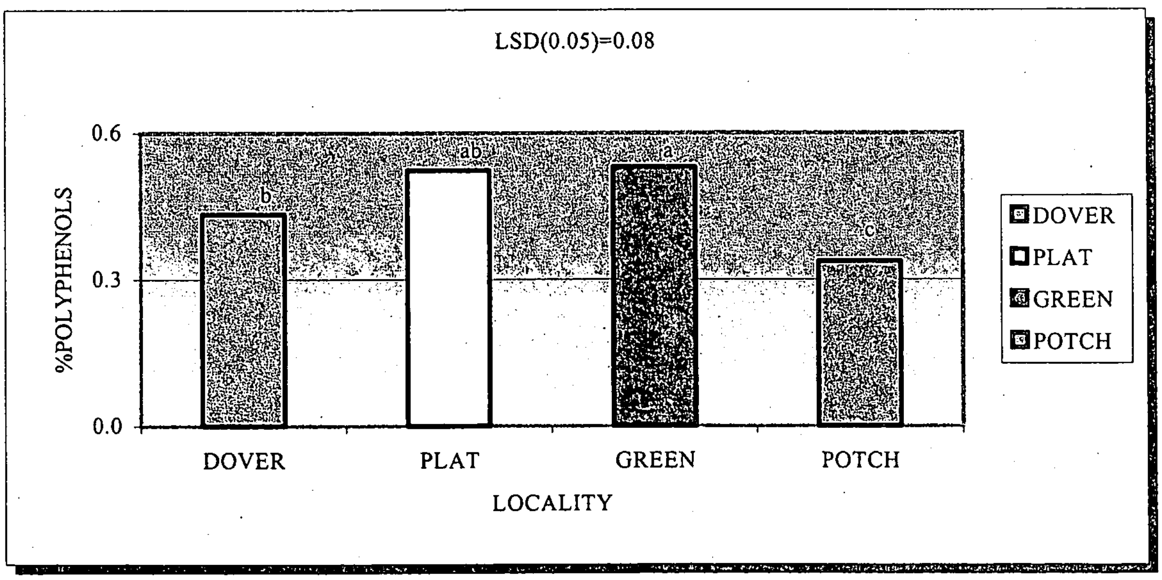


FIG. 2.4

THE SIGNIFICANT DIFFERENCES IN THE MEAN POLYPHENOL CONTENT OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES OF GROWTH

TABLE 2.4

ANALYSIS OF VARIANCE OF THE % POLYPHENOLS OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	0.3976	0.3976	14.6269	0.0004	***
Main Effects						
CULTIVAR	23	30.1735	1.3119	48.2659	0.0000	***
LOCALITY	3	1.3366	0.4455	16.3922	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	2.0376	0.0295	1.0864	0.3856	ns
Error	47	1.2775	0.0272<-			
Total	143	36.7764				

p=0.05

ns=not significant

The ANOVA (Table 2.4) indicates significant differences between the polyphenol content of sorghum cultivars. As expected, SNK 3860, SNK 3620 and NS 5511 (Table 2.5) showed significantly higher tannin contents ($p<0.05$) than the rest of the cultivars (Fig. 2.2) as these cultivars were also identified to be the only three birdproof cultivars by the chlorox-bleaching test.). The latter cultivar showed a lower ($p<0.05$) polyphenol content than SNK 3620, but had a higher condensed tannin content than the rest (Fig. 2.2). Although significant variation between the polyphenol content of some of the sweet cultivars were found, no other cultivar had a polyphenol content close to the birdproof cultivars (Fig. 2.2), indicating the presence of polyphenols in all sorghum cultivars. Only the birdproof sorghum cultivars can produce condensed tannins from phenols (Serna-Saldivar & Rooney, 1995), though. The white cultivar SNK 3883 was the lowest ranked cultivar for polyphenols (Table 2.4), with a polyphenol content corresponding with those of 15 other cultivars of low tannin content ($p<0.05$).

TABLE 2.5

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN POLYPHENOL CONTENT

Rank	Cultivar	Mean	n	Groups not significantly different
1	SNK 3620	1.781	6	a
2	SNK 3860	1.699	6	ab
3	NS 5511	1.562	6	b
4	PAN 8370	0.416	6	c
5	SNK 3975	0.358	6	cd
6	SNK 3443	0.354	6	cd
7	APN 881	0.348	6	cd
8	PAN 8171	0.348	6	cd
9	PAN 8446	0.306	6	cde
10	PAN 8262	0.306	6	cde
11	PAN 8272	0.305	6	cde
12	ADV 5010	0.300	6	cde
13	SNK 3663	0.294	6	cde
14	SNK 3337	0.278	6	cde
15	SNK 3567	0.277	6	cde
16	PAN 8660	0.251	6	cde
17	SNK 3863	0.227	6	cde
18	PAN 8564	0.227	6	cde
19	NK 283	0.217	6	de
20	PAN 8061	0.217	6	de
21	NK 286	0.210	6	de
22	SNK 3939	0.194	6	de
23	NS 5666	0.169	6	de
24	SNK 3883	0.117	6	e

Significant differences between the polyphenol content of sorghum cultivars over the two growing seasons were found (Table 2.4). The 1998/99 season showed a lower ($p<0.05$) mean polyphenol content than the 1997/98 season (Table 2.3; Fig. 2.3), while differences (Table 2.4) between the polyphenol content ($p<0.05$) at different localities were also observed (Fig. 2.4). The lowest polyphenol levels were found at Potch. As only the polyphenol content of birdproof sorghum cultivars are considered in the malting process and all should be treated with formaldehyde before malting in practice, the influence of seasonal and locality differences in the polyphenol content are eliminated. The cultivar x locality interaction for polyphenols was not significant (Table 2.4).

2.3.2 MALTING LOSS

The ML values of different sorghum cultivars at different localities and over different seasons of growth are shown in Table 2.6 and Fig. 2.5.

Significant differences between the ML value means of different cultivars are found (Table 2.7), as seen from Fig. 2.5. The highest ranked cultivar for ML was PAN 8272 (Table 2.8). This cultivar corresponded ($p>0.05$) with other cultivars of high ML such as, PAN 8262, SNK 3443, SNK 3663 and SNK 3883. The lowest ranked cultivar for ML was PAN 8564, which corresponded with cultivars such, as SNK 3337, SNK 3860 and SNK 3620 in ML value means (Table 2.8). As mentioned earlier, low ML values are important to obtain a high yield of malt. Malting loss is therefore not an indication of the actual malt quality as such, but more important as an economic consideration, as dry matter losses in the form of malting losses result in lower malt yields, with consequential lower income to the maltster.

Significant differences in ML value means were found over different localities of growth and seasons (Table 2.7). Higher ($p<0.05$) ML value means were found in grain from the 1998/99 season, than in those from the 1997/98 season (Fig. 2.6). The highest ($p<0.05$) ML value means were found at Plat, while the lowest ($p<0.05$) values were found at Potch (Fig. 2.7). Therefore, larger economic losses can be expected in terms of malting losses with sorghum from Plat, while lower losses will be found with grain from Potch. The ML value means of Green and Dover did not differ ($p>0.05$). The cultivar x locality interaction was again insignificant.

TABLE 2.6

THE %MALTING LOSS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES OVER 2 SEASONS

CULTIVAR	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999
ADV 5010	14.274	15.580	13.057	13.380	11.695	13.717	13.009	14.226	1.290	1.185
APN 881	13.800	15.351	12.657	15.634	12.775	13.617	13.077	14.867	0.628	1.092
NK 283	12.358	15.091	12.555	13.977	12.795	12.355	12.569	13.808	0.219	1.376
NK 286	12.400	14.294	12.540	12.517	11.675	13.212	12.205	13.341	0.464	0.895
NS 5511	12.917	15.614	13.380	14.100	11.740	12.657	12.679	14.124	0.846	1.478
NS 5655	12.712	16.340	13.660	15.231	12.135	14.254	12.836	15.275	0.770	1.044
PAN 8061	13.852	13.974	14.900	13.914	11.558	12.592	13.436	13.494	1.709	0.781
PAN 8171	13.695	14.137	12.335	13.335	10.840	12.153	12.290	13.208	1.428	0.998
PAN 8262	15.514	13.880	15.320	14.631	13.215	12.867	14.683	13.793	1.275	0.885
PAN 8272	14.357	17.836	15.980	14.617	9.856	14.337	13.398	15.597	3.173	1.945
PAN 8370	13.472	16.460	13.757	14.060	11.338	12.570	12.856	14.363	1.322	1.963
PAN 8446	13.312	14.517	13.197	12.960	10.978	11.955	12.496	13.144	1.316	1.291
PAN 8564	10.640	10.640	12.697	13.357	11.378	12.135	11.572	12.044	1.042	1.361
PAN 8660	14.000	14.000	13.800	13.080	11.353	13.800	13.051	13.627	1.474	0.484
SNK 3337	12.537	13.517	10.678	13.292	11.218	11.633	11.478	12.814	0.957	1.029
SNK 3443	14.357	15.154	15.377	14.174	13.095	13.075	14.276	14.134	1.143	1.040
SNK 3567	11.720	15.120	12.075	14.177	12.218	12.273	12.004	13.857	0.256	1.450
SNK 3620	11.260	14.817	11.893	14.474	10.258	12.073	11.137	13.788	0.824	1.495
SNK 3663	15.271	16.733	13.460	13.377	12.697	13.429	13.809	14.513	1.322	1.923
SNK 3860	12.338	14.720	10.460	13.572	10.518	11.280	11.105	13.191	1.068	1.751
SNK 3863	14.560	16.590	13.794	15.277	11.293	13.197	13.216	15.021	1.709	1.711
SNK 3883	15.551	14.094	14.017	14.060	12.515	14.611	14.028	14.255	1.518	0.309
SNK 3939	13.877	14.157	13.117	14.054	12.657	12.210	13.217	13.474	0.616	1.096
SNK 3975	12.735	14.117	13.754	10.614	11.438	12.213	12.642	12.314	1.161	1.754
MEAN	13.396	14.864	13.269	13.828	11.718	12.842	12.795	13.845		
MIN	10.640	10.640	10.460	10.614	9.856	11.280	11.105	12.044		
MAX	15.551	17.836	15.980	15.634	13.215	14.611	14.683	15.597		
RANGE	4.911	7.196	5.520	5.020	3.359	3.331	3.578	3.553		
SD	1.281	1.420	1.336	1.024	0.899	0.887	0.930	0.867		

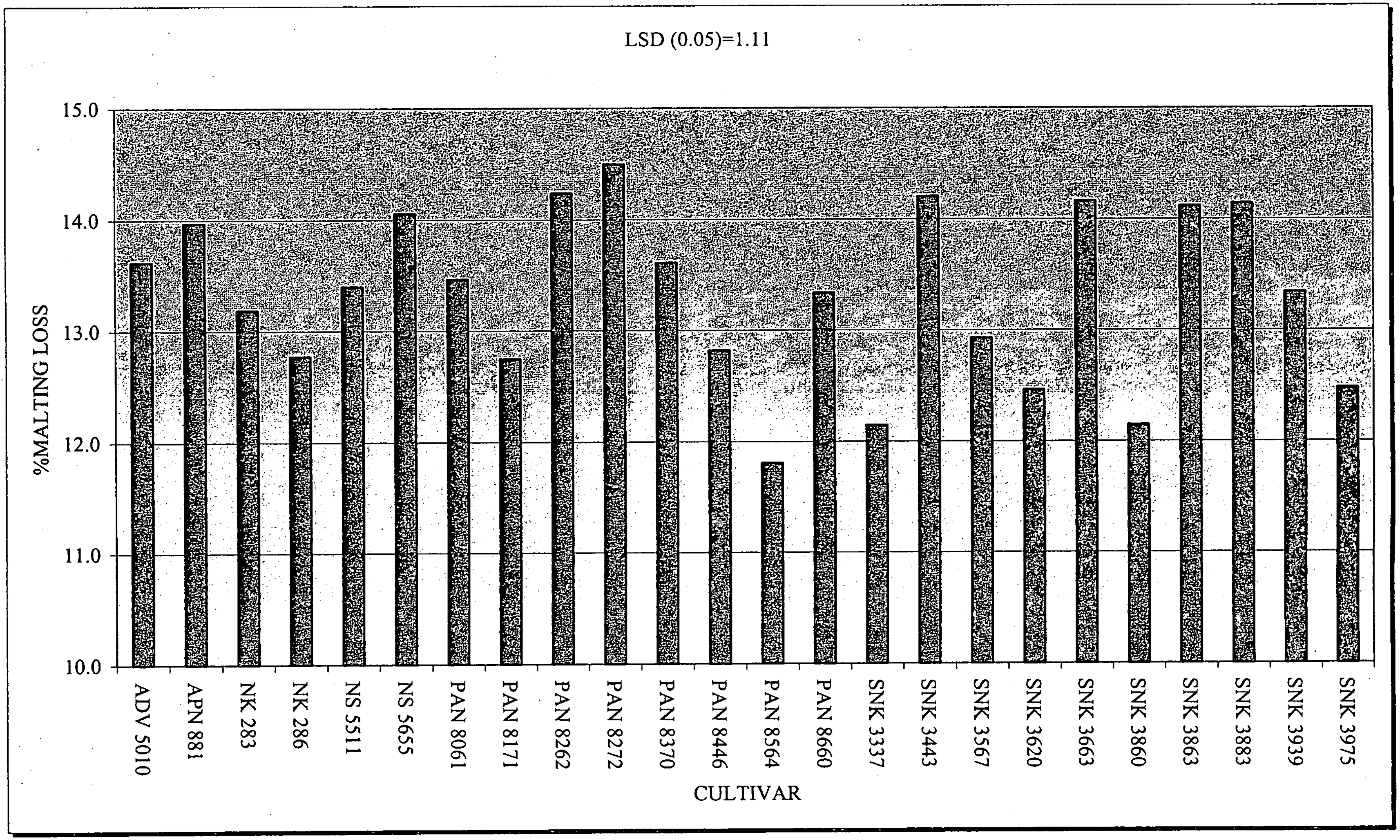


FIG. 2.5

THE SIGNIFICANT DIFFERENCES BETWEEN THE MEAN %MALTING LOSS OF DIFFERENT SORGHUM CULTIVARS

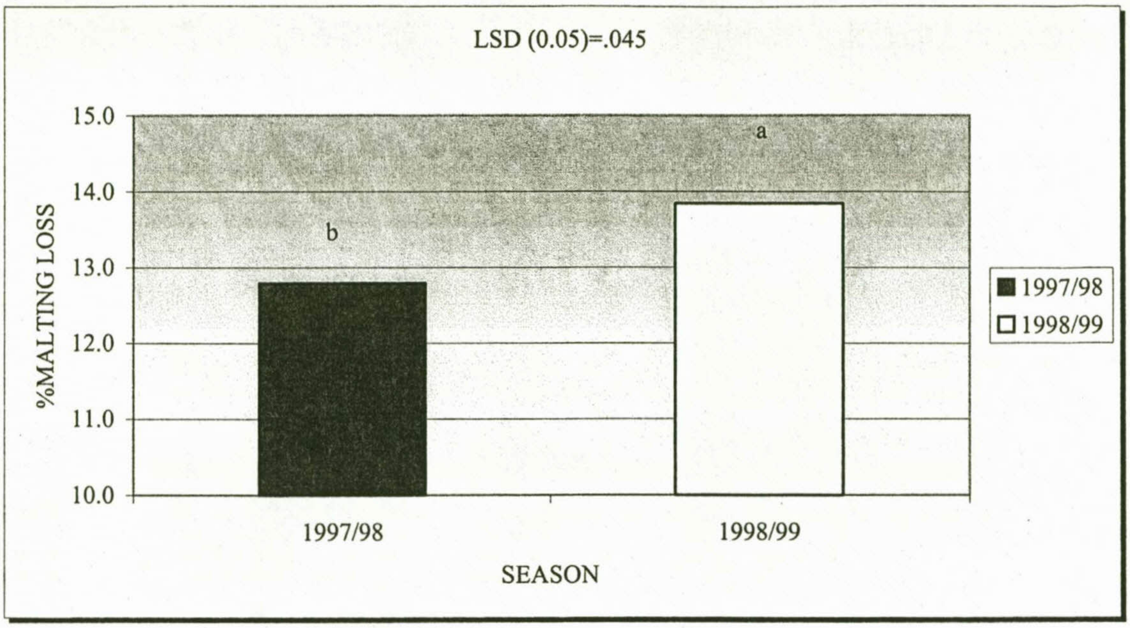


FIG. 2.6

THE SIGNIFICANT DIFFERENCES BETWEEN THE %MALTING LOSS MEANS OF SORGHUM CULTIVARS GROWN OVER DIFFERENT SEASONS

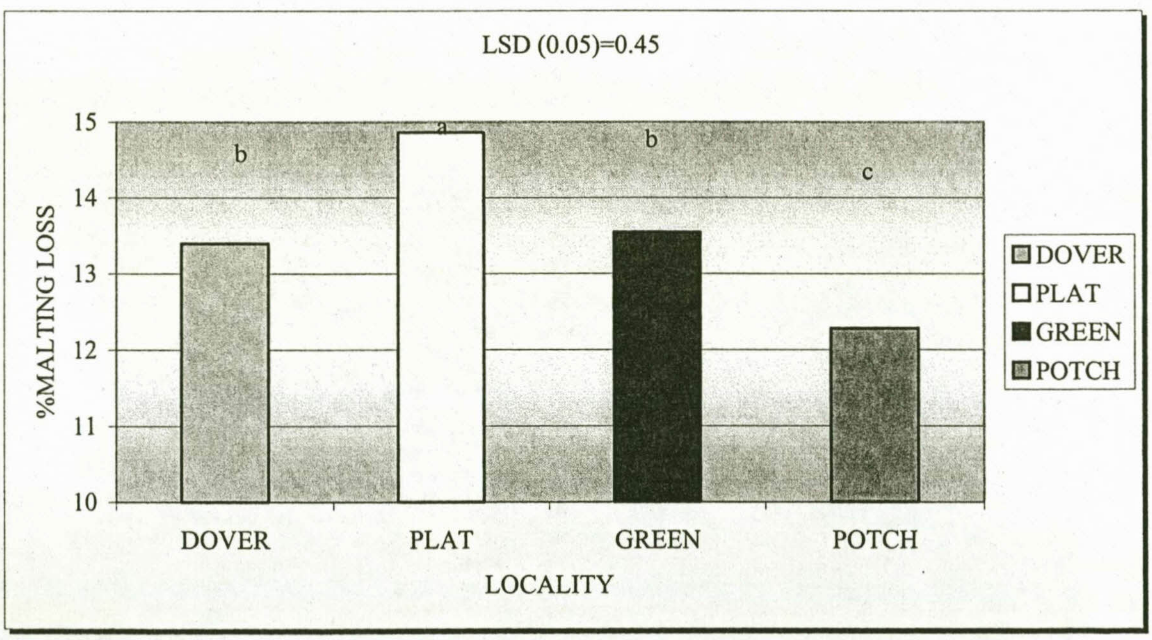


FIG.2.7

THE SIGNIFICANT DIFFERENCES BETWEEN THE %ML MEANS AT DIFFERENT LOCALITIES OF GROWTH

TABLE 2.7

ANALYSIS OF VARIANCE OF THE % MALTING LOSS OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	16.9868	16.9868	18.6717	0.0001	***
Main Effects						
CULTIVAR	23	85.9628	3.7375	4.1082	0.0000	***
LOCALITY	3	89.0323	29.6774	32.6210	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	62.7286	0.9091	0.9993	0.5078	ns
Error	47	42.7589	0.9098<-			
Total	143	316.5783				

P=0.05

ns=not significant

TABLE 2.8

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN MALTING LOSS VALUES

Rank	Cultivar	Mean	n	Groups not significantly Different
1	PAN 8272	14.497	6	a
2	PAN 8262	14.238	6	ab
3	SNK 3443	14.205	6	ab
4	SNK 3663	14.161	6	ab
5	SNK 3883	14.141	6	ab
6	SNK 3863	14.119	6	ab
7	NS 5655	14.055	6	ab
8	APN 881	13.972	6	abc
9	ADV 5010	13.617	6	abcd
10	PAN 8370	13.609	6	abcd
11	PAN 8061	13.465	6	abcde
12	NS 5511	13.401	6	abcde
13	SNK 393	13.346	6	bcde
14	PAN 8660	13.339	6	bcde
15	NK 283	13.188	6	bcdef
16	SNK 3567	12.930	6	cdef
17	PAN 8446	12.820	6	defg
18	NK 286	12.773	6	defg
19	PAN 8171	12.749	6	defg
20	SNK 3975	12.478	6	efg
21	SNK 3620	12.462	6	efg
22	SNK 3860	12.148	6	fg
23	SNK 3337	12.146	6	fg
24	PAN 8564	11.808	6	g

2.3.3 WATER ABSORPTION

The WA of the different sorghum cultivars, grown at different localities over 2 growing seasons, is shown in Table 2.9. The highly significant differences in the mean %WA of the different cultivars indicated by the ANOVA (Table 2.10) are illustrated by Fig. 2.8. It is clear that the %WA of SNK 3620 was the highest and WA values of this cultivar corresponded ($p>0.05$) only with SNK 3860, NS 5511 and NK 283 in WA value means. Cultivars such as PAN 8446, PAN 8061, PAN 8171, PAN 8272 and SNK 3443 all corresponded ($p>0.05$) with the lowest ranked cultivar for WA value means, namely SNK 3337 (Table 2.11; Fig. 2.8).

Significant differences (Table 2.10) between different seasons were found for WA value means, as illustrated by Fig. 2.9, with the 1997/98 season having the highest ($p<0.05$) values of the two seasons. The level of significance of the difference was not high, however (Table 2.10).

Significant differences in the WA value means of sorghum from different localities were also found (Table 2.10). Levels of WA were found to be higher at Potch ($p<0.05$). No significant differences were found between the WA value means at Plat and Green and both indicated lower values than those found at the other two localities (Fig. 2.10). Grain from Potch could thus be expected to have better abilities to release enzymes from the protein-starch-binding complex, as mentioned earlier and could therefore be expected to have better malting properties. The cultivar x locality interaction was again not significant.

TABLE 2.9

THE %WATER ABSORPTION DURING STEEPING OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES OVER 2 SEASONS

CULTIVAR	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999
ADV 5010	40.604	36.100	36.873	33.800	41.563	36.193	39.680	35.364	2.478	1.355
APN 881	39.300	33.980	37.752	37.505	38.784	41.452	38.612	37.645	0.788	3.738
NK 283	41.532	37.438	37.805	34.573	44.022	41.563	41.120	37.858	3.129	3.514
NK 286	36.880	34.266	34.780	33.033	39.244	34.679	36.968	33.993	2.233	0.856
NS 5511	38.592	38.305	35.400	36.920	42.280	46.331	38.757	40.518	3.443	5.081
NS 5655	40.616	35.260	40.760	37.917	41.004	37.105	40.793	36.761	0.196	1.362
PAN 8061	35.858	35.046	34.600	33.107	37.473	33.520	35.977	33.891	1.440	1.021
PAN 8171	36.385	32.214	31.188	33.727	39.220	38.537	35.598	34.826	4.074	3.302
PAN 8262	36.905	34.220	37.180	35.299	41.783	39.720	38.623	36.413	2.740	2.914
PAN 8272	33.713	33.433	33.700	34.153	39.704	36.793	35.706	34.793	3.463	1.769
PAN 8370	33.320	31.180	32.993	40.860	37.672	37.330	34.662	36.457	2.612	4.899
4PAN 8446	37.498	33.653	31.134	32.220	36.153	36.305	34.928	34.060	3.354	2.073
PAN 8564	38.280	38.280	34.573	32.294	38.252	36.625	37.035	35.733	2.132	3.091
PAN 8660	38.460	38.460	34.680	35.280	39.616	39.300	37.585	37.680	2.582	2.120
SNK 3337	36.093	29.894	29.714	30.941	37.093	33.900	34.300	31.578	4.003	2.077
SNK 3443	32.314	34.226	34.093	32.267	40.724	37.925	35.710	34.806	4.432	2.873
SNK 3567	34.780	35.320	34.806	33.453	38.072	37.797	35.886	35.523	1.893	2.179
SNK 3620	42.460	40.872	38.837	42.863	43.431	43.794	41.576	42.510	2.422	1.493
SNK 3663	33.680	33.727	33.660	32.533	42.032	37.830	36.457	34.696	4.828	2.778
SNK 3860	40.512	38.480	38.940	41.675	41.292	42.460	40.248	40.872	1.198	2.108
SNK 3863	36.900	36.158	33.187	36.453	39.157	40.192	36.414	37.601	3.014	2.249
SNK 3883	37.877	35.446	31.714	34.086	41.024	36.698	36.872	35.410	4.736	1.306
SNK 3939	35.653	34.153	36.173	34.506	41.992	36.171	37.939	34.943	3.519	1.078
SNK 3975	36.885	32.693	37.625	33.820	37.932	37.118	37.481	34.544	0.538	2.299
MEAN	37.396	35.444	35.247	34.933	39.840	38.530	37.455	36.186		
MIN	32.314	29.894	29.714	30.035	36.153	33.520	31.578	31.578		
MAX	42.460	43.300	40.760	42.863	44.022	46.331	42.509	42.509		
RANGE	10.146	13.406	11.046	12.827	7.870	12.811	10.931	10.931		
SD	2.676	3.001	2.818	3.210	2.166	3.226	2.469	2.469		

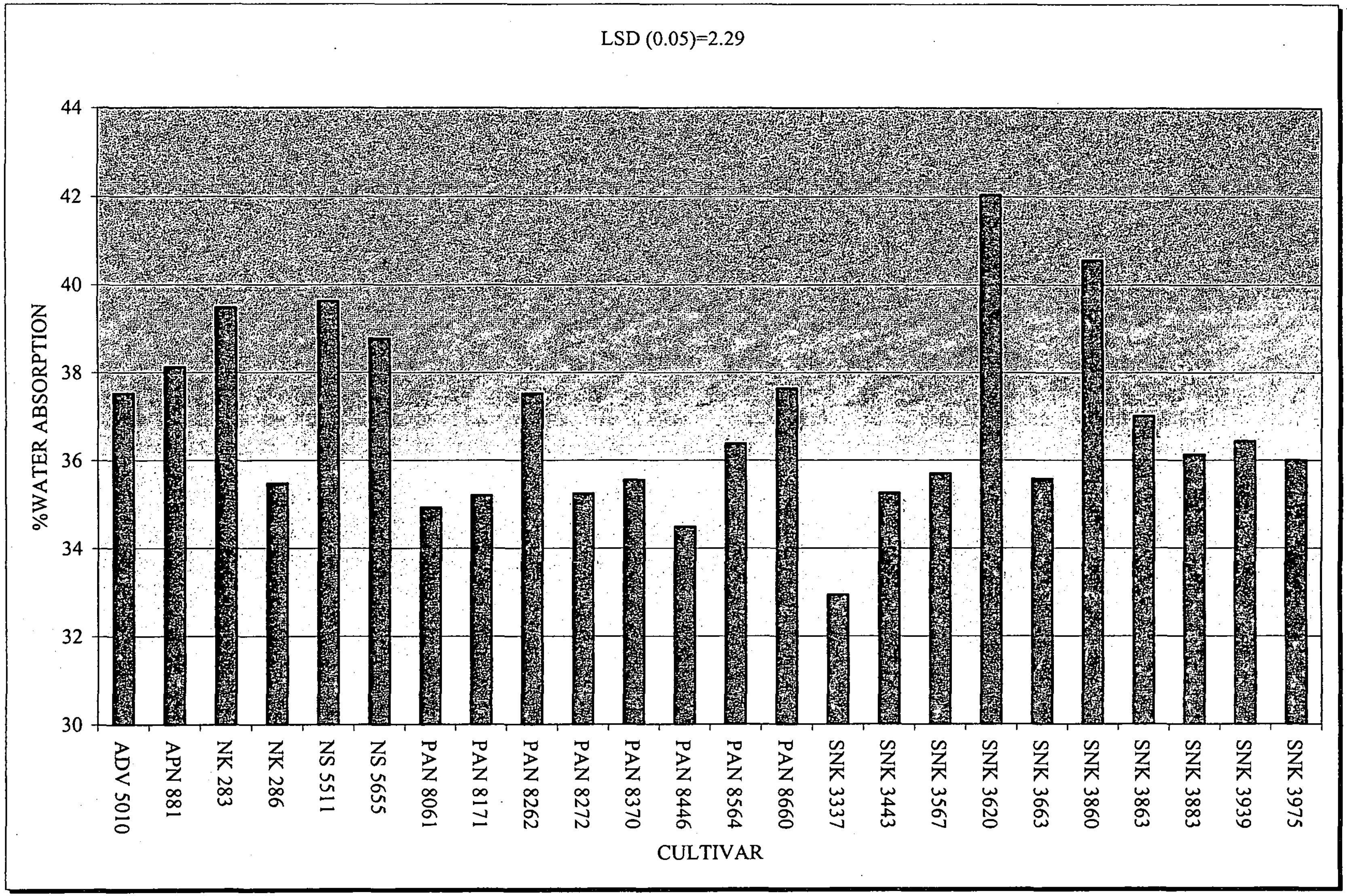


FIG. 2.8

THE SIGNIFICANT DIFFERENCE BETWEEN THE MEAN %WATER ABSORPTION OF DIFFERENT SORGHUM CULTIVARS

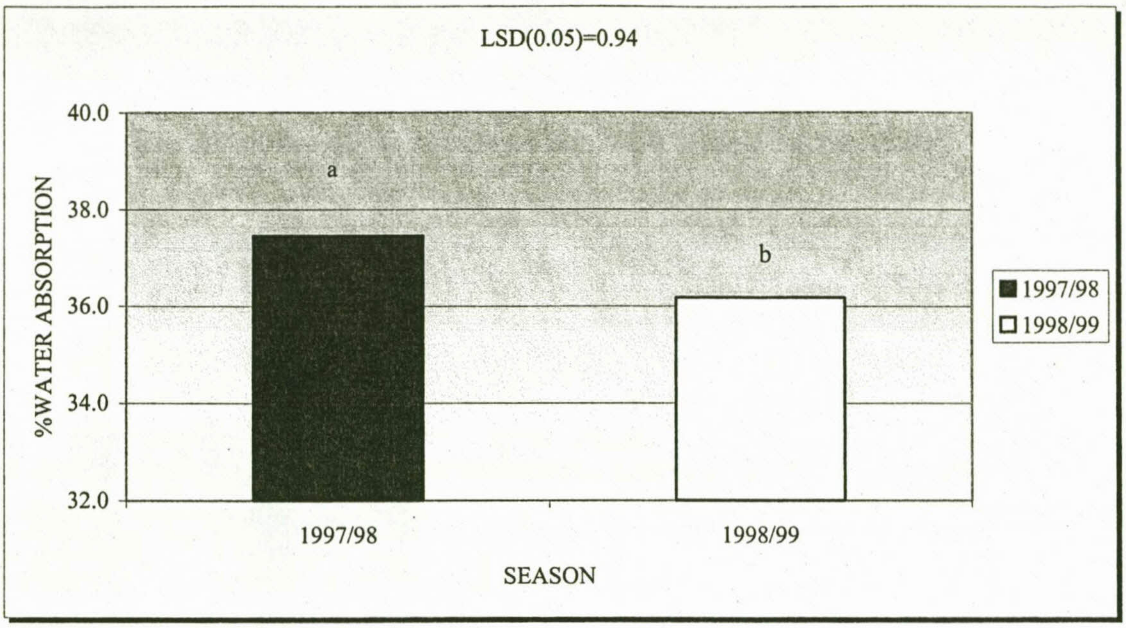


FIG. 2.9

THE SIGNIFICANT DIFFERENCES BETWEEN THE %WATER ABSORPTION MEANS OF SORGHUM CULTIVARS GROWN OVER DIFFERENT SEASONS

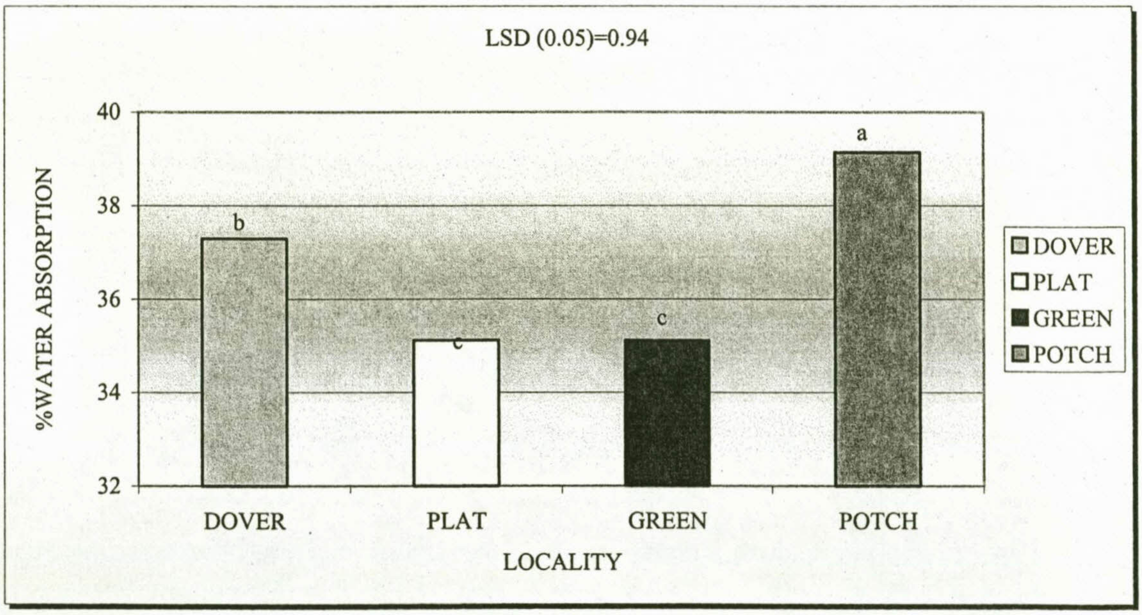


FIG. 2.10

THE SIGNIFICANT DIFFERENCES BETWEEN THE %WATER ABSORPTION MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES OF GROWTH

TABLE 2.10

ANALYSIS OF VARIANCE OF THE % WATER ABSORPTION OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	15.8941	15.8941	4.0869	0.0489	*
Main Effects						
CULTIVAR	23	553.3066	24.0568	6.1858	0.0000	***
LOCALITY	3	431.7498	143.9166	37.0060	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	255.0912	3.6970	0.9506	0.5815	ns
Error	47	182.7836	3.8890	<-		
Total	143	1543.7059				

P=0.05

ns=not significant

TABLE 2.11

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN WATER ABSORPTION VALUES

Rank	Cultivar	Mean	n	Groups of not significantly different
1	SNK 3620	42.043	6	a
2	SNK 3860	40.560	6	ab
3	NS 5511	39.638	6	abc
4	NK 283	39.489	6	abcd
5	NS 5655	38.777	6	bcde
6	APN 881	38.129	6	bcdef
7	PAN 8660	37.633	6	bcdefg
8	ADV 5010	37.522	6	bcdefg
9	PAN 8272	37.518	6	bcdefg
10	SNK 3863	37.008	6	bcdefg
11	SNK 3939	36.441	6	defg
12	PAN 8564	36.384	6	defg
13	SNK 3883	36.141	6	efg
14	SNK 3975	36.012	6	efgh
15	SNK 3567	35.705	6	efgh
16	SNK 3663	35.577	6	fgh
17	PAN 8370	35.559	6	fgh
18	NK 286	35.481	6	fgh
19	SNK 3443	35.258	6	fgh
20	PAN 8272	35.249	6	fgh
21	PAN 8171	35.212	6	fgh
22	PAN 8061	34.934	6	gh
23	PAN 8446	34.494	6	gh
24	SNK 3337	32.939	6	h

2.3.4 GERMINATIVE VIGOUR

Table 2.12 shows the GV values of cultivars over 2 seasons at 3 localities per season. Only highly significant differences in GV values were found for locality of growth while far lower significant differences were found for season of growth. Differences in cultivar value means were insignificant, as were the cultivar x locality interaction (Table 2.13).

Table 2.14 and Fig. 2.11 indicate the insignificant differences in cultivars. It is clear that no single cultivar differs significantly from all the other cultivars and values range from a mean of 80.00 to 93.67, i.e. a range of only 13.67 for 24 cultivar means. Although not significantly different from many other cultivars, APN 881 was again ranked in the top position for GV value means (Table 2.14) and differed from the 11^{th} to 24^{th} ranked cultivars. As the GV measures germination uniformity (Taylor & Dewar, 1996), it could be said that only cultivars ranked 1^{st}, 2^{nd} and 24^{th} differed in germination uniformity.

Differences ($p<0.05$) in seasons of growth, indicated in Fig. 2.12, are not that significant (Table 2.12), with the 1997/98 season being the better of the two.

The differences in GV value means at different localities are indicated in Fig. 2.13. Only GV value means at Potch differed ($p<0.05$) from the other localities, in it being the lowest ranked locality for GV (Fig. 2.13). Once again, the high WA levels found at Potch were proved not to enhance malting performance in the form of GV values.

TABLE 2.12

THE % GERMINATIVE VIGOUR OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES OVER 2 SEASONS

CULTIVAR	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999
ADV 5010	93.0	91.0	96.0	94.0	67.0	90.0	85.3	91.7	15.9	2.1
APN 881	96.0	98.0	96.0	94.0	93.0	85.0	95.0	92.3	1.7	6.7
NK 283	91.0	89.0	90.0	84.0	67.0	63.0	82.7	78.7	13.6	13.8
NK 286	90.0	86.0	90.0	90.0	72.0	62.0	84.0	79.3	10.4	15.1
NS 5511	94.0	92.0	90.0	89.0	81.0	75.0	88.3	85.3	6.7	9.1
NS 5655	97.0	94.0	98.0	91.0	88.0	80.0	94.3	88.3	5.5	7.4
PAN 8061	94.0	92.0	96.0	88.0	82.0	68.0	90.7	82.7	7.6	12.9
PAN 8171	92.0	95.0	96.0	87.0	82.0	68.0	90.0	83.3	7.2	13.9
PAN 8262	96.0	84.0	98.0	85.0	57.0	60.0	83.7	76.3	23.1	14.2
PAN 8272	96.0	92.0	97.0	98.0	73.0	75.0	88.7	88.3	13.6	11.9
PAN 8370	91.0	89.0	91.0	90.0	73.0	85.0	85.0	88.0	10.4	2.6
PAN 8446	95.0	92.0	84.0	89.0	81.0	64.0	86.7	81.7	7.4	15.4
PAN 8564	99.0	97.0	89.0	94.0	86.0	81.0	91.3	90.7	6.8	8.5
PAN 8660	84.0	90.0	86.0	87.0	70.0	84.0	80.0	87.0	8.7	3.0
SNK 3337	90.0	93.0	94.0	91.0	73.0	63.0	85.7	82.3	11.2	16.8
SNK 3443	93.0	94.0	97.0	94.0	88.0	79.0	92.7	89.0	4.5	8.7
SNK 3567	96.0	91.0	92.0	93.0	72.0	75.0	86.7	86.3	12.9	9.9
SNK 3620	90.0	94.0	91.0	90.0	88.0	69.0	89.7	84.3	1.5	13.4
SNK 3663	91.0	82.0	97.0	91.0	74.0	76.0	87.3	83.0	11.9	7.6
SNK 3860	82.0	90.0	93.0	90.0	94.0	85.0	89.7	88.3	6.7	2.9
SNK 3863	93.0	81.0	97.0	90.0	73.0	76.0	87.7	82.3	12.9	7.1
SNK 3883	91.0	89.0	95.0	91.0	81.0	90.0	89.0	90.0	7.2	1.0
SNK 3939	91.0	91.0	94.0	92.0	80.0	82.0	88.3	88.3	7.4	5.5
SNK 3975	95.0	90.0	98.0	89.0	85.0	71.0	92.7	83.3	6.8	10.7
MEAN	92.5	90.7	93.5	90.5	78.3	75.3	88.1	85.5		
MIN	82.0	81.0	84.0	84.0	57.0	60.0	80.0	76.3		
MAX	99.0	98.0	98.0	98.0	94.0	90.0	95.0	92.3		
RANGE	17.0	17.0	14.0	14.0	37.0	30.0	15.0	16.0		
SD	3.9	4.2	3.9	3.1	9.1	9.1	3.7	4.2		

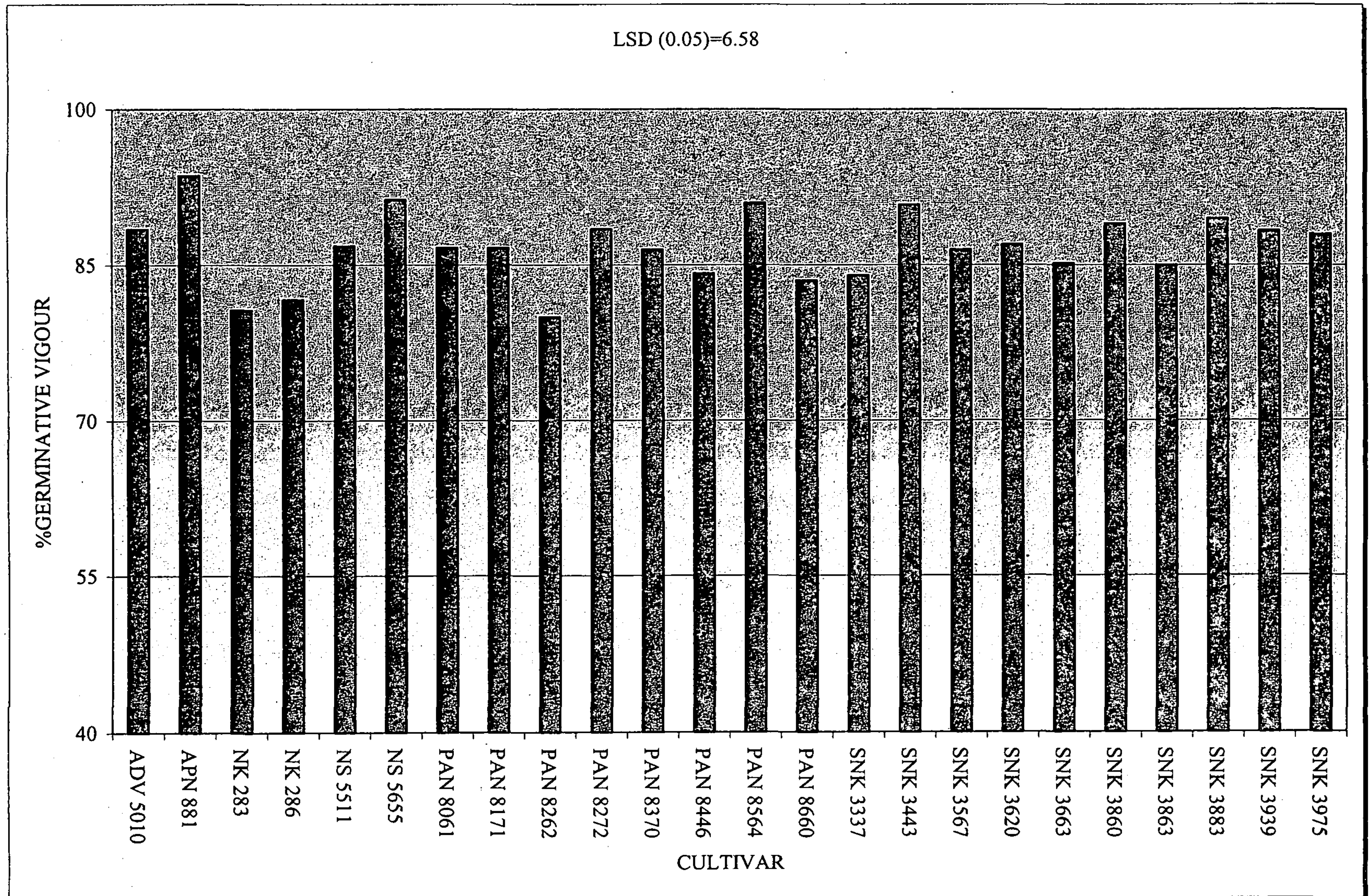


FIG. 2.11

THE INSIGNIFICANT DIFFERENCES IN THE GERMINATIVE VIGOUR VALUE MEANS OF DIFFERENT SORGHUM CULTIVARS

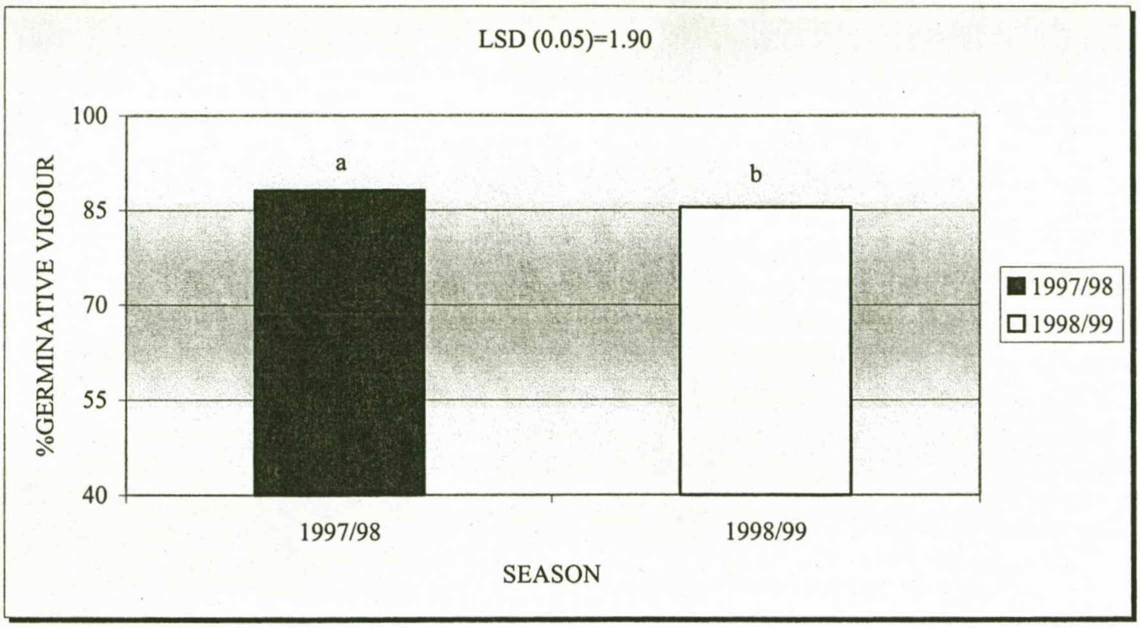


FIG. 2.12

THE SIGNIFICANT DIFFERENCES BETWEEN THE GERMINATIVE VIGOUR VALUE MEANS OVER DIFFERENT SEASONS OF GROWTH

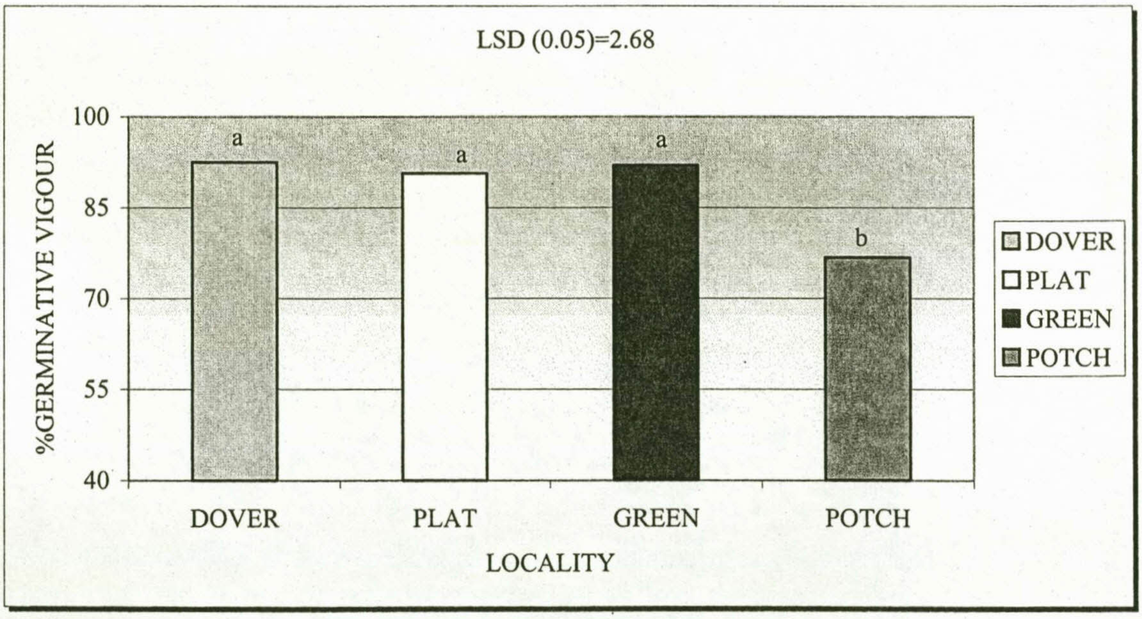


FIG. 2.13

THE SIGNIFICANT DIFFERENCES BETWEEN THE GERMINATIVE VIGOUR VALUE MEANS AT DIFFERENT LOCALITIES OF GROWTH

TABLE 2.13

ANALYSIS OF VARIANCE OF THE %GERMINATIVE VIGOUR OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	228.1667	228.1667	7.1168	0.0104	*
Main Effects						
CULTIVAR	23	1160.8194	50.4704	1.5742	0.0933	ns
LOCALITY	3	7216.6667	2405.5556	75.0323	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	2028.1667	29.3937	0.9168	0.6335	ns
Error	47	1506.8333	32.060	<-		
Total	143	12599.7500				

* P=0.05

ns=not significant

TABLE 2.14

RANKING OF CULTIVARS ACCORDING TO INSIGNIFICANT DIFFERENCES IN MEAN GERMINATIVE VIGOUR VALUES OF SORGHUM CULTIVARS

Rank	Cultivar	Mean	n	Groups not significantly different
1	APN 881	93.670	6	a
2	NS 5655	91.330	6	ab
3	PAN 8564	91.000	6	ab
4	SNK 3443	90.830	6	ab
5	SNK 3883	89.500	6	abc
6	SNK 3860	89.000	6	abc
7	ADV 5010	88.500	6	abc
8	PAN 8272	88.500	6	abc
9	SNK 3939	88.330	6	abc
10	SNK 3975	88.000	6	abcd
11	SNK 3620	87.000	6	bcde
12	NS 5511	86.830	6	bcde
13	PAN 8061	86.670	6	bcde
14	PAN 8171	86.670	6	bcde
15	SNK 3567	86.500	6	bcdef
16	PAN 8370	86.500	6	bcdef
17	SNK 3663	85.170	6	bcdef
18	SNK 3863	85.000	6	bcdef
19	PAN 8446	84.170	6	cdef
20	SNK 3337	84.000	6	cdef
21	PAN 8660	83.500	6	cdef
22	NK 286	81.670	6	def
23	NK 283	80.670	6	ef
24	PAN 8262	80.000	6	f

2.3.5 GERMINATIVE ENERGY

The GE of 24 cultivars at different localities and seasons are shown in Table 2.15. From Table 2.16 it is observed that differences in the %GE means, are not significant for cultivars. The differences are illustrated by Fig. 2.14, where differences, although none of them significant, are seen. Table 2.17 shows that only APN 881, SNK 3860, NS 5655 and SNK 3620 differed from PAN 8660, NK 283 and PAN 8262. As seen for GV, APN 881 is again ranked in the top position, although its GE value means is not significantly higher than most of the other cultivars. PAN 8660 and NK 283 corresponded ($p>0.05$) with the lowest ranked cultivar, namely PAN 8262 for GE value means. These three cultivars were also the only ones not to correspond with the highest ranked cultivar for GE value means, namely APN 881. Except for PAN 8660, NK 283 and PAN 8262, all cultivars indicated acceptable potential germinability during malting (Taylor & Dewar, 1996).

Compared to GV (Table 2.15), seasonal differences for the GE value means, were much more significant (Table 2.16). From Fig. 2.15 it is clear that GE value means were higher during the 1998/99 season, while GV value means were higher during the 1997/98 season. This may implicate that lower GE values are reached in a season such as 1997/98, when GV values were higher, because of a more rapid germination rate. When high levels of germination are already reached after 48 h, lower germination counts could be found after 72h. The season of growth could influence germination rates, but as the significance of GV differences was low, more research is necessary two identify a seasonal trend in germination rates. Great differences ($p<0.05$) between the GE value means of sorghum grown at different localities were found (Table 2.16). The GE values followed exactly the same pattern at the localities as for GV, with Potch being the worst performing locality regarding GE (Fig. 2.15; Table 2.15). Therefore, Potch overall indicated poor malting performances, despite the good WA values found in 2.3.3, indicating that good WA levels might not be an indication of good malting performance.

TABLE 2.15

THE %GERMINATIVE ENERGY OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES OVER 2 SEASONS

CULTIVAR	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999
ADV 5010	96.0	97.0	98.0	97.0	70.0	92.0	88.0	95.3	15.6	2.9
APN 881	97.0	96.0	98.0	95.0	98.0	96.0	97.7	95.7	0.6	0.6
NK 283	95.0	96.0	94.0	95.0	73.0	78.0	87.3	89.7	12.4	10.1
NK 286	94.0	99.0	98.0	96.0	74.0	88.0	88.7	94.3	12.9	5.7
NS 5511	97.0	98.0	96.0	96.0	84.0	92.0	92.3	95.3	7.2	3.1
NS 5655	98.0	97.0	99.0	96.0	89.0	95.0	95.3	96.0	5.5	1.0
PAN 8061	97.0	96.0	100.0	97.0	86.0	91.0	94.3	94.7	7.4	3.2
PAN 8171	95.0	94.0	98.0	96.0	82.0	90.0	91.7	93.3	8.5	3.1
PAN 8262	97.0	89.0	99.0	92.0	60.0	72.0	85.3	84.3	22.0	10.8
PAN 8272	97.0	93.0	99.0	99.0	77.0	87.0	91.0	93.0	12.2	6.0
PAN 8370	96.0	99.0	94.0	95.0	77.0	88.0	89.0	94.0	10.4	5.6
PAN 8446	97.0	94.0	97.0	92.0	87.0	92.0	93.7	92.7	5.8	1.2
PAN 8564	99.0	94.0	97.0	99.0	88.0	95.0	94.7	96.0	5.9	2.6
PAN 8660	92.0	96.0	93.0	97.0	72.0	90.0	85.7	94.3	11.8	3.8
SNK 3337	92.0	96.0	95.0	98.0	85.0	88.0	90.7	94.0	5.1	5.3
SNK 3443	97.0	98.0	98.0	97.0	80.0	97.0	91.7	97.3	10.1	0.6
SNK 3567	97.0	97.0	96.0	98.0	77.0	89.0	90.0	94.7	11.3	4.9
SNK 3620	92.0	99.0	98.0	98.0	92.0	95.0	94.0	97.3	3.5	2.1
SNK 3663	95.0	98.0	100.0	100.0	80.0	95.0	91.7	97.7	10.4	2.5
SNK 3860	92.0	100.0	97.0	98.0	96.0	95.0	95.0	97.7	2.6	2.5
SNK 3863	95.0	94.0	98.0	96.0	75.0	91.0	89.3	93.7	12.5	2.5
SNK 3883	94.0	94.0	96.0	94.0	83.0	90.0	91.0	92.7	7.0	2.3
SNK 3939	93.0	97.0	96.0	93.0	83.0	95.0	90.7	95.0	6.8	2.0
SNK 3975	96.0	89.0	98.0	98.0	89.0	95.0	94.3	94.0	4.7	4.6
ADV 5010	96.0	97.0	98.0	97.0	70.0	92.0	88.0	95.3		
APN 881	97.0	96.0	98.0	95.0	98.0	96.0	97.7	95.7		
NK 283	95.0	96.0	94.0	95.0	73.0	78.0	87.3	89.7		
NK 286	94.0	99.0	98.0	96.0	74.0	88.0	88.7	94.3		
NS 5511	97.0	98.0	96.0	96.0	84.0	92.0	92.3	95.3		

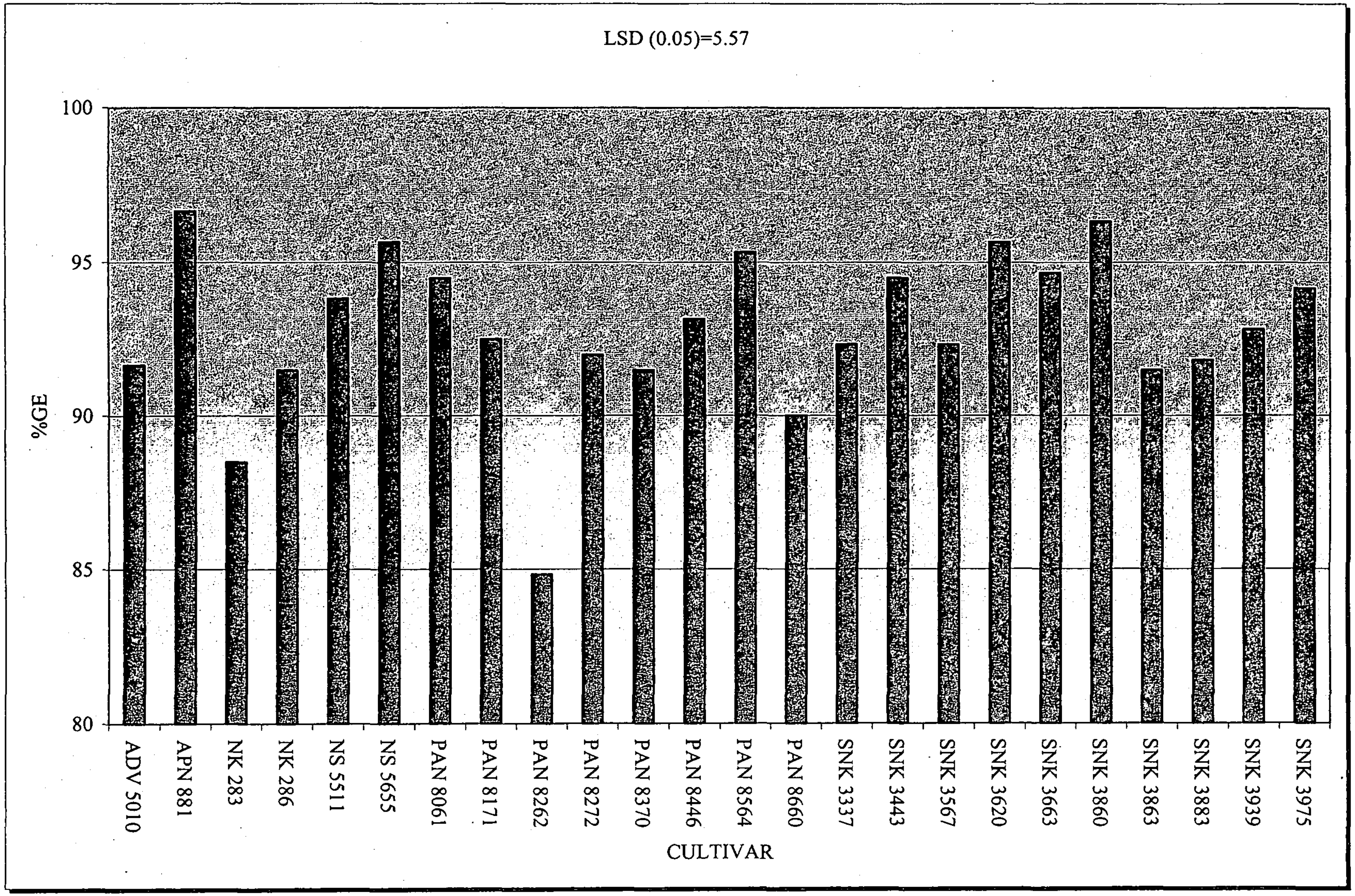


FIG. 2.14

THE INSIGNIFICANT DIFFERENCES IN THE MEAN %GERMINATIVE ENERGY OF DIFFERENT SORGHUM CULTIVARS

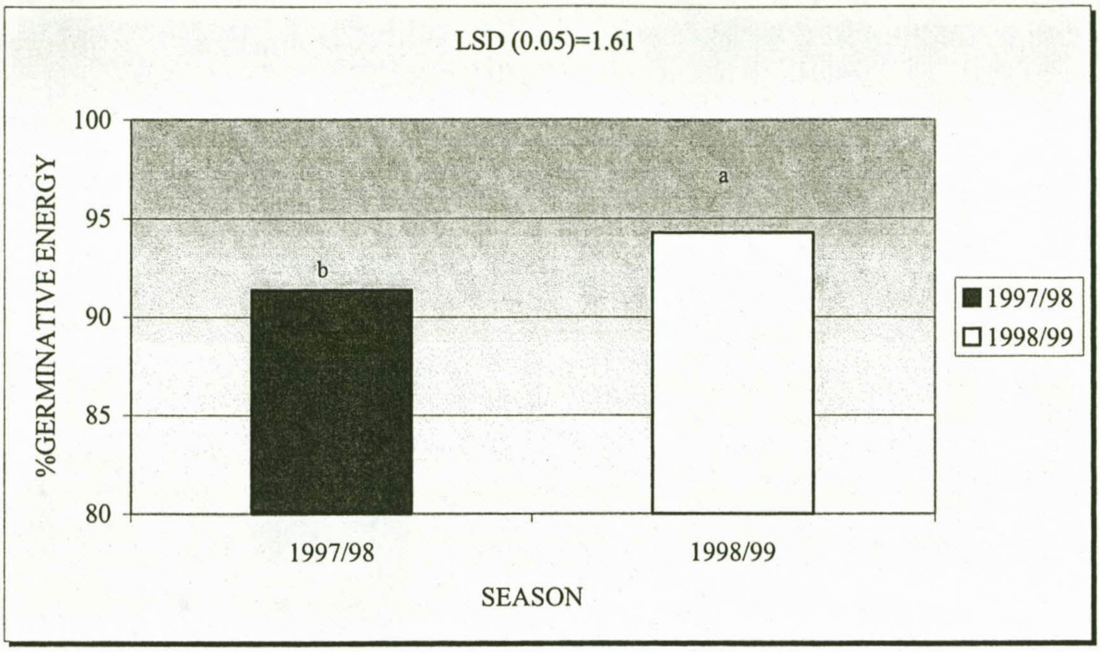


FIG. 2.15

THE SIGNIFICANT DIFFERENCES BETWEEN THE GERMINATIVE ENERGY VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS OF GROWTH

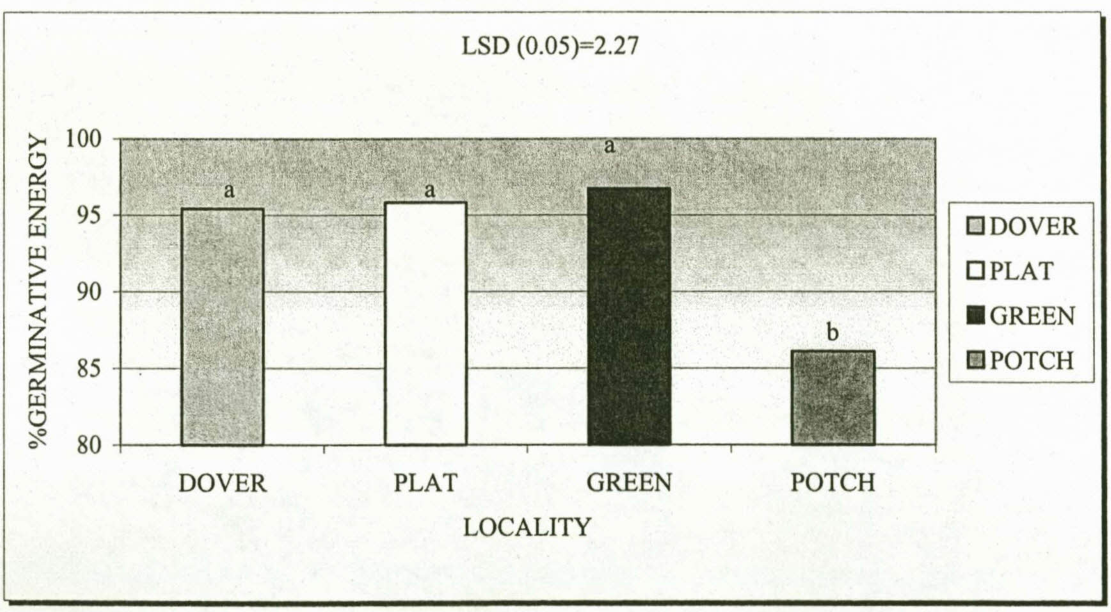


FIG. 2.16

THE SIGNIFICANT DIFFERENCES BETWEEN THE GERMINATIVE ENERGY VALUE MEANS AT DIFFERENT LOCALITIES OF GROWTH

TABLE 2.16

ANALYSIS OF VARIANCE OF THE %GERMINATIVE ENERGY OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	412.5104	412.5104	17.9354	0.0001	***
Main Effects						
CULTIVAR	23	581.3299	25.2752	1.0989	0.3810	ns
LOCALITY	3	3395.1840	1131.7280	49.2060	0.0000	***
Interaction						
CULTIVAR x LOCALITY		1509.9861	21.8839	0.9515	0.5802	ns
Error	47	1080.9896	22.9998	<-		
Total	143	7254.6597				

P=0.05

ns=not significant

TABLE 2.17

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN GE VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	APN 881	96.670	6	a
2	SNK 3860	96.330	6	a
3	NS 5655	95.670	6	a
4	SNK 3620	95.670	6	a
5	PAN 8564	95.330	6	ab
6	SNK 3663	94.670	6	ab
7	PAN 8061	94.500	6	ab
8	SNK 3443	94.500	6	ab
9	SNK 3975	94.170	6	ab
10	NS 5511	93.830	6	abc
11	PAN 8446	93.170	6	abc
12	SNK 3939	92.830	6	abc
13	PAN 8171	92.500	6	abc
14	SNK 3337	92.330	6	abc
15	SNK 3567	92.330	6	abc
16	PAN 8272	92.000	6	abc
17	SNK 3883	91.830	6	abc
18	ADV 5010	91.670	6	abc
19	SNK 3863	91.500	6	abc
20	NK 286	91.500	6	abc
21	PAN 8370	91.500	6	abc
22	PAN 8660	90.000	6	bcd
23	NK 283	88.500	6	cd
24	PAN 8262	84.830	6	d

2.3.6 FREE AMINO NITROGEN

The FAN values of malts from different sorghum cultivars over 2 seasons and 3 localities per season, are indicated in Table 2.18. From the ANOVA it is clear that two significant main effects for FAN exist (Table 2.19), namely cultivar and locality. The differences between the FAN value means of cultivars are shown in Table 2.20. APN 881 was the top placed cultivar with regard to FAN value and corresponds only with SNK 3620 and NS 5511 in FAN value means.. PAN 8370, PAN 8262, PAN 8171 and SNK 3883 ($p>0.05$) fell among the lowest ranked cultivars. The higher ranked cultivars for FAN values can be expected to have good malting properties, as FAN in malt is essential to yeasts for survival and fermentation during the brewing stage of beer production, as discussed in Chapter 1.

Differences in FAN values at different localities were also significant (Table 2.19). Green showed the best performance with respect to FAN values, as seen in Fig. 2.19, while Plat had lower FAN values than Green and Potch. Neither the influence of season of growth (Fig. 2.18), nor the cultivar x locality interaction was significant (Table 2.19).

TABLE 2.18

THE FREE AMINO NITROGEN (mg FAN/100g) OF MALTS FROM SORGHUM CULTIVARS AT DIFFERENT LOCALITIES OVER 2 SEASONS

CULTIVAR	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999
ADV 5010	118.219	102.376	107.532	102.058	93.810	83.216	106.520	95.883	12.236	10.972
APN 881	143.990	124.779	193.276	236.382	193.723	146.213	176.996	169.125	28.585	59.224
NK 283	81.941	106.616	128.923	157.717	122.001	92.026	110.955	118.786	25.364	34.495
NK 286	99.122	87.175	113.474	164.012	95.533	106.024	102.710	119.070	9.493	40.045
NS 5511	123.858	114.061	125.581	146.509	180.452	152.806	143.297	137.792	32.189	20.791
NS 5655	107.967	84.476	118.835	140.208	124.810	91.120	117.204	105.268	8.539	30.441
PAN 8061	101.756	81.854	132.647	105.137	85.333	79.715	106.579	88.902	24.023	14.100
PAN 8171	83.976	56.247	131.051	141.921	71.455	62.350	95.494	86.840	31.423	47.800
PAN 8262	83.869	69.115	111.436	147.771	81.742	51.911	92.349	89.599	16.564	51.107
PAN 8272	86.219	86.673	148.750	125.328	82.924	69.775	105.965	93.925	37.090	28.478
PAN 8370	75.043	83.419	78.407	113.437	98.876	68.468	84.108	88.441	12.899	22.901
PAN 8446	94.663	73.948	104.213	116.669	98.762	87.669	99.213	92.762	4.791	21.811
PAN 8564	91.823	91.823	123.514	156.730	146.917	146.917	120.751	131.823	27.651	34.987
PAN 8660	89.967	89.967	128.854	120.550	94.807	94.807	104.543	101.775	21.193	16.439
SNK 3337	100.233	85.986	100.955	157.821	101.630	93.577	100.939	112.462	0.699	39.466
SNK 3443	112.680	99.912	130.912	155.811	134.988	148.445	126.194	134.723	11.879	30.371
SNK 3567	89.263	94.482	116.052	150.449	86.608	96.127	97.308	113.686	16.287	31.848
SNK 3620	127.595	114.564	121.908	202.739	172.076	135.867	140.526	151.057	27.470	46.008
SNK 3663	106.383	94.477	131.480	150.134	96.909	96.645	111.591	113.752	17.864	31.526
SNK 3860	104.979	127.813	111.633	145.917	159.430	125.911	125.348	133.214	29.703	11.042
SNK 3863	78.061	76.145	98.999	171.211	69.696	72.143	82.252	106.500	15.094	56.077
SNK 3883	93.013	88.462	122.843	111.239	73.513	66.207	96.457	88.636	24.845	22.516
SNK 3939	98.255	79.522	122.057	142.725	123.561	93.877	114.624	105.375	14.196	33.133
SNK 3975	93.449	73.802	118.962	159.026	88.062	79.653	100.158	104.160	16.506	47.605
MEAN	99.430	91.154	121.762	146.729	111.567	97.561	110.920	111.815		
MIN	75.043	56.247	78.407	102.058	69.696	51.911	82.252	86.840		
MAX	143.990	127.813	193.276	236.382	193.723	152.806	176.996	169.125		
RANGE	68.948	71.566	114.869	134.324	124.026	100.895	94.744	82.285		
SD	16.716	17.365	20.866	30.144	35.843	29.791	20.772	21.795		

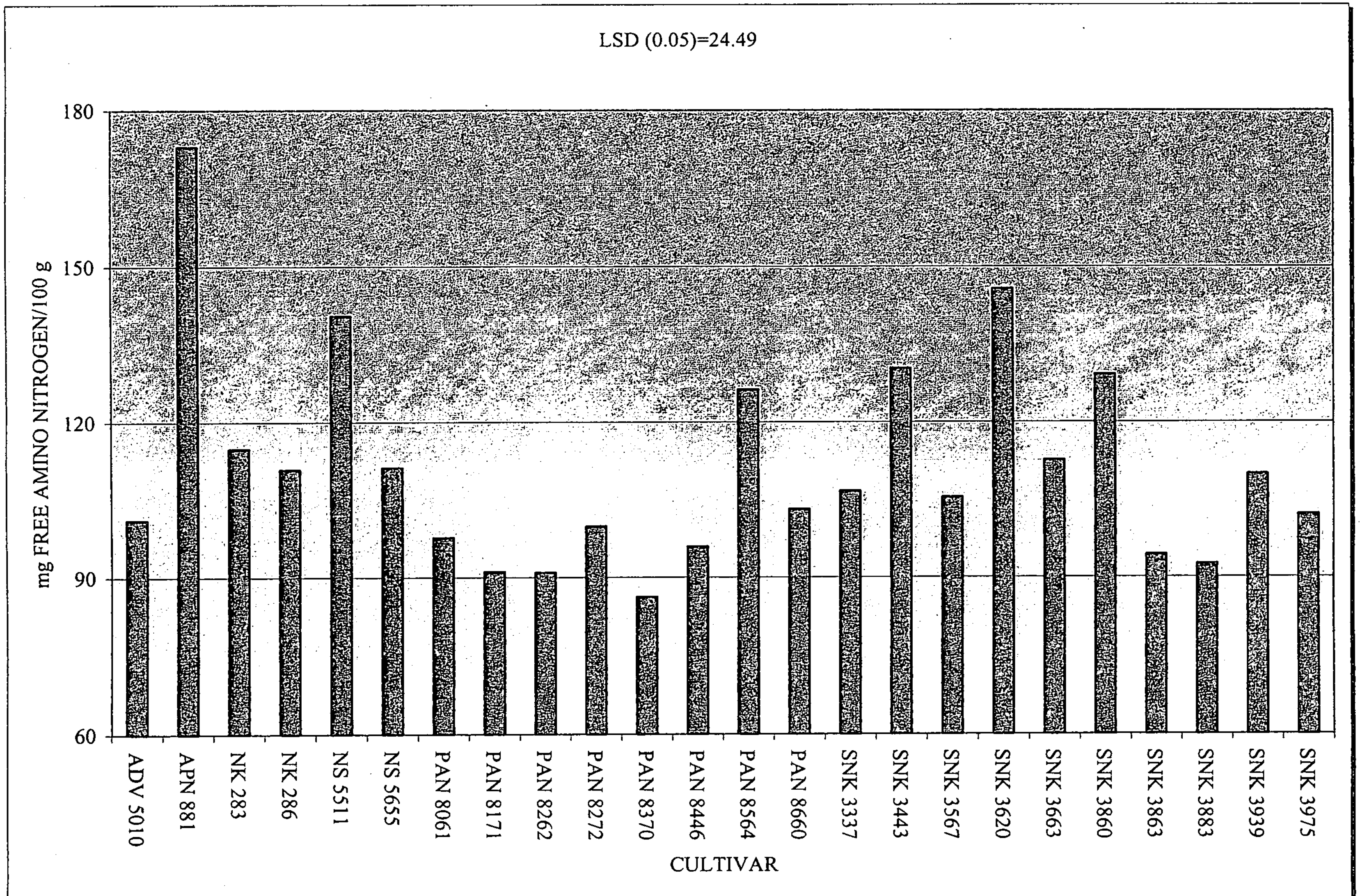


FIG. 2.17

THE SIGNIFICANT DIFFERENCE BETWEEN THE MEAN FREE AMINO NITROGEN VALUES OF DIFFERENT SORGHUM CULTIVARS

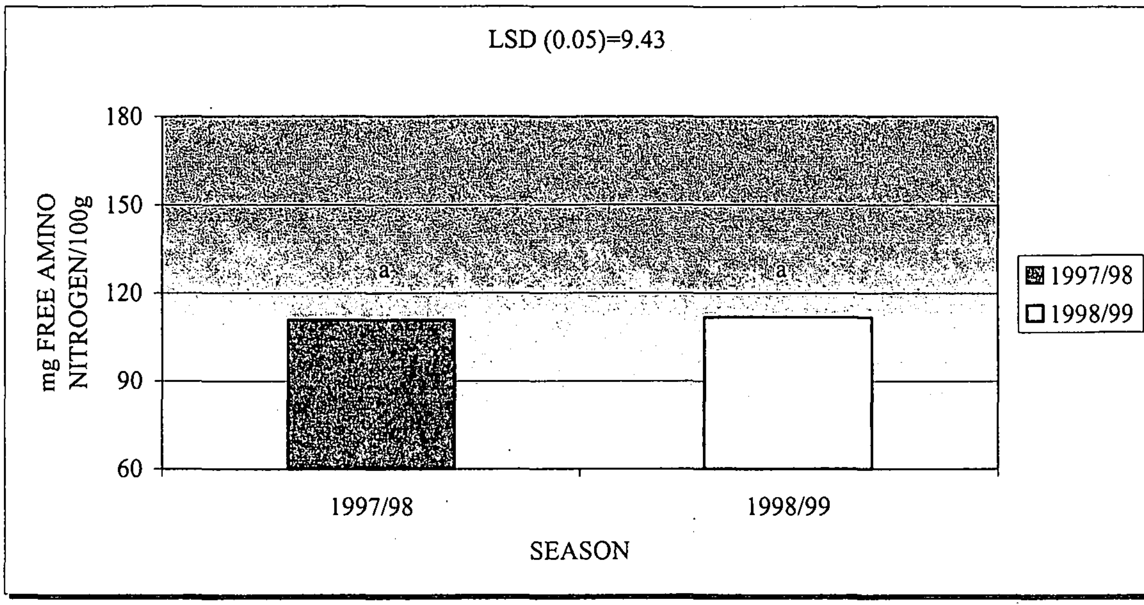


FIG. 2.18

THE INSIGNIFICANT DIFFERENCES BETWEEN THE FREE AMINO NITROGEN VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS OF GROWTH

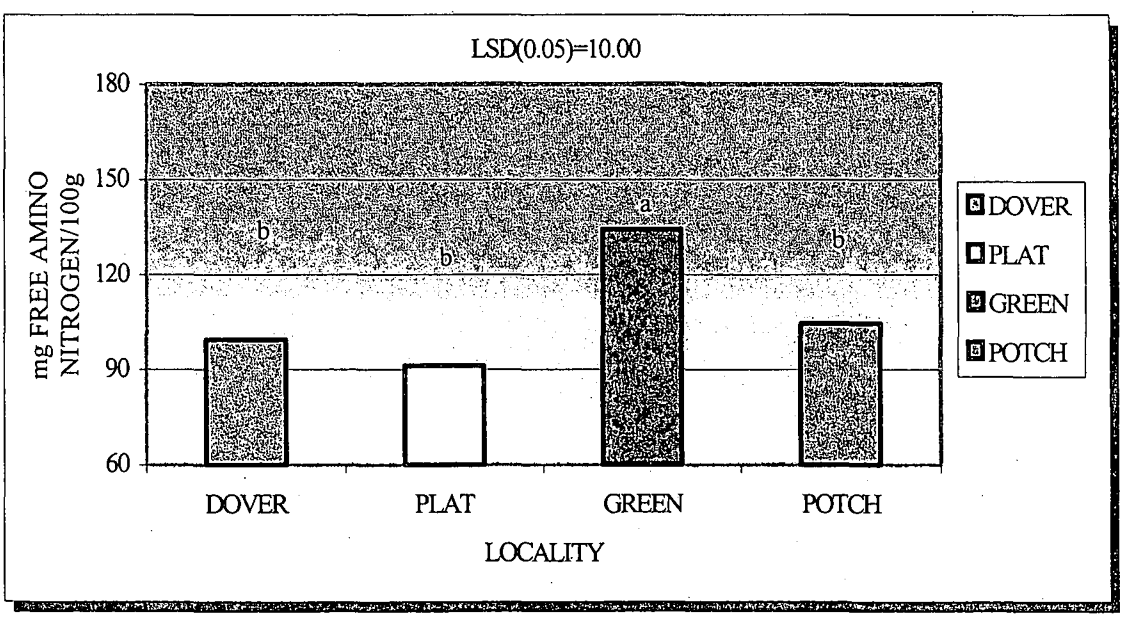


FIG. 2.19

THE SIGNIFICANT DIFFERENCES BETWEEN THE FAN VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES OF GROWTH

TABLE 2.19

ANALYSIS OF VARIANCE OF THE FREE AMINO NITROGEN OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	720.8192	720.8192	1.6217	0.2091	ns
Main Effects						
CULTIVAR	23	44206.3194	1922.0139	4.3240	0.0000	***
LOCALITY	3	41263.6186	13754.5400	30.9441	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	24096.0650	349.2183	0.7856	0.8214	ns
Error	47	20891.3496	444.4968<-			
Total	143	144644.2269				

* P=0.05

ns=not significant

TABLE 2.20

RANKING OF CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN FREE AMINO NITROGEN VALUES OF SORGHUM CULTIVARS

Rank	Cultivar	Mean	n	Groups not significantly different
1	APN 881	173.061	6	a
2	SNK 3620	145.791	6	ab
3	NS 5511	140.545	6	abc
4	SNK 3443	130.458	6	bcd
5	SNK 3860	129.281	6	bcde
6	PAN 8564	126.287	6	bcdef
7	NK 283	114.871	6	bcdefg
8	SNK 3663	112.671	6	cdefg
9	NS 5655	111.236	6	cdefg
10	NK 286	110.890	6	cdefg
11	SNK 3939	110.000	6	cdefg
12	SNK 3337	106.700	6	defg
13	SNK 3567	105.497	6	defg
14	PAN 8660	103.159	6	defg
15	SNK 3975	102.159	6	defg
16	ADV 5010	101.202	6	defg
17	PAN 8272	99.945	6	defg
18	PAN 8061	97.740	6	efg
19	PAN 8446	95.988	6	fg
20	SNK 3863	94.376	6	fg
21	SNK 3883	92.546	6	g
22	PAN 8171	91.167	6	g
23	PAN 8262	90.974	6	g
24	PAN 8370	86.275	6	g

2.3.7 DIASTATIC POWER

The DP values of the malts of 24 sorghum cultivars over 2 seasons at 3 localities per season, are incicated in Table 2.21. From the ANOVA for the DP values of sorghum cultivars (Table 2.22), it is clear that all main effects are significant, but once again, not the cultivar x locality interaction. The highly significant differences in the DP values of cultivars are seen in Fig. 2.14. No single cultivar differed ($p<0.05$) from all the other cultivars. For example, the top ranked cultivar APN 881 (Table 2.22) did not differ significantly from the second placed NS 5511 or SNK 3443 in third place. These three cultivars were also among the top four ranked cultivars for FAN values (Table 2.20). PAN 8370, PAN 8181, PAN 8272 and SNK 3863 were amongst the lowest ranked cultivars for FAN value means (Table 2.20).

Seasonal differences ($p<0.05$) were seen for DP (Table 2.21), but differences are of less significance. DP values were lower during the 1997/98 season (Fig. 2.22).

Highly significant differences in DP value means at different localities, are also observed (Table 2.22) and each locality differed ($p<0.05$) from all the other localities (Fig. 2.21). As in the case of FAN value means, Green was the top positioned locality for DP, but Potch was the lowest ranked locality for DP value means. Potch was found to have good WA values (2.3.3) and were expected to have good DP values, as well as other malting quality parameters, due to the expected higher release of enzymes from the protein-starch-binding matrix, as explained in 2.3.3, but this was found not to be the case.

TABLE 2.21

THE DIASTATIC POWER (SDU/g) OF THE MALT OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES OVER 2 SEASONS

CULTIVAR	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999	1997/1998	1998/1999
ADV 5010	39.282	34.149	43.961	41.437	20.821	29.095	34.688	34.894	12.235	6.204
APN 881	51.442	33.750	53.721	38.298	50.788	46.526	51.984	39.525	1.540	6.476
NK 283	26.038	33.934	42.119	42.628	25.165	17.387	31.107	31.316	9.547	12.822
NK 286	40.469	30.495	42.615	50.733	23.073	36.000	35.386	39.076	10.717	10.464
NS 5511	42.512	33.967	46.305	44.179	49.985	47.846	46.267	41.997	3.737	7.192
NS 5655	40.291	29.625	40.070	47.516	30.990	29.076	37.117	35.405	5.307	10.491
PAN 8061	37.553	28.025	44.392	47.675	21.699	26.632	34.548	34.110	11.641	11.768
PAN 8171	31.525	25.906	33.222	42.505	21.804	18.951	28.850	29.121	6.161	12.102
PAN 8262	36.808	28.728	50.974	54.761	25.667	21.568	37.816	35.019	12.684	17.468
PAN 8272	35.765	23.977	39.093	44.582	18.044	24.291	30.967	30.950	11.315	11.806
PAN 8370	26.444	27.273	35.408	35.952	22.407	22.292	28.086	28.506	6.654	6.913
PAN 8446	41.703	32.392	39.749	43.594	23.719	29.045	35.057	35.010	9.868	7.620
PAN 8564	33.297	33.297	45.583	45.583	33.173	28.867	37.351	35.916	7.129	8.660
PAN 8660	30.888	30.888	42.805	42.805	22.087	31.114	31.926	34.936	10.398	6.816
SNK 3337	37.744	31.105	42.516	53.776	23.368	32.737	34.543	39.206	9.967	12.645
SNK 3443	38.194	39.708	41.512	50.304	37.650	40.124	39.119	43.379	2.090	6.001
SNK 3567	31.901	29.893	36.442	52.128	18.211	33.053	28.851	38.358	9.490	12.029
SNK 3620	31.819	33.072	42.437	48.477	41.421	33.368	38.559	38.306	5.859	8.810
SNK 3663	39.306	30.205	46.517	48.696	14.705	30.494	33.509	36.465	16.679	10.593
SNK 3860	35.343	35.765	42.129	46.121	21.103	45.061	32.858	42.316	10.731	5.698
SNK 3863	29.075	26.228	39.256	48.269	17.526	25.657	28.619	33.385	10.872	12.894
SNK 3883	36.692	31.745	42.546	46.759	15.608	14.329	31.615	30.944	14.168	16.230
SNK 3939	42.722	32.283	49.527	38.893	32.836	25.368	41.695	32.181	8.392	6.763
SNK 3975	38.063	37.031	48.163	54.079	27.607	23.453	37.945	38.188	10.279	15.346
MEAN	36.453	31.393	42.961	46.240	26.644	29.681	35.353	35.771		
MIN	26.038	23.977	33.222	35.952	14.705	14.329	28.086	28.506		
MAX	51.442	39.708	53.721	54.761	50.788	47.846	51.984	43.379		
RANGE	25.404	15.730	20.499	18.810	36.082	33.517	23.897	14.873		
SD	5.734	3.670	4.800	5.024	9.884	8.778	5.662	4.082		

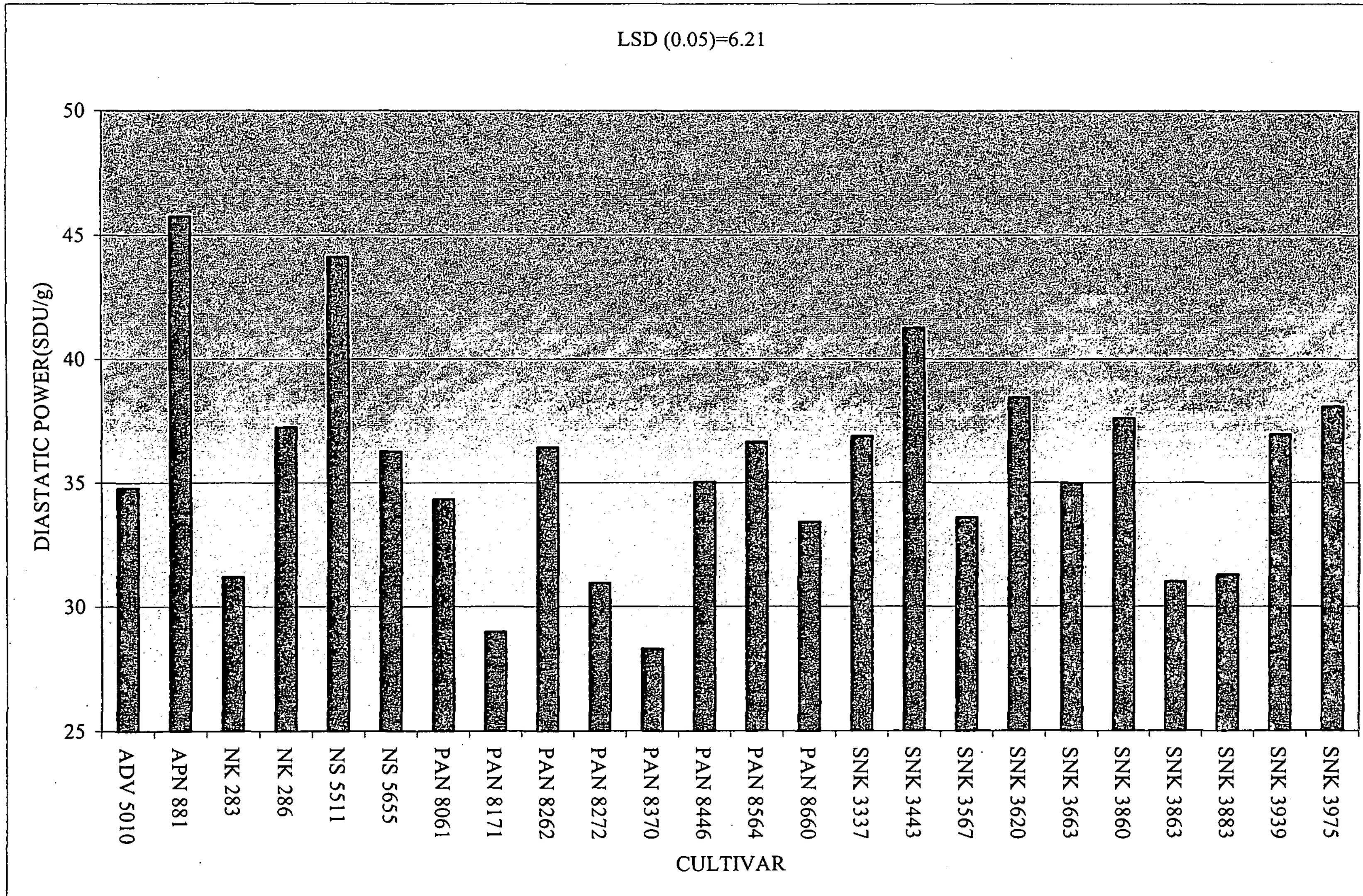


FIG. 2.20

THE SIGNIFICANT DIFFERENCE BETWEEN THE MEAN DIASTATIC POWER VALUES OF DIFFERENT SORGHUM CULTIVARS

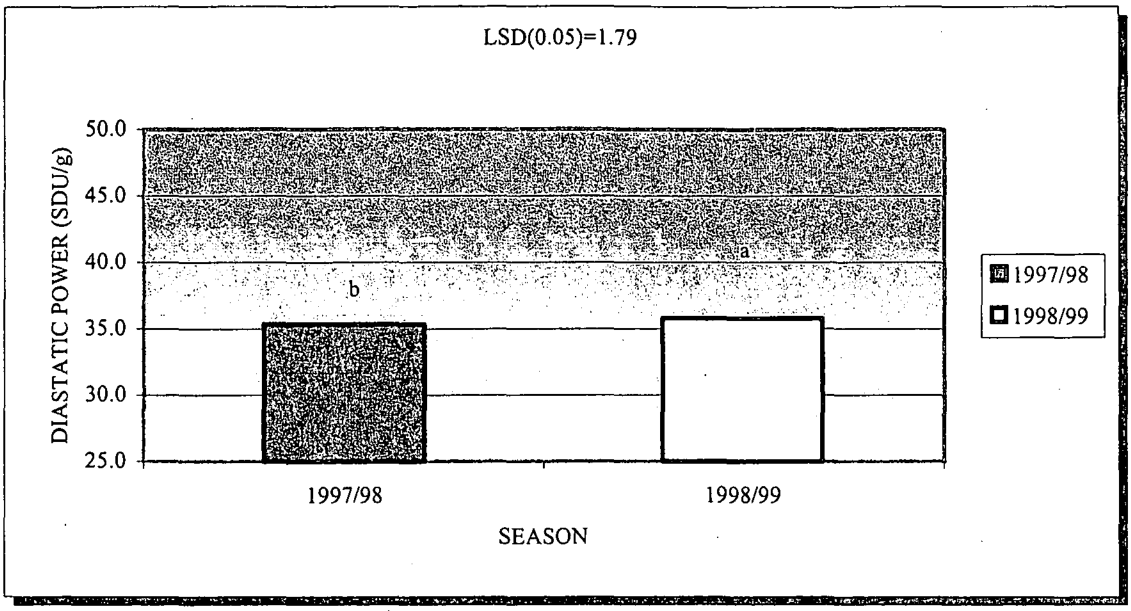


FIG. 2.21

THE SIGNIFICANT DIFFERENCES BETWEEN THE DIASTATICE POWER VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS OF GROWTH

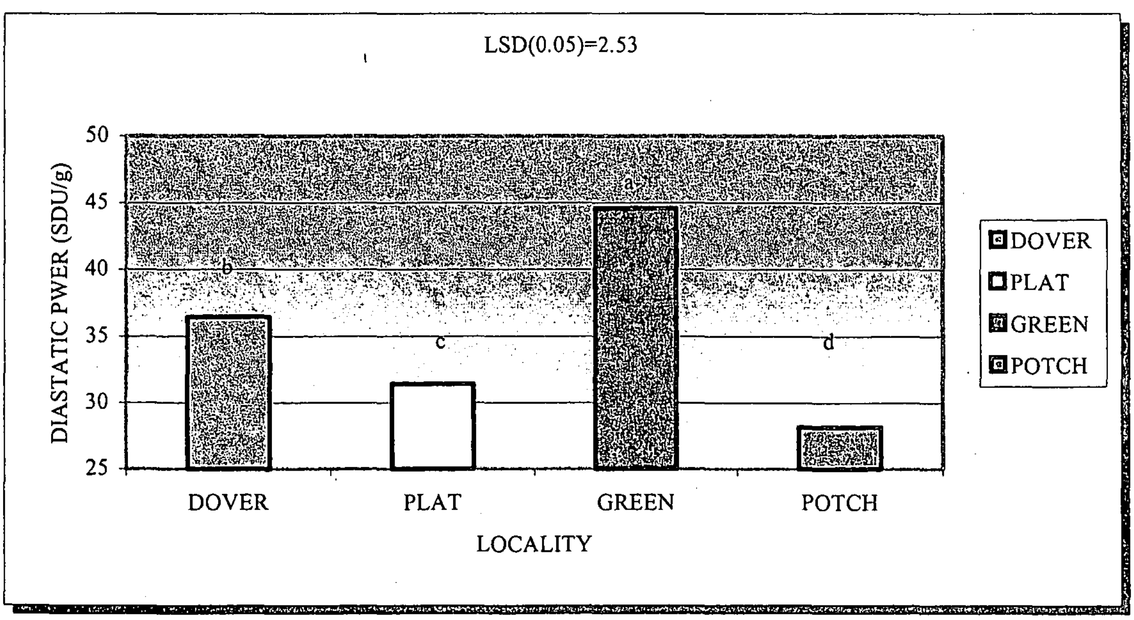


FIG. 2.22

THE SIGNIFICANT DIFFERENCES BETWEEN THE DIASTATICE POWER VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES OF GROWTH

TABLE 2.22

ANALYSIS OF VARIANCE OF THE DIASTATICE POWER OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	239.2952	239.2952	8.3778	0.0057	**
Main Effects						
CULTIVAR	23	2039.3734	88.6684	3.1043	0.0005	***
LOCALITY	3	7218.5230	2406.1743	84.2412	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	2312.9382	33.5208	1.1736	0.2825	ns
Error	47	1342.45652 2	8.5629	<-		
Total	143	13420.8970				

P=0.05

ns=not significant

TABLE 2.23

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN DIASTATIC POWER VALUES

Rank	Cultivar	Mean	N	Groups not significantly different
1	APN 881	45.754	6	a
2	NS 5511	44.132	6	ab
3	SNK 3443	41.249	6	abc
4	SNK 3620	38.432	6	bcd
5	SNK 3975	38.066	6	bcd
6	SNK 3860	37.587	6	cd
7	NK 286	37.231	6	cde
8	SNK 3939	36.938	6	cdef
9	SNK 3337	36.874	6	cdef
10	PAN 8564	36.633	6	cdef
11	PAN 8262	36.418	6	cdef
12	NS 5655	36.261	6	cdef
13	PAN 8446	35.034	6	defg
14	SNK 3663	34.987	6	defg
15	ADV 5010	34.791	6	defg
16	PAN 8061	34.329	6	defgh
17	SNK 3567	33.605	6	defgh
18	PAN 8660	33.431	6	defgh
19	SNK 3883	31.280	6	efgh
20	NK 283	31.212	6	efgh
21	SNK 3863	31.002	6	fgh
22	PAN 8272	30.959	6	fgh
23	PAN 8171	28.985	6	gh
24	PAN 8370	28.296	6	h

2.3.8 COEFFICIENT OF VARIATION

From Table 2.24 it is clear that the coefficient of variation (%CV) in some cases was relatively larger than normally expected. This is the case with polyphenols, FAN and DP for example. The reason for this is that the different assays were not performed in replication. Instead of the mere usage of replications, different cultivars, localities of growth and seasons were used to "replace" replications, as was done by Purchase (1997), where no replications were performed, but genotype, season and environment were used to perform an ANOVA. In each case the variable analyzed, determined the variables serving as replications. For example, when a cultivar was analyzed, the localities and the seasons of growth served as replications or when season was analyzed, cultivars and localities served as replications. As seen, great differences occur in the malting quality of sorghum over cultivars, localities and seasons, thereby increasing the %CV.

TABLE 2.24

THE COEFFICIENTS OF VARIATION FOR DIFFERENT MALTING QUALITY PARAMETERS

MALTING PARAMETER	%CV
POLYPHENOL	36.766
MALTING LOSS	7.161
WATER ABSORPTION	5.356
FREE AMINO NITROGEN	18.931
DIASTATIC POWER	15.029
GERMINATIVE VIGOUR	6.524
GERMINATIVE ENERGY	5.166

2.3.9 CORRELATIONS

The malting performance of sorghum cultivars is measured by more than one malting parameter. To determine the actual malting quality of cultivars is therefore difficult, as all parameters should be considered. Two cultivars were identified to be of better malting quality than the others, namely NS 5511 and APN 881, as both performed well in a range of malting quality properties measured. NS 5511 was identified to consist of favourable DP, FAN and WA values, despite the presence of high levels of polyphenols. APN 881 displayed excellent FAN, DP, GV and GE values, indicating not only favourable germination quality, but also very high quality malt. The other two cultivars containing high polyphenol levels, namely SNK 3860 and SNK 3620 both, had very low ML and high WA values, which is of economic importance, while SNK 3860 displayed favourable GE and SNK 3620 favourable values. The worst performing malting cultivars were NK 283 (low GE value), PAN 8171 (low WA, FAN and DP values), PAN 8262 (low FAN, GV and GE values) and PAN 8272 (low WA and DP values). To determine which season produced the best quality malt is more difficult, as both seasons delivered malt with some good and some poor qualities. Malt from the 1997/98 season, for example, resulted in low DP values, but with good WA and germinating abilities and the 1998/99 season malt had high ML values and low GE values, but with satisfactory DP values. Potch was a poor locality for malt quality, due to poor germination values, despite good WA values. On the other hand, Green had high DP and FAN values, despite poor WA values, indicating the satisfactory malting performance of sorghum from this locality. The strong possibility for the existence of correlations between malting quality parameters does therefore exist and needs further investigation.

Table 2.25 indicates the correlation matrix of all malting quality parameters. Only correlation coefficients with $r>0.4$ were considered for the purpose of this study, as was by De Lange (1999) for dry bean cultivar trials. A relatively strong correlation exists between DP and FAN ($r=0.681$), which was expected, as malt with high amylase activity (diastase) for sugar production is expected to also have good protease activity for enough FAN production. Sufficient DP and FAN development in malt, are essential for the successful fermentation of malt by yeasts, during beer brewing, as mentioned earlier.

TABLE 2.25

CORRELATION COEFFICIENTS AMONG MALTING QUALITY PARAMETERS MEASURED ACROSS 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON (P<0.05)

	FAN	**DP**	**ML**	**WA**	**GV**	**GE**	**POLY-PHENOLS**
FAN	1.000	0.681	-0.067	0.182	0.199	0.250	0.304
DP	-	1.000	0.084	-0.142	0.478	0.527	0.193
ML	-	-	1.000	-0.360	0.298	0.374	-0.060
WA	-	-	-	1.000	-0.316	-0.373	0.353
GV	-	-	-	-	1.000	0.746	0.134
GE	-	-	-	-	-	-	0.199

DP correlates well with GE and GV respectively (r=0.527 and 0.478). The reason for this is that both measure germination quality traits, as GV measures germination uniformity and GE, germination potential during malting (Chapter 1) and DP development takes place as germination proceeds. This explains why DP correlates better with germination after 72 h (GE), than at 48 h (GV), since in the last instance the DP development was less. The correlations found between DP and GV, and DP and GE were expected, as Taylor & Dewar (1996) found favourable germination in sorghum grain to be essential when a high DP value is required.

The correlation found between GV and GE (r=0.746) is also expected as both indicate germination quality and a large difference between the GE and GV indicates poor grain quality (Chapter 1) and each also correlated with DP. The correlation between GE and dry matter losses, found by Beta *et al.*, (1995) is observed, but only very poorly (r<0.4).

The ML, WA and polyphenol content displayed no (r<0.4) correlation with any other malting quality parameter. Although it is important not to increase the ML too much by improving germination, a balance between malting quality and ML should be found (Dewar *et al.*, 1999). As a final consideration, ML should be taken into account after cultivars were recommended in terms of malting quality. Although ML did not correlate well with any of the other malting quality parameters, a weak correlation was found between ML and GE (r=0.374). This correlation indicates that sufficient germination could play a role in increasing malting losses. PAN 8446, PAN 8061 and PAN 8171 ($p>0.05$) fell amongst the cultivars with poor WA levels. As Beta *et al.* (1998) indicated WA rates to be significant in the release of proteins from the starch binding matrix, WA levels was expected to enhance enzyme releases during malting, as mentioned earlier. No significant correlation ($r<0.4$) between the levels of WA in sorghum cultivars and any other malting quality parameters was found, though. Taylor & Dewar (1996) identified good correlations between steep-out moisture (WA) and DP, between WA and FAN and between WA and extract. This was not the case in the present study.

No correlation ($r<0.4$) between the polyphenol content of sorghum cultivars and any other malting quality parameter was found. Therefore, only the polyphenols in the form of condensed tannins underneath the pericarp, as observed in birdproof cultivars, are important where malting quality is considered. As mentioned in 2.1 and in the present study, peptone was used as an extractant to prevent birdproof (high tannin) properties of sorghum from interfering with DP performance.

2.3.10 CANONICAL VARIATE ANALYSIS

The only malting quality parameters indicating correlations ($r>0.04$) with any other parameters, were GV, GE, DP and FAN. For the grouping of malting cultivars, localities, etc. a canonical variate analysis (CVA) was performed. Only those malting quality parameters considered important were included in the analysis in order to select from them, the canonical variates (CVs) that contribute most to the variability between cultivars. Only the parameters that showed correlations other parameters were considered for the CVA performance, to try and reveal the differences between cultivars, in terms of malting quality. The CVA does not indicate differences between cultivars as in the case of the ANOVA, but indicates the overall positioning of a cultivar in terms of malting quality, by considering all relevant malting quality parameters.

TABLE 2.26

THE CORRELATION MATRIX BETWEEN VARIABLES AND SCORES FOR GROUPINGS BETWEEN SORGHUM CULTIVARS IN TERMS OF MALTING QUALITY IN THE CONONICAL VARIATE ANALYSIS

USCORE[1]	0.897	0.402	0.304	0.388
USCORE[2]	-0.419	-0.607	0.278	0.225
USCORE[3]	-0.107	-0.116	-0.490	0.198
	FAN	**DP**	**GV**	**GE**

From the CVA it was observed that the contribution of CV1 to the groupings of cultivars is 61.37 %, while that of CV2 was 23.05 %. The total contribution of CV1 and CV2 to the variation between cultivars was therefore 84.42 %. Table 2.26 indicates correlation between malting parameters and the score of CV1, CV2 and CV3 (USCORE 1, 2 and 3). From Table 2.26, it is clear that FAN discriminates mainly between cultivars for CV1 (r=0.897) and DP mainly for CV2 (r=-0.607). This discrimination between cultivars on the base of FAN (CV1) and DP (CV2), is important for two reasons. Firstly, these two variates are most commonly used in practice to distinguish between cultivars for malting quality. Secondly, FAN correlates well with DP (r=0.681) and DP displayed a good correlation with GE (r=0.527) and GV (r=0.478), respectively (Table 2.25).

Table 2.27 indicates the CV1 and CV2 scores for cultivars. The closer these scores are to zero, the closer the cultivar lies to the average, with respect to the variate. Fig. 2.23 shows a plot of these scores. The closer cultivars are situated to the gridlines, the more stable they are with respect to the variate concerned. Table 2.26 indicates a positive regression coefficient for CV1 and a negative coefficient for CV2. Therefore, cultivars performing well with respect to CV1 (FAN) will lie to the right-hand side of the plot, while those with a good performance with respect to CV2 (DP), will appear in the lower parts of the plot. The positioning of cultivars on the plot therefore gives an indication of the malting performance of cultivars compared to the average, with respect to the variates. Cultivars positioned close together are the most similar, while the more remote cultivars differ the most from other cultivars.

It is already clear from Table 2.27 that PAN 8262 differed the most from the other cultivars, as both the scores for CV1 (score=-1.6268) and CV2 (score=-1.2906) are highly negative. From the plot (Fig. 2.23), it is evident that this cultivar is situated far away from all the others, indicating dissimilarity, as mentioned before. The positioning of PAN 8262 on the lower left-hand side of the plot is confirmed by its low mean FAN value (mean=91.0) and above average DP value (mean=36.42) (Table 2.28). Earlier this cultivar was identified to have the second lowest ranking for FAN ($p>0.05$) (Table 2.20), GV ($p>0.05$) and GE ($p>0.05$), while the DP value ($p>0.05$) means was ranked eleventh (Table 2.23). Therefore, it is confirmed that this cultivar is acceptable in terms of DP, but not quite in terms of FAN.

APN 881 showed the highest mean score (Table 2.27) for CV1 (score=2.3703) and is positioned to the very right of the plot (Fig. 2.23). APN 881 showed the highest mean FAN value (mean=173.1), as well as the highest mean DP value (mean=45.75) of all cultivars (Table 2.28), which ensured its placing in the best position on the plot, namely in the bottom right quadrant. Previously APN 881 was found to have the highest overall FAN, DP, GV and GE (Table 2.20, 2.23, 2.14 and 2.17). None of these malting parameters were found to be significantly different from cultivars such as SNK 3620, NS 5511 and SNK 3443. From Fig. 2.23 it is possible to distinguish APN 881 from these cultivars by its far more favourable positioning, in terms of malting quality. The good malting performance of APN 881, illustrates the correlation that exists between DP and FAN, DP and GE, DP and GV, and GV and GE (Table 2.25).

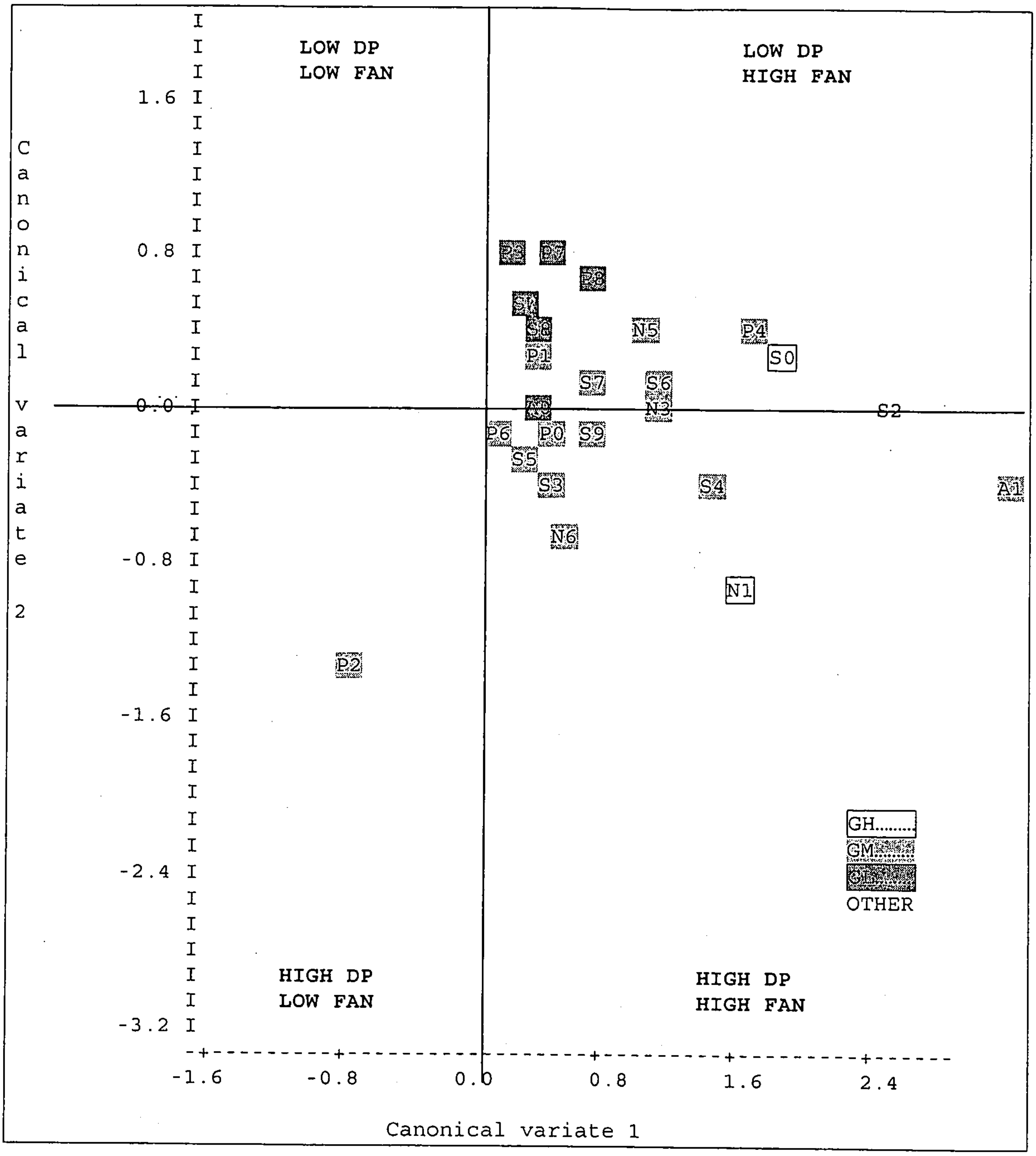
TABLE 2.27

CANONICAL VARIATE 1 AND 2 SCORES FOR SORGHUM CULTIVAR GROUP MEANS ACCORDING TO THE CANONICAL VARIATE ANALYSIS FOR MALTING PARAMETERS

CODE	CULTIVAR	CV1	CV2
A0	ADV5010	-0.4896	0.0505
A1	APN881	2.3703	-0.3943
N3	NK283	0.2401	-0.0604
N6	NK286	-0.2888	-0.6412
N1	NS5511	0.7143	-0.9727
N5	NS5655	0.1432	0.3911
P1	PAN8061	-0.4417	0.2295
P7	PAN8171	-0.4134	0.7912
P2	PAN8262	-1.6268	-1.2906
P8	PAN8272	-0.1863	0.6209
P3	PAN8370	-0.6552	0.7687
P6	PAN8446	-0.6913	-0.1336
P4	PAN8564	0.8157	0.3794
P0	PAN8660	-0.4113	-0.1631
S3	SNK3337	-0.3920	-0.4138
S4	SNK3443	0.5500	-0.3374
S7	SNK3567	-0.1435	0.1890
S2	SNK3620	1.5987	0.0382
S6	SNK3663	0.2254	0.1521
S0	SNK3860	0.9293	0.2309
S8	SNK3863	-0.5131	0.3435
SW	SNK3883	-0.5787	0.5738
S9	SNK3939	-0.1798	-0.1182
S5	SNK3975	-0.5754	-0.2336

The excellent malting quality of APN 881, according to the CVA is confirmed by its classification as a GM Class (Table 2.2) cultivar in the National Sorghum Cultivar Trials. The only other GM Class cultivar in the same area as APN 881 on the plot is SNK 3443, which also performed well above the average with respect to CV1 (mean=130.5) and CV2 (mean=41.25). Although this cultivar did not perform as well as APN 881 did, as observed from the distance between the two, it performed better than the other GM Class cultivars, situated further away (Fig. 2.23). With the ANOVA it was impossible to distinguish the malting quality of this GM cultivar from the malting qualities of at least four other GM cultivars (excluding APN 881) in terms of DP, FAN, GV and GE value means (Table 2.23, 2.20, 2.14 and 2.17). The four cultivars are SNK 3975, SNK 3939, PAN 8564 and NS 5655 and from the plot, it is clear that SNK 3443 is indeed the second best GM cultivar in terms of malting quality (Fig. 2.23).

Except for APN 881, SNK 3443 and PAN 8262 that were already discussed, all the other GM Class cultivars (Table 2.2) are situated below the GL Class cultivars closely grouped together (Fig. 2.23). No differences ($p>0.05$) in the FAN values of any of these GM Class cultivars were found (Table 2.20). In terms of DP value means, the only difference was found between SNK 3975 and NK 283 ($p<0.05$), the latter having lower DP value means (Table 2.23). This explains the lower positioning of SNK 3975 compared to NK 283 on the plot. Thus, cultivars close to SNK 3975 on the plot, such as SNK 3939 and NK 286 represents it closely in DP values. In terms of the GV of GM cultivars, SNK 3939 performed better than NK 286 and NK 283, while PAN 8564 also performed better than these two cultivars, as well as PAN 8446 and SNK 3337 (Table 2.14). SNK 3663 in turn performed better than NK 283 in terms of GE ($p<0.05$) (Table 2.17).



GH=MALTING CLASS

GM=NOT MALTING CLASS

GL=BIRDPROOF WITH MALTING ABILITIES CLASS

OTHER=NOT GM, GL FOR GH CLASS

FIG. 2.23

PLOT OF THE CANONICAL VARIATE ANALYSIS OF THE MALTING PROPERTIES OF SORGHUM TO DISCRIMINATE BETWEEN SORGHUM CULIVARS

TABLE 2.28

MEAN VALUES OF SORGHUM CULTIVARS FOR ALL VARIATES CONSIDERED IN THE CANONICAL VARIATE ANALYSIS FOR MALTING PARAMETERS

CODE	CULTIVAR	FAN (mg/100g)	DP (SDU/100g)	GV (%)	GE (%)
A0	ADV5010	101.20	34.79	88.50	91.67
A1	APN881	173.10	45.75	93.67	96.67
N3	NK283	114.90	31.21	80.67	88.50
N6	NK286	110.90	37.23	81.67	91.50
N1	NS5511	140.50	44.13	86.83	93.83
N5	NS5655	111.20	36.26	91.33	95.67
P1	PAN8061	97.70	34.33	86.67	94.50
P7	PAN8171	91.20	28.99	86.67	92.50
P8	PAN8262	91.00	36.42	80.00	84.83
P8	PAN8272	99.90	30.96	88.50	92.00
P3	PAN8370	86.30	28.30	86.50	91.50
P6	PAN8446	96.00	35.03	84.17	93.17
P4	PAN8564	126.30	36.63	91.00	95.33
P0	PAN8660	103.20	33.43	83.50	90.00
S3	SNK3337	106.70	36.87	84.00	92.33
S4	SNK3443	130.50	41.25	90.83	94.50
S7	SNK3567	105.50	33.60	86.50	92.33
S2	SNK3620	145.80	38.43	87.00	95.67
S6	SNK3663	112.70	34.99	85.17	94.67
S0	SNK3860	129.30	37.59	89.00	96.33
S8	SNK3863	94.40	31.00	85.00	91.50
SW	SNK3883	92.50	31.28	89.50	91.83
S9	SNK3939	110.00	36.94	88.33	92.83
S5	SNK3975	102.20	38.07	88.00	94.17
	MEAN	**111.40**	**35.56**	**86.79**	**92.83**

The fact that only a few GM cultivars differed from other cultivars in terms of malting quality parameters explains the close positioning of these cultivars to one-another on the plot. NK 283 is one of the worst performing cultivars among the GM class, as cultivars performing better than NK 283 for GV, GE and DP were found. It can be summarized that GM cultivars grouped in the lower left-hand side quadrant are those with generally good DP values, while those in the bottom right-hand side quadrant are those with excellent malting performance in terms of DP and FAN. Those in the top right-hand side showed good FAN values, but lower DP values. Cultivars in the top left-hand side quadrant are the worst malting performing GM cultivars, as observed from their positioning close to the GL cultivars. PAN 8061 and SNK 3567 fell within this group (Fig. 2.24).

The closest cultivar to APN 881 on the plot (Fig. 2.23) is SNK 3620. This cultivar also displayed an extremely high FAN value (mean=145.8) and a well above the average DP value (mean=38.43). Excellent GV (mean=87.00) and GE (mean=95.67) values were also observed. Again the DP and FAN values did not differ (Table 2.23 and 2.20) significantly from the other cultivars, but the FAN value corresponded ($p>0.05$) to that of APN 881, thereby explaining the positioning to the very right of the plot. DP values of this cultivar were lower than that of APN 881, though. Despite its very good performance, this cultivar belongs to no class, because of its high tannin properties (Table 2.2). Regulations for the inclusion of high tannin cultivars to the GH Class is higher than those for the GM Class and despite the good malting performance of SNK 3620, this cultivar did not qualify for the GH Class yet.

NS 5511, situated in the same quadrant as APN 881 and SNK 3620, is also remotely positioned to other cultivars (Fig. 2.23). In this case, both the FAN and the DP values of the cultivar corresponded ($p>0.05$) to that of APN 881. This explains its remote placing on the plot. NS 5511 is a birdproof cultivar (Table 2.2) and falls within the GH Class for cultivars (Table 2.2). SNK 3860 is the only other GH cultivar and is situated to the right on the plot (Fig. 2.23). The FAN (mean=129.3) value of this cultivar did not differ from that of NS 5511 ($p>0.05$), but did not correspond ($p<0.05$) to that of APN 881 in the way NS 5511 did. The DP value (mean=37.59) in turn was lower than that of NS 5511 ($p<0.05$). The dissimilarity between the two cultivars is displayed in the distance between them on the plot. The reason for the inclusion of SNK 3860 and NS 5511 in the GH Class, whilst SNK 3620 was not allowed, is due to the higher standards set for cultivars to be included into the GH Class than the GM Class. SNK 3620 did not qualify for the GH Class in terms of these standards.

The GL Class cultivars are positioned to the upper left-hand on the plot in the area for low DP and FAN values. From Table 2.29 it can be seen that all these cultivars had FAN and DP values below the average. Their GE values were also below average, which can be expected, as the DP and GE are correlated (Table 2.25) even though environment may greatly affect GE and GV. E.g. PAN 8370, the worst positioned cultivar with respect to CV1 and CV2 (Fig. 2.23), had the lowest overall FAN (mean=86.3), DP (mean=28.310) and GE (mean=91.50) values. The best performing cultivar among the GL Class was ADV 5010, with below average FAN (mean=101.2), DP (mean=34.79) and GE (mean=91.67) values. Because of its better performance than the rest of the GL Class cultivars, it is situated amongst the GM Class cultivars on the plot. From Table 2.20 and 2.23 it is observed that the GL Class cultivars are found in the lower rankings of FAN and DP values. The GL Class cultivars all corresponded with the lowest ranked cultivar for DP and FAN ($p<0.05$), but not with the top ranked ones ($p>0.05$). The only exception to this, is the highest ranked GL Class cultivar ADV 5010, which did not correspond with the lowest ranked cultivar for DP. In fact, this cultivar may in time even be added to the GM Class cultivars, if it keeps up this performance.

From the above, it is therefore clear that different sorghum cultivars display wide variations in malting quality. Differences in the malting quality characteristics of the same cultivar grown over different seasons and at different localities were also seen. Each season was for example observed to perform well with respect to some properties and poor in others and the Green locality was determined to be the best and Potch the poorest malting performance locality, as discussed in 2.3.9. As locality and season of growth was expected to influence the performance of cultivars even further, a CVA was done to distinguish between environments (localities x seasons) on the base of malting quality parameters. The same variates as for cultivar discrimination were used, namely FAN, DP, GV and GE. This CVA indicated that CV1 contributes 57.56 % and CV2 26.73 % to the variation between localities x season. The total contribution of CV1 and CV2 to the variation was thus 84.3 %. From Table 2.29 it is evident that GV (r=0.812), GE (r=0.901) and DP (r=0.653) discriminate mostly between localities x seasons for CV1 and FAN (r=0.498) for CV2.

TABLE 2.29

THE CORRELATION MATRIX BETWEEN VARIABLES AND SCORES FOR GROUPINGS BETWEEN ENVIRONMENTS (LOCALITY X SEASON) IN TERMS OF MALTING QUALITY IN THE CONONICAL VARIATE ANALYSIS

USCORE[1]	0.109	0.653	0.812	0.901
USCORE[2]	0.498	0.392	0.451	0.132
USCORE[3]	-0.730	-0.640	0.230	-0.139
	FAN	**DP**	**GV**	**GE**

TABLE 2.30

CANONICAL VARIATGE 1 AND 2 SCORES FOR SORGHUM ENVIRONMENT GROUP MEANS FROM THE CANONICAL VARIATE ANALYSIS FOR MALTING PARAMETERS

CODE	LOCALITY	SEASON	CV1	CV2
Do	DOVER	1997/98	1.069	0.172
PR	PLAT	1998/99	0.762	-0.597
G8	GREEN	1997/98	1.384	0.545
G9	GREEN	1998/99	0.736	0.775
P8	POTCH	1997/98	-2.898	1.081
P9	POTCH	1998/99	-1.052	-1.976

From Table 2.30 it is seen that Potch 1997/98 was the most different when compared to other environments (localities x seasons), because the scores for CV1 (score=-2.898) and CV2 (score=1.081) were further below and above zero respectively, than for the other environments. This is also demonstrated by Fig. 2.24, where Potch 1997/98 is situated distant to other localities x seasons in the region on the plot where low DP, GV and GE values and high FAN values are found. Table 2.31 indicates that the mean FAN (mean=111.6) and DP (mean=26.64), GV (mean=86.79) and GE (mean=92.83) values for Potch 1997/98 were above the mean FAN (mean=111.4) and below the DP (mean=35.56), GV (mean=78.33) and GE (mean=81.54) mean values for localities x seasons. Potch 1997/98 is situated to the very left of the plot, indicating very low DP, GV and GE values

(Fig. 2.24). This is confirmed by the lowest overall mean values for DP and GE (Table 2.27). The dissimilarity of Potch 1997/98 to other environments is due to the very low DP, GE and GV values found for cultivars, combined with high FAN values. DP values were not only the lowest (mean=26.64), but also well below the standard for acceptability of 28 SDU/g.

According to the scores for CV1 (score=-1.052) and CV2 (score=-1.976) Potch 1998/99 is the environment varying second most to the others (Table 2.26). This environment is positioned on the plot in the area for low DP, GV and GE values and low FAN values (Fig. 2.24). The mean FAN (mean=97.60), DP (mean=29.68), GV (mean=75.25) and GE (mean=90.67) values for Potch 1998/99 is below the average of other localities x seasons. The same tendency as for Potch 1997/98 is seen in Table 2.31. The difference between cultivar performances at Potch for the 1997/98 and 1998/99 seasons lay in the FAN values. The mean FAN (mean=97.6) value for 1998/99 was well below the average and much lower than in 1997/98 (mean=111.4). Differences between FAN values over different growing seasons were not significant (2.3.6), but an interaction between Potch as locality and season may exist, which was not tested.

It is clear that Potch is the locality with the poorest DP value for both seasons. This was also seen in 2.3.5, where DP value means were found to be significantly lower at Potch. When DP is considered, it seems as if 1998/99 was a better season for malting performance at Potch than 1997/98. But when the poor performance with respect to FAN is considered, it is seen that the 1998/99 season was in fact the worst malting quality season at Potch. The weak malting performances of cultivars at Potch is further demonstrated by the weak GV (means=75.2 and 78.33 respectively) and GE (means=81.54 and 90.67 respectively) values for 1997/98 and 1998/99 respectively. Potch was the locality with lower ($p<0.05$) DP (2.3.7), GV (2.3.4) and GE (2.3.5) values. The distant positioning of Potch in 1997/98, compared to 1998/99 on the plot (Fig. 2.24), demonstrates that Potch as a planting locality is highly sensitive to variation in season where malting quality of sorghum is considered. The fact that Potch is situated far away from any other environment on the plot for both planting seasons indicates its dissimilarity to other environments. On further investigation it is clear that the difference lies in the poor malting performance of sorghum planted at Potch.

Green was situated closely on the plot (Fig. 2.24) for both seasons. Table 2.26 confirms that Green for 1997/98 and 1998/99 were the two localities x seasons with the scores for CV1 and CV2 nearest to one-another. Both are situated in the area on the plot where good FAN and DP, GV and GE values are found. Table 2.31 indicates that Green had mean FAN values of 121.8 and 146.7 mg FAN/100g and mean DP values of 42.96 and 46.24 SDU/g malt for the 1997/98 and 1998/99 seasons respectively. Therefore Green as a locality had higher FAN and DP values for both seasons than any other locality x season combination. The mean GV (93.54 and 90.46 respectively) and mean GE (97.17 and 96.33 respectively) of Green for the 1997/98 and 1998/99 seasons were also well above the average GV (mean=86.79) and GE (mean=92.83) for other localities x seasons (Table 2.31). The DP (2.3.7) and FAN (2.3.6 value means at Green were found to be significantly higher than those of other localities.

The close positioning of Green for 1997/98 and 1998/99 on the plot, indicates that Green as a planting locality resulted in good malting quality stability over more than one season. This is contrasting to the instability of Potch as a malting quality locality over more than one planting season.

The two localities that were only tested over one season each, namely Dover for 1997/98 and Plat for 1998/99, are situated closely together on the plot. Dover had a good DP value (mean=36.45), but the FAN value (mean=99.4) is below the average (Table 2.19). The DP value of Plat is lower than the average, but higher than the standard of acceptability of 28 SDU/g malt. Dover and Plat also had GV and GE values above the average. Dover is situated close to Green on the plot (Fig. 2.24). Therefore Dover also falls in the favourable group of excellent malting quality performance. Plat is situated closer to Potch for the 1998/99 season. The FAN value means was lower ($p<0.05$) at Plat than at Potch, while the

DP (2.3.7), GV (2.3.4) and GE (2.3.5) value means were higher at Plat than at Potch. Therefore, Plat is a better locality for malting quality than Potch, when all malting quality parameters are considered.

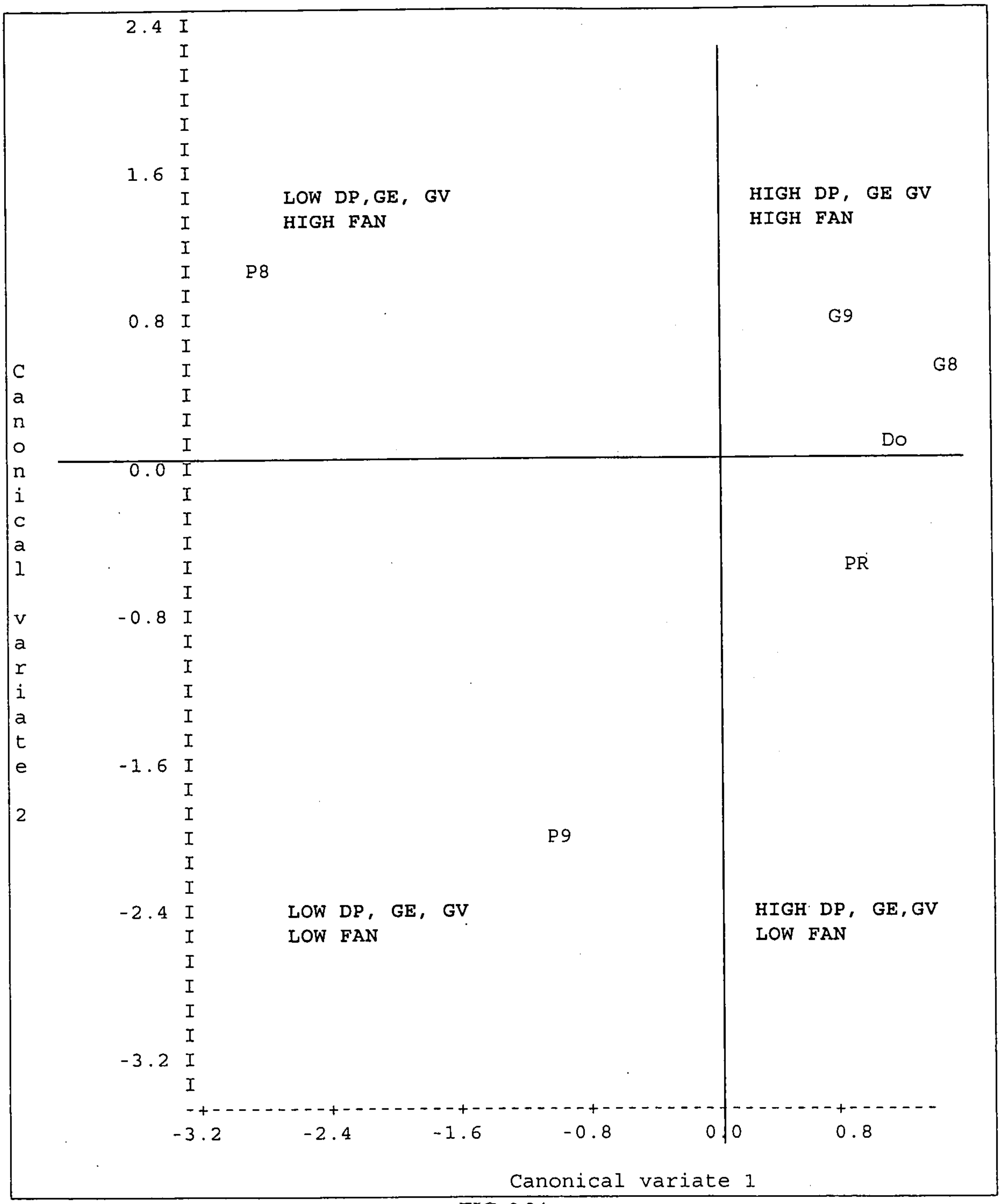


FIG. 2.24

PLOT OF THE CANONICAL VARIATE ANALYSIS OF THE MALTING PROPERTIES OF SORGHUM CULTIVARS TO DISCRIMINATE BETWEEN LOCALITES X SEASONS

TABLE 2.31

MEAN VALUES OF SORGHUM LOCALITY X SEASON FOR ALL VARIATES CONSIDERED IN THE CANONICAL VARIATE ANALYSIS FOR MALTING PARAMETERS

CODE	LOCALITY	SEASON	FAN (mg/100g)	DP (SDU/g)	GV (%)	GE (%)
Do	DOVER	1997/98	99.40	36.45	92.50	95.42
PR	PLAT	1998/99	91.20	31.39	90.67	95.83
G8	GREEN	1997/98	121.80	42.96	93.54	97.17
G9	GREEN	1998/99	146.70	46.24	90.46	96.33
P8	POTCH	1997/98	111.60	26.64	78.33	81.54
P9	POTCH	1998/99	97.60	29.68	75.25	90.67
	MEAN		**111.40**	**35.56**	**86.79**	**92.83**

Seasonal differences in the malting quality of sorghum were found to be significant for DP (2.3.7), GV (2.3.4) and GE (2.3.5). In all instances the 1998/99 season was found to be the better malting quality season of the two.

As mentioned earlier, the %ML should be the final criterion in the evaluation of good malting performance cultivars before it can be recommended, as it is of economic importance. The ML cannot be too low, however as it will reduce DP, FAN and germination. Earlier it was seen that APN 881 had the best performance in terms of malting quality of the GM cultivars, while SNK 3443 was placed second. As expected APN 881 corresponded ($p>0.05$) with cultivars in high ML levels, but its %ML was also found not to significantly differ from the cultivar placed ninth for low levels of ML. Therefore the ML of APN 881 is considered to be around the average for ML and when its excellent malting performance is considered, the cultivar can be recommended in terms of malting quality. SNK 3443, on the other hand, performed very well in terms of malting quality, but it is also positioned in the second position for ML. Although its ML did not differ from the cultivar in tenth position for low ML, it should be considered that the cultivar displayed higher ML than APN 881, while the malting performance was not of the same standard. The economic losses, should be measured against the malting performance required by the maltster, or the time of germination could be shortened in the case of cultivars of excellent malting quality, to lower the malting quality somewhat, but also decreasing ML levels. In the case of the GH cultivar SNK 3860, the excellent malting performance of the cultivars, was accompanied by a low mean %ML that corresponded ($p>0.05$) with the ML of the lowest ranked cultivars for ML.

As mentioned earlier, Potch was found to be the locality with significantly higher ML value means than the rest of the localities, while the overall malting quality was lower at Potch. Therefore Potch is not recommended as locality in terms of malting performance overall.

2.4 CONCLUSION

The total polyphenol content, although variable over cultivars, localities and seasons, was found to play only a significant role in the case of birdproof sorghum cultivars. As the chlorox-bleaching test only identifies cultivars with condensed tannins underneath the pericarp (birdproof cultivars), it seems as if only this assay is necessary in the determination of malting quality, but these results are only based on three birdproof cultivars and further investigation is therefore necessary. The only birdproof cultivars identified among the 24 cultivars were SNK 3860, NS 5511 and SNK 3620.

ML and WA did not correlate well ($r<0.4$) with any other malting quality parameters and were thus identified as less important malting quality parameters as higher levels were found here and were therefore not included in the CVA. The poor correlations found for WA and ML with other malting quality parameters differs from those determined by Taylor & Dewar (1996) who found good correlations between the steep-out moisture (WA) and malting quality parameters, namely DP, FAN and extract. The influence of ML is thus an economic factor that should only be taken into consideration in cultivar evaluation, after all other malting quality parameters were considered. Water absorption levels did not determine the release of malting enzymes from the protein-binding matrix as expected, but WA levels showed differences ($p<0.05$) between cultivars, localities and seasons.

The most important malting quality parameters identified during the present study to group cultivars according to malting quality as identified by the CVA, were FAN, DP, GV and GE. Free amino nitrogen is the most important and DP the second most important factor to group cultivars according to malting quality, as seen by the correlations of FAN and DP with the scores in the CVA. Taylor & Dewar (1996) earlier found DP to be the most important malting quality parameter, and although the GV and GE values could be used as a speedier indication of malting quality, they cannot replace DP determinations. The present study indicates that WA is not a suitable indication of the final malt quality, because of the poor correlations with other malting parameters (DP and FAN). Differences ($p<0.05$) between cultivars were found for the FAN and DP. The best performing GM Class cultivar when all malting parameters were considered was APN 881, followed by SNK 3443. The rest of the GM Class cultivars showed little variation, except for PAN 8262 that differs due to a high ($p>0.05$) DP and low ($p>0.05$) FAN combination. Although PAN 8061 and SNK 3567 qualified for the GM Class, these cultivars had malting performances closer to the GL Class than the rest of the GM Class. The GH Class cultivars showed excellent malting performances, close to that of APN 881, whilst the GL Class overall, performed worse than the GM Class.

Differences ($p<0.05$) in the malting quality of different localities were found for DP, FAN, GV and GE. In all cases, as well as in terms of overall malting performance, Green was the best malting locality. Potch was in terms of DP, GV and GE the overall worst malting performing locality. From the CVA for locality x season, grain from Potch was also found to be of poor malting quality. It was also observed that Green as a locality for malting sorghum, displays great stability in terms of malting quality performance over more than one malting season, while Potch displayed poor consistency.

Seasonal differences ($p<0.05$) were only found for DP, GV and GE. In all cases, as well as in terms of overall malting performance, the 1998/99 season was the better of the two seasons in terms of malting performance.

The role of WA as a malting quality parameter was not identified in the current study. Somehow WA should play a role in the determination of the malting quality of sorghum, as good steeping procedures and conditions form an essential part of malting. Further research may involve a deeper look into the role that WA levels as such, could play in malting quality.

During the study certain environments (localities x seasons) were found to deliver sorghum with better malting performances than others, indicating a possible (significance was not tested) interaction between localities and seasons. Therefore future research may identify the environmental conditions during a certain season that causes malting sorghum to perform better at the specific locality in terms of malting quality.

CHAPTER 3

PHYSICAL PROPERTIES WITH AN INFLUENCE ON MILLING QUALITY

3.1 INTRODUCTION

The milling quality of sorghum is its most important physical property. The reason for the importance of milling quality lies in the wide utilization of the milled product and the acceptance of the end product by the consumer. Although sorghum porridges are the staple food of many African and Asian people (Akingbala *et al.*, 1988), there is a movement amongst consumers to less fiber and coarseness in food products (Novellie, 1982) and therefore milling quality parameters should be adapted accordingly. The milling quality of sorghum in turn is determined by several other physical factors.

The percentage water absorbed, which was discussed in Chapter 2, is also an important physical property for milling quality. The soft endosperm of sorghum consists of loosely packed endosperm cells with small voids in-between and little protein (Rooney & Miller, 1982). The rate of water uptake of these cells are higher than the hard endosperm, due to the more compact endosperm found in the latter (Hoseney, 1994), which should lead to better water absorption abilities in softer sorghum cultivars. Cultivars with good water absorption abilities will absorb water during conditioning before milling. As mentioned in Chapter 1 the roller milling process is started with a conditioning process. Although the endosperm may become more soft and friable (Hahn, 1969) during conditioning, this is not the main objective of conditioning. The real purpose of the process is to moisten the pericarp to become looser (Desikachar, 1982), tough and rubbery (Hahn, 1969) for easier separation from the endosperm (Desikachar, 1982). Therefore too much water uptake during conditioning would be undesirable. High water absorption abilities in cultivars will also lead to increased water absorption on storing under less than ideal storage conditions, with important implications for shelf life of products.

An important parameter in the determination of milling quality and milling yield is the sorghum kernel size. Smaller kernels result in higher milling yields due to less breakage of kernels (Wills & Ali, 1982), but too small kernels will result in greater losses, as it will be removed from the sample together with the bran during milling (Gomez *et al.*, 1997) due to the larger surface area of the kernels. A uniform particle-size distribution in sorghum is thus favourable for the milling process. It is necessary to use grain of uniform size to assure that sorghum meal with a uniform particle-size distribution is produced in the milling process (Gomez *et al.*, 1997). Large kernels, that are not hard enough, on the other hand have the tendency to crack (Munck *et al.*, 1982). The sieve fraction assay is a means of determining grain size distribution, as well as the grain size occurring in the highest percentage (Gomez *et al.*, 1997). The latter is also applicable for the sieve fractions of the meal of sorghum.

The shape and structure of a sorghum kernel also has a great influence on milling quality and yield. During the abrasive process, the instrument only removes the outer layers of the grain (Dewar *et al.*, 1993; Subramanian *et al.*, 1994), causing the formation of spherically shaped kernels. Therefore, greater endosperm losses are found in oval shaped kernels than with round kernels, causing not only kernel size to be important in determining dehulling yield, but also kernel shape (Munck *et al.*, 1982). The sieve fraction determination is also a means of selecting the best-shaped sorghum kernels, since sorghum with less spherically shaped kernels will have the tendency to pass more difficult through smaller sized screens. Kernel structure, which differs highly with locality of growth and cultivar in turn, determines the ease of dehulling and grain hardness (Reichert *et al.*, 1982).

The meal was sifted in the current study in an attempt to determine the sieve fraction of the meal in a similar way to that of the kernels. The primary milled product should have an even particle-size distribution in order to be desirable (Gomez *et al.*, 1997). The sifting of meal separates the fines in the meal from the coarse materials (Pretorius & Du Plessis, 1999) thereby indicating the particle-size distribution of meal fractions.

Density of sorghum grain is also influenced by kernel structure. This is mainly because of endosperm properties, such as endosperm texture and type. Density, which is another important physical property of the sorghum kernel, is strongly negatively correlated to endosperm texture (Maxson *et al.*, 1971). Endosperm texture and endosperm type in turn, plays an important role in the determination of product quality (Pushpamma & Vogel, 1982) and milling performance (Maxson *et al.*, 1971). The reason for the negative correlation between density and endosperm texture could be explained by the fact that endosperm texture is determined by the proportion of horny to floury endosperm (Cagampang & Kirleis, 1984), which may vary in density due to different compositions. The TKW is a function of density, but also of kernel size (Kirleis & Crosby, 1982).

The HKW and TKW determine the density of kernels and are expressed in grams per 100 kernels ($g.100^{-1}$) (Gomez *et al.*, 1997) and grams per 1000 kernels ($g.1000^{-1}$) (Dewar *et al.*, 1993) respectively. As only the unit of expression between the TKW and HKW differs, the HKW can be used instead of the TKW and it can be assumed, that they measure the same properties. Although the TKW is mainly used as a tool for the determination of density, it was found to be a better indication of kernel size than kernel density, as the major component of TKW consists of kernel size and the minor component of density (Kirleis & Crosby, 1982). This again stresses the importance of kernel size determination to find out what the contribution of kernel size is to the TKW. The TKW was also found to correlate well with hardness (Kirleis & Crosby, 1982; McDonough *et al.*, 1998), which could be expected due to the correlation that exists between density and endosperm texture, as mentioned earlier.

Both in the malting and milling industry, it is important to know the moisture content before processing, in order to ensure that the correct conditioning process, when applicable, is applied. The moisture content or uptake of grain also influences hardness, as water entering the endosperm weakens or breaks the protein-starch bonds that contribute to hardness (Hoseney, 1994). No average moisture content for sorghum and sorghum meal is mentioned in the literature, as there is too much variation between different samples and the moisture content of the same type of grain varies, depending on the surrounding air (Hoseney, 1994). This emphasizes the importance of moisture determination as part of quality control, in the further processing of sorghum.

The main objectives of this chapter are to:

1. Determine and identify the importance of the different physical quality parameters of 24 sorghum cultivars over 2 seasons at 3 localities per season that might have an influence on the milling performance of sorghum cultivars, in order to identify reliable predictions of sorghum milling quality.
2. Determine an interrelationship between some of the physical quality traits of sorghum that might be used in the prediction of the milling performance of sorghum cultivars.

3.2 MATERIALS AND METHODS

3.2.1 SORGHUM CULTIVARS

The same 24 sorghum cultivars from the same localities and seasons were used as described in 2.2.1 in Chapter 2 and the same method of preparation for cleaning of grain was used. Again replications were only performed where mentioned, as explained in 2.2.1.

3.2.2 WATER ABSORPTION

The determination of the water absorption (WA) percentage of the sorghum cultivars was discussed in 2.2.5 in Chapter 2, and the same data will be used.

3.2.3 SIEVE FRACTIONS (KERNELS)

Sieve fractions (SF) of whole kernels were determined in duplicate, according to the method described by Gomez *et al.*, (1997). Hand testing screens with mesh sizes of 4000, 2800, 0 μm (diameter=200 mm) respectively, stacked onto one another, and placed onto a Fritsch Vibratory Screen Shaker were used. Samples of 50 g sorghum were poured onto the screens and the shaker was allowed to run for 1 min. The mass of grain from each screen was noted and expressed as a percentage of the original sample mass. Grain collected on the 4000 μm screen was classified as large (SFL), those on the 2800 μm screen as medium (SFM) and those on the 0 μm as small (SFS) sized grain for the purpose of the study to distinguish between the three size fractions.

3.2.4 SIEVE FRACTIONS (MEAL)

Samples (100 g) were milled by using a Cyclotec 1093 sample mill, equipped with a 2-mm screen. Samples are passed through the mill in a stream of air to break kernels on a grinding ring, surrounding the inner surface of the mill. Grain enters the mill with a stream of air. A high speed rotating impeller throws the grain against the grinding (abrasive) ring, until the material is fine enough to pass through the 2-mm screen. Samples of meal (50 g) were put through a Roff Separation Sieve equipped with a 399 and 338 μm mesh screen. The mass of sieve fractions from each screen were determined and expressed as a percentage of the original sample mass. Meal from the top of the 399 μm and 338 μm screens were classified as large (MFL) and medium sized (MFM) sieve fraction respectively, while those that went through the screens were classified as small sized sieve fractions (MFS).

3.2.5 HUNDRED KERNEL WEIGHT

The hundred-kernel weight (HKW) of the samples was determined in duplicate according to the method described by Gomez *et al.*, (1997). A Numigral Seed Counter was used for the automatic counting of 100 kernels, after which the counted kernels were weighed. The HKW was expressed on a dry (zero % moisture) basis by using the moisture content of the grain determined in 3.2.6.

3.2.6 MOISTURE CONTENT

Samples were milled on a 1093 Cyclotec Sample Mill equipped with a 2 mm screen and the moisture content (MC) of the meal was determined in a Memmert UL 80 drying oven, according to the method described by Gomez *et al.*, 1997. Pre-weighed samples (10 g) were dried at 130°C for 2.5 hours in weighing bottles and weighed again after drying.

3.2.7 STATISTICAL ANALYSIS OF DATA

Data was statistically analysed as was described in 2.2.8 in Chapter 2.

A three-way randomised block ANOVA was performed on the SF and MF as each fraction consisted of 3 fractions, namely large, medium and small. This was followed by the performance of a two-way randomised block ANOVA on each individual fraction, i.e. for grain kernels (SFL, SFM, SFS) and meal (MFL, MFM and MFS). All ANOVA's were done by using Costat (Cohort Version 3.02).

3.3 RESULTS AND DISCUSSION

3.3.1 WATER ABSORPTION

The water absorption capacities of the 24 sorghum cultivar samples over 2 seasons at 3 localities per season, were discussed in 2.3.3 of Chapter 2, where it was determined that cultivar, locality and season significantly influenced the WA abilities of sorghum kernels (Table 2.9). As the soft endosperm absorbs water better than the hard endosperm as mentioned in 3.1, cultivars with higher WA levels can be expected to be softer cultivars, while low WA levels may indicate harder cultivars. Cultivars with good water absorption abilities will absorb more water during conditioning before milling. As the main purpose of conditioning is to moisten the pericarp and not solely to soften the endosperm, too high a WA level, may again indicate cultivars of low milling quality. As only SNK 3860, NS 5511 and NK 283 corresponded ($p>0.05$) with the highest ranked cultivar (SNK 3620) for WA (Table 2.7), these cultivars are expected to be softer and have higher rates of WA during the conditioning process of sorghum during milling. Cultivars, such as PAN 8171, PAN 8061, PAN 8272, SNK 3443, NK 286, PAN 8370, SNK 3663, SNK 3567, SNK 3975 and PAN 8446 that corresponded with the lowest ranked cultivar for WA, namely SNK 3337, are expected to be harder cultivars, with higher milling quality and lower WA levels during the conditioning process.

The higher WA levels found at Potch, which was discussed in Chapter 2 (2.3.3), may also indicate that grain from this locality is of lower milling quality, due to increased softness and WA levels that may be found during conditioning. Plat and Green, on the other hand had lower levels of WA, indicating possible hardness and better milling performance due to lower levels of WA during conditioning. As also mentioned in 2.3.3, seasonal differences in WA of sorghum grain were not very large, but still significant (Fig. 2.9). The higher WA levels found during the 1997/98 season indicate the possibility of softer grain during this season, accompanied by higher WA levels during conditioning and consequential lower milling performances are expected.

3.3.2 SIEVE FRACTIONS (KERNELS)

The SF values of whole kernels for the 24 cultivars over 2 seasons at 3 localities per season are shown in Table 3.1. From the ANOVA (Table 3.2) including all three SFs, it is seen that significant differences in SF sizes exists and that the cultivar x locality and cultivar x size interactions are significant. As these interactions are important but difficult to explain and a clear ranking of cultivars is not made by this type of ANOVA, a second ANOVA (2-way randomised blocks) was performed on each different SF (Table 3.3, 3.5 and 3.7). The rankings of cultivars for each SF due to its ANOVA are shown in Table 3.4, 3.6 and 3.8. From Table 3.3, 3.5 and 3.7, it is seen that all three sieve fractions show significant differences for different cultivars. The greatest percentage of large kernels was found in SNK 3860 ($p<0.05$), followed by SNK 3567 ($p<0.05$) (Fig. 3.1). No other cultivar differed significantly from all the other cultivars in the SFL value means (Table 3.4). Although differences between the SFM mean values were found, no single cultivar differed significantly from all other cultivars (Table 3.6) and means ranged from 88.40 % (PAN 8370) to 97.44 % (SNK 3337). PAN 8446, PAN 8370 and PAN 8262 had significant higher (Table 3.8) numbers of small kernels than all the other cultivars, except for PAN 8272 and SNK 3663 ($p>0.05$). No other cultivar differed ($p<0.05$) from all the other cultivars in SFS value means. From Table 3.6 it is clear that the above-mentioned cultivars with higher numbers of small kernels, are also the lowest ranked for SFM. Although not significantly different from many other cultivars, only PAN 8446, PAN 8262, as well as SNK 3663, corresponded in SFM value means with the lowest ranked cultivar for SFM, namely SNK 3860. Therefore, the high number of small kernels present in these cultivars reduced the number of medium sized kernels present. This effect can also be seen in Fig. 3.2, where the particle-size distribution of the cultivars with large numbers of large and small kernels is shown. It is clear that the increased small sized fractions reduced the medium sized fraction in PAN 8446, PAN 8370 and PAN 8262. This effect on the SFM was not seen in SNK 3860, SNK 3567 and PAN 8446, with increased SFL values. Despite the presence of larger numbers of small or large kernels in some cultivars, it can be seen from Fig. 3.2 that the majority of sorghum kernels in these cultivars was still medium sized, and the distribution is not that much influenced by the small or large sized fractions.

It is known that the uniformity in particle-size distribution in meal is dependent on the uniformity of kernel size (Gomez *et al.*, 1997). Therefore, sorghum grain with an excessively large number of small or large kernels amongst average sized kernels, is not acceptable in terms of milling quality. Thus, the particle-size distribution of SNK 3860 and SNK 3567 (many large kernels) and PAN 8446, PAN 8370 and PAN 8262 (many small kernels) is expected to be less uniform than with other cultivars. However, in all the above-mentioned cultivars, the SFM value was dominant over the SFL and SFS values and as seen from Fig. 3.2, the contribution of the SFL and SFS to the total particle-size distribution is minor, compared to the particle-size distribution of SFM.

TABLE 3.1
SIEVE FRACTIONS OF SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 PERIODS

CULTIVAR	SIZE	DOVER	PLAT	GREEN		POTCH		MEAN	
		1997\98	1998\99	1997\98	1998\99	1997\98	1998\99	1997\98	1998\99
ADV 5010	LARGE	1.709	0.480	1.170	0.330	4.000	1.380	2.293	0.730
	MEDIUM	96.811	95.910	96.110	96.511	95.220	95.910	96.047	96.111
	SMALL	1.399	3.430	2.550	3.269	0.710	2.520	1.553	3.073
APN 881	LARGE	0.240	0.510	0.380	0.000	0.140	0.120	0.253	0.210
	MEDIUM	96.831	98.531	97.220	96.721	99.050	96.201	97.700	97.151
	SMALL	2.899	0.880	2.400	4.279	0.750	3.579	2.016	2.913
NK 283	LARGE	3.360	0.260	1.570	1.730	1.620	0.550	2.183	0.847
	MEDIUM	95.120	95.761	94.990	97.251	94.951	98.440	95.020	97.150
	SMALL	1.390	3.929	3.460	0.960	3.299	0.930	2.716	1.940
NK 286	LARGE	2.490	0.900	1.320	1.360	4.112	0.980	2.641	1.080
	MEDIUM	95.620	95.250	97.060	94.930	94.688	97.351	95.789	95.844
	SMALL	1.760	3.800	1.570	3.490	1.040	1.610	1.457	2.966
NS 5511	LARGE	1.689	1.480	0.560	0.220	0.320	0.080	0.856	0.593
	MEDIUM	96.911	96.201	94.490	97.060	94.809	96.800	95.404	96.687
	SMALL	1.270	2.190	4.880	2.740	4.820	2.860	3.657	2.596
NS 5655	LARGE	1.440	0.860	0.480	0.660	1.160	0.490	1.027	0.670
	MEDIUM	97.420	96.521	95.930	89.970	95.990	95.780	96.447	94.090
	SMALL	1.100	2.469	3.510	9.350	2.614	3.610	2.408	5.143
PAN 8061	LARGE	0.290	1.400	7.130	0.120	0.270	0.470	2.563	0.663
	MEDIUM	96.581	84.643	91.720	89.521	97.060	96.481	95.120	90.215
	SMALL	3.019	13.537	1.030	10.169	2.590	2.860	2.213	8.855
PAN 8171	LARGE	0.310	0.080	0.000	0.250	0.030	0.030	0.113	0.120
	MEDIUM	95.611	96.961	93.492	92.222	96.121	96.641	95.075	95.275
	SMALL	4.059	2.680	6.398	7.418	3.609	3.179	4.689	4.426
PAN 8262	LARGE	0.650	0.540	0.390	0.180	0.320	0.310	0.453	0.343
	MEDIUM	95.110	88.573	77.220	91.500	93.341	93.801	88.557	91.292
	SMALL	4.170	10.847	22.320	8.450	6.229	5.839	10.906	8.379
PAN 8272	LARGE	0.330	0.720	0.190	0.040	0.210	2.200	0.243	0.987
	MEDIUM	96.092	90.474	93.812	82.607	97.480	94.591	95.794	89.224
	SMALL	3.379	8.547	5.828	17.323	2.220	3.069	3.809	9.646
PAN 8370	LARGE	0.100	0.590	0.250	0.190	0.210	6.260	0.187	2.347
	MEDIUM	95.600	85.901	90.451	73.180	95.851	89.420	93.968	82.834
	SMALL	4.150	13.379	9.039	26.680	3.849	3.220	5.679	14.426
PAN 8446	LARGE	0.000	1.120	0.160	0.240	0.170	0.000	0.110	0.453
	MEDIUM	92.341	80.904	90.320	80.056	95.780	95.370	92.814	85.443
	SMALL	7.529	17.766	8.170	19.664	3.930	4.570	6.543	14.000
PAN 8564	LARGE	0.820	0.990	0.040	0.080	0.380	0.400	0.413	0.490
	MEDIUM	97.680	98.130	91.551	97.410	97.630	98.990	95.620	98.177
	SMALL	0.870	0.790	8.429	2.560	1.900	0.560	3.733	1.303
PAN 8660	LARGE	0.180	0.280	0.160	0.060	0.310	0.210	0.217	0.183
	MEDIUM	96.161	92.353	92.880	89.852	97.150	97.781	95.397	93.329
	SMALL	3.539	6.737	6.780	9.538	2.410	2.000	4.243	6.092
SNK 3337	LARGE	3.589	0.830	1.060	0.280	1.530	3.100	2.060	1.403
	MEDIUM	97.420	98.980	98.400	97.750	97.430	96.380	97.750	97.704
	SMALL	1.100	0.160	0.540	1.870	0.860	0.450	0.833	0.827
SNK 3443	LARGE	0.530	3.769	0.670	1.320	0.200	0.760	0.467	1.950
	MEDIUM	97.070	85.233	91.091	92.531	97.480	96.081	95.214	91.282
	SMALL	2.340	10.747	7.899	6.099	2.220	3.109	4.153	6.652
SNK 3567	LARGE	6.098	2.200	0.300	4.269	5.500	7.288	3.966	4.586
	MEDIUM	93.103	96.920	91.050	94.451	93.451	91.692	92.534	94.355
	SMALL	0.790	0.720	8.540	1.060	0.890	0.860	3.406	0.880

TABLE 3.1
(CONTINUED)
SIEVE FRACTIONS OF SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 PERIODS

CULTIVAR	SIZE	DOVER	PLAT	GREEN		POTCH		MEAN	
		1997\98	1998\99	1997\98	1998\99	1997\98	1998\99	1997\98	1998\99
SNK 3620	LARGE	8.549	0.940	2.370	0.160	1.200	1.370	4.040	0.823
	MEDIUM	97.070	98.220	97.030	97.941	97.870	97.360	97.323	97.840
	SMALL	2.340	0.770	0.470	1.819	0.920	0.990	1.243	1.193
SNK 3663	LARGE	0.280	1.800	0.490	0.000	0.060	0.150	0.277	0.650
	MEDIUM	96.880	87.281	96.330	85.190	96.420	91.331	96.544	87.934
	SMALL	2.640	10.889	3.110	14.570	3.480	8.529	3.076	11.329
SNK 3860	LARGE	3.810	9.428	5.520	7.418	4.300	6.767	4.543	7.871
	MEDIUM	95.350	90.112	94.270	92.282	94.810	90.913	94.810	91.102
	SMALL	0.660	0.320	0.170	0.400	0.600	2.200	0.477	0.973
SNK 3863	LARGE	0.270	0.580	0.440	0.160	3.180	0.810	1.297	0.517
	MEDIUM	97.380	96.811	94.852	94.881	95.570	98.160	95.934	96.617
	SMALL	2.190	2.449	4.708	4.889	1.190	0.960	2.696	2.766
SNK 3883	LARGE	0.780	0.340	0.660	0.080	1.910	0.270	1.117	0.230
	MEDIUM	94.411	94.901	95.311	94.552	96.790	96.180	95.504	95.211
	SMALL	4.589	4.439	3.949	5.318	1.200	3.540	3.246	4.433
SNK 3939	LARGE	0.840	0.890	0.430	0.361	0.430	0.240	0.567	0.497
	MEDIUM	97.761	96.100	95.131	93.500	97.400	98.400	96.764	96.000
	SMALL	1.280	2.980	4.429	6.060	2.150	1.190	2.620	3.410
SNK 3975	LARGE	0.340	0.150	0.030	0.070	0.280	0.210	0.217	0.143
	MEDIUM	97.860	94.801	97.170	94.131	97.030	98.600	97.354	95.844
	SMALL	1.730	4.899	2.770	5.719	2.650	1.160	2.383	3.926

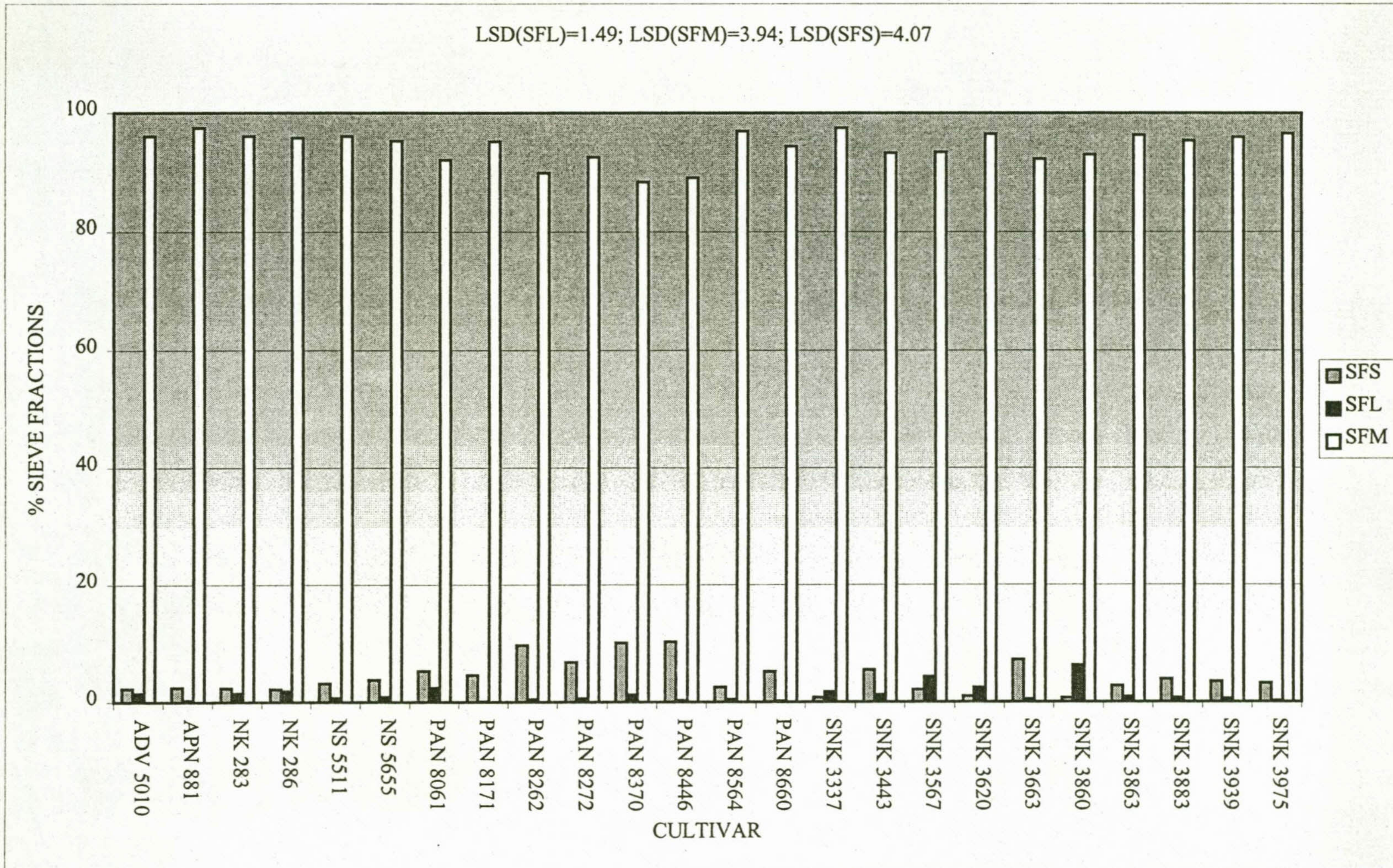


FIG. 3.1

THE SIGNIFICANT DIFFERENCES BETWEEN THE SIEVE FRACTION VALUE MEANS OF DIFFERENT SORGHUM CULTIVARS

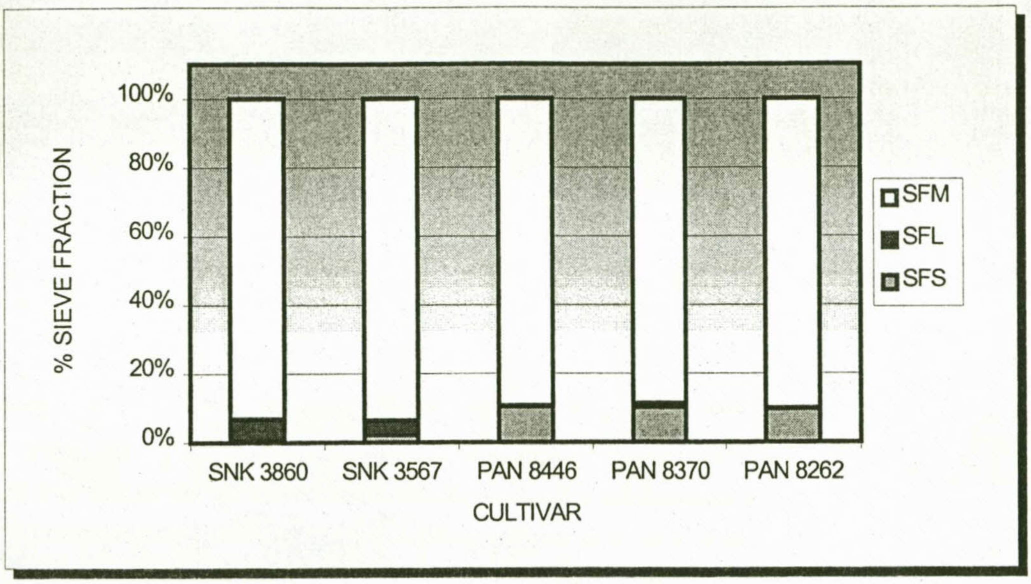


FIG. 3.2

THE PARTICLE-SIZE DISTRIBUTION OF THE KERNELS OF SOME SORGHUM CULTIVARS

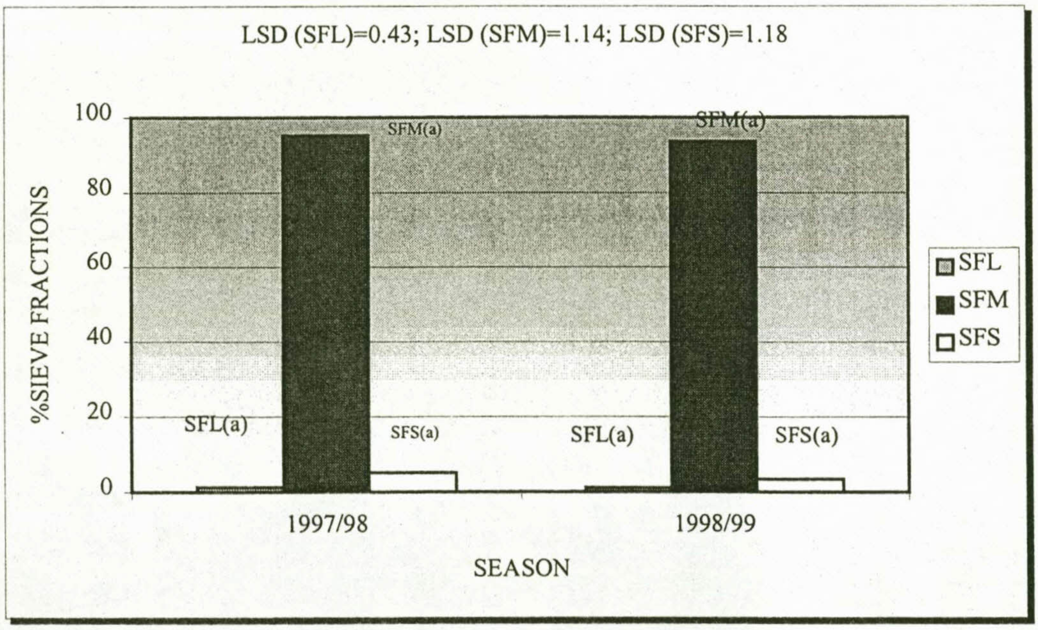
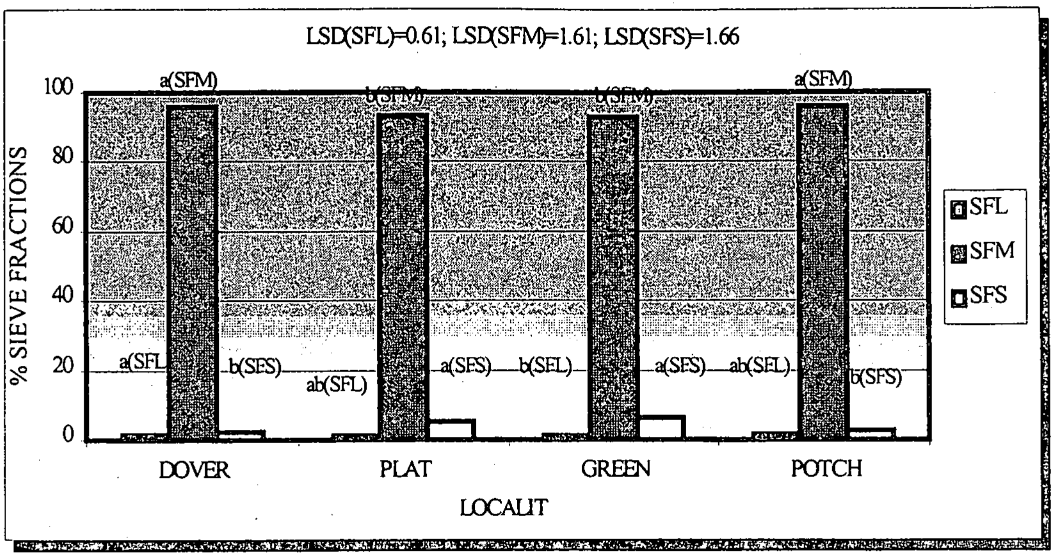


FIG. 3.3

THE INSIGNIFICANT DIFFERENCES IN THE SF VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS



F IG. 3.4

THE DIFFERENCES IN THE SIEVE FRACTIONS VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 3.2

A THREE WAY RANDOMIZED BLOCK ANALYSIS OF VARIANCE FOR ALL THREE SIEVE FRACTIONS LARGE MEDIUM AND SMALL) OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	**df**	**Type III**	**SS**	**MS**	**F**	**P**
Blocks (SEASON)	1	0.0094	0.0094	0.0011	0.9740	ns
Main Effects						
CULTIVAR	23	0.2478	0.0108	0.0012	1.0000	ns
LOCALITY	3	0.0448	0.0149	0.0017	0.9999	ns
SF	2	718174.4762	359087.2400	40539.2660	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	0.7076	0.0103	0.0012	1.0000	ns
CULTIVAR x SF	46	2061.5412	44.8161	5.0595	0.0000	***
LOCALITY x SF	6	797.3215	132.8869	15.0023	0.0000	***
CULTIVAR x LOCALITY x SF	138	1474.9236	10.6879	1.2066	0.1331	ns
Error	143	1266.6602	8.8578	<-		
Total	431	813244.9700				

*p=0.05

ns=not significant

TABLE 3.3

ANALYSIS OF VARIANCE OF THE SIEVE FRACTION LARGE OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	0.1552	0.1552	0.0939	0.7607	ns
Main Effects						
CULTIVAR	23	250.1181	10.8747	6.5761	0.0000	***
LOCALITY	3	7.8816	2.6272	1.5887	0.2047	ns
Interaction						
CULTIVAR x LOCALITY	69	144.3240	2.0917	1.2648	0.1976	ns
Error	47	77.7230	1.6537<-			
Total	143	502.7901				

*p=0.05

ns=not significant

TABLE 3.4

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN SIEVE FRACTION LARGE VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	SNK 3860	6.207	6	a
2	SNK 3567	4.276	6	b
3	SNK 3620	2.432	6	c
4	NK 286	1.860	6	cd
5	SNK 3337	1.731	6	cde
6	PAN 8061	1.613	6	cdef
7	NK 283	1.515	6	cdefg
8	ADV 5010	1.512	6	cdefg
9	PAN 8370	1.267	6	cdefg
10	SNK 3443	1.208	6	cdefg
11	SNK 3863	0.907	6	defg
12	NS 5655	0.848	6	defg
13	NS 5511	0.725	6	defg
14	SNK 3883	0.673	6	defg
15	PAN 8272	0.615	6	defg
16	SNK 3939	0.497	6	defg
17	SNK 3663	0.463	6	defg
18	PAN 8564	0.452	6	defg
19	PAN 8262	0.398	6	defg
20	PAN 8446	0.282	6	efg
21	APN 881	0.232	6	fg
22	PAN 8660	0.210	6	fg
23	SNK 3975	0.180	6	fg
24	PAN 8171	0.117	6	g

TABLE 3.5
ANALYSIS OF VARIANCE OF THE SIEVE FRACTION MEDIUM OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	31.3600	31.3600	2.7211	0.1057	ns
Main Effects						
CULTIVAR	23	813.8227	35.3836	3.0702	0.0006	***
LOCALITY	3	274.1555	91.3852	7.9294	0.0002	***
Interaction						
CULTIVAR x LOCALITY	69	742.6614	10.7632	0.9339	0.6072	ns
Error	47	541.6701	11.5249<-			
Total	143	2568.2657				

*p=0.05

ns=not significant

TABLE 3.6
RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN SIEVE FRACTION MEDIUM VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	SNK 3337	97.435	6	a
2	APN 881	97.425	6	a
3	PAN 8564	96.899	6	ab
4	SNK 3975	96.599	6	abc
5	SNK 3620	96.472	6	abc
6	SNK 3863	96.276	6	abcd
7	NK 283	96.085	6	abcde
8	ADV 5010	96.079	6	abcde
9	NS 5511	96.045	6	abcde
10	SNK 3939	96.004	6	abcde
11	NK 286	95.817	6	abcde
12	SNK 3883	95.357	6	abcde
13	NS 5655	95.269	6	abcde
14	PAN 8171	95.175	6	abcde
15	PAN 8660	94.363	6	abcde
16	SNK 3567	93.445	6	bcdef
17	SNK 3443	93.248	6	bcdef
18	SNK 3860	92.956	6	bcdefg
19	PAN 8061	92.668	6	cdefg
20	PAN 8272	92.509	6	defg
21	SNK 3663	92.239	6	efgh
22	PAN 8262	89.924	6	fgh
23	PAN 8446	89.128	6	gh
24	PAN 8370	88.401	6	h

TABLE 3.7

ANALYSIS OF VARIANCE OF THE SIEVE FRACTION SMALL OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1.0000	37.9698	37.9698	3.0886	0.0854	ns
Main Effects						
CULTIVAR	23.0000	997.8483	43.3847	3.5291	0.0001	***
LOCALITY	3.0000	365.2900	121.7633	9.9047	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69.0000	588.6458	8.5311	0.6940	0.9176	ns
Error	47.0000	577.7916	12.2934<-			
Total	143.0000	2738.8695				

*p=0.05

ns=not significant

TABLE 3.8

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN SIEVE FRACTION SMALL VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	PAN 8446	10.272	6	a
2	PAN 8370	10.053	6	a
3	PAN 8262	9.642	6	a
4	SNK 3663	7.203	6	ab
5	PAN 8272	6.728	6	abc
6	PAN 8061	5.534	6	bcd
7	SNK 3443	5.402	6	bcd
8	PAN 8660	5.167	6	bcd
9	PAN 8171	4.557	6	bcde
10	SNK 3883	3.839	6	bcde
11	NS 5655	3.775	6	bcde
12	SNK 3939	3.410	6	bcde
13	SNK 3975	3.155	6	bcde
14	NS 5655	3.127	6	cde
15	SNK 3863	2.731	6	cde
16	PAN 8564	2.518	6	de
17	APN 881	2.465	6	de
18	NK 283	2.328	6	de
19	ADV 5010	2.313	6	de
20	NK 286	2.212	6	de
21	SNK 3567	2.143	6	de
22	SNK 3620	0.978	6	e
23	SNK 3337	0.753	6	e
24	SNK 3860	0.725	6	e

Milling yields of PAN 8446, PAN 8370 and PAN 8262 are expected to be higher, since smaller kernels result in higher milling yields due to less breakage of kernels (Wills & Ali, 1982), but milling losses may be higher (Gomez *et al.*, 1997) due to the larger surface area expose to the milling surface. SNK 3860 and SNK 3567 may have lower milling yields as large kernels that are not hard enough, have the tendency to crack (Munck *et al.*, 1982). As the majority of the kernels in samples from all 24 cultivars are medium sized, the effect of kernel size on milling yields may not be significant in the present study. Milling yields will be discussed in Chapter 4.

Only significant differences between the SF value means at different localities of growth were found for the SFS and SFM values (Table 3.3, 3.5 and 3.7). Dover and Potch had higher ($p<0.05$) SFM value means than Plat and Green (Fig. 3.4), while the opposite is seen for the SFS value means. This observation of the SF values over localities is in agreement with what was seen earlier for the SF of cultivars, namely that an increase in the SFS value means of sorghum, led to a decrease in the SFM value means. The influence of seasonal differences (Fig. 3.3), as well the cultivar x locality interaction, on the SF value means was not significant, as shown by the ANOVA's (Table 3.3, 3.5 and 3.7).

3.3.3 SIEVE FRACTIONS (MEAL)

Table 3.9 shows the sieve fraction values of the meal of sorghum. As with SF's an ANOVA with the size of MF included as a factor (i.e. a 3-way randomized block ANOVA), was done to identify differences in MF's (Table 3.10). Again, significant differences in MF sizes, cultivar x size and locality x size were found. For the same reasons as explained in 3.3.2 with SF, a two-way ANOVA was performed for each MF (Table 3.11, 3.13 and 3.15) and the ranking of cultivars for each SF according to its ANOVA, are shown in Table 3.12, 3.14 and 3.16. According to the ANOVA significant differences (Table 3.11, 3.13 and 3.15) were only found between the MFS and MFL values of different sorghum cultivars and MFM value means for cultivars did not differ. No single cultivar differed significantly in MFL, MFM and MFS value means from all the other cultivars (Table 3.12, 3.14 and 3.16 respectively). SNK

3620 and NS 5511 corresponded with the lowest ranked cultivar (PAN 8262) for MFL value means ($p>0.05$) (Table 3.11). Sixteen other cultivars were not different from ($p>0.05$) the highest ranked cultivar (SNK 3567) for MFL. PAN 8272 was the highest ranked cultivar for MFM, but was not different from ($p>0.05$) 20 other cultivars in MFM value means, while the lowest ranked cultivar for MFM, namely PAN 8446, were also not different form ($p>0.05$) 20 other cultivars in MFM value means (Table 3.14). The highest ranked cultivar for MFS (PAN 8262) was not different from ($p>0.05$) 11 other cultivars and the lowest ranked cultivar (ADV 5010) with 14 other cultivars in MFS value means.

TABLE 3.9

SIEVE FRACTIONS OF SORGHUM MEAL OF SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 PERIODS

CULTIVAR	SIZE	DOVER	PLAT	GREEN		POTCH	
	FRACTIONS	1997/98	1998 /99	1997/98	1998 /99	1997/98	1998 /99
ADV 5010	MFL	36.95	28.30	40.71	32.64	39.67	36.51
	MFM	24.48	26.39	24.04	27.14	20.74	22.67
	MFS	35.80	39.13	32.07	35.51	33.95	37.60
APN 881	MFL	37.25	32.40	40.32	33.45	38.56	34.47
	MFM	22.36	22.39	21.86	21.03	23.05	22.71
	MFS	35.14	43.54	34.94	41.06	36.39	41.79
NK 283	MFL	36.55	31.23	35.69	32.92	36.86	33.91
	MFM	25.15	23.88	24.86	23.80	19.94	24.04
	MFS	34.47	44.62	38.37	43.03	40.31	39.63
NK 286	MFL	31.17	29.64	38.59	37.21	35.76	37.18
	MFM	19.23	20.85	24.46	19.30	18.84	23.24
	MFS	48.35	45.22	36.56	41.50	42.91	39.88
NS 5511	MFL	31.57	26.23	38.52	27.44	33.92	34.95
	MFM	20.35	20.93	21.88	24.28	25.94	21.92
	MFS	46.35	48.50	39.19	45.67	35.51	41.45
NS 5655	MFL	43.96	28.24	43.18	32.08	37.21	36.91
	MFM	25.07	27.16	21.14	27.69	18.08	27.75
	MFS	27.57	42.38	35.76	35.31	43.01	36.65
PAN 8061	MFL	31.78	35.69	33.89	32.70	34.45	33.46
	MFM	18.74	21.04	20.32	31.39	17.97	21.03
	MFS	48.11	44.18	42.84	31.60	45.93	41.05
PAN 8171	MFL	41.64	26.29	38.73	35.61	36.19	30.20
	MFM	22.81	24.40	25.97	23.42	21.91	29.26
	MFS	32.45	50.12	32.26	39.93	39.96	33.35
PAN 8262	MFL	27.31	23.66	35.44	30.12	35.57	26.69
	MFM	20.72	25.51	20.06	21.54	23.02	21.64
	MFS	47.79	52.63	41.41	40.44	38.08	46.15
PAN 8272	MFL	36.88	27.53	38.15	34.56	39.58	31.77
	MFM	24.38	26.55	20.53	26.75	23.37	26.62
	MFS	38.93	43.96	39.42	40.37	33.26	40.13
PAN 8370	MFL	40.85	29.67	33.26	33.85	35.83	31.50
	MFM	27.58	21.10	19.74	22.97	24.01	25.15
	MFS	28.93	45.99	41.00	40.79	37.98	40.93
PAN 8446	MFL	33.19	26.40	39.41	38.28	37.86	35.55
	MFM	16.14	17.69	22.56	19.37	22.34	26.01
	MFS	49.25	53.51	39.64	39.53	37.40	40.66
PAN 8564	MFL	33.73	36.11	34.09	40.72	37.40	36.60
	MFM	18.88	25.72	19.43	21.10	17.33	23.32
	MFS	45.93	34.91	43.68	35.23	44.36	39.93
PAN 8660	MFL	35.35	31.00	39.23	35.71	33.48	34.59
	MFM	18.76	25.02	23.88	20.52	23.43	27.02
	MFS	43.44	42.24	35.75	43.04	40.74	36.30
SNK 3337	MFL	40.89	35.56	42.82	32.45	36.23	35.82
	MFM	24.21	27.41	25.35	20.79	20.96	25.24
	MFS	32.81	35.44	29.58	45.23	43.54	37.08

TABLE 3.9

SIEVE FRACTIONS OF SORGHUM MEAL OF SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 PERIODS TABLE 3.9 (CONTINUED)

CULTIVAR	SIZE	DOVER	PLAT	GREEN		POTCH	
	FRACTIONS	1997/98	1998 /99	1997/98	1998 /99	1997/98	1998 /99
SNK 3443	MFL	44.91	34.28	36.42	36.31	39.23	35.99
	MFM	14.93	23.34	27.34	20.11	21.88	26.33
	MFS	30.88	37.41	34.29	41.64	37.59	37.50
SNK 3567	MFL	37.16	35.70	42.46	36.96	35.64	39.77
	MFM	24.50	24.04	20.43	23.88	23.85	20.06
	MFS	37.47	40.22	37.35	40.13	39.05	38.96
SNK 3620	MFL	28.26	27.88	39.05	35.46	37.99	28.84
	MFM	20.24	21.91	20.10	21.84	23.59	26.60
	MFS	46.95	45.45	43.19	43.57	40.35	42.41
SNK 3663	MFL	36.90	30.77	40.95	34.89	35.00	34.12
	MFM	19.36	23.96	24.30	20.27	23.28	25.06
	MFS	41.75	45.86	32.11	40.01	42.52	35.95
SNK 3860	MFL	29.98	32.90	38.94	36.61	36.88	27.44
	MFM	22.33	24.86	24.04	22.42	23.57	24.28
	MFS	43.93	39.14	38.50	38.85	37.88	45.66
SNK 3863	MFL	39.86	30.56	31.30	38.49	41.15	36.47
	MFM	23.06	23.33	19.15	22.76	19.59	25.55
	MFS	35.24	41.92	43.82	36.51	39.59	39.00
SNK 3883	MFL	36.54	31.06	42.14	31.30	37.21	33.19
	MFM	22.35	25.53	23.29	23.81	18.90	30.02
	MFS	40.46	41.23	30.98	38.88	39.81	34.41
SNK 3939	MFL	40.16	28.96	43.60	37.37	33.78	34.15
	MFM	26.79	17.46	22.19	21.42	22.72	24.10
	MFS	30.51	47.55	31.79	40.95	40.31	39.79
SNK 3975	MFL	30.93	31.30	32.88	36.96	36.56	35.97
	MFM	18.31	24.81	24.07	23.96	23.33	26.62
	MFS	47.83	38.88	41.64	34.67	38.57	48.56

The particle-size distribution of the meal from cultivars with a greater number of small and large-sized kernels, are shown in Fig. 3.5. Firstly it is noticed that the particle sizes of sorghum meal is much more evenly distributed between small, medium and large sized particles, than in the case of the kernel size distribution (Fig. 3.2). From Fig. 3.6 it is also seen that the MFM is smaller than the MFS and MFL, compared to the SF of the kernels in Fig. 3.2, where it was seen that the SF is mainly composed of medium sized kernels. As mentioned earlier, the meal particle-size distribution of cultivars with a large number of small or large kernels in their grain, is expected to have meal SF with less uniform particle-size distributions than other cultivars. The different SF of the meal of these cultivars did not differ from other cultivars, however. This may be acclaimed to the fact that all 24 cultivars were found to consist mainly of medium sized kernels, which therefore dominated in the particle-size distribution of kernels. From these results it is clear that the particle-size distribution of sorghum kernels, contributes little to the particle-size distribution of sorghum meal in cases where the majority of the kernels are more or less uniform in size.

Seasonal differences were only found to be significant for MFL and MFM. In Fig. 3.7 it can be seen that the MFM values were higher ($p<0.05$) in 1997/98, while MFL values were lower ($p<0.05$) during the same season.

Significant differences in the SFL and SFS values were found at different localities of growth (Table 3.11, 3.13 and 3.15) as illustrated in Fig. 3.8. The MFL value means were smaller ($p<0.05$) at Plat than at the other localities, while Plat had higher MFS values than the rest of the localities ($p<0.05$).

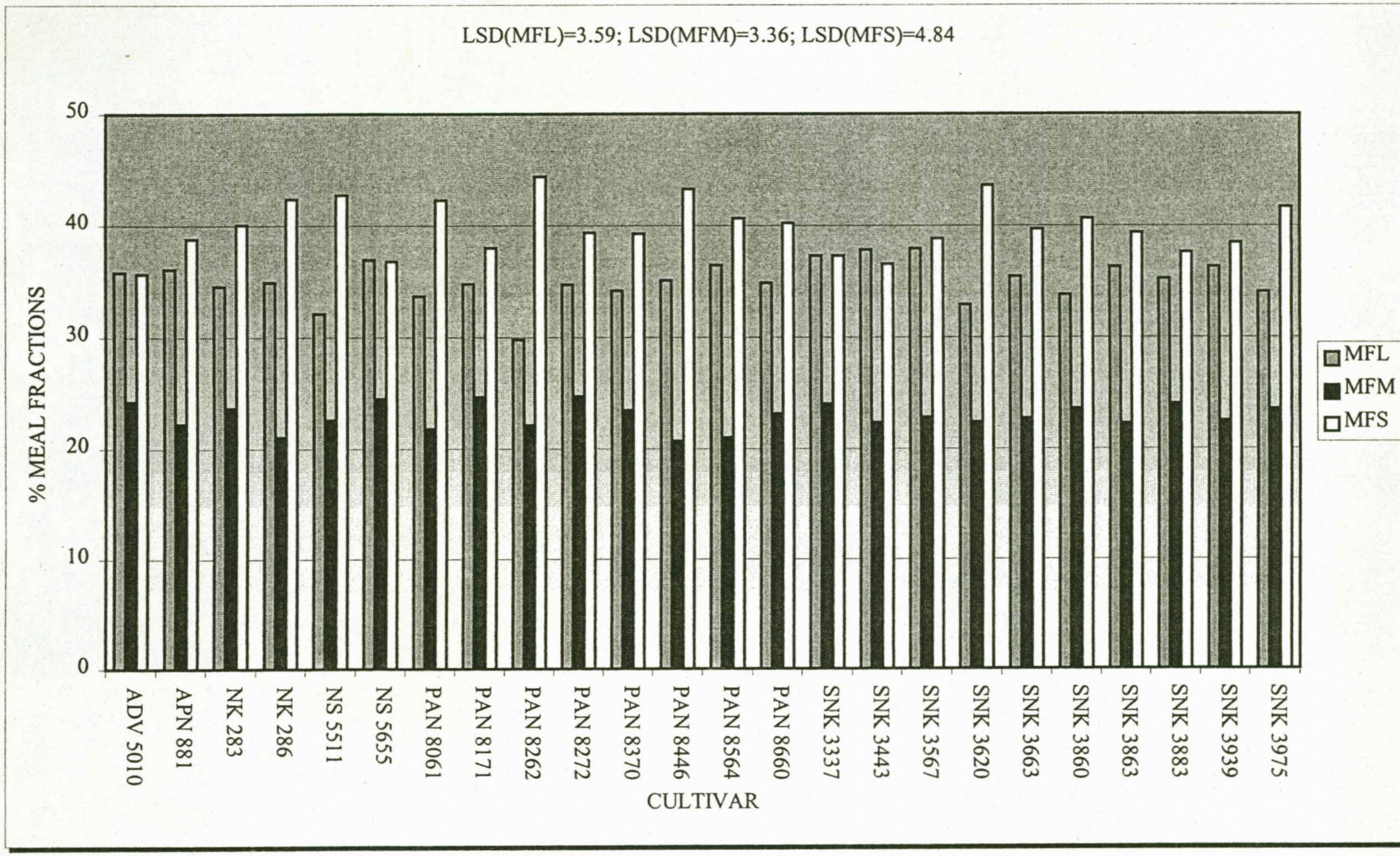


FIG. 3.5

THE SIGNIFICANT DIFFERENCES BETWEEN THE MEAL FRACTION VALUE MEANS OF DIFFERENT SORGHUM CULTIVARS

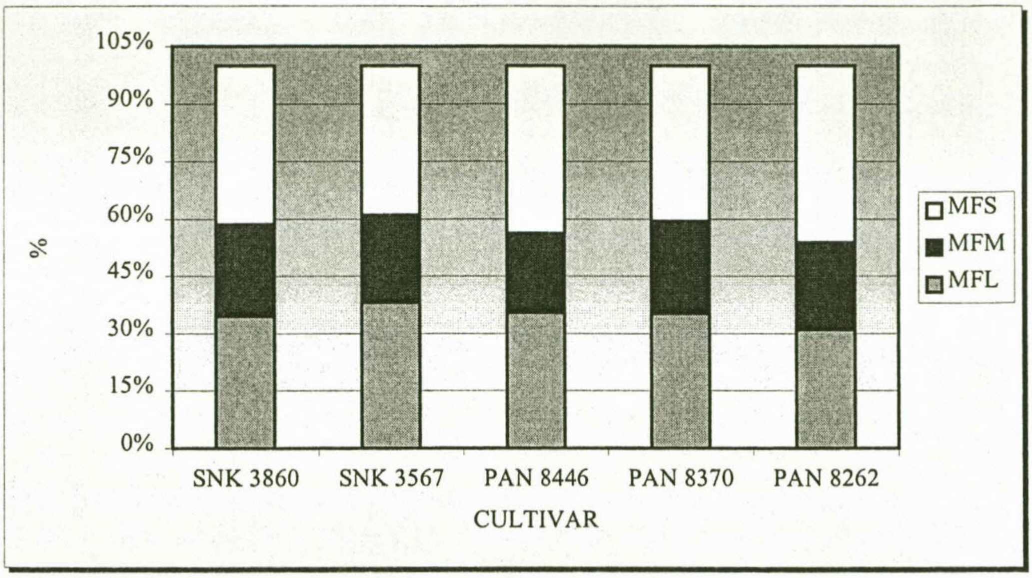


FIG. 3.6

THE PARTICLE-SIZE DISTRIBUTION OF THE MEAL OF SOME SORGHUM CULTIVARS

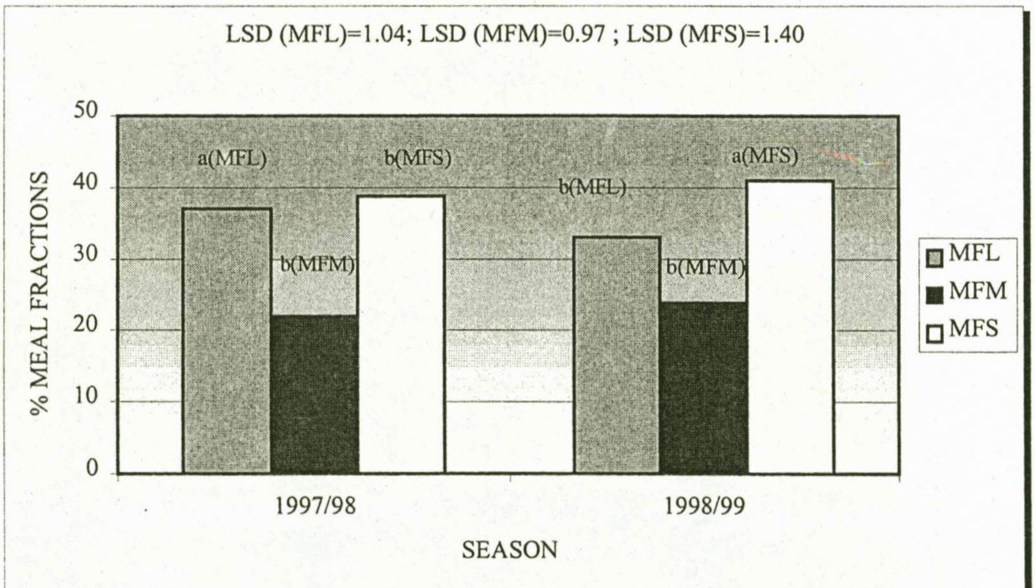


FIG. 3.7

THE DIFFERENCES IN THE MEAL FRACTION VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

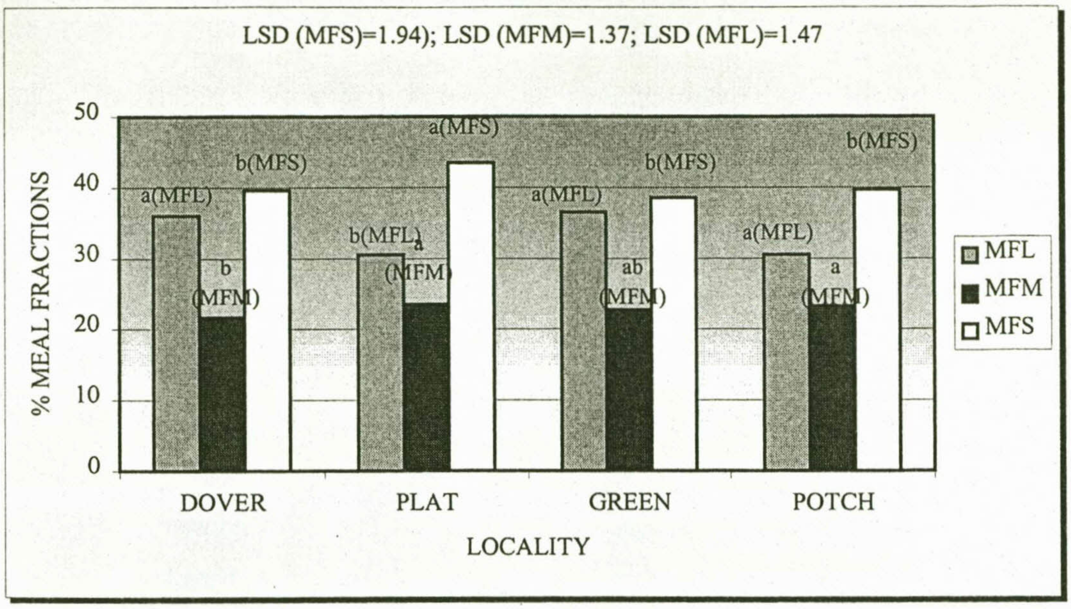


FIG. 3.8

THE DIFFERENCES IN THE MEAL FRACTION VALUE MEANS SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 3.10

THREE WAY RANDOMIZED BLOCK ANALYSIS OF VARIANCE OF ALL THREE MEAL FRACTIONS (LARGE, MEDIUM AND SMALL) OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	**df**	**Type III**	**SS**	**MS**	**F**	**P**
Blocks (SEASON)	1	0.0390	0.0390	0.0028	0.9581	ns
Main						
CULTIVAR	23	34.5081	1.5004	0.1065	1.0000	ns
LOCALITY	3	7.0764	2.3588	0.1675	0.9181	ns
SIZE	2	20373.4722	10186.7360	723.3767	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	135.5151	1.9640	0.1395	1.0000	ns
CULTIVAR x SIZE	46	1763.8916	38.3455	2.7230	0.0000	***
LOCALITY x SIZE	6	1087.2477	181.2080	12.8679	0.0000	***
CULTIVAR x LOCALITY x SIZE	138	2398.4124	17.3798	1.2342	0.1065	ns
Error	143	2013.7548	14.0822	<-		
Total	431	29219.9839				

TABLE 3.11

ANALYSIS OF VARIANCE OF THE MEAL FRACTION LARGE OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	239.6209	239.6209	25.0969	0.0000	***
Main Effects						
CULTIVAR	23	549.1840	23.8776	2.5008	0.0039	**
LOCALITY	3	314.5254	104.8418	10.9807	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	698.8657	10.1285	1.0608	0.4198	ns
Error	47	448.7481	9.5478	<-		
Total	143	2492.4769				

*p=0.05

ns=not significant

TABLE 3.12

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN MEAL FRACTION LARGE VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	SNK 3567	37.946	6	a
2	SNK 3443	37.855	6	a
3	SNK 3337	37.295	6	ab
4	NS 5655	36.929	6	abc
5	PAN 8564	36.441	6	abcd
6	SNK 3939	36.335	6	abcd
7	SNK 3863	36.306	6	abcd
8	APN 881	36.076	6	abcd
9	ADV 5010	35.796	6	abcd
10	SNK 3663	35.438	6	abcde
11	SNK 3883	35.239	6	abcde
12	PAN 8446	35.114	6	abcde
13	NK 286	34.925	6	abcde
14	PAN 8660	34.895	6	abcde
15	PAN 8171	34.778	6	abcde
16	PAN 8272	34.745	6	abcde
17	NK 283	34.527	6	abcde
18	PAN 8370	34.161	6	bcde
19	SNK 3975	34.100	6	bcde
20	SNK 3860	33.791	6	bcde
21	PAN 8061	33.662	6	cde
22	SNK 3620	32.912	6	def
23	NS 5511	32.105	6	ef
24	PAN 8262	29.797	6	f

TABLE 3.13

ANALYSIS OF VARIANCE OF THE MEAL FRACTION MEDIUM OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	75.5949	75.5949	9.0287	0.0043	**
Main Effects						
CULTIVAR	23	227.4890	9.8908	1.1813	0.3068	ns
LOCALITY	3	11.8620	3.9540	0.4722	0.7031	ns
Interaction						
CULTIVAR x LOCALITY	69	462.8602	6.7081	0.8012	0.8015	ns
Error	47	393.5202	8.3728	<-		
Total	143	1169.5620				

*p=0.05

ns=not significant

TABLE 3.14

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN MEAL FRACION MEDIUM VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	PAN 8272	24.700	6	a
2	PAN 8171	24.629	6	a
3	NS 5655	24.479	6	a
4	ADV 5010	24.244	6	ab
5	SNK 3337	23.995	6	abc
6	SNK 3883	23.983	6	abc
7	NK 283	23.611	6	abc
8	SNK 3860	23.584	6	abc
9	SNK 3975	23.516	6	abc
10	PAN 8370	23.426	6	abc
11	PAN 8660	23.104	6	abc
12	SNK 3567	22.794	6	abc
13	SNK 3663	22.705	6	abc
14	SNK 5511	22.550	6	abc
15	SNK 3939	22.447	6	abc
16	SNK 3620	22.381	6	abc
17	SNK 3443	22.321	6	abc
18	SNK 3863	22.240	6	abc
19	APN 881	22.233	6	abc
20	PAN 8262	22.080	6	abc
21	PAN 8061	21.749	6	abc
22	NK 286	20.987	6	bc
23	PAN 8564	20.965	6	bc
24	PAN 8446	20.685	6	c

TABLE 3.15

ANALYSIS OF VARIANCE OF THE MEAL FRACTION SMALL OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	41.5139	41.5139	2.3947	0.1285	ns
Main						
CULTIVAR	23	1021.7267	44.4229	2.5625	0.0031	**
LOCALITY	3	276.5218	92.1739	5.3169	0.0031	**
Interaction						
CULTIVAR x LOCALITY	69	1372.2016	19.8870	1.1471	0.3115	ns
Error	47	814.7958	17.3361	<-		
Total	143	3418.6974				

*p=0.05

ns=not significant

TABLE 3.16

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN MEAL FRACTION SMALL VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	PAN 8262	44.416	6	a
2	SNK 3620	43.654	6	ab
3	PAN 8446	43.331	6	abc
4	NS 5511	42.777	6	abcd
5	NK 286	42.403	6	abcde
6	PAN 8061	42.285	6	abcde
7	SNK 3975	41.691	6	abcdef
8	PAN 8564	40.673	6	abcdefg
9	SNK 3860	40.659	6	abcdefg
10	PAN 8660	40.251	6	abcdefgh
11	NK 283	40.071	6	abcdefgh
12	SNK 3663	39.699	6	abcdefgh
13	SNK 3863	39.347	6	bcdefgh
14	PAN 8272	39.344	6	bcdefgh
15	PAN 8370	39.270	6	bcdefgh
16	SNK 3567	38.862	6	bcdefgh
17	APN 881	38.809	6	cdefgh
18	SNK 3939	38.484	6	defgh
19	PAN 8171	38.012	6	defgh
20	SNK 3883	37.627	6	efgh
21	SNK 3337	37.280	6	fgh
22	NS 5655	36.779	6	gh
23	SNK 3443	36.551	6	gh
24	ADV 5010	35.676	6	h

3.3.4 HUNDRED-KERNEL WEIGHT

The HKW of sorghum cultivars grown at different localities over 2 seasons are shown in Table 3.17. Significant differences in the HKW value means of different sorghum cultivars were found (Table 3.18). SNK 3860, although not significantly different from SNK 3337, was not different from ($p>0.05$) the highest ranked cultivar, namely SNK 3567, in HKW value means (Table 3.19). These two cultivars also showed significantly higher SFL value means than the other cultivars (Table 3.4). PAN 8370, PAN 8660 and PAN 8262 showed high levels of small sized kernels (Table 3.8) and all corresponded with the lowest ranked cultivar HKW values, namely PAN 8446 (Table 3.19). PAN 8446 also had the highest proportion of SFS value means and confirms the influence that kernel size has on the HKW of sorghum grain, which was speculated about earlier. The HKW of grain is also an indication of the density of grain (Kirleis & Crosby, 1982). Thus, the density of grain with many small sized kernels is lower (e.g. PAN 8370 and PAN 8446) and that of grain with many large sized kernels is larger (e.g. SNK 3567 and SNK 3860).

Significant differences between the HKW value means were also found at different localities of growth (Table 3.18). No significant difference between the HKW value means at Potch and Dover was found, and these two localities showed higher HKW value means than the other localities (Fig. 3.11). Green showed the second highest values, while Plat had the lowest values for the HKW. Earlier it was found that the proportion of small kernels in sorghum is greater in grain from Plat and Green, than those from Dover and Potch. Therefore, the large proportion of small kernels in grain from Plat and Green reduced the HKW, as smaller kernels weigh less. The effect of season on HKW value means (Fig. 3.10), as well as the influence of the cultivar x locality interaction was not significant (Table 3.18).

TABLE 3.17

THE HUNDRED-KERNEL WEIGHT OF DIFFERENT SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 SEASONS

CULTIVAR	HKW (g/100 KERNELS) DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99
ADV 5010	2.67	2.22	2.39	2.52	2.67	3.04	2.57	2.59	0.16	0.42
APN 881	2.43	2.26	2.27	2.26	2.43	2.50	2.38	2.34	0.09	0.14
NK 283	2.12	2.10	2.28	2.47	2.12	2.32	2.17	2.30	0.09	0.19
NK 286	2.71	2.41	2.38	2.24	2.71	2.55	2.60	2.40	0.18	0.16
NS 5511	2.17	2.03	2.13	2.14	2.17	2.70	2.16	2.29	0.03	0.36
NS 5655	2.22	2.02	2.31	2.10	2.22	2.43	2.25	2.19	0.06	0.22
PAN 8061	2.23	1.66	2.02	2.08	2.23	2.22	2.16	1.99	0.13	0.29
PAN 8171	2.13	1.96	2.12	2.03	2.13	2.11	2.13	2.03	0.00	0.08
PAN 8262	2.14	1.84	1.62	2.14	2.14	2.18	1.97	2.05	0.30	0.18
PAN 8272	2.40	1.77	2.11	1.82	2.40	2.21	2.30	1.93	0.17	0.24
PAN 8370	2.15	1.58	2.08	1.63	2.15	2.08	2.13	1.76	0.04	0.28
PAN 8446	1.99	1.83	1.88	1.78	1.99	2.09	1.95	1.90	0.06	0.17
PAN 8564	2.29	2.32	2.04	2.18	2.29	2.56	2.20	2.35	0.14	0.19
PAN 8660	2.10	1.61	1.94	1.93	2.10	2.03	2.04	1.86	0.09	0.22
SNK 3337	2.63	2.40	2.62	2.46	2.63	3.32	2.63	2.73	0.01	0.51
SNK 3443	2.34	1.81	1.99	2.11	2.34	2.25	2.22	2.06	0.20	0.23
SNK 3567	2.99	2.61	2.96	2.74	2.99	3.05	2.98	2.80	0.02	0.22
SNK 3620	2.61	2.28	2.78	2.34	2.61	2.85	2.66	2.49	0.10	0.31
SNK 3663	2.03	1.74	2.32	2.05	2.03	2.50	2.13	2.10	0.17	0.38
SNK 3860	2.91	2.49	2.70	2.76	2.91	2.97	2.84	2.74	0.12	0.24
SNK 3863	2.60	2.49	2.34	2.18	2.60	2.64	2.51	2.44	0.15	0.23
SNK 3883	2.52	1.95	2.65	2.09	2.52	2.48	2.56	2.18	0.08	0.28
SNK 3939	2.36	1.96	2.09	1.97	2.36	2.35	2.27	2.09	0.15	0.22
SNK 3975	2.31	2.06	2.22	2.05	2.31	2.53	2.28	2.21	0.06	0.27
MEAN	2.38	21.06	2.26	2.17	2.38	2.50	2.34	2.24		
MIN	1.99	1.58	1.62	1.63	1.99	2.03	1.95	1.76		
MAX	2.99	2.61	2.96	2.76	2.99	3.32	2.98	2.80		
RANGE	1.01	1.03	1.34	1.13	1.01	1.28	1.03	1.04		
SD	0.27	0.30	0.31	0.28	0.27	0.35	0.27	0.29		

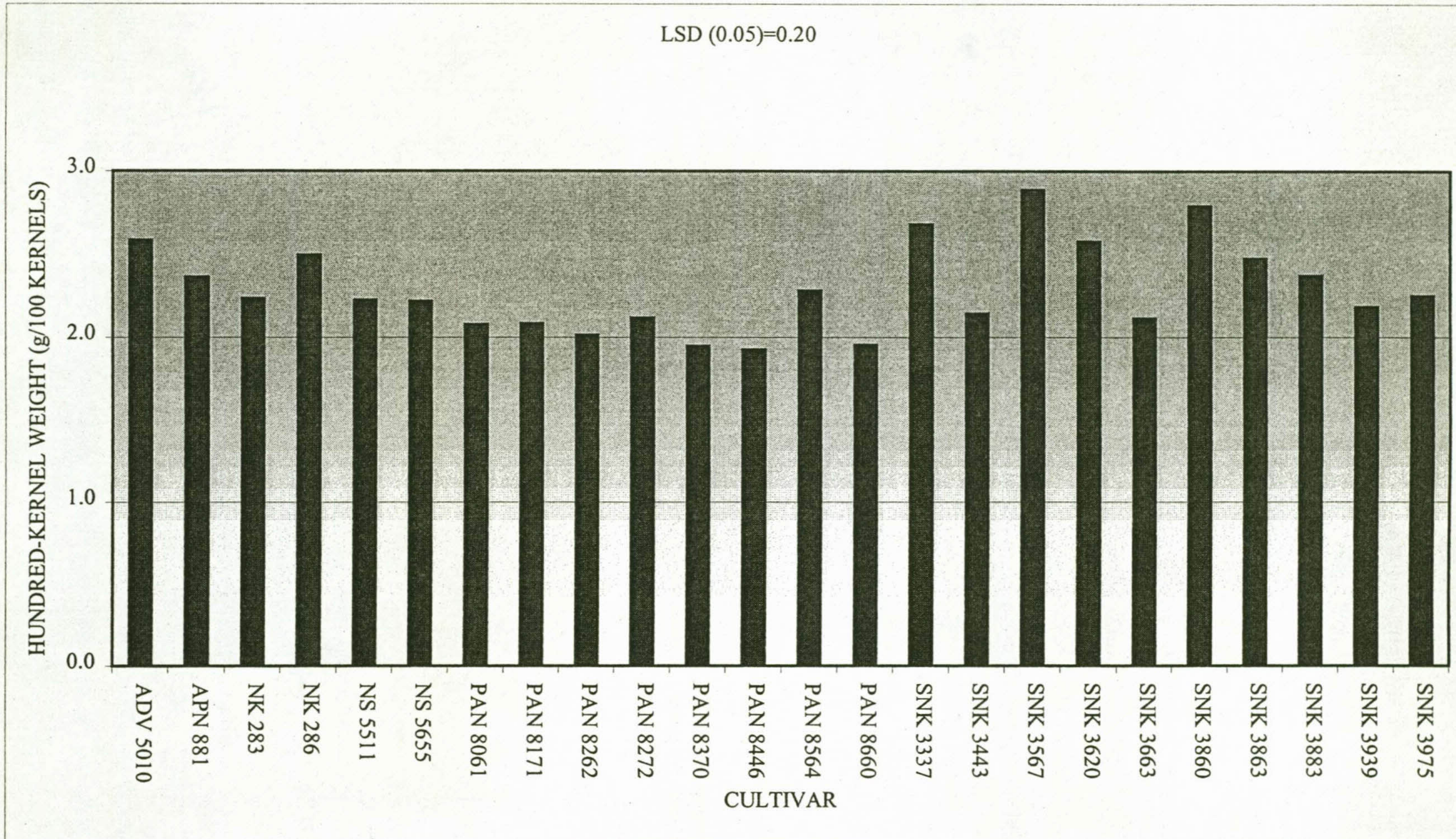


FIG. 3.9

THE SIGNIFICANT DIFFERENCES BETWEEN THE HUNDRED-KERNEL WEIGHT VALUE MEANS OF DIFFERENT SORGHUM CULTIVARS

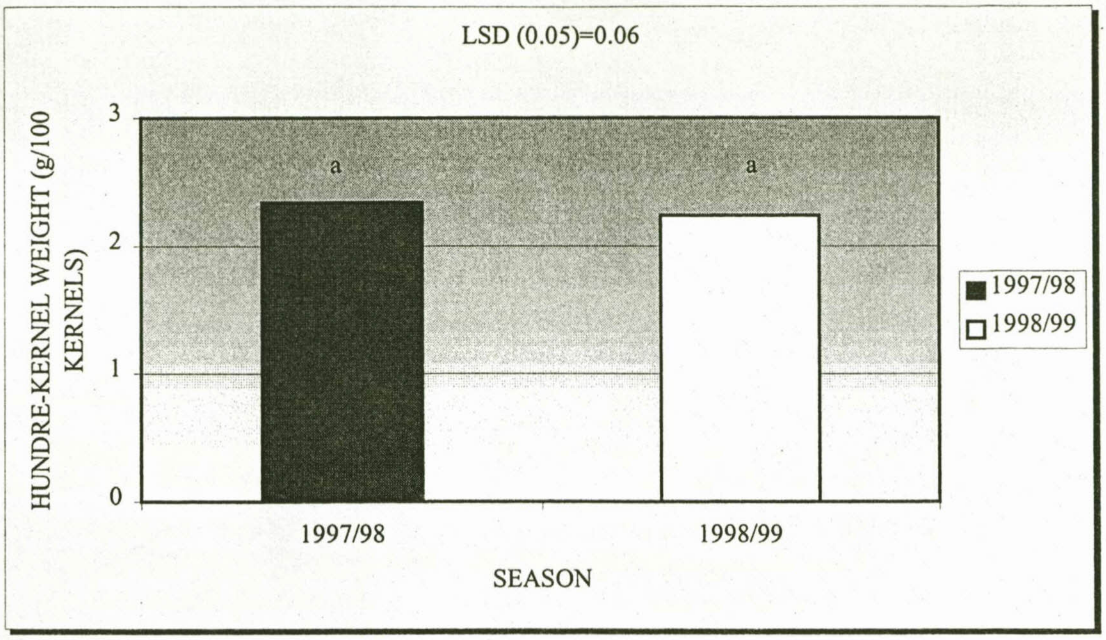


FIG. 3.10

THE INSIGNIFICANT DIFFERENCES IN THE HUNDRED-KERNEL WEIGHT VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

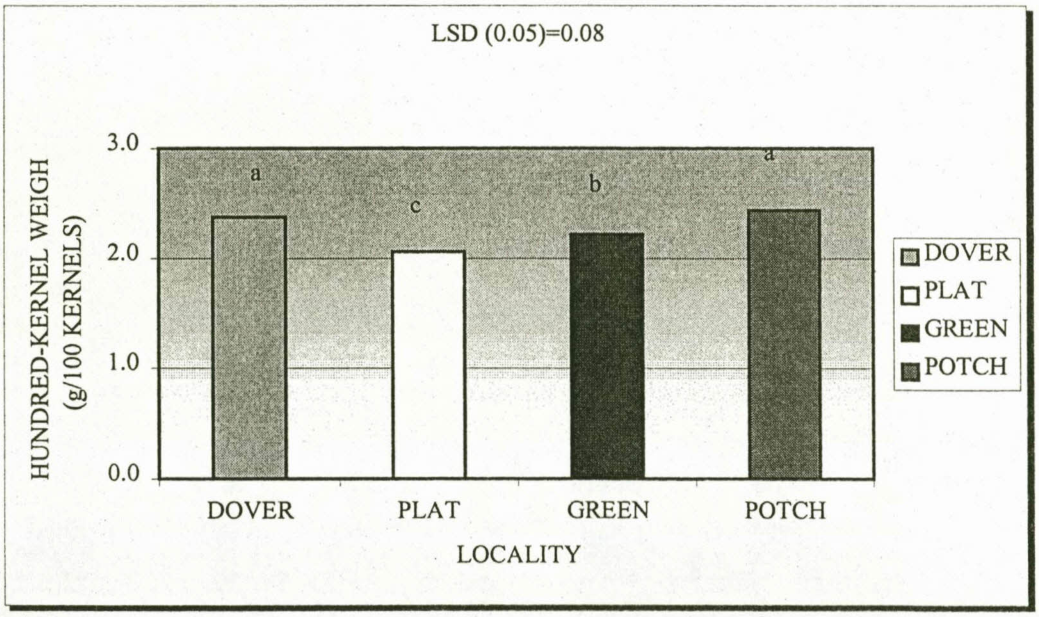


FIG. 3.11

THE DIFFERENCES IN THE HUNDRE-KERNEL WEIGHT VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 3.18

ANALYSIS OF VARIANCE OF THE HUNDRED-KERNEL WEIGHT OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	0.0063	0.0063	0.2040	0.6536	ns
Main Effects						
CULTIVAR	23	8.8362	0.3842	12.4145	0.0000	***
LOCALITY	3	2.4658	0.8219	26.5596	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	1.1291	0.0164	0.5288	0.9922	ns
Error	47	1.4545	0.0309	<-		
Total	143	15.3784				

*p=0.05

ns=not significant

TABLE 3.19

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN HUNDRED-KERNEL WEIGHT VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	SNK 3567	2.891	6	a
2	SNK 3860	2.791	6	ab
3	SNK 3337	2.677	6	bc
4	ADV 5010	2.584	6	c
5	SNK 3620	2.578	6	c
6	NK 286	2.497	6	cd
7	SNK 3863	2.476	6	cde
8	SNK 3883	2.371	6	def
9	APN 881	2.359	6	def
10	PAN 8564	2.279	6	def
11	SNK 3975	2.248	6	fg
12	NK 283	2.233	6	fg
13	NS 5511	2.223	6	fg
14	NS 5655	2.217	6	fg
15	SNK 3939	2.180	6	fgh
16	SNK 3443	2.140	6	ghi
17	PAN 8272	2.116	6	ghij
18	SNK 3663	2.111	6	ghij
19	PAN 8171	2.080	6	ghij
20	PAN 8061	2.075	6	ghij
21	PAN 8262	2.011	6	hij
22	PAN 8660	1.951	6	ij
23	PAN 8370	1.946	6	ij
24	PAN 8446	1.925	6	j

3.3.5 MOISTURE CONTENT

The MC values of different sorghum cultivars over 2 seasons at 3 localities per season, are shown in Table 3.20. No significant differences were found between the MC value means of different sorghum cultivars (Table 3.21). The only main effect with an influence on the MC value means was locality and the influence of season (Fig. 3.13) and the cultivar x locality interaction were insignificant. From Fig. 3.16 it is clear that higher MC value means ($p<0.05$) are found at Plat, as Plat is situated more to the East of the country where the average rainfall is higher than in the West. No differences ($p>0.05$) between the MC value means of Potch, Dover and Green are found, as these localities are situated more to the West of the country, where conditions are dryer. As MC may influence the protein-starch binding properties of grain (3.1), grain from Plat, which is moister, can be expected to be softer. The MC of grain equilibrates with the relative humidity of the air surrounding the grain (Hoseney, 1994). The MC of sorghum is therefore highly influenced by locality of growth and the associated rainfall conditions at a specific locality, rather than by the grain itself. The physical quality of sorghum grain (e.g. milling yield and density) is affected by the MC. It is therefore necessary that the MC of grain should always be determined as part of the determination of the physical quality of grain, to standardize the MC of the grain to the same level (Gomez *et al.*, 1997). In the present study the physical properties were determined on a moisture-free basis.

TABLE 3.20

THE MOISTURE CONTENT OF SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 PERIODS

CULTIVAR	% MOISTURE						MEAN		SD	
	DOVER	PLAT	GREEN		POTCH					
	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99
ADV 5010	12.380	14.100	10.310	13.500	13.870	11.660	12.187	13.087	1.788	1.271
APN 881	11.010	14.700	12.230	13.100	13.060	11.110	12.100	12.970	1.031	1.799
NK 283	13.510	14.300	12.450	13.200	13.440	11.740	13.133	13.080	0.593	1.284
NK 286	11.780	13.800	14.220	13.500	11.890	12.150	12.630	13.150	1.378	0.879
NS 5511	12.480	14.100	10.860	14.100	14.000	10.540	12.447	12.913	1.570	2.055
NS 5655	13.250	13.700	11.120	13.600	14.300	12.130	12.890	13.143	1.620	0.879
PAN 8061	13.740	13.900	11.100	13.600	12.710	12.430	12.517	13.310	1.331	0.777
PAN 8171	12.390	14.600	10.760	13.700	12.870	11.810	12.007	13.370	1.106	1.424
PAN 8262	11.470	14.700	11.100	11.400	10.580	12.810	11.050	12.970	0.447	1.656
PAN 8272	12.280	14.400	12.290	13.600	13.070	11.170	12.547	13.057	0.453	1.682
PAN 8370	11.660	14.600	12.740	13.300	11.720	11.830	12.040	13.243	0.607	1.386
PAN 8446	12.950	14.500	11.770	13.600	14.430	12.910	13.050	13.670	1.333	0.797
PAN 8564	13.510	15.000	10.160	13.000	11.070	10.990	11.580	12.997	1.732	2.005
PAN 8660	13.860	14.300	10.730	13.200	14.390	11.900	12.993	13.133	1.978	1.201
SNK 3337	12.600	14.300	11.440	13.500	10.460	12.110	11.500	13.303	1.071	1.108
SNK 3443	11.330	14.200	13.540	13.700	12.840	11.600	12.570	13.167	1.129	1.380
SNK 3567	11.730	14.300	10.600	13.300	11.700	10.200	11.343	12.600	0.644	2.138
SNK 3620	12.070	14.600	13.380	13.800	12.410	13.360	12.620	13.920	0.680	0.629
SNK 3663	10.530	14.500	12.040	13.900	13.170	12.010	11.913	13.470	1.325	1.299
SNK 3860	13.860	14.900	11.960	13.500	12.440	10.820	12.753	13.073	0.988	2.073
SNK 3863	11.980	14.300	12.360	13.500	11.350	12.110	11.897	13.303	0.510	1.108
SNK 3883	11.670	14.300	11.220	13.500	12.820	11.630	11.903	13.143	0.825	1.370
SNK 3939	12.820	15.100	12.270	13.500	12.410	11.990	12.500	13.530	0.286	1.555
SNK 3975	12.150	14.500	11.680	13.400	13.320	10.770	12.383	12.890	0.845	1.917
MEAN	12.375	14.404	11.764	13.417	12.680	11.741	12.273	13.187		
MIN	10.530	13.700	10.160	11.400	10.460	10.200	11.050	12.600		
MAX	13.860	15.100	14.220	14.100	14.430	13.360	13.133	13.920		
RANGE	3.330	1.400	4.060	2.700	3.970	3.160	2.083	1.320		
SD	0.920	0.350	1.044	0.496	1.138	0.761	0.554	0.275		

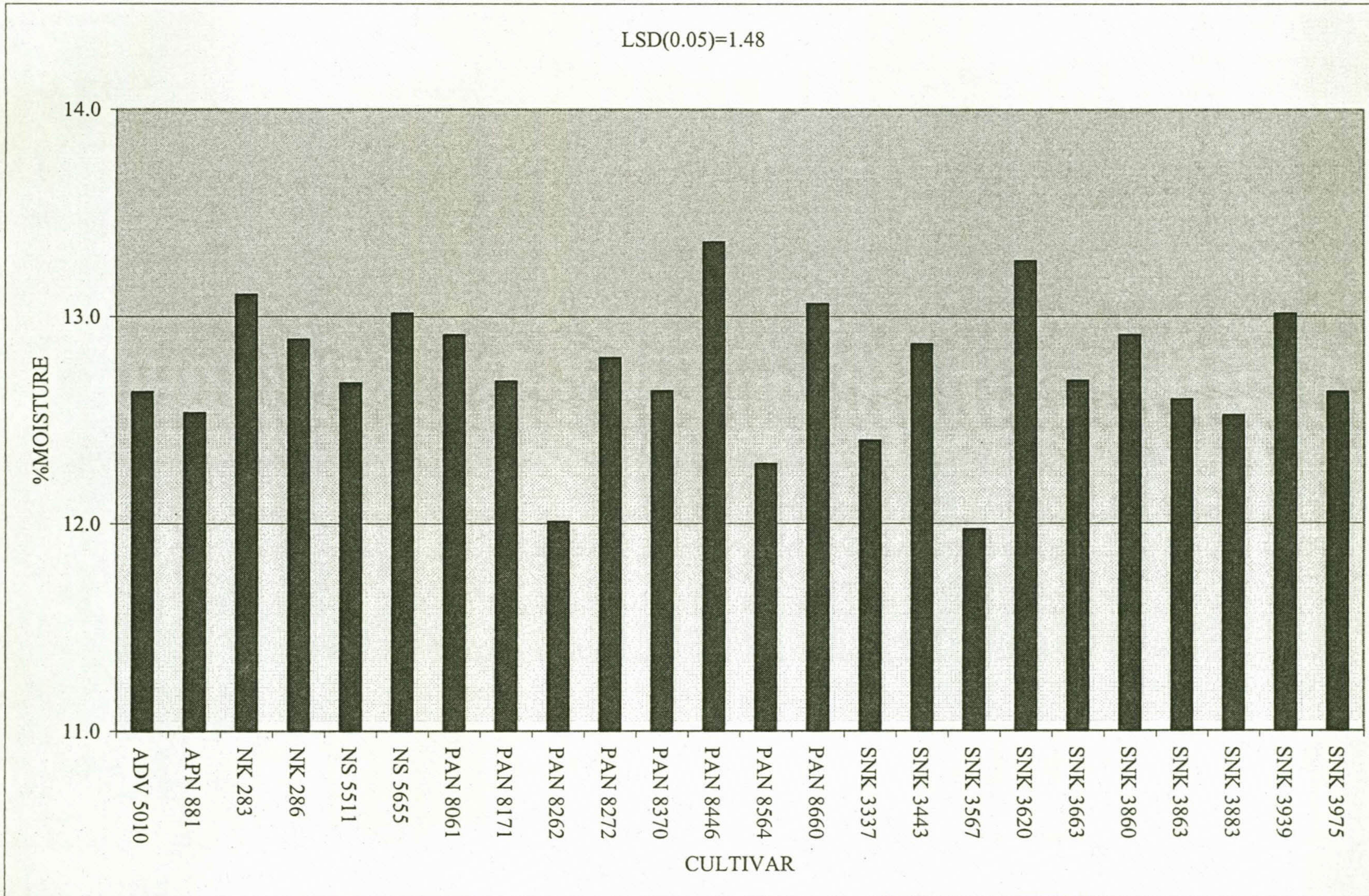


FIG. 3.12

THE INSIGNIFICANT DIFFERENCES BETWEEN THE MOISTURE CONTENT VALUE MEANS OF DIFFERENT SORGHUM CULTIVARS

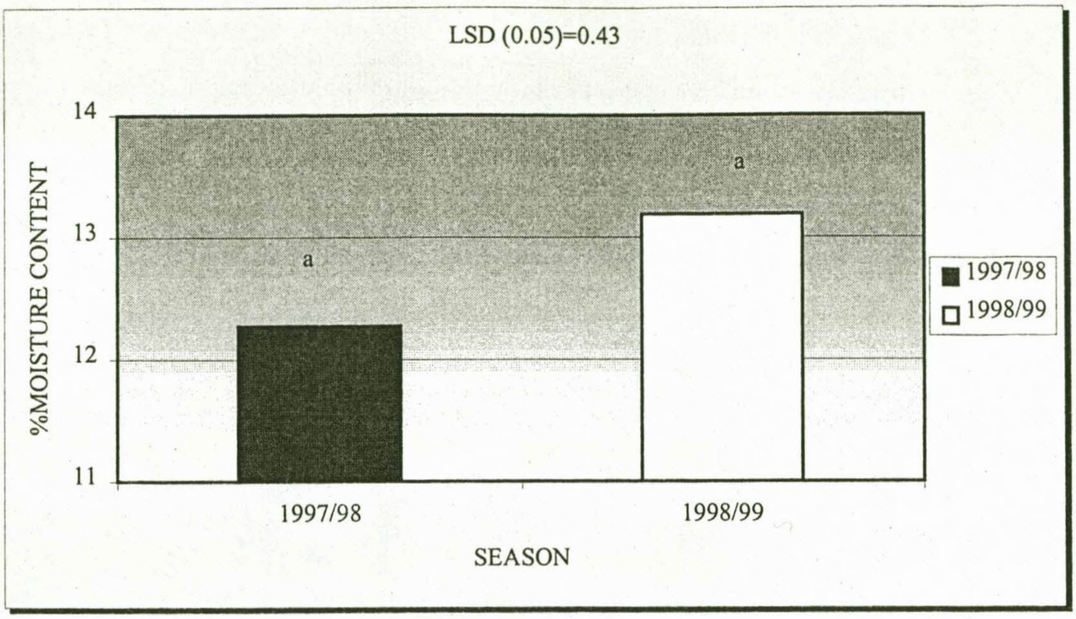


FIG. 3.13

THE INGISNIFCANT DIFFERENCES IN THE MOISTURE CONTENT VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

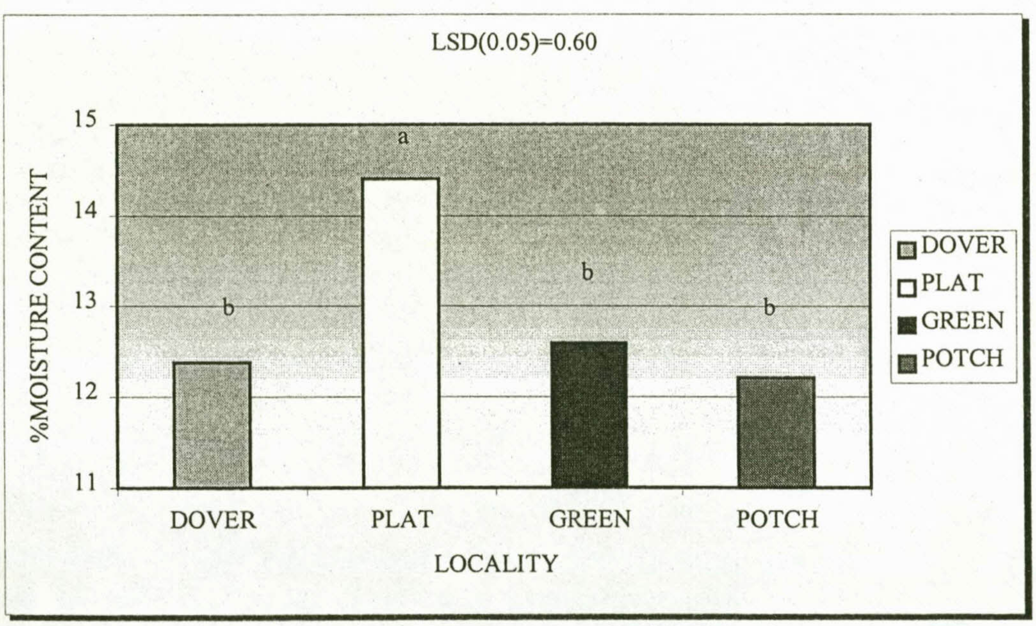


FIG. 3.14

THE DIFFERENCES IN THE MOISTURE CONTENT VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 3.21

ANALYSIS OF VARIANCE OF THE MOISTURE CONTENT OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	3.0566	3.0566	1.8865	0.1761	ns
Main Effects						
CULTIVAR	23	12.6022	0.5479	0.3382	0.9968	ns
LOCALITY	3	57.1533	19.0511	11.7578	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	43.7821	0.6345	0.3916	0.9998	ns
Error	47	76.1536	1.6203	<-		
Total	143	223.6560				

*p=0.05

ns=not significant

TABLE 3.22

RANKING OF SORGHUM CULTIVARS ACCORDING TO INSIGNIFICANT DIFFERENCES IN MEAN MOISTURE CONTENT VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	PAN 8446	13.360	6	a
2	SNK 3620	13.270	6	a
3	NK 283	13.110	6	a
4	PAN 8660	13.060	6	a
5	NS 5655	13.020	6	a
6	SNK 3939	13.020	6	a
7	PAN 8061	12.910	6	a
8	SNK 3860	12.910	6	a
9	NK 286	12.890	6	a
10	SNK 3443	12.870	6	a
11	PAN 8272	12.800	6	a
12	SNK 3663	12.690	6	a
13	PAN 8171	12.690	6	a
14	NS 5511	12.680	6	a
15	PAN 8370	12.640	6	a
16	SNK 3975	12.640	6	a
17	ADV 5010	12.640	6	a
18	SNK 3863	12.600	6	a
19	APN 881	12.540	6	a
20	SNK 3883	12.520	6	a
21	SNK 3337	12.400	6	a
22	PAN 8564	12.290	6	a
23	PAN 8262	12.010	6	a
24	SNK 3567	11.970	6	a

To summarize the results found, the following has to be mentioned: It had already been observed that kernel size, density and hardness are important factors in determining the milling quality of sorghum cultivars. SNK 3860 and SNK 3567 both had high SFL and HKW values, indicating larger-sized kernels with subsequent poorer milling performance expected when the grain is not hard enough (Gomez *et al.*, 1997). SNK 3860 is also expected to be a softer cultivar, due to the high WA levels found, which may further jeopardize the milling performance of the cultivar. On the other hand PAN 8446 is expected to consist of better milling properties, due to its mainly medium sized kernels (low SFS and high SFM values) and hardness (low WA values). The meal fractions of this cultivar consist mainly of medium sized particles. PAN 8370 and PAN 8262 can also be expected to have good milling abilities as kernels are mainly medium sized (low SFS and high SFM values) kernels, that lie closer to the small rather than the large size (low HKW). PAN 8660 is a cultivar that consisted mainly of small sized kernels (low HKW), while the kernels of SNK 3663 were mainly medium sized. Smaller sized kernels may present greater milling losses, while evenly sized kernels will mainly produce evenly sized meal (Gomez *et al.*, 1997). An even meal particle-size distribution is expected from PAN 8272, due to the high levels of MFM present. The meal of PAN 8370 will contain low levels of large size particles (MFL) and will thus be less coarse. SNK 3337 consists of both hardness (low WA) and larger, denser (high HKW) kernels. The hardness of the large size kernels may prevent them from cracking during the milling process, with the consequential satisfactory milling performance expected of this cultivar. PAN 8171 and PAN 8061 both had low levels of WA, which indicate greater hardness and the possibility of good milling performances in these two cultivars.

The high levels of SFM particles present in the meal from Dover and Potch may indicate good milling performances with sorghum from these two localities, as the even particle-size distribution of the grain (high SFM) may lead to evenly distributed particles in the meal (Gomez *et al.*, 1997). Grain from Potch might however, tend to crack during milling, as the grain from this locality is softer (high WA). Grain from Plat showed low WA levels and high MC values. The latter causes softness, by influencing the starch-binding properties of the grain (Hoseney, 1994). Softness, together with the small sized kernels (low HKW) of sorghum from Plat, indicates poorer milling quality possibilities, as smaller kernels increase milling losses when the kernels are too small (Gomez *et al.*, 1997). The uneven grain particle-size distribution of grain from Plat also led to an uneven distribution of particles in the meal of the same grain, as high levels of small sized particles were found to be present in the meal of grain. Grain from Green was hard, as seen from its low WA levels. The meal of grain from the 1998/99 season mainly consisted of MFM and MFS particles, but harder grain were found during the 1998/99 season (low WA).

3.3.6 COEFFICIENT OF VARIATION

Table 3.23 shows the coefficients of variation for the physical properties of sorghum grain. As found in 2.3.8 of Chapter 2, the %CV was very large in some instances. As explained in Chapter 2, larger %CV's might be expected in the present study, due to the different cultivars, localities and seasons that were used, instead of mere replications. The occurrence of small CV values indicates only small differences over localities and seasons. This was the case with the %CV of MF's. The larger %CV for MF can be acclaimed to the highly significant differences between cultivars and localities that were found in some MF's.

TABLE 3.23

THE COEFFICIENTS OF VARIATION FOR DIFFERENT PHYSICAL QUALITY PARAMETERS OF SORGUM CULTIVARS

PHYSICAL PARAMETER	%CV
WATER ABSORPTION	5.36
SIEVE FRACTIONS	8.94
MEAL FRACTIONS	11.51
THOUSAND-KERNEL WEIGHT	7.68
MOISTURE CONTENT	10.00

3.3.7 CORRELATIONS

The correlation matrix of the main physical properties of sorghum grain, is indicated in Table 3.22. It is clear that only a few physical quality parameters of the sorghum were correlated (r>0.40) with any of the other physical parameters. The water absorption did not correlate well with any other physical quality of sorghum grain. As seen in 3.1, the WA abilities of sorghum are related to the endosperm structure (Hoseney, 1994) and may therefore be correlated with some milling quality aspects of sorghum, such as hardness, which will be discussed later.

TABLE 3.22

CORRELATION COEFFICIENTS AMONG PHYSICAL QUALITY PARAMETERS ACROSS 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON (P<0.05)

	HKW	MC	SFL	SFM	SFS	MFL	MFM	MFS	WA
HKW	1.00	-0.30	0.45	0.46	-0.63	0.25	0.04	-0.18	0.28
MC	-	1.00	-0.04	-0.15	0.17	-0.37	-0.04	0.28	-0.11
SFL	-	-	1.00	-0.14	-0.30	-0.02	-0.03	0.05	0.22
SFM	-	-	-	1.00	-0.90	0.17	0.08	-0.16	0.19
SFS	-	-	-	-	1.00	-0.15	-0.07	0.13	-0.27
MFL	-	-	-	-	-	1.000	-0.08	-0.72	-0.03
MFM	-	-	-	-	-	-	1.000	-0.45	-0.03
MFS	-	-	-	-	-	-	-	1.00	0.06

The SF (i.e. SFL, SFM and SFS) correlated well with the HKW. This observation was expected, as both the HKW and SF assays indicate amongst other properties, kernel size (3.1). This observation proved the important contribution of kernel size to the HKW. SFS showed a negative correlation (r=-0.63) with HKW, as a large number of small kernels in a sample, would decrease the mass of a thousand kernels. The positive correlation found between the HKW and SFM (r=0.46) and the HKW and SFL (r=0.45), indicate that samples consisting mainly of average to large sized kernels, will have a larger HKW. As the HKW is known to be an indicator of the density of sorghum grain (Kirleis & Crosby, 1982) larger kernels (high HKW) will also be denser.

SFS was found to correlate well (r=-0.90) with SFM, indicating that a large number of small kernels in a sample will be accompanied by a small number of medium sized kernels in the same sample, as was seen from the results in 3.3.2. In the same way MFM (r=-0.45) and MFL (r=-0.72) had negative correlations with MFS, indicating that the large medium or large sized fraction reduced the MFS fraction, which was also clear from the results in 3.3.3.

The MC did not correlate well with any other physical quality parameter, as the MC is mainly determined by environmental conditions, rather than other physical properties, as mentioned in 3.3.5.

3.3.8 CANONICAL VARIATE ANALYSIS

A Canonical Variate Analysis was performed to select the physical properties that discriminate mostly between cultivars. At first all parameters were used, after which MC was removed from the analysis, as this variate did not correlate with any other physical properties (Table 3.22) and also had the lowest correlation with CV1 when all physical properties were considered in the analysis. In 3.3.5 it was seen that MC was highly influenced by environmental conditions and is thus less easily defined as a physical property of the grain itself, but rather as a factor that influences physical properties, which further motivated the removal of MC from the analysis. The CVA that excluded MC showed that CV1 contributes 66.34 % and CV2 17.20 % (i.e. a total value of 83.54 %) to the discrimination between cultivars by means of physical properties.

The physical properties that correlated best with CV1, was SFL (r=0.745) and HKW (r=0.893) (Table 3.23). Water absorption was found to correlate best with CV2 (r=0.933). Therefore, cultivars performing well with respect to CV1, generally had high SFL and HKW values, i.e. consisted of larger sized grain. Cultivars with acceptable CV2 scores were those with higher WA levels, and since high WA levels indicate softness of grain (3.3.1), this grain will belong to the softer category of sorghum.

TABLE 3.23

THE CORRELATION MATRIX BETWEEN VARIABLES AND SCORES FOR GROUPINGS BETWEEN SORGHUM CULTIVARS IN TERMS OF PHYSICAL QUALITIES

USCORE[1]	0.082	0.745	-0.465	0.893
USCORE[2]	0.933	0.376	-0.194	0.069
USCORE[3]	-0.231	0.387	0.747	-0.397
	WA	**SFL**	**SFS**	**HKW**

Table 3.24 indicates the CV1 and CV2 scores of different cultivars. From these scores it can be seen that SNK 3860 differs most from other cultivars, with the score of CV1 (score=3.7754) and CV2 (score=1.6768) high above zero. SNK 3337 is also very different from other cultivars as CV1 (score=2.2170) is highly above and CV2 (score=-1.7445) below zero. This explains the positioning of SNK 3860 and SNK 3337 far away from all the other cultivars on the plot of the scores (Fig. 3.15).

Cultivars situated to the left side in Fig. 3.15 were generally smaller sized grain, while those on the right-hand side were larger sized, as SFL indicates size distribution of kernels (3.3.2), while the HKW also indicates grain size (3.3.4). Cultivars on the lower half of the plot were those with low WA levels, thus the harder cultivars (3.3.1), while those on the top half of the plot represent the softer cultivars with higher WA levels.

TABLE 3.24

CV1 AND CV2 SCORES FOR SORGHUM CULTIVAR GROUP MEANS IN TERMS OF FOR PHYSICAL PROPERTIES ACCORDING TO THE CANONICAL VARIATE ANALYSIS

CODE	CULTIVAR	CV1	CV2
A0	ADV5010	1.2587	-0.0942
A1	APN881	-0.3798	0.1808
N3	NK283	-0.5735	1.1154
N6	NK286	1.2404	-0.5999
N1	NS5511	-0.9263	0.9963
N5	NS5655	-0.7626	0.7151
P1	PAN8061	-0.5322	-0.2959
P7	PAN8171	-1.2440	-0.4947
P2	PAN8262	-1.4005	0.3425
P8	PAN8272	-0.7380	-0.4862
P3	PAN8370	-1.0735	-0.0713
P6	PAN8446	-1.4579	-0.6220
P4	PAN8564	-0.4506	-0.2613
P0	PAN8660	-2.0408	0.5461
S3	SNK3337	2.2170	-1.7445
S4	SNK3443	-0.4541	-0.3615
S7	SNK3567	4.0511	-0.6032
S2	SNK3620	1.0224	1.7153
S6	SNK3663	-0.8360	-0.4081
S0	SNK3860	3.7754	1.6768
S8	SNK3863	0.5881	-0.2488
SW	SNK3883	0.1751	-0.4709
S9	SNK3939	-0.8338	-0.1077
S5	SNK3975	-0.6245	-0.4184

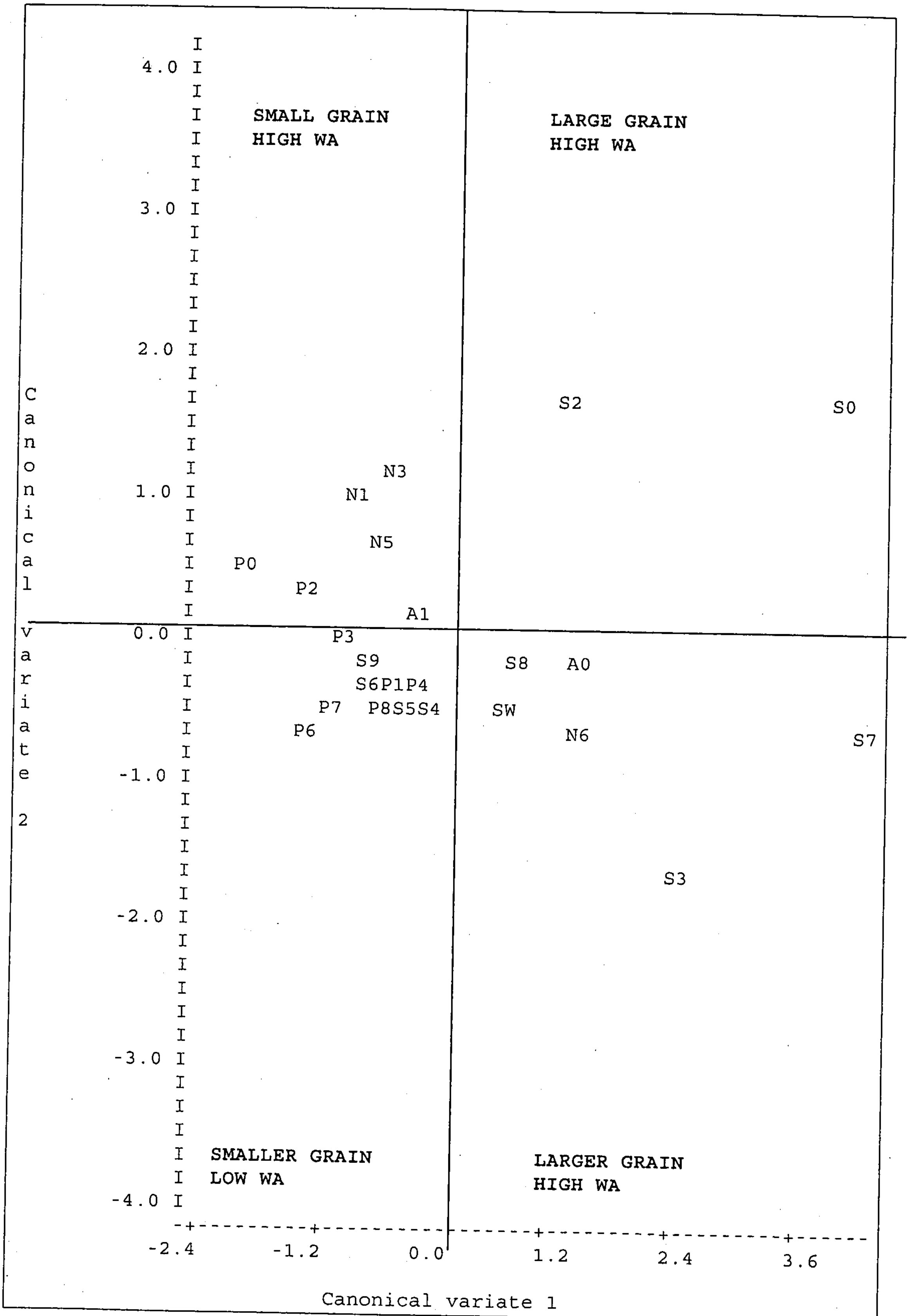


FIG. 3.15

PLOT OF THE CANONICAL VARIATE ANALYSIS OF THE PHYSICAL PROPERTIES OF SORGHUM TO IDENTIFY GROUPINGS BETWEEN CULTIVARS

TABLE 3.25

MEAN SIEVE FRACTION LARGE, HUNDRED-KERNEL WEIGHT AND WATER ABSORPTION VALUES OF SORGHUM CULTIVARS THAT CORRELATE WITH CANONICAL VARIATE 1 AND 2 RESPECTIVELY IN THE CANONICAL VARIATE ANALYSIS

CODE	CULTIVAR	WA	SFL	HKW
A0	ADV5010	37.520	1.512	2.584
A1	APN881	38.130	0.232	2.359
N3	NK283	39.490	1.515	2.233
N6	NK286	35.480	1.860	2.497
N1	NS5511	39.640	0.725	2.223
N5	NS5655	38.780	0.848	2.217
P1	PAN8061	34.930	1.613	2.075
P7	PAN8171	35.210	0.117	2.080
P2	PAN8262	37.520	0.398	2.011
P8	PAN8272	35.250	0.615	2.116
P3	PAN8370	35.560	1.267	1.946
P6	PAN8446	34.490	0.282	1.925
P4	PAN8564	36.380	0.452	2.279
P0	PAN8660	37.630	0.210	1.951
S3	SNK3337	32.940	1.731	2.677
S4	SNK3443	35.260	1.208	2.140
S7	SNK3567	35.700	4.276	2.891
S2	SNK3620	42.040	2.432	2.578
S6	SNK3663	35.580	0.463	2.111
S0	SNK3860	40.560	6.207	2.791
S8	SNK3863	37.010	0.907	2.476
SW	SNK3883	36.140	0.673	2.371
S9	SNK3939	36.440	0.497	2.180
S5	SNK3975	36.010	0.180	2.248
	MEAN	**36.820**	**1.259**	**2.29**

PAN 8370, SNK 3939, SNK 3663, PAN 8061, PAN 8564, PAN 8171, PAN 8272, SNK 3975, SNK 3443 and PAN 8446 are all situated to the lower left-hand side of the plot (Fig. 3.15), indicating that these cultivars generally had smaller sized kernels that were harder. PAN 8446 for example, had a below average WA (mean=34.49), SFL (mean=0.282) and HKW (mean=19.25) value means (Table 3.25). The same was found for all the other cultivars, mentioned to be situated in this area on the plot, except for PAN 8370 with a larger SFL value mean than the average (Table 3.25). The position of these cultivars on the plot is confirmed by the observations in 3.3.7, where PAN 8370, SNK 3663 and PAN 8446 were found to consist of mainly medium sized kernels, with good milling abilities (Gomez *et al.*, 1997). PAN 8061 and PAN 8171 are expected to be harder cultivars, due to low WA levels (Hoseney, 1994) in 3.3.7, indicating good milling possibilities, while the even particle-size distribution (3.3.7) of the meal of PAN 8272, could also indicate good milling quality (Gomez *et al.*, 1997). These cultivars can be expected to have high milling yields and could thus be expected to perform well with respect to milling quality, which will be discussed in Chapter 4. Another property of these cultivars is the fact that they are, with the exceptions of PAN 8370, PAN 8446 and PAN 8171, all situated very closely together on the plot (Fig. 3.15), as was represented by the scores of CV1 and CV2 (Table 3.24).

NK 286, SNK 3567, SNK 3863, ADV 5010, SNK 3883 and SNK 3337 are all situated to the lower right-hand side of the plot (Fig. 3.15), indicating that these cultivars were generally hard, but with larger sized kernels. The larger kernel sizes of these cultivars were confirmed in 3.3.7, where it was seen that SNK 3567 (high SFL and high HKW) and SNK 3337 (high HKW) consist mainly of medium to larger sized kernels. Large kernels that are not hard enough will crack during milling, indicating poor milling quality (Munck *et al.*, 1982). Therefore these cultivars may still have had good milling properties on account of their hardness, despite the larger kernel sizes. On the other hand, cultivars in this area, that were not hard enough, might not have good milling properties. SNK 3863 and ADV 5010 are situated closer to the gridlines than the other cultivars in this area, and could accordingly be expected to be softer than the other cultivars. This is confirmed by their higher than the average WA value means (Table 3.25) and their higher CV1 scores (Table 3.24). SNK 3337 was identified in 3.3.7 to be a possible harder cultivar (low WA) and could thus still have good milling abilities, despite the larger kernels of the cultivar. SNK 3337 is also expected to be harder than the other cultivars in this area on the plot, due to its lower positioning (Fig. 3.15). This positioning of the culitvar is confirmed by Table 2.10 (Chapter 2), where SNK 3337 received the lowest ranking with respect to WA value means (mean=32.94) (Table 3.25).

NK 283, NS 5655, NS 5511, PAN 8262, PAN 8660 and APN 881 are situated in the top left-hand side of the plot (Fig. 3.15) where the kernels of cultivars are expected to be smaller in size, but softer. As softness is an indication of poor milling quality, these cultivars might be of inferior milling quality, but this will only be revealed in Chapter 4. APN 881, which is situated closely to the gridlines, may still fall within the group of cultivars with good milling properties. The very small sized grain of PAN 8660 (very left of plot) is similar to observations made in 3.3.7, where a very low HKW was found for the cultivar (mean=2.075) (Table 3.25), while PAN 8262 was identified to consist mainly of medium sized kernels (3.3.7). NK 283 is the cultivar amongst this group with the largest kernels (mean (SFL)=1.515; mean (HKW)=2.233) and also the softest (mean (WA)=39.49), as it is situated the furthest away from the other cultivars in this group. Therefore, this cultivar can be expected to be inferior in terms of milling quality.

As stated, large sorghum kernels with a lack of hardness will have the tendency to crack during the milling process (Munck *et al.*, 1982). SNK 3860 and SNK 3620 are the two cultivars with the possibility to confirm this statement. These are the only two cultivars belonging to the group with the possibility of the worst milling performance, as these two cultivars are situated in the area on the plot (Fig. 3.15) where large sized soft kernel properties are expected (top right hand position). Both cultivars are birdproof (Chapter 2) with very extreme above-average SFL, TKW and WA value means (Table 3.25) and are also the only cultivars with both the scores of CV1 and CV2 positive (Table 3.24). The large kernel sizes and softness of these two cultivars are confirmed in 3.3.7, where kernels of SNK 3860 (high SFL and high HKW) were found to be large and both SNK 3860 and SNK 3620 showed high WA levels, thus indicating softness.

The CVA for cultivars gives an indication of cultivar groupings on the basis of physical properties and could only predict the milling properties of these cultivars based on physical properties. The actual milling properties still have to be measured to identify acceptable milling performing cultivars, which will be reported in Chapter 4.

Moisture content was left out from the CVA where groupings between cultivars were investigated, for reasons explained earlier. In the CVA where groupings between environments (localities x seasons) were investigated, MC could however not be removed. Moisture content was the variate that correlated (r=0.882) the best with

CV1 in the CVA where all physical quality parameters were considered. Omitting MC from the analysis would therefore be senseless. The latent roots in the CVA confirm that MC cannot be left out of consideration in the CVA. At least one latent root should be larger than one (>1.0) for a CVA performance to be sensible. When MC was left from the CVA, all roots were lower than one (<1.0), i.e. the analysis was senseless (Table 3.26).

TABLE 3.26

THE LATENT ROOTS FOUND FOR THE CANONICAL VARIATE ANALYSIS WHEN EXCLUDING DIFFERENT PHYSICAL PROPERTIES FROM THE CANONICAL VARIATE ANALYSIS FOR ENVIRONMENTS (LOCALITIES X SEASONS) OF SORGHUM CULTIVARS

PROPERTIES EXCLUDED	LATENT ROOTS OF CVA				
	1	2	3	4	5
NONE	2.02	0.5	0.45	0.13	0.02
MC	0.84	0.41	0.1	0.05	-
SFS, SFM, SFL, MFM	1.85	0.39	0.3	0.01	0.01

In the CVA where all physical quality parameters were investigated, it was found that SFL (r=-0.063), SFM (r=-0.346), SFS (r=0.363) and MFM (r=0.074) contributed least to the variation in environments for CV1. Therefore, it was decided that the CVA for the discrimination between environments, should not include these properties. The CVA for physical properties (excluding SF's and MFM) indicated that MC (r=0.906) discriminated mainly between environments for CV1, while WA (r=0.869) discriminated mainly for CV2, as shown in the correlation matrix of variates and scores (Table 3.27). Canonical Variate 1 contributed 72.47 % (MC) to the differences between environments, while CV2 contributed 15.33 % (WA). The total contribution of CV1 and CV2 to the differences in sorghum grain from different environments, is 87.8 %.

TABLE 3.27

THE CORRELATION MATRIX BETWEEN VARIABLES AND SCORES FOR GROUPINGS BETWEEN ENVIRONMENTS (LOCALITY X SEASON) OF SORGHUM CULTIVAR GROWTH IN TERMS OF PHYSICAL QUALITIES

USCORE[1]	-0.591	0.386	0.906	-0.489	-0.41
USCORE[2]	-0.394	0.326	0.248	0.319	0.869
USCORE[3]	-0.593	0.176	-0.295	0.223	-0.172
	MFL	**MFS**	**MC**	**HKW**	**WA**

Table 3.28 indicates that Plat during 1998/99 differs most from all other environments, as both the scores of CV1 and CV2 are highly positive. Green 1997/98, also differed from other environments, with both scores being highly negative. This observation is confirmed by the positioning of Plat 1998/99, to the higher right side of a plot of the scores (Fig. 3.15) and far away from any other cultivars. On the other hand, Green 1997/98 was situated to the lower left-hand side of the plot. Therefore, the positioning of Plat 1998/99 on the plot indicates that grain from this area will have high MC (mean=14.40) and close to the average WA (mean=35.12) values. The fact that the higher rainfall conditions found to the East (where Plat is situated) of South Africa, could contribute to grain with higher MC was discussed in 3.3.5. Increased MC values in grain contribute to softness (3.3.7). In 3.3.7 the small sized grain from Plat, which could further increase milling losses (Gomez *et al.*, 1997) from kernels, was also mentioned. Green 1997/98 situated in exactly the opposite position of Plat on the plot, indicated lower WA (mean=35.09) and MC (mean=11.76) levels. In 3.3.7 the hardness of grain from Green, as indicated by the low WA was also described. Green could thus be expected to show very good milling performances.

TABLE 3.28

CANONICAL VARIATE 1 AND 2 SCORES FOR ENVIRONMENTAL (LOCALITY X SEASON) GROUP MEANS OF SORGHUM CULTIVAR GROWTH IN THE CANONICAL VARIATE ANALYSIS

CODE	LOCALITY	SEASON	CV1	CV2
Do	DOVER	1997/98	-0.559	0.042
PR	PLAT	1998/99	2.513	0.167
G8	GREEN	1997/98	-1.033	-1.092
G9	GREEN	1998/99	1.010	-0.379
P8	POTCH	1997/98	-0.786	0.843
P9	POTCH	1998/99	-1.146	0.419

Green 1998/99 was found to the lower right-hand side of the plot (Fig. 3.16), indicating higher MC (mean=13.42) value means than during the previous season, while little changes in WA (mean=35.14) were found (Table 3.29). This may indicate that grain from Green in general would be harder, but the higher MC levels of the 1998/99 season could still have decreased the hardness. This was confirmed by the closer positioning of Green 1998/99 to Plat on the plot than the position of Green in 1997/98, as Plat is situated in the area where grain of a more soft nature is expected to be found, as mentioned before (Fig. 3.16).

From the plot it is obvious that Potch 1997/98 and 1998/99 are the two environments situated closest together in terms of physical properties (Fig. 3.16). For both seasons the Potch locality was situated in the area of low MC and high WA levels. The CV1 and CV2 scores of Potch for the two seasons closely together, confirmed this observation. In 3.3.7 it was seen that grain from Potch was generally soft (high WA) and mainly medium sized kernels were found at Potch. The particle-size distribution of the grain from Potch is therefore even, but the softness of the grain could increase milling losses. Grain was softer and had a higher MC at Potch during the 1997/98 (WA=39.98; MC=12.68) season than in 1998/99 (WA=38.31; MC=11.74), which could indicate softer grain in the 1998/99 season and therefore, poorer milling performances are expected for the latter season.

Dover was situated on the gridline for WA, but in the region for low MC values on the plot (Fig. 3.16). The WA (mean=37.30) value of Dover close to the average WA values for environmental effect, as well as the lower than average MC (mean=12.38) value, confirmed this positioning of Dover (Table 3.29). A prediction for Dover would be difficult, as results are only representative of one season. It seems as if grain from Dover during the 1997/98 season, might have fallen on the border for hardness and softness, as indicated by the positioning on the gridline. In 2.3.3 (Chapter 2) it was seen that grain from Dover was the second highest ranked for WA values behind Potch, indicating softness of this grain. Kernels from Dover were found to be mainly medium sized, indicating the possibility of good milling performance (3.3.7), but due to softness milling losses might be high.

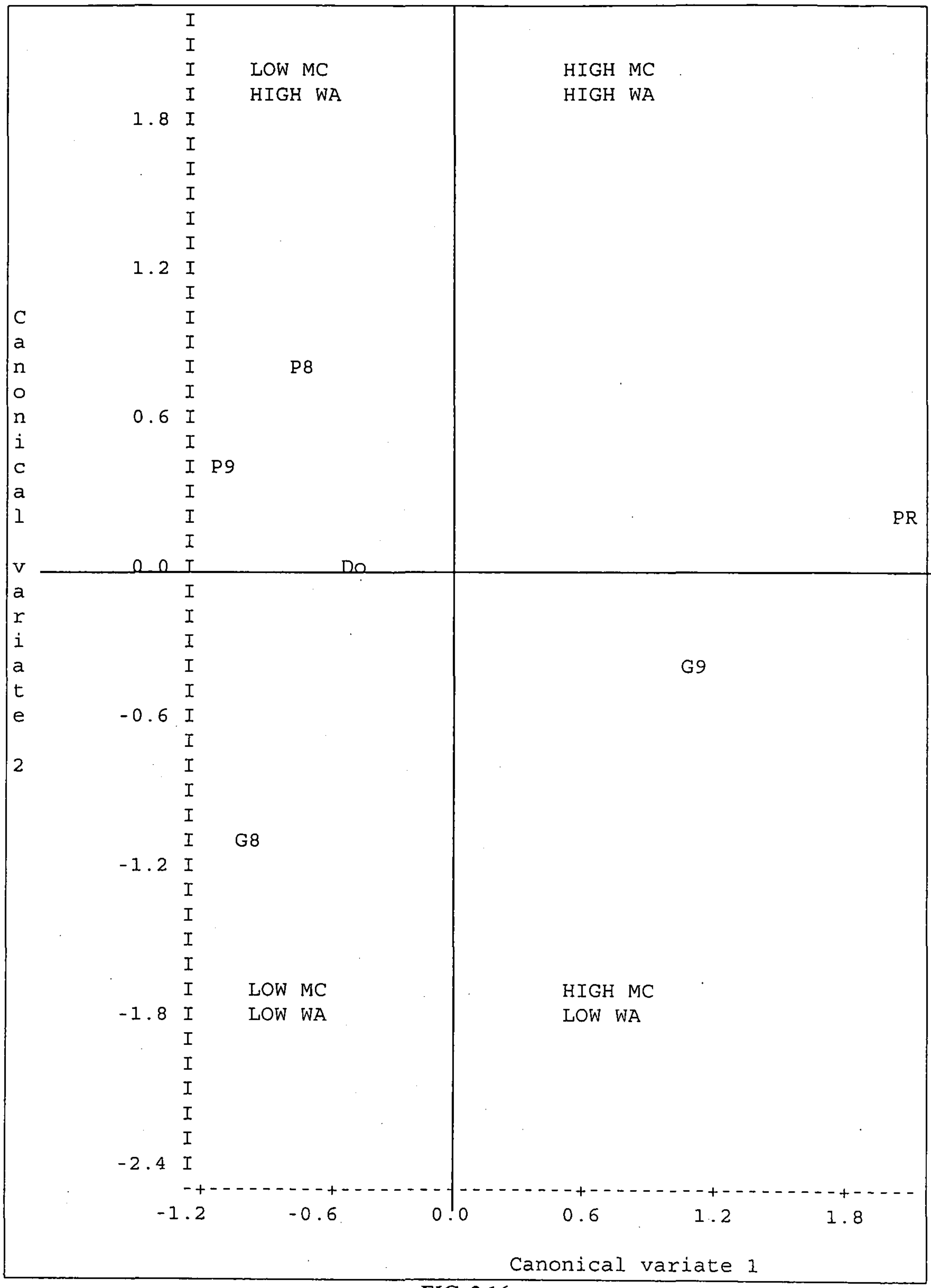


FIG. 3.16

PLOT OF THE CANONICAL VARIATE ANALYSIS OF THE PHYSICAL PROPERTIES OF SORGHUM TO IDENTIFY GROUPINGS BETWEEN ENVIRONMENTS (LOCALITIES X SEASONS)

TABLE 3.29

MEAN VALUES OF LOCALITY X SEASONS OF SORGHUM CULTIVAR GROWTH FOR ALL VARIATES CONSIDERED IN THE CANONICAL VARAITE ANALYSIS FOR PHYSICAL PROPERTIES

CODE	LOCALITY	SEASON	MFL	MFS	MC	HKW	WA
Do	DOVER	1997/98	35.99	39.60	12.38	2.38	7.30
PR	PLAT	1998/99	30.47	43.50	14.40	2.06	35.12
G8	GREEN	1997/98	38.32	37.34	11.76	2.26	35.09
G9	GREEN	1998/99	34.75	39.73	13.42	2.17	35.14
P8	POTCH	1997/98	36.75	39.54	12.68	2.38	39.98
P9	POTCH	1998/99	34.00	39.78	11.74	2.50	38.31
	MEAN		**35.05**	**39.92**	**12.73**	**2.29**	**36.82**

3.4 CONCLUSION

The differences in the physical qualities of sorghum grain that could have a direct or indirect influence on the milling quality of different sorghum cultivars, as well as the influence of locality and season of growth on the physical qualities, were investigated. To accomplish this, it was necessary to identify the most important sorghum physical quality parameters.

The only physical assays able to give an indication of hardness without the actual milling process are the WA and MC. No differences between the MC values of cultivars were found however, thus WA levels were the only indication of hardness. Possible harder cultivars identified through lower WA levels, are PAN 8171, PAN 8061 and PAN 8446, while and SNK 3860 were identified amongst the softest cultivars.

Kernel size, another important physical property with an influence on milling quality, was indicated by SF and TKW and as expected, these properties correlated with one another. SNK 3567 and SNK 3860 consist mainly of larger sized kernels, while more small sized kernels were found in PAN 8446, PAN 8370 and PAN 8262. The latter group of cultivars could therefore be expected to have better milling properties. Both groups could experience problems with milling losses, as the best milling quality results are obtained when medium sized sorghum kernels are used, as measured in the present study.

The particle-size distribution of sorghum kernels is known to influence the particle-size distribution of the meal. Sieve fraction values of kernels were found in the present study not to correlate with meal sieve fractions. It was therefore noticed that when grain consists mainly of medium sized kernels, the particle-size distribution of the meal would not be affected negatively by increasing the SFL or SFS values. Thus, it could be expected that the meal particle-size distribution might in fact be influenced negatively, where grain is not mainly consist of medium sized kernels.

With the CVA, the following cultivars with hardness and other physical properties potentially suitable for milling, were identified, namely: APN 881, NK 286, PAN 8370, PAN 8564, PAN 8446, SNK 3337, SNK 3443, SNK 3567, SNK 3663, SNK 3883, SNK 3939 and SNK 3975.

In the current chapter, sorghum from Green was identified to consist of the physical properties necessary to achieve good milling quality, as it had low MC and WA levels, indicating hardness, and kernels were generally medium to smaller in size according to the division of kernel sizes used in the current study. Grain from Plat, on the other hand contained more large sized kernels and had higher MC values, indicating possible poor milling quality. Sorghum from Potch and Dover contained mainly medium to large sized kernels and grain were softer (high WA values) for both localities. Therefore sorghum from Potch and Plat could be of poorer milling quality than the other localities.

Significant seasonal effects were only found for MFL, MFM and WA. Levels of WA and MFM were higher during the 1997/98 season than during the 1998/99 season. Higher WA levels indicate softer grain during this season, while increased MFM values are attributed to lower MFL values. The increased SFL values of the 1998/99 seasons together with lower WA values indicate that harder grain was found during this season.

During the investigation of the physical properties of sorghum grain, certain environmental (locality x season) effects were identified. The significance of these effects was not investigated however, as the purpose of the CVA for environments are solely to identify possible environmental effects on the physical quality of sorghum grain. Further research could identify the significance of these interactions.

CHAPTER 4

A COMPARISON OF AN ABRASIVE DECORTICATION PROCESS AND ROLLER MILL TECHNIQUES IN SORGHUM MEAL PRODUCTION

4.1 INTRODUCTION

The utilization of sorghum in the meal industry as porridges is just as important as its use for the manufacturing of malted food products. Many African and Asian people utilize sorghum porridges as a staple food (Akingbala *et al.*, 1988) and classify them according to the fineness of the meal, preparation method or the type of fermentation (Novellie, 1982).

The milling of sorghum is usually aimed at the production of meal for the porridge-making industry, but the milled grain also has some other uses. As sorghum is less successfully cooked as a whole grain than rice, the milling of sorghum gives the opportunity for sorghum flour or grits to be utilized in foodstuffs (Desikachar, 1982). Therefore it is clear that because sorghum as a whole grain has little use in the food industry, the determination of milling quality is important in determining product quality (De Francisco *et al.*, 1982). In this chapter, two milling techniques for the manufacturing of sorghum meal will be discussed, namely abrasive decortication milling and roller milling.

In the sorghum meal industry the most common process used, is decortication of the grain followed by milling with a hammer mill (Hoseney, 1994). The use of the TADD on laboratory scale simulates this process. During the abrasive process the TADD only removes the outer layers of the grain (Dewar *et al.*, 1993; Subramanian *et al.*, 1994) and some pigments present in the pericarp (Subramanian *et al.*, 1994). A part of the endosperm is also removed (Subramanian *et al.*, 1994), but should mostly be left unharmed for further milling into meal (Dewar *et al.*, 1993). The pericarp is removed in large flakes (De Francisco *et al.*, 1982) that will not easily pass through a 1-mm round hole sieve without further attrition (Shepherd, 1979). Desikachar (1982) recommended a maximum of 10 to 12 % dehulling to obtain the best grain recovery and the lowest nutrient losses. Hard varieties result in higher whole grain yields (Desikachar, 1982) as hard endosperm is less easily broken (Desikachar, 1982; Munck *et al.*, 1982) under the pressure of the abrasive surface (Reichert *et al.*, 1982). Therefore the TADD gives an indication of the hardness of the sorghum grain.

The process of roller milling is less well known in the sorghum meal industry and is investigated in the current study as it may offer possible advantages. The process of milling separates different parts of the kernel, such as the pericarp, testa, aleurone, embryo and the endosperm. In the end the endosperm is pulverized (Munck *et al.*, 1982). The roller milling process starts with a conditioning process to moisten the bran, which then becomes looser (Desikachar, 1982), tough and rubbery (Hahn, 1969), for easier separation from the endosperm (Desikachar, 1982). The principle of milling is mostly breaking, sifting and purification (Hahn, 1969).

Two food quality properties of sorghum meal are discussed in the present study, namely the colour of sorghum meal and porridge viscosity. Firstly, the colour of sorghum meal products is of extreme importance. The consumer prefers a light-coloured sorghum product (Pretorius *et al.*, 1996). A very critical factor affecting the production of an acceptable light-coloured flour or meal from sorghum is the adequacy of milling technology implemented during processing (Munck *et al.*, 1982). Therefore, colour is used in the current study as the most important means of identifying the quality of sorghum meal produced by the TADD and roller milling processes. A popular method of determining the colour of sorghum products on laboratory scale is with the Hunter Lab Colorquest, which is a Tristimilus Colorimetric instrument. This instrument uses the L, a and b scales, where L indicates lightness (100) or darkness (0), +a redness, -a greenness, +b yellowness and –b blueness. For sorghum the "L" and "a" scales are normally used and the "b" scale, being difficult to interpret, is left out of consideration (Dewar *et al.*, 1993; Pretorius *et al.*, 1996).

Viscosity is a second very important quality aspect of the porridges prepared from sorghum meal. The importance of the colour of sorghum meal was discussed above, but another problem with sorghum porridges lies in the lack of stiffness, which is important as these porridges are usually eaten by hand (Taylor *et al.*, 1997). Therefore the viscosity of the porridge manufactured from the meal obtained from the TADD and roller mills is determined in the current study. Milling affects the cooking properties of sorghum meal during porridge making, since it affects the amount of damaged starch and endosperm particles during processing (Akingbala *et al.*, 1982) and starches present in sorghum meal participate in starch-starch and/or starch-protein interactions during gelatinization (Singh & Singh, 1991). Milling is expected to influence the viscosity of sorghum porridges, as the amounts and availability of amylose and amylopectin may be influenced by the applied milling technique.

In the present study the differences in the food quality characteristics of a sorghum meal product manufactured by the TADD vs. roller milling techniques, will be investigated. The dehulled product, as well as the product from the roller mill will be investigated for colour, as well as viscosity dissimilarities.

The objectives of this chapter are therefore to:

1. Determine the milling performance of different sorghum cultivars milled by means of the TADD process and roller milling.

2. Determine the quality of a sorghum end product, namely meal obtained from TADD abrasive milling and roller milling, in terms of colour and viscosity measurements.

3. Compare the TADD abrasive milling and roller milling processes by means of the milling quality and the influence of different processes on different cultivars over different localities and grown over 2 seasons.

4. Determine the relationship between some important physical quality parameters of sorghum , already determined in Chapter 3, and the milling quality.

4.2 MATERIALS AND METHODS

4.2.1 SORGHUM CULTIVARS

The same sorghum from the same localities and seasons were used as described in 2.2.1 in Chapter 2 and the same method of preparation for cleaning was used.

4.2.2 MILLING PERFORMANCE

4.2.2.1 TANGENTIAL ABRASIVE DEHULLING DEVICE MILLING (TADD)

Two replications per sample were subjected to the TADD, using the procedure described by Pretorius *et al.* (1996). Unlike, in the case of malting, tow replications had to be performed to ensure the correct setting of the TADD sample cups distance from the abrasive surface, as the cups are set by hand, which is a subjective way of setting. However, pearling times of 1 to 5 minutes, with 1-minute intervals were used, as recommended by Pretorius *et al.* (1996). Eight 50-g samples were placed simultaneously in the sample cups of the TADD, with sandpaper (P60, 454HL, 3 M-ite Resin Bond Cloth) attached to a round disk (diameter=37 cm) underneath. The space between the sample cups and the sandpaper were adjusted by hand to be the same for each sample (approximately 1 mm). The machine was started and the grain abraded by the disk, rotating at 1725 rpm. The abraded material from the samples was removed by a DVC industrial vacuum cleaner, connected to the machine. After dehulling, the abrasion percentage was determined by weighing of the abraded samples. After abrasion, the samples were milled with a Cyclotec 1093 Sample mill, equipped with a 2-mm screen for meal production. A whole grain sample was also milled with the Cyclotec 1093 Sample mill, to serve as meal of sorghum that was abraded for zero minutes. The abrasive hardness index (AHI) was calculated from the regression line of the abrasion time (X-axis) vs. the abrasion percentage at each time-interval (0 to 5 min) (Y-axis). The inverse of the slope of the regression line, multiplied by 60 gave the AHI, which was defined in Chapter 1, as the time in seconds necessary to abrade 1 % of the kernel.

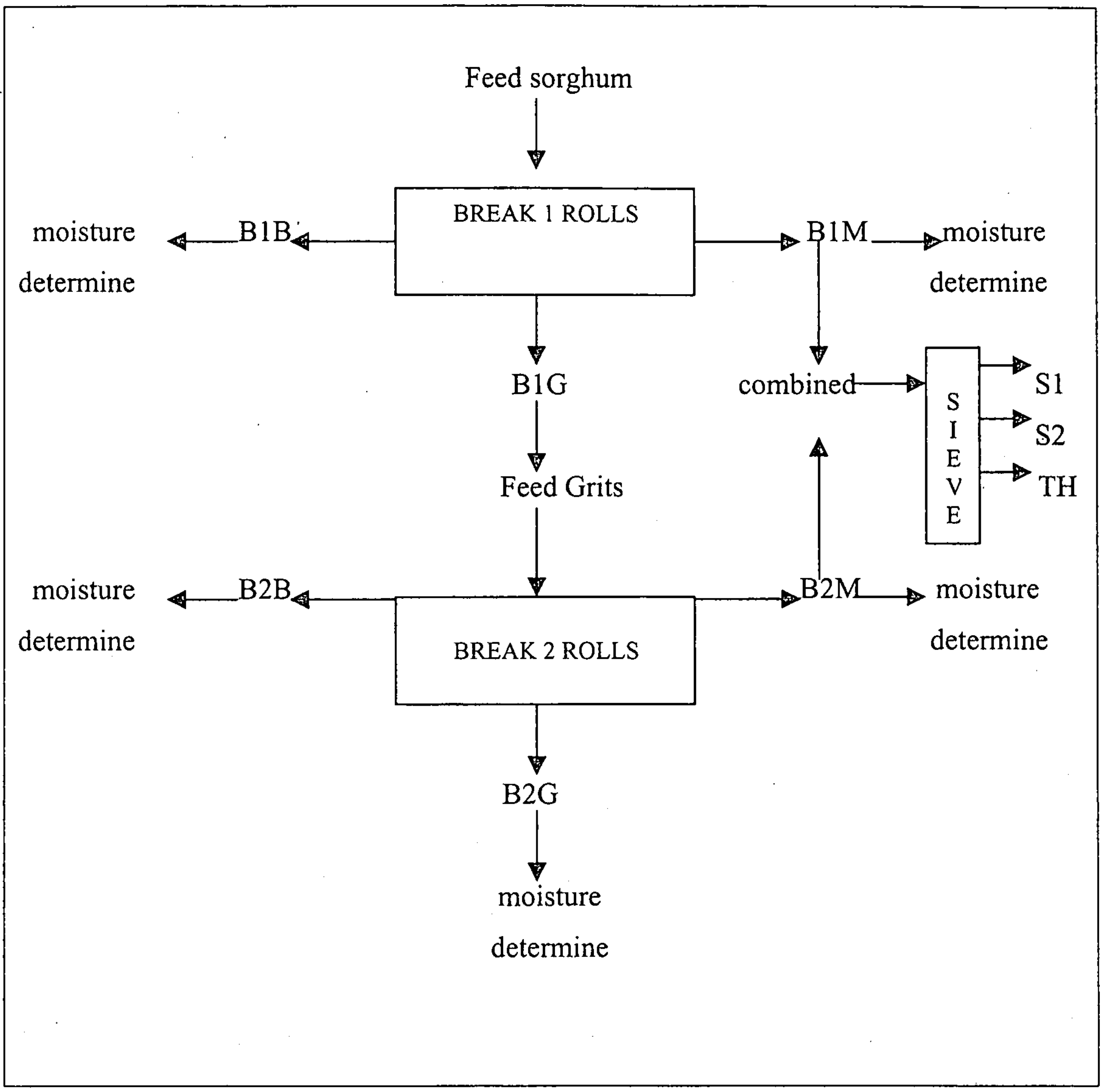
4.2.2.2 ROLLER MILLING

The moisture content of 500-g sorghum samples, that was determined in 3.2.6 (Chapter 3), were adjusted to 15 % by the addition of distilled water 24 h before milling. This was done by the determination of the moisture content of sorghum grain according to the method described in 3.2.6 in Chapter 3. The mass of water to be added to reach a 15 % moisture content, was determined as follows:

$$\text{Mass of water added} = \frac{\text{new moisture percentage (i.e. 15 \%)}}{\text{original moisture content}} \times \text{sample mass (i.e. 500 g)}$$

The mass water (volume) water calculated to be added were added with a measuring cylinder to the sorghum samples in buckets with lids. After the addition of the water, the buckets were shaken and left for 24 h. Gomez (1993) found the addition of water up to 16 %, to be efficient for roller milling. As the aim of water addition is to adapt the moisture content of all samples to the same level of moisture and the maximum moisture content in a sample was 15 % (Table 3.20, Chapter 3), it was decided to take all samples to this maximum of 15 %. After all samples were adapted to 15 %, an extra volume of 25 ml water was added with a measuring cylinder to the samples 50 min before milling for

40 min and immediately after this period, another 5 ml of water was added for 10 min for the conditioning process. During the conditioning period, samples were shaken every 10 min to enhance the moistening process of the pericarp. After each water addition step, the samples were also shaken. Samples were milled with Roller mills (ROFF Ind. RSA, P.O. Box 1285, Kroonstad, 9500, South Africa) immediately after the 50 min conditioning process. Break 1 consisted of 20-fluted rolls, with a 0.2 mm gap between the rollers and was equipped with 15340 and 495 µm screens. Break 2 was a 25-fluted mill, with a 0.1 mm gap between the rollers and was equipped with 727 and 495 µm screens. The screens served to separate the bran, grits and meal fractions at the output of the mills. The grits from break 1 were fed to break 2. The grits of break 2 were again fed to the break 2 mill in order to extract any remaining meal from the grits. The bran (B1B and B2B) and meal (B1M and B2M) fractions from break 1 and 2, as well as the grits from break 2 (B2G) were weighed. Moisture determinations were performed on all fractions, by means of the oven method described by Gomez *et al.* (1997) for sorghum meal as described in Chapter 3 (3.2.6). Meal from break 1 and break 2 was mixed and sieved on a sieve (ROFF Ind. RSA, P.O. Box 1285, Kroonstad, 9500, South Africa) equipped with a 399 and 338 µm sieve. Meal from the top two sieves were collected, weighed and expressed as sieve 1 and 2 (S1 and S2). The material that went through the 338 µm sieve was weighed and expressed as that which went through the sieves (TH). All three sieve fractions were expressed as percentages of the total meal sample mass (Fig. 4.1). The total loss (TL), as well as the extraction from the mills, was determined. The extraction values were calculated by expressing the meal (B1M and B2M) gained on the mills as a percentage of all the products from the mills (B1M, B2M, B1B, B2B and B2G). The TL was calculated by expressing the losses (i.e. B1B, B2B and TH) as a percentage of the total of products gained from the mills (i.e. B1B, B1M, B2B, B2M and B2G) as was done by Pretorius & Du Plessis (1999) for maize. The TH was included (soft endosperm) as the aim of dry milling is to obtain hard endosperm, unlike wet milling where soft endosperm is the aim.



B1B= BREAK 1 BRAN

B1M= BREAK 1 MEAL

B2B= BREAK 2 BRAN

B2M= BREAK 2 MEAL

B2G= BREAK 2 GRITS

S1= SIEVE 1

S2= SIEVE 2

TH= THROUGH

FIG. 4.1

FLOW DIAGRAM OF THE ROLLER MILLING AND SIFTING PROCESS

4.2.3 FOOD QUALITY PROPERTIES

4.2.3.1 COLOUR

4.2.3.1.1 TADD SAMPLES

Samples from the 0- to 5-minute intervals from the TADD, were subjected to colour measurements. Colour measurements were done with a Hunter Lab Colorquest 45/0 (Hunter Associates Laboratory, Inc. Reston, Virginia, U.S.A.) according to the method described by Pretorius *et al.* (1996). The settings of the instrument were as follows: scale=CIELAB; illuminant=D65; observer=10° and differences=DE. Measurements were done on the dry samples by filling the sample cup with meal and on wet samples, by mixing 40 g of meal from samples with 40 ml of distilled water. The reason for the wet determination of colour was to try and simulate the colour of the cooked product (porridge), without the actual cooking of the product. The sample cup was dropped once from about two centimeters above the working surface to remove air and distribute the sample evenly. The samples were turned between readings with the Hunter Lab. Three readings were taken for each sample. Only the L- and a- values and the whiteness index (WI) values were considered. The dehulling index (DI) (i.e. the percentage dehulling necessary to give meal with a colour similar to that of a commercial sample selected as the standards) was calculated. The regression line of % dehulling at each time-interval (X-axis) vs. the Hunter Lab L-, a- and WI value (Y-axis) at this specific time-interval were used to calculate the DI. The mean value of two commercial samples (King Food Fine Mabele (1998) and Nola Monate Super Mabela (1998)) was used as the standard. The time of abrasion necessary to produce the colour of the standard sample was calculated from the regression line of the abrasion time (X-axis) and the colour at each interval (Y-axis). Samples from Green and Potch, for both seasons, were abraded for the time indicated by the regression line and saved for viscosity measurement (4.2.3.2).

4.2.3.1.2 ROLLER-MILLED SAMPLES

The meal from breaks 1 and 2 that was mixed in 4.2.2.2 was used for colour measurements before sieving. Colour measurements were done as in 4.2.3.1.1, but only on the dry meal, due to results found in 4.3.2.1.1.3 for TADD samples. Meal from Green and Potch were saved for viscosity measurements (4.2.3.2).

4.2.3.2 VISCOSITY

4.2.3.2.1 TADD SAMPLES

Viscosity measurements were done on samples from Green and Potch for both seasons. Samples prepared in 4.2.2.1 by abrasion for specific times to obtain a suitable colour were used. The method of Gomez *et al.*, 1997 was adapted to perform viscosity measurements. A 1:15 (w/w) ratio of meal to water (as is) was used for the preparation of the porridge, instead of the suggested 1:5 ratio, which was too stiff for the viscometer, due to the formation of a gel, which breaks during the rotation of the spindle. A mass of 30 g of meal was prepared into a slurry by the addition of 200 g distilled water. A further 250 g of boiled distilled water was added to the slurry and the product was stirred. The combination of cold and boiled water, instead of only cold water, was used to shorten the cooking period. Samples were cooked in a 1250 W microwave oven for 5 min, while stirring every minute. A microwave oven was used instead of a hotplate to shorten the cooking time by 10 minutes. After cooking was complete, the porridge was stirred for 30 sec and then placed in a water bath at 25 °C for 10 min. The samples were weighed and the water lost through evaporation, was replaced by the addition of distilled water at room temperature. This was followed by another 60 min in the water bath at 25 °C. During this period samples were covered with watch glasses to prevent evaporation losses. This period was followed by another period of cooling of the sample to 25±0.6 °C. This was done to ensure that the viscosity of each sample was read at exactly the same temperature, because viscometer readings vary with heating and cooling when moisture is present

(Akingbala *et al.*, 1982) and maximum viscosities are reached after the temperature falls below 50 °C (Wankhede *et al.*, 1989). The viscosity was read on a Brookfield Programmable DV II+ Viscometer by means of a #6 spindle, rotating at 20 rpm. One reading was recorded every 15 sec, until 15 readings were recorded. The viscosity of a sample was calculated by using the mean value of 15 readings in cP. The temperature was not allowed to vary more than 0.6 °C from 25 °C during viscosity measurements.

4.2.3.2.2 ROLLER-MILLED SAMPLES

The samples that were used for colour determinations (section 4.2.3.1.2) were also used for viscosity measurements. The same method was used as for the TADD samples described in 4.2.3.2.1.

4.2.4 STATISTICAL ANALYSIS OF DATA

Statistical analysis of data was performed as described in section 2.2.8 in Chapter 2.

The regressions for the determinations of the AHI and the DI were done in Costat (Cohort Version 3.02).

As was described in Chapter 3 (3.2.7) regarding SFs and MFs, a three-way randomized block ANOVA was performed on the sieve fractions (i.e. S1, S2 and TH) of the roller milling samples. This was followed by the performance of a two-way randomized block ANOVA on each individual fraction, i.e. for S1, S2 and TH. All ANOVA's were done by using Costat (Cohort Version 3.02).

4.3 RESULTS AND DISCUSSION

4.3.1 MILLING PERFORMANCE

4.3.1.1 TANGENTIAL ABRASIVE DEHULLING DEVICE

Dehulling of sorghum grain is the most popular method used for the determination of the hardness of the grain. Hardness is an important milling quality property as it influences milling time, energy expenditure as well as the appearance of the end product (De Francisco *et al.*, 1982). The hardness of the grain influences the yield and quality of the product (Munck *et al.*, 1982), as well as the ease of dehulling (Reichert *et al.*, 1982) during the abrasion of the grain. Therefore, the TADD technique and specifically the AHI, is a good indication of the actual hardness of the grain. Harder grain will be less easily dehulled than softer grain.

Table 4.1 indicates the AHI values of sorghum cultivars. Significant differences in the AHI value means between cultivars were found (Table 4.2) and this was also observed by Pretorius *et al.*, 1996). APN 881 was found to be the hardest cultivar of all (Table 4.3 and Fig. 4.2). PAN 8564, SNK 3663, PAN 8660, NS 5655, SNK 3337, SNK 3443, SNK 3863 and NK 286 all were not significantly different ($p>0.05$) from the second highest ranked cultivar for AHI value means, namely SNK 3567. Although the remaining cultivars were not significantly different from these cultivars, they all corresponded ($p>0.05$) with the lowest ranked cultivars for AHI value means, namely NK 283, PAN 8171, PAN 8262, SNK 3860 and PAN 8446 (Table 4.3 and Fig. 4.2). Thus, the first 10 ranked cultivars in Table 4.3 can be classified as hard, although APN 881 was the only cultivar to differ ($p<0.05$) from all the other cultivars. Cultivars ranked from the eleventh to the twenty-fourth position could be classified as softer cultivars. Although the latter group of cultivars did not necessarily differ ($p>0.05$) from the harder cultivars, they were the only ones to correspond ($p>0.05$) with the softest ranked cultivars.

TABLE 4.1
THE ABRASIVE HARDENESS INDEX AND THE CORRELATION BETWEEN DEHULLING % AND THE TIME (0 TO 5 MIN) OF ABRASION FOR 24 SORGHUM CULTIVARS OVER 2 PERIODS AT 3 LOCALITIES PER SEASON

CULTI-VAR	DOVER		PLAT		GREEN				POTCH				MEAN		SD	
	1997 /98		1998 /99		1997 /98		1998 /99		1997 /98		1998 /99		1997 /98	1998 /99	1997/98	1997 /98
	AHI		AHI	r	AHI	r	AHI	r	AHI	AHI	AHI	AHI	r	AHI	r	r
ADV 5010	9.13	1.000	10.07	1.000	11.02	0.999	7.26	0.991	8.87	8.01	2.30	9.13	1.000	10.07	1.000	1.000
APN 881	16.65	0.995	15.60	0.997	14.15	1.000	10.99	0.999	13.09	12.31	4.18	16.65	0.997	15.60	0.998	0.997
NK 283	7.69	0.999	7.83	0.999	7.38	0.999	6.92	0.991	7.27	6.93	0.48	7.69	0.999	7.83	0.999	0.999
NK 286	8.40	0.993	10.86	0.999	10.31	0.998	8.93	0.999	8.87	8.82	1.27	8.40	0.996	10.86	0.999	0.999
NS 5511	8.19	0.998	8.83	0.999	9.13	0.999	7.00	0.996	7.93	7.24	1.35	8.19	0.999	8.83	0.999	0.999
NS 5655	9.57	0.995	10.84	0.998	10.30	0.997	8.89	0.998	8.99	9.03	1.67	9.57	0.997	10.84	0.999	0.998
PAN 8061	9.08	0.998	10.88	0.999	8.80	0.999	8.54	0.997	8.01	8.51	1.62	9.08	0.999	10.88	0.999	0.999
PAN 8171	6.89	1.000	8.50	0.999	9.43	0.995	6.78	0.998	7.36	7.03	1.88	6.89	1.000	8.50	0.999	0.999
PAN 8262	6.85	0.997	9.12	0.992	8.75	0.999	6.56	0.994	7.18	7.21	1.44	6.85	0.998	9.12	0.996	0.992
PAN 8272	8.77	0.999	10.66	0.999	10.68	1.000	7.49	0.997	8.77	7.98	1.92	8.77	0.999	10.66	0.999	0.999
PAN 8370	8.90	0.999	10.00	0.999	10.28	0.999	7.96	0.999	8.54	8.26	1.96	8.90	0.999	10.00	0.999	0.999
PAN 8446	7.56	0.999	8.81	1.000	8.26	0.999	7.61	0.998	7.51	7.20	0.78	7.56	0.999	8.81	1.000	1.000
PAN 8564	11.56	0.999	9.36	0.979	12.03	0.999	8.91	0.998	10.58	8.86	2.11	11.56	0.999	9.36	0.989	0.979
PAN 8660	10.45	0.998	11.52	0.997	10.21	0.998	8.85	0.995	9.07	9.07	2.20	10.45	0.999	11.52	0.998	0.997
SNK 3337	8.62	0.997	9.88	0.999	10.08	0.998	9.64	0.999	8.85	9.15	1.14	8.62	0.998	9.88	0.999	0.999
SNK 3443	8.73	0.998	10.96	0.999	9.53	0.999	8.73	0.999	8.74	9.24	0.80	8.73	0.999	10.96	0.999	0.999
SNK 3567	9.62	0.998	9.92	0.999	12.35	0.998	9.54	0.999	10.62	9.39	1.51	9.62	0.999	9.92	0.999	0.999
SNK 3620	9.84	0.999	7.79	0.999	8.83	0.999	7.16	0.999	8.22	7.11	2.00	9.84	0.999	7.79	0.999	0.999
SNK 3663	10.52	0.971	11.91	1.000	8.35	1.000	8.14	0.998	8.71	9.91	1.66	10.52	0.985	11.91	1.000	1.000
SNK 3860	7.12	0.999	8.35	0.999	9.65	0.999	7.03	0.998	7.40	7.15	2.12	7.12	0.999	8.35	0.999	0.999
SNK 3863	9.85	1.000	10.01	0.999	11.21	1.000	8.35	0.997	9.48	8.28	1.95	9.85	1.000	10.01	0.999	0.999
SNK 3883	9.22	0.999	10.32	0.999	8.18	0.999	7.45	0.998	7.95	7.89	1.40	9.22	0.999	10.32	0.999	0.999
SNK 3939	7.53	0.999	8.81	1.000	7.89	0.999	9.36	0.998	7.74	8.40	0.19	7.53	0.999	8.81	1.000	1.000
SNK 3975	8.57	0.994	8.70	0.999	8.92	0.999	9.74	0.998	7.69	8.43	1.84	8.57	0.997	8.70	0.999	0.999
MEAN	9.14	0.997	9.98	0.998	9.82	0.999	8.24	0.997	8.64	8.39	1.66	9.14	9.14	0.998	9.980	0.999
MIN	6.85	0.971	7.79	0.979	7.38	0.995	6.56	0.991	7.18	6.93	0.19	6.85	6.85	0.985	7.790	0.989
MAX	16.65	1.000	15.60	1.000	14.15	1.000	10.99	0.999	13.09	12.31	4.18	16.65	16.65	1.000	15.600	1.000
RANGE	9.80	0.029	7.82	0.021	6.77	0.005	4.42	0.009	5.92	5.37	3.99	9.80	9.80	0.015	7.810	0.011
SD	1.99	0.006	1.65	0.004	1.57	0.001	1.15	0.002	1.33	1.20	0.77	1.99	1.99	0.003	1.650	0.002

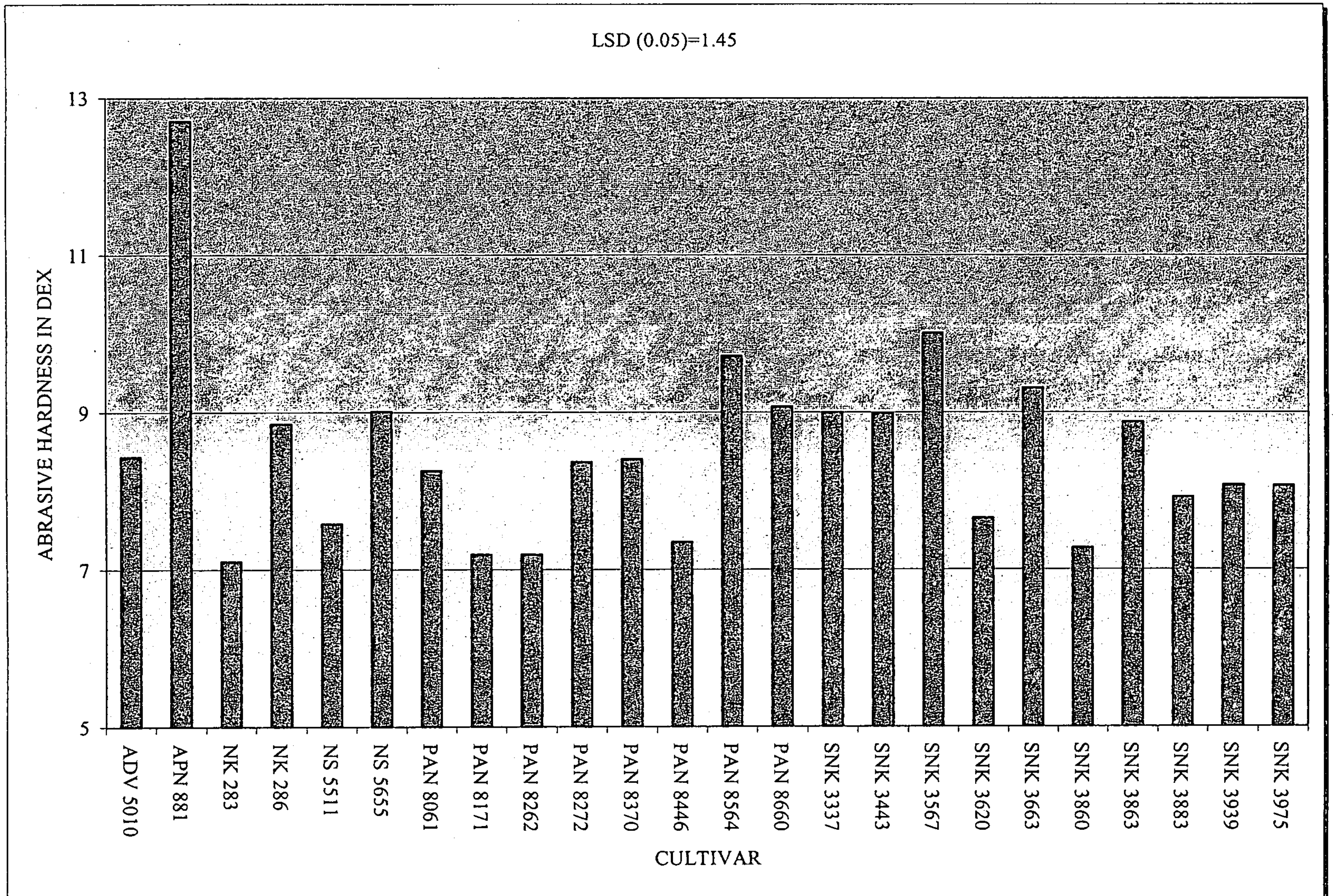


FIG. 4.2

THE SIGNIFICANT DIFFERENCES BETWEEN THE ABARSIVE HARDNESS INDEXES OF DIFFERENT SORGHUM CULTIVARS

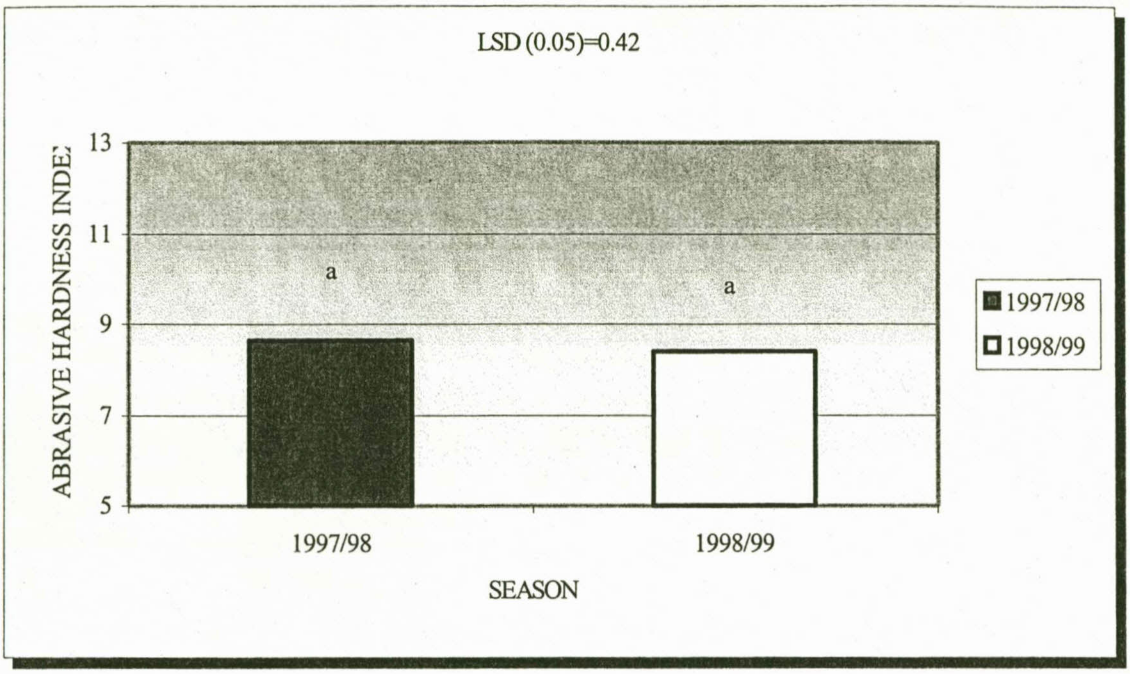


FIG. 4.3

THE INSIGNIFICANT DIFFERENCES IN THE ABRSIVE HARDNESS INDEX VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

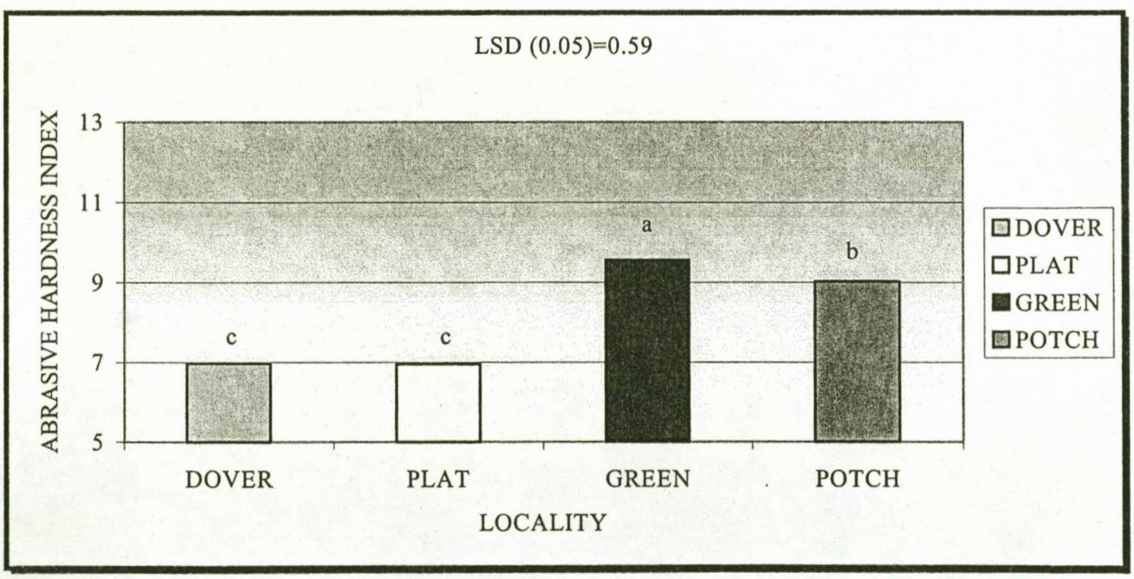


FIG. 4.4

THE DIFFERENCES IN THE ABRASIVE HARDNESS INDEX VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 4.2

ANALYSIS OF VARIANCE OF THE ABRASIVE HARNDESS INDEX OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	3.259	3.259	2.093	0.155	ns
Main Effects						
CULTIVAR	23	163.010	7.087	4.552	0.000	***
LOCALITY	3	182.391	60.797	39.045	0.000	***
Interaction						
CULTIVAR x LOCALITY	69	63.374	0.918	0.590	0.977	ns
Error	47	73.183	1.557 <-			
Total	143	524.586				

P=0.05

ns=not significant

TABLE 4.3

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN ABRASIVE HARDNESS INDEX VALUE MEANS

Rank	Cultivar	Mean	n	Groups not significantly different
1	APN 881	12.700	6	a
2	SNK 3567	10.002	6	b
3	PAN 8564	9.717	6	bc
4	SNK 3663	9.310	6	bcd
5	PAN 8660	9.068	6	bcde
6	NS 5655	9.013	6	bcdef
7	SNK 3337	8.998	6	bcdef
8	SNK 3443	8.985	6	bcdef
9	SNK 3863	8.876	6	bcdef
10	NK 286	8.846	6	bcdef
11	ADV 5010	8.435	6	cdefg
12	PAN 8370	8.399	6	cdefg
13	PAN 8272	8.372	6	cdefg
14	PAN 8061	8.258	6	defg
15	SNK 3939	8.069	6	defg
16	SNK 3975	8.063	6	defg
17	SNK 3883	7.921	6	defg
18	SNK 3620	7.661	6	efg
19	NS 5511	7.585	6	fg
20	PAN 8446	7.352	6	g
21	SNK 3860	7.276	6	g
22	PAN 8262	7.191	6	g
23	PAN 8171	7.191	6	g
24	NK 283	7.101	6	g

In Chapter 1 it was seen that the success of TADD milling is dependent on several factors. Losses caused by differences in gap size of the machine, were prevented by the manual adjustment of the gap sizes between the sample cups and the abrasive surface to be equal in sizes as described in 4.2.2.1. According to Wills & Ali (1982), the TADD milling quality of sorghum grain is also improved when small, hard grain is used, but in chapter 2 it was seen that medium size kernels are predicted to deliver better milling results. It was also mentioned that larger grain should be hard enough to prevent it from breaking under the force of the abrasive process (Chapter 3). SNK 3567 for example, consists mainly of large-sized kernels (Chapter 3; Table 3.12), but due to its hardness (Table 4.3) may still result in good milling quality. The soft cultivar, SNK 3860 with its large-sized kernels, will however not result in good milling properties, due to its softness.

Differences in AHI value means over different seasons were insignificant (Fig. 4.3), although significant differences in locality value means were found (Table 4.2). From Fig. 4.4 it can be confirmed that the highest AHI values were found at Green, whilst the lowest values were found at Dover and Plat. The AHI values of the latter two localities did not differ ($p>0.05$) and grain from Potch was found to be the second hardest.

4.3.1.2 ROLLER MILLING

The different fractions from the roller mills are break 1 bran (B1B) and meal (B1M); break 2 grits (B2G), bran (B2B) and meal (B2M) and sieve fractions, namely sieve 1 (S1), 2 (S2) and throughs (TH), as well as the extraction and total loss (TL) values. Each fraction will be discussed separately in this section.

4.3.1.2.1 BREAK 1 BRAN

In Chapter 1 (1.2) it was seen that the bran refers to the outer part of the sorghum kernel, although it may be defined in different ways by different millers, e.g. the pericarp, seed coat, etc. During the conditioning-process water is added to moisten the bran, which then becomes looser (Desikachar, 1982), tough and rubbery (Hahn, 1969) for easier separation from the endosperm (Desikachar, 1982). Table 4.4 indicates the B1B values, which were removed from a 500-g sample by means of the break 1 mill, in grams.

Significant differences between the B1B values means were found for different cultivars, as seen in Table 4.5. The differences were not highly significant however, as seen in Fig. 4.5 and Table 4.6. No cultivar differed significantly from all the other cultivars. The bran can be seen as a milling loss that should be limited, as was found in the case of maize (Pretorius & Du Plessis, 1999). Therefore cultivars with lower losses, in the form of bran, are those with expected good milling performances. NS 5511, APN 881, NK 286, SNK 3939, SNK 3337, SNK 3860 and SNK 3975 all differed ($p<0.05$) from the highest ranked cultivar for B1B values, namely PAN 8061.

From Table 4.6 it is clear that significant differences were found between the B1B value means over different seasons and at different localities. Differences were more significant in the case of different localities than in the cases of cultivars and seasons (Table 4.6), however. From Fig. 4.6 it is seen that higher B1B values were found during the 1998/99 season, than in the 1997/98 season. No single locality differed significantly in B1B value means from all other localities. Grain from Dover and Plat were determined to have higher B1B value means (Fig. 4.7) than that from Potch, while those from Potch and Green had lower values than those from Dover. Lower milling losses could thus be expected at Potch and Green.

TABLE 4.4
THE BREAK 1 BRAN VALUES OF DIFFERENT SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

CULTIVAR	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99
ADV 5010	30.15	27.15	28.82	23.50	17.09	29.12	25.35	26.59	7.19	2.85
APN 881	27.15	22.40	24.34	23.38	20.72	27.82	24.07	24.53	3.22	2.89
NK 283	26.47	25.04	22.34	24.15	21.06	32.91	23.29	27.37	2.82	4.82
NK 286	25.95	26.90	21.27	23.97	20.71	25.33	22.64	25.40	2.88	1.47
NS 5511	22.67	22.42	23.84	22.95	18.91	36.38	21.81	27.25	2.58	7.91
NS 5655	28.64	25.19	26.80	21.70	22.11	25.52	25.85	24.13	3.37	2.12
PAN 8061	26.59	40.08	34.45	25.44	26.32	27.64	29.12	31.05	4.62	7.89
PAN 8171	29.40	29.61	32.37	25.08	23.77	30.30	28.51	28.33	4.37	2.83
PAN 8262	28.95	25.37	36.47	26.62	20.16	32.61	28.52	28.20	8.16	3.87
PAN 8272	30.36	29.12	30.58	26.96	19.87	32.38	26.94	29.49	6.12	2.73
PAN 8370	31.52	31.20	31.97	27.09	24.90	33.58	29.46	30.62	3.96	3.28
PAN 8446	32.64	34.13	30.11	25.87	20.16	30.54	27.64	30.18	6.60	4.14
PAN 8564	24.55	28.74	26.66	22.15	20.91	26.72	24.04	25.87	2.91	3.38
PAN 8660	33.20	33.32	26.68	28.48	22.30	32.14	27.39	31.31	5.48	2.53
SNK 3337	25.69	24.01	24.58	21.05	17.12	21.86	22.46	22.30	4.66	1.53
SNK 3443	29.01	28.81	30.70	23.44	21.81	30.82	27.17	27.69	4.72	3.82
SNK 3567	28.28	27.28	33.31	26.07	21.36	28.00	27.65	27.12	6.00	0.98
SNK 3620	27.20	19.98	16.84	16.53	16.90	21.30	20.31	19.27	5.96	2.47
SNK 3663	35.51	34.53	22.81	22.08	20.50	31.63	26.27	29.41	8.09	6.51
SNK 3860	26.45	20.46	21.29	19.44	18.28	26.81	22.00	22.24	4.13	3.99
SNK 3863	26.76	26.47	24.53	23.90	19.86	26.06	23.72	25.48	3.52	1.38
SNK 3883	28.07	26.16	26.28	19.06	20.31	29.60	24.89	24.94	4.07	5.38
SNK 3939	22.89	22.96	22.40	23.69	24.15	27.10	23.15	24.59	0.90	2.21
SNK 3975	24.93	24.84	20.30	21.99	17.39	20.60	20.88	22.48	3.80	2.16
MEAN	28.04	27.34	26.66	23.52	20.69	28.62	25.13	26.49		
MAX	35.51	40.08	36.47	28.48	26.32	36.38	29.46	31.31		
MIN	22.67	19.98	16.84	16.53	16.90	20.60	20.31	19.27		
RANGE	15.78	15.78	15.78	15.78	15.78	15.78	15.78	15.78		
SD	28.18	27.45	26.93	23.59	20.84	28.96	25.32	26.67		

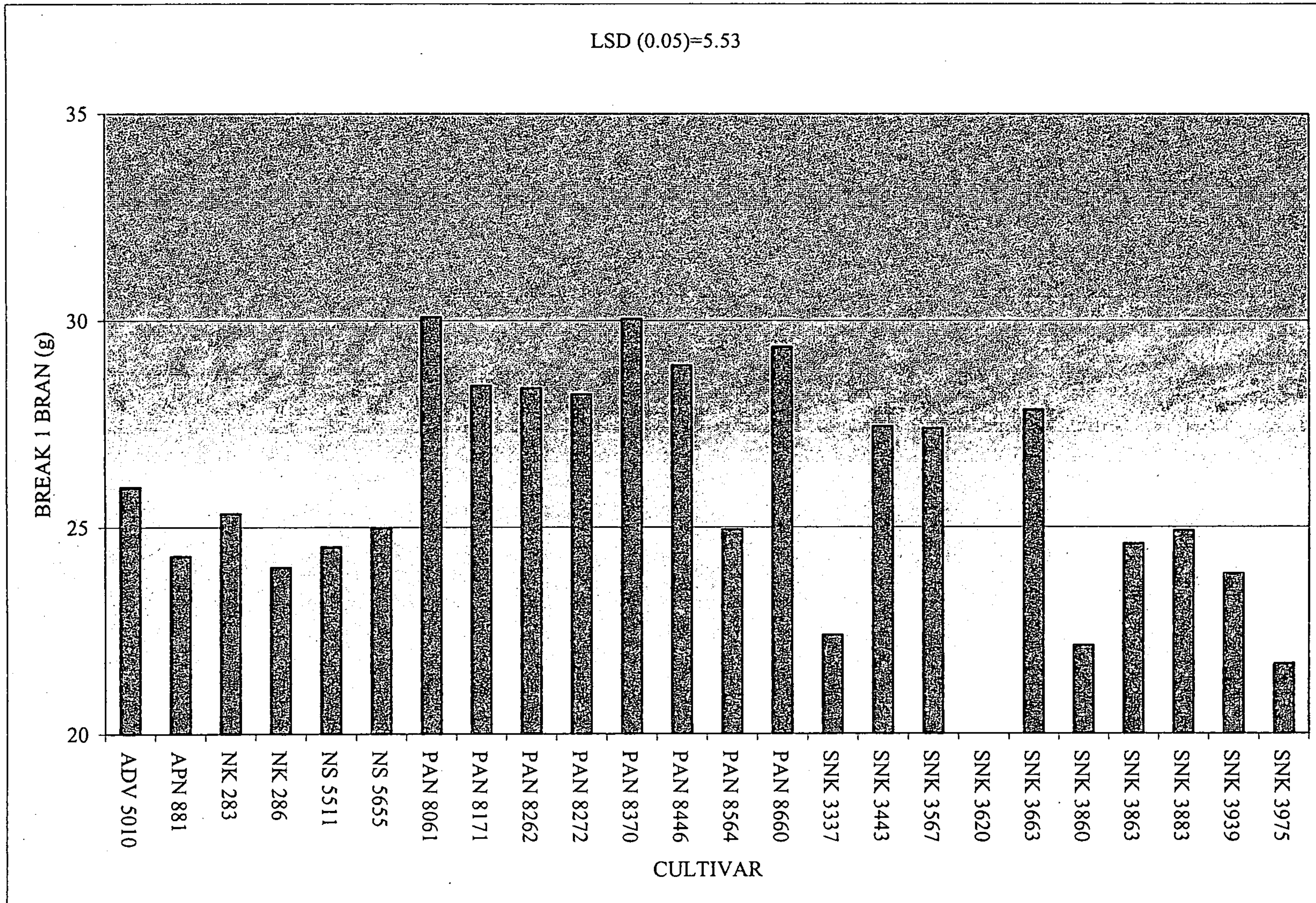


FIG. 4.5

THE SIGNIFICANT DIFFERENCES BETWEEN THE BREAK 1 BRAN FRACTION OF DIFFERENT SORGHUM CULTIVARS

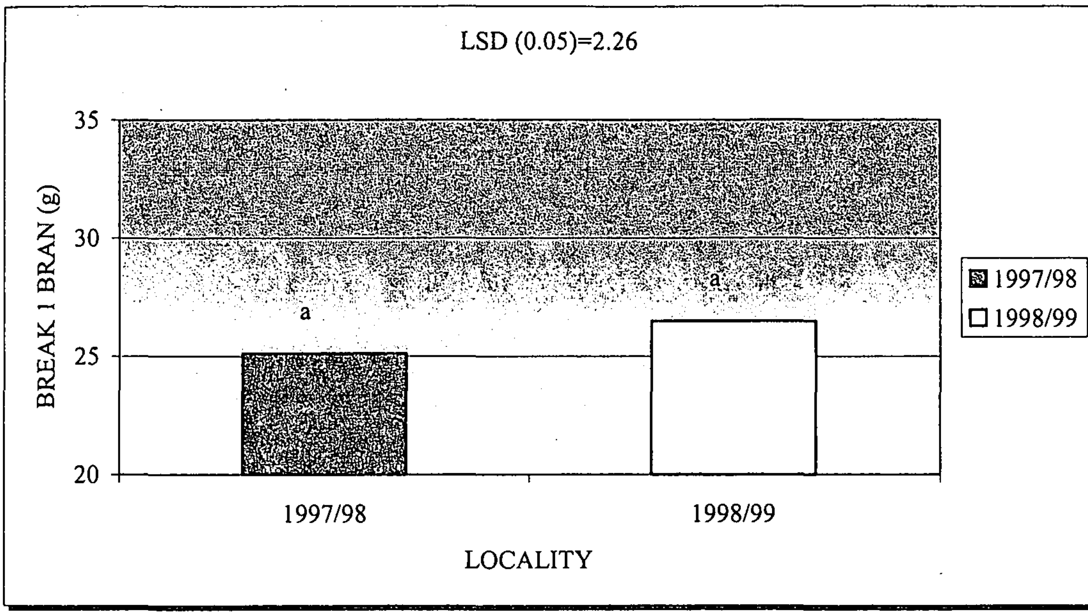


FIG. 4.6

THE INSIGNIFICANT DIFFERENCES IN THE BREAK 1 BRAN VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT GROWING SEASONS

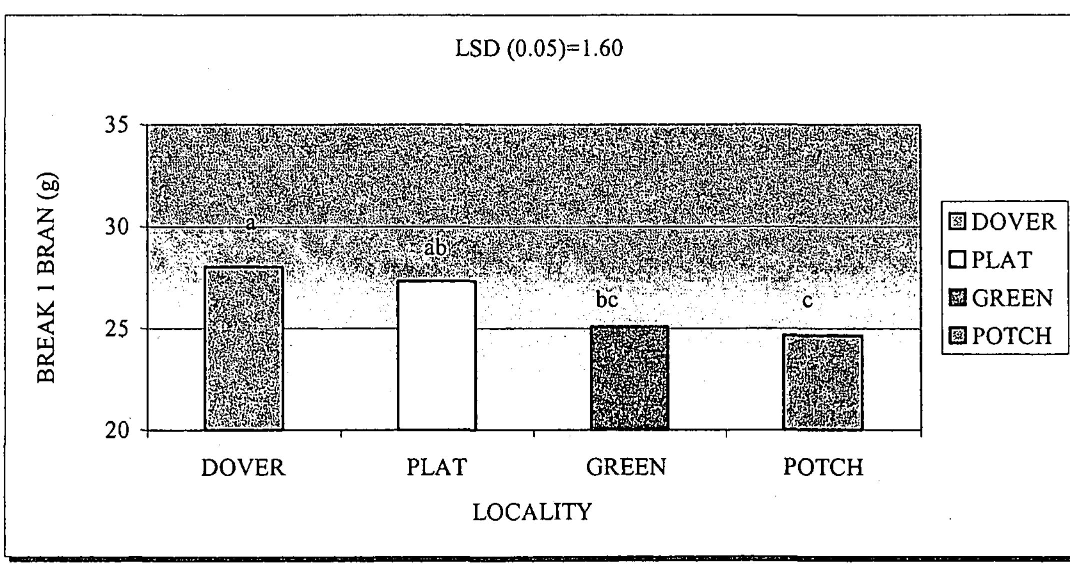


FIG. 4.7

THE DIFFERENCES IN THE BREAK 1 BRAN VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 4.5

ANALYSIS OF VARIANCE OF THE BREAK 1 BRAN OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	137.7380	137.7380	6.0759	0.0174	*
Main Effects						
CULTIVAR	23	1019.1371	44.3103	1.9546	0.0258	*
LOCALITY	3	335.8371	111.9457	4.9381	0.0046	**
Interaction						
CULTIVAR x LOCALITY	69	605.8566	8.7805	0.3873	0.9998	ns
Error	47	1065.4768	22.6697	<-		
Total	143	3155.1775				

P=0.05

ns=not significant

TABLE 4.6

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN BREAK 1 BRAN VALUE MEANS

Rank	Cultivars	Mean	n	Groups not significantly different
1	PAN 8061	30.088	6	a
2	PAN 8370	30.041	6	ab
3	PAN 8660	29.353	6	abc
4	PAN 8446	28.911	6	abc
5	PAN 8171	28.422	6	abc
6	PAN 8262	28.362	6	abc
7	PAN 8272	28.212	6	abc
8	SNK 3663	27.842	6	abcd
9	SNK 3443	27.432	6	abcde
10	SNK 3567	27.383	6	abcde
11	ADV 5010	25.971	6	abcdef
12	NK 283	25.329	6	abcdef
13	NS 5655	24.992	6	abcdefg
14	PAN 8564	24.955	6	abcdefg
15	SNK 3883	24.912	6	abcdefg
16	SNK 3863	24.597	6	abcdefg
17	NS 5511	24.527	6	bcdefg
18	APN 881	24.300	6	cdefg
19	NK 286	24.021	6	cdefg
20	SNK 3939	23.867	6	cdefg
21	SNK 3337	22.385	6	defg
22	SNK 3860	22.121	6	efg
23	SNK 3975	21.677	6	fg
24	SNK 3620	19.792	6	g

4.3.1.2.2 BREAK 1 MEAL

The B1M fraction of sorghum cultivars grown over different seasons and different localities of growth can be seen in Table 4.7. Significant differences between the B1M value means of different cultivars were found (Table 4.8) (Fig. 4.8), but the level of significance was not very high. No single cultivar differed significantly from all other cultivars in B1M value means (Table 4.9). SNK 3860, NS 5511, SNK 3620, SNK 3863, SNK 3975, NK 283 and PAN 8171 all corresponded ($p>0.05$) with the highest ranked cultivar, namely PAN 8262, in B1M value means. In Chapter 1, it was explained that the first pair of rollers squeezes and abrades the kernel (Munck, 1995), breaks it open and leave the endosperm exposed (Taylor, 1998b). Therefore, harder kernels will break up less easily during this process and less endosperm (meal) will be produced. Meal from the first break is consequently an indication of softness, and cultivars with high B1M values will mainly belong to the softer group. Pretorius & Du Plessis (1999) also found B1M to be a negative quality trait for maize, as the largest percentage of softest endosperm is produced on the break 1 rollers. In 4.3.1.1 it was mentioned that softer grain is generally an indication that the milling quality of the grain will be worse than that of harder grain. The cultivars with high B1M values can thus be expected to be of poor milling quality. SNK 3337, PAN 8272, PAN 8370, NK 286, PAN 8061, PAN 8446, SNK 3663, NS 5655, SNK 3443, PAN 8564 and APN 881 all corresponded ($p>0.05$) with the lowest ranked cultivar, namely PAN 8660, in B1M value means (Table 4.9). These cultivars could be expected to be harder, with subsequent better milling performances.

No significant differences in B1M value means over different seasons were found (Fig. 4.9) and the cultivar x locality interaction were insignificant (Table 4.8). Significant differences in B1M value means at different localities of growth were also found (Table 4.8; Fig. 4.10) and the level of significance was much higher than for cultivars. Plat showed the highest B1M value means, indicating softer grain at this locality, while Green showed the lowest B1M value means. Therefore, harder grain with better milling performances was produced at Green, while no differences in the hardness of grain from Dover and Potch is expected.

TABLE 4.7

THE BREAK 1 MEAL VALUES OF DIFFERENT SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 SEASONS

CULTIVAR	B1M (g)									
	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99
ADV 5010	150.99	153.25	151.14	123.30	122.90	155.23	141.68	143.93	16.26	17.90
APN 881	141.73	142.01	124.67	109.53	124.27	142.27	130.22	131.27	9.97	18.83
NK 283	152.92	158.45	133.96	128.17	128.96	160.69	138.61	149.10	12.64	18.16
NK 286	150.89	158.42	136.58	110.44	138.87	148.23	142.11	139.03	7.69	25.28
NS 5511	161.84	168.88	146.50	146.23	139.24	171.28	149.19	162.13	11.54	13.82
NS 5655	150.46	153.40	139.80	115.60	117.37	144.60	135.88	137.87	16.89	19.78
PAN 8061	149.06	153.46	129.71	119.92	138.46	145.77	139.08	139.72	9.69	17.57
PAN 8171	153.38	161.70	148.43	118.77	126.94	152.47	142.92	144.31	14.05	22.60
PAN 8262	165.04	181.10	149.74	138.45	149.32	171.38	154.70	163.64	8.96	22.35
PAN 8272	145.70	165.26	137.79	111.81	127.59	158.32	137.03	145.13	9.08	29.06
PAN 8370	147.75	156.59	135.59	124.07	130.98	150.20	138.11	143.62	8.66	17.23
PAN 8446	145.28	160.73	133.69	123.21	126.45	142.35	135.14	142.09	9.50	18.76
PAN 8564	138.18	144.02	127.98	115.10	129.32	147.17	131.83	135.43	5.54	17.68
PAN 8660	117.25	143.57	121.73	112.05	119.97	141.45	119.65	132.35	2.26	17.62
SNK 3337	147.65	152.61	142.25	111.81	149.88	144.78	146.59	136.40	3.92	21.65
SNK 3443	122.74	149.71	138.81	125.75	133.48	139.40	131.68	138.29	8.19	12.02
SNK 3567	150.86	153.24	142.10	124.30	140.23	147.54	144.40	141.69	5.68	15.33
SNK 3620	163.61	166.48	147.62	128.71	155.16	164.16	155.46	153.12	8.00	21.17
SNK 3663	145.02	154.25	127.66	115.48	135.81	145.58	136.16	138.44	8.69	20.35
SNK 3860	165.14	161.16	162.69	135.97	151.53	177.10	159.79	158.08	7.26	20.74
SNK 3863	157.46	169.05	146.67	121.29	143.30	144.89	149.14	145.08	7.39	23.88
SNK 3883	148.17	156.81	142.26	127.10	139.35	156.61	143.26	146.84	4.50	17.10
SNK 3939	141.42	164.98	132.90	129.94	134.11	148.99	136.14	147.97	4.61	17.54
SNK 3975	153.74	168.90	140.69	122.64	134.79	147.85	143.07	146.46	9.70	23.16
MEAN	148.60	158.25	139.21	122.48	134.93	152.01	140.91	144.25		
MAX	165.14	181.10	162.69	146.23	155.16	177.10	159.79	163.64		
MIN	117.25	142.01	121.73	109.53	117.37	139.40	119.65	131.27		
RANGE	37.79	37.79	37.79	37.79	37.79	37.79	37.79	37.79		
SD	11.43	9.23	9.52	9.30	10.10	10.33	8.91	8.43		

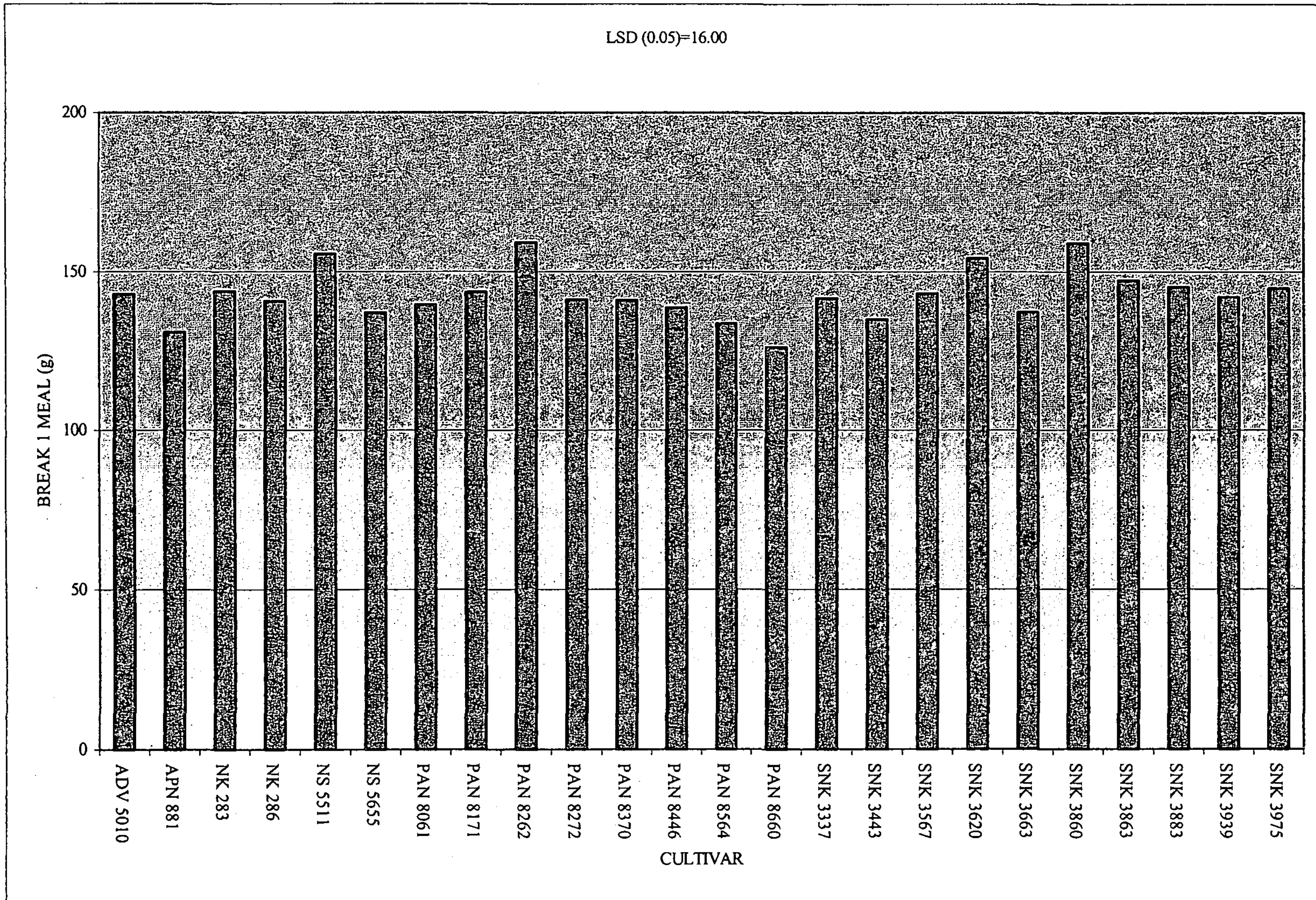


FIG. 4.8

THE SIGNIFICANT DIFFERENCES BETWEEN THE BREAK 1 MEAL FRACTION OF DIFFERENT SORGHUM CULTIVARS

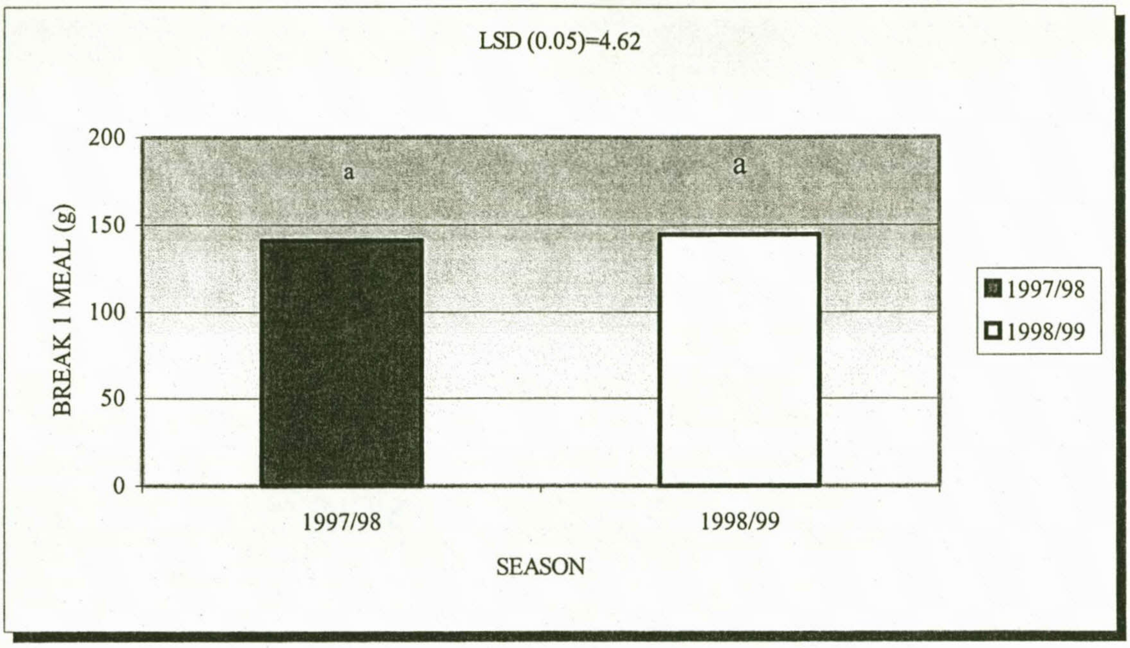


FIG. 4.9

THE DIFFERENCES IN THE BREAK 1 MEAL VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

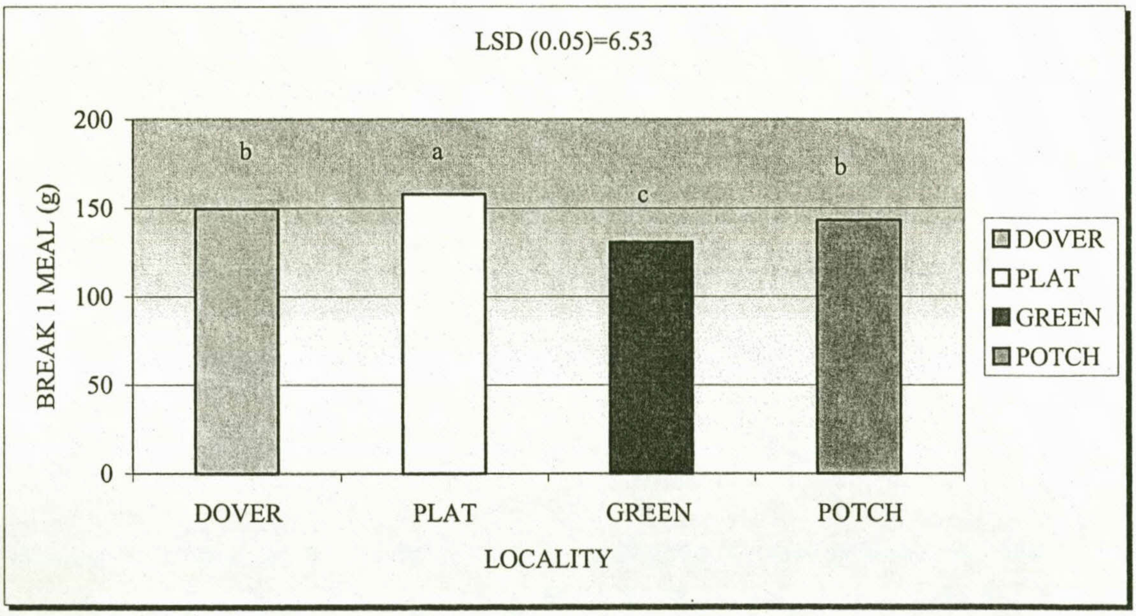


FIG. 4.10

THE DIFFERENCES IN THE BREAK 1 MEAL VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 4.8

ANALYSIS OF VARIANCE OF THE BREAK 1 MEAL OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	0.7889	0.7889	0.0042	0.9489	ns
Main Effects						
CULTIVAR	23	8582.6275	373.1577	1.9667	0.0248	*
LOCALITY	3	13009.9919	4336.6640	22.8563	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	2566.3814	37.1939	0.1960	1.0000	ns
Error	47	8917.5873	189.7359	<-		
Total	143	3410.8246	5.8246			

P=0.05

ns=not significant

TABLE 4.9
RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN BREAK 1 MEAL VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	PAN 8262	159.171	6	a
2	SNK 3860	158.933	6	ab
3	NS 5511	155.662	6	abc
4	SNK 3620	154.291	6	abcd
5	SNK 3863	147.111	6	abcde
6	SNK 3883	145.050	6	abcdef
7	SNK 3975	144.769	6	abcdef
8	NK 283	143.858	6	abcdef
9	PAN 8171	143.616	6	abcdef
10	SNK 3567	143.044	6	abcdef
11	ADV 5010	142.803	6	cdef
12	SNK 3939	142.057	6	cdefg
13	SNK 3337	141.495	6	cdefg
14	PAN 8272	141.079	6	cdefg
15	PAN 8370	140.864	6	cdefg
16	NK 286	140.572	6	cdefg
17	PAN 8061	139.397	6	defg
18	PAN 8446	138.616	6	defg
19	SNK 3663	137.300	6	efg
20	NS 5655	136.872	6	efg
21	SNK 3443	134.982	6	efg
22	PAN 8564	133.629	6	efg
23	APN 881	130.747	6	fg
24	PAN 8660	126.001	6	g

4.3.1.2.3 BREAK 2 BRAN

The B2B values of different cultivars at different localities and over different seasons of growth are shown in Table 4.10. Table 4.11 indicates that significant differences in cultivar value means were found. In 4.3.1.2.1 it was observed that bran refers to the outer part of the sorghum, which is separated from the endosperm during milling. Break 2 bran is therefore also classified as a loss and cultivars with high B2B values will result in greater milling losses for that cultivar.

From Table 4.12 it can be seen that no single cultivar differed significantly from all other cultivars in B2B value means. APN 881 and SNK 3860 corresponded ($p>0.05$) with the highest ranked cultivar, namely NS 5511 (highest bran), in B2B value means. These cultivars will show higher milling losses in the form of B2B. The birdproof cultivars NS 5511, SNK 3860 and SNK 3620 were ranked in the 1st, 3rd and 4th position respectively, for B2B value means. This is on account of the fact that birdproof cultivars generally contain more pericarp and less endosperm, due to the presence of the pigmented layer in the pericarp (Jambunathan & Mertz, 1973) and B2B is part of the pericarp. PAN 8564, SNK 3975, SNK 3863, SNK 3337, SNK 3883 and NK 286 corresponded ($p>0.05$) with the lowest ranked cultivar, namely SNK 3939, in B2B value means and will present lower milling losses in the form of B2B (Table 4.12). No significant differences in the B2B value means for seasons and localities (Fig. 4.12; Fig. 4.13) were found and the cultivar x locality interaction was insignificant (Table 4.11).

TABLE 4.10

THE BREAK 2 BRAN VALUES OF DIFFERENT SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 SEASONS

CULTIVAR	B2B (g)									
	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99
ADV 5010	26.10	28.59	29.10	26.31	25.97	27.76	27.06	27.55	1.77	1.15
APN 881	30.69	28.41	29.66	31.39	26.92	31.41	29.09	30.40	1.95	1.73
NK 283	25.99	27.70	26.66	26.39	28.35	28.52	27.00	27.54	1.21	1.07
NK 286	26.87	25.46	25.16	24.23	25.21	25.33	25.75	25.01	0.97	0.67
NS 5511	29.90	31.46	29.97	26.85	29.94	34.10	29.94	30.80	0.03	3.67
NS 5655	26.76	27.54	27.60	27.39	25.42	27.89	26.59	27.61	1.10	0.26
PAN 8061	26.70	28.48	29.90	27.62	28.51	28.46	28.37	28.19	1.61	0.49
PAN 8171	28.41	27.19	28.04	27.88	26.45	27.77	27.63	27.61	1.04	0.37
PAN 8262	27.95	26.86	28.28	28.75	30.57	28.19	28.93	27.93	1.43	0.97
PAN 8272	27.63	27.39	26.97	27.39	27.38	29.08	27.33	27.95	0.34	0.98
PAN 8370	27.08	26.16	28.00	26.98	27.19	26.43	27.77	28.06	0.50	0.42
PAN 8446	28.50	27.88	29.57	29.81	25.77	27.26	27.95	28.32	1.96	1.33
PAN 8564	26.13	24.14	28.01	26.23	27.05	26.60	27.06	25.66	0.94	1.32
PAN 8660	28.36	26.82	28.18	24.87	25.20	27.90	27.25	26.53	1.78	1.53
SNK 3337	26.82	25.18	27.45	24.58	26.99	25.43	27.09	25.07	0.33	0.44
SNK 3443	30.61	28.74	27.66	28.33	27.82	29.08	28.70	28.72	1.66	0.38
SNK 3567	26.83	24.79	27.75	26.07	27.07	27.19	27.22	26.02	0.48	1.20
SNK 3620	28.87	31.90	25.71	26.07	29.76	30.44	28.11	29.47	2.13	3.03
SNK 3663	31.17	28.31	26.96	26.35	27.85	28.17	28.66	27.61	2.22	1.10
SNK 3860	28.77	28.76	28.42	28.34	28.13	32.58	28.44	29.90	0.32	2.34
SNK 3863	25.33	26.23	26.13	24.83	27.25	26.69	26.24	25.92	0.97	0.97
SNK 3883	26.35	25.84	26.16	26.16	25.69	25.92	26.07	25.97	0.34	0.16
SNK 3939	19.83	25.51	25.36	25.35	27.76	25.40	24.32	25.42	4.07	0.08
SNK 3975	26.58	26.93	26.61	25.55	25.71	26.65	26.30	26.38	0.51	0.73
MEAN	27.43	27.35	27.64	26.82	27.25	28.09	27.45	27.48		
MAX	31.17	31.90	29.97	31.39	30.57	34.10	29.94	30.80		
MIN	19.83	24.14	25.16	24.23	25.20	25.33	24.32	25.01		
RANGE	11.33	7.75	4.80	7.16	5.37	8.78	5.62	5.79		
SD	2.28	1.88	1.39	1.70	1.48	2.21	1.24	1.63		

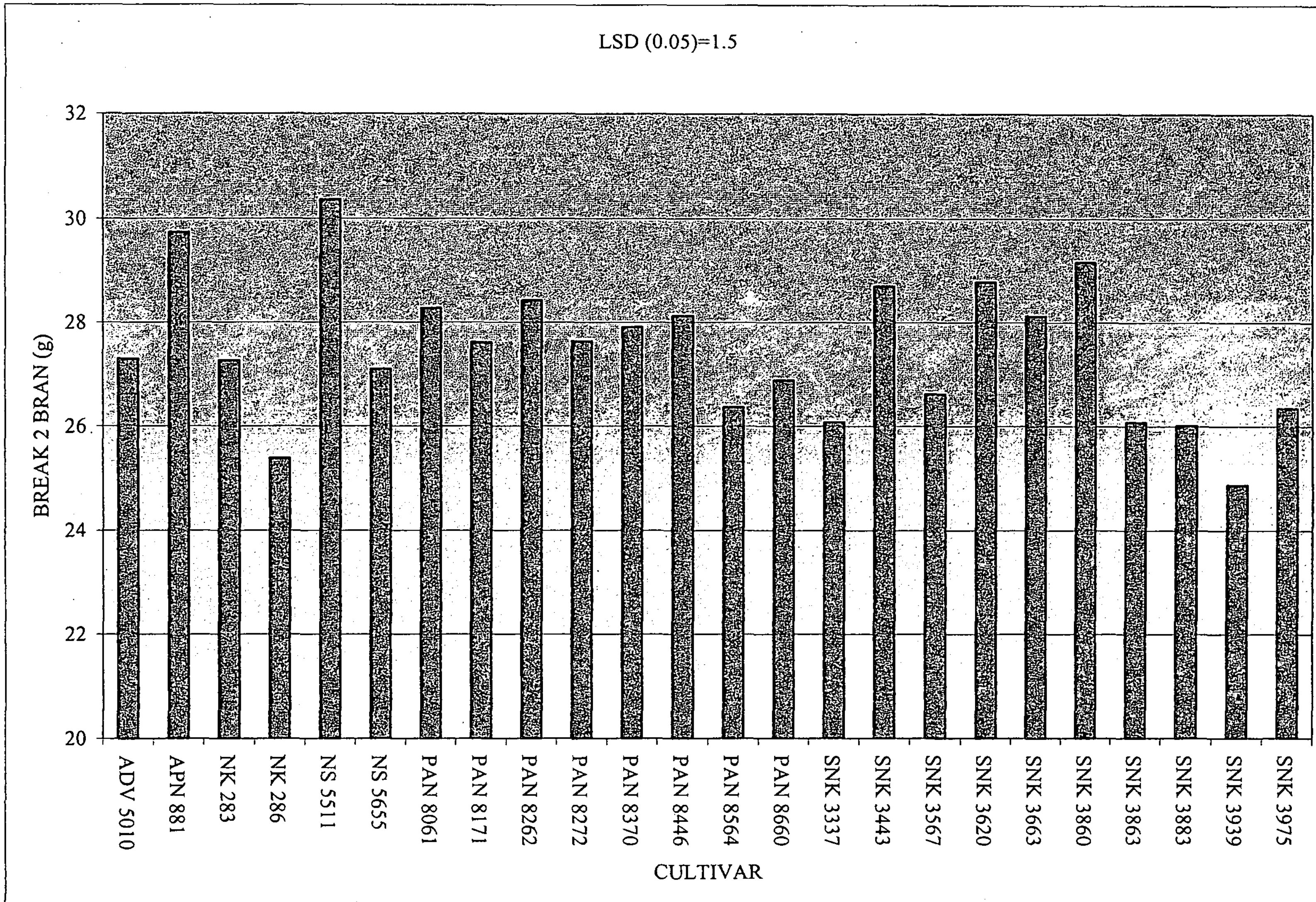


FIG. 4.11

THE SIGNIFICANT DIFFERENCES BETWEEN THE BREAK 2 BRAN VALUES OF DIFFERENT SORGHUM CULTIVARS

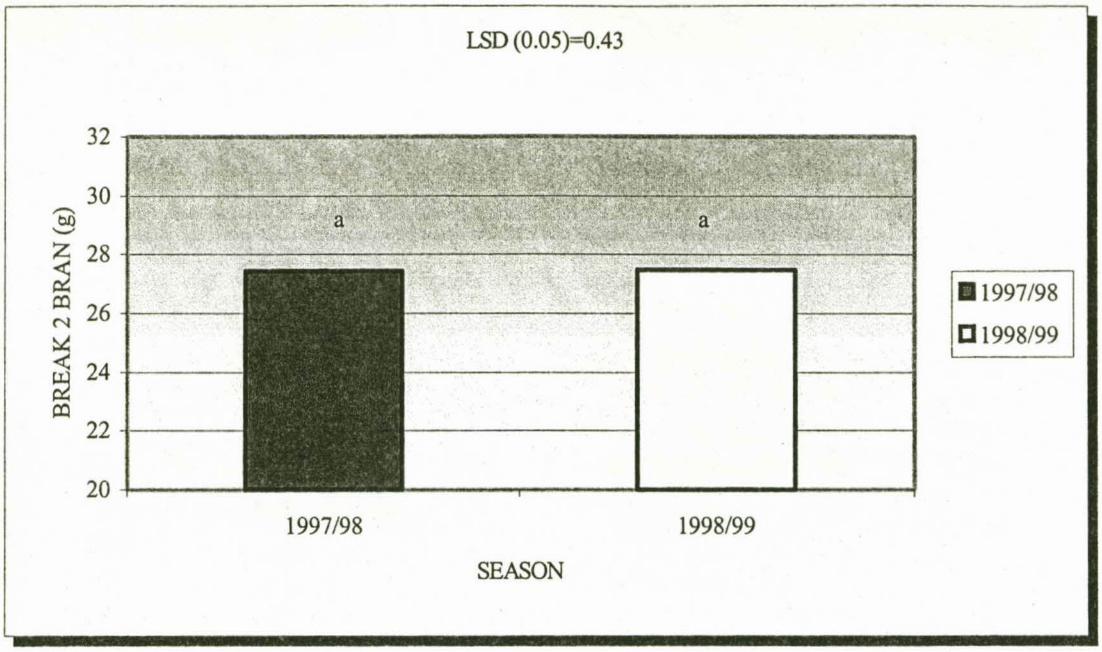


FIG. 4.12

THE INSIGNIFICANT DIFFERNCES IN THE BREAK 2 BRAN VALUE MEANS SORGHUM CULTIVARS OVER DIFFERENT SEASONS

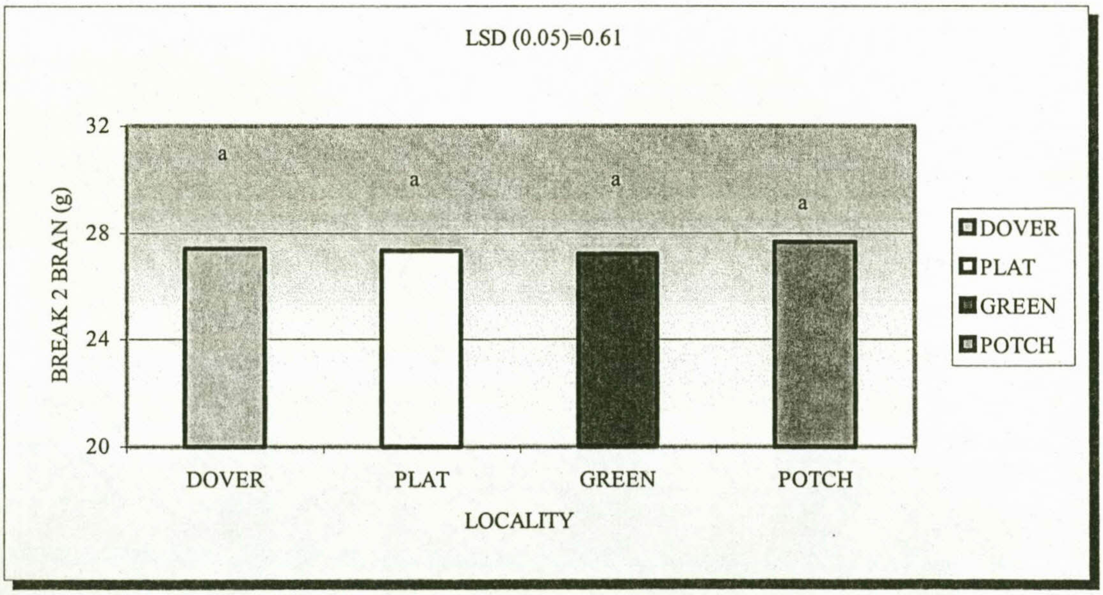


FIG. 4.13

THE INSIGNIFICANT DIFFERNCES IN THE BREAK 2 BRAN VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 4.11

ANALYSIS OF VARIANCE OF THE BREAK 2 BRAN VALUES OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASONS)	1	0.005	0.005	0.003	0.956	ns
Main Effects						
CULTIVAR	23	259.369	11.277	6.802	0.000	***
LOCALITY	3	4.855	1.618	0.976	0.412	ns
Interaction						
CULTIVAR x LOCALITY	69	153.079	2.219	1.338	0.146	ns
Error	47	77.922	1.6579	<-		
Total	143	496.089				

P=0.05

ns=not significant

TABLE 4.12

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN MEAN BREAK 2 BRAN VALUE MEANS

Rank	Cultivar	Mean	n	Groups not significantly different
1	NS 5511	30.370	6	ab
2	APN 881	29.746	6	ab
3	SNK 3860	29.168	6	abc
4	SNK 3620	28.789	6	bcd
5	SNK 3443	28.706	6	bcde
6	PAN 8262	28.431	6	bcdef
7	PAN 8061	28.278	6	bcdefg
8	SNK 3663	28.134	6	cdefg
9	PAN 8446	28.131	6	cdefg
10	PAN 8272	27.638	6	defgh
11	PAN 8171	27.620	6	defgh
12	ADV 5010	27.305	6	defghi
13	NK 283	27.268	6	efghi
14	NS 5655	27.101	6	fghi
15	PAN 8370	26.974	6	fghi
16	PAN 8660	26.887	6	ghi
17	SNK 3567	26.617	6	hij
18	PAN 8564	26.360	6	hijk
19	SNK 3975	26.337	6	hijk
20	SNK 3863	26.076	6	ijk
21	SNK 3337	26.076	6	ijk
22	SNK 3883	26.019	6	ijk
23	NK 286	25.377	6	jk
24	SNK 3939	24.870	6	k

4.3.1.2.4 BREAK 2 MEAL

The B2M values of different sorghum cultivars at 3 localities and 2 growing seasons are shown in Table 4.13. Table 4.14, indicates that no significant differences in cultivar value means exist. As no significant differences between cultivars were found, no cultivar differed significantly from all other cultivars. Table 4.15 shows only 4 cultivars to be significantly different from the top ranked cultivar (PAN 8660) in B2M value means, namely SNK 3860, NS 5511, PAN 8262 and SNK 3620. The B2M value could be considered as a positive milling trait, as it was indicated to consist mainly of hard endosperm in maize (Pretorius & Du Plessis, 1999). SNK 3860, NS 5511, PAN 8262 and SNK 3620, could therefore be expected to contain lower levels of hard endosperm, resulting in softer grain, since the hardness of sorghum is influenced by the endosperm texture (Kirleis & Crosby, 1982). SNK 3860, NS 5511, PAN 8262 and SNK 3620 were also ranked low for AHI, indicating softness of these cultivars.

The B2M values did not differ significantly over different seasons (Table 4.14; Fig. 4.16). The B2M value means at different localities of growth differed significantly (Table 4.14). The highest B2M values were found at Green, indicating that grain from this locality might be harder, with subsequent better milling performances (Fig. 4.10). The lowest ranked cultivar for B2M values, namely Plat, did not differ from Dover in B2M value means, while B2M values from Dover also corresponded with that of Potch ($p>0.05$).

TABLE 4.13

THE BREAK 2 MEAL VALUES OF DIFFERENT SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 SEASONS

CULTIVAR	B2M (g) DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99
ADV 5010	179.14	180.49	180.11	211.12	215.75	170.76	191.67	187.46	20.86	21.07
APN 881	183.51	198.92	212.99	224.99	222.44	185.77	206.31	203.23	20.30	19.96
NK 283	184.54	178.02	201.19	204.37	213.87	161.37	199.87	181.25	14.71	21.68
NK 286	182.20	181.69	208.21	222.69	207.38	188.53	199.26	197.63	14.78	21.96
NS 5511	173.76	157.99	183.40	192.07	201.31	138.56	186.16	162.87	13.99	27.09
NS 5655	182.59	187.84	198.57	223.49	223.31	188.61	201.49	199.98	20.52	20.36
PAN 8061	189.26	171.06	197.96	215.60	206.59	185.82	197.93	190.82	8.66	22.69
PAN 8171	177.38	171.00	184.55	215.03	217.13	175.26	193.02	187.09	21.18	24.28
PAN 8262	166.05	157.29	177.58	194.88	195.04	158.08	179.56	170.08	14.60	21.48
PAN 8272	187.61	170.84	196.65	222.94	218.24	170.22	200.84	188.00	15.73	30.26
PAN 8370	186.83	179.49	197.09	206.60	215.06	178.85	199.66	188.31	14.29	15.84
PAN 8446	181.44	162.55	195.38	205.13	219.66	184.26	198.83	183.98	19.34	21.29
PAN 8564	199.79	192.02	204.83	224.63	215.87	186.53	206.83	201.06	8.22	20.60
PAN 8660	210.57	185.34	211.90	222.77	221.40	183.27	214.62	197.13	5.91	22.23
SNK 3337	184.76	187.84	196.05	226.00	197.96	194.31	192.92	202.72	7.13	20.42
SNK 3443	208.93	181.82	196.19	210.59	210.65	188.22	205.26	193.54	7.90	15.10
SNK 3567	183.06	177.31	190.73	212.34	206.39	182.89	193.39	190.85	11.89	18.82
SNK 3620	160.80	162.09	194.02	210.34	188.20	162.92	181.01	178.45	17.74	27.62
SNK 3663	178.51	167.54	214.36	219.86	205.98	179.72	199.62	189.04	18.76	27.38
SNK 3860	158.35	169.33	170.02	194.61	189.09	142.36	172.49	168.77	15.52	26.13
SNK 3863	181.11	169.42	193.88	226.55	204.17	187.62	193.05	194.53	11.55	29.19
SNK 3883	187.57	181.55	199.58	214.95	207.11	172.42	198.09	189.64	9.85	22.39
SNK 3939	192.83	179.42	204.88	208.18	205.65	184.33	201.12	190.64	7.19	15.38
SNK 3975	179.36	169.23	199.29	214.98	214.45	182.21	197.70	188.81	17.60	23.58
MEAN	183.33	175.84	196.23	213.53	209.28	176.37	196.28	188.58		
MAX	210.57	198.92	214.36	226.55	223.31	194.31	214.62	203.23		
MIN	158.35	157.29	170.02	192.07	188.20	138.56	172.49	162.87		
RANGE	52.22	41.63	44.34	34.48	35.11	55.76	42.14	40.35		
SD	12.28	10.68	11.11	10.24	9.90	14.52	9.33	10.44		

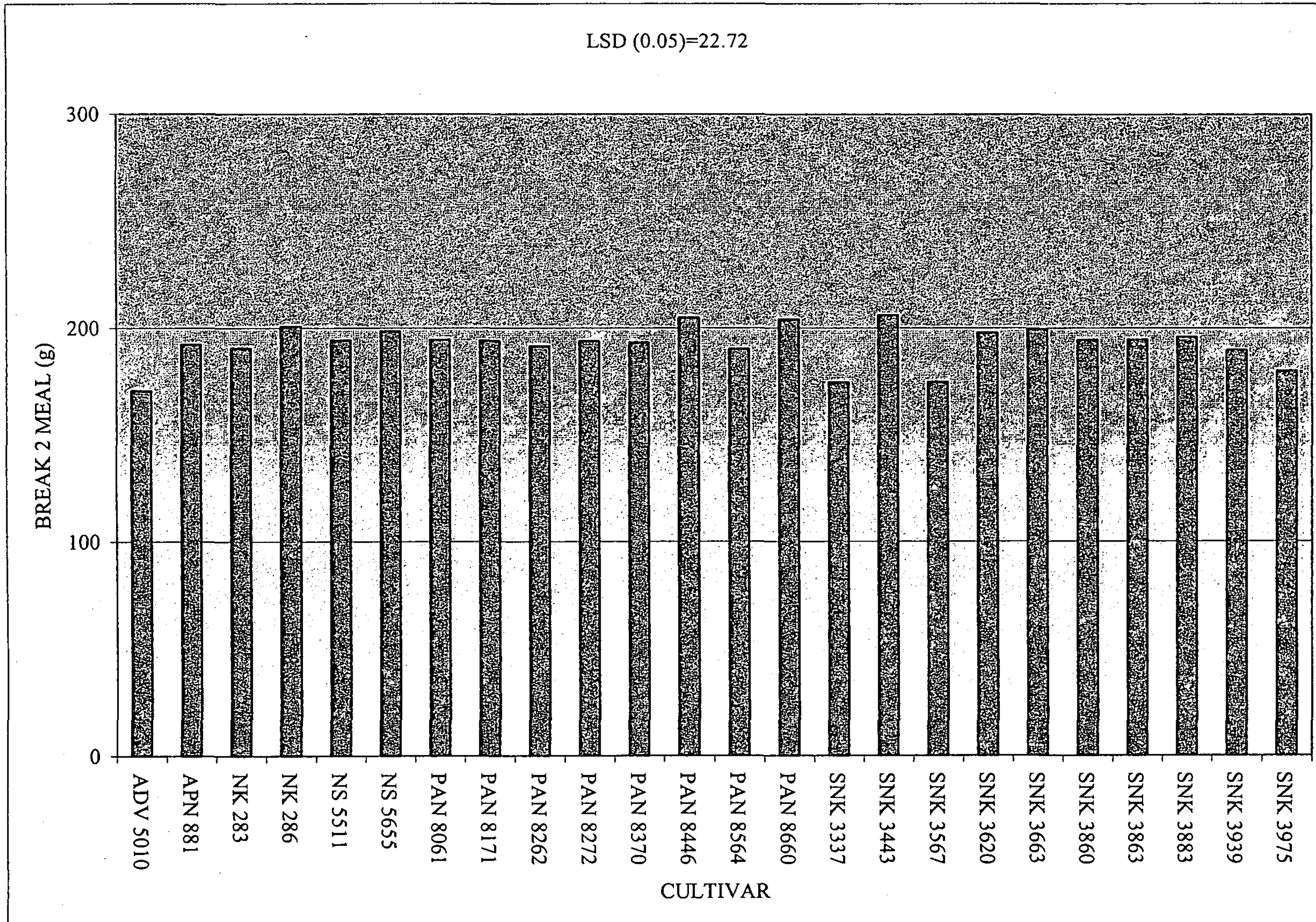


FIG. 4.14

THE INSIGNIFICANT DIFFERENCES BETWEEN THE BREAK 2 MEAL VALUES OF DIFFERENT SORGHUM CULTIVARS

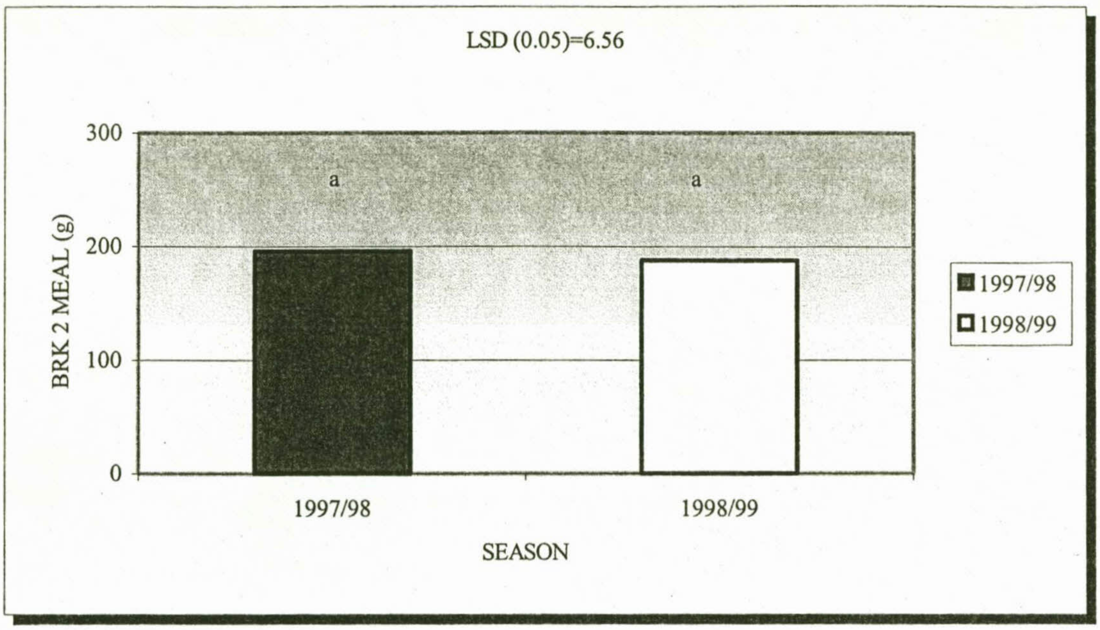


FIG. 4.15

THE DIFFERENCES IN THE BREAK 2 MEAL VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

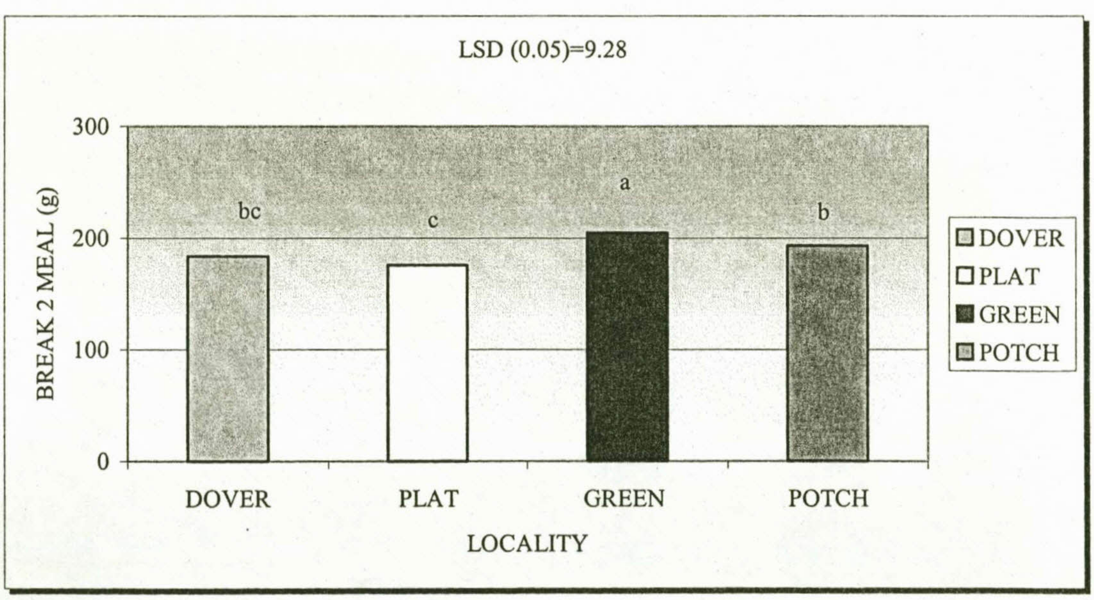


FIG. 4.16

THE DIFFERENCES IN THE BREAK 2 MEAL VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 4.14

ANALYSIS OF VARIANCE OF THE BREAK 2 MEAL VALUES OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	1461.1718	1461.1718	3.8186	0.0567	ns
Main Effects						
CULTIVAR	23	10601.2520	460.9240	1.2046	0.2878	ns
LOCALITY	3	15365.0454	5121.6818	13.3849	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	3801.7496	55.0978	0.1440	1.0000	ns
Error	47	17984.4271	382.6474	<-		
Total	143	51075.9470				

P=0.05

ns=not significant

TABLE 4.15

RANKING OF SORGHUM CULTIVARS ACCORDING TO INSIGNIFICANT DIFFERENCES IN MEAN BREAK 2 MEAL VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	PAN 8660	205.876	6	a
2	APN 881	204.769	6	a
3	PAN 8564	203.945	6	a
4	NS 5655	200.734	6	ab
5	SNK 3443	199.401	6	ab
6	NK 286	198.448	6	ab
7	SNK 3337	197.82	6	ab
8	SNK 3939	195.881	6	abc
9	PAN 8272	194.417	6	abc
10	PAN 8061	194.379	6	abc
11	SNK 3663	194.328	6	abc
12	PAN 8370	193.987	6	abc
13	SNK 3883	193.864	6	abc
14	SNK 3863	193.792	6	abc
15	SNK 3975	193.254	6	abcd
16	SNK 3567	192.118	6	abcd
17	PAN 8446	191.402	6	abcd
18	NK283	190.562	6	abcd
19	PAN 8171	190.056	6	abcd
20	ADV 5010	189.562	6	abcd
21	SNK 3620	179.728	6	bcd
22	PAN 8262	174.82	6	cd
23	NS 5511	174.514	6	cd
24	SNK 3860	170.628	6	d

4.3.1.2.5 BREAK 2 GRITS

Table 4.16 indicates the B2G values of different sorghum cultivars over 2 seasons at 3 localities per season. Significant differences in the mean B2G values of different cultivars were found (Table 4.17; Fig. 4.17). The B2G value was found to be an indication of the hard endosperm of maize (Pretorius & Du Plessis, 1999) and can therefore also be expected to give an indication of the hardness of sorghum. The fact that the grits at break w rolls are fed back to break 2, might have led to grits not indicating hardness in the way Pretorius & Du Plessis (1999) found in the case of maize. Cultivars with higher values could accordingly be seen as harder, while lower values will indicate softer cultivars. In Table 4.17 it is seen that NS 5511, SNK 3443, SNK 3620 and SNK 3860 all corresponded ($p>0.05$) with the highest ranked cultivar, namely APN 881, B2G value means. NS 5511, SNK 3620 and SNK 3860 had low B2M values and APN 881 high B2M values, indicating that the higher B2M the lower B2G. PAN 8370 and SNK 3863 corresponded with the lowest ranked cultivar (PAN 8262) in B2G value means (Fig. 4.17).

Significant differences in the B2G values over different seasons and different localities of growth were also found (Table 4.16). The 1997/98 season was the season with the highest B2G values (Fig. 4.18), but the level of significance was less than for cultivars and localities (Table 4.17). Grain from the Green locality showed higher B2G values than the other localities, while those from Plat were significantly lower (Fig. 4.19). No differences ($p>0.05$) between the B2G values of grain from Dover and Potch were seen (Fig. 4.19).

TABLE 4.16
THE BREAK 2 GRITS VALUES OF DIFFERENT SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 SEASONS

CULTIVAR	B2G (g)						MEAN		SD	
	DOVER	PLAT	GREEN		POTCH					
	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99	1997/98	1998/99
ADV 5010	27.85	26.19	28.64	31.77	29.95	28.38	28.81	28.78	1.06	2.81
APN 881	30.61	28.01	31.50	34.03	29.00	31.69	30.37	31.24	1.27	3.03
NK 283	26.78	25.84	29.06	29.87	28.22	25.84	28.02	27.18	1.15	2.32
NK 286	29.28	23.73	30.06	29.13	27.49	26.72	28.94	26.53	1.32	2.70
NS 5511	28.85	28.39	29.30	28.43	30.40	29.89	29.52	28.90	0.80	0.85
NS 5655	26.45	25.44	26.92	31.45	26.50	28.30	26.62	28.40	0.26	3.01
PAN 8061	26.04	23.03	29.35	30.49	26.40	28.03	27.26	27.18	1.82	3.80
PAN 8171	27.46	24.42	26.02	32.11	27.12	27.01	26.87	27.85	0.76	3.91
PAN 8262	25.12	20.69	24.83	28.29	25.94	22.69	25.30	23.89	0.58	3.94
PAN 8272	25.42	24.19	27.03	31.07	28.37	27.28	26.94	27.51	1.48	3.44
PAN 8370	25.56	23.28	26.22	29.54	27.93	24.97	26.57	25.93	1.22	3.24
PAN 8446	26.97	23.75	30.35	29.79	28.67	28.17	28.66	27.24	1.69	3.13
PAN 8564	28.62	23.89	31.46	31.75	28.34	29.08	29.48	28.24	1.73	4.00
PAN 8660	29.78	23.91	30.35	29.61	28.39	28.81	29.51	27.44	1.01	3.09
SNK 3337	27.98	26.10	28.95	31.44	28.34	28.85	28.42	28.80	0.49	2.67
SNK 3443	30.15	27.73	28.20	30.72	28.27	30.53	28.87	29.66	1.10	1.67
SNK 3567	28.66	25.77	26.85	26.79	28.00	28.11	27.84	26.89	0.91	1.18
SNK 3620	29.65	30.20	31.12	31.68	29.91	29.74	30.23	30.54	0.79	1.01
SNK 3663	27.81	24.33	30.05	28.87	28.00	28.70	28.62	27.30	1.24	2.57
SNK 3860	29.24	31.13	31.40	33.95	29.60	28.41	30.08	31.16	1.16	2.77
SNK 3863	23.90	22.81	24.74	29.41	25.94	26.31	24.86	26.17	1.03	3.30
SNK 3883	29.93	22.90	25.40	29.89	25.12	26.20	26.81	26.33	2.70	3.49
SNK 3939	26.53	21.84	27.67	29.69	26.79	28.13	27.00	26.55	0.60	4.16
SNK 3975	26.54	23.18	30.43	29.34	28.16	25.28	28.38	25.93	1.95	3.13
MEAN	27.72	25.03	28.58	30.38	27.95	27.80	28.08	27.74		
MAX	30.61	31.13	31.50	34.03	30.40	31.69	30.37	31.24		
MIN	23.90	20.69	24.74	26.79	25.12	22.69	24.86	23.89		
RANGE	6.71	10.44	6.76	7.23	5.28	9.00	5.51	7.35		
SD	1.81	2.57	2.16	1.71	1.35	1.95	1.50	1.75		

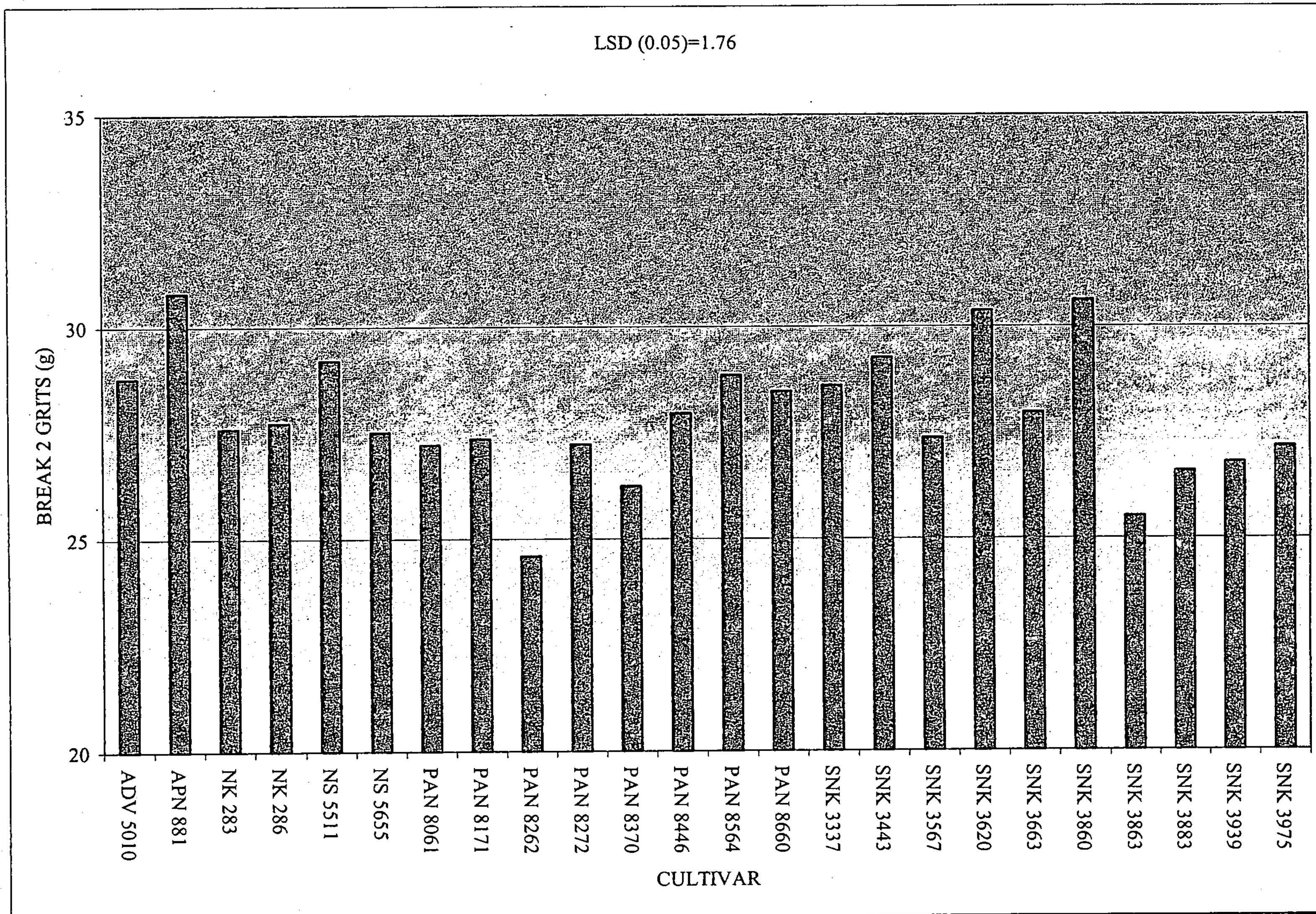


FIG. 4.17

THE SIGNIFICANT DIFFERENCES BETWEEN BREAK 2 GRITS VALUES OF DIFFERENT SORGHUM CULTIVARS

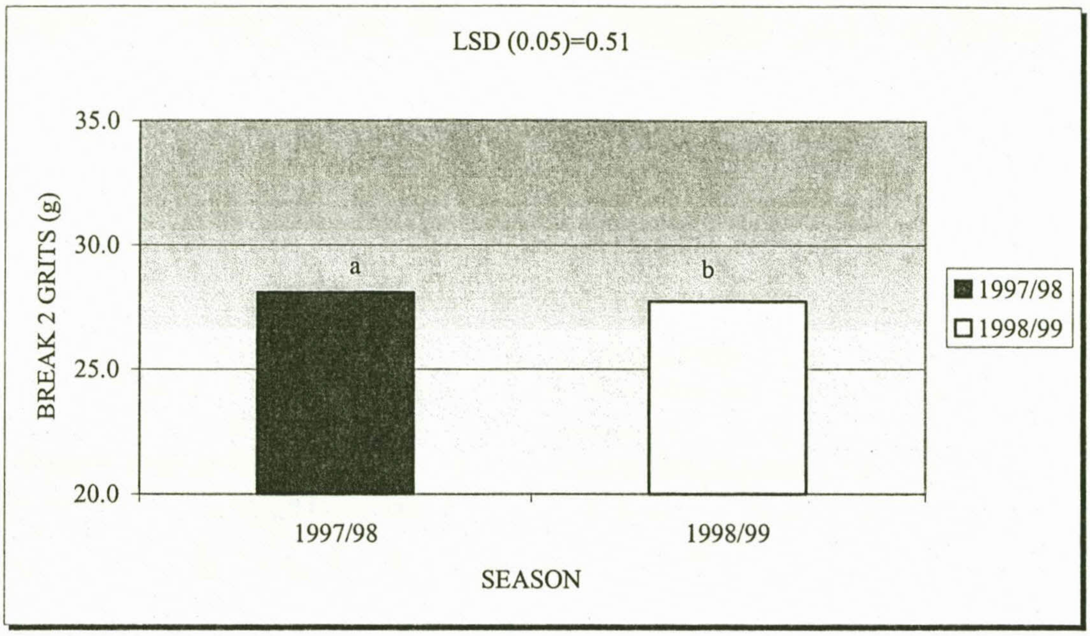


FIG. 4.18

THE DIFFERENCES IN THE BREAK 2 GRITS VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

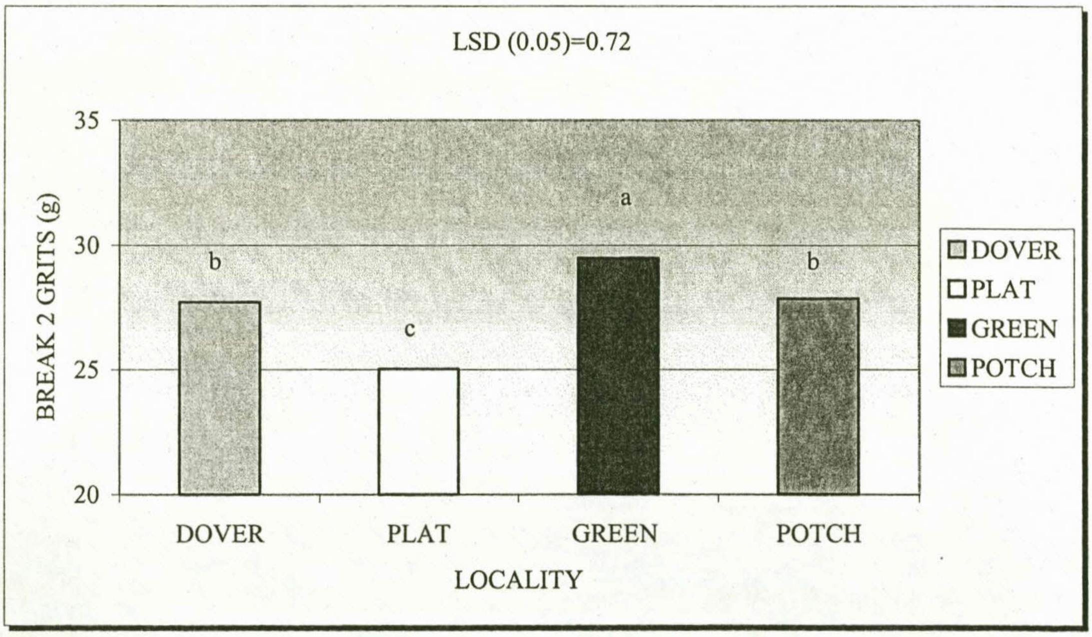


FIG. 4.19

THE DIFFERENCES IN THE BREAK 2 GRITS VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 4.17

ANALYSIS OF VARIANCE OF THE BREAK 2 GRITS VALUES OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	16.2234	16.2234	7.0773	0.0106	*
Main Effects						
CULTIVAR	23	314.1535	13.6588	5.9586	0.0000	***
LOCALITY	3	329.9493	109.9831	47.9792	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	128.4365	1.8614	0.8120	0.7871	ns
Error	47	107.7384	2.2923	<-		
Total	43	887.5950				

P=0.05

ns=not significant

TABLE 4.18

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN BREAK 2 GRITS VALUE MEANS

Rank	Cultivar	Mean	n	Groups not significantly different
1	APN 881	30.807	6	a
2	SNK 3860	30.622	6	a
3	SNK 3620	30.384	6	abc
4	SNK 3443	29.267	6	abc
5	NS 5511	29.209	6	abc
6	PAN 8564	28.858	6	bcd
7	ADV 5010	28.796	6	bcd
8	SNK 3337	28.610	6	cd
9	PAN 8660	28.475	6	cde
10	SNK 3663	27.959	6	cdef
11	PAN 8446	27.951	6	cdef
12	NK 286	27.736	6	cdef
13	NK 283	27.603	6	cdef
14	NS 5655	27.511	6	cdef
15	SNK 3567	27.365	6	def
16	PAN 8171	27.359	6	def
17	PAN 8272	27.228	6	defg
18	PAN 8061	27.223	6	defg
19	SNK 3975	27.155	6	defg
20	SNK 3939	26.775	6	efg
21	SNK 3883	26.572	6	fg
22	PAN 8370	26.249	6	fgh
23	SNK 3863	25.516	6	fgh
24	PAN 8262	24.593	6	h

4.3.1.2.6 EXTRACTION

Table 4.19 shows the extraction value means of 24 cultivars over 2 seasons at 3 localities per season. Significant differences in cultivar value means were also found (Table 4.20; Fig. 4.20) and the ranking of cultivars according to cultivar value means, are shown in Table 4.21. Eleven cultivars, namely SNK 3939, SNK 3863, SNK 3337, NK 286, SNK 3883, NS 5655, SNK 3620, PAN 8564, NK 283, SNK 3567 and PAN 8262, corresponded (p>0.05) with the highest ranked cultivar (SNK 3975) for extraction value means. Cultivars corresponding (p>0.05) with the cultivar with the lowest extraction value mean (PAN 8446), but not with the highest ranked cultivar, were ADV 5010, PAN 8272, SNK 3860, PAN 8370, PAN 8171, APN 881, SNK 3663, NS 5511, PAN 8660, SNK 3443 and PAN 8061. The birdproof cultivars, SNK 3860 and NS 5511, are in this group due to the lower endosperm and higher pericarp levels present in birdproof cultivars (Jambunathan & Mertz, 1973) and due to softness (high B1M and low B2M). The extraction refers to products from the mills with economic advantages, i.e. the meal B1M and B2M) as percentage of total products, which emphasises the importance of proficient extraction values from the mills. Although the differences between extraction value means were significant, (Table 4.20) a relative small range of 79.51 to 81.80 % (Table 4.21). The meal yield indicated by Hahn (1969) for roller milling sorghum samples, varied between 70 and 90 %, but the meal was very "specky" in appearance, which was not the case in the present study. Meal in the current study was uniform and mostly light in colour. Therefore this indicates that the method developed for roller milling in the present study with the added conditioning procedure, could also be very successful in obtaining high meal yields, but with a better appearance than the "specky" appearance of the meal found by Hahn (1969). Despite the differences in extraction values, the overall extraction levels from the mills did not vary very much, indicating the dependability of the developed method in terms of good extraction values. SNK 3620 and PAN 8262 were determined to be soft (4.3.1.2.5), indicating that hardness does not necessarily influence extraction values with roller milling, which is contrary to the conclusion of Deshpande *et al.* (1982a), namely that hardness influences milling yield.

Significant differences in extraction values were also found at different localities and over different seasons (Table 4.20). The level of significance was higher in the case of season than with cultivars and localities. The 1997/98 season showed the highest extraction values (Fig. 4.21). No single locality differed significantly from all other localities in extraction value means (Fig. 4.22). Values from Plat and Green corresponded (p>0.05) with those of the highest ranked locality (Potch), whilst values from Green did not differ (p>0.05) from those of the lowest ranked locality, namely Dover. In 4.3.1.2.5 Green was found to have harder grain and Plat softer grain, which again indicates that hardness does not necessarily predict good extraction values with roller milling and other factors might possibly also play a role.

TABLE 4.19
THE % EXTRACTION FOR SORGHUM CULTIVARS OVER 2 PERIODS AT 3 LOCALITIES PER SEASON MILLED ON ROLLER MILLS

CULTIVAR	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99
ADV 5010	79.70	80.29	79.28	80.39	82.26	79.27	80.42	79.98	1.62	0.62
APN 881	78.62	81.22	79.79	79.02	81.90	78.30	80.10	79.51	1.66	1.52
NK 283	80.98	81.07	81.11	80.53	81.54	78.68	81.21	80.09	0.29	1.25
NK 286	80.23	81.72	81.84	81.16	82.51	81.31	81.53	81.40	1.17	0.29
NS 5511	80.47	79.89	79.88	81.22	81.12	75.53	80.49	78.88	0.62	2.98
NS 5655	80.27	81.36	80.63	80.81	82.15	80.31	81.02	80.82	1.00	0.53
PAN 8061	81.01	77.99	77.76	80.06	80.94	79.76	79.90	79.27	1.86	1.12
PAN 8171	79.50	80.38	79.39	79.69	81.65	79.39	80.18	79.82	1.27	0.51
PAN 8262	80.15	82.27	78.51	79.94	81.79	79.78	80.15	80.66	1.64	1.39
PAN 8272	79.98	80.64	79.82	79.67	82.06	78.73	80.62	79.68	1.25	0.95
PAN 8370	79.90	80.65	79.42	79.82	81.22	79.47	80.56	80.01	0.93	0.60
PAN 8446	78.76	79.03	78.52	79.34	82.27	79.16	79.85	79.18	2.10	0.16
PAN 8564	80.99	81.40	79.44	80.91	81.90	80.20	80.78	80.84	1.24	0.61
PAN 8660	78.21	79.65	79.65	80.14	81.81	78.52	79.89	79.44	1.81	0.83
SNK 3337	80.51	81.89	80.68	81.42	82.76	81.66	81.32	81.66	1.25	0.23
SNK 3443	78.70	79.54	79.47	80.30	81.54	78.37	79.90	79.40	1.47	0.98
SNK 3567	79.94	80.94	79.10	81.01	81.93	79.87	80.33	80.60	1.45	0.64
SNK 3620	79.10	80.01	82.26	82.03	81.77	80.06	81.04	80.70	1.70	1.15
SNK 3663	77.40	78.69	81.08	81.27	81.74	78.61	80.07	79.52	2.34	1.51
SNK 3860	79.30	80.44	80.40	80.18	81.76	78.44	80.48	79.69	1.23	1.09
SNK 3863	81.67	81.76	81.87	81.66	82.63	80.79	82.06	81.40	0.50	0.53
SNK 3883	79.92	81.87	81.45	82.00	82.97	80.11	81.45	81.33	1.52	1.06
SNK 3939	82.84	83.05	81.74	81.11	81.19	80.52	81.92	81.56	0.84	1.32
SNK 3975	81.02	81.86	81.47	81.45	83.05	81.98	81.85	81.76	1.07	0.28
MEAN	79.965	80.733	80.191	80.631	81.936	79.535	80.713	80.301		
MIN	77.396	77.989	77.761	79.022	80.945	75.532	79.848	78.882		
MAX	82.837	83.045	82.262	82.030	83.054	81.984	82.058	81.764		
RANGE	5.441	5.056	4.501	3.007	2.109	6.452	2.209	2.882		
SD	1.184	1.211	1.218	0.829	0.565	1.347	0.694	0.892		

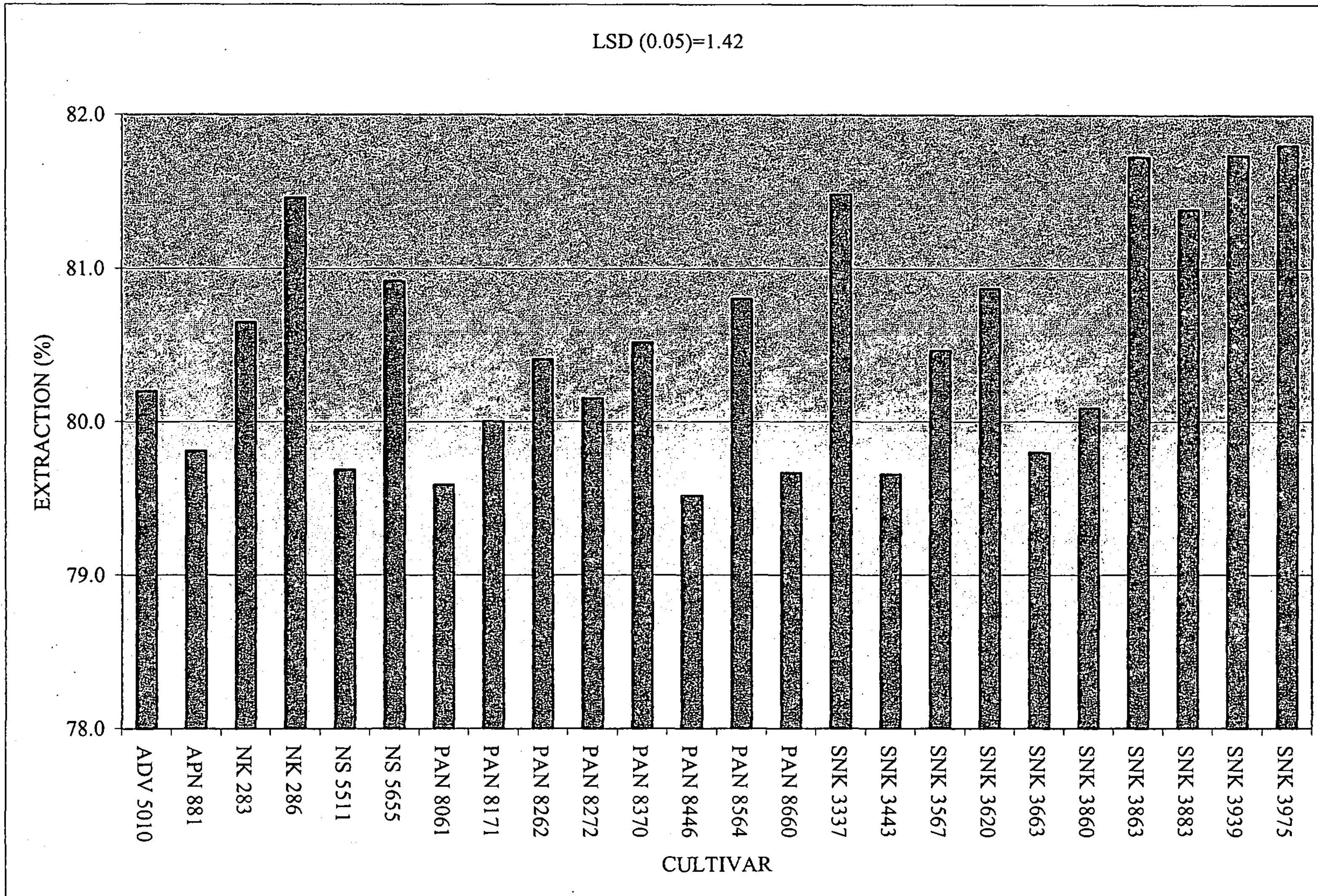


FIG. 4.20

THE SIGNIFICANT DIFFERENCES BETWEEN THE EXTRACTION VALUES OF DIFFERENT SORGHUM CULTIVARS

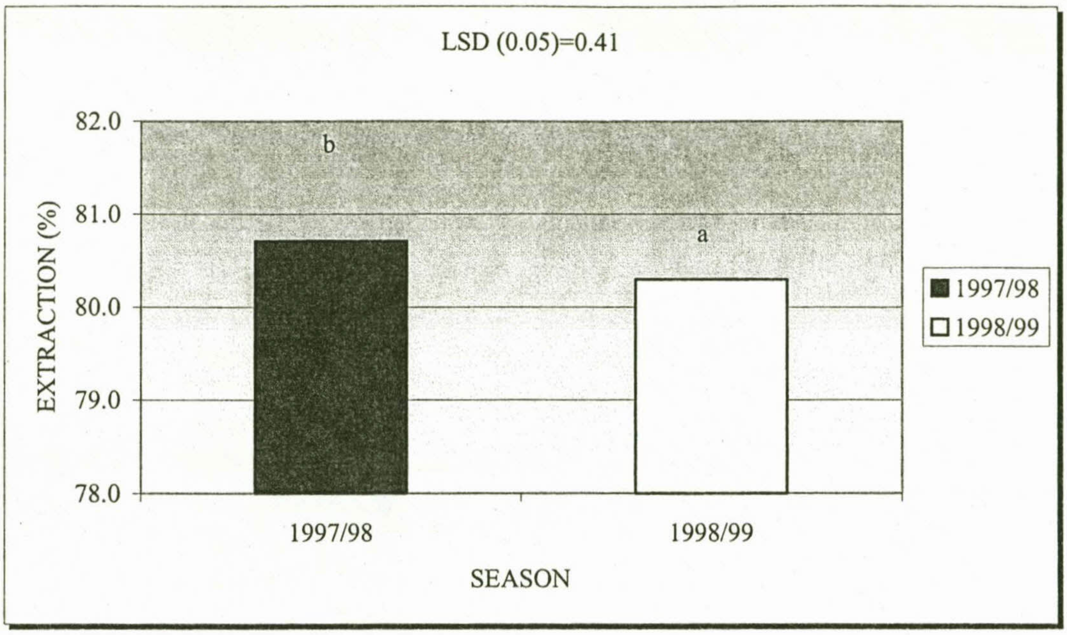


FIG. 4.21

THE DIFFERENCES IN THE EXTRACTION VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

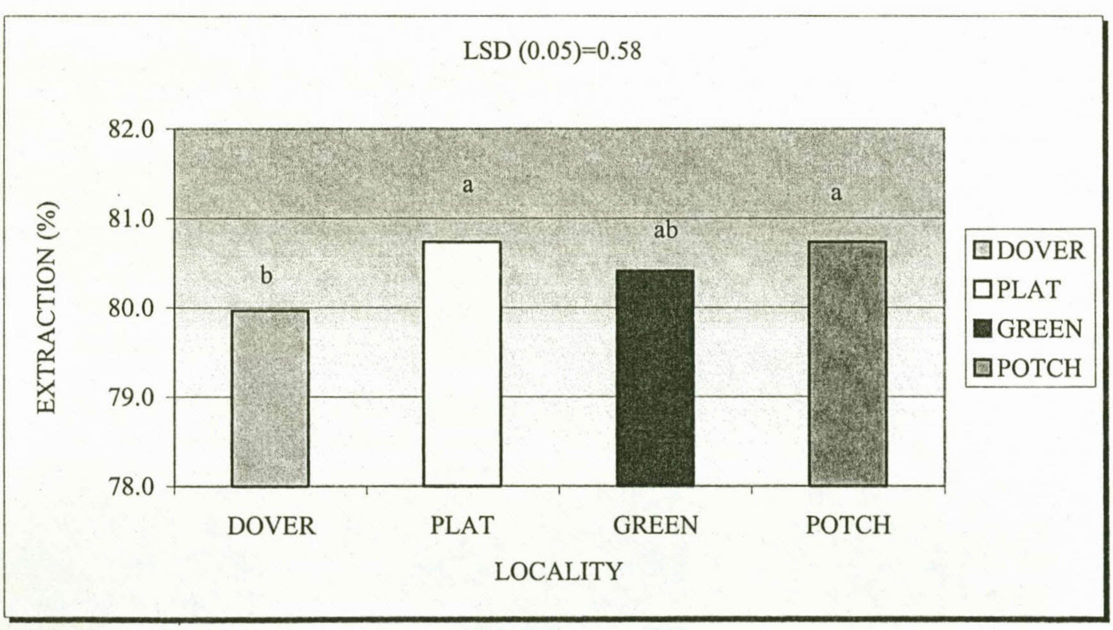


FIG. 4.22

THE DIFFERENCES IN THE EXTRACTION VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITES

TABLE 4.20

ANALYSIS OF VARIANCE OF THE EXTRACTION VALUES OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	23.0926	23.0926	15.3627	0.0003	***
Main Effects						
CULTIVAR	23	80.3878	3.4951	2.3252	0.0071	**
LOCALITY	3	28.6081	9.5360	6.3440	0.0011	**
Interaction						
CULTIVAR x LOCALITY	69	61.3999	0.8899	0.5920	0.9767	ns
Error	47	70.6484	1.5032	<-		
Total	143	247.6590				

P=0.05

ns=not significant

TABLE 4.21

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN EXTRACTION VALUE MEANS

Rank	Cultivar	Mean	n	Groups not significantly different
1	SNK 3975	81.805	6	a
2	SNK 3939	81.742	6	a
3	SNK 3863	81.730	6	a
4	SNK 3337	81.488	6	ab
5	NK 286	81.461	6	ab
6	SNK 3883	81.387	6	abc
7	NS 5655	80.920	6	abcd
8	SNK 3620	80.871	6	abcd
9	PAN 8564	80.808	6	abcd
10	NK 283	80.651	6	abcd
11	SNK 3567	80.466	6	abcd
12	PAN 8262	80.407	6	abcd
13	ADV 5010	80.199	6	bcd
14	PAN 8272	80.150	6	bcd
15	SNK 3860	80.086	6	bcd
16	PAN 8370	80.081	6	bcd
17	PAN 8171	80.000	6	cd
18	APN 881	79.809	6	d
19	SNK 3663	79.797	6	d
20	NS 5511	79.687	6	d
21	PAN 8660	79.664	6	d
22	SNK 3443	79.654	6	d
23	PAN 8061	79.588	6	d
24	PAN 8446	79.514	6	d

4.3.1.2.7 TOTAL LOSS

Table 4.22 shows the TL values of 24 cultivars over 2 seasons at 3 localities per season. Differences in cultivars were significant (Table 4.23) as illustrated by Fig. 4.23. NK 283, SNK 3883, SNK 3860, PAN 8370 and NS 5511 all corresponded (p>0.05) with the highest ranked cultivar (PAN 8262) for TL value means (Table 4.24). These are the cultivars with the highest losses on the mills, as TL indicates the percentage of bran from break 1 and 2, as well as TH from the sifting process. In the present study only the high quality hard endosperm meal, i.e. S1 and S2 was considered as part of the extraction value, while the TH, that consist mainly of soft endosperm were considered as part of the TL. This was done in this study to distinguish clearly between hard and soft endosperm, as one of the objectives of the study is to compare cultivars on hardness properties and also to compare this method an abrasive decortication milling procedure. When the soft endosperm are required as part of the extraction for economic reasons, this can be done and data from this study provided in this chapter can be used to calculate the extraction value with TH included and TL with the TH excluded. As TH was mainly found to consist of soft endosperm in the case of maize (Pretorius & Du Plessis, 1999), greater levels of TH in samples indicate softness and subsequent poorer milling properties. PAN 8446, SNK 3939, SNK 3443, PAN 8564, ADV 5010 and SNK 3337 corresponded (p>0.05) with the lowest ranked cultivar, namely APN 881 in TL value means (Table 4.24). Total loss values of these cultivars will be very low, resulting in limited economic losses in the milling process and a better overall milling performance.

Significant differences in TL value means of sorghum from different localities and over different seasons were found, but differences for seasons were less significant than for cultivars and localities (Table 4.23). The 1998/99 season presented higher TL value means than the 1997/98 season (Fig. 4.24). Green and Potch showed the highest TL value means, followed by Plat and the lowest values were observed at Dover (Fig. 4.25). The cultivar x locality interaction was also significant (Table 4.23), as illustrated by Fig. 4.26 where the cultivars x locality interactions for some cultivars are shown. The interaction is difficult to explain and for the purpose of this study it can only be said that certain cultivars displayed higher TL values at certain localities, while the same cultivar will have lower TL values at another locality. PAN 8370 for example, had low levels of TL's at Dover, while the same cultivar displayed high TL values at Potch (Fig. 4.26).

TABLE 4.22
TOTAL LOSS VALUES OF SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 PERIODS MILLED ON ROLLER MILLS

CULTIVAR	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99
ADV 5010	36.33	51.41	61.88	60.86	56.16	61.94	51.45	58.07	13.41	5.79
APN 881	37.80	41.28	65.02	60.11	59.28	59.28	54.04	53.56	14.35	10.64
NK 283	45.20	66.24	62.88	65.00	61.25	62.48	56.44	64.57	9.77	1.92
NK 286	46.14	53.53	60.98	63.49	61.40	58.78	56.17	58.60	8.69	4.98
NS 5511	48.02	53.90	63.82	63.51	60.73	64.24	57.52	60.55	8.37	5.77
NS 5655	44.09	49.80	61.54	67.45	59.67	62.73	55.10	59.99	9.58	9.14
PAN 8061	40.80	53.62	63.72	64.94	61.40	62.88	55.31	60.48	12.62	6.03
PAN 8171	36.83	52.39	62.14	64.00	62.53	64.69	53.83	60.36	14.73	6.91
PAN 8262	51.03	56.33	66.61	64.78	61.12	69.10	59.59	63.40	7.90	6.49
PAN 8272	39.55	53.55	60.03	65.57	57.66	66.09	52.41	61.74	11.20	7.10
PAN 8370	37.82	53.94	65.73	65.49	65.94	67.53	55.19	60.13	12.53	7.33
PAN 8446	42.63	48.31	64.55	60.29	58.17	64.87	55.11	57.82	11.27	8.55
PAN 8564	44.62	48.58	60.83	60.41	58.63	62.22	54.70	57.07	8.79	7.41
PAN 8660	38.62	57.61	63.68	64.07	60.10	63.09	54.13	61.59	13.56	3.48
SNK 3337	43.67	48.82	60.12	59.84	55.38	58.16	53.06	55.61	8.47	5.93
SNK 3443	43.15	51.03	51.75	63.77	62.61	63.77	52.51	59.52	9.75	7.36
SNK 3567	49.66	48.28	58.72	63.11	59.49	61.99	55.96	57.79	5.47	8.26
SNK 3620	40.18	61.80	58.71	60.21	62.32	62.88	53.73	61.63	11.88	1.35
SNK 3663	46.09	51.27	66.98	62.04	61.85	62.83	58.31	58.72	10.89	6.46
SNK 3860	45.34	64.06	62.60	62.21	61.15	61.35	56.36	62.54	9.57	1.39
SNK 3863	38.19	55.90	62.93	62.35	59.31	62.44	53.48	60.23	13.36	3.75
SNK 3883	42.22	67.03	62.23	61.95	62.58	64.24	55.67	64.41	11.65	2.54
SNK 3939	39.97	52.28	60.70	59.82	59.50	66.23	53.39	59.44	11.64	6.98
SNK 3975	35.66	53.78	65.41	61.86	62.26	63.57	54.44	59.74	16.34	5.23
MEAN	42.23	53.95	62.23	62.80	60.44	63.22	54.91	59.90		
MIN	35.66	41.28	51.75	59.82	55.38	58.16	51.45	53.56		
MAX	51.03	67.03	66.98	67.45	65.94	69.10	59.59	64.57		
RANGE	15.38	25.75	15.23	7.63	10.56	10.94	8.14	11.02		
SD	4.28	6.02	3.20	2.14	2.30	2.54	1.91	2.59		

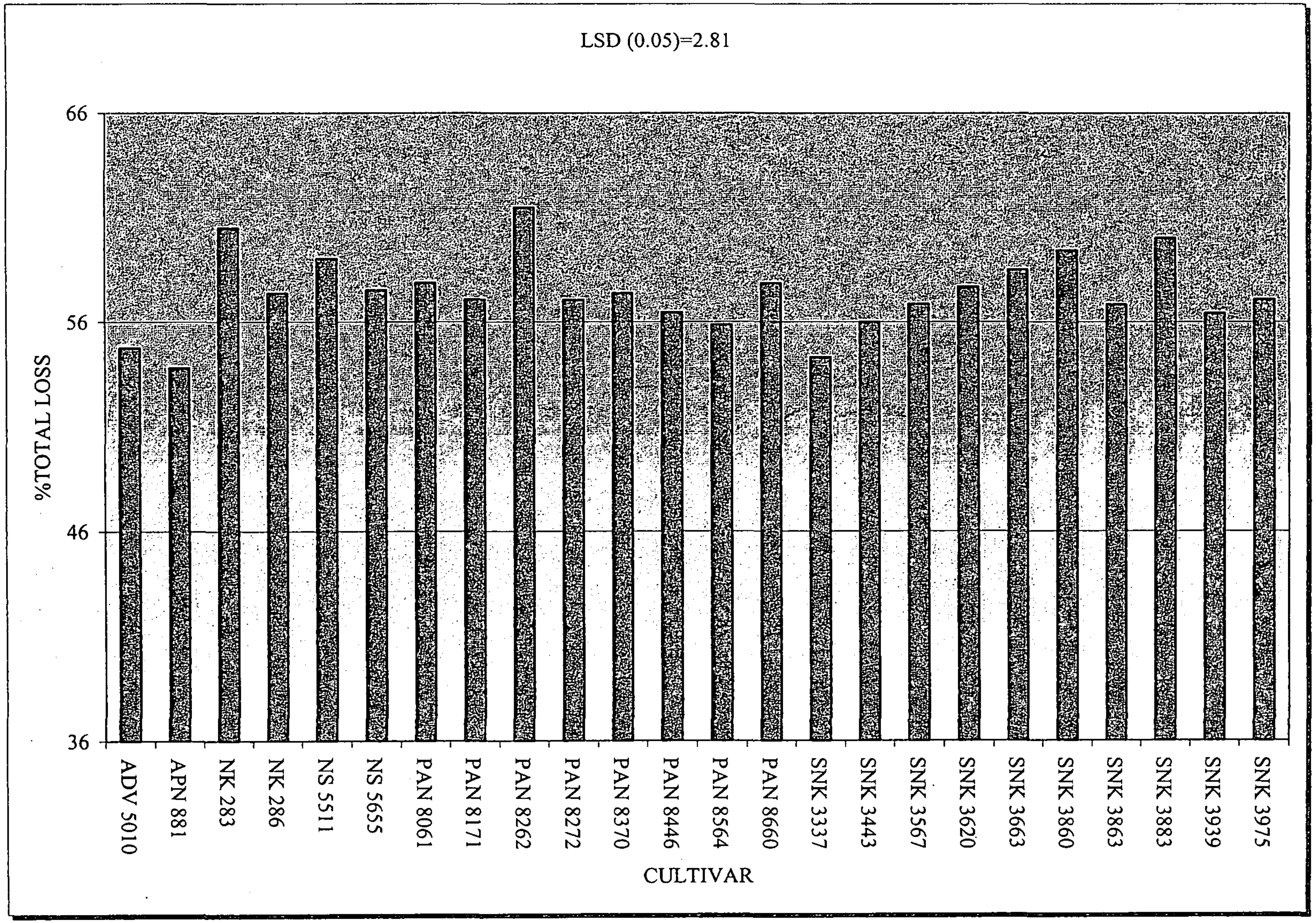


FIG. 4.23

THE SIGNIFICANT DIFFERENCES BETWEEN THE MEAN TOTAL LOSS VALUES OF DIFFERENT SORGHUM CULTIVARS

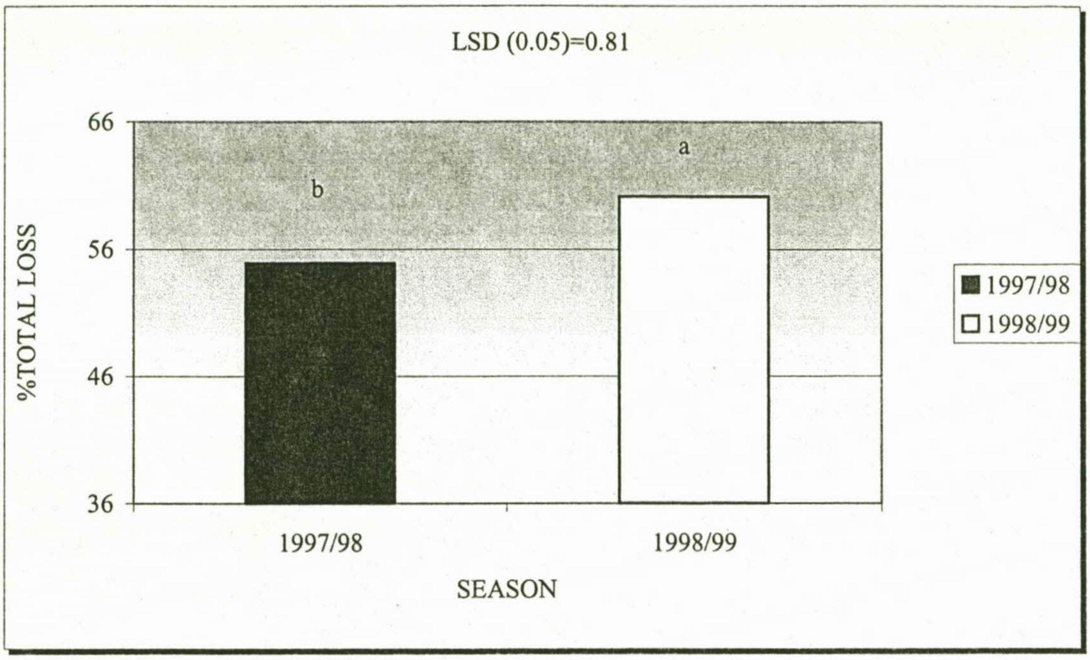


FIG. 4.24

THE DIFFERENCES IN THE TOTAL LOSS VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

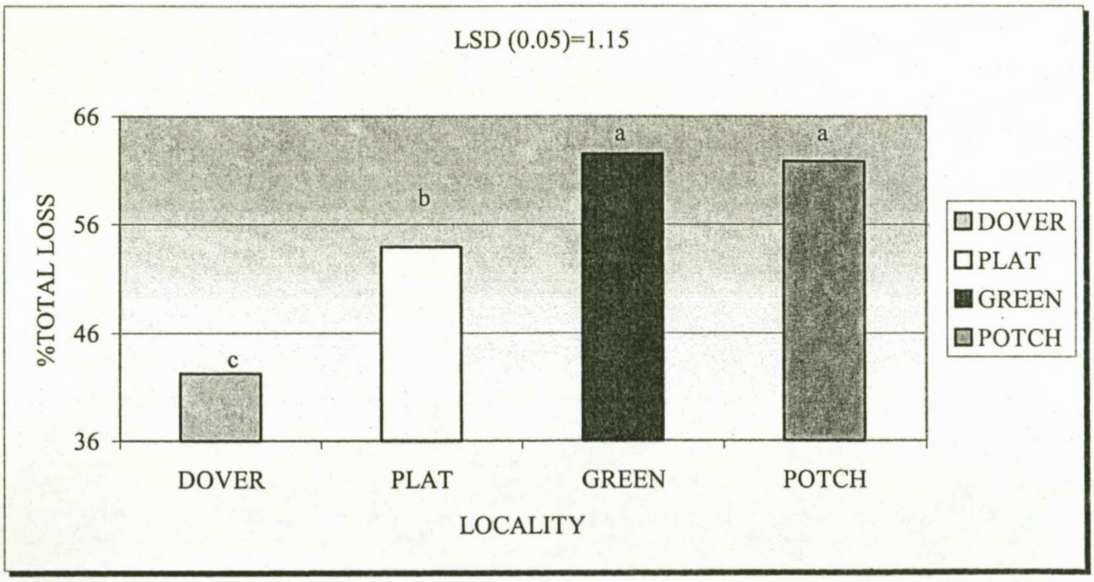


FIG. 4.25

THE DIFFERENCES IN THE TOTAL LOSS VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

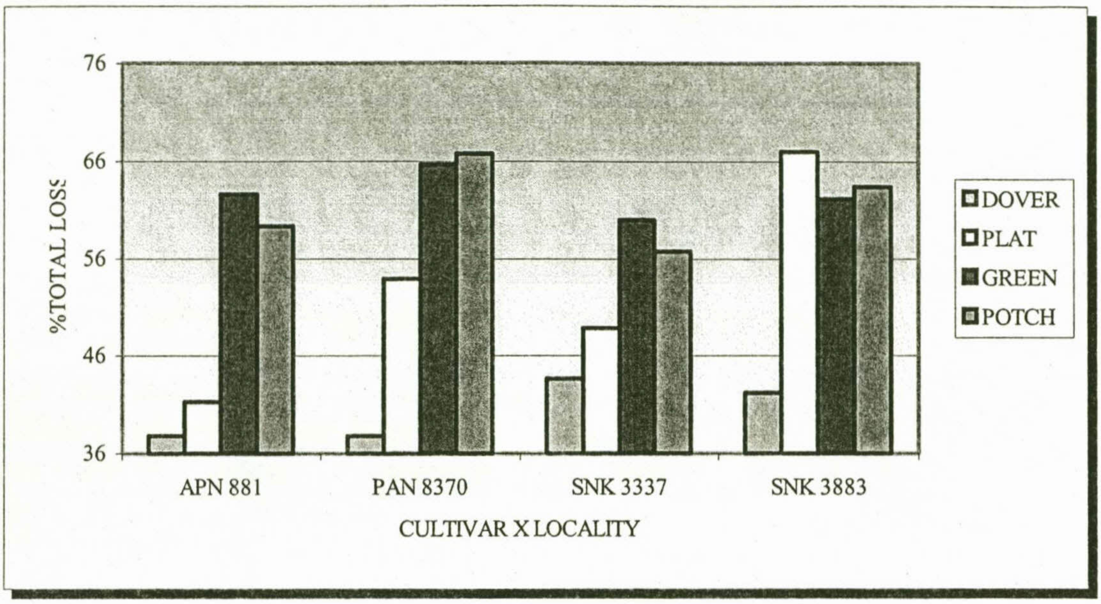


FIG. 4.26

THE SIGNIFICANT CULTIVAR X LOCALITY INTERACTION OF SOME SORGHUM CULTIVARS FOR TOTAL LOSS VALUE MEANS

TABLE 4.23

ANALYSIS OF VARIANCE OF THE TOTAL LOSS VALUES OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	**df**	**Type III**	**SS**	**MS**	**F**	**P**
Blocks (SEASON)	1	67.4725	67.4725	11.5666	0.0014	**
Main Effects						
CULTIVAR	23	633.6598	27.5504	4.7229	0.0000	***
LOCALITY	3	7162.1087	2387.3696	409.2592	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	1126.8953	16.3318	2.7997	0.0001	***
Error	47	274.1695	5.8334	<-		
Total	143	9964.8105				

P=0.05

ns=not significant

TABLE 4.24

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN TOTAL LOSS VALUE MEANS

Rank	Cultivar	Mean	n	Group not significantly different
1	PAN 8262	61.497	6	a
2	NK 283	60.509	6	ab
3	SNK 3883	60.04	6	abc
4	SNK 3860	59.454	6	abcd
5	PAN 8370	59.409	6	abcd
6	NS 5511	59.038	6	abcde
7	SNK 3663	58.513	6	bcdef
8	PAN 8061	57.895	6	bcdef
9	PAN 8660	57.862	6	bcdef
10	SNK 3620	57.682	6	cdef
11	NS 5655	57.546	6	cdefg
12	NK 286	57.386	6	cdefg
13	PAN 8171	57.095	6	defgh
14	SNK 3975	57.089	6	defgh
15	PAN 8272	57.077	6	defgh
16	SNK 3567	56.877	6	defgh
17	SNK 3863	56.854	6	defgh
18	PAN 8446	56.469	6	efghi
19	SNK 3939	56.417	6	efghi
20	SNK 3443	56.013	6	fghi
21	PAN 8564	55.883	6	fghi
22	ADV 5010	54.763	6	ghi
23	SNK 3337	54.332	6	hi
24	APN 881	53.796	6	i

4.3.1.2.8 SIEVE FRACTIONS (S1, S2 AND TH)

Table 4.25 shows the S1, S2 and TH values of 24 cultivars over 2 seasons at 3 localities per season. From the ANOVA (Table 4.26) including all three sieve fractions, it is seen that significant differences in fraction sizes exist and that the cultivar x size, locality x size and cultivar x locality x size interactions are significant. As these interactions are important but difficult to explain and this type of ANOVA does not clearly indicate a ranking of cultivars, a second ANOVA (2-way randomised blocks) was performed on each different sieve fraction. Highly significant differences in the S1, S2 and TH value means for different cultivars were found (Table 4.27, 4.29, 4.31 and Fig. 4.27). From Fig. 4.27 it is clear that each cultivar contains larger fractions of TH than S1 and S2. Pretorius & Du Plessis (1999), found the S1 and S2 values to be composed of different parts of the hard endosperm (HE) of grain, while the TH value referred to the soft endosperm (SE) in maize. Harder cultivars might therefore still contain larger TH fractions than S1 and S2, but TH values can be expected to be smaller than those of other cultivars. The highest ranked cultivar (ADV 5010) for S1 value means did not differ ($p>0.05$) from other cultivars, such as SNK 3443, APN 881, PAN 8171, SNK 3337, PAN 8446, SNK 3620, PAN 8564, SNK 3939, SNK 3863, SNK 3975, SNK 3567, PAN 8272 and PAN 8061 (Table 4.28). All these cultivars therefore, contained high levels of HE1 and were therefore harder. NK 286, NS 5511, SNK 3860, NS 5655, SNK 3663, PAN 8370, SNK 3883, NK 283 all corresponded ($p>0.05$) with the lowest ranked cultivar, namely PAN 8262 for S1 value means (Table 4.28). These cultivars were softer, as lower levels of HE1 were present. SNK 3883, NS 5511, NK 283 and SNK 3860 also corresponded ($p>0.05$) with the lowest ranked cultivar (SNK 3620) in S2 value means, thereby indicating the very low levels of both types of hard endosperm (HE1 and HE2) in these cultivars (Table 4.30). SNK 3860, NS 5511, PAN 8262 and SNK 3620 were expected to contain lower levels of HE, as these cultivars had low B2M values and B2M is mainly composed of HE (4.3.1.2.4). SNK 3337, NS 5655, SNK 3567, PAN 8272, SNK 3863, SNK 3663 and NK 286 all corresponded with the highest ranked cultivar, namely APN 881, in S2 value means (Table 4.30). This group of cultivars, excluding NK 286 and SNK 3663, also contained high levels of S1, indicating hardness due to high levels of both types of hard endosperm (HE 1 and HE2).

NK 283, SNK 3883, SNK 3860, NS 5511, PAN 8370, SNK 3620 and SNK 3663 all corresponded ($p>0.05$) with the highest ranked cultivar, namely PAN 8262, in TH value means (Table 4.32). SNK 3883, NK 283 and PAN 8262 had higher extraction values (4.3.1.2.6), indicating that endosperm texture did not influence the extraction values with regard to roller milling. Maxson *et al.* (1971) observed contrary to these results that endosperm texture correlates with milling yield with abrasive milling. High levels of SE were found in this group of cultivars. SNK 3883, NS 5511, NK 283 and SNK 3860 and

SNK 3620 also contained low levels of HE 1 and HE2 (Table 4.28 and 4.30), while PAN 8370 and SNK 3663 were found to contain low levels of HE1. In general, this group of cultivars were softer, with a lack of hardness for milling. SNK 3863, PAN 8272, SNK 3567, PAN 8171, PAN 8564, PAN 8446, SNK 3443, SNK 3337 and ADV 5010 corresponded ($p>0.05$) with the lowest ranked cultivar for TH value means, namely APN 881. These cultivars belong to the harder group with low levels of SE. SNK 3863, SNK 3567, SNK 3337 and APN 881 also had high levels of HE 1 and HE2, thereby emphasising the hardness of these cultivars.

Significant differences in the S1 and TH value means over different seasons were found (Table 4.27 and 4.31), but the level of significance was lower than for cultivars. Seasonal differences for S2 were insignificant (Fig. 4.28). The highest S1 value means were found during the 1997/98 season, the highest TH values were found in 1998/99 (Fig. 4.28). Sorghum from the latter season was thus softer than that from the previous season.

Significant differences were also found for S1, S2 and TH values at different localities of growth (Table 4.27, 4.29 and 4.31). The highest S1 and S2 values were found at Dover, followed by Plat. The lowest S2 values were found at Green, while both Green and Potch ($p>0.05$) had the lowest S1 values. Contrary to these results, the lowest TH values were found at Dover, followed by Plat, while Green and Potch ($p>0.05$) showed the highest TH values (Fig. 4.29). Green and Potch therefore gave higher levels of SE and lower levels of HE, but grain from these localities was found to be harder, as low levels of B1M were found (Fig. 4.10). A large fraction of the hard endosperm of sorghum from these localities was lost in the form of B2G, though (Fig. 4.19).

The cultivar x locality interaction was significant for S1, S2 and TH value means (Table 4.27, 4.29 and 4.31). The level of significance for S1 was lower, though. An example of the interaction is illustrated in Fig. 4.24 at the hand of the hard cultivar APN 881. It can be seen that the S1 and S2 values for APN 881 are higher at Dover and Plat, while the TH values of the same cultivar are higher at Green and Potch.

TABLE 4.25

THE SIEVE FRACTIONS OF THE MEAL OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

CULTIVAR	SIEVE FRACTION	DOVER 1997 /98	PLAT 1998 /99	GREEN 1997 /98	GREEN 1998 /99	POTCH 1997 /98	POTCH 1998 /99
ADV 5010	S1	45.99	26.60	20.72	22.63	25.38	20.28
	S2	25.46	26.06	18.71	16.55	19.07	19.03
	TH	28.54	47.33	60.56	60.82	55.55	60.69
APN 881	S1	42.02	31.73	17.78	21.35	21.70	22.54
	S2	27.68	32.35	16.72	18.97	19.65	19.81
	TH	30.30	35.92	65.50	59.69	58.64	57.66
NK 283	S1	32.73	16.85	18.55	17.19	19.71	22.05
	S2	27.00	17.11	18.55	17.29	19.58	17.61
	TH	40.27	66.04	62.90	65.52	60.71	60.34
NK 286	S1	30.07	24.42	21.02	19.91	19.50	23.55
	S2	28.28	25.47	17.93	16.33	19.34	19.20
	TH	41.66	50.11	61.04	63.75	61.16	57.24
NS 5511	S1	29.29	24.70	18.09	23.73	23.62	18.36
	S2	26.70	24.32	18.33	12.79	15.86	19.34
	TH	44.01	50.98	63.58	63.48	60.52	62.31
NS 5655	S1	32.56	27.37	20.27	13.52	22.93	19.98
	S2	29.15	26.88	19.48	17.49	18.39	17.93
	TH	38.29	45.75	60.25	68.99	58.68	62.09
PAN 8061	S1	36.59	25.63	21.17	18.90	21.45	20.05
	S2	28.79	26.74	16.52	15.80	18.59	18.03
	TH	34.62	47.63	62.30	65.30	59.96	61.92
PAN 8171	S1	48.51	25.68	22.02	19.22	21.14	18.56
	S2	22.64	26.22	17.85	16.34	16.87	17.67
	TH	28.85	48.10	60.12	64.45	61.99	63.76
PAN 8262	S1	27.49	23.20	17.95	18.29	22.28	15.18
	S2	26.02	23.76	16.98	17.29	17.72	16.66
	TH	46.49	53.04	65.06	64.42	60.00	68.16
PAN 8272	S1	40.51	24.44	21.91	17.28	22.58	17.12
	S2	27.44	25.96	20.08	16.65	20.81	17.65
	TH	32.05	49.60	58.01	66.07	56.61	65.23
PAN 8370	S1	40.40	23.51	18.82	17.43	18.09	16.21
	S2	29.78	26.68	16.45	16.88	15.78	17.05
	TH	29.82	49.81	64.73	65.70	66.13	66.74
PAN 8446	S1	34.88	32.72	19.59	23.62	22.17	19.24
	S2	29.71	25.34	16.35	17.35	20.40	16.51
	TH	35.41	41.95	64.07	59.03	57.43	64.24
PAN 8564	S1	32.24	29.05	23.63	21.17	23.63	20.70
	S2	27.66	27.00	16.23	18.41	18.67	17.70
	TH	40.10	43.94	60.14	60.42	57.70	61.60
PAN 8660	S1	42.86	23.11	19.00	17.78	20.93	18.94
	S2	26.54	22.84	17.50	18.21	19.52	19.19
	TH	30.60	54.05	63.50	64.01	59.55	61.87

TABLE 4.25

(CONTINUED)

THE SIEVE FRACTIONS OF THE MEAL OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

CULTIVAR	SIEVE FRACTION	DOVER	PLAT	GREEN		POTCH	
		1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99
SNK 3337	S1	32.99	27.89	22.35	21.84	25.07	23.73
	S2	28.56	26.94	18.51	18.18	20.70	18.99
	TH	38.45	45.17	59.14	59.98	54.23	57.27
SNK 3443	S1	36.58	26.84	35.60	19.27	20.43	19.38
	S2	26.56	26.37	16.70	16.72	17.21	17.54
	TH	36.86	46.79	47.70	64.01	62.37	63.09
SNK 3567	S1	28.88	27.83	24.21	19.14	23.59	20.35
	S2	25.51	28.27	19.90	18.45	17.77	18.73
	TH	45.62	43.90	55.89	62.42	58.64	60.92
SNK 3620	S1	42.00	21.66	23.19	22.21	20.82	20.57
	S2	24.48	16.89	17.90	16.96	16.56	16.69
	TH	33.51	61.44	58.91	60.83	62.62	62.73
SNK 3663	S1	33.17	27.77	15.16	20.58	19.01	19.60
	S2	27.88	26.59	16.77	17.51	19.47	18.85
	TH	38.95	45.64	68.06	61.90	61.52	61.54
SNK 3860	S1	32.19	18.63	23.33	20.11	22.31	20.27
	S2	27.69	16.63	13.75	16.75	16.52	20.11
	TH	40.11	64.75	62.92	63.14	61.17	59.62
SNK 3863	S1	41.46	22.76	20.76	19.65	20.98	19.24
	S2	27.16	24.44	17.26	17.99	20.80	19.33
	TH	31.38	52.80	61.99	62.35	58.22	61.43
SNK 3883	S1	36.54	16.35	21.32	19.61	19.09	17.55
	S2	26.85	17.15	17.62	18.05	18.77	19.14
	TH	36.61	66.50	61.06	62.34	62.14	63.32
SNK 3939	S1	37.81	26.25	21.81	22.81	22.32	16.44
	S2	26.73	24.87	18.07	17.94	19.67	17.07
	TH	35.47	48.88	60.12	59.25	58.01	66.50
SNK 3975	S1	42.01	25.17	17.75	20.62	19.43	19.32
	S2	29.44	24.45	15.77	17.52	17.95	17.46
	TH	28.55	50.39	66.49	61.87	62.63	63.22

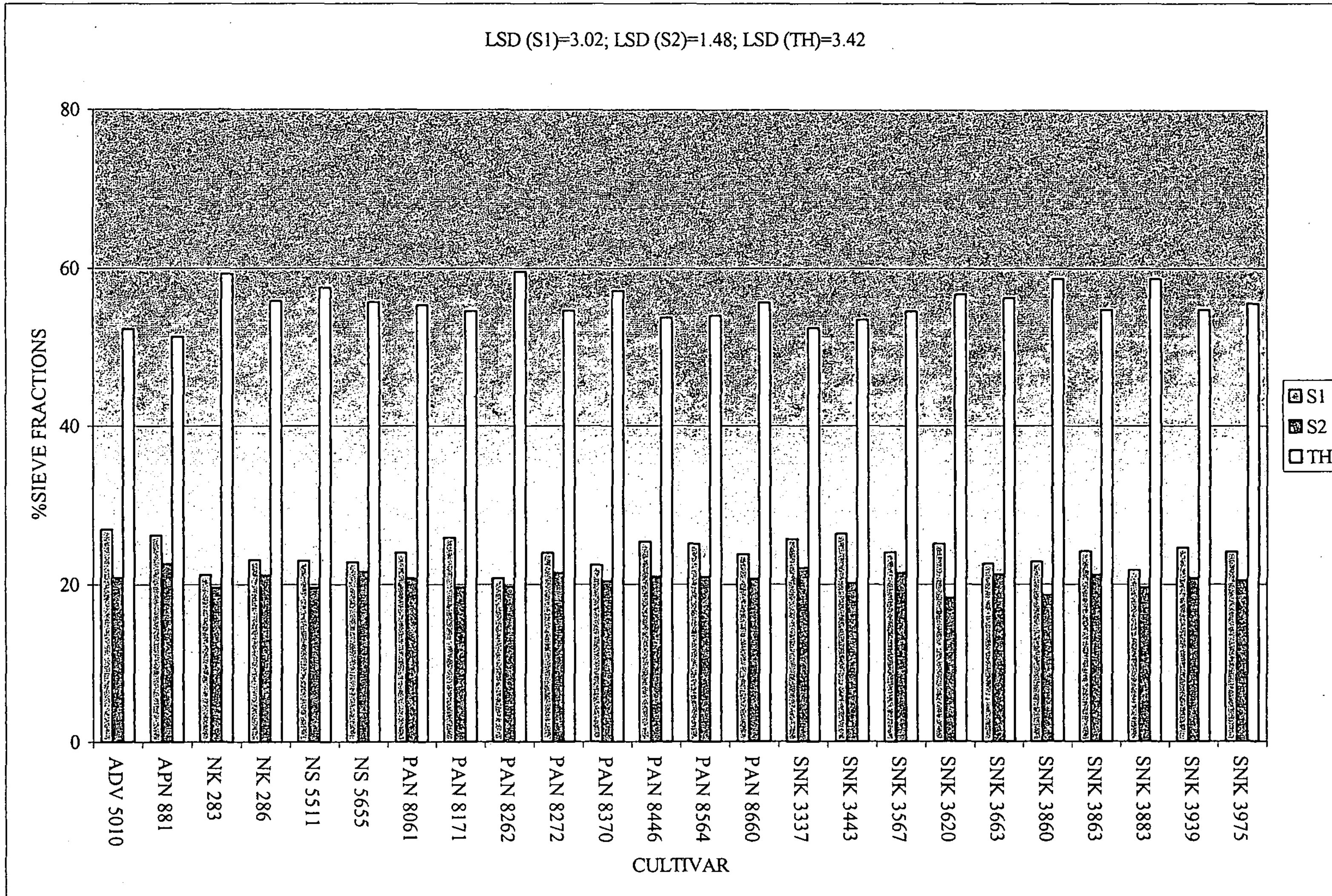


FIG. 4.27

THE SIGNIFICANT DIFFERENCES BETWEEN THE MEAN SIEVE FRACTION VALUES OF DIFFERENT SORGHUM CULTIVARS

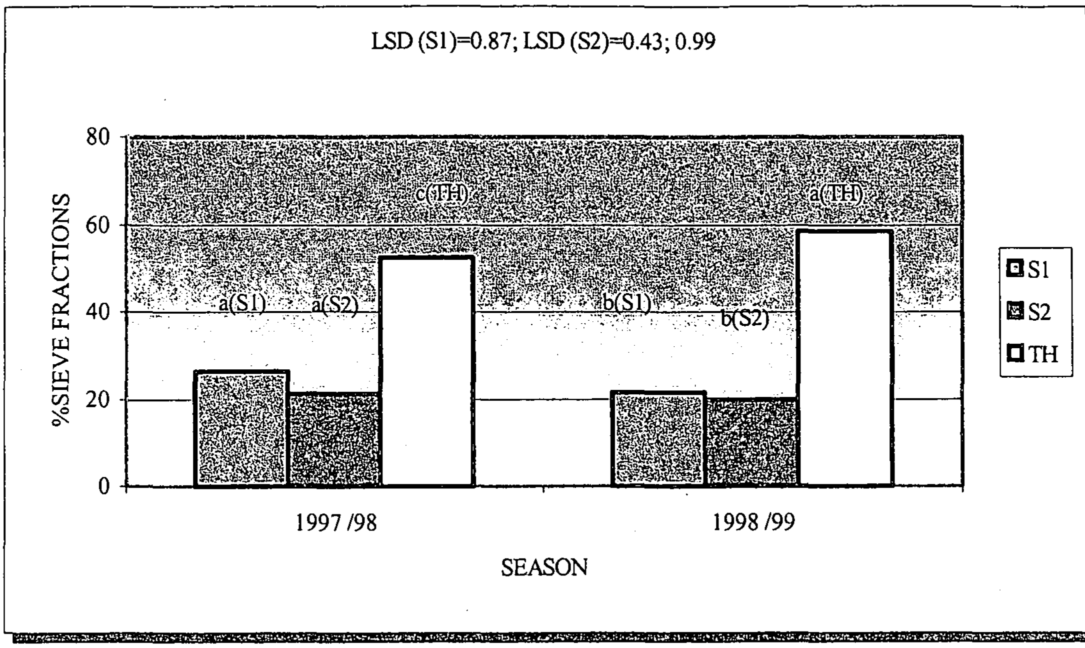


FIG. 4.28

THE DIFFERENCES IN THE SIEVE FRACTION VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

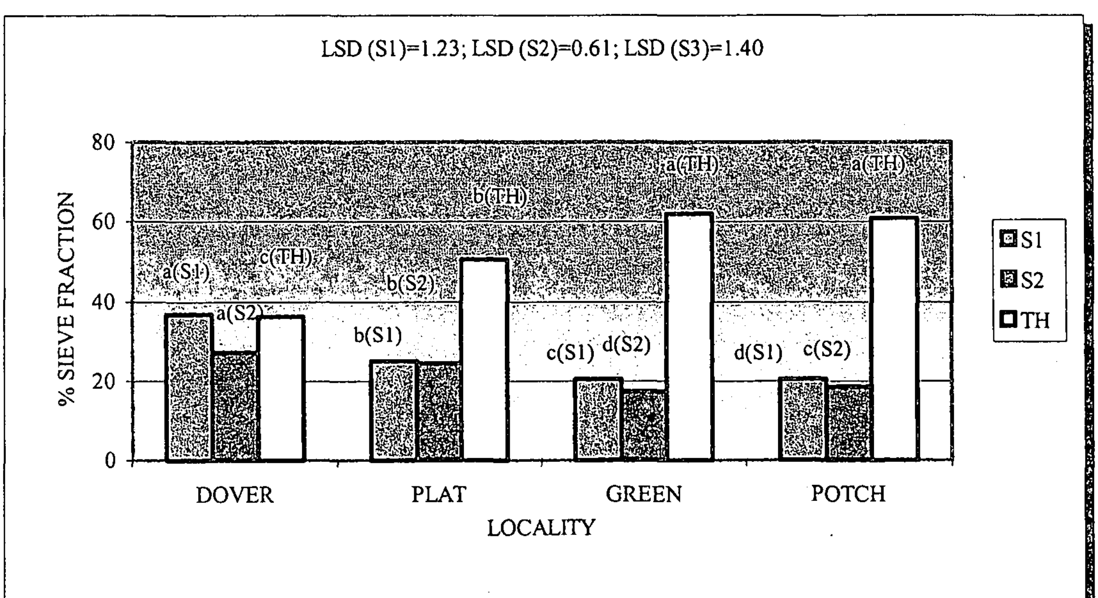


FIG. 4.29

THE DIFFERENCES IN THE SIEVE FRACTION VALUE MEANS OF SORGHUM AT DIFFERENT LOCALITIES

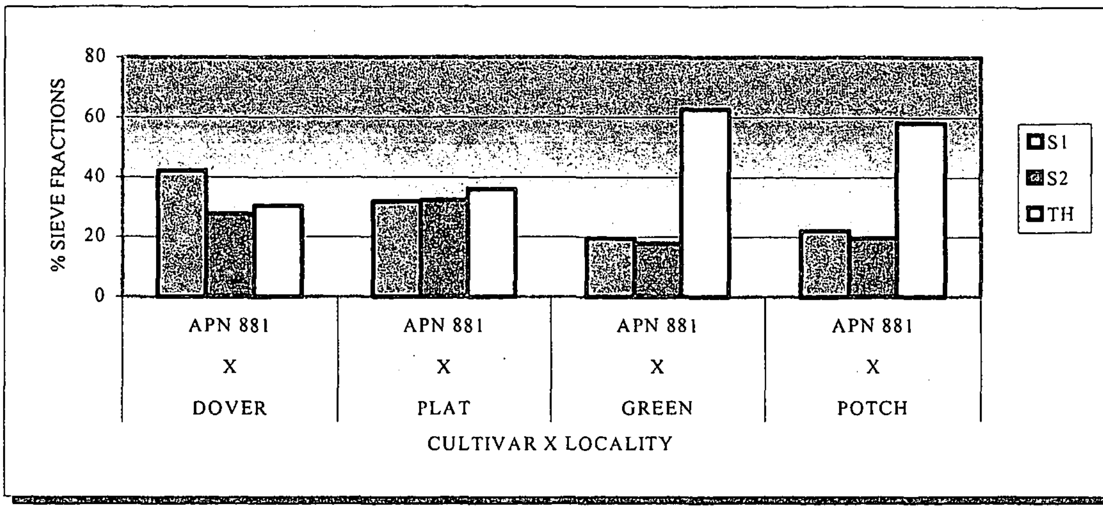


FIG. 4.30

THE SIGNIFICANT CULTIVAR X LOCALITY INTERACTION ILLUSTRATED ON A CULTIVAR FOR S1, S2 AND TH VALUE MEANS

TABLE 4.26

THREE WAY RANDOMIZED BLOCK ANALYSIS OF VARIANCE FOR ALL THREE SIEVE FRACTIONS OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	464.6859	464.6859	6.0533	6 .0151	*
Main Effects						
CULTIVAR	23	456.8027	19.8610	0.2587	0.9998	ns
LOCALITY	3	353.8924	117.9641	1.5367	0.2076	ns
SIZE	2	798022.4209	399011.2100	5197.7602	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	449.3448	6.5122	0.0848	1.0000	ns
CULTIVAR x SIZE	46	17965.1511	390.5468	5.0875	0.0000	***
LOCALITY x SIZE	6	231043.9103	38507.3180	501.6195	0.0000	***
CULTIVAR x LOCALITY x SIZE	138	36349.4259	263.4016	3.4312	0.0000	***
Error	143	10977.5367	76.7660	<-		
Total	431	1495916.1230				

*p=0.05

ns=not significant

TABLE 4.27

ANALYSIS OF VARIANCE OF THE SIEVE 1 VALUES OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	61.8711	61.8711	9.1375	0.0040	**
Main Effects						
CULTIVAR	23	495.9263	21.5620	3.1844	0.0004	***
LOCALITY	3	4200.8174	1400.2725	206.8000	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	1078.9300	15.6367	2.3093	0.0014	**
Error	47	318.2437	6.7711	<-		
Total	43	6858.4401				

*p=0.05

ns=not significant

TABLE 4.28

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN SIEVE 1 VALUE MEANS

Rank	Cultivar	Mean	n	Groups not significantly different
1	ADV 5010	26.936	6	a
2	SNK 3443	26.349	6	ab
3	APN 881	26.187	6	ab
4	PAN 8171	25.856	6	abc
5	SNK 3337	25.643	6	abcd
6	PAN 8446	25.368	6	abcde
7	SNK 3620	25.075	6	abcde
8	PAN 8564	25.07	6	abcde
9	SNK 3939	24.574	6	abcdef
10	SNK 3863	24.142	6	abcdefg
11	SNK 3975	24.048	6	abcdefg
12	SNK 3567	24.001	6	abcdefg
13	PAN 8272	23.972	6	abcdefg
14	PAN 8061	23.967	6	abcdefg
15	PAN 8660	23.77	6	bcdefg
16	NK 286	23.081	6	cdefgh
17	NSK 5511	22.965	6	cdefgh
18	SNK 3860	22.806	6	defgh
19	NS 5655	22.772	6	defgh
20	SNK 3663	22.551	6	efgh
21	PAN 8370	22.409	6	efgh
22	SNK 3883	21.742	6	fgh
23	NK 283	21.18	6	gh
24	PAN 8262	20.732	6	h

TABLE 4.29

ANALYSIS OF VARIANCE OF THE SIEVE 2 VALUES OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	2.6366	2.6366	1.6150	8 .2100	ns
Main Effects						
CULTIVAR	23	204.4128	8.8875	5.4439	0.0000	***
LOCALITY	3	2133.9062	711.3021	435.6953	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	357.3585	5.1791	3.1724	0.0000	***
Error	47	76.7307	1.6326	<-		
Total	143	2756.4146				

*p=0.05

ns=not significant

TABLE 4.30

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN SIEVE 2 VALUE MEANS

Rank	Cultivar	Mean	n	Groups not significantly different
1	APN 881	22.529	6	a
2	SNK 3337	21.983	6	ab
3	NS 5655	21.552	6	abc
4	SNK 3567	21.436	6	abc
5	PAN 8272	21.434	6	abc
6	SNK 3663	21.181	6	abcd
7	SNK 3863	21.165	6	abcd
8	NK 286	21.092	6	abcd
9	PAN 8564	20.946	6	bcde
10	PAN 8446	20.943	6	bcde
11	ADV 5010	20.814	6	bcde
12	PAN 8061	20.744	6	bcde
13	SNK 3939	20.724	6	bcde
14	PAN 8660	20.634	6	bcde
15	PAN 8370	20.435	6	cde
16	SNK 3975	20.429	6	cde
17	SNK 3443	20.182	6	cde
18	PAN 8262	19.74	6	def
19	PAN 8171	19.598	6	efg
20	SNK 3883	19.596	6	efg
21	NS 5511	19.555	6	efg
22	NK 283	19.524	6	efg
23	SNK 3860	18.575	6	fg
24	SNK 3620	18.248	6	g

TABLE 4.31

ANALYSIS OF VARIANCE OF THE THROUGHS VALUES OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	90.0521	90.0521	10.4041	0.0023	**
Main Effects						
CULTIVAR	23	942.4486	40.9760	4.7342	0.0000	***
LOCALITY	3	12008.0853	4002.6951	462.4499	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	1806.4278	26.1801	3.0247	0.0001	***
Error	47	406.8044	8.6554	<-		
Total	143	16212.6218				

*p=0.05

ns=not significant

TABLE 4.32

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN THROUGHS VALUE MEANS

Rank	Cultivar	Mean	n	Groups not significantly different
1	PAN 8262	59.528	6	a
2	NK 283	59.296	6	a
3	SNK 3883	58.662	6	ab
4	SNK 3860	58.619	6	ab
5	NS 5511	57.48	6	abc
6	PAN 8370	57.156	6	abcd
7	SNK 3620	56.676	6	abcde
8	SNK 3663	56.269	6	abcde
9	NK 286	55.827	6	bcde
10	NS 5655	55.676	6	bcdef
11	PAN 8660	55.596	6	bcdefg
12	SNK 3975	55.523	6	bcdefg
13	PAN 8061	55.289	6	bcdefg
14	SNK 3939	54.702	6	cdefg
15	SNK 3863	54.693	6	cdefgh
16	PAN 8272	54.594	6	cdefgh
17	SNK 3567	54.563	6	cdefgh
18	PAN 8171	54.546	6	cdefgh
19	PAN 8564	53.985	6	defgh
20	PAN 8446	53.688	6	efgh
21	SNK 3443	53.469	6	efgh
22	SNK 3337	52.374	6	fgh
23	ADV 5010	52.249	6	gh
24	APN 881	51.285	6	h

4.3.2 FOOD QUALITY PROPERTIES

4.3.2.1 COLOUR

4.3.2.1.1 TADD SAMPLES

Table 4.33 indicates the mean L-, a- and WI values of 2 commercial sorghum meal samples, determined on a dry and wet basis. As discussed in 4.2.3.1.1 these values of two commercial sorghum meal samples were used to determine the DI values, i.e. the abrasion percentage necessary to obtain sorghum meal with a colour similar to the mean colour of two commercial sorghum meal samples. The DI values are discussed in 4.3.2.1.1.1 to 4.3.2.1.1.4.

TABLE 4.33
MEAN L-, a- AND WI VALUES OF COMMERCIAL SORGHUM MEAL SAMPLES

PRODUCT	MEAN VALUES		
	L-VALUE	a-VALUE	WI
MABELE MEAL (DRY)	78.00	3.99	-12.64
MABELE MEAL (WET 40 g MEAL: 40ML WATER)	65.53	6.50	-8.96

4.3.2.1.1.1 DEHULLING INDEX (DI) FOR L-VALUES (DRY DETERMINATION)

The DIs for the L-values of 24 sorghum cultivars over 2 seasons at 3 localities per season on a dry basis is shown in Table 4.34. Significant differences in the DI value means for different cultivars were found (Table 4.35), as illustrated by Fig. 4.31. SNK 3860 did not differ ($p>0.05$) significantly from the highest ranked cultivar, namely SNK 3620 in DI value means. The ranking of these two cultivars were followed by the third ranked NS 5511, which corresponded with SNK 3860 in DI value means. These cultivars need higher levels of abrasion to produce the same acceptable colour of the commercial samples. All three cultivars are birdproof (Chapter 2), which explain their darker colour due to the presence of a dark layer of condensed tannins underneath the pericarp. This layer has to be totally removed to produce meal with an acceptable colour. SNK 3663 was also found not to differ significantly ($p>0.05$) from the birdproof cultivar NS 5511, in DI value means. Although SNK 3663 is not birdproof, this cultivar does not have good colour properties and needed higher levels of dehulling. PAN 8564, SNK 3975, NK 283, SNK 3939, NS 5655, PAN 8262, PAN 8660, SNK 3863, SNK 3443 and ADV 5010 did not differ ($p>0.05$) significantly from the lowest ranked cultivar for DI value means, namely SNK 3883. These cultivars also fell within the 10 to 12 % maximum dehulling recommended for sorghum by Desikachar (1982). These cultivars do not need high levels of abrasion to produce an acceptable colour and therefore, have good colour properties in general. The lowest rank of SNK 3883 was expected, as this cultivar is white with little abrasion necessary to deliver a white product. Even in the case of a white sorghum cultivar such as SNK 3883, a certain level of dehulling is necessary, since the highest concentration of fibre is found in the pericarp and its levels in the milled product, is determined by the extent of milling (Serna-Saldivar & Rooney, 1995). As seen in Chapter 1, the tendency amongst people is towards more refined food, with less fibre and coarseness (Novellie, 1982), as this is important for consumer acceptability of the product (Pushpamma & Vogel, 1982).

From Table 4.35 it can also be seen that significant differences in DI value means are found at different localities of growth and seasons, but the level of significance for seasons, is not as high as in the case of different cultivars and localities. From Fig. 4.32, it is noticed that DI values were higher during the 1998/99 season than in the previous season, therefore indicating that sorghum from the 1997/98 season had more favourable colour properties, with lower levels of dehulling necessary to produce grain that delivered acceptable coloured meals.

From Fig. 4.33 it is seen that Plat and Dover were the highest ranked localities for DI value means, while Potch and Green were ranked the lowest. The colours of meals from Green and Potch were thus lighter in colour and more acceptable, with lower levels of dehulling necessary, when compared to those of Dover and Plat. The cultivar x locality interaction was insignificant (Table 4.35).

TABLE 4.34
THE DEHULLING INDEX AND CORRELATION COEFFICIENTS OF 24 SORGHUM CULTIVARS OVER 2 PERIODS AT 3 LOCALITIES PER SEASON TO GIVE A L-VALUE OF 78.00 (DRY DETERMINATION)

CULTIVAR	DOVER		PLAT		GREEN				POTCH				MEAN	
	DI	r	DI	r	DI	r	DI	r	DI	r	DI	r	DI	
	1998 /99		1997 /98		1998 /99		1997 /98		1998 /99		1998 /99			1998 /99
ADV 5010	14.10	0.99	11.18	1.00	6.16	0.99	3.25	0.99	11.33	0.99	14.10	0.99	9.58	10.53
APN 881	9.88	1.00	12.65	0.99	12.41	0.99	3.33	0.99	12.61	0.99	9.88	1.00	10.46	11.64
NK 283	8.19	1.00	0.73	0.98	0.49	0.97	17.37	0.99	11.78	1.00	8.19	1.00	7.72	7.10
NK 286	13.42	0.99	6.35	0.99	7.02	0.99	3.77	0.99	13.14	0.99	13.42	0.99	10.09	10.74
NS 5511	27.63	0.99	16.67	0.99	16.48	1.00	10.49	1.00	31.23	1.00	27.63	0.99	16.64	19.08
NS 5655	7.92	0.96	4.39	1.00	5.75	1.00	12.17	0.98	8.53	0.96	7.92	0.96	8.21	14.97
PAN 8061	29.04	1.00	5.82	0.99	9.48	1.00	3.23	1.00	14.16	0.99	29.04	1.00	8.82	15.68
PAN 8171	18.45	1.00	11.42	0.99	15.17	0.99	3.12	0.94	16.06	0.99	18.45	1.00	9.65	16.56
PAN 8262	18.25	0.99	0.71	0.99	4.68	1.00	8.19	1.00	16.51	1.00	18.25	0.99	2.99	13.00
PAN 8272	19.86	1.00	9.97	0.99	7.39	1.00	0.05	0.97	11.53	1.00	19.86	1.00	8.13	12.93
PAN 8370	21.01	1.00	11.45	0.99	6.56	0.99	5.77	1.00	15.03	1.00	21.01	1.00	11.90	14.20
PAN 8446	16.03	0.99	7.39	1.00	9.03	0.99	16.95	0.99	9.16	0.97	16.03	0.99	13.13	13.36
PAN 8564	9.35	0.99	6.43	0.96	2.77	0.96	0.55	0.99	6.25	0.99	9.35	0.99	5.52	7.10
PAN 8660	15.16	0.99	7.20	0.98	5.71	1.00	3.63	0.97	17.01	0.99	15.16	0.99	3.88	9.04
SNK 3337	15.71	1.00	7.24	0.99	10.14	0.99	17.94	0.99	11.77	0.99	15.71	1.00	11.28	14.29
SNK 3443	12.30	1.00	14.91	0.97	5.53	0.99	4.36	1.00	10.28	1.00	12.30	1.00	10.15	9.86
SNK 3567	20.54	0.99	17.68	0.99	10.86	1.00	0.87	0.98	12.14	0.99	20.54	0.99	10.89	13.89
SNK 3620	34.00	1.00	23.09	1.00	41.69	1.00	12.84	1.00	29.09	1.00	34.00	1.00	26.69	29.28
SNK 3663	25.26	0.99	7.82	1.00	9.60	0.99	11.24	0.99	17.60	0.99	25.26	0.99	14.25	17.49
SNK 3860	32.91	0.99	27.75	0.97	21.21	1.00	8.17	1.00	26.32	1.00	32.91	0.99	25.44	23.91
SNK 3863	13.63	1.00	8.90	0.99	6.05	1.00	3.01	1.00	9.97	1.00	13.63	1.00	7.89	9.88
SNK 3883	4.39	0.99	1.54	0.97	5.48	0.95	9.07	0.99	1.12	1.00	4.39	0.99	4.26	3.66
SNK 3939	6.78	0.99	2.37	0.98	3.39	0.99	13.98	0.99	9.79	0.97	6.78	0.99	8.05	6.65
SNK 3975	7.39	0.99	6.19	0.98	4.42	0.99	1.56	1.00	8.56	1.00	7.39	0.99	5.19	6.79
MEAN	16.72	1.00	9.58	0.99	9.48	0.99	7.29	0.99	13.79	0.99	16.72	1.00	10.49	13.09
MIN	4.39	0.96	0.71	0.96	0.49	0.95	0.05	0.94	1.12	0.96	4.39	0.96	2.99	3.66
MAX	34.00	1.00	27.75	1.00	41.69	1.00	17.94	1.00	31.23	1.00	34.00	1.00	26.69	29.28
RANGE	29.61	0.04	27.04	0.04	41.20	0.05	17.90	0.06	30.12	0.04	29.61	0.04	23.70	25.62
SD	8.32	0.01	6.73	0.01	8.29	0.01	5.64	0.01	6.90	0.01	8.32	0.01	5.93	5.83

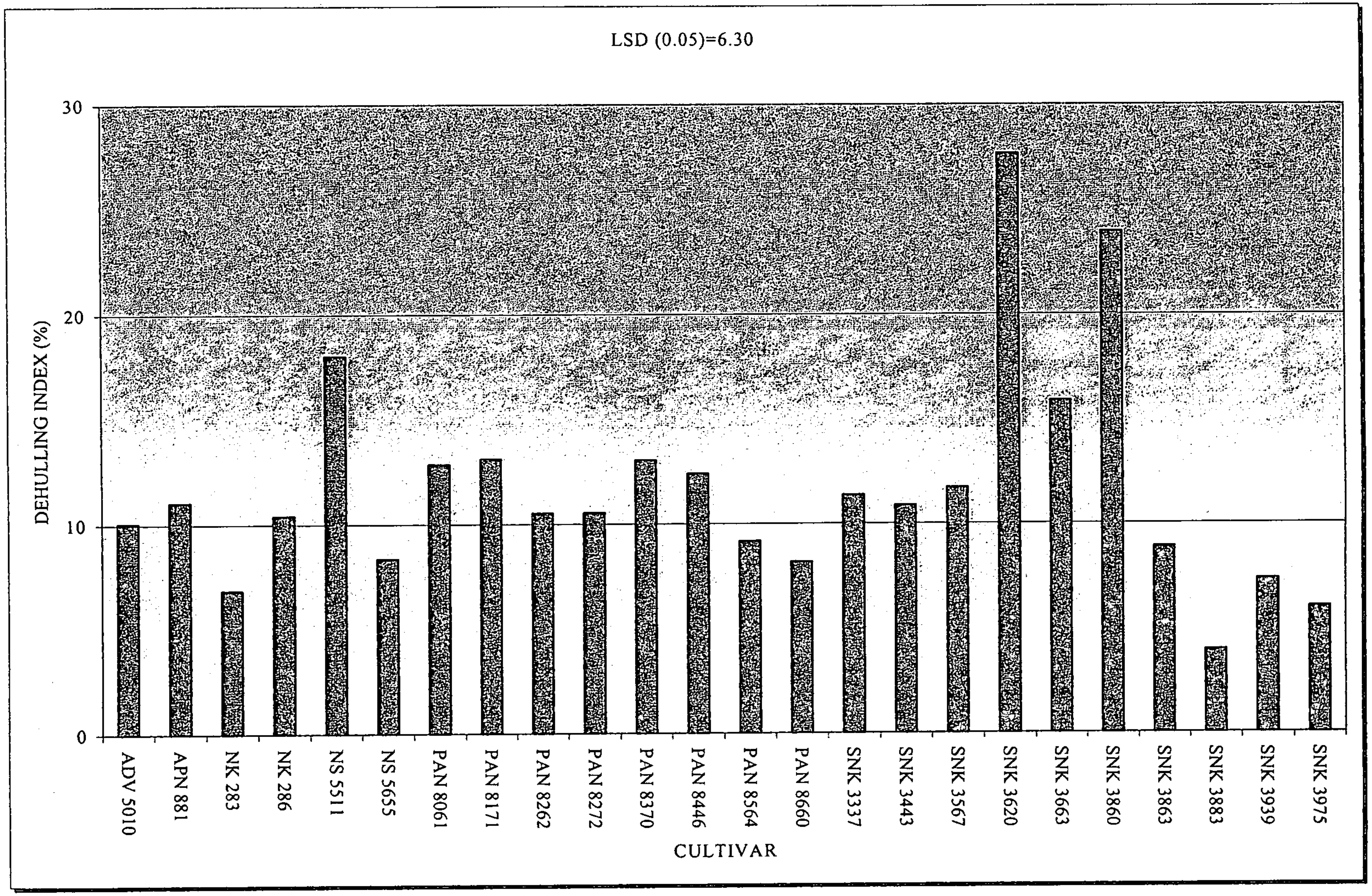


FIG. 4.31

THE SIGNIFICANT DIFFERENCES BETWEEN THE MEAN DEHULLING INDEX FOR L-VALUES (DRY) VALUES OF DIFFERENT SORGHUM CULTIVARS

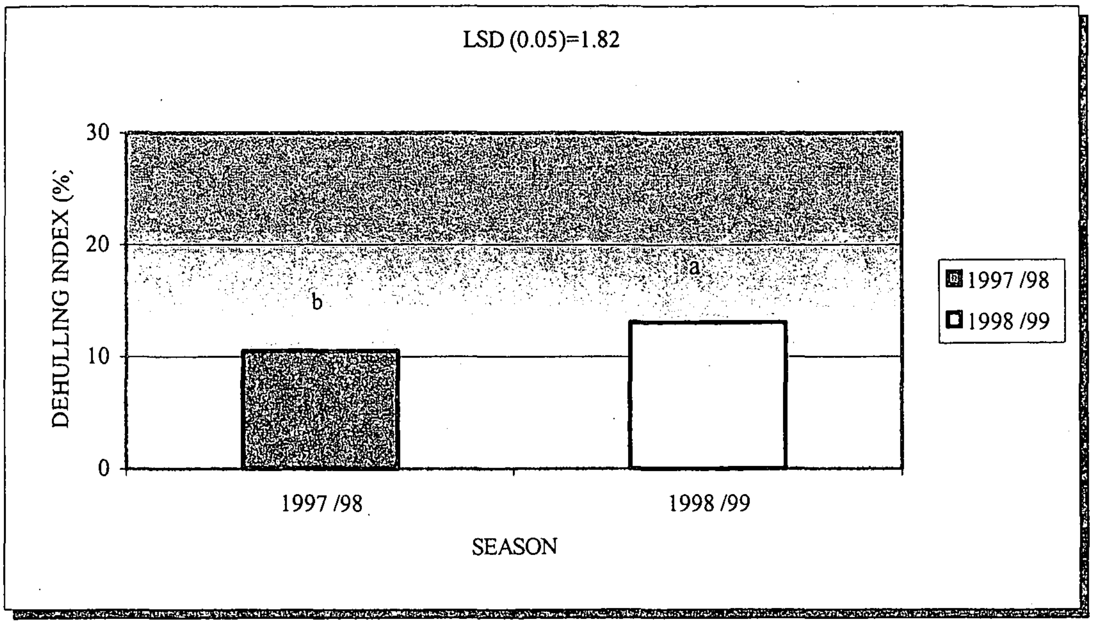


FIG. 4.32

THE DIFFERENCES IN THE DEHULLING INDEX VALUE MEANS (DRY) OF THE L-VALUES OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

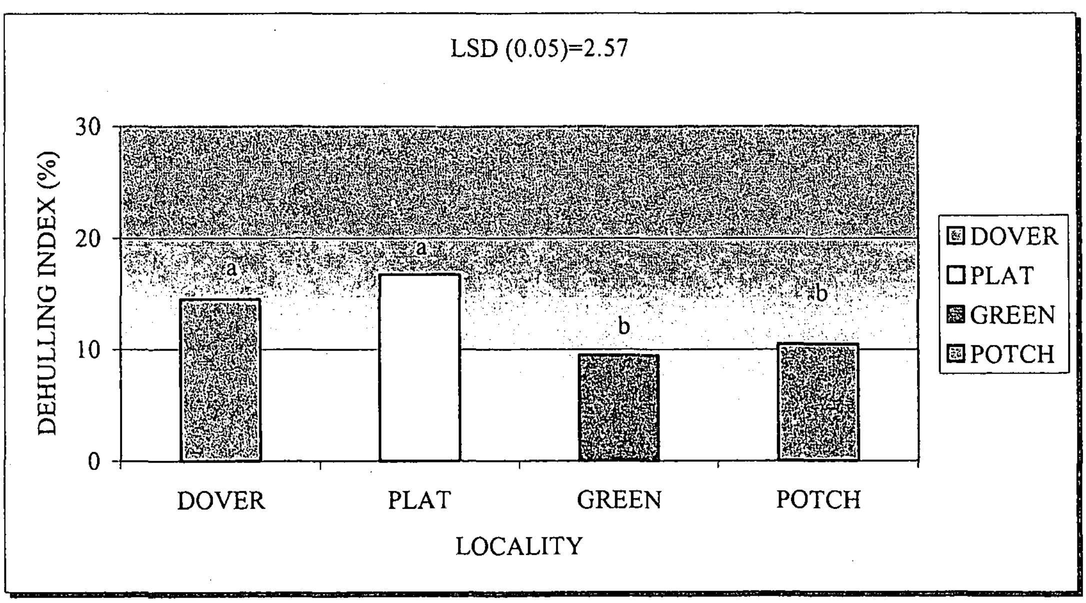


FIG. 4.33

THE DIFFERENCES IN THE DEHULLING INDEX VALUE MEANS (DRY) OF THE L-VALUES OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 4.35

THE DIFFERENCES IN THE DEHULLING INDEX VALUE MEANS (DRY) OF THE L-VALUES OF SORGHUM CULTIVARS OVER 2 SEASONS AT DIFFERENT LOCALITIES

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	246.0415	246.0415	8.3716	0.0058	**
Main Effects						
CULTIVAR	23	5821.7126	253.1179	8.6124	0.0000	***
LOCALITY	3	1024.7726	341.5909	11.6227	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	2097.7051	30.4015	1.0344	0.4566	ns
Error	47	1381.3252	29.3899	<-		
Total	143	10228.8314				

P=0.05

ns=not significant

TABLE 4.36

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN DEHULLING INDEX VALUE MEANS (DRY) OF THE L-VALUES

Rank	Cultivar	Means	n	Groups not significantly different
1	SNK 3620	30.808	6	a
2	SNK 3860	26.127	6	ab
3	NS 5511	20.875	6	bc
4	SNK 3663	15.871	6	cd
5	PAN 8061	13.191	6	de
6	PAN 8171	13.105	6	de
7	PAN 8370	13.051	6	de
8	SNK 3567	12.701	6	de
9	PAN 8446	12.269	6	def
10	SNK 3337	11.912	6	defg
11	APN 881	11.046	6	defg
12	NK 286	10.641	6	defg
13	PAN 8272	10.529	6	defg
14	ADV 5010	10.056	6	defgh
15	SNK 3443	9.757	6	defgh
16	SNK 3863	8.885	6	efgh
17	PAN 8660	8.255	6	efgh
18	PAN 8262	8.069	6	efgh
19	NS 5655	7.805	6	efgh
20	SNK 3939	7.349	6	efgh
21	NK 283	7.272	6	efgh
22	SNK 3975	5.990	6	fgh
23	PAN 8564	5.823	6	gh
24	SNK 3883	3.960	6	h

4.3.2.1.1.2 DEHULLING INDEX (DI) FOR a-VALUES (DRY DETERMINATION)

The DI values for the a-values of 24 cultivars over 2 seasons at 3 localities per season on a dry basis, are shown in Table 4.37. Significant differences in the DI value means of different cultivars were found (Table 4.38) as seen in Fig. 4.34. In 4.1, it was described that the +a-value indicates redness and the -a-value, greenness. Therefore, sorghum has to be dehulled to decrease the redness of the grain to a value of 3.99 (Table 4.33). The ranking of cultivars according to significant different DI value means, are shown in Table 4.39. From this Table and Fig. 4.34 it can immediately be seen that the highest ranked cultivar for DI value means, SNK 3883 needed 61.51 % of dehulling to deliver an acceptable light colour. This data is incorrect as SNK 3883 (white cultivar) was already less red in colour than the standard before dehulling (a-value=1.99). The high DI value for SNK 3883 is thus incorrect, as this cultivar needed no dehulling when only the a-value are considered, which place NK 283 in the highest position for dehulling. When the L-values were considered (4.3.2.1.1.1), NK 283 was ranked amongst the cultivars with the lowest DI value means, as this cultivar is generally light in colour even before dehulling (mean L-value=75.45). When the DI value for the a-value of SNK 3883 and NK 283 are considered, it seems as if the a–values do not provide such a reliable indication of the DI of sorghum, as in the case of the L-value. This is especially true in the case where the a-values are already lower than the standard before milling. This may be attributed to the fact that the property to be measured is whiteness and although sorghum contains a red colour, this colour may not necessarily be the important one to measure when the whiteness of sorghum meal is considered.

SNK 3620, PAN 8262, NS 5511, SNK 3663 and ADV 5010 all corresponded with the second highest ranked cultivar for DI value means, namely NK 283. Again, two of the birdproof cultivars, namely SNK 3620 and NS 5511, were found among the top ranked cultivars for DI, as well as the cultivar SNK 3663. Similar results for these cultivars were found in 4.3.2.1.1.1 where the DI value for the L-values was determined. SNK 3975, SNK 3939, NS 5655, SNK 3443, APN 881, SNK 3337, PAN 8272 and SNK 3567 all corresponded with the lowest ranked cultivar, namely PAN 8564 in DI value means. Therefore, these cultivars would need higher levels of dehulling when the a-value is considered. Except for APN 881, SNK 3337, PAN 8272 and SNK 3567 all these cultivars mentioned were also amongst the highest ranked cultivars for the DI of the L-values. The meal of these cultivars is thus definitely darker in colour than the other cultivars.

Significant differences in the DI value means for different localities were also found (Table 4.38). From Fig. 4.36 it can be seen that the highest DI values ($p<0.05$) were found at Plat, indicating grain of a poorer colour necessitating more dehulling. Sorghum from Green had significantly lower DI value means than those from the other localities, while DI value means from Dover and Potch did not differ significantly. The cultivar x locality interaction was also found to be significant, as illustrated by four cultivars (Fig. 4.37). SNK 3620 for example, displayed higher DI values at Plat than at the other localities and SNK 3663 had much lower DI values at Green than at the other localities. The influence of season on DI value means was insignificant (Table 4.38; Fig. 4.35).

TABLE 4.37

THE DEHULLING INDEX AND CORRELATIONS COEFFICIENT OF 24 SORGHUM CULTIVARS OVER 2 PERIODS AT 3 LOCALITIES PER SEASON TO GIVE AN a-VALUE OF 3.99 (DRY DETERMINATION)

CULTIVAR	DOVER		PLAT		GREEN				POTCH				MEAN	
	DI	r	DI	r	DI	r	DI	r	DI	r	DI	r	DI	
	1997 /98		1998 /99		1997 /98		1998 /99		1997 /98		1998 /99		1997 /98	1998 /99
ADV 5010	21.78	1.00	23.67	0.97	16.74	1.00	11.74	0.99	17.09	0.99	25.42	0.99	18.54	17.71
APN 881	4.31	0.97	11.04	1.00	10.47	0.99	9.68	0.99	13.12	0.99	12.63	0.99	9.30	15.38
NK 283	108.42	1.00	20.05	1.00	0.50	1.00	0.54	0.96	14.37	0.99	17.96	1.00	41.10	11.07
NK 286	13.75	1.00	19.43	1.00	5.38	0.99	8.39	0.99	18.41	1.00	15.21	1.00	12.52	15.26
NS 5511	19.05	1.00	28.55	0.99	14.76	1.00	16.41	1.00	21.56	0.99	36.88	1.00	18.45	20.06
NS 5655	6.65	0.99	19.27	0.99	6.33	1.00	10.23	1.00	13.61	0.99	13.75	0.98	8.86	22.13
PAN 8061	20.29	0.99	26.47	1.00	7.97	1.00	12.25	1.00	23.33	1.00	19.30	1.00	17.20	17.49
PAN 8171	16.34	0.98	27.00	1.00	7.62	1.00	12.03	0.99	16.11	0.99	21.49	1.00	13.36	19.44
PAN 8262	25.67	0.99	41.11	1.00	1.20	0.99	4.79	0.99	53.57	0.99	27.21	0.99	26.81	22.46
PAN 8272	8.47	0.98	22.37	1.00	9.78	1.00	8.46	1.00	8.23	1.00	13.13	1.00	8.83	19.35
PAN 8370	8.93	0.95	25.32	0.99	9.90	1.00	9.20	1.00	22.53	1.00	22.16	1.00	13.79	15.88
PAN 8446	13.95	1.00	24.49	1.00	6.53	1.00	11.62	1.00	17.32	1.00	15.23	0.99	12.60	19.42
PAN 8564	5.22	1.00	8.03	0.99	4.62	1.00	1.24	0.92	5.02	0.99	5.09	0.99	4.95	8.17
PAN 8660	17.87	1.00	19.08	1.00	9.26	0.99	7.36	1.00	21.60	0.98	20.36	1.00	16.24	10.51
SNK 3337	10.79	1.00	13.98	1.00	3.79	1.00	8.60	0.99	17.28	1.00	12.59	1.00	10.62	14.31
SNK 3443	5.08	0.99	7.07	1.00	5.87	0.99	3.63	0.99	20.26	1.00	6.29	1.00	10.41	7.76
SNK 3567	14.83	0.99	16.04	1.00	6.96	1.00	9.15	1.00	17.70	0.95	9.08	1.00	13.16	10.49
SNK 3620	27.04	0.99	35.51	1.00	20.08	0.99	26.71	1.00	23.56	1.00	26.26	1.00	23.56	23.77
SNK 3663	19.23	0.93	20.93	1.00	8.09	1.00	10.38	1.00	36.21	0.99	22.97	0.98	21.18	19.19
SNK 3860	20.95	1.00	20.60	1.00	9.98	1.00	16.91	1.00	13.82	1.00	21.96	1.00	14.92	20.16
SNK 3863	19.22	0.99	31.84	1.00	12.09	0.99	10.06	1.00	18.78	1.00	15.27	1.00	16.70	21.28
SNK 3883	56.70	0.96	170.26	0.98	22.08	0.98	47.30	0.70	17.39	0.99	55.35	1.00	32.05	77.61
SNK 3939	9.57	1.00	16.04	0.99	1.61	0.99	8.96	0.98	12.87	1.00	12.31	0.99	8.02	12.44
SNK 3975	5.93	0.98	12.39	1.00	7.65	0.98	9.27	0.99	18.46	1.00	12.71	1.00	10.68	11.33
MEAN	19.93	0.99	27.69	1.00	8.37	0.99	11.44	0.98	19.35	0.99	18.92	0.99	15.883	18.911
MIN	4.32	0.93	7.07	0.97	0.50	0.98	0.54	0.70	5.02	0.95	5.09	0.98	4.954	7.763
MAX	108.42	1.00	170.26	1.00	22.08	1.00	47.30	1.00	53.58	1.00	55.35	1.00	41.096	77.607
RANGE	104.10	0.07	163.19	0.03	21.58	0.02	46.76	0.30	48.55	0.05	50.26	0.02	36.142	69.845
SD	21.78	1.00	23.67	0.97	16.74	1.00	11.74	0.99	9.62		25.42	0.01	8.428	13.654

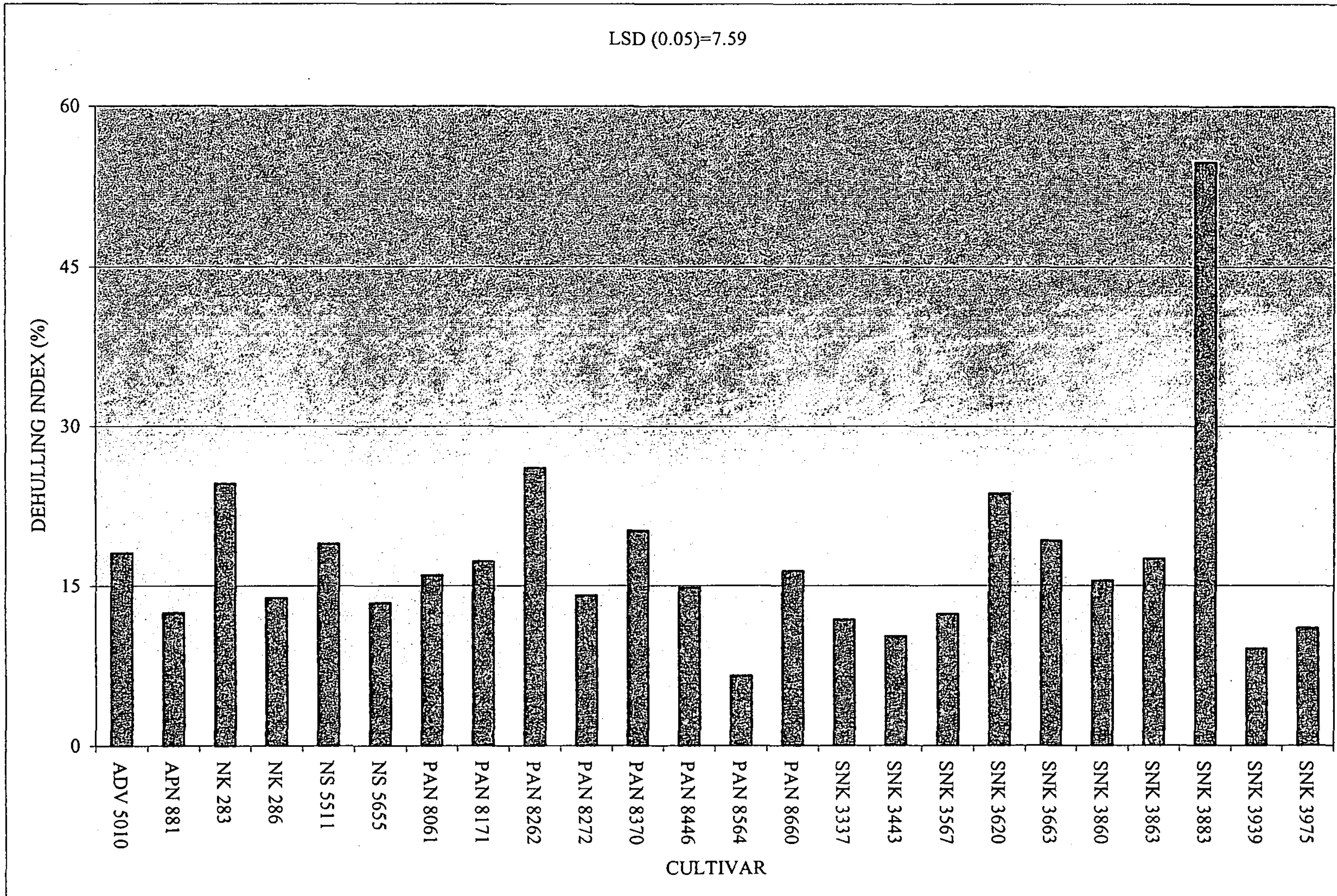


FIG.4.34

THE SIGNIFICANT DIFFERENCES BETWEEN THE MEAN DEHULLING INDEX FOR a-VALUES (DRY) VALUES OF DIFFERENT SORGHUM CULTIVARS

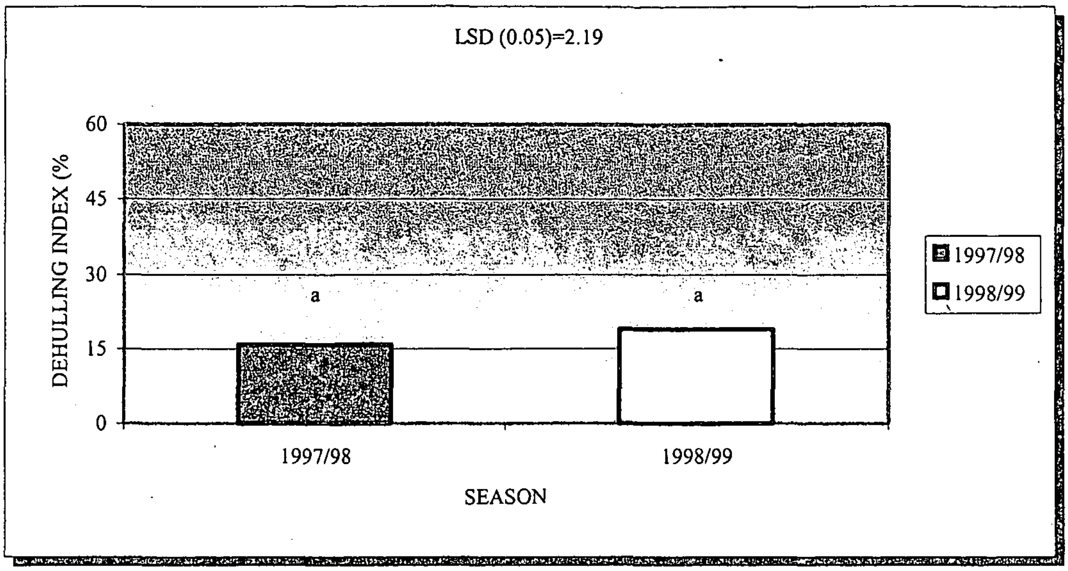


FIG 4.35

THE INSIGNIFICANT DIFFERENCES IN THE DEHULLING INDEX VALUE MEANS (DRY) OF THE a-VALUES OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

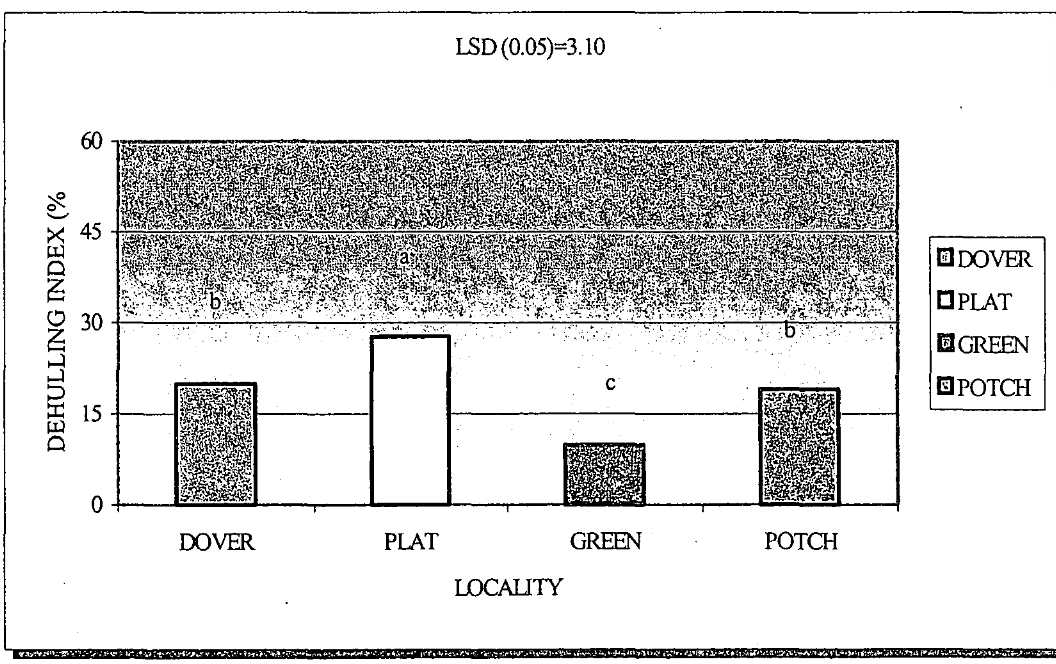


FIG. 4.36

THE DIFFERENCES IN THE DEHULLING INDEX VALUE MEANS (DRY) OF THE a-VALUES OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

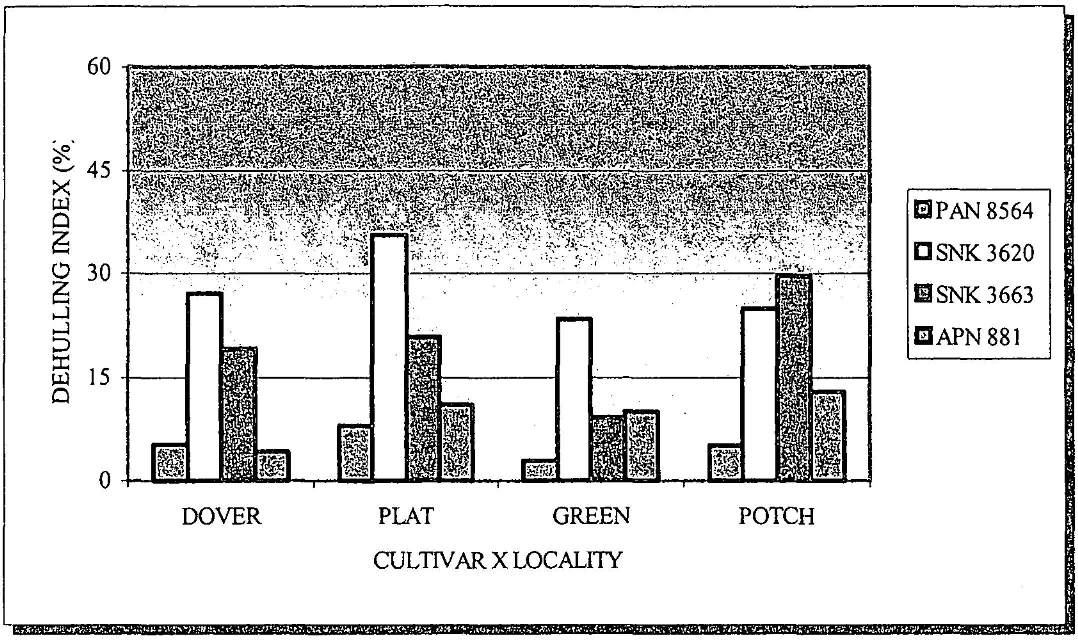


FIG. 4.37

THE CULTIVAR X LOCALITY INTERACTION OF SOME SORGHUM CULTIVARS FOR THE DEHULLING INDEX VALUE MEANS (DRY) OF THE a-VALUES

TABLE 4.38

THE DIFFERENCES IN THE DEHULLING INDEX VALUE MEANS (DRY) OF THE a-VALUES OF SORGHUM CULTIVARS OVER 2 SEASONS AT DIFFERENT LOCALITIES

Source	**df**	**Type III**	**SS**	**MS**	**F**	**P**
Blocks (SEASON)	1	42.7248	42.7248	1.0009	0.3222	ns
Main Effects						
CULTIVAR	23	23031.8719	1001.3857	23.4594	0.0000	***
LOCALITY	3	4964.0423	1654.6808	38.7642	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	22366.3036	324.1493	7.5938	0.0000	***
Error	47	2006.2335	42.6858	<-		
Total	143	46370.0804				

P=0.05

ns=not significant

TABLE 4.39

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN DEHULLING INDEX VALUE MEANS (DRY) OF THE a-VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	SNK 3883	54.83	6	a
2	PAN 8262	26.09	6	b
3	NK 283	24.64	6	b
4	SNK 3620	23.67	6	bc
5	PAN 8370	20.19	6	bcd
6	SNK 3663	19.26	6	bcde
7	NS 5511	18.99	6	bcde
8	ADV 5010	18.13	6	cdef
9	SNK 3863	17.54	6	def
10	PAN 8171	17.35	6	defg
11	PAN 8660	16.40	6	defg
12	PAN 8061	16.01	6	defg
13	SNK 3860	15.50	6	defg
14	PAN 8446	14.84	6	efgh
15	PAN 8272	14.09	6	efgh
16	NK 286	13.89	6	efghi
17	NS 5655	13.38	6	fghi
18	APN 881	12.47	6	fghi
19	SNK 3567	12.34	6	fghi
20	SNK 3337	11.83	6	fghi
21	SNK 3975	11.01	6	ghi
22	SNK 3443	10.23	6	ghi
23	SNK 3939	9.09	6	hi
24	PAN 8564	6.56	6	i

4.3.2.1.1.3 DEHULLING INDEX (DI) FOR L-VALUES (WET DETERMINATION)

Table 4.40 shows the DI values calculated from the L-values (wet determination) of 24 cultivars over 2 seasons at 3 localities per season. Significant differences between the DI value means of cultivars were found (Table 4.41; Fig. 4.38). The highest ranked cultivars for DI value means were SNK 3620, SNK 3860 and NS 5511 (Table 4.42). As explained in 4.3.2.1.1.1, the darkness in colour of these cultivars can be attributed to the fact that they are birdproof, with a dark condensed tannin layer underneath the pericarp. SNK 3337, ADV 5010, PAN 8446, NK 286, PAN 8272, APN 881, SNK 3443, SNK 3863, NK 283, SNK 3939, SNK 3975, SNK 3883, NS 5655 all corresponded ($p>0.05$) with the lowest ranked cultivar, namely PAN 8564 in DI value means. All these low-ranked cultivars were also ranked among the lowest ranked cultivars for the DI value of a-values (dry). These cultivars would need little dehulling, due to their light colour measured on a wet basis.

The DI for the L-values of sorghum on both a wet and dry base showed similar results for cultivars, localities and seasons and both displayed very high mean r values, namely 0.991 (dry) and 0.994 (wet). The r-values are the regression coefficient between the % dehulled of the products at each time interval and the colour at that specific point. Both can thus be used with success to determine the DI values, but the mean DI was higher for the wet determination. Consequently more of the grain has to be dehulled to deliver an acceptable colour on wet terms (mean=14.24 %), while less dehulling is necessary for the dry determination (mean=11.79 %). As losses are greater when colour is measured on a wet basis and the technique of the determination of the DI on a wet basis is faster, it might be necessary to only determine the DI on a dry basis, since both methods are equally successful in measuring the DI.

Significant differences in the DI value means over different seasons and at different localities were found (Table 4.41). The level of significance for seasons was less significant than for cultivars and localities. From Fig. 4.39 it is seen that lower DI values were found during the 1997/98 season, indicating that this season produced grain with a lighter colour, as was found with the DI of the L-values (dry determination).

Plat was the highest ranked locality for DI value means (Fig. 4.40), indicating that grain from this locality needed more dehulling to produce grain with an acceptable colour. Green showed the lowest DI values, but these values did not differ ($p>0.05$) significantly from those of Potch, while those of Potch did not differ from those of Dover. The cultivar x locality interaction was insignificant.

TABLE 4.40

DEHULLING INDEX FOR SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 PERIODS TO GIVE A L-VALUE OF 65.53 -(WET DETERMINATION)

CULTIVAR	DOVER		PLAT		GREEN				POTCH				MEAN	
	DI	r	DI	r	DI	r	DI	r	DI	r	DI	r	DI	
	1997 /98				1997 /98				1998 /99			1997 /98		1998 /99
ADV 5010	22.00	0.96	14.30	1.00	22.49	0.96	11.95	0.96	7.47	0.96	4.46	0.96	10.24	14.67
APN 881	9.28	0.96	14.84	1.00	9.77	0.96	11.48	0.96	12.86	0.96	3.69	0.96	10.00	11.98
NK 283	9.00	0.94	11.70	0.99	13.36	0.94	4.63	0.94	0.16	0.94	2.78	0.94	6.37	10.81
NK 286	14.48	0.95	13.57	0.98	17.15	0.95	6.72	0.95	8.01	0.95	6.93	0.95	9.07	13.20
NS 5511	44.05	0.96	32.77	0.99	37.21	0.96	31.27	0.96	21.12	0.96	16.66	0.96	26.90	32.52
NS 5655	15.90	0.99	6.08	0.99	10.63	0.99	5.78	0.99	6.40	0.99	0.85	0.99	4.24	9.00
PAN 8061	21.19	0.97	15.64	1.00	44.85	0.97	13.04	0.97	10.10	0.97	8.15	0.97	12.28	23.48
PAN 8171	18.06	0.89	14.57	0.99	28.03	0.89	12.18	0.89	9.15	0.89	11.99	0.89	12.91	19.25
PAN 8262	20.82	0.96	12.98	0.99	24.43	0.96	10.72	0.96	3.36	0.96	12.97	0.96	12.22	17.22
PAN 8272	15.11	0.99	14.21	1.00	26.81	0.99	1.42	0.99	7.12	0.99	4.34	0.99	6.66	15.46
PAN 8370	15.44	0.99	12.20	1.00	25.56	0.99	11.71	0.99	8.17	0.99	6.85	0.99	10.25	17.32
PAN 8446	18.64	1.00	11.51	1.00	23.61	1.00	9.05	1.00	9.70	1.00	4.93	1.00	8.49	15.31
PAN 8564	7.29	0.98	5.99	1.00	11.25	0.98	7.13	0.98	2.21	0.98	2.19	0.98	5.10	6.87
PAN 8660	19.82	0.98	15.42	1.00	22.05	0.98	7.62	0.98	7.48	0.98	6.89	0.98	9.97	16.58
SNK 3337	9.86	0.97	12.86	1.00	20.63	0.97	9.53	0.97	11.10	0.97	6.90	0.97	9.76	15.47
SNK 3443	1.08	0.96	8.68	1.00	13.13	0.96	14.50	0.96	5.15	0.96	5.99	0.96	9.72	9.95
SNK 3567	16.52	0.95	15.47	0.99	27.54	0.95	17.84	0.95	11.23	0.95	8.96	0.95	14.09	17.79
SNK 3620	65.43	0.94	51.11	0.99	46.93	0.94	28.30	0.94	27.90	0.94	19.04	0.94	32.82	37.70
SNK 3663	21.87	0.94	14.37	0.96	29.40	0.94	7.82	0.94	10.62	0.94	14.55	0.94	12.25	20.10
SNK 3860	72.45	0.99	46.44	0.99	48.71	0.99	34.83	0.99	27.64	0.99	15.20	0.99	32.16	37.92
SNK 3863	17.98	0.93	8.70	0.95	16.25	0.93	9.07	0.93	7.72	0.93	4.66	0.93	7.48	11.96
SNK 3883	44.94	0.88	7.78	0.99	3.60	0.88	10.79	0.88	4.03	0.88	14.82	0.88	11.13	3.05
SNK 3939	9.36	0.99	4.47	1.00	10.12	0.99	4.16	0.99	2.93	0.99	15.41	0.99	8.02	7.97
SNK 3975	17.24	0.99	10.48	0.99	9.82	0.99	6.99	0.99	5.61	0.99	3.28	0.99	6.91	8.65
MEAN	21.99	0.96	15.67	0.99	22.64	0.96	12.02	0.96	9.47	0.96	8.44	0.96	12.04	16.43
MIN	1.08	0.88	4.47	0.95	3.60	0.88	1.42	0.88	0.16	0.88	0.85	0.88	4.24	3.05
MAX	72.45	1.00	51.11	1.00	48.71	1.00	34.83	1.00	27.90	1.00	19.04	1.00	32.82	37.92
RANGE	71.36	0.12	46.64	0.05	45.11	0.12	33.41	0.12	27.74	0.12	18.19	0.12	28.58	34.87
SD	17.86	0.03	11.55	0.01	12.30	0.03	8.36	0.03	7.03	0.03	5.27	0.03	7.64	8.93

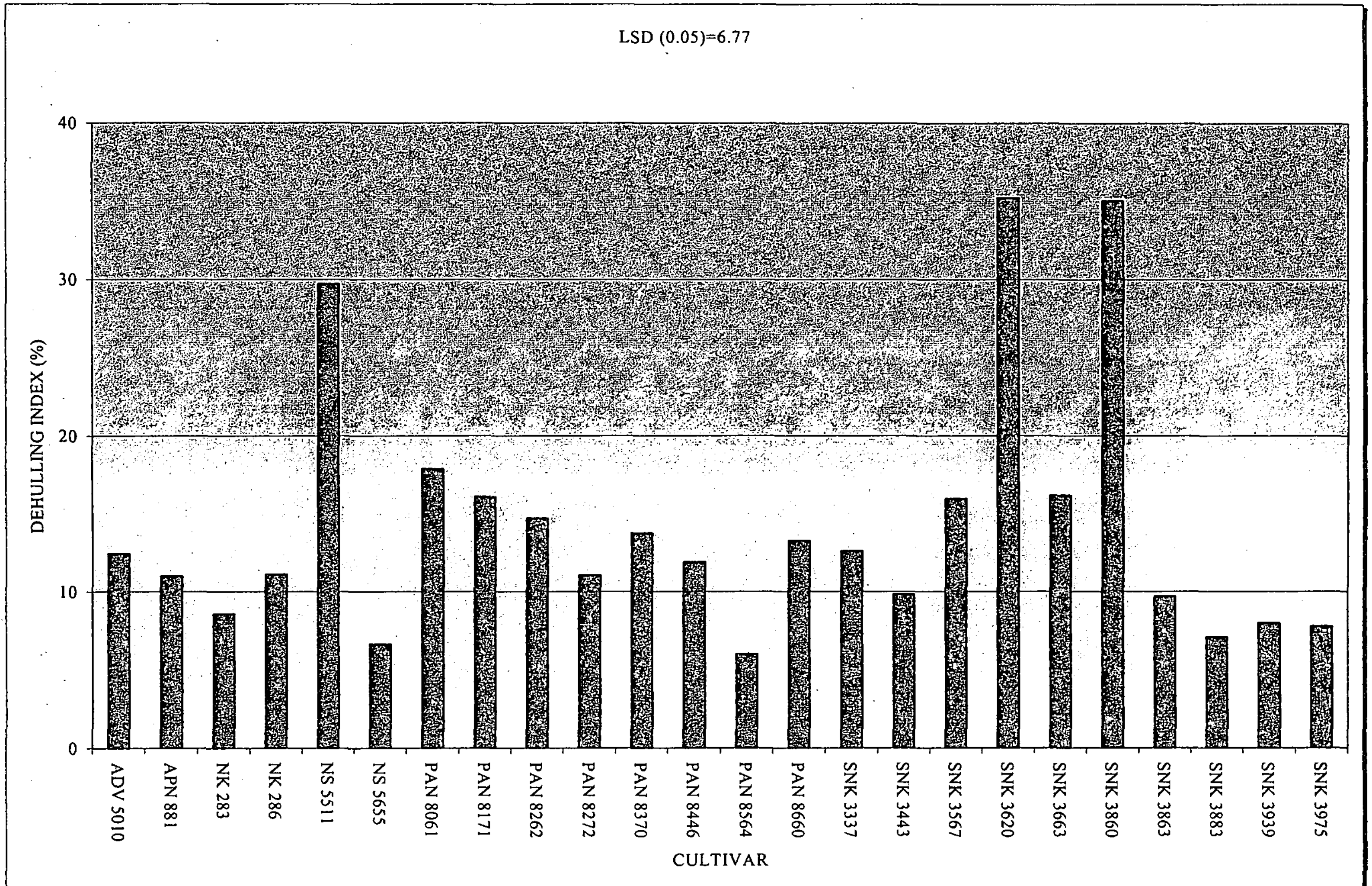


FIG. 4.38

THE SIGNIFICANT DIFFERENCES BETWEEN THE MEAN DEHULLING INDEX FOR L-VALUES (WET) OF DIFFERENT SORGHUM CULTIVARS

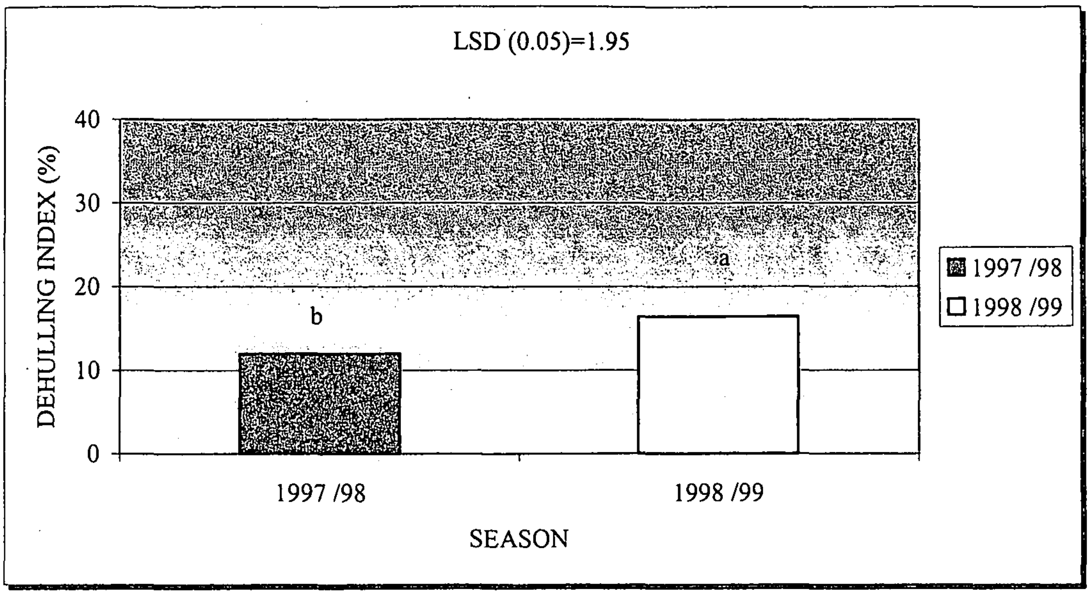


FIG. 4.39

THE DIFFERENCES IN THE DEHULLING INDEX VALUE MEANS (WET) OF THE L-VALUES OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

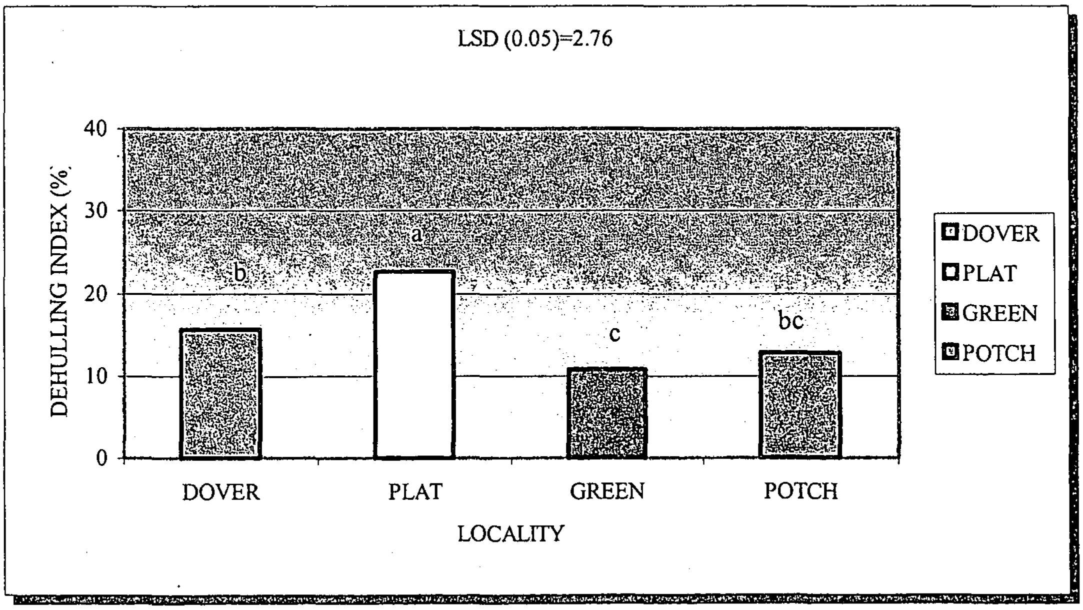


FIG. 4.40

THE DIFFERENCES IN THE DEHULLING INDEX VALUE MEANS (WET) OF THE L-VALUES OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 4.41

THE DIFFERENCES IN THE DEHULLING INDEX VALUE MEANS (WET) OF THE L-VALUES OF SORGHUM CULTIVARS OVER 2 SEASONS AT DIFFERENT LOCALITIES

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	229.1662	229.1662	6.7509	0.0125	*
Main Effects						
CULTIVAR	23	9629.1185	418.6573	12.3331	0.0000	***
LOCALITY	3	1965.4018	655.1339	19.2994	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	2088.6634	30.2705	0.8917	0.6718	ns
Error	47	1595.4576	33.9459	<-		
Total	143	15399.0589				

P=0.05

ns=not significant

TABLE 4.42

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN DEHULLING INDEX VALUE MEANS (WET) OF L-VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	SNK 3620	35.257	6	a
2	SNK 3860	35.040	6	a
3	NS 5511	29.709	6	a
4	PAN 8061	17.876	6	b
5	SNK 3663	16.174	6	bc
6	PAN 8171	16.081	6	bc
7	SNK 3567	15.936	6	bc
8	PAN 8262	14.721	6	bcd
9	PAN 8370	13.783	6	bcde
10	PAN 8660	13.279	6	bcdef
11	SNK 3337	12.618	6	bcdefg
12	ADV 5010	12.451	6	bcdefg
13	PAN 8446	11.904	6	bcdefg
14	NK 286	11.138	6	bcdefg
15	PAN 8272	11.058	6	cdefg
16	APN 881	10.989	6	cdefg
17	SNK 3443	9.838	6	cdefg
18	SNK 3863	9.718	6	cdefg
19	NK 283	8.591	6	defg
20	SNK 3939	7.994	6	defg
21	SNK 3975	7.780	6	efg
22	SNK 3883	7.090	6	efg
23	NS 5655	6.618	6	fg
24	PAN 8564	5.985	6	g

4.3.2.1.1.4 DEHULLING INDEX (DI) FOR a-VALUES (WET DETERMINATION)

Table 4.43 indicates the DI values for the a-value (wet determination) of 24 sorghum cultivars over 2 seasons at 3 localities per season. Significant differences in the cultivar DI value means were found (Table 4.44; Fig. 4.41). SNK 3620 was not significant different from ($p>0.05$) the highest ranked cultivar (SNK 3860) in DI value means, while NS 551 corresponded ($p>0.05$) with SNK 3620 in DI value (Table 4.45). Again, it is seen that these birdproof cultivars needed more dehulling than other cultivars. SNK 3883 is again, as in the case with the DI for the a-values on a dry basis, ranked very high. This is due to the same reasons as explained in 4.3.2.1.1.2, as it is again noticed that the colour of SNK 3883 was lighter in redness than the standard (Table 4.33), even before dehulling (a-value=3.85). This again indicates that the a-value is a less valuable indicator of the DI, than lightness, which is measured by the L-value. SNK 3567, NK 283, SNK 3939, SNK 3337, APN 881 and PAN 8564 all corresponded with the lowest ranked cultivar SNK 3443, in DI value means ($p>0.05$). These cultivars were also ranked low in terms of the DI for the a-value (dry basis), except for SNK 3567 and NK 283.

The DI value means over different seasons were not significant different (Table 4.44; Fig. 4.42), while the influence of locality on DI values were significant. From Fig. 4.43 it is seen that the highest ($p<0.05$) DI values are found at Plat and the lowest values were found at Green. The second highest ($p<0.05$) were found at Dover, followed by Potch. Again, it is confirmed that grain from Green had the lightest colour, while the colour of grain from Plat was darker and more dehulling would be necessary to obtain an acceptable colour. The cultivar x locality interaction was insignificant (Table 4.44).

When the DI is calculated for the L-values (both wet and dry) all three main effects were found to be significant (Table 4.31 and 4.45), while only two of the three main effects were significant in each case with the DI of the a-values (Table 4.38 and 4.44). It is therefore clear that the L-values are a better means of determining the DI of cultivars.

The DI values are higher when wet L-values are used, indicating that the dry L-values are better indicators of the DI values and they are less labour-intensive to determine.

The DI for the WI was also determined, as the WI indicates whiteness. These values for the wet and dry determination of the DI were not used though, as r-values for the dry values ranged from 0.37 to 1.00 (mean=0.94) and DI value from 0.222 to 22535.36 (mean=195.1782). The r of wet values ranged from 0.20 to 0.999 (mean=0.902) and DI values from 0.064 to 238309.9 (mean=1872.97). As the use DI of the WI values was senseless for both wet and dry determinations, it was left out of consideration and instead the L-values were used for the calculation of the DI values.

TABLE 4.43

DEHULLING INDEX FOR SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 PERIODS TO GIVE AN a-VALUE OF 5.9 -(WET DETERMINATION)

CULTIVAR	DOVER		PLAT		GREEN				POTCH				MEAN	
	DI	r	DI	r	DI	r	DI	r	DI	r	DI	r	DI	
	1998 /99		1997 /98		1998 /99		1997 /98				1998 /99			1998 /99
ADV 5010	38.90	1.00	20.85	1.00	17.01	1.00	22.16	1.00	33.27	0.97	38.90	1.00	21.67	29.73
APN 881	14.07	0.99	10.32	0.98	10.97	1.00	13.52	0.99	12.06	0.97	14.07	0.99	11.04	12.37
NK 283	20.91	0.98	5.08	0.98	0.75	0.94	25.06	0.96	29.82	0.98	20.91	0.98	13.05	17.16
NK 286	27.18	0.99	12.76	0.98	12.01	1.00	29.97	0.99	24.69	1.00	27.18	0.99	19.07	21.29
NS 5511	64.63	1.00	41.76	1.00	32.79	1.00	41.19	0.99	63.01	0.99	64.63	1.00	42.33	53.48
NS 5655	27.32	0.99	14.06	1.00	16.15	1.00	25.91	1.00	23.40	0.98	27.32	0.99	18.62	22.29
PAN 8061	35.25	1.00	17.13	1.00	15.92	1.00	38.87	1.00	25.84	1.00	35.25	1.00	25.73	25.67
PAN 8171	35.14	0.98	10.78	1.00	12.08	1.00	20.21	0.98	32.72	1.00	35.14	0.98	16.35	26.65
PAN 8262	53.32	0.99	14.05	0.98	8.98	1.00	62.56	0.98	41.90	1.00	53.32	0.99	32.48	34.73
PAN 8272	27.86	1.00	16.05	1.00	11.54	1.00	19.09	0.99	22.56	0.99	27.86	1.00	16.75	20.65
PAN 8370	33.57	0.98	15.57	1.00	13.12	1.00	28.35	1.00	29.66	0.99	33.57	0.98	19.79	25.45
PAN 8446	30.53	1.00	13.70	1.00	13.55	1.00	25.84	1.00	23.86	0.99	30.53	1.00	19.39	22.65
PAN 8564	14.21	0.97	7.80	1.00	1.36	0.87	13.45	0.99	9.35	0.95	14.21	0.97	9.51	8.31
PAN 8660	34.69	0.99	12.27	0.99	11.80	1.00	28.68	0.99	29.46	0.97	34.69	0.99	20.25	25.32
SNK 3337	15.49	0.98	9.58	1.00	8.98	0.99	26.05	1.00	17.12	0.98	15.49	0.98	15.16	13.86
SNK 3443	6.59	1.00	5.68	1.00	4.07	1.00	21.52	0.99	9.07	0.99	6.59	1.00	9.43	6.58
SNK 3567	14.03	1.00	12.35	0.97	9.29	1.00	27.21	1.00	15.34	1.00	14.03	1.00	18.70	12.89
SNK 3620	76.80	0.98	39.10	0.99	37.85	1.00	41.65	1.00	54.38	1.00	76.80	0.98	48.72	56.34
SNK 3663	22.46	1.00	9.94	1.00	12.46	1.00	39.78	1.00	25.50	0.99	22.46	1.00	23.86	20.14
SNK 3860	80.40	1.00	49.26	1.00	39.22	1.00	41.65	1.00	59.33	0.98	80.40	1.00	54.45	59.65
SNK 3863	44.02	0.99	15.61	0.97	15.18	1.00	25.91	1.00	23.02	0.99	44.02	0.99	19.83	27.40
SNK 3883	63.63	0.99	47.52	0.97	9.71	0.84	11.37	1.00	36.15	0.99	63.63	0.99	34.61	36.50
SNK 3939	22.67	1.00	7.49	0.99	9.61	0.98	22.64	0.96	16.67	0.99	22.67	1.00	13.16	16.32
SNK 3975	20.00	0.99	11.49	0.98	11.08	0.99	27.47	1.00	19.13	1.00	20.00	0.99	18.73	16.74
MEAN	34.32	0.99	17.51	0.99	13.98	0.98	28.34	0.99	28.22	0.99	34.32	0.99	22.61	25.51
MIN	6.59	0.97	5.08	0.97	0.75	0.84	11.37	0.96	9.07	0.95	6.59	0.97	9.43	6.58
MAX	80.40	1.00	49.26	1.00	39.22	1.00	62.56	1.00	63.01	1.00	80.40	1.00	54.45	59.65
RANGE	73.81	0.03	44.18	0.03	38.47	0.16	51.19	0.04	53.94	0.05	73.81	0.03	45.02	53.07
SD	20.16	0.01	12.92	0.01	9.69	0.04	11.36	0.01	14.42	0.01	20.16	0.01	11.83	14.09

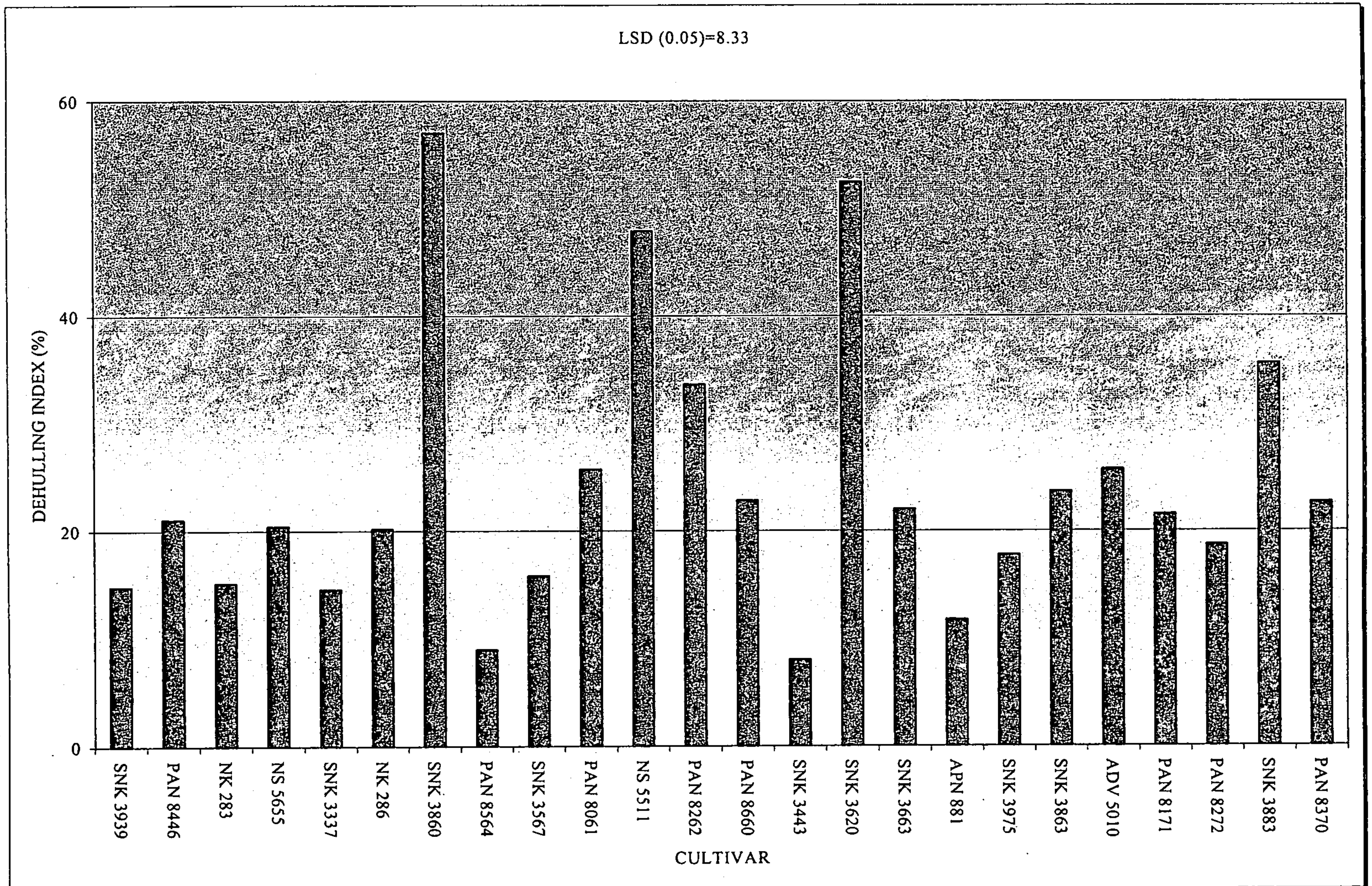


FIG. 4.41

THE SIGNIFICANT DIFFERENCES BETWEEN THE MEAN DEHULLING INDEX FOR a-VALUES (WET) OF DIFFERENT SORGHUM CULTIVARS

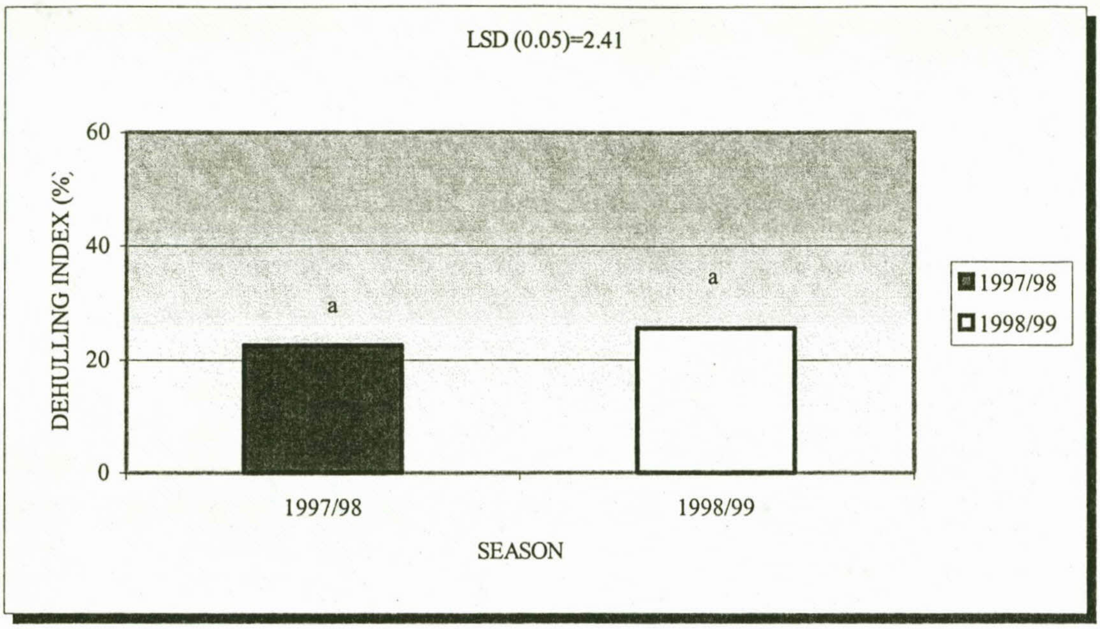


FIG. 4.42

THE INSIGNIFICANT DIFFERENCES IN THE DEHULLING INDEX VALUE MEANS (WET) OF THE a-VALUE OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

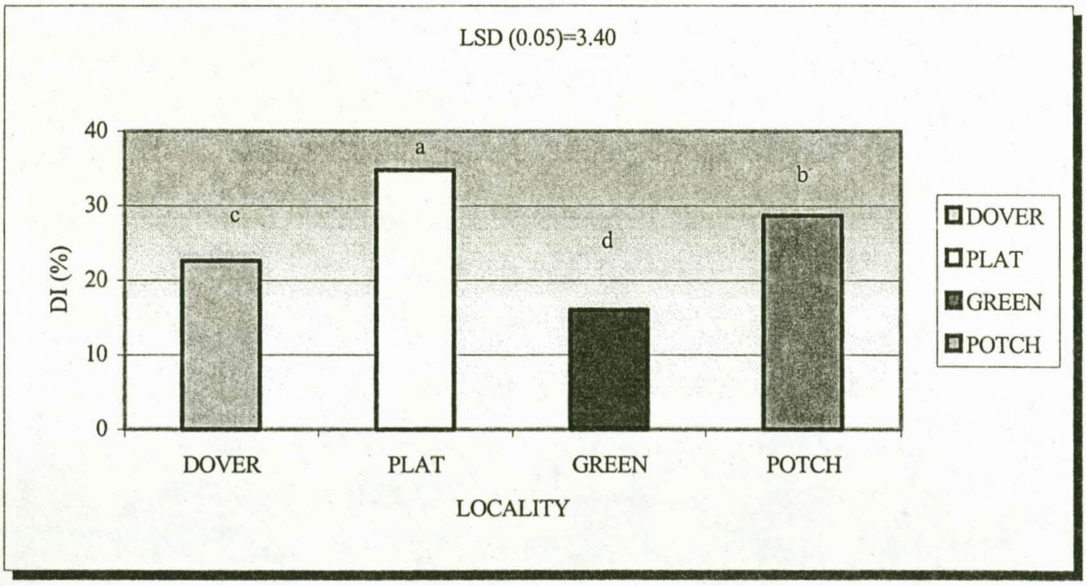


FIG. 4.43

THE DIFFERENCES IN THE DEHULLING INDEX VALUE MEANS (WET) OF THE a-VALUE OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 4.44

THE DIFFERENCES IN THE DEHULLING INDEX VALUE MEANS (WET) OF THE a-VALUES OF SORGHUM CULTIVARS OVER 2 SEASONS AT DIFFERENT LOCALITIES

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	79.7730	79.7730	1.5494	0.2194	ns
Main Effects						
CULTIVAR	23	24665.5319	1072.4144	20.8287	0.0000	***
LOCALITY	3	6582.0567	2194.0189	42.6127	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	5071.7241	73.5032	1.4276	0.0985	ns
Error	47	2419.9100	51.4874	<-		
Total	143	37076.5109				

P=0.05

ns=not significant

TABLE 4.45

RANKING OF SORGHUMCULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN DEHULLING INDEX VALUE MEANS (WET) OF a-VALUES

Rank	Cultivar	Mean	n	Groups not significantly different
1	SNK 3860	57.050	6	a
2	SNK 3620	52.531	6	ab
3	NS 5511	47.906	6	b
4	SNK 3883	35.553	6	c
5	PAN 8262	33.604	6	cd
6	PAN 8061	25.699	6	de
7	ADV 5010	25.698	6	de
8	SNK 3863	23.618	6	ef
9	PAN 8660	22.787	6	efg
10	PAN 8370	22.617	6	efg
11	SNK 3663	22.001	6	efg
12	PAN 8171	21.499	6	efg
13	PAN 8446	21.020	6	efg
14	NS 5655	20.456	6	efg
15	NK 286	20.181	6	efg
16	PAN 8272	18.700	6	efgh
17	SNK 3975	17.734	6	efgh
18	SNK 3567	15.792	6	fghi
19	NK 283	15.104	6	ghi
20	SNK 3939	14.739	6	ghi
21	SNK 3337	14.514	6	ghi
22	APN 881	11.702	6	hi
23	PAN 8564	8.910	6	i
24	SNK 3443	8.002	6	i

4.3.2.2 ROLLER-MILLED SAMPLES

4.3.2.2.1 L-VALUES

Due to the results obtained for the DI of the L and a-values of sorghum meal on a dry basis, it was decided to only do colour measurements on roller-milled samples on a dry basis, as more meaningful results were obtained when colour measurements were made this way. The L-values of different sorghum cultivars over 2 seasons at 3 localities per season can be seen in Table 4.46. Highly significant differences between the L-value means of different cultivars were found (Table 4.47; Fig. 4.44). The white cultivar SNK 3883 was the highest ranked cultivar for L-value means, thereby indicating the whiteness of the meal of this cultivar. SNK 3863, SNK 3975, SNK 3939 and PAN 8564 all corresponded with the second ranked cultivar (NS 5655) in L-value means ($p>0.05$) (Table 4.48). All these cultivars mentioned above, as well as PAN 8272, PAN 8171, PAN 8262 and SNK 3443, had L-value means above the L-value mean of the commercial samples of 78.00 (Table 4.33). These cultivars would therefore reach L-value of 78.00 of the standard without dehulling before milling, by simple dry milling with the roller mills. Therefore roller milling gives the colour of the standard without the necessity of dehulling as in the case of abrasive milling. Other cultivars, namely PAN 8370, NK 286, NK 283, ADV 5010, PAN 8061, PAN 8446, SNK 3663, PAN 8660, SNK 3567 and SNK 3337 did not differ ($p>0.05$) from SNK 3443 that meets the requirement of the standard and are therefore also acceptable in terms of colour. Therefore, the only cultivars that fall outside this group are APN 881, SNK 3860, NS 5511 and SNK 3620. The latter three cultivars, which are the birdproof cultivars, did not differ ($p>0.05$) from one another in L-value means and had the lowest L-values. As in the case of the TADD samples (4.3.2.1.1), these birdproof cultivars are unacceptable in terms of milling quality, due to poor colour properties.

TABLE 4.46

L-VALUES FOR SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 PERIODS MILLED ON ROLLER MILLS

CULTIVAR	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99
ADV 5010	77.25	77.94	78.91	79.03	75.41	77.12	77.19	78.03	1.75	0.96
APN 881	76.06	77.38	75.70	75.68	75.04	76.35	75.60	76.47	0.52	0.86
NK 283	76.59	77.24	79.09	80.76	75.17	77.48	76.95	78.49	1.98	1.97
NK 286	79.61	77.71	77.97	79.08	74.68	77.55	77.42	78.11	2.51	0.84
NS 5511	74.37	75.18	73.25	74.02	72.53	74.99	73.38	74.73	0.93	0.62
NS 5655	80.63	80.50	80.83	79.98	77.02	79.49	79.49	79.99	2.14	0.51
PAN 8061	77.27	78.44	78.21	78.44	75.53	77.63	77.00	78.17	1.36	0.47
PAN 8171	78.81	78.60	80.04	79.18	76.82	77.55	78.56	78.44	1.62	0.83
PAN 8262	77.80	77.96	80.47	80.75	74.11	79.11	77.46	79.27	3.19	1.40
PAN 8272	78.05	78.67	79.34	79.54	76.74	78.87	78.04	79.03	1.30	0.46
PAN 8370	77.94	77.31	77.92	79.1	76.36	78.24	77.41	78.22	0.91	0.90
PAN 8446	77.72	77.71	78.03	79	75.27	77.19	77.01	77.97	1.51	0.93
PAN 8564	79.93	80.53	79.20	80.6	77.48	79.55	78.87	80.23	1.26	0.59
PAN 8660	78.77	77.32	78.79	78.3	74.11	77.04	77.22	77.55	2.70	0.66
SNK 3337	77.53	77.53	78.02	78.08	74.46	76.91	76.67	77.51	1.93	0.59
SNK 3443	77.83	78.79	79.05	80.36	74.26	77.86	77.05	79.00	2.49	1.26
SNK 3567	78.05	77.11	77.14	79.51	74.36	78.13	76.52	78.25	1.92	1.20
SNK 3620	74.46	75.78	71.83	72.8	71.68	73.52	72.66	74.03	1.56	1.55
SNK 3663	77.24	78.29	79.46	79.03	73	77.71	76.57	78.34	3.28	0.66
SNK 3860	74.53	74.86	73.95	74.05	72.48	75.43	73.65	74.78	1.06	0.69
SNK 3863	79.47	79.01	80.16	80.25	77.63	80.04	79.09	79.77	1.31	0.66
SNK 3883	83.47	83.67	83.35	84.39	82.08	83.88	82.97	83.98	0.77	0.37
SNK 3939	79.18	80.53	79.39	80.78	77.73	79.68	78.77	80.33	0.90	0.58
SNK 3975	80.12	80.30	79.69	80.68	77.36	78.95	79.06	79.98	1.49	0.91
MEAN	78.03	78.27	78.32	78.89	75.47	77.93	77.27	78.36		
MIN	74.37	74.86	71.83	72.80	71.68	73.52	72.66	74.03		
MAX	83.47	83.67	83.35	84.39	82.08	83.88	82.97	83.98		
RANGE	9.10	8.81	11.52	11.59	10.40	10.36	10.31	9.95		
SD	2.06	1.90	2.52	2.54	2.23	2.00	2.14	2.06		

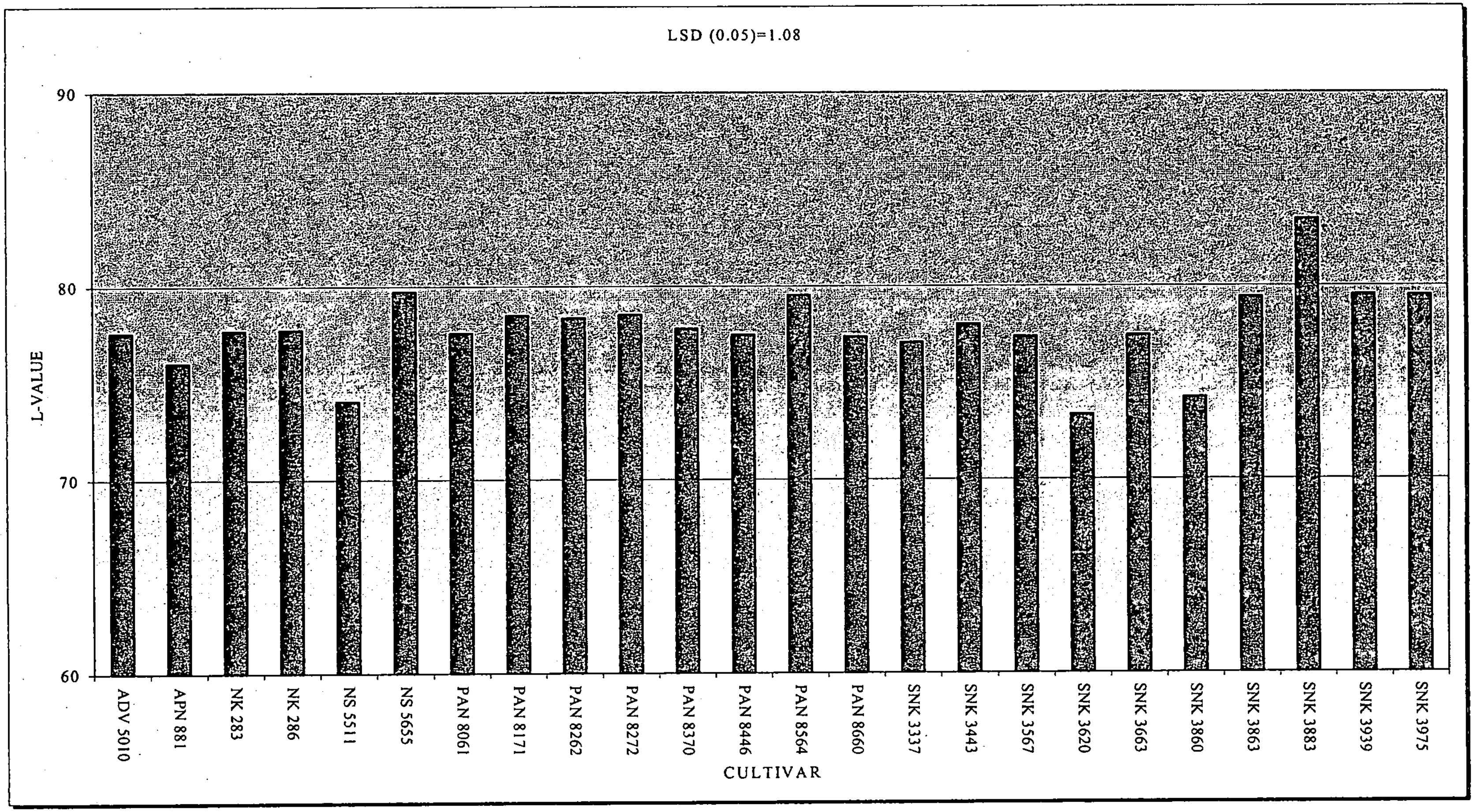


FIG. 4.44

THE SIGNIFICANT DIFFERENCES BETWEEN THE MEAN L-VALUES OF DIFFERENT SORGHUM CULTIVARS

Figures 4.45, 4.46 and 4.47 illustrate the effect of TADD milling compared to roller milling on a red, birdproof and white sorghum cultivar respectively. With red sorghum it is clear that both TADD milling (Fig. 4.45(c)) and roller milling (Fig. 4.45(e)) were able to improve the colour of meal. Milling of whole grain (Fig. 4.45(b)) was unsuccessful in the development of a light acceptable colour meal. Even the colour of whole grain showed an improvement after 3 min of dehulling (Fig. 4.45(d)). In this example for red sorghum (NK 283) (Fig. 4.45), roller milling was able to produce a whiter meal than in the case where TADD abrasive milling was used, but this may vary with other cultivars. In the case of birdproof sorghum (NS 5511) (Fig. 4.46), TADD and roller milling did little to improve the colour of the meal (Fig. 4.46(b) and (e)). It is also clear that dehulling for 3 min was not enough to remove the dark colour of condensed tannins underneath the pericarp of grain (Fig. 4.46(d)). Roller milling however improved the colour of birdproof sorghum meal somewhat, but the meal was still darker than that of red sorghum. Again, roller milling is a better means for the milling of birdproof sorghum as is the case with red sorghum, although the meal may still have an astringent taste (Chapter 1). Sorghum that is already white to begin with (SNK 3883) (Fig. 4.47 (a)) was already light in colour and milling with the roller mill (Fig. 4. 47(e)) improved the colour even more. Again, TADD abrasive milling for 3 min was found to improve the colour of the whole grain (Fig. 4.47(d)), but differences in the meal of dehulled and whole grain were not very clear (Fig. 4.47(b) and (c)).

In the case of NK 283, NS 5511 and SNK 3883 DI values with the TADD was 7.27, 20.88 and 3.96 % respectively, i.e. extraction values of 92.73, 79.12 and 96.04 % respectively. With roller milling extraction values for the same cultivars were 80.61, 79.69 and 81.39 % respectively. Extraction values were thus higher for these three cultivars in the case of TADD milling, when dehulled to a specific colour, but bran levels might still be high at this colour value.

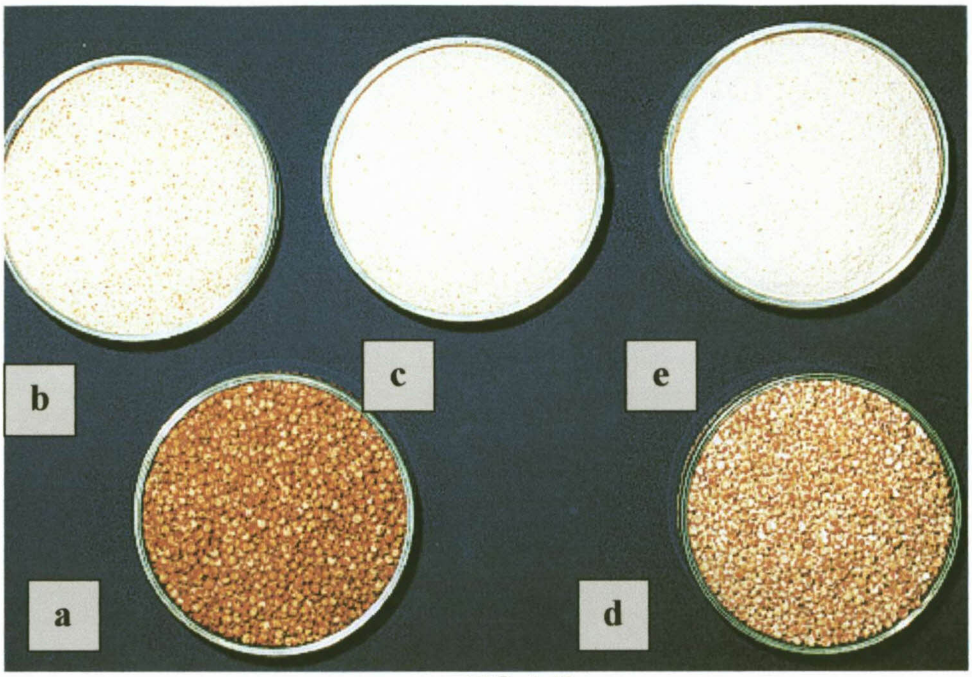


FIG. 4.45

COMPARISON OF THE EFFECT OF TADD AND ROLLER MILLING ON THE COLOUR OF RED SORGHUM (NK 283): (a) WHOLE GRAIN (b) MEAL OF WHOLE GRAIN MILLED ON SAMPLE MILL (c) MEAL OF WHOLE GRAIN MILLED ON ROLLER MILL (d) GRAIN AFTER 3 MIN OF TADD DEHULLING (e) MEAL OF 3 MIN OF TADD DEHULLED GRAIN

Highly significant differences in the L-value means over different seasons and at different localities were found (Table 4.47). Higher L-value means were found during the 1998/99 season than during the previous season (Fig. 4.48). In Fig. 4.48 it was seen that the DI values were lower during the 1997/98 season, indicating whiter grain obtained by abrasion during this season. It seems therefore as if the roller mills improved the colour of grain from the 1998/99 season during the milling process. The colour of grain from the 1997/98 season was still very good after roller milling, though (mean=77.27).

FIG. 4.46

COMPARISON OF THE EFFECT OF TADD AND ROLLER MILLING ON THE COLOUR OF BIRDPROOF SORGHUM (NS 5511): (a) WHOLE GRAIN (b) MEAL OF WHOLE GRAIN MILLED ON SAMPLE MILL (c) MEAL OF WHOLE GRAIN MILLED ON ROLLER MILL (d) GRAIN AFTER 3 MIN OF TADD DEHULLING (e) MEAL OF 3 MIN TADD DEHULLED GRAIN

Meal of sorghum from Potch prepared by roller milling was significantly darker in colour (low L-values) than those from other localities (Fig. 4.49). The highest ranked locality for L-value means was Green, but the value was not significantly different from that of the second ranked locality, Plat. The colour of grain from Dover did not differ ($p>0.05$) from that of Plat. These results differed from those found in 4.3.2.1.1.1 for the DI of the L-values of TADD-samples (dry), where the lightest coloured meal was found with grain from Potch and Green and the darkest coloured meal was found at Plat and Dover. In both cases the meal of grain from Green was found to be lighter in colour, which emphasises the good colour properties of the meal of grain from this locality. The cultivar x locality interaction was insignificant.

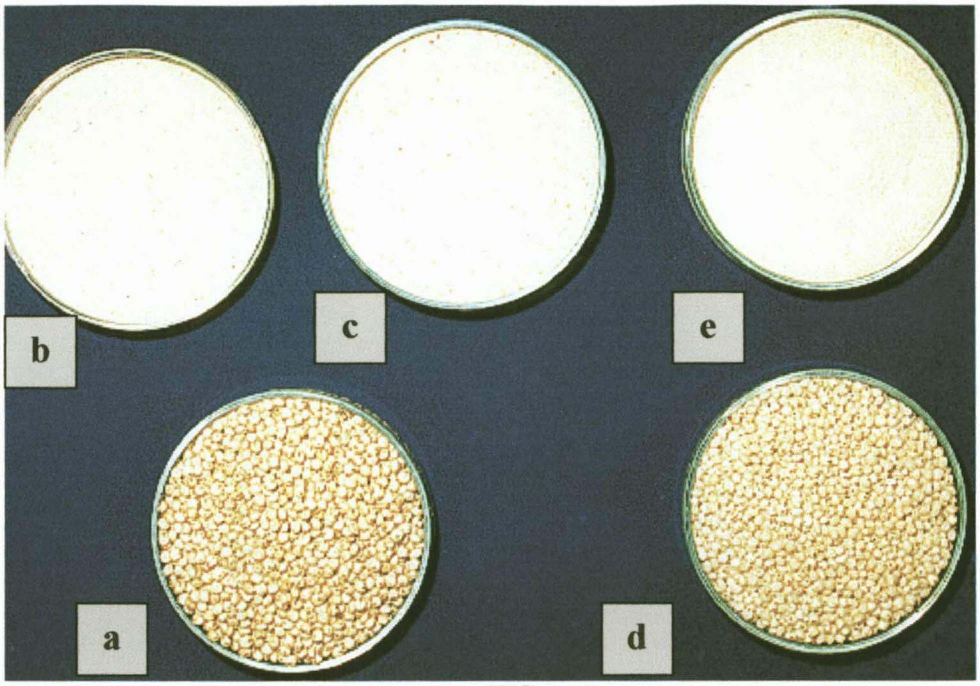


FIG. 4.47

COMPARISON OF THE EFFECT OF TADD AND ROLLER MILLING ON THE COLOUR OF WHITE SORGHUM (SNK 3883): (a) WHOLE GRAIN (b) MEAL OF WHOLE GRAIN MILLED ON SAMPLE MILL (c) MEAL OF WHOLE GRAIN MILLED ON ROLLER MILL (d) GRAIN AFTER 3 MIN OF TADD DEHULLING (e) MEAL OF 3 MIN TADD DEHULLED GRAIN

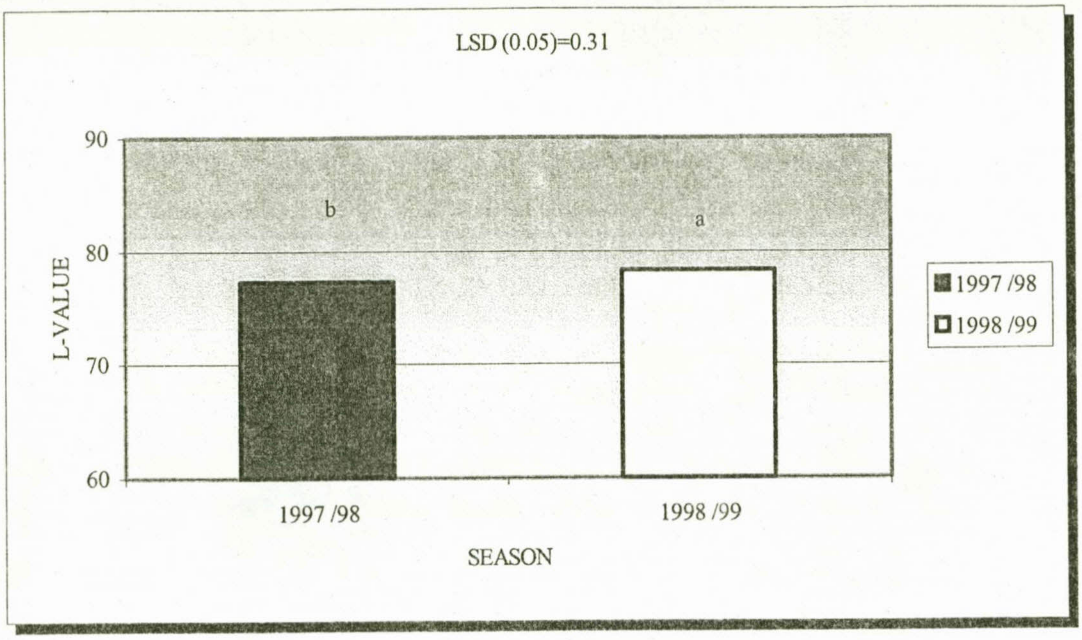


FIG. 4.48

THE DIFFERENCES IN THE L-VALUE VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

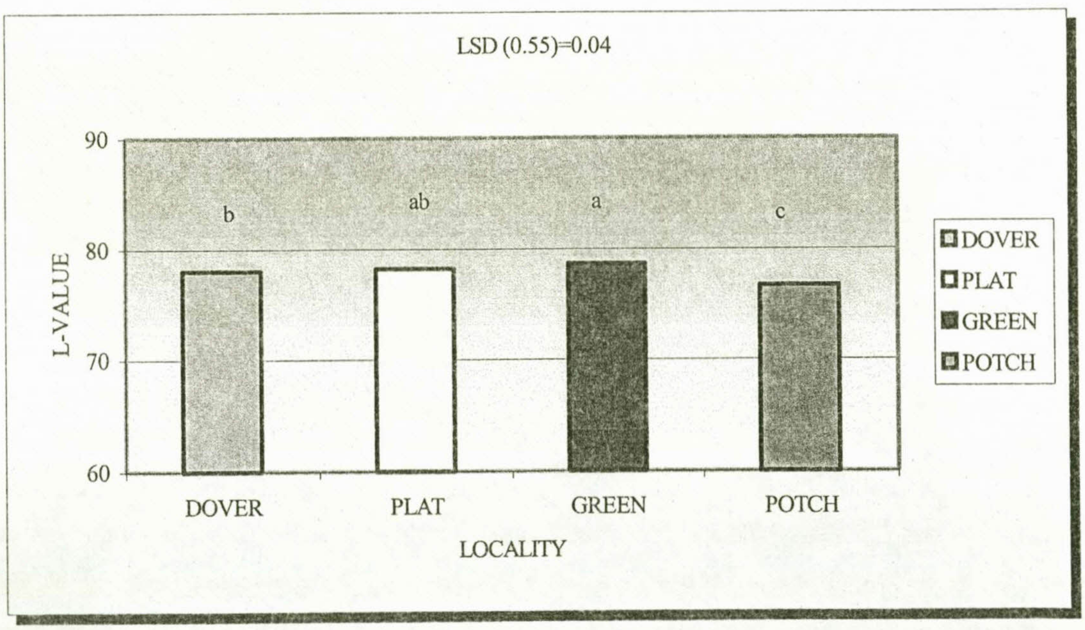


FIG. 4.49

THE DIFFERENCES IN THE L-VALUE VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

TABLE 4.47

THE DIFFERENCES IN THE L-VALUE MEANS OF SORGHUM CULTIVARS OVER 2 SEASONS AT DIFFERENT LOCALITIES

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	54.8433	54.8433	63.3748	0.0000	***
Main Effects						
CULTIVAR	23	509.0065	22.1307	25.5734	0.0000	***
LOCALITY	3	108.1816	36.0605	41.6702	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	62.9068	0.9117	1.0535	0.4298	ns
Error	47	40.6728	0.8654	<-		
Total	143	854.4401				

P=0.05

ns=not significant

TABLE 4.48

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN L-VALUE MEANS

Rank	Cultivar	Mean	n	Groups of not significantly different
1	SNK 3883	83.473	6	a
2	NS 5655	79.742	6	b
3	PAN 8564	79.548	6	bc
4	SNK 3939	79.548	6	bc
5	SNK 3975	79.517	6	bc
6	SNK 3863	79.427	6	bcd
7	PAN 8272	78.535	6	cde
8	PAN 8171	78.500	6	cde
9	PAN 8262	78.367	6	def
10	SNK 3443	78.025	6	efg
11	PAN 8370	77.812	6	efg
12	NK 286	77.767	6	efg
13	NK 283	77.722	6	efg
14	ADV 5010	77.610	6	efg
15	PAN 8061	77.587	6	efg
16	PAN 8446	77.487	6	efg
17	SNK 3663	77.455	6	efg
18	PAN 8660	77.388	6	fg
19	SNK 3567	77.383	6	fg
20	SNK 3337	77.088	6	gh
21	APN 881	76.035	6	h
22	SNK 3860	74.217	6	i
23	NS 5511	74.057	6	i
24	SNK 3620	73.345	6	i

4.3.2.2.2 a-VALUES

The a-values of cultivars grown over 2 seasons and 3 localities per season, milled on the roller mills, are shown in Table 4.49. Significant differences in a-value means of different cultivars were found (Table 4.50; Fig. 4.50). All other main effects, as well as the cultivar x locality interaction, were also significant. The lightest coloured cultivar, ranked in the lowest position for a-value means, again was SNK 3883 (Table 4.51). PAN 8272, NS 5655, SNK 3860 and SNK 3443 all corresponded ($p>0.05$) with the second lowest ranked cultivar (PAN 8564) for a-value means. All these cultivars with light coloured meal had lower a-values than the commercial standard a-value of 3.99 (Table 4.33). All other cultivars are more red in colour than the standard. The highest a-value cultivar was ADV 5010, indicating that this cultivar was more red in colour than the other cultivars. The second ranked cultivar for a-value means was APN 881, but this cultivar corresponded with many other cultivars in a-value means.

From Fig. 4.51 it is seen that the highest a-value means were found during the 1997/98 season. In 4.3.2.1.2.1 this season also had lower L-values, indicating darker grain, as the level of redness (a-values higher) in meal of grain from this season increased. In general roller-milled meal from the 1998/99 season was lighter.

Meal of sorghum from Potch displayed the highest a-values, while the lowest a-values were found in meal of grain from Green and Plat (Fig. 4.52). The second highest a-values were found in meal from the Dover locality. Therefore, the best-coloured meal in terms of the a-values was from Green and Plat, while those of Dover and Potch showed poor colour properties when a-values were considered. These results of colour properties of roller-milled meal were similar to that in 4.3.2.1.2.1 and the same localities showed good colour quality properties.

Fig. 4.53 illustrates the cultivar x locality interaction at the hand of three cultivars. NK 283 and ADV 5010 for example, had lower a-values at Green than at other localities, while SNK 3883 showed lower values at Potch.

TABLE 4.49

THE a-VALUES FOR SORGHUM CULTIVARS OVER 2 PERIODS AT 3 LOCALITIES PER SEASON MILLED ON ROLLER MILLLS

CULTIVAR	DOVER	PLAT	GREEN		POTCH		MEAN		SD	
	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99	1997 /98	1998 /99
ADV 5010	4.78	5.20	4.66	4.35	5.18	5.24	4.87	4.93	0.27	0.50
APN 881	4.16	4.17	4.68	4.45	4.97	4.59	4.60	4.40	0.41	0.21
NK 283	4.12	4.66	3.96	2.97	4.82	4.60	4.30	4.08	0.46	0.96
NK 286	3.51	4.62	4.41	3.70	5.32	4.57	4.41	4.30	0.91	0.52
NS 5511	3.50	3.89	4.56	4.60	4.31	4.82	4.12	4.44	0.55	0.49
NS 5655	3.43	3.82	3.79	3.52	4.61	4.00	3.94	3.78	0.60	0.24
PAN 8061	4.30	4.54	4.15	3.98	5.28	4.50	4.58	4.34	0.61	0.31
PAN 8171	3.91	4.41	3.55	3.53	4.66	4.71	4.04	4.22	0.57	0.61
PAN 8262	4.18	5.30	3.22	2.78	5.89	3.98	4.43	4.02	1.35	1.26
PAN 8272	3.99	4.17	3.66	3.35	4.31	3.79	3.99	3.77	0.33	0.41
PAN 8370	4.01	4.72	3.92	3.57	4.64	4.05	4.19	4.11	0.39	0.58
PAN 8446	4.11	4.54	4.29	3.59	4.85	4.31	4.42	4.15	0.39	0.50
PAN 8564	3.16	3.39	4.02	3.41	4.04	3.56	3.74	3.45	0.50	0.09
PAN 8660	3.45	4.69	4.03	3.74	5.18	4.25	4.22	4.23	0.88	0.48
SNK 3337	3.76	4.50	4.14	3.72	5.47	4.65	4.46	4.29	0.90	0.50
SNK 3443	3.84	3.52	3.50	2.97	4.94	3.93	4.09	3.47	0.75	0.48
SNK 3567	3.88	4.44	4.06	3.36	5.04	3.96	4.33	3.92	0.62	0.54
SNK 3620	3.79	3.73	4.64	4.73	4.38	4.34	4.27	4.27	0.44	0.50
SNK 3663	4.02	4.30	3.93	3.75	5.56	4.31	4.50	4.12	0.92	0.32
SNK 3860	3.07	3.46	4.09	4.07	4.12	4.01	3.76	3.85	0.60	0.34
SNK 3863	4.30	4.99	4.15	3.66	4.62	3.94	4.36	4.20	0.24	0.70
SNK 3883	1.56	1.51	1.82	1.34	1.26	1.13	1.55	1.33	0.28	0.19
SNK 3939	4.00	4.21	4.01	3.84	4.29	3.98	4.10	4.01	0.16	0.19
SNK 3975	3.74	3.97	4.10	3.82	4.82	4.42	4.22	4.07	0.55	0.31
MEAN	3.77	4.20	3.97	3.62	4.69	4.15	4.15	3.99		
MAX	4.78	5.30	4.68	4.73	5.89	5.24	4.87	4.93		
MIN	1.56	1.51	1.82	1.34	1.26	1.13	1.55	1.33		
RANGE	3.22	3.79	2.86	3.39	4.63	4.11	3.33	3.60		
SD	0.61	0.77	0.59	0.69	0.87	0.75	0.61	0.65		

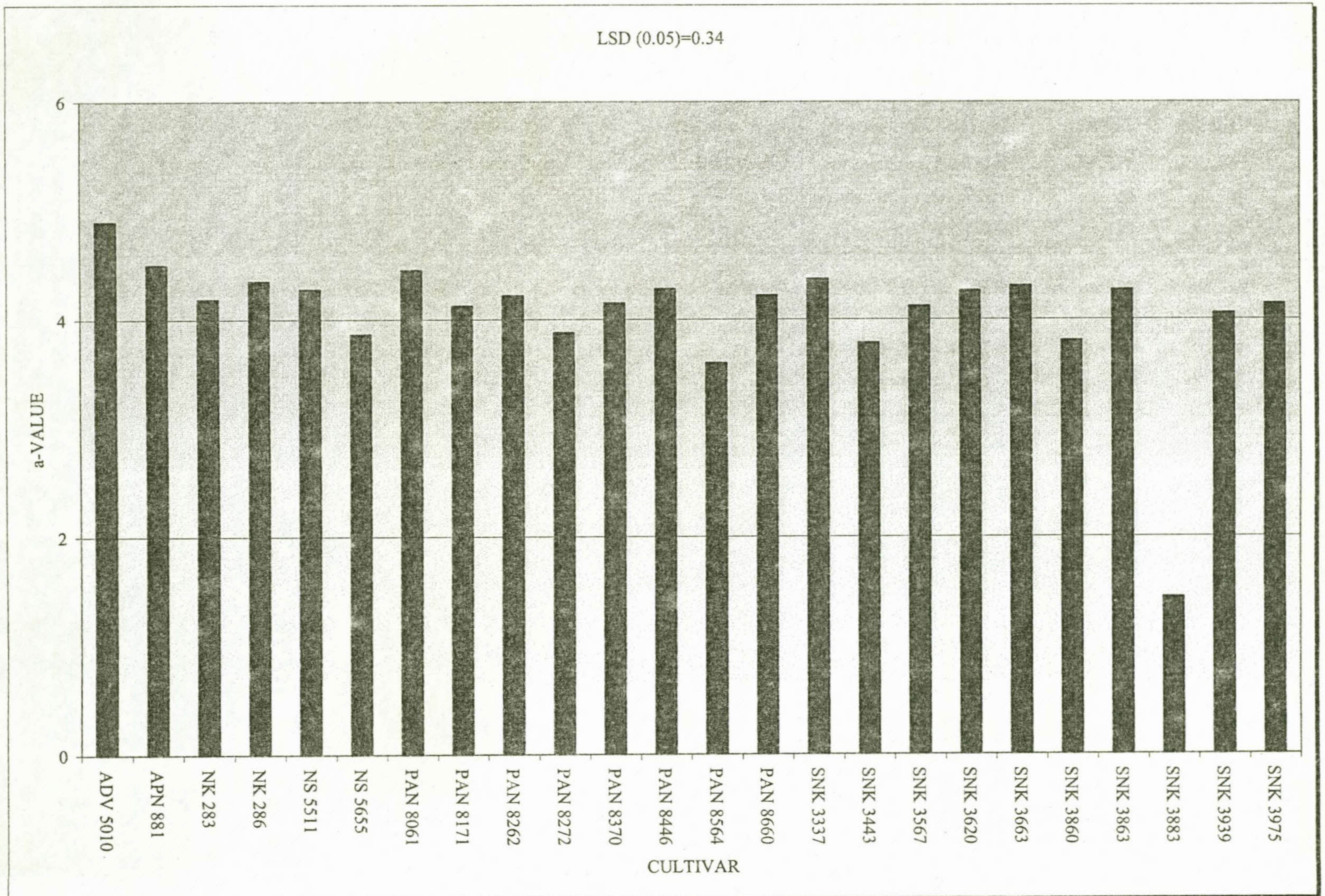


FIG. 4.50

THE SIGNIFICANT DIFFERENCES BETWEEN THE MEAN a-VALUES OF DIFFERENT SORGHUM CULTIVARS

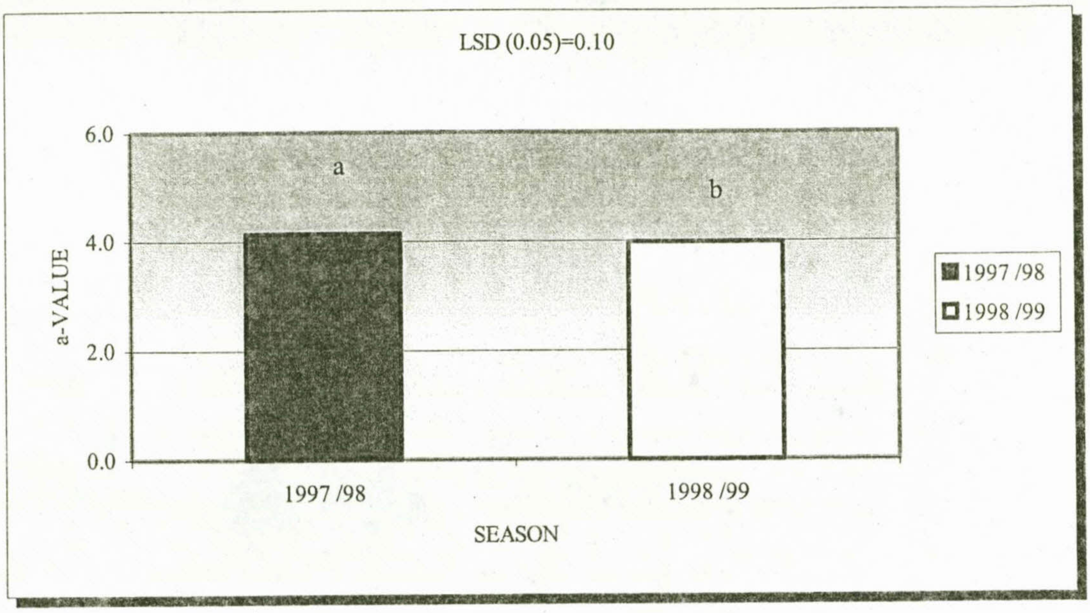


FIG. 4.51

THE DIFFERENCES IN THE DI OF THE a-VALUE VALUE MEANS OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS

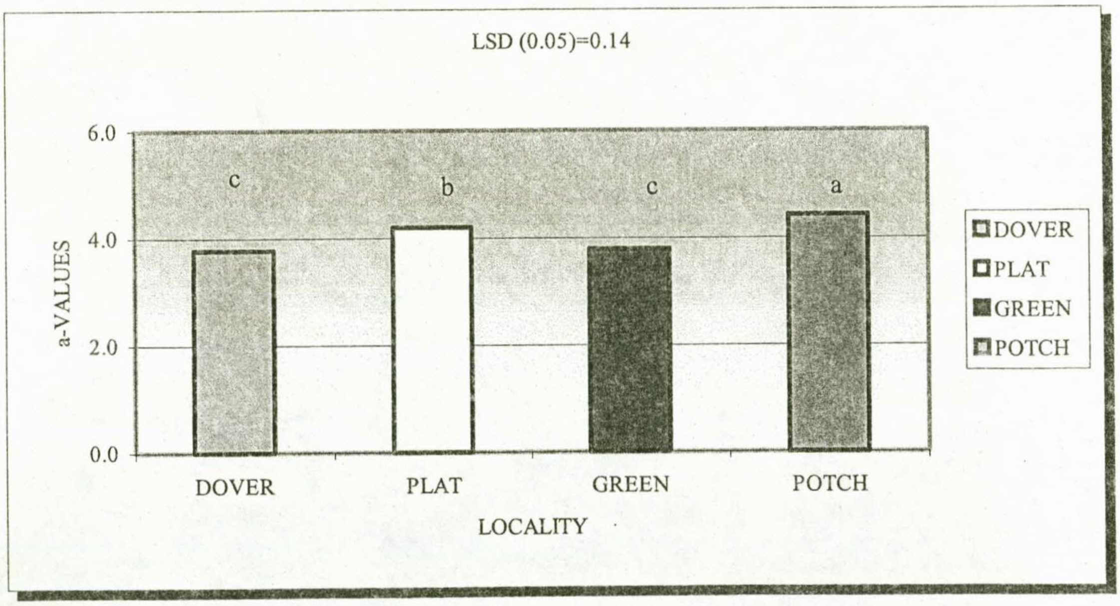


FIG. 4.52

THE DIFFERENCES IN THE DI OF THE a-VALUE VALUE MEANS OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES

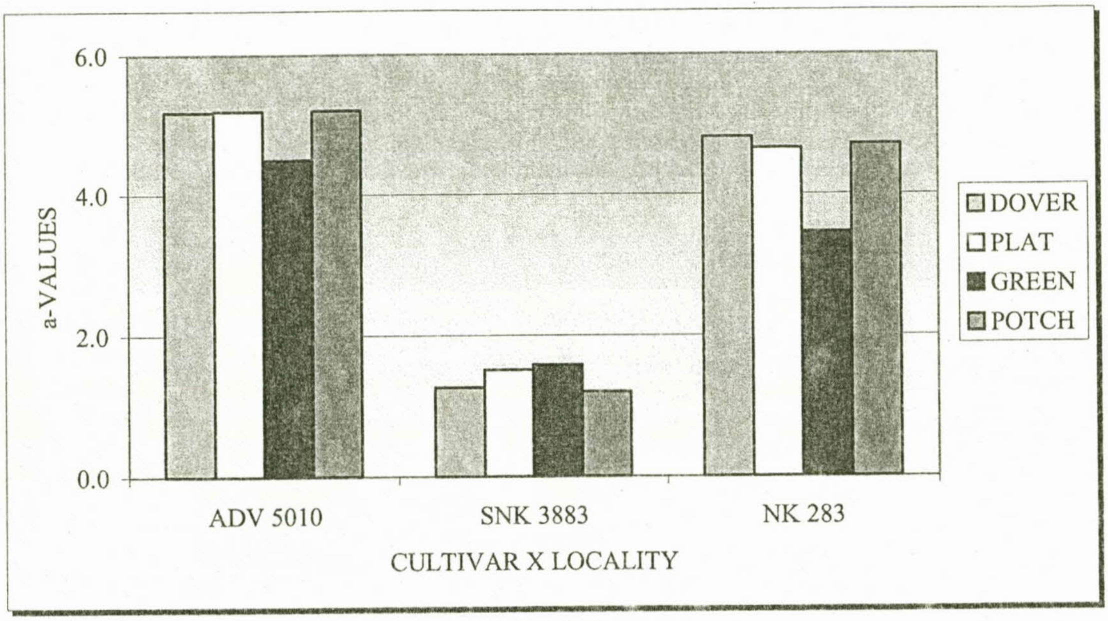


FIG. 4.53

THE CULTIVAR X LOCALITY INTERACTION OF SOME SORGHUM CULTIVARS

TABLE 4.50

THE DIFFERENCES IN THE a-VALUE MEANS OF SORGHUM CULTIVARS OVER 2 SEASONS AT DIFFERENT LOCALITIES

Source	**df**	**Type III**	**SS**	**MS**	**F**	**P**
Blocks (SEASON)	1	4.7972	4.7972	57.1313	0.0000	***
Main Effects						
CULTIVAR	23	47.3894	2.0604	24.5380	0.0000	***
LOCALITY	3	15.9605	5.3202	63.3593	0.0000	***
Interaction						
CULTIVAR x LOCALITY	69	14.0073	0.2030	2.4176	0.0009	***
Error		3.9465	0.0840	<-		
Total	143	88.2270				

P=0.05

ns=not significant

TABLE 4.51

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN a-VALUE MEANS

Rank	Cultivar	Mean	n	Groups of not significantly different
1	ADV 5010	4.902	6	a
2	APN 881	4.503	6	b
3	PAN 8061	4.458	6	bc
4	SNK 3337	4.373	6	bcd
5	NK 286	4.355	6	bcd
6	SNK 3663	4.312	6	bcd
7	PAN 8446	4.282	6	bcd
8	NS 5511	4.280	6	bcd
9	SNK 3863	4.277	6	bcd
10	SNK 3620	4.268	6	bcd
11	PAN 8262	4.225	6	bcd
12	PAN 8660	4.223	6	bcd
13	NK 283	4.188	6	bcde
14	PAN 8370	4.152	6	cde
15	SNK 3975	4.145	6	cde
16	PAN 8171	4.128	6	cdef
17	SNK 3567	4.123	6	cdef
18	SNK 3939	4.055	6	defg
19	PAN 8272	3.878	6	efgh
20	NS 5655	3.862	6	efgh
21	SNK 3860	3.803	6	fgh
22	SNK 3443	3.783	6	gh
23	PAN 8564	3.597	6	h
24	SNK 3883	1.437	6	i

4.3.2 PORRIDGE VISCOSITY

4.3.2.1 TADD SAMPLES

The porridge viscosity value means of 24 sorghum cultivars over 2 seasons at 2 localities per season are shown in Table 4.52. Due to the extremely time-consuming method of viscosity measurements and the lack of enough meal samples, it was decided to perform viscosity measurements only on the grain from localities where samples from two seasons were available, namely Green and Potch. Differences in cultivar value means were found, but were insignificant (Table 4.53; Fig. 4.54). From Table 4.54 it can be seen that no single cultivar differed significantly from all other cultivars. The only cultivars not to correspond (p>0.05) with the highest ranked cultivar (PAN 8660) in viscosity value means were SNK 3337, APN 881, NS 5655, NS 5511, NK 286 and SNK 3620. PAN8660, NK 283, PAN 8272, PAN 8370, SNK 3443, ADV 5010, SNK 3975 and PAN 8061 were the only cultivars to differ significantly from the lowest ranked cultivar for viscosity value means, namely SNK 3620. SNK 3443, ADV 5010 and PAN 8272 also had low levels of SE (4.3.1.2.8), which agrees with the statement made by Cagampang *et al.* (1996), namely that an increase in SE in meal lowers viscosity values. The latter group of cultivars is those with better porridge-making properties, due to their ability to produce porridges with a stiff texture. The meals of these cultivars could be expected to contain mainly non-waxy starch, as these types of starches lead to higher end viscosity values. Differences between viscosity value means were insignificant for different seasons (Fig. 4.55) and localities (Fig. 4.56), as were the cultivar x locality interaction (Table 4.57).

TABLE 4.52
THE VISCOSITY OR THE PORRIDGES OF DIFFERENT SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 SEASONS (TADD SAMPLES)

CULTIVAR	GREEN				POTCH				MEAN	
	1997/98		1998/99		1997/98		1998/99		1997/98	1998/99
	VISCOSITY (Cp)	TEMP (°C)	VISCOSITY (Cp)	TEMP (°C)	VISCOSITY (Cp)	TEMP (°C)	VISCOSITY (Cp)	TEMP (°C)	VISCOSITY (Cp)	
ADV 5010	3646.7	24.9	2040.0	25.1	1476.7	25.3	2653.3	25.3	2561.7	2346.7
APN 881	1550.0	25.2	1023.3	25.2	2656.7	25.4	2086.7	25.3	2103.4	1555.0
NK 283	2706.7	25.2	2763.3	25.0	2050.0	25.0	4230.0	25.1	2378.4	3496.7
NK 286	1930.0	25.1	1350.0	25.0	1153.3	25.3	2323.3	25.2	1541.7	1836.7
NS 5511	1613.3	25.4	2310.0	25.2	1420.0	25.3	1520.0	25.4	1516.7	1915.0
NS 5655	1993.3	25.1	1840.0	25.2	1116.7	25.0	2216.7	25.4	1555.0	2028.4
PAN 8061	2093.3	25.2	2000.0	25.4	2446.7	25.0	2866.7	25.4	2270.0	2433.4
PAN 8171	2686.7	25.1	2146.7	25.1	1670.0	25.2	2753.3	25.1	2178.4	2450.0
PAN 8262	1940.0	25.2	2023.3	25.0	1886.7	25.3	3093.3	25.1	1913.4	2558.3
PAN 8272	5256.7	25.1	1783.3	25.3	2013.3	25.2	1416.7	25.2	3635.0	1600.0
PAN 8370	2406.7	25.4	2350.0	25.2	1966.7	25.3	3490.0	25.6	2186.7	2920.0
PAN 8446	2473.3	25.3	2040.0	25.3	1563.3	24.8	2683.3	25.2	2018.3	2361.7
PAN 8564	2826.7	25.3	1530.0	25.2	1283.3	25.1	2453.3	25.1	2055.0	1991.7
PAN 8660	2416.7	25.1	2143.3	25.2	3570.0	24.9	3730.0	25.4	2993.4	2936.7
SNK 3337	1993.3	25.1	1523.3	25.2	1636.7	25.4	2396.7	25.1	1815.0	1960.0
SNK 3443	1520.0	25.1	3240.0	25.4	2980.0	25.3	2183.3	25.4	2250.0	2711.7
SNK 3567	2300.0	25.4	1590.0	25.0	2226.7	25.4	2180.0	25.2	2263.4	1885.0
SNK 3620	1300.0	25.2	1050.0	25.0	1150.0	25.2	1916.7	25.1	1225.0	1483.4
SNK 3663	1630.0	25.2	2060.0	25.2	2373.3	25.1	2786.7	25.1	2001.7	2423.4
SNK 3860	2120.0	25.4	1883.3	25.2	1310.7	25.2	2856.7	24.9	1715.4	2370.0
SNK 3863	2606.7	25.0	2026.7	25.3	1763.3	25.3	2223.3	25.4	2185.0	2125.0
SNK 3883	2006.7	25.3	1876.7	25.3	2190.0	25.3	2540.0	25.3	2098.4	2208.4
SNK 3939	2550.0	25.2	1826.7	25.3	1546.3	24.4	2253.3	25.5	2048.2	2040.0
SNK 3975	2543.3	25.0	2126.7	25.3	2283.3	25.3	2566.7	25.0	2413.3	2346.7
MEAN	2337.9	25.2	1939.4	25.2	1905.6	25.2	2559.2	25.2	2121.7	2249.3
MIN	1300.0	24.9	1023.3	25.0	1116.7	24.4	1416.7	24.9	1225.0	1483.4
MAX	5256.7	25.4	3240.0	25.4	3570.0	25.4	4230.0	25.6	3635.0	3496.7
RANGE	3956.7	0.5	2216.7	0.4	2453.3	1.0	2813.3	0.7	2410.0	2013.3
SD	810.0	0.1	482.0	0.1	614.2	0.2	637.1	0.2	494.8	471.0

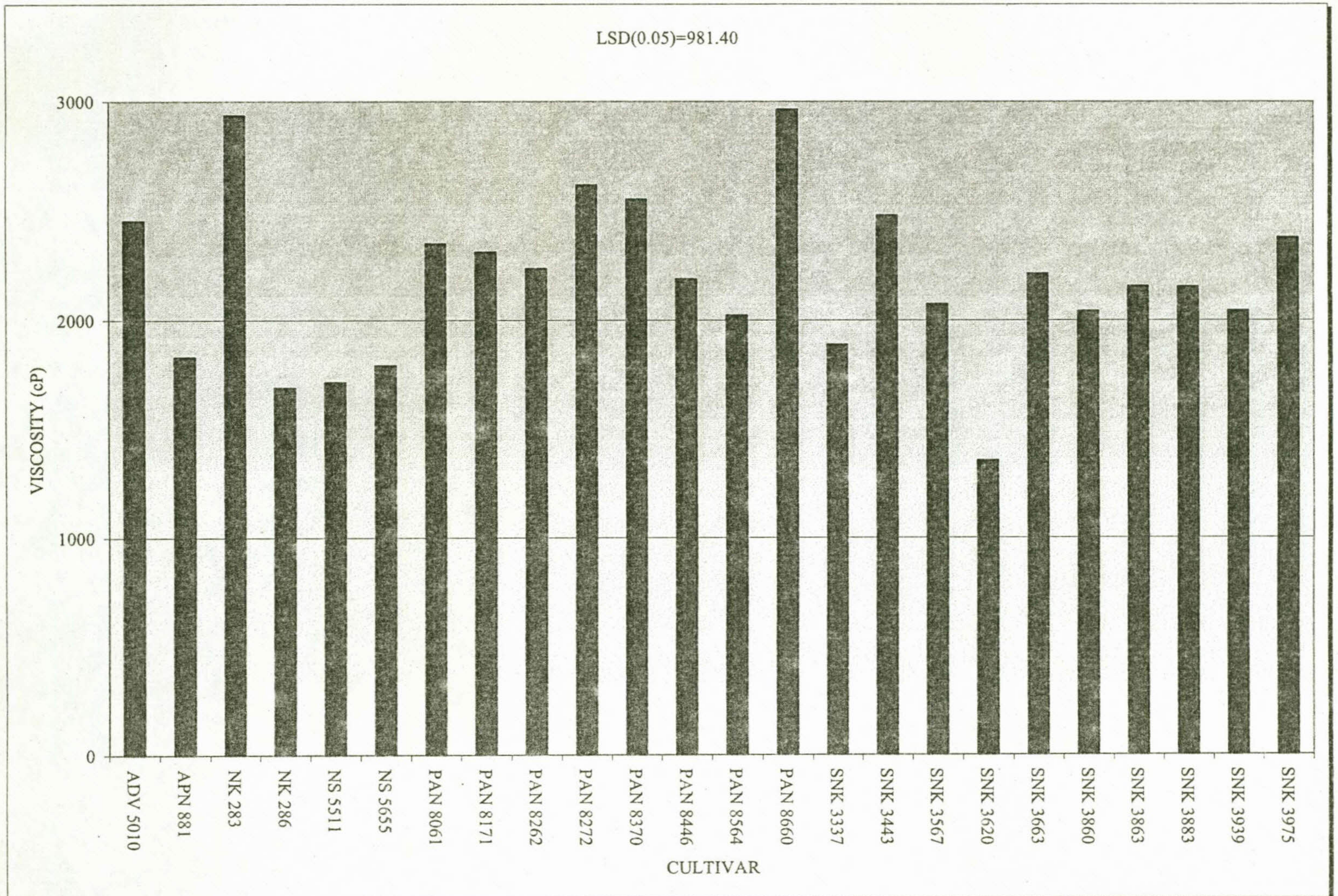


FIG.4.54

THE INSIGNIFICANT DIFFERENCES BETWEEN THE MEAN VISCOSITY VALUES OF THE PORRIDGES OF DIFFERENT SORGHUM CULTIVARS (TADD SAMPLES)

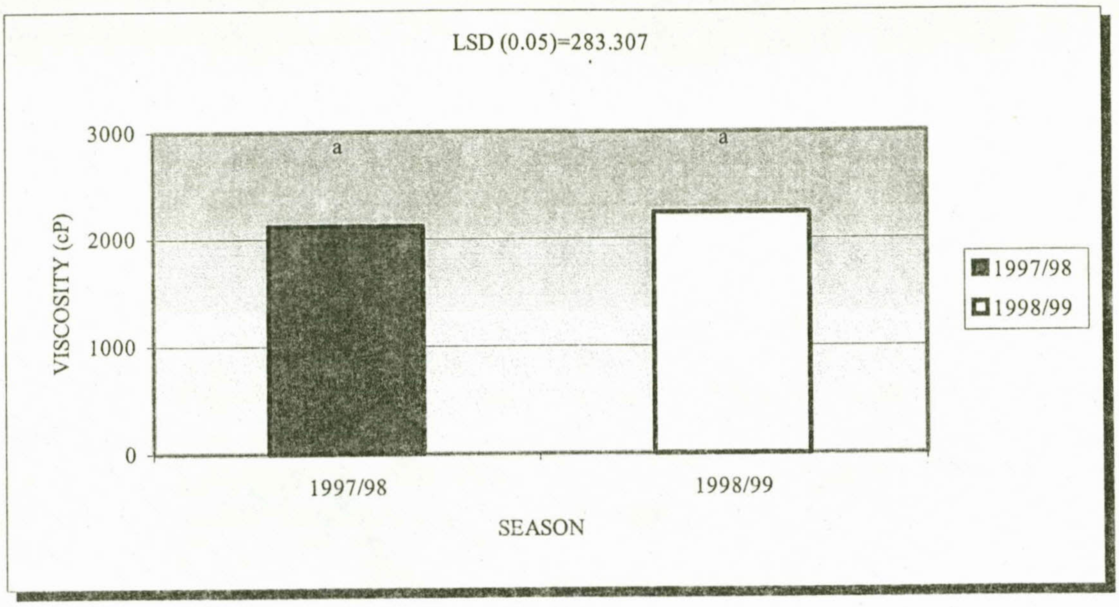


FIG. 4.55

THE INSIGNIFICANT DIFFERENCES IN THE VISCOSITY VALUE MEANS OF THE PORRIDGES OF SORGHUM CULTIVARS TADD-SAMPLES OVER DIFFERENT SEASONS

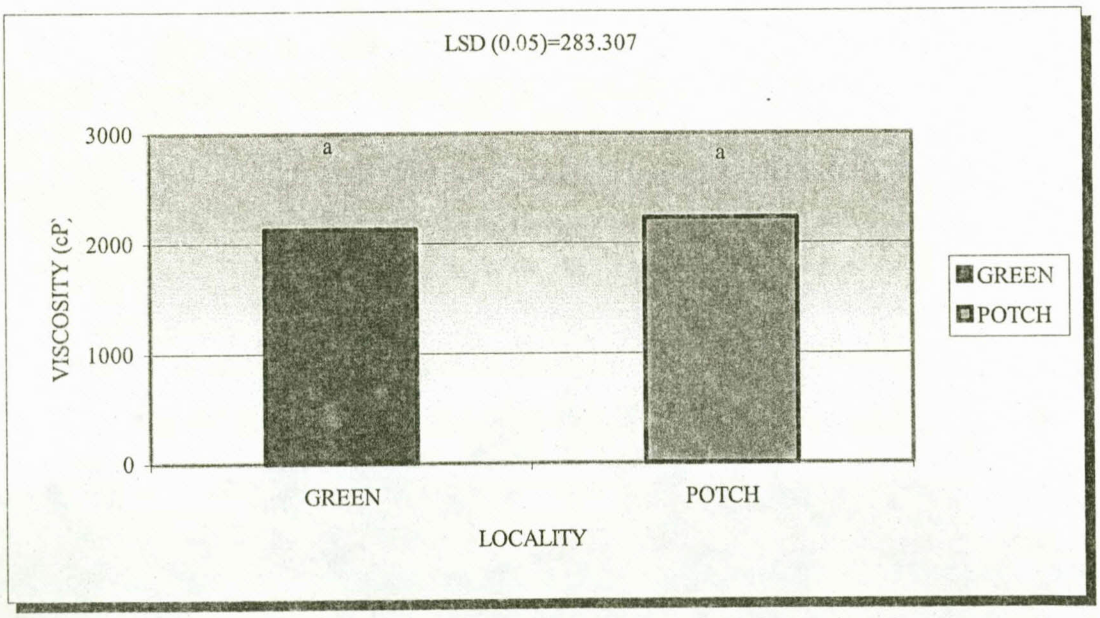


FIG. 4.56

THE INSIGNIFICANT DIFFERENCES IN THE VISCOSITY VALUE MEANS OF THE PORRIDGES OF SORGHUM CULTIVARS TADD SAMPLES AT DIFFERENT LOCALITIES

TABLE 4.53

THE DIFFERENCES IN THE VISCOSITY VALUE MEANS OF THE PORRIDGES OF SORGHUM CULTIVARS OVER 2 SEASONS AT DIFFERENT LOCALITIES (TADD SAMPLES)

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	390507.0817	390507.0800	0.8204	0.3697	ns
Main Effects						
CULTIVAR	23	13398939.7000	582562.6000	1.2239	0.2727	ns
LOCALITY	1	210656.3438	210656.3400	0.4426	0.5091	ns
Interaction						
CULTIVAR x LOCALITY	23	9319034.4310	405175.4100	0.8513	0.6549	ns
Error	47	22370711.5600	475972.5900	<-		
Total	95	45689849.1200				

P=0.05

ns=not significant

TABLE 4.54

RANKING OF SORGHUM CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN VISCOSITY VALUE MEANS OF PORRIDGES (TADD SAMPLES)

Rank	Cultivar	Mean	n	Groups of not significantly different
1	PAN 8660	2965.000	4	a
2	NK 283	2937.500	4	a
3	PAN 8272	2617.500	4	ab
4	PAN 8370	2553.350	4	ab
5	SNK 3443	2480.825	4	ab
6	ADV 5010	2454.175	4	ab
7	SNK 3975	2380.000	4	ab
8	PAN 8061	2351.675	4	ab
9	PAN 8171	2314.175	4	abc
10	PAN 8262	2235.825	4	abc
11	SNK 3663	2212.500	4	abc
12	PAN 8446	2189.975	4	abc
13	SNK 3863	2155.000	4	abc
14	SNK 3883	2153.350	4	abc
15	SNK 3567	2074.175	4	abc
16	SNK 3939	2044.075	4	abc
17	SNK 3860	2042.675	4	abc
18	PAN 8564	2023.325	4	abc
19	SNK 3337	1887.500	4	bc
20	APN 881	1829.175	4	bc
21	NS 5655	1791.675	4	bc
22	NS 5511	1715.825	4	bc
23	NK 286	1689.150	4	bc
24	SNK 3620	1354.175	4	c

4.3.2.2 ROLLER-MILLED SAMPLES

In Table 4.55 the poor viscosity values of the porridges of 24 sorghum cultivars over 2 seasons at 2 localities per season, can be seen. Significant differences in the cultivar viscosity value means were found (Table 4.56), as were found by Cagampang *et al.* (1985) for different cultivars. Taylor *et al.* (1997) also found the PPVs of different cultivars to vary. SNK 3443 did not differ from the highest ranked cultivar (NK 283) in viscosity value means (Table 4.56). PAN 8272, PAN 8262, PAN 8446, PAN 8061, SNK 3975, PAN 8370, PAN 8660, PAN 8171 and SNK 3663 did not differ from the second ranked SNK 3443 in viscosity value means (Fig. 4.57). These cultivars consist of higher viscosity properties. Akingbala *et al.* (1982) found that non-waxy sorghum starches can better withstand external pressure from the endosperm matrix in sorghum flour, as it is less fragile, resulting in higher pasting viscosities. The starches in the grain from the latter group of cultivars with higher viscosities might therefore mainly consist of non-waxy starches. NS 5511, SNK 3939, SNK 3860, SNK 3883, SNK 3863, SNK 3337, SNK 3663, APN 881, PAN 8564, ADV 5010, NS 5655 and NK 286 all corresponded ($p>0.05$) with the lowest ranked cultivar, SNK 3567, in viscosity value means. Cultivars that lack stiffness, may contain more waxy starches, that cannot withstand external pressure from the endosperm matrix in sorghum flour as it is more fragile (Akingbala *et al.* (1982) and waxy starches were found to have lower end viscosity values (Cruzy Celis *et al.*, 1996). Viscosity values could provide an indication of the waxiness of cultivars, but to identify sorghum starches as waxy or non-waxy, it is necessary to analyse the starches, which stretches beyond the limits of the present study.

Significant differences in viscosity value means of sorghum over different seasons were found (Table. 4.56; Fig. 4.58), but the level of significance was lower than in the case of different cultivars. The 1997/98 season produced significantly lower viscosity values than the 1998/99 season. The porridge-making quality of grain from the 1998/99 season was thus better. This can be attributed to rainfall conditions that varied over the two seasons, as Taylor *et al.* (1997) found the starch of irrigated sorghum to have significantly higher amylose contents than the rainfed ones. High rainfall conditions with dryland sorghum may therefore also increase the proportion of amylose responsible for higher viscosity values, of sorghum. The differences in viscosity value means at different localities (Fig. 4.59), as well as the cultivar x locality interaction, were insignificant (Table 4.56). This was contrary to the significant influence of locality found by Cagampang *et al.* (1985), but this may be explained by the fact that only two localities were used in the present study.

Overall the viscosity value means were higher for the TADD samples (mean=2185 cP), than for the roller-milled samples (mean=1435.85 cP). One explanation for higher viscosity values for TADD samples might be attributed to the fact that Yang & Seib (1996) observed, that the removal of the pericarp decrease protein and starch contents of grain and Chandrashekar & Kirleis (1988) found higher levels of protein to act as a barrier against starch gelatinisation. Hahn (1969) found high viscosities, due to the increases in starchy endosperm fraction and the decrease in protein content, in roller milling samples. The composition of the meal might however, have differed from that of the current study. Particle size distribution was not determined for TADD and roller milled samples in the present study, which make the prediction of the role that particle size distribution played in the viscosity properties of the different types of meal impossible.

TABLE 4.55
THE VISCOSITY OF THE PORRIDGES OF DIFFERENT SORGHUM CULTIVARS AT 3 LOCALITIES OVER 2 SEASONS (ROLLER MILLING)

CULTIVAR	GREEN				POTCH				MEAN	
	1997/98		1998/99		1997/98		1998/99		1997/98	1998/99
	VISCOSITY (Cp)	TEMP (°C)	VISCOSITY (Cp)	TEMP (°C)	VISCOSITY (Cp)	TEMP (°C)	VISCOSITY (Cp)	TEMP (°C)	VISCOSITY (Cp)	
ADV 5010	1300.0	25.1	1440.0	25.3	1113.3	25.4	1383.3	25.0	804.4	1411.7
APN 881	1313.3	25.2	1053.3	25.3	1796.7	25.4	1363.3	25.1	1036.7	1208.3
NK 283	2716.7	25.0	3290.0	25.2	2323.3	25.5	2816.7	25.0	1680.0	3053.4
NK 286	1490.0	25.1	1193.3	25.0	1066.7	25.0	1386.7	25.2	852.2	1290.0
NS 5511	1080.0	25.0	2430.0	25.2	900.0	25.4	2026.7	25.2	660.0	2228.4
NS 5655	1300.0	25.2	1170.0	25.1	1250.0	25.7	1466.7	25.1	850.0	1318.4
PAN 8061	1836.7	25.1	2010.0	25.2	1913.3	25.4	2063.3	25.2	1250.0	2036.7
PAN 8171	1713.3	25.2	1573.3	25.1	1856.7	25.3	1980.0	25.3	1190.0	1776.7
PAN 8262	1940.0	25.2	1513.3	25.2	1453.3	25.3	3293.3	25.1	1131.1	2403.3
PAN 8272	2490.0	25.0	2046.7	25.2	1690.0	25.2	2056.7	25.0	1393.3	2051.7
PAN 8370	1640.0	25.0	1813.3	25.3	1653.3	25.2	2150.0	25.2	1097.8	1981.7
PAN 8446	1880.0	25.3	1966.7	25.2	1873.3	25.2	2400.0	25.3	1251.1	2183.4
PAN 8564	1600.0	25.2	1540.0	25.1	860.0	25.3	1310.0	24.9	820.0	1425.0
PAN 8660	1820.0	25.1	1670.0	25.2	1273.3	25.0	2410.0	25.0	1031.1	2040.0
SNK 3337	1726.7	25.2	1193.3	25.3	1340.0	25.0	1663.3	25.2	1022.2	1428.3
SNK 3443	2503.3	25.2	2583.3	25.1	2080.0	25.2	2016.7	25.0	1527.8	2300.0
SNK 3567	1156.7	25.3	1663.3	25.0	776.7	25.2	1193.3	25.1	644.5	1428.3
SNK 3620	1163.3	25.2	1396.7	25.2	1123.3	24.9	2197.0	25.2	762.2	1796.9
SNK 3663	936.7	25.3	2183.3	25.1	1936.7	25.1	2053.3	25.1	957.8	2118.3
SNK 3860	1603.3	25.2	1646.7	25.0	1213.3	25.0	1720.0	25.2	938.9	1683.4
SNK 3863	1890.0	25.1	1300.0	25.2	1256.7	25.4	1500.0	25.3	1048.9	1400.0
SNK 3883	1120.0	25.1	1676.7	25.0	1540.0	24.8	1693.3	25.1	886.7	1685.0
SNK 3939	1413.3	25.2	1690.0	25.3	1643.3	24.9	1606.7	25.3	1018.9	1648.4
SNK 3975	2076.7	25.1	2183.3	25.1	2150.0	25.4	1360.0	25.1	1408.9	1771.7
MEAN	1654.6	25.2	1759.4	25.2	1503.5	25.2	1879.6	25.1	1052.7	1819.5
MIN	936.7	25.0	1053.3	25.0	776.7	24.8	1193.3	24.9	644.5	1208.3
MAX	2716.7	25.3	3290.0	25.3	2323.3	25.7	3293.3	25.3	1680.0	3053.4
RANGE	1780.0	0.3	2236.7	0.3	1546.6	0.9	2100.0	0.4	1035.5	1845.1
SD	469.1	0.1	516.6	0.1	431.8	0.2	513.5	0.1	265.6	439.3

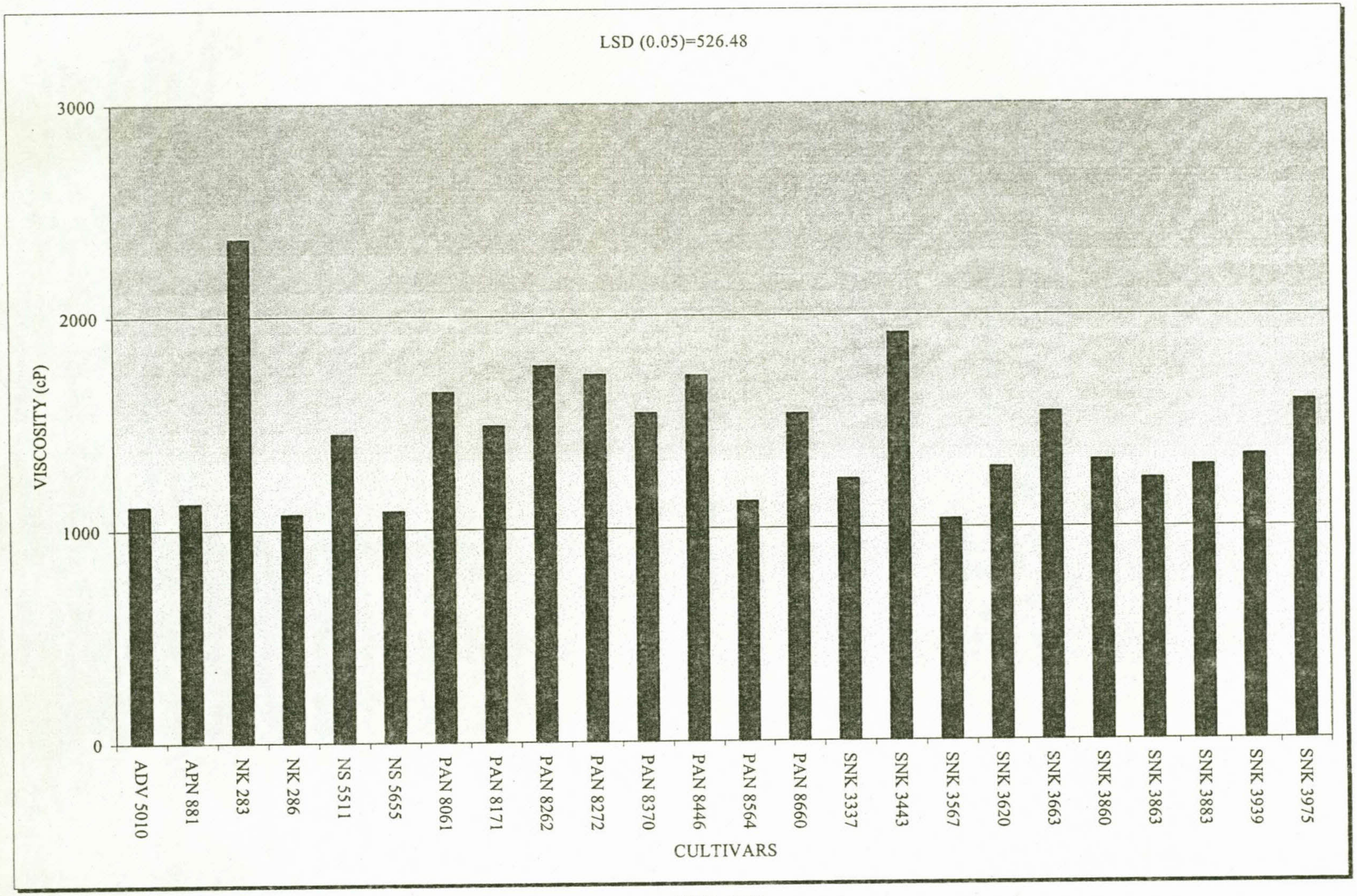


FIG. 4.57

THE SIGNIFICANT DIFFERENCES BETWEEN THE MEAN VISCOSITY VALUES OF THE PORRIDGES OF DIFFERENT SORGHUM CULTIVARS (ROLLER MILL SAMPLES)

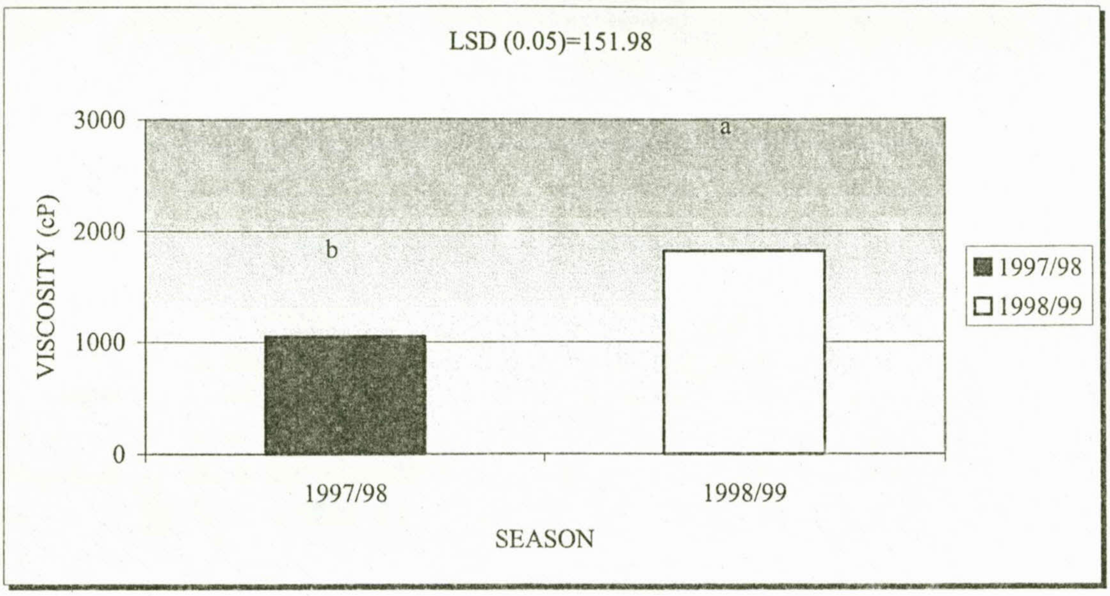


FIG. 4.58

THE DIFFERENCES IN THE VISCOSITY VALUE MEANS OF THE PORRIDGES OF SORGHUM CULTIVARS OVER DIFFERENT SEASONS (ROLLER MILL SAMPLES)

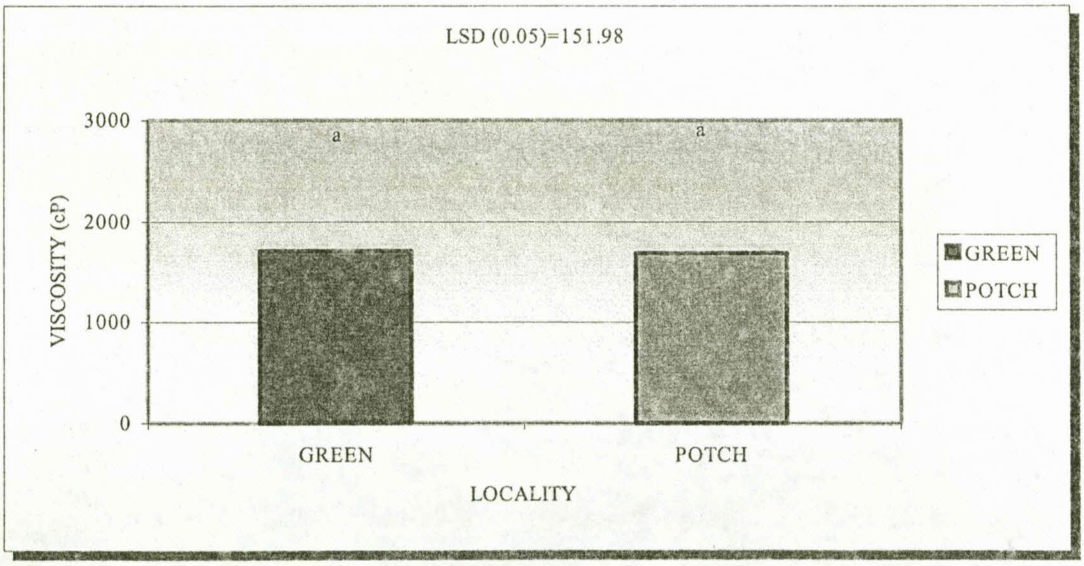


FIG. 4.59

THE INSIGNIFICANT DIFFERENCES IN THE VISCOSITY VALUE MEANS OF THE PORRIDGES OF SORGHUM CULTIVARS AT DIFFERENT LOCALITIES (ROLLER MILL SAMPLES)

TABLE 4.56

THE DIFFERENCES IN THE VISCOSITY VALUE MEANS OF THE PORRIDGES OF SORGHUM CULTIVARS OVER 2 SEASONS AT DIFFERENT LOCALITIES (ROLLER-MILLED SAMPLES)

Source	df	Type III	SS	MS	F	P
Blocks (SEASON)	1	1388069.8020	1388069.8000	10.1337	0.0020	**
Main Effects						
CULTIVAR	23	13088850.7100	569080.4700	4.1546	0.0000	***
LOCALITY	1	5750.5104	5750.5104	0.0420	0.8385	ns
Interaction						
CULTIVAR x LOCALITY	23	2469198.5850	107356.4600	0.7838	0.7326	ns
Error	47	6437885.9680	136976.3000	<-		
Total	95	23389755.5800				

P=0.05

ns=not significant

TABLE 4.57

RANKING OF CULTIVARS ACCORDING TO SIGNIFICANT DIFFERENCES IN VISCOSITY VALUE MEANS OF THE PORRIDGES OF SORGHUM CULTIVARS (ROLLER-MILLED SAMPLES)

Rank	Cultivar	Mean	n	Groups of not significantly different
1	NK283	2786.675	4	a
2	SNK 3443	2295.825	4	ab
3	PAN 8272	2070.850	4	bc
4	PAN 8262	2049.975	4	bc
5	PAN 8446	2030.000	4	bcd
6	PAN 8061	1955.825	4	bcde
7	SNK 3975	1942.500	4	bcde
8	PAN 8370	1814.150	4	bcdef
9	PAN 8660	1793.325	4	bcdefg
10	PAN 8171	1780.825	4	bcdefg
11	SNK 3663	1777.500	4	bcdefg
12	NS 5511	1609.175	4	cdefgh
13	SNK 3939	1588.325	4	cdefgh
14	SNK 3860	1545.825	4	cdefgh
15	SNK 3883	1507.500	4	defgh
16	SNK 3863	1486.675	4	efgh
17	SNK 3337	1480.825	4	efgh
18	SNK 3620	1470.075	4	efgh
19	APN 881	1381.650	4	fgh
20	PAN 8564	1327.500	4	fgh
21	ADV 5010	1309.150	4	fgh
22	NS 5655	1296.675	4	fgh
23	NK 286	1284.175	4	gh
24	SNK 3567	1197.500	4	h

To summarize the milling and food quality properties results found, the following: The milling quality of the different sorghum cultivars varied with regard to different milling and food quality properties, as summarized in Table 4.58. SNK 3443 had good milling and hardness properties (high AHI, B2G, S1 and low B1M, TL and TH), but extraction values were low. Food quality characteristics of TADD (low DI and high viscosity) and roller milling (low a-value and high viscosity) samples were also very good. PAN 8272 also had good milling and hardness properties (low B1M and TH and high S1). Extraction values were low, but TADD (low DI and high viscosity) and roller milling (low a and high viscosity) samples had excellent food quality characteristics. PAN 8564 showed excellent hardness and milling performances (high AHI, extraction and S1 and low B1M, B2B, TL and TH) and the colour of roller-milled (high L and low a) and TADD (low DI) samples were good, but viscosity values of roller milling samples were poor. PAN 8660 showed acceptable milling and hardness properties (high AHI and B2M and low B1M), but extraction values were poor. Viscosity values of both TADD and roller milling samples were poor. PAN 8446 showed good milling properties on the roller mills (low B1M, TL and TH and high S1), but AHI and extraction values were low. Good food quality properties for TADD (low DI) and roller milling (high viscosity) samples were also observed.

TABLE 4.58

THE MOST IMPORTANT MILLING AND FOOD QUALITY PROPERTIES (MEAL COLOUR AND PORRIDGE VISCOSITY) OF SORGHUM CULTIVARS

CULTIVAR	PROPERTIES			
	TADD MILLING	TADD FOOD QUALITY	ROLLER MILLING	ROLLER MILLING FOOD QUALITY
ADV 5010		LOW DI & HIGH VISCOSITY	LOW EXTRACTION & HIGH TL	HIGH a-VALUE & LOW VISCOSITY
APN 881	HIGH AHI	LOW DI & VISCOSITY	HIGH B2G, S1, S2 & LOW B1B, TH	LOW L-VALUE & VISCOSITY
NK283	LOW AHI	LOW DI & HIGH VISCOSITY	LOW S1 & HIGH B1M, TL, TH	HIGH VISCOSITY
NK 286	HIGH AHI	LOW DI & VISCOSITY	HIGH EXTRACTION, S2 & LOW B1M	HIGH L-VLAUE & LOW VISCOSITY
NS 5511		HIGH DI & LOW VISCOSITY	HIGH B1M, B2B, TL, TH & LOW B2M, EXTRACTION, S1	LOW L-VALUE & VISCOSITY
NS 5655	HIGH AHI	HIGH DI & LOW VISCOSITY	HIGH B1M, TH & LOW B2M	LOW L-VALUE &VISCOSITY
PAN 8061				
PAN 8171				
PAN 8262	LOW AHI		LOW B2G, B2M, S1 & HIGH B1M, TL, TH	HIGH VISCOSITY
PAN 8272		LOW DI & HIGH VISCOSITY	LOW B1M, TH & HIGH S1	LOW a-VALUES & HIGH VISCOSITY
PAN 8370		HIGH VISCOSITY	LOW B2G, EXTRACTION, S1 & HIGH TL, TH	HIGH VISCOSITY
PAN 8446	LOW AHI	LOW DI	LOW B1M, TL, TH & HIGH S1	HIGH VISCOSITY
PAN 8564	HIGH AHI	LOW DI & VISCOSITY	HIGH EXTRACTION, S1& LOW B1M, B2B, TL & TH	HIGH L- & a-VALUES
PAN 8660	HIGH AHI	HIGH VISCOSITY	HIGH B2M & LOW B1M	HIGH VISCOSITY
SNK 3337	HIGH AHI	LOW DI & VISCOSITY	HIGH S1, S2, EXTRACTION & LOW B1B, B1M, B2B, TL, TH	LOW VISCOSITY
SNK 3443	HIGH AHI	LOW DI & HIGH VISCOSITY	HIGH B2G, S1 & LOW B1M, TL, TH	LOW a-VALUE & HIGH VISCOSITY
SNK 3567	HIGH AHI	HIGH DI	HIGH EXTRACTION, S1, S2 & LOW TH	LOW VISCOSITY
SNK 3620		HIGH DI & LOW VISCOSITY	HIGH B1M, TH & LOW B2M	LOW VISCOSITY
SNK 3663				
SNK 3860		HIGH DI	HIGH B1M, B2B, TL, TH & LOW B2M, S	LOW L-VALUE & VISCOSITY
SNK 3863	HIGH AHI	LOW DI	HIGH EXTRACTION, S1, S2 & LOW B2B, TH	HIGH L-VALUE & LOW VISCOSITY
SNK 3883		LOW DI	HIGH EXTRACTION, TL, TH & LOW S1	LOW a-VALUE & VISCOSITY
SNK 3939		LOW DI	HIGH EXTRACTION, S1 & LOW B1B, B2B, TL	HIGH L-VALUE & LOW VISCOSITY
SNK 3975	LOW AHI	LOW DI & HIGH VISCOSITY	HIGH EXTRACT, S1,B1M & LOW B1B, B2M	HIGH L-VALUE, VISCOSITY

SNK 3567 had good milling and hardness properties (high AHI, extraction, S1 and S2 and low TH), but the colour of TADD samples was poor and the viscosity of roller milling samples was low. SNK 3337 had excellent milling and hardness properties (high AHI, S1, S2 and extraction and low B1B, B1M, B2B, TL and TH) and good colour properties for TADD milling (low DI), but viscosity values for both TADD and roller-milled samples were poor. The milling properties of SNK 3939 were very good (high extraction and S1 and low B1B, B2B and TL) and the colour of TADD and roller-milled samples were very white, but the viscosity values of roller milling samples were low. SNK 3863 showed favourable milling and hardness properties (high AHI, extraction, S1 and S2 and low B2B and TH), but B2G was low and B2M high. Colour properties of TADD (low DI) and roller-milled samples (high L-value) were suitable but roller-milled samples had low viscosities. NK 286 also had good milling and hardness properties (AHI, extract and S2 high and B1M low), but poor food quality properties in terms viscosity of TADD and roller-milled samples were found, but S1 values were low. The TADD (low DI) and roller milling (low a-value) samples had good colour properties. The cultivar ADV 5010 did not have favourable milling properties, as low extract and high TL values were found, but S1 was high and TH low. The food quality characteristics for TADD samples were good (DI low and viscosity high), but poor for roller milling samples (a-value high and viscosity low). APN 881 had excellent milling and hardness properties (AHI, B2G, S1, S2 high, B1B, and TH low), but extractions were low and food quality properties of roller-milled samples poor (L-value and viscosity low). The TADD samples had satisfactory colour properties (DI low), but the viscosity was low.

SNK 3975 displayed very poor milling and hardness properties (B1M were high and AHI low), but low B2B and high extraction and S1 were found but. Food quality characteristics of both TADD (low DI and high viscosity) and roller milling samples (high L-value and viscosity) were very good. This finding is similar to the findings of Dewar *et al.* (1993), who observed SNK 3975 to be unsuitable for meal production in terms of hardness properties. NK 283 had poor hardness and milling properties (AHI, and S1 low and B1M, TL and TH high), but extraction values were good. Both TADD and roller-milled samples had good food quality properties (high viscosity for TADD and roller-milled samples and low DI). PAN 8262 had poor milling and hardness properties (low AHI, B2G, B2M and S1 and high B1M, TL and TH), but extraction values were high. Both roller milling viscosity values and TADD DI values were good. The milling properties of SNK 3883 were poor (high TL and TH and low S1), but extraction values were high and B2B low. The colour of TADD (DI low) and roller milling (a-values low) samples was acceptable, but the viscosity of roller-milled samples was poor. PAN 8370 had poor milling and hardness qualities (low B2G, extraction and S1 and high TL and TH), but B1M values were low. Both roller milling and TADD samples had good viscosity properties.

SNK 3860 had poor milling and hardness properties (high B1M, B2B, TL and TH and low B2M and S1), but extraction and B2G values were high. Colour properties of roller milling (low L-value) and TADD (high DI) samples were poor and viscosity values of roller-milled samples were low. NS 5511 had poor milling and hardness properties (high B1M, B2B, TL and TH values and low B2M, extraction and S1 values), but B1B values were low and B2G values were high. Colour and viscosity properties of both TADD (high DI and low viscosity) and roller-milled (low L-values and viscosities) samples were poor. SNK 3620 had poor milling and hardness properties (high B1M and TH and low B2M), but extraction, B2G and S1 values were high. The DI of TADD samples were high and the viscosity of TADD and roller-milled samples low. The poor milling and colour properties of these cultivars were due to the high tannin properties of these cultivars.

The 1997/98 seasons had more desirable hardness and milling (high B2G, extraction and S1 and low TL and TH and low B1B), as well as TADD colour properties (low DI of L-values wet and dry) than the 1998/99 season. Food quality properties of roller-milled samples were poor, during this season (low L- and high a-value and low viscosity).

The locality of Dover gave poor hardness, milling and food quality properties (low AHI, extraction and TH and high B1B and DI of L-values (dry)). The S1 and S2 values were high though, while TH values were low, indicating that meal mainly consisted of hard endosperm when from this locality. Poor milling and hardness properties (low AHI, B2M and B2G, while B1B, B1M and DI values were high) were found at Plat, but again S1 and S2 values were high and TH values low. The B2M values were low though for both Dover and Plat, indicating softness. Colour properties of roller-milled samples from these localities were good (high a-value), but DI values of TADD samples were high. The best milling and hardness properties were found in grain from Green (high AHI and B2G), but S1 and S2 values were low, while TH values were high. This may be due to the fact that high B2G values are found, which indicates that HE was mainly present in the grits. Colour properties of TADD samples from Green were good (low DI), as were those of roller milling samples (low a-values). The same with regard to the milling and colour properties of Green were found to be true for milling performances at Potch, but to a lesser extent (low B1B and S1 and L-values and higher extraction, S2 and a-values).

4.3.3 COEFFICIENT OF VARIATION

Table 4.59 shows the coefficients of variation for the physical properties of sorghum grain. As discussed in 2.3.6, the %CV was very large in some instances. It was also explained that larger %CV's might be expected in the present study, due to the different cultivars, localities and seasons that were used, instead of mere replications and differences over cultivars, localities and seasons, which serve as replications, is larger than replications at the same locality, etc. The occurrence of small CV values indicates only small differences over localities and seasons. The %CV's of the DI values, as well as those of viscosity values was higher than the other values, for example. In the case of the dehulling indexes for example, highly significant differences between cultivars and localities were present at all four types DI values, while differences in seasons were also found for DI values of the L-values.

TABLE 4.59
THE COEFFICIENTS OF VARIATION FOR DIFFERENT PHYSICAL QUALITY PARAMETERS OF 24 SORGHUM CULTIVARS OVER 2 SEASONS AT 3 LOCALITIES PER SEASON

MILLING PROPERTY	%CV
ABRASIVE HARDNESS INDEX	14.65
BREAK 1 BRAN	18.45
BREAK 1 MEAL	9.66
BREAK 2 BRAN	4.69
BREAK 2 MEAL	10.17
BREAK 2 GRITS	5.42
EXTRACTION	1.52
TOTAL LOSS	4.20
SIEVE FRACTIONS (S1, S2 AND TH)	7.85
DEHULLING INDEX (L-VALUES, DRY)	45.60
DEHULLING INDEX (a-VALUES, DRY)	36.93
DEHULLING INDEX (L-VALUES, WET)	40.93
DEHULLING INDEX (a-VALUES, WET)	29.82
L-VALUE (ROLLER MILLING, DRY)	1.20
a-VALUE (ROLLER MILLING, DRY)	7.13
VISCOSITY (TADD)	31.57
VISCOSITY (ROLLER MILLING)	21.78

4.3.3 CORRELATION

From Table 4.60 many significant correlations for milling quality and colour are seen. The AHI correlated with TH (r=0.42) and inversely with S2 (r=-0.43). This correlation implies that the AHI correlates with SE, which is senseless as AHI indicate hardness and SE softness. In the same way will the correlation of AHI with S2, indicate that a hardness factor (AHI) correlate negatively with another hardness factor (HE2), which is also senseless. As none of these correlations were very high, they were considered as coincidental and therefore unimportant.

AHI was also found to correlate well with several fractions from the roller mills, namely B2G (r=0.46), B2M (r=0.70) and B1M (r=-0.68) (Fig. 4.60). Pretorius & Du Plessis (1999) also found B1M to be a negative quality trait for maize, as the largest percentage of softest endosperm is produced at the break 1 rolls. The correlation of the AHI with B2G can be explained by the fact that both indicate hardness, as B2G values were found to be an indication of the hard endosperm of maize (Pretorius & Du Plessis, 1999). The correlation with B2G was not very high though, due to the back feed of grits at break 2 and might have been higher if this was not the case. The correlation between AHI and B2M can be explained by the fact that the AHI measure hardness and B2M value can be seen as a positive milling trait, since it was found to consist mainly of hard endosperm in maize (Pretorius & Du Plessis, 1999). This correlation between B2M and AHI give an indication that B2M in sorghum may also consist of mainly HE as found in maize. Break 2 meal is part of the milling yield and Maxson *et al.* (1971) found the hardness of sorghum to correlate with milling yield. A negative correlation between AHI and B1M were found, as AHI indicates hardness and Pretorius & Du Plessis (1999) found the largest percentage of softest endosperm to be produced at B1M.

The AHI correlated negatively with the DI values (wet determination) of the L- (r=-0.44) and a-(r=-0.42) values (Fig. 4.60). As hardness, which is measured by the AHI, is an indication of the milling performances of sorghum cultivars and the DI is totally dependent on the actual colour of sorghum grain, this correlation is difficult to explain. Some other correlations between colour and hardness were also observed. The DI values of the L-values (dry determination) correlated negatively with B2M (r=-0.55) and positively with B1M (r=0.47). The negative correlation between DI and B2M implicates that the higher the B2M values the smaller the DI values will be. As mentioned, B2M is mainly composed of hard endosperm as seen by its correlation with AHI and as this was also found to be the case in maize (Pretorius & Du Plessis, 1999). A small DI value is an indication of good colour sorghum, with little dehulling necessary to give a good coloured product. Therefore, cultivars with harder endosperm will have better colour properties. The correlation between DI and B1M implies the opposite, namely cultivars with softer endosperm (high B1M) will have higher DI and thus, will need higher levels of dehulling to achieve acceptable coloured products, as B1M is mainly composed of soft endosperm. If these correlations were not coincidental, the correlation between AHI and DI of the L- and the a-values (wet determination) would have meant that the harder the grain (high AHI), the less dehulling will be necessary to achieve an acceptable colour. The DI of the L-values (wet) also correlated with some fractions from the roller mills.

The DI correlated with B2M (r=-0.67), with B2B (r=0.45) and with B1M (r=0.59). The correlation between DI and B2M once again indicates that grain with better colour properties (less dehulling necessary) will also be harder, as B2M seems to be mainly consist of hard endosperm, as explained. The correlation found between the DI and B1M indicates the opposite, namely that grain with softer endosperm will have poorer colour properties, i.e. higher DI values. The correlation between the DI and B2B is difficult to explain and the correlation might be by coincidence, as the correlation coefficient is not very high. All that can be said about this correlation is that both values are negative milling properties when they are high. For reasons just explained, the DI of a-values (wet determination) correlated B2M (r=-0.55) and B1M (r=0.58). As previously mentioned, these correlations might be coincidental, but some of the correlation coefficients that show the relationship between colour and hardness properties are relatively high. The influence of the hardness and the level of hard endosperm in grain on the colour of the product are unclear from this study and further research is necessary.

The DI of the L-values (dry determination) of TADD samples correlated negatively with the L-values from the roller milling samples (r=-0.47) (Table 4.60). This was expected as TADD samples with low DI values already have good colour properties since they need less dehulling, and therefore the colour of the product from the roller mills will also be acceptable in colour when the same samples are used as for the TADD process. In the same manner DI values of the L-values (wet determination) correlated (r=-0.46) with L-values from the roller mills and the DI of a-values (wet determination) also correlated (r=-0.44) with the L-values of roller-milled samples. The correlation between the measurements of colour for TADD and roller milled-samples indicates that both the TADD and roller milling methods serve as means to improve the colour of sorghum meal.

The DI of the L-value (dry determination) of TADD samples correlated well with the DI values of the L-(r=0.87) and a-(r=0.59) values (wet determination,) as all DI values measured the level of dehulling necessary to obtain an acceptable colour product (Table 4.58). These correlations further support what was said in 4.3.2.1.1.4, namely that the L-value can be used alone for the DI determination and that only determinations on a dry basis is necessary as they measure the same properties. The DI of the L-value (dry) correlated better with the DI of the L-value (wet), as the L-value measure whiteness and not redness, whether it is on a wet or a dry basis. The DI of the a-value (dry) also correlated (r=0.49) with the DI of the a-value (wet) for the same reason explained above, but the correlation coefficient is not very high, as it was said that the L-value is a better means of determining DI values (4.3.2.1.1.4). The DI of the L-values (wet) correlated well (r=0.71) with the DI of the a-values (wet).

The L-values of roller-milled samples correlated well with the a-values of the same samples (r=-0.68), indicating that lighter samples (high L-value) will also have less redness (low a-value), as was also determined by Dewar *et al* (1993). In 4.3.2.1.1 it was suggested that the DI of TADD samples should only be calculated for L-values and on a dry basis. As whiteness is also a property of interest in roller milling samples and the L- and a-values are correlated well, it is only necessary to determine the L-values on a dry basis, as for TADD milling samples.

Break 1 bran correlated negatively with extraction (r=-0.78) and B2M (r=-0.47) (Table 4.60). The first correlation can be explained by the fact that the % extraction refers to products from the mills with economic advantages, i.e. the meal (4.3.1.2.6), and as B2B is a loss, a negative correlation with extraction was found. Break 1 bran also correlated negatively with B2M, as the latter is part of the extraction gained on the mills, while B2B is a loss. In the same way and for the same reasons that B1B correlated with extraction, a highly significant correlation between B2B and extraction were found, as B2B is also a loss.

Break 1meal showed highly negative correlations with B2G (r=-0.55) and with B2M (r=-0.94) (Table 4.60). This may motivate the theory that B1M mainly consists of SE, while B2G and B2M consist mainly of HE, as found in maize (Pretorius & Du Plessis, 1999). This explains both correlations, because the higher the hard endosperm levels in sorghum grain, the lower the SE levels, as endosperm texture is determined by the proportion of hard to soft endosperm (Cagampang & Kirleis, 1984). Break 2 meal correlated with extraction (r=0.42) and with B2G (r=0.44). Although the correlation of B2M with B2G is not very high, it can be explained that both B2G and B2M mainly consist of HE and high levels of these fractions indicates hardness. The correlation of B2M with extraction was also expected, as B2M is one of the fractions that extraction is composed of. Break 2 meal also indicates hardness and Desikachar (1982) found harder varieties to result in higher milling yields, but in 4.3.1.2.6 it was seen that soft cultivars can deliver good extraction values in the case of roller milling.

Break 2 grits correlated negatively with S2 (r=-0.41). This correlation is difficult to explain as both B2G and S2 are probably mainly composed of hard endosperm, as found by Pretorius & Du Plessis (1999) for maize. The only possible explanation might be that the more of the hard endosperm is lost in B2G, since this is not a meal product gained by milling, the smaller the B2M fraction on the mills will be. The correlation is not high, however and the correlation might thus be coincidental.

The highest correlation coefficient was found for TH, which correlated well (r=0.996) with TL. This correlation can be explained by the fact that TH was one of the constituents in the calculation of TL. Pretorius & Du Plessis (1999) found the TH value to indicate the soft endosperm (SE) in maize and the level of soft endosperm in samples will therefore determine milling losses, as high levels of SE in sorghum increase milling losses. The TL also correlated well with S2 (r=-0.89)) and with S1 (r=-0.97). This can be explained by the fact that both S1 and S2 are the sieve fractions that consist mainly of HE. Sorghum grain with high S1 or S2 values will therefore contain more hard endosperm and will be harder, and harder grain results in lower milling losses (Munck *et al.*, 1982), explaining the negative correlations found between TL and S2 and TL and S1. Maxson *et al.* (1971) found milling performance to correlate with endosperm texture, which further motivates these correlations. No correlation between extraction and S1, S2 and TH were found, although Maxson *et al.* (1971) noticed endosperm texture to correlate with milling yield. Extraction also did not correlate with B1M or B2M, which is probably mainly composed of SE and HE respectively. This was due to the fact that some cultivars with high TH values showed good extraction values, as explained in 4.3.1.2.8 and therefore endosperm texture does not influence extraction values much in the case of roller milling. Maxson *et al.* (1971) also indicated good correlations between endosperm texture and hardness, which was not found in the present study, as cultivars had high levels of TH compared to levels of S1 and S2 (4.3.1.2.8).

TABLE 4.60

CORRELATION MATRIX FOR ALL MILLING PERFORMANCE AND FOOD QUALITY PARAMETERS OF SORGHUM FOR TADD- AND ROLLER MILLING –EXCLUDING VISCOSITY (P<0.05)

	AHI	DI (L-VALUE) (DRY)	DI (a-VALUE) (DRY)	DI (L- VALUE) (WET)	DI (a-VALUE) (WET)	B1B	B1M	B2B	B2M	B2G	EXTRAC-TION	TL	S1	S2	TH	L-VALUE (ROLLER MILL)	a-VALUE (ROLLER MILL)
a-VALUE (ROLLER MILL)	0.1	0.16	-0.16	0.13	0.13	-0.11	0.08	0.12	-0.03	-0.07	0.1	0.01	-0.02	-0.01	0.01	-0.68	1
L-VALUE (ROLLER MILL)	-0.08	-0.47	0.04	-0.46	-0.44	0.31	-0.12	-0.37	0.09	-0.28	-0.02	-0.01	-0.02	0.1	-0.03	1	-
TH	0.42	-0.22	-0.02	-0.15	0.04	-0.26	-0.3	0.04	0.3	0.27	0.11	0.996	-0.96	-0.91	1	-	-
S2	-0.43	0.21	0.07	0.17	-0.02	0.3	0.37	-0.06	-0.36	-0.41	-0.07	-0.89	0.76	1	-	-	-
S1	-0.38	0.2	-0.01	0.13	-0.05	0.21	0.22	-0.03	-0.24	-0.15	-0.12	-0.97	1	-	-	-	-
TL	0.39	-0.2	-0.01	-0.13	0.06	-0.19	-0.26	0.08	0.26	0.22	0.05	1	-	-	-	-	-
EXTRACTION	0.2	-0.32	0.09	-0.36	-0.04	-0.78	-0.14	-0.65	0.42	-0.19	1	-	-	-	-	-	-
B2G	0.46	0.04	-0.27	-0.04	-0.13	-0.38	-0.55	0.27	0.44	1	-	-	-	-	-	-	-
B2M	0.7	-0.55	-0.27	-0.67	-0.55	-0.47	-0.94	-0.38	1	-	-	-	-	-	-	-	-
B2B	-0.08	0.38	0.01	0.45	0.36	0.23	0.25	1	-	-	-	-	-	-	-	-	-
B1M	-0.68	0.47	0.33	0.59	0.58	0.27	1	-	-	-	-	-	-	-	-	-	-
B1B	-0.37	0.13	0.01	0.18	-0.08	1	-	-	-	-	-	-	-	-	-	-	-
DI (a-VALUE WET)	-0.42	0.59	0.49	0.71	1	-	-	-	-	-	-	-	-	-	-	-	-
DI (L-VALUES WET)	-0.44	0.87	0.14	1	-	-	-	-	-	-	-	-	-	-	-	-	-
DI (a-VALUE DRY)	-0.29	0.08	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DI (L-VALUE DRY)	-0.38	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AHI	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Both S1 and S2 showed high negative correlations with TH (r=-0.96 and r=-0.91 respectively). These negative correlations can be expected as S1 and S2 are probably mainly composed of hard endosperm, while TH is probably composed of soft endosperm. The high negative correlations found confirm the complete dissimilarity of the hard and soft endosperm. A highly positive correlation between S1 and S2 was also found, which can be expected, as both probably mainly consist of hard endosperm.

A significant negative correlation between the L-values of meal from the roller mills and the a-values of the same samples was found. This can be explained by the fact that the L-value measures lightness and the a-value redness (Chapter 1). Grain with high L-values has high lightness values and as the colour is lighter in redness, a-values will be lower, which explains the negative correlation.

In Table 4.61 the correlation matrix of viscosity with other milling and food quality properties is shown. A separate correlation matrix for viscosity was drawn, as this is the only property for which correlation data was calculated from only two localities, i.e. Green and Potch for both seasons, as explained earlier. Only three correlations with r>0.4 were found in this correlation matrix. The viscosity of the TADD samples correlated (r=0.52) with the viscosity of the roller milling samples. The viscosity value of the TADD correlated with B1B (r=0.44), but this correlation is not very high and difficult to explain, as the relationship between the property of viscosity and B1B is unknown. Novellie (1982) stated that the bran contents in sorghum meal decreases the starch content available during porridge making, with subsequently lower viscosities in the end product. This correlation could be by coincidence, as it is not very high, but it might indicate that the higher the bran content removed during milling in the form of B1B, the less the bran content left in the meal itself and the higher the viscosity. Viscosity of roller milling samples also correlated with B1B (r=0.37), but this correlation is even lower. The next correlation was between the viscosity values of roller-milled samples and the AHI (r=-0.41). Viscosity values of roller-milled samples also correlated negatively with AHI, but this correlation was even lower. This correlation indicates that the harder grain will have lower viscosity values when roller-milled samples are considered and is significant, as Cagampang & Kirleis (1984) also found vitreousness to be significantly inversely correlated to the viscosity of sorghum. Therefore, the hardest sorghum cultivars with the best milling performances will have poor viscosity properties and viscosity cannot be solely used as a criterion for cultivar selection. The miller of sorghum has to find a compromise between hardness and viscosity, while the stiffness of porridge, desired for a specific market, will also need to be considered. No correlation between viscosity and S1, S2 or TH was found. This might be due to the fact that floury endosperm varieties have lower intrinsic viscosities (Cagampang *et al.*, 1995). Some cultivars showed low TH and high viscosity values (4.3.2.2), but this was only true for a few cases.

TABEL 4.61

CORRELATION MATRIX FOR VISCOSITY MEASUREMENTS WITH ALL OTHER MILLING PERFORMANCE AND FOOD QUALITY PROPERTIES (MEAL COLOUR AND PORRIDGE VISCOSITY) (P=0.05)

	VISCOSITY (TADD)	VISCOSITY (ROLLER MILL)
VISCOSITY (TADD)	1.00	-
VISCOSITY (ROLLER MILL)	0.52	1.00
a-VALUE (ROLLER MILL)	-0.03	-0.11
L-VALUE (ROLLER MILL)	0.22	0.19
TH	0.11	0.22
S2	0.07	-0.18
S1	-0.16	-0.16
TL	0.21	0.29
EXTRACTION	0.29	0.30
B2G	-0.31	-0.19
B2M	-0.32	-0.25
B2B	0.01	0.09
B1M	0.26	0.16
B1B	0.44	0.37
DI (a-VALUES WET)	-0.05	-0.06
DI (L-VALUE WET)	-0.04	0.05
DI (a-VALUES DRY)	0.02	-0.02
DI (L-VALUE DRY)	-0.09	0.07
AHI	-0.27	-0.41

4.3.5 CANONICAL VARIATE ANALYSIS

Canonical variate analyses were performed to identify groupings between cultivars and between environments (locality x season) for the TADD and roller milling samples respectively, in order to compare the milling performances of sorghum grain on the TADD and roller mills.

4.3.5.1 TADD SAMPLES

In order to identify groupings between cultivars, a CVA for all three TADD milling and food quality properties was performed. Only the DI values of the L-values (dry) were used in the CVA and not the a-values and wet values, for reasons explained in 4.3.2.1.1. As only three quality parameters were investigated for TADD, all three properties were included in the CVA for cultivars. Viscosity measurements were however, only done over the two seasons for Green and Potch, as discussed in 4.2.3.2. Therefore the CVA for cultivars were only performed on mean values from these two localities in the case of viscosity, while mean values of all localities were used in the case of DI and AHI values. From the CVA it was found that CV1 contributed 55.61 % and CV2 37.79 % to the variation between cultivars. The total contribution of CV1 and CV2 to the discrimination between cultivars was thus 93.4 %. In Table 4.62 the correlation matrix between variates and scores indicate that AHI (r=0.893) discriminated mainly with regard to CV1 and DI (r=0.897) mainly for CV2.

TABLE 4.62

THE CORRELATION MATRIX BETWEEN VARIABLES AND SCORES FOR GROUPINGS BETWEEN SORGHUM CULTIVARS IN TERMS OF MILLING AND FOOD QUALITY PROPERTIES IN THE CANONICAL VARIATE ANALYSIS

USCORE[1]	-0.179		0.893	0.127	
USCORE[2]	-0.478		-0.330	0.897	
USCORE[3]	0.860		-0.307	0.424	
	VISCOSITY		**AHI**	**DI**	

The scores for CV1 and CV2 for cultivars are shown in Table 4.63. From these scores it can immediately be seen that APN 881 differs the most from other cultivars, with the CV1 score high above zero (score=4.641) and CV2 below zero (score=-0.448). The positioning of this cultivar on the plot of the scores (Fig. 4.59) far away from all other cultivars, stresses the distinctiveness of this cultivar. APN 881 is found in the area on the plot where low DI values and high AHI values are found, i.e. in the best position on the plot for a good milling quality cultivar. This cultivar is thus very hard, whilst the colour properties are excellent, as seen in Table 4.64 for the mean values, where it was seen that the AHI value (mean=121.7) is much higher and the DI value (mean=11.05), lower than the average

The other cultivars in the same area as APN 881 on the plot (Fig. 4.59), although distant from APN 881, were SNK 3567, SNK 3863, SNK 3443, NK 286, NS 5655, PAN 8660, PAN 8564, PAN 8272 and PAN 8370. The CV1 scores of these cultivars were above and the CV2 scores below zero for these cultivars, as in the case of APN 881 (Table 4.63). All these cultivars had higher than the average mean AHI values, but lower than the average DI values, except for PAN 8272, PAN 8370 and SNK 3567. The DI value of SNK 3567 (mean=11.72) was slightly higher than the average, while PAN 8272 and PAN 8370 had lower than the average AHI values. In 4.3.4, it was found that APN 881 had excellent milling and hardness properties and TADD samples had good colour properties, but the viscosity values were low. NK 286 had low AHI values and the viscosity of

TADD samples was low, but colour properties of TADD samples were good. SNK 3863 showed good milling, hardness and colour properties for TADD abrasive milling. PAN 8660 showed high AHI values and viscosity values were good. SNK 3443 had good milling and hardness properties, as well as food quality characteristics (low DI and high viscosity), that render SNK 3443 the best overall performing cultivar for TADD milling performance. PAN 8564 showed excellent hardness and milling performances, while the colour of TADD samples were also good. PAN 8272 had low DI and high viscosity values and PAN 8370 also had good viscosity properties. SNK 3567 had good milling and hardness properties and the colour of TADD samples was good. This group of cultivars on the plot is the best cultivars for TADD milling performance. Although not all cultivars performed well with respect to AHI, DI and viscosity, they mainly performed well in two categories. The worst performing cultivar in this group, was SNK 3567, as this cultivar displayed below the average viscosity values and DI values were higher than the average.

TABLE 4.63

CANONICAL VARIATE 1 AND 2 SCORES FOR SORGHUM CULTIVAR GROUP MEANS FOR TADD MILLING PROPERTIES IN THE CANONICAL VARIATE ANALYSIS

CODE	CULTIVAR	CV1	CV2
A0	ADV5010	-0.046	-0.551
A1	APN881	4.641	-0.448
N3	NK283	-1.723	-0.736
N6	NK286	-0.097	0.031
N1	NS5511	-0.235	1.845
N5	NS5655	0.208	-0.083
P1	PAN8061	-0.103	-0.424
P7	PAN8171	-1.127	0.311
P2	PAN8262	-1.617	-0.178
P8	PAN8272	-0.039	-0.810
P3	PAN8370	0.077	-0.375
P6	PAN8446	-1.097	0.279
P4	PAN8564	0.442	-0.920
P0	PAN8660	0.993	-1.087
S3	SNK3337	0.319	0.478
S4	SNK3443	0.149	-0.478
S7	SNK3567	0.995	-0.017
S2	SNK3620	0.546	3.310
S6	SNK3663	0.569	0.131
S0	SNK3860	-0.150	1.906
S8	SNK3863	0.212	-0.506
SW	SNK3883	-1.051	-0.728
S9	SNK3939	-1.151	-0.119
S5	SNK3975	-0.712	-0.832

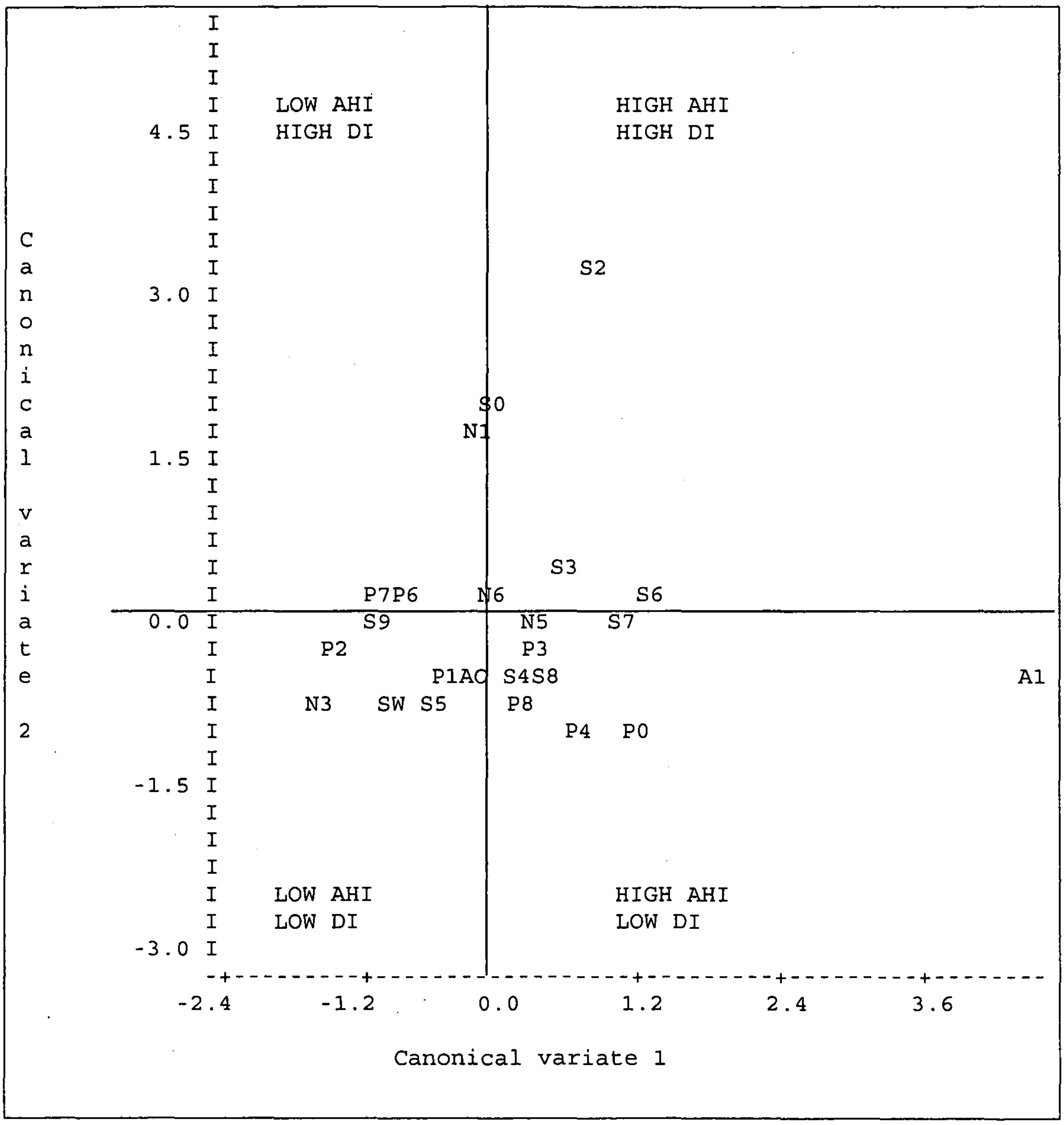


FIG. 4.59

PLOT OF THE CANONICAL VARIATE ANALYSIS OF THE TADD MILLING AND FOOD QUALITY PROPERTIES OF SORGHUM CULTIVARS TO IDENTIFY GROUPINGS BETWEEN CULTIVARS

TABLE 4.64

MEAN VISCOSITY, DEHULLING INDEX AND ABRASIVE HARDNESS INDEX VALUES OF SORGHUM CULTIVARS THAT CORRELATE WITH CANONICAL VARIATE 1 AND 2 RESPECTIVELY

CODE	CULTIVAR	AHI	DI (%)	VISCOSITY (cP)
A0	ADV5010	8.435	10.056	2454.2
A1	APN881	12.700	11.046	1829.2
N3	NK283	7.101	6.835	2937.5
N6	NK286	8.846	10.412	1689.2
N1	NS5511	7.585	18.030	1715.8
N5	NS5655	9.013	8.348	1791.7
P1	PAN8061	8.258	12.853	2351.7
P7	PAN8171	7.191	13.105	2314.2
P2	PAN8262	7.191	10.523	2235.8
P8	PAN8272	8.372	10.529	2617.5
P3	PAN8370	8.399	13.051	2553.4
P6	PAN8446	7.352	12.373	2190.0
P4	PAN8564	9.717	9.167	2023.3
P0	PAN8660	9.068	8.172	2965.0
S3	SNK3337	8.998	11.372	1887.5
S4	SNK3443	8.985	10.879	2480.8
S7	SNK3567	10.002	11.719	2074.2
S2	SNK3620	7.661	27.672	1354.2
S6	SNK3663	9.310	15.871	2212.5
S0	SNK3860	7.276	23.931	2042.7
S8	SNK3863	8.876	8.885	2155.0
SW	SNK3883	7.921	3.960	2153.4
S9	SNK3939	8.069	7.349	2044.1
S5	SNK3975	8.063	5.990	2380.0
MEAN		8.516	11.755	2185.538

The cultivar SNK 3620, was also very different from all other cultivars on the plot (Fig. 4.59), as the score CV1 (score=0.546) and CV 2 (score=3.310) were both positive (Table 4.63). The CV2 score was highly positive, explaining the positioning of this cultivar very high up on the plot. The location of this cultivar is in the area on the plot where grain with high AHI and DI values are found. This cultivar is thus situated very high on the plot, due to its very dark colour and subsequently high levels of dehulling required (mean DI=30.81). The AHI (mean=7.660) of this cultivar is lower than the average, indicating that this cultivar is totally unacceptable in terms of TADD milling quality. Viscosity levels (mean=1354) were also lower than the average. The poor colour of this cultivar can be attributed to its dark condensed tannin layer underneath the pericarp, as the cultivar is birdproof (Chapter 2). SNK 3663 and SNK 3337 were also found in this area on the plot and had high AHI values and the colour of TADD samples was good, but the viscosity values for TADD samples were poor in the case of SNK 3337. The DI values were higher than the average. The milling quality of these cultivars in terms of food quality characteristics was still poor, although the colour of these cultivars is better than SNK 3620 in the same area on the plot.

NS 5511 and SNK 3860 were the closest positioned cultivars to SNK 3620 on the plot (Fig. 4.59), with high CV2 scores of 1.845 and 1.906, respectively. Both were situated in the area on the plot where high DI and low AHI values are found. These cultivars had average AHI (means=7.59 and 7.28 respectively) values much lower than the, and much higher than the average DI values (means=20.87 and 26.12 respectively). These two cultivars, as well as SNK 3620, have very poor colour properties, due to the dark condensed tannin layer underneath the pericarp (4.3.4). In 4.3.4, the colour of TADD samples were found to be poor for both SNK 3860 and NS 5511 and the viscosity values were found to be low. Cultivars in this area on the plot are the poor performers with respect to colour properties of food. The birdproof properties of these cultivars will also render them unsuitable for milling, due to the astringent tastes caused by polyphenols present (Beta, 1998). The fact that DI values were high indicates that polyphenols will be left in the meal under normal milling conditions of 10 to 12 % dehulling (Desikachar, 1982). The only two cultivars situated in the top left hand side of the plot (Fig. 4.59), were PAN 8171 and PAN 8446, while NK 286 was also situated in this area, but very close to both gridlines, with the scores of CV1 (score=-0.097) and CV2 (score=0.031). This area is the worst area on the plot for a cultivar to be situated in, as cultivars with high DI values and low AHI values are found here. PAN 8171 and PAN 8446 both had lower than the average AHI values (means=7.192 and 7.352 respectively) and higher than the average DI values (means=13.11 and 12.27 respectively) (Table 4.64). Both had higher than the average viscosity values, though. NK 286 had close to the average AHI (mean=8.845) and DI values (mean=10.64), but porridge viscosity values were low (mean=1716). This explains the positioning of NK 286 very close to both gridlines, as values were close to the average. In 4.3.4, PAN 8446 was found to have low AHI values, while DI values were also found to be low. NK 286 had good milling, hardness and colour properties, but poor food quality in terms of viscosity. Therefore, this cultivar still has good milling and food quality properties, when porridge viscosity values are not of interest to the miller.

Cultivars found on the lower left side of the plot (Fig. 4.59) were SNK 3939, PAN 8262, PAN 8061, ADV 5010, NK 283, SNK 3883 and SNK 3975. All these cultivars had lower than the average AHI values and except for PAN 8061, all had good TADD colour properties (Table 4.64). The viscosity values of all, but SNK 3883 and SNK 3939 were high. In 4.3.4, SNK 3975 was found to display good food quality characteristics (meal colour and porridge viscosity) for TADD samples (low DI and high viscosity), but TADD milling properties was good. It was also said that these results agrees with those found by Dewar *et al.* (1993), who found SNK 3975 to be unsuited for meal production in terms of hardness properties. The results form the CVA confirms what was earlier said, as this cultivar has low AHI values and will thus have poor milling properties for TADD abrasive milling. Section 4.3.4 showed PAN 8061 to have good viscosity values. SNK 3939 and SNK 3883 had very good DI values for TADD, while ADV 5010 had good food quality characteristics for TADD samples (DI low and viscosity high). NK 283 had poor hardness properties, but TADD samples had excellent porridge making properties (high viscosity and low DI). PAN 8262 had poor milling and hardness properties, but DI values were good. When food quality characteristics are considered, these cultivars will produce meal with a good quality, except for PAN 8061 (poor colour) and SNK 3883 and SNK 3939 (poor viscosity values). When hardness is considered these cultivars are unsuitable for milling as softness will increase milling losses, but ADV 5010 and SNK 3975 might be considered for milling as their AHI values are close to the average (means=8.437 and 8.062 respectively) (Table 4.64).

A CVA was also performed to distinguish between different environments (cultivar x locality) according to TADD milling performance. The CVA with all TADD milling performance parameters included in the CVA, was senseless however as all latent roots were smaller than one. This may be due to the fact that only three variates were included in the CVA and only 4 environments were analysed, as Plat and Dover was left out of consideration when viscosity were considered. As only three variates were included in the CVA, no other properties could have been removed from the CVA and the performance of a CVA for the environment with regard to TADD milling properties was not possible. The following is a summary of what has been found in 4.3.4 regarding the TADD hardness and milling performance, as well as food quality properties for different environments: The 1997/98 season gave more favourable TADD colour properties (low DI) than the 1998/99 season. The locality of Dover gave poor hardness, milling and food quality properties (low AHI), extraction and DI. The best milling and hardness properties were found in grain from Green (high AHI), while colour properties of TADD samples were good (low DI). The best milling-performing quality grain was from Green in the current study, while grain from Dover and Plat should not be used for TADD abrasive milling, whilst the season of 1997/98 was more desirable in terms of TADD milling performance than the 1998/99 season.

4.3.6.2 ROLLER-MILLED SAMPLES

In order to identify possible groupings between cultivars for roller milling quality, as well as the food quality characteristics of samples, a CVA was performed with all parameters, except for a-values, included. The a-values were excluded, as both L- and a-values measure colour and with sorghum meal for the porridge making industry the interest lies in the whiteness and not the redness. In 4.3.2.1.1 it was for similar reasons, also decided to only calculate DI values on L-values. The total contribution of CV1 and CV2 to the discrimination between cultivars was 74.98 %. As viscosity was not performed over all localities, it was decided to firstly remove this property from the CVA, on order to try and improve the total contribution of CV1 and CV2 to the differences in cultivars. With viscosity removed, the total contributions of CV1 and CV2 to the discrimination between cultivars were increased to 87.38 %. CV1 contributed 71.28 % and CV2 a total of 16.10 %.

In Table 4.65 it can be seen that B2B (R=0.59) and the L-value (r=0.90) discriminated mainly with regard to CV1 between cultivars and B1B and extraction values, mainly with regard to CV2. From Table 4.66 it is clear that SNK 3883 is the cultivar most different to the other cultivars with the both the scores of CV1 (score=-4.96) and CV2 (score=-1.37) negative. This cultivar was situated in the area where both B1B and B2B are low, while extraction and L-values are high, i.e. the area on the plot (Fig. 4.60) where cultivars with the best milling and colour properties are found. In Table 4.67 it can be seen that B1B (mean=24.91) and B2B (mean=26.02) values are lower than the average, while the L-value (mean=83.47) and extraction value (mean=81.39) were higher than the average. The roller milling quality of this cultivar is therefore excellent and the cultivar is situated far away from other cultivars, due to its excellent whiteness properties. Other cultivars in this area on the plot are SNK 3939, SNK 3863, SNK 3975, NS 5655 and NK 286 (Fig. 4.60). SNK 3863, SNK 3939 and SNK 3975 all had B1B and B2B values lower than the average, while L- and extraction values were higher than the average (Table 4.67). NS 5655 also had below the average B1B (mean=24.99) value and higher than the average L- (mean 79.74) and extraction values (mean=80.92), but the B2B value (mean =27.10) was above the average. The B1B (mean=24.02) and B2B values (mean=25.38) of NK 286 were below the average and extraction value means (mean=81.46) were higher than the average, but the L-values were lower. These cultivars still had good milling performances in more than one aspect. In 4.3.4, SNK 3883 was indicated to have poor roller milling priorities, but the colour was good. SNK 3975 had very good milling, hardness, and food quality characteristics, as was the case with SNK 3863, SNK 3939 and NK 286, but the latter three cultivars had low viscosities. These results therefore confirm that these cultivars are good roller milling performance cultivars, except for SNK 3883, but the CVA indicates that this cultivar does in fact consist of good roller milling performing abilities. In 4.3.5.1 only two of these cultivars were found to be suitable cultivars in terms of TADD milling performance, namely SNK 3863 and NS 5655, while NK 286 was in the average class for TADD milling quality. SNK 3883 and SNK 3939 indicated poor hardness and viscosity properties for TADD milling, but colour properties were good. It is therefore clear that NK 286, SNK 3883 and SNK 3939 deliver better milling results when milled on the roller mills, than in the TADD abrasive milling process. Roller milling can therefore improve the milling performances of some cultivars compared to the abrasive decortication process. All cultivars, except for SNK 3863 and NS 5655, in this area on the plot (Fig. 4.60), were also in Chapter 3 predicted to have acceptable hardness and milling performance (Fig. 3.12).

TABLE 4.65

THE CORRELATION MATRIX BETWEEN VARIABLES AND SCORES FOR GROUPINGS BETWEEN SORGHUM CULTIVARS IN TERMS OF ROLLER MILLING AND FOOD QUALITY PROPERTIES (MEAL COLOUR AND PORRIDGE VISCOSITY) OF THE CANONICAL VARIATE ANALYSIS

USCORE[1]	0.59	-0.15	0.48	-0.90	-0.32
USCORE[2]	0.20	0.70	-0.11	-0.06	-0.54
USCORE[3]	0.76	0.10	-0.04	0.12	-0.29
	B2B	**B1B**	**B2G**	**L-VALUE**	**EXTRAC-TION**

TABLE 4.66

CANONICAL VARIATE 1 AND 2 SCORES FOR CULTIVAR GROUP MEANS FOR MILLING AND FOOD QUALITY PROPERTIES (MEAL COLOUR AND PORRIDGE VISCOSITY) OF ROLLER MILLING SAMPLES

CODE	CULTIVAR	CV1	CV2
A0	ADV5010	0.64	-0.19
A1	APN881	1.99	0.57
N3	NK283	0.15	-0.43
N6	NK286	-0.64	-0.15
N1	NS5511	4.09	-0.39
N5	NS5655	-1.82	-0.43
P1	PAN8061	-0.03	1.80
P7	PAN8171	-0.57	0.72
P2	PAN8262	-0.84	0.16
P8	PAN8272	-0.88	0.96
P3	PAN8370	-0.60	1.64
P6	PAN8446	0.83	0.58
P4	PAN8564	-1.54	-0.12
P0	PAN8660	0.51	1.34
S3	SNK3337	0.15	-0.51
S4	SNK3443	0.11	1.02
S7	SNK3567	0.00	0.76
S2	SNK3620	4.40	-1.47
S6	SNK3663	0.68	0.42
S0	SNK3860	4.33	-1.41
S8	SNK3863	-2.41	-0.41
SW	SNK3883	-4.96	-1.37
S9	SNK3939	-2.00	-1.06
S5	SNK3975	-1.59	-2.02

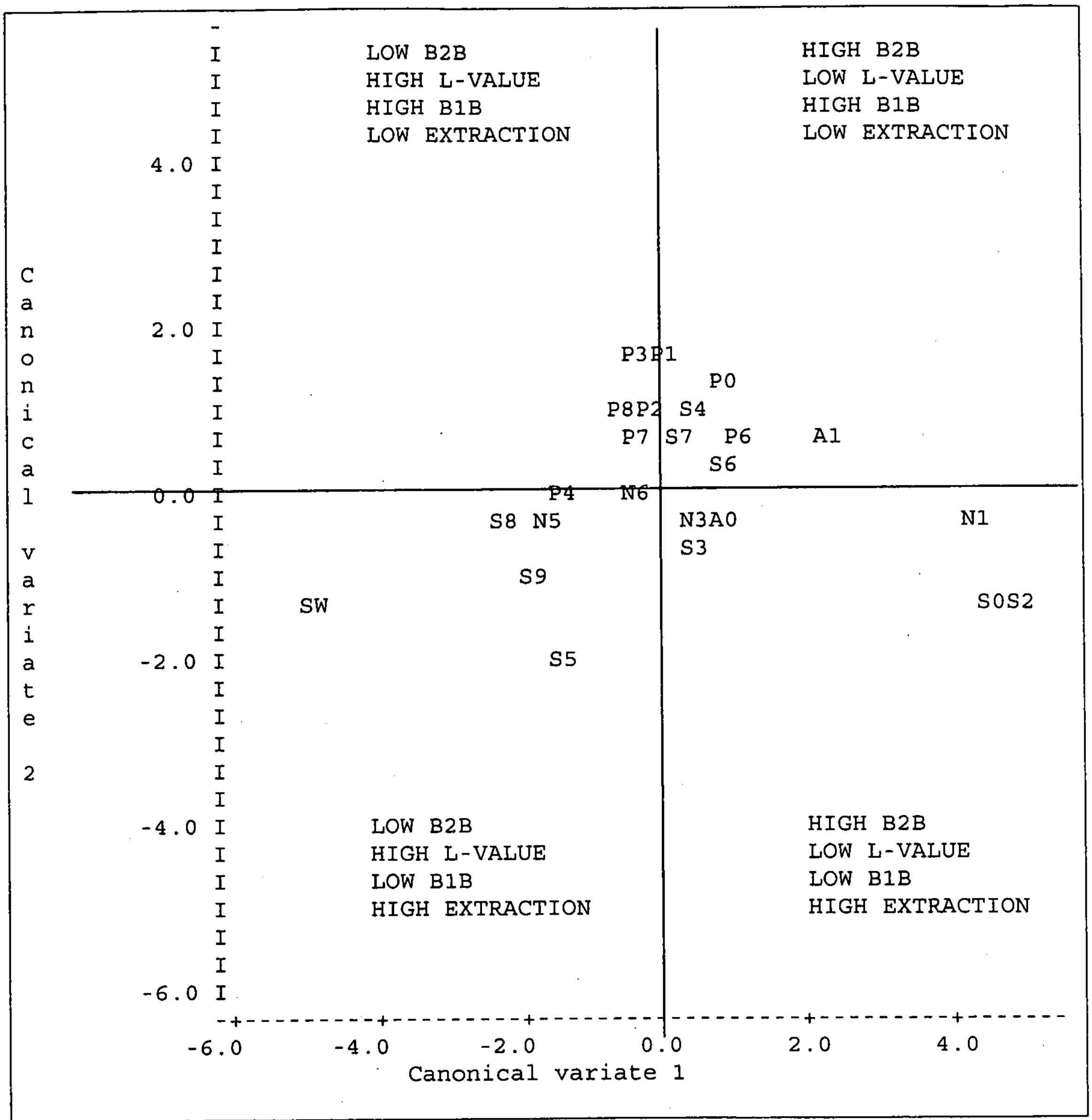


FIG. 4.60

PLOT OF THE CANONICAL VARIATE ANALYSIS OF THE MILLING AND FOOD QUALITY PROPERTIES (MEAL COLOUR AND PORRIDGE VISCOSITY) OF SORGHUM CULTIVAR ROLLER MILLING SAMPLES TO IDENTIFY GROUPINGS BETWEEN CULTIVARS

TABLE 4.67

MEAN BREAK 2 BRAN, L-, BREAK 1 BRAN AND EXTRACTION VALUES OF SORGHUM CULTIVAR ROLLER MILLING SAMPLES THAT CORRELATE WITH CV1 AND CV2 RESPECTIVELY IN THE CANONICAL VARIATE ANALYSIS

CODE	CULTIVAR	B2B (g)	L-VALUE	B1B (g)	EXTRACTION (%)
A0	ADV5010	27.3	77.61	25.97	80.2
A1	APN881	29.75	76.03	24.3	79.81
N3	NK283	27.27	77.72	25.33	80.65
N6	NK286	25.38	77.77	24.02	81.46
N1	NS5511	30.37	74.06	24.53	79.69
N5	NS5655	27.1	79.74	24.99	80.92
P1	PAN8061	28.28	77.59	30.09	79.59
P7	PAN8171	27.62	78.5	28.42	80
P2	PAN8262	28.43	78.37	28.36	80.41
P8	PAN8272	27.64	78.53	28.21	80.15
P3	PAN8370	26.97	77.81	30.04	80.52
P6	PAN8446	28.13	77.49	28.91	79.51
P4	PAN8564	26.36	79.55	24.96	80.81
P0	PAN8660	26.89	77.39	29.35	79.66
S3	SNK3337	26.07	77.09	22.38	81.49
S4	SNK3443	28.71	78.03	27.43	79.65
S7	SNK3567	26.62	77.38	27.38	80.47
S2	SNK3620	28.79	73.34	19.79	80.87
S6	SNK3663	28.14	77.45	27.84	79.8
S0	SNK3860	29.17	74.22	22.12	80.09
S8	SNK3863	26.08	79.43	24.6	81.73
SW	SNK3883	26.02	83.47	24.91	81.39
S9	SNK3939	24.87	79.55	23.87	81.74
S5	SNK3975	26.34	79.52	21.68	81.8
	MEAN	**27.43**	**77.82**	**25.81**	**80.52**

The cultivars NK 283, ADV 5010, SNK 3337, NS 5511, SNK 3860 and SNK 3620 were all situated in the area on the plot where high B2B and extraction values are found and low B1B and L-values (Fig 4.60). The colour of these cultivars is therefore poor after roller milling, although extraction values are high. NS 5511 (score=4.09), SNK 3620 (score=4.42) and SNK 3860 (score=4.33) are situated to the very right on this area on the plot close to one another, with the score of CV1 very high (Table 4.66). All three these cultivars had much lower L-values than the average, while B2B values were higher (Table 4.67). The poor colour of these cultivars is due to the condensed tannin layer underneath the pericarp, which is dark in colour. NK 283, ADV 5010 and SNK 3337 all had lower B2B values than the average and higher L-values than the average. The B1B value of ADV 5010 was slightly higher than the average and this cultivar also had lower extraction values than the average. NS 5511, SNK 3860, ADV 5010 and SNK 3620 were unacceptable in terms of milling and food quality properties. In 4.3.4, SNK 3337 was indicated to have very good milling and hardness properties, but porridge viscosity values were poor. ADV 5010 did not have very good milling and colour properties, but hardness properties were good. The food quality characteristics were poor for roller-milled samples (a-value high and viscosity low). NK 283 had poor hardness and milling properties, but extraction and porridge viscosity values were good. From these data and the CVA, it can be concluded that ADV 5010 and NK 283 are unacceptable in terms of milling and food quality properties. SNK 3337 is a good roller milling cultivar for use in cases where high porridge viscosity is not very important. SNK 3860 had poor milling, colour and viscosity properties. NS 5511 had poor milling, hardness and colour properties. SNK 3620 also had poor milling and hardness properties. These cultivars are again indicated to be unsuitable for milling purposes. In 4.3.4 SNK 3620, SNK 3860 and NS 5511 were found to also be unsuitable for TADD milling, due to its dark colour and poor hardness and viscosity properties. SNK 3337 were observed to have good TADD hardness and colour properties, but viscosity values were poor. The cultivar ADV 5010 was found to be suitable for TADD milling, as hardness properties were average and food quality properties good. NK 283 were unsuitable for TADD milling due to softness, but food quality properties were good. Again, it is verified that the milling performance of cultivars unsuitable for TADD abrasive milling purposes could be improved by roller milling. This was the case with SNK 3337, but a cultivar such as ADV 5010 was on the other hand suitable for TADD milling, but not for roller milling. This may be attribute to the meganism of the milling action of the two instruments. Even roller milling could not improve the milling performances of the three birdproof cultivars. In Chapter 3 the hardness properties of the birdproof cultivars were also predicted to be poor.

APN 881, PAN 8660, PAN 8446, SNK 3663, SNK 3567 and SNK 3443 all fell in the area on the plot (Fig. 4.60) where high B2B and B1B values and low L- and extraction values are found. For these cultivars, losses are high and colour properties poor. SNK 3663 and PAN 8446 indicated higher B2B (means=28.14 and 28.13 respectively) and B1B (means=27.84 and 28.91 respectively) values than the average, but lower than the average extraction (means=79.80 and 79.51 respectively) and L-values (means=77.45 and 77.49 respectively). The same was found for the other cultivars in this area on the plot, but APN 881 had lower B1B and higher extraction values than the average. In the case of PAN 8660 and SNK 3567 lower than the average B2B values were found and with SNK 3443 displaying higher than the average L-value means. These cultivars are all unacceptable in terms of roller milling quality, but APN 881 is the best performing cultivar in this group. In 4.3.4, APN 881 was found to have excellent milling and hardness properties, but extractions were low and food colour and viscosity properties were poor. In 4.3.4, SNK 3443 was found to have good milling and hardness properties, but extraction, colour and viscosity values were poor. PAN 8660 showed good milling, hardness and viscosity properties, but extraction values were poor. PAN 8446 showed good milling and viscosity properties, but extraction values were low. SNK 3567 had good milling and hardness properties, but viscosity values were low. In 4.6.1 it was seen that APN 881 had good hardness and colour properties for TADD abrasive milling. PAN 8660 showed high AHI values and viscosity values were good for TADD milling. SNK 3443 was the best overall performing cultivar for TADD milling performance. SNK 3567 was hard enough for TADD milling but had lower than the average viscosity values and DI values were higher than the average. SNK 3663 was hard enough for TADD milling and the colour was good, but viscosity values were poor. PAN 8446 had lower than the average AHI and viscosity values and lower than the average DI values. PAN 8370 displayed good viscosity properties for TADD milling, but hardness was poor. All of these cultivars, except for PAN 8446, SNK 3663 and PAN 8370, were suitable for TADD milling, but roller milling gave poor extraction values and colour properties in general. In Chapter 3 all of these cultivars, except for APN 881 were situated in the area of the CVA plot (Fig. 3.15), where good hardness properties are predicted. APN 881, though, was close to the gridlines for hardness.

The cultivars PAN 8061, PAN 8171, PAN 8272, PAN 8370, PAN 8262 and PAN 8564 were all situated in the area where low B2B and extraction values and high B1B and L-values are found on the plot (Fig. 4.60). PAN 8061 was situated close to the gridline on the plot and had properties similar to cultivars in the top right side of the plot. This cultivar displayed higher than the average B2B (mean=28.28) and B1B (mean=30.09) values, while L- (mean=77.59) and extraction values (mean=79.59) were lower than the average (Table 4.67). This cultivar therefore had poor milling properties. PAN 8564 was also situated close to a gridline on the plot and had milling properties similar to cultivars in the lower left side on the plot. This cultivar displayed lower than the average B2B (mean=26.36) and B1B (mean=24.96) values, while L- (mean=79.55) and extraction (mean=80.81) were higher than the average. This cultivar therefore fell in the class of milling cultivars with excellent milling performance for roller milling. PAN 8370 showed lower than the average B2B (mean=26.97) values and B1B values were higher than the average (mean=30.04), while L- (mean=77.81) and extraction values (mean=80.52) were close to the average. PAN 8171, PAN 8272 and PAN 8262 indicated B2B and L-values higher than the average and lower than the average extraction values. In 4.3.4, PAN 8061 was found to have good hardness and viscosity properties, but extraction values were poor. Due to the poor colour and extraction values, this cultivar is unsuitable for roller milling purposes. PAN 8370 had poor milling and hardness qualities, but good viscosity properties were found (4.3.4). Due to its poor roller milling performance, this cultivar is unsuitable for roller milling purposes. PAN 8272, showed good milling and hardness properties, but extraction values were low. Roller milling samples had high viscosity values. The extraction value of this cultivar was close to the average (Table 4.66) and the cultivar may still be suitable for roller milling purposes, due to its hardness and acceptable food quality properties. PAN 8564 indicated excellent hardness, milling and colour properties, but viscosity values were poor. This cultivar will be suited for roller milling when high porridge viscosity values are not important. In 4.3.4 PAN 8272 and PAN 8370 were determined to have poor hardness properties for TADD abrasive milling, but food quality properties were good, which meant that these cultivars are unsuitable for abrasive decortication milling. Through the use of roller milling, the milling performance of PAN 8272 was somewhat improved. PAN 8171 had poor hardness and food quality properties and was found to be unsuitable for abrasive decortication milling. PAN 8564 showed excellent hardness and milling, as well as colour performances, for TADD samples. This cultivar also had an excellent roller milling performance. PAN 8061 showed poor TADD milling properties, due to softness and poor colour properties. Roller milling performance of this cultivar was also poor. The best milling-performing cultivars in this group were PAN 8564 and PAN 8272, with the first-mentioned the better of the two. In Chapter 3, all these cultivars were predicted to be hard with small kernels. The small kernels may explain the lower extraction values (Gomez *et al.*, 1997) of PAN 8564, PAN 8171 and PAN 8272. In Chapter 3 (Fig. 3.15), PAN 8370 was situated close to the area where soft kernels are found during the prediction of milling properties and in the current chapter the hardness properties of this cultivar were also observed to be poor.

To identify possible grouping between environments (locality x season) of sorghum growth, a CVA was performed on all roller milling properties for environments. However, the a-values were left out of consideration again for this CVA, as for cultivars. It was found that CV1 contributed 67.72 % to the discrimination between localities on the basis of roller milling properties, while CV2 contributed 28.40 %. The total contribution of CV1 and CV2 is thus 96.12 %.

From the correlation matrix of variables and scores in Table 4.68, it can be seen that B1B (r=-0.67), B2M (r=0.64) and extraction (r=0.72) mainly discriminated between environments for CV1, while B1M (r=0.82) and B2G (r=-0.63) discriminated mainly with regard to CV2. In Table 4.69 it is seen that no scores were given to Dover 1997/98 and Plat 1998/99, as no viscosity measurements were made for these environments and viscosity was included in the CVA. From the scores in Table 4.69 it can be seen that all four environments were very different with scores very distant to one another. From the plot (Fig. 4.61), it is clear that Green 1997/98 and Potch 1998/99 were situated the closest together on the plot, as both had negative scores for CV1 (scores=-0.4397 and –2.3470 respectively) and positive scores for CV2 (scores=0.0192 and 1.2428 respectively). These two environments were situated in the area where high B1B and B1M values and low B2M, extraction and B2G values are found. As the B2M, extraction and B2G values of these cultivars were low and B1M and B1B values are high, grain from these environments were soft with low extraction values and thus had poor milling performances. Therefore, sorghum from Green displayed poor milling performance during the 1997/98 season and Potch, poor performance during the 1998/99 season. For both Green 1997/98 and 1998/99 and Potch 1998/99, B1B and B1M values higher than the average were noticed, while extraction, B2M and B2G values below the average were found. Extractions and B2M values of Potch 1998/99 were lower than those of Green 1997/98.

TABLE 4.68

THE CORRELATION MATRIX BETWEEN VARIABLES AND SCORES FOR GROUPINGS BETWEEN ENVIRONMENTS IN TERMS OF ROLLER MILLING AND FOOD QUALITY PROPERTIES (MEAL COLOUR AND PORRIDGE VISCOSITY) OF SORGHUM CULTIVARS IN THE CANONICAL VARIATE ANALYSIS

USCORE[1]	-0.67	-0.17	-0.39	0.64	-0.04	0.41	0.39	-0.43	0.72	-0.42	-0.30	0.03
USCORE[2]	0.22	0.28	0.82	-0.68	-0.63	0.07	0.37	-0.37	-0.07	-0.12	-0.03	-0.31
USCORE[3]	-0.32	-0.09	-0.07	0.01	0.07	-0.35	0.26	-0.23	0.19	0.08	0.20	0.10
	B1B	**B2B**	**B1M**	**B2M**	**B2G**	**S1**	**S2**	**L-VALUE**	**EXTRACTION**	**TL**	**VISCOSITY**	**TH**

TABLE 4.69

CANINICAL VARIATE 1 AND 2 SCORES FOR ENVIRONMENT (CULTIVAR X LOCALTY) GROUP MEANS FOR MILLING AND FOOD QUALITY PROPERTIES (MEAL COLOUR AND PORRIDGE VISCOSITY) OF SORGHUHUM CULTIVARS (ROLLER MILLING SAMPLES) IN THE CANONICAL VARIATE ANALYSIS

CODE	LOCALITY	SEASON	CV1	CV2
Do	DOVER	1997/98	*	*
PR	PLAT	1998/99	*	*
G8	GREEN	1997/98	-0.44	0.02
G9	GREEN	1998/99	-0.27	-2.04
P8	POTCH	1997/98	3.05	0.78
P9	POTCH	1998/99	-2.35	1.24

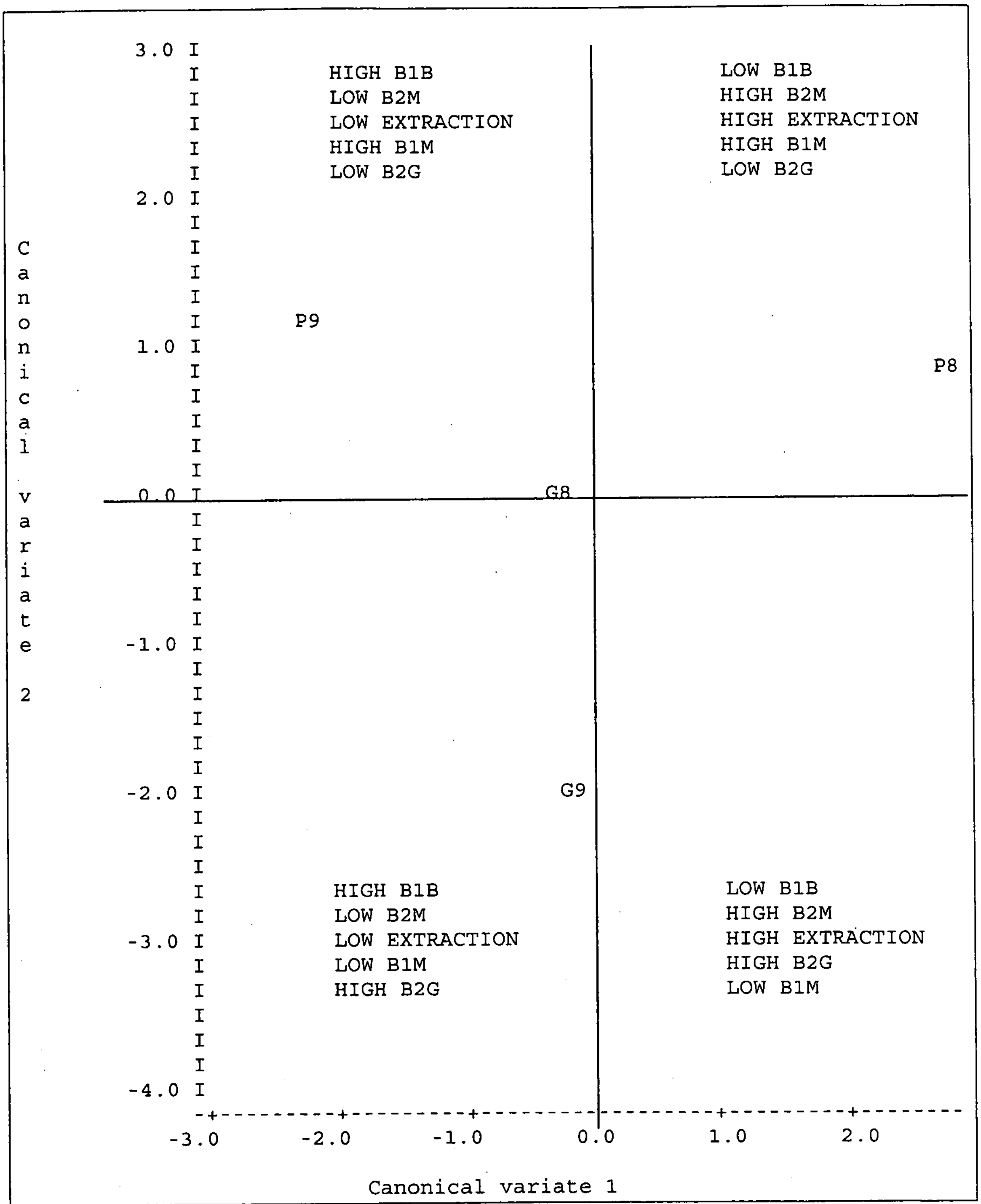


FIG. 4.61

PLOT OF THE CANONICAL VARISTE ANALYSIS OF THE MILLING AND FOOD QUALITY PROPERTIES (MEAL COLOUR AND PORRIDGE VISCOSITY) OF SORGHUM CULTIVARS ROLLER MILLING SAMPLES TO IDENTIFY GROUPINGS BETWEEN ENVIRONMENTS (LOCALITY X SEASON)

TABLE 4.70

MEAN BREAK 2 MEAL, BREAK 1 BRAN, EXTRACTION, BREAK 1 MEAL AND BREAK 2 GRITS VALUES OF ENVIRONMENTS OF SORGHUM CULTIVAR ROLLER MILLING SAMPLES THAT CORRELATE WITH CV1 AND CV2 RESPECTIVELY IN THE CANONICAL VARIATE ANALYSIS

CODE	LOCALITY	SEASON	B1B	B2M	EXTRACTION	B1M	B2G
G8	GREEN	1997/98	26.66	196.23	80.19	139.21	28.58
G9	GREEN	1998/99	23.52	213.53	80.63	122.48	30.38
P8	POTCH	1997/98	20.69	209.28	81.94	134.93	27.95
P9	POTCH	1998/99	28.62	176.37	79.54	152.01	27.80
	MEAN		**24.87**	**198.85**	**80.57**	**137.16**	**28.68**

For the 1997/98 season, Potch was situated in the area on the plot where low B1B and B2G values, as well as high B2M, extraction and B1M, are found (Fig. 4.61). Grain from this environment displayed very good extraction values in terms of meal and losses in the form of bran and grits were low. The low B2G value indicates that the grain was not very hard, as does the high B1M value. In general, grain from this locality was not very hard and was not suited for milling, but delivered high extraction values when milled on roller mills. This environment showed higher than the average extraction (mean=81.936) and B2M (mean=209.28) values, whilst the lowest B1B (mean=20.69) value was also found. Break 2 grits (mean=27.95) were lower than the average (Table 4.69). The B1M values were lower than the average, which might be explained by the fact that this environment is situated rather close to the gridline (score=0.7808), where environments with low B1M values are found.

For 1998/99, Green was found in the area on the plot where grain of excellent hardness, but poor milling performances are found (Fig. 4.61). This area on the plot is the area where high B1B and B2G values and low B2M, extraction and B1M values are found. The CV 1 score (score=-0.27) of this environment (Table 4.68) indicates that it is situated very close to the gridline of the area where grain with low B1B and B1M and high B2M, extraction and B2G values are found. Table 4.70 indicates that grain from this environment had lower than the average B1B (mean=23.52) and B1M (mean=122.48) values, as well as higher than the average B2M (mean=213.53), B2G (mean=30.38) and extraction values (mean=80.631). Due to its milling properties just mentioned, this cultivar belongs on the lower right side of the plot, where its positioning, close to the gridline, tends to be. This is thus the best milling performance environment with excellent hardness, extraction and low milling loss properties.

In 4.3.4, sorghum from the 1997/98 seasons were shown to have better hardness and roller milling properties, than the 1998/99 season, but food quality properties of roller milling samples were poor, during this season. In the case of Potch, this was found to be true, as better milling properties were found for the Potch 1997/98 environment (Fig. 4.61) than the Potch 1998/99 environment. The Green 1998/99 environment had better milling performances than the 1998/99 environment, indicating that a possible cultivar x locality interaction, which was not tested for in the present study, might be present. Results from this study therefore confirms that locality of growth can influence roller milling, as was predicted by Gomez (1993).

In 4.3.4, the best milling and hardness properties were found in grain from Green. Colour properties of roller milling samples were also good. This good milling performance at Green was found only to be true for the 1998/99 season, as the previous season displayed soft grain with poor milling performances, as were just discussed.

Grain from Potch also had good milling and hardness properties, but not as good as those from Green (4.3.4). In 4.3.4 sorghum from Potch showed low B1B, S1 and L-values and higher extraction, S2 and a-values. The colour of the grain was poorer than in the case of Green. Only the Potch 1997/98 environment showed these good milling properties (Fig. 4.61).

The environments of Dover 1997/98 and Plat 1998/99 were not discussed in the CVA, as viscosity was included as a variate. In 4.3.4, Dover was found to have poor hardness and milling properties. Poor milling and hardness properties were also found at Plat. Colour properties at this locality were also poor.

4.3 CONCLUSION

The most important milling performance parameter for TADD abrasive milling is the AHI, as this provides a good indication of the hardness of the grain. The AHI correlated with other hardness indicating properties from the roller mills, namely positively with B2G and B2M and negatively with B1M. Although the milling performance of sorghum cultivars with TADD and roller milling techniques may differ, the essential hardness remains the same.

The food quality properties of TADD milling samples were measured with the DI and viscosity values. The DI correlated with the colour properties of the roller milling samples, indicating that grain with good colour properties will produce meal with good colour in both the TADD and roller milling process. It also indicates that both methods of milling serve as means to improve the colour of sorghum meal. The AHI correlated negatively with the viscosity values, indicating that harder cultivars will have poor viscosity values. Therefore, when selecting cultivars, the miller of sorghum will need to consider the stiffness of the porridge needed for a specific market and the milling performance in terms of hardness.

Hardness, together with total loss and extraction, is also the most important milling performance property for the roller milling of sorghum as indicated by the CVA. The roller milling performance of sorghum cultivars were also measured in terms of hardness, colour and viscosity properties. Hardness was determined by means of the products from the mills at different stage of milling and these products were also used to determine the milling performance. The B2M and B2G values indicated hardness as the soft endosperm is probably removed at break 1 and the hard endosperm at break 2, as this was the case with maize (Pretorius & Du Plessis, 1999) and the correlation of B2M and B2G with AHI confirm that this could be true for sorghum. The B1M value measures softness as does the TH values, while S1 and S2 also measure hardness. The B1B and B2B values are part of the losses. Extraction value is a good indication of milling performance, as is TL. The B1B correlated inversely with extraction and B2M, as the bran increased losses, with negative effects on extraction and B2M values. An inverse correlation between B2B and extraction also illustrated this. Negative correlations between B1M (indicates softness) and B2G and B1M and B2M (indicates hardness) were also found and TH values were found to correlate with TL, as softness will lead to greater losses. Break 2 meal (hardness) on the other hand, correlated well with extraction and B2G, as hardness is known to lead to greater yields in milling. Total loss correlated inversely with S1 and S2 (HE1 and HE2) and S1 and S2 negatively with TH, while S1 and S2 correlated well with one another.

Again, the most important porridge making food quality properties of roller-milled samples were colour and viscosity as identified with the CVA. The L-value correlated negatively with the a-values, as an increase in lightness (L-values) will decrease redness (a-values) in sorghum grain. Viscosity values correlated poorly negatively with AHI values, but no correlation between viscosity values and hardness values (B2G and B2M) from the roller mills were found.

TABEL 4.71

SUMMARY OF THE TYPE OF MILLING MOST SUITABLE FOR SORGHUM CULTIVARS

CULTIVAR	MIILLING PROPERTIES	
	GOOD ABRASIVE DECORTICATION MILLING	GOOD ROLLER MILLING
ADV5010	X	
APN881	X	
NK283		
NK286	X	X
NS5511		
NS5655		X
PAN8061		
PAN8171		
PAN8262		
PAN8272		
PAN8370	X	
PAN8446		
PAN8564	X	X
PAN8660	X	
SNK3337		
SNK3443	X	
SNK3567	X	
SNK3620		
SNK3663		
SNK3860		
SNK3863	X	
SNK3883		X
SNK3939		X
SNK3975		

The type of milling most suitable for specific sorghum cultivars is summarized in Table 4.71. The best overall abrasive decortication milling cultivar was SNK 3443 with high AHI and viscosity values and low DI values. The second best group for TADD milling was APN 881, SNK 3567, SNK 3863 and PAN 8564 with good colour and hardness properties and PAN 8660 and PAN 8370 with good hardness and viscosity properties. Except for SNK 3443, PAN 8272 had the best food quality properties in terms of colour and viscosity. The poorest TADD milling performances were found with the three birdproof cultivars (SNK 3620, SNK 3860 and NS 5511), as well as SNK 3663 and SNK 3337. Colour and hardness properties of these cultivars were poor and viscosity values were mostly low (except for SNK 3663). NK 286 was a cultivar with close to the average TADD milling performance and colour properties, but with poor viscosity values.

The best roller milling performing cultivars were SNK 3883 and PAN 8564, with good colour and extraction properties and low losses in terms of bran values. SNK 3939 and NK 286 also had good extraction, colour and low bran values, but had poor viscosities. The worst roller milling performing cultivars were PAN 8446, PAN 8660 and SNK 3567, due to poor colour and extraction properties and high losses in terms of bran. The worst colour properties for roller-milled samples were again the birdproof cultivars (SNK 3860, SNK 3620 and NS 5511) and losses in terms of bran were high. APN 881 and ADV 5010 had poor meal colour properties. PAN 8061, PAN 8370, and PAN 8171 were all unacceptable in terms of roller milling performances.

Only two cultivars were identified to have good milling performances for both TADD and roller milling, namely PAN 8564 and NK 286. PAN 8564 is the best overall performer for roller and TADD milling and was also predicted to be of good milling quality on the basis of physical properties. The TADD and roller milling performance of NS 5511, SNK 3860, SNK 3620, NK 283, PAN 8370 and PAN 8262 were poor, while the milling performance prediction on physical properties of all, except PAN 8370, were also poor. These are the worst overall milling performing cultivars. PAN 8446, PAN 8061, and PAN 8171 had poor TADD and roller milling properties, but the prediction was good in the case of physical properties. These cultivars all had poor extraction values and all were small-sized, indicating that the small kernel sizes might have influenced extraction values for roller milling samples. SNK 3567 was a large kernel sized cultivar predicted to have good milling performances, but performed well with respect to TADD milling.

ADV 5010, APN 881 and SNK 3443 had good TADD milling properties, but roller-milling performances were poor. Milling performances of the latter two were predicted to be good, but colour properties of roller milling samples were poor. PAN 8660 showed good TADD, but poor roller milling performances and the milling properties were predicted to be poor. SNK 3939, SNK 3975 and SNK 3883 all had poor TADD, but good roller milling performances and the milling performance based on a prediction from the physical properties, were good. The roller milling technique was able to upgrade the general poor TADD milling performances of this grain.

Dover was the locality that gave the worst TADD milling performances for sorghum, as well as poor colour properties, followed by Plat, while milling performances and colour properties of grain from Green was very good. Viscosity values did not differ between localities for TADD samples. The 1997/98 season gave better TADD colour properties than the 1998/99 season, while AHI and viscosity values did not differ between seasons. In 1997/98, Green was found to be the best milling performing environment with good hardness, extraction and low milling loss properties. Overall, Green also displayed the best roller milling performances as in the case of TADD milling, followed by Potch and Dover, while Plat again produced poor milling performances. In the 1998/99 season, sorghum from Green displayed poor roller milling performances. Potch was the second best milling performing locality during the 1999/98 season, considering that sorghum generally, was not very hard and not suited for milling, but delivered high extraction values when milled on roller mills. During the 1998/99 season however, Potch delivered poor performances. Overall, the 1997/98 season indicated better milling performances for roller milling, as was the case with TADD samples.

From this Chapter it can be concluded that abrasive decortication milling could improve the milling performance and food quality properties of some cultivars compared to roller milling, while roller milling may better suit other cultivars. Some cultivars are suited for both abrasive decortication and roller milling techniques. This might be due to the differences in the functioning of the instruments, which may suit certain cultivars better, as well as the specific techniques applied in each case. No seasonal effects were found to favour either abrasive decortication or roller milling, but with some localities this was the case. In the case of abrasive decortication samples better viscosity values were found due to the removal of more of the bran, which in turn caused higher protein contents, with consequential better gelation abilities. Due to the small range in extraction values for different cultivars found in the roller milling, the roller milling process was found to be dependable in providing acceptable extraction values. Hardness, as indicated by high B2M and low B1M values, was also found not to be the single most important factor to influence extraction values. The CVA for roller milling indicated that locality x seasonal effects were present for sorghum milling quality, but the significance of these effects was not tested and provides a possibility for future research. The relationship between the bran yield from the roller mills and viscosity values were identified through correlations, but further research into this is also necessary. The relationship between DI values and hardness properties were also identified through correlations, but to identify the exact implications of this, as well as its significance, further research will also be necessary.

CHAPTER 5

GENERAL DISCUSSION AND CONCLUSION

Sorghum is primarily known in the food industry as a grain for malting (Beta *et al.*, 1995) and milling purposes (Desikachar, 1982), especially in African countries (Akingbala *et al.*, 1988). Although the grain has the ability to withstand a wide range of weather and rainfall conditions (Zipf *et al.*, 1950), the quality of sorghum cultivars is highly variable with regard to locality and season (Pretorius *et al.*, 1996). In the malting-industry poor malting quality of sorghum may lead to economic losses on the side of the brewer, maltster, producer of grain and even the seed company. In the present study, it was found that good quality malt should have good germination ability properties to activate enzymes enough to produce malt from sorghum, while malting losses should be limited. The Class of the cultivar used (GM or GH), was also found to influence the quality of the malt end product, while high tannin properties should also be taken into consideration. While the malting of sorghum is more of a chemically based process, due to the major role that enzymes play in the process (Beta *et al.*, 1995), dry-milling quality is a process highly influenced by physical properties, such as hardness (De Francisco *et al.*, 1982). As with malting quality, the primary consideration with milling should be economic losses. In this case the miller, producer and seed company may suffer severe economic losses when non-milling cultivars are used for milling. To make matters even more difficult, the commercial availability of specific sorghum cultivars for milling or malting is found to be scarce.

In the current study the milling, physical and malting properties of 24 sorghum cultivars over 2 seasons and at 3 localities per season, were determined. The influence of cultivar, locality and season on sorghum quality was determined and the most important malting, physical and milling properties were determined to identify the interrelationship between quality properties and to identify cultivars suitable for milling and malting purposes. The malting quality of sorghum was determined by measurements made during the malting process as such, as well as the measurement of the combination of known parameters for malting on a laboratory scale. The same was done for the physical properties, in attempt of predicting the milling properties of grain without physical milling of the grain. The actual milling was done by both TADD abrasive milling and roller milling. The latter method was developed during the present study as a means of a quicker one-step method, instead of the two-step abrasive milling process. The products obtained through roller milling and TADD abrasive milling was used to determine the milling quality of the sorghum. The colour and viscosity food quality characteristics of the milled products were determined to compare the effect of milling on end product quality.

One of the aims of the study was to identify the most important malting, physical and milling properties in order to determine sorghum grain quality. Malting properties that were investigated were the chlorox-bleaching test, polyphenol content, FAN, DP, ML, WA, GV and GE. The chlorox-bleaching test should be performed before malting (Dewar *et al.*, 1999) to identify if grain should be treated with formaldehyde before malting (Taylor, 1998a). Free amino nitrogen and DP were the chemical properties identified in the present study to distinguish between the malting quality of different cultivars, while GE, GV, FAN and DP are important to distinguish between environments for malting quality. It was also found that malting losses should be taken into consideration as a final consideration when a malting cultivar is chosen, as it may cause economic losses. Physical properties under investigation were the HKW, MC, SFs, MFs and WA. The physical properties found to best distinguish between the physical properties of different sorghum cultivars, were SFL, HKW and WA. The MC and WA were found to mainly distinguish between different environments on the basis of physical properties. For TADD milling the AHI, DI and viscosity were investigated. The AHI and DI were found to be the most important in order to distinguish between the TADD milling performances of sorghum cultivars. It was also found that AHI, DI (L-values dry) and viscosity, should all be taken into consideration when the TADD milling performances of sorghum from different environments are evaluated. The roller milling properties investigated during the current study were B1B, B1M, B2B, B2M, B2G, TL, extraction, S1, S2, TH, L- and a-values. The most important roller milling performance properties identified that need to be considered when differences in cultivars are evaluated, were B2B, B1B, L-values and extraction values, while the B1B, B2M, extraction, B1M and B2G values were mostly important when the roller milling performances of sorghum from different environments, were considered.

The interrelationship between malting, physical and milling properties were also investigated to determine which properties might influence other types of properties. The influence of the polyphenol contents of sorghum cultivars on the colour properties of the milled product, was illustrated by the negative correlation (r=-0.56) found between the polyphenol content and L-values and a positive correlation between polyphenol and DI (r=0.60). It was also found that the condensed tannin layer underneath the pericarp of some cultivars, investigated under the malting properties of sorghum will not only influence malting properties in sorghum, but will also deteriorate the colour of sorghum meal when the grain is milled. In the present study the investigation into the milling properties of sorghum, identified significant correlations between hardness properties and colour properties, indicating that harder grain will have better colour properties. An inverse correlation (r=-0.56) between L-values and WA was also found. This correlation between a physical and milling property, again illustrates that harder cultivars (low WA) will have better colour properties. Not only does it seem as if harder sorghum cultivars have better colour properties, but also that hard cultivars have better malting performances, as B2G correlated well with FAN (r=0.62), with SDU (r=0.53) and with GV (r=0.41), while B1M correlated inversely (r=-0.40) with FAN. A correlation between AHI and FAN (r=0.40) was also found. The HKW was found to correlate with B1M (r-=0.44), indicating that larger kernels will mainly have poor milling properties, as B1M mainly consists of soft endosperm.

The malting, physical, TADD- and roller milling properties of single- and multi-purpose cultivars, are summarized in Table 5.1. During the present study the cultivars with the best malting performances were found to be APN 881, SNK 3443, PAN 8564, NS 5655, SNK 3939, SNK 3975, PAN 8446 and SNK 3860, NS 5511. The latter two cultivars are from the GH Class, while all the others are GM Class cultivars (Table 2.28). NK 286 was also found to have an acceptable malting performance. The worst malting-performing cultivars were PAN 8370, ADV 5010, PAN 8171, PAN 8272, SNK 3883 and SNK 3863. Cultivars with physical properties predicting good milling perfromances were SNK 3939, SNK 3663, PAN 8061, PAN 8564, PAN

8171, PAN 8272, PAN 8370, SNK 3567, SNK 3443, APN 881, SNK 3975, SNK 3883 and PAN 8446. These cultivars had smaller kernel sizes and were hard. Very small sized kernel cultivars were not found in this group, as milling losses would have been too high. Larger-sized kernel cultivars, that were hard, were SNK 3337and NK 286. This group consisted of good physical properties. NK 283, NS 5655, NS 5511, PAN 8262, PAN 8660, APN 881, SNK 3860 and SNK 3620 were all found to have poor physical properties. Cultivars found to have good TADD abrasive milling properties were APN 881, SNK 3567, SNK 3863, NK 286, PAN 8370, ADV 5010 and PAN 8564, but SNK 3443 and PAN 8660 performed the best overall. The worst overall milling performing cultivars found were SNK 3860, SNK 3663, SNK 3620, NS 5511, PAN 8171, SNK 3337 and PAN 8446. SNK 3860, NS 5511 and SNK 3620 performed poor due to their high tannin content. The best roller milling performing cultivars were found to be SNK 3883, SNK 3939, PAN 8564, NK 286, NS 5655 and SNK 3975. The worst roller milling performing cultivars found were SNK 3863, PAN 8446, PAN 8660, SNK 3567, SNK 3860, SNK 3620, NS 5511, PAN 8370 and PAN 8171. NK 286 and PAN 8564 were shown to be suitable for both TADD and roller milling purposes and were therefore good overall milling cultivars, irrespective of the milling techniques used.

NS 5511, PAN 8446, SNK 3663, SNK 3337 and SNK 3860 were only suitable for malting purposes, but PAN 8446, SNK 3337 and SNK 3663 also had good physical properties. SNK 3883 was found to be only suitable for roller milling purposes, but also had good physical properties. ADV 5010, SNK 3863, SNK 3567 and PAN 8370 are only suited for TADD milling properties, but the latter two also had good physical properties. NK 283, PAN 8061, PAN 8171, PAN 8262, PAN 8272 and SNK 3620 did not display good malting, TADD or roller milling properties, but PAN 8061, PAN 8171 and PAN 8272 had physical properties that predict good milling performance abilities. With respect to malting and milling quality, these are the worst overall-performing cultivars.

TABLE 5.1

SUMMARY OF THE MALTING, TADD- AND ROLLER MILLING PERFORMANCES OF SORGHUM CULTIVARS

CULTIVAR	OUTSTANDING PROPERTIES			
	GOOD MALTING	GOOD PHYSICAL PROPERTIES	GOOD TADD MILLING	GOOD ROLLER MILLING
ADV 5010			X	
APN 881	X	X	X	
NK 283				
NK 286	X	X	X	X
NS 5511	X			
NS 5655	X			X
PAN 8061		X		
PAN 8171		X		
PAN 8262				
PAN 8272		X		
PAN 8370		X	X	
PAN 8446	X	X		
PAN 8564	X	X	X	X
PAN 8660	X		X	
SNK 3337	X	X		
SNK 3443	X	X	X	
SNK 3567		X	X	
SNK 3620				
SNK 3663	X	X		
SNK 3860	X			
SNK 3863			X	
SNK 3883		X		X
SNK 3939	X	X		X
SNK 3975	X	X		

NK 286 and PAN 8564 had good malting, TADD, roller milling and physical properties. These cultivars were the best multi-functional performing cultivars. APN 881 and SNK 3443 had good malting, physical and TADD properties, while PAN 8660 also showed good malting and TADD milling properties. NS 5655 had good roller milling and malting properties, while SNK 3939 displayed good malting, roller milling and physical properties. All the above-mentioned cultivars are multi-functional as they performed well in malting and at least one type of milling.

In the 1997/98 season, sorghum revealed better malting performances than during the 1998/99 season and the physical properties were also better during this season. The 1998/99 season was more ideal for milling performances and both TADD and roller milling performances were better during this season. It is therefore clear that grain from some seasons are better suited for malting, while others are more suitable for milling.

The best malting performance sorghum was from the Dover and Green localities whilst those at Potch showed poor malting properties. Green and Dover also gave the grain with the best physical properties, while those of Potch and Plat were poor. The best TADD milling performances were found at Green and Potch, whilst those of Dover and Plat were poor. The same localities used for TADD milling indicated the same milling performances for roller milling performances. Green is therefore the locality that produced the best quality sorghum overall, since sorghum from this locality has good malting, physical, TADD and roller milling properties. Plat on the other hand, produced sorghum of poor physical, TADD and roller milling quality. Grain from Potch was only suitable for malting purposes, and although the physical properties of this sorghum were good, all milling properties were poor. Sorghum from Potch was suitable for TADD and roller milling, but malting and roller milling properties were poor.

From the present study it is therefore clear, that different sorghum cultivars, localities and seasons give sorghum grain with different quality properties. Over different localities, cultivars and seasons sorghum with different malting, physical, TADD and roller milling properties are found. Some localities and cultivars, however give sorghum with multi-purpose quality properties and this enables the identification of cultivars suitable for more than one processing purpose, implying that producers from specific localities could market their sorghum for multiple purposes.

SUMMARY

Consumer demands for sorghum food acceptability stress the need for quality evaluation of milled and malted products. The aim of this study was to determine the milling and malting quality of sorghum cultivars with different physical and chemical qualities.

The malting, physical and milling qualities of 24 sorghum cultivars were investigated over 2 seasons at 3 localities per season. The most important malting quality parameters that were identified with the canonical variate analysis were free amino nitrogen, diastatic power, germinative energy and vigour, compared to polyphenols, malting loss and water absorption that was identified as less important. From the canonical variate analysis, the most important physical qualities measured were sieve fraction large, hundred kernel weight, water absorption and moisture content and were used to predict milling quality, while sieve fraction medium and small and meal fractions were found to be less important. Food quality properties were determined from roller and abrasive decortication milled meal. The abrasive hardness index, dehulling index and viscosity were important abrasive decortication milling parameters, with break 2 bran, break 1 bran, L-values, extraction, break 2 meal, break 1 meal and break 2 grits being important roller milling parameters.

The best malting cultivars were APN 881, NK 286, PAN 8446, PAN 8660, SNK 3443, SNK 3337, SNK 3663, SNK 3939, SNK 3975, PAN 8564, NS 5655, SNK 3860 and NS 5511.

Cultivars with the best physical properties were SNK 3939, SNK 3663, PAN 8061, PAN 8564, PAN 8171, SNK 3443, PAN 8446, SNK 3337, NK 286, APN 881, SNK 3883, SNK 3975, SNK 3567, PAN 8272 and PAN 8370.

Good abrasive decortication milling property cultivars were APN 881, SNK 3567, SNK 3863, NK 286, ADV 5010, PAN 8564, SNK 3443, PAN 8370 and PAN 8660.

Good roller milling cultivars were SNK 3883, SNK 3939, PAN 8564, NK 286 and SNK 3975.

Cultivars with multi-functions were NK 286, PAN 8564 APN 881, SNK 3443, PAN 8660, SNK 3939, NS 5655 and SNK 3975 (good malting and milling).

OPSOMMING

Die behoefte aan kwaliteitsevaluering van sorghum vermoute- en gemaalde produkte word onderstreep deur verbruikersbehoeftes aan aanvaarbare sorghum voedselprodukte. Die doel van die studie was om die mout- en maalkwaliteit van sorghumkultivars met verskillende fisiese en chemise eienskappe, te ondersoek

Die mout-, fisiese- en maalkwaliteite van 24 sorghumkultivars is ondersoek oor 2 seisoene en by 3 lokaliteite per seisoen. Die belangrikste moutkwaliteitsparameters wat met behulp van die kanononiese variansieanalise geidentifiseer is, was vry aminostikstof, diastatiese vermoë, kiemkapasiteit en –energie, in vergelyking met polifenole, moutverlies en wateropname wat as minder belangrik geidentifiseer is. Vanuit die kanoniese variansieanslise is siffraksie (groot), honderdpitmassa, waterabsorpsie en voginhoud as die belangrike fisiese eienskappe bepaal en is gebruik vir maalkwaliteitsvoorpellings, teenoor siffraksie (medium en klein) en meelfraksies wat minder belangrik geag is. Roller- en afslyp vermaling is uitgevoer en meel se voedselkwaliteitseienskappe is bepaal. Die afslyphardheidsindeks, afslypindeks en viskositeit was belangrike afslypvermaling maaleienskappe en vir die rollermeule was breuk 1 semel en -meel, breuk 2 semel, -meel en -gruis, ekstraksie en siffraksies belangrik in vergelyking met totale verlies, siffraksie 1, siffraksie 2 en die wat deur die sif gegaan het, soos met behulp van die kanoniese variansieanalise bepaal.

APN 881, NK 286, PAN 8446, PAN 8660, SNK 3443, SNK 3337, SNK 3663, SNK 3939, SNK 3975, PAN 8564, NS 5655, SNK 3860 en NS 5511 was die beste moutkultivars.

Kultivars met die beste fisiese kwaliteit was SNK 3939, SNK 3663, PAN 8061, PAN 8564, PAN 8171, SNK 3443, PAN 8446, SNK 3337, NK 286, APN 881, SNK 3883, SNK 3975, SNK 3567, PAN 8272 en PAN 8370.

APN 881, SNK 3567, SNK 3863, NK 286, ADV 5010, PAN 8564, SNK 3443, PAN 8370 en PAN 8660 het goeie afslypvermalingseienskappe gehad.

SNK 3883, SNK 3939, PAN 8564 en NK 286 was die beste rollermeulekultivars.

Sommige kultivars het meer as een funksie, naamlik NK 286, PAN 8564 APN 881, SNK 3443, PAN 8660, SNK 3939 en NS 5655 (goeie mout- en maaleienskappe)

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