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# EFFECT OF SEED SIZE, TREATMENT AND SOWING DEPTH ON QUALITY AND YIELD OF ETHIOPIAN WHEAT (*Triticum Spp.*), FABA BEAN (*Vicia faba* L.) AND CHICKPEA (*Cicer arietinum* L.) CULTIVARS

by

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DECLARATION

I declare that the thesis hereby submitted by me for the degree Master of Science in Agriculture at the University of the Orange Free state is my own independent work and has not previously been submitted by me at another University/Faculty. I further cede copy right of the thesis in favour of the University of the Orange Free State.

DEMISSIE MITIKU MENGISTIE

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## LIST OF ABBREVIATIONS

AACC = American Association of Cereal Chemists

AI = Active ingredient

ARC = agricultural research council

AUA = Alemaya University of Agriculture

BBF = Broad bed and furrow

BDI = Bio diversity Institute

BP = Between paper

CIMMYT = International maize and wheat Research Center

CL = Coleoptile length

CSA = Central Statistics Authority

CV % = Coefficient of variation (percent)

NDA = NATIONAL DEPARTMENT OF AGRICULURE

DZARC = Debre Zeit Agricutural Research Center

EAF = Ethiopian Agricultural Fair

EARO = Ethiopian Agricultural Research Organization

EL = Epicotyle length

ER = Emergence Rate

ESE = Ethiopian Seed Enterprise

FAO = Food and Agricultural Organization

FIS = Seed Treatment and Environment Committee of the International Seed trade Federation

GDP = Gross domestic product

GFP = Grain filling period

GP = Germination percentage

GY = Grain yield

DH = Days to 50% heading

HLM = Hectolitre Mass

IAR = Institute of Agricultural Research now known as EARO

ICARDA = International Center for Agricultural Research in the Dry Areas

ICRISAT = International crops Research Institute for the Semi-arid Tropics

ISTA = International Seed Testing Associations

KPS = Kernels per spike

KRC = Kulumsa research centre

LSD = Lowest significant difference

MASL = Meters above sea level

MBSL = Meters below sea level

MC = Moisture content

DM = Days to 50% maturity

MOA = Ministry of Agriculture

NDOA =National Department of Agriculture

NSIA = National Seed Industry Agency

AS = Abnormal Seedlings

DS = Dead Seeds

ES = emerged seedlings

PC = Protein content

RF = Ridge and furrow

RH = Relative humidity

SAGAL = South African Grain Laboratory

SANSOR = South African National Seed Organization

SDM = Seedling Dry Matter (Mass)

SGI = Small Grain Institute

SL = Seedling Length

SFM = Seedling Fresh Mass

SPMS = Spikes per $m^{-2}$

SRFM = Seedling root fresh mass

SRDM = Seedling root dry mass

SRL = Seedling root length

SS = Seed Size

TKM = Thousand kernel mass

TPP = Tiller per plant

WANA = West Asia and North Africa

# CHAPTER 1

# INTRODUCTION AND RATIONALE FOR THE STUDY

## 1.1 Background Information

Ethiopia is classified into 18 major agroecological zones and 49 sub zones. This classification is based on thermal zones and length of the growing season (EARO, 1998). The average temperature across the country ranges from 15 to 34°C. The rainfall in Ethiopia varies from less than 100 mm in the northeastern part to about 2700 mm in the southwestern Highlands. Due to the high precipitation occurring mainly on the windward side escarpments of the mountains, there is tremendous loss of soils due to erosion. Erkosa *et al.* (1998) reported that from about one to two billion tons of soil is lost annually due to erosion in Ethiopia.

Nevertheless, the agricultural sector plays an important role in the Ethiopian economy (NSIA, 1997). It accounts for about 55% of the gross domestic product (GDP), employs about 85% of the labour force, generates 90% of commodity export earnings and provides raw materials for nearly all agro-related industries. Crop production contributes to about 60% of the total sector output. According to Selamta (1998) the principal agronomic export commodities of the country are coffee, oilseeds, pulses, flowers, vegetables, sugar and animal fodder.

At present the land is partly owned by small holders or is otherwise owned. According to the Central Statistics Authority (CSA, 1997) there are 9 090 000 smallholder farmers in Ethiopia who cultivate close to 10 000 000 ha of land annually. The most important crops under cultivation are cereals (6 690 000 ha or 76%), pulses (91 000 ha or 10%) and oil seeds (46 000 ha or 5%). Permanent crops are cultivated on only about 59 000 ha or 6.7% of the total land.

Ten of the eighteen major soil types found in Ethiopia constitute to 87% of the soils in the country. Among these *Lithosols, Nitosols, Cambisols* and *Vertisols* are the major ones Debele (1986). In Ethiopia, bread wheat and faba beans are cultivated on both well-drained *Andosols* and to some extent in water logged soils (*Vertisols*). However, durum wheat and chickpea are mainly grown on moist black waterlogged *vertisols*.

*Vertisols* are distributed around the 45° N latitude, mainly in the tropical and subtropical areas of the world. Srivastiva *et al.* (1993) reported that an estimated 311 000 000 ha or 2.4% of the global land area consist of *vertisols*. *Vertisols* occupy about 105 000 000 ha in Africa and about 12 600 000 ha in Ethiopia (Debelie, 1986; Srivastava *et al.*, 1993). *Vertisols* are characterized by extensive cracking of the surface up to depths of 50 cm or more as a result of seasonal drying. Asamenew *et al.* (1993) reported that with 12 600 000 ha of *vertisols*, Ethiopia ranks third in *vertisols* abundance in Africa after the Sudan and Chad. Of these about 8 000 000 ha are in the Ethiopian highlands and these account for 63% of all *vertisols* in the country.

Abebe *et al.* (1994) indicated that the dark clay soils of the highlands (above 2000 masl) are among the most under utilized areas within the traditional farming system due to water logging from the heavy rains of June to September. Mamo *et al.* (1993) reported that such soils are generally hard when dry and sticky when wet and these create serious limitations to their use. Poor internal drainage is the major problem and associated with *vertisols* in high rainfall as well as in irrigated areas. As a result the roots of crops grown on *vertisols* are poorly aerated and nutrient uptake for growth and development is impaired. These soils are used for both crop production and animal grazing. In Ethiopia, only about 2 000 0000 ha (25%) of the *vertisol* area are presently cultivated (Asamenew *et al.*, 1993). Durum wheat, chickpea and to some extent bread wheat and faba bean are among the dominant crops cultivated on these soils. At present, where chickpea is grown on flat heavy clay soils, the recommended option is to use ridge and furrow (RF) drainage plots. Since it facilitates the removal of excess water from the field, broad bed and furrow (BBF) can also be used on gentle slopes of 0 - 8 percent.

## 1.2 Rationale for this study

In most developing countries crop yields obtained by farmers are much lower than in those obtained by research centers (Tesemma 1987; Beyene, *et al.*, 1999; Alemayehu *et al.*, 1999). A number of constraints can probably be listed to explain this gap, but in the past and even in most cases at present, the unavailability of seeds from high-yielding cultivars is one of the most important reasons for low crop yields. Although, the situation is improving, Ethiopia and Kenya can be cited as good examples where the unavailability of seeds still prevails (Beyene, *et al.*, 1999; Gamba, *et al.*, 1999; Hailye, *et al.*, 1999).

Seed is the cornerstone and essential starting point in the production of food animal feed fiber plant oils and forage (Sansor, 1995). To this end, the importance of seeds used in the cultivation of crop poses the capacity to produce sustainable yields and the importance of monitoring seed quality becomes apparent. Hence, seed testing techniques have been developed to minimize this risk by assessing the quality of seed before it is sown.

Seed quality is determined by a wide range of factors including germination capacity, germination rate, seed size and uniformity as well as the effect of seed treatment with certain fungicides. Moreover, sowing depth, when not properly managed, can make the difference between sustainable and the under potential cultivation of crops (Simane, 1993)

Very little information on the effect of seed treatments with fungicides, seed size and sowing depth on harvestable yields in the major crops cultivated in Ethiopia is available in literature. This necessitated the underlying study on bread wheat, durum wheat, faba bean and chickpea. These crops are important for sustaining the agricultural economy in Ethiopia. The study was conducted on Ethiopian cultivars of these crops except in the case of durum wheat where one South African cultivar was included.

Pulses, e.g. faba bean and chickpea, are leguminous plants producing edible seeds that are primarily used for human consumption (Bashir and Malik, 1994). Pulse seeds are low in fat but high in protein (20 to 27%) and form an integral part of the diet for the majority of the rural population and urban dwellers in Ethiopia, particularly the poor, in supplementing protein. Since pulse crops are grown in rotation with cereals in Ethiopia, they are also very important in the maintenance of soil fertility and benefit precursor crops to a large extent in this regard (Bashir and Malik, 1994). According to Beltagy (1995), Ethiopia produces 799 000 tons pulse seed per annum on average. In 1985, when famine was experienced, it dropped to 539 000 tons. Faba bean, lentil, field pea, chickpea and grass pea are all important pulse crops in the country. Not everybody can afford meat as part of their regular diet and these crops are key sources of protein to the population of 60 million in Ethiopia. In addition, as it supplements crude protein in the feed, the straw of legume crops is popular as animal fodder.

Pulse cultivation also plays an important role as part of the cropping system in Ethiopia because, as elsewhere, soil structure and fertility can be threatened by cereal monoculture. Rotation with legumes can mitigate this by providing atmospheric nitrogen to the precursor crop. As a result, the need for nitrogen fertilizer for the precursor cereal crop is minimized. Both faba bean and chickpea are considered in this investigation for both of these are frequently rotated with wheat in Ethiopia.

Improved varieties can benefit farmers by increasing their yields only if quality seed is used in the production process. In Ethiopia, seed production has not kept pace with the development of new varieties. With the exception of a few crops like bread wheat (*Triticum aestivum*), and to some extent maize (*Zea mays*) as well as teff (*Eragrostis tef*), improved varieties released so far are not grown by farmers. This is mainly due to insufficient seed production schemes, on the one hand, and poor quality seed coupled with inadequate supply of seeds on the other (CSA, 1997).

For the crops under investigation, the annual seed need in Ethiopia is summarized in Table 1.1.

Table 1.1 Estimate of the current annual seed requirements for bread wheat, durum wheat, faba bean and chickpea in Ethiopia.

| Crop type | Cultivated Area ha | Seed rate Ton $ha^{-1}$ | Total seed need Ton $ha^{-1}$ |
|---|---|---|---|
| Durum wheat | 409 490 | 0.15 | 61 424 |
| Bread wheat | 409 490 | 0.15 | 61 424 |
| Faba bean | 333 330 | 0.12 | 38 919 |
| Chickpea | 157 450 | 0.12 | 18 786 |
| Total | 1 309 600 | | 180 553 |

CSA (1997; 1998)

Some factors must be considered when seeds are saved from a previous yield for future cultivation of the crop. Kernel size is an inherited characteristic, but the development of the kernel and hence also its size is greatly affected by the environment viz. soil moisture, nutrients, diseases and abiotic factors. Both size and uniformity are among the most important aspects of seed quality (Thompson, 1979). Mostly large and uniform seeds are preferred in the market for consumption while medium types are preferred for planting purposes.

For many reasons Ethiopian farmers practice stagger planting of their crops, among which risk aversion against any unforeseen climatic hazard is the major one. According to Simane (1993), late planting is practiced in anticipation of dependable rain in drought prone areas and in order to escape water logging in high rainfall areas. As a result of different sowing dates and locations, there are variations in seed sizes within even the same cultivar. In most of the cases, seeds harvested from early plantings, unless diseased, are usually more plumb and larger than those from late plantings. The main reason for shriveling of seed from late sown fields is terminal moisture stress. In wheat, terminal moisture stress does not only decrease seed sizes, but also reduces yield by about 30% (Simane, 1993). In a faba bean study conducted in Australia, Loss *et al.* (1997) reported that mean seed weight decreased with delayed sowing in dry environments.

In some crops, despite the use of the recommended seeding rate, seedling emergence is poor and this results in a very poor crop stand. One of the underlying reasons for this is that seed borne diseases mostly attack seeds. Chickpea can be considered a typical example of this. Seed treatment with an appropriate fungicide before sowing is most of the times considered as a remedy for such problems. With this in mind, two seed treatments were compared to an untreated control in this investigation.

In most developing countries land preparation is mostly undertaken by using animal power. Hence, seeds are buried deep in the soil during planting and this results in poor emergence of seedlings even if the seeding rate is increased. The situation is even worse in drought prone environments. Sowing depth depends on seed size, soil type and its moisture content (Purchase *et al.,* 1992; Ybema, 1994). Therefore, the determination of appropriate sowing depths for the three different seed sizes and the mentioned crops were considered to be of prime importance. Subsequently, the generation of information on sowing depths for the crops under investigation was an additional focus area in this investigation in order to determine the optimum sowing depths for the four crops of interest.

The objectives of the study can be summarized as follows:

1. To classify the seeds of each crop and each cultivar into three different sizes (small, medium and large), and to characterize seeds in terms of kernel mass, hectolitre mass, moisture content and protein content where applicable.

2. To determine the differences in germination percentages of treated and untreated seeds of three different seed sizes for each of the bread wheat, durum wheat, chickpea and faba bean cultivars under laboratory and field conditions.

3. To evaluate the field performance, including yield components and other valuable agronomic parameters, of treated and untreated seeds of three different seed sizes for different cultivars of each of the different crops.

4. To investigate the effect of two different sowing depths on emergence, seed yield and other yield components of treated and untreated seeds for different cultivars of each crop.

5. To statistically determine cultivar, seed size, fungicide treatment and sowing depth interactions in a variety of ways.

With the exception of chickpea that is contained in only one chapter, results for all other crops are discussed in two chapters. The first chapter of each crop deals with interactions between cultivars, fungicide treatments and seed sizes while the second reports on bulked seed (no seed size classification) of cultivars, seed treatments and sowing depth.

Chapter four deals with the preliminary seed size classification and characterization of each of the cultivars from the four different crops in question. Chapter five reports on the effect of seed size and treatments, quality and yield in bread wheat while chapter six deals with bulked seed of bread wheat and sowing depth as factor influencing seed quality and yield. Similarly, chapters seven and eight report on durum wheat while chapters nine and ten deals with faba bean in the same fashion as for bread wheat. Chickpea is very sensitive to waterlogging (Abebe *et al.,* 1994). On top of this such a weather condition was favourable to the globally known devastating chickpea disease of *Aschochyta blight* (Diekmann, 1988). Therefore, unlike the other three crops, the unusually very high rainfall that occurred prior to flowering destroyed the properly emerged but the most sensitve seedlings of chickpea. As a result, no data and yield was collected from this crop. Consequently, all aspects investigated on chickpea are reported in only one chapter 11. A general discussion on all crops is presented in Chapter 12. A summary is given at the end just before apendices.

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# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Wheat

Wheat (*Triticum aestivum* L. em. thel. and *T. turgidum* L.) is the world's leading cereal and most important food grain. Its importance derives from the properties of wheat gluten, a cohesive network of tough endosperm proteins that stretch with the expansion of fermenting dough, yet coagulate and hold together when heated to produce a well 'risen' loaf of bread (Poelhman and Sleper, 1995). Only wheat, and to a lesser extent rye and triticale, has this property. Wheat has been cultivated in southwestern Asia, its geographic center of origin, for more than 10 000 years. Related wild species still grow in Lebanon, Syria, Northern Israel, Iraq and eastern Turkey (Poelhman and Sleper, 1995).

The world's wheat acreage and production are clearly concentrated in the northern hemisphere (Stubbs *et al.,* 1986) and both bread- and durum wheat are the two principal commercial types of cultivated wheat. Bread wheat is cultivated on about 90 % of the world's wheat land and makes up approximately 94% of the total wheat production. Durum wheat is less cosmopolitan in its distribution, being grown principally in North Africa, the near and middle East, the former USSR, India, Italy, France, northern USA and in some areas of Canada. In general (FAO, 1998), 588 842 000 metric tons (MT) of wheat is annually produced from an area of about 224 374 000 ha. From this Africa produces 18 263 000 MT on 9 947 000 ha. The former USSR, USA, Canada, China, India, Australia, Argentina and most of the countries in Europe are the major wheat producers.

As one of the world's most important staple foods, wheat is consumed in a variety of ways. It is mostly used for producing flour, the basis of all bread, biscuit and pastry products. In addition, wheat is used extensively in breakfast cereals, bulur, couscous, and macaroni products. Wheat is also a commercial source of starch and thus finds use in a wide range of industries from food processing to paper manufacturing and from laundering to oil well drilling (Stubbs *et al.,* 1986).

Wheat quality is of primary importance in the Republic of South Africa while in Ethiopia quantity traditionally comes first. However, particularly in urban areas of Ethiopia, quality has become a more important issue in recent times. In South Africa both winter and spring types are produced which are either white or red (Ybema, 1994). The tendency is towards the selection of red wheat. However, in Ethiopia, white, red and purple seeded wheat types are grown. Farmers in Ethiopia prefer to grow the white grain colour type for it fetches better prices than the rest. In some places, purple seeded land races are popular for some specific purposes such as usage in local beverages (Tsegaye *et al.*, 1993; Belay *et al.*, 1995).

### 2.1.1 Wheat Production in South Africa

Wheat production in South Africa commenced in 1652 (Van Niekerk, 1999). The author further reported that South African wheat farmers, on average, produce 2 million metric tons per year on about 1.02 million hectares of land. Wheat production in this country has increased consistently during the past fifty years but leveled off during the past decade. Of this crop, 50% of the total yield is derived from dry land winter-, 30% from dry land spring- and 20% from irrigated spring cultivation. The local consumption is 2.4 million tons per annum, which makes South Africa a net importer of wheat (Van Niekerk, 1999).

In South Africa, wheat stands as a second cereal next to maize while bread wheat is mainly cultivated. Ybema (1994) reported that small volumes of durum and biscuit wheat are produced in specific areas and classified wheat into three classes namely Class B, for those cultivars with good baking quality and which are mainly used for the baking of bread, Class C, for cultivars with good cookie baking qualities (biscuit wheat) and Class D, for cultivars used for the manufacturing of pasta products. All others are placed in the utility grade.

On the other hand, in accordance with adaptability, wheat cultivars in this country can also be subdivided into winter, intermediate and spring types. Distinct differences between spring and winter types are that genuine winter types will not produce a normal crop when planted in spring. Intermediate and winter types are normally cultivated in the Free State (Ybema, 1994). About forty five percent of South African wheat is produced in the Free State (Purchase, 1997). A comparison of wheat production between South Africa and Ethiopia is illustrated table 2.1:

Table 2.1: A comparison of wheat production between Ethiopia and South Africa

| | Ethiopia | South Africa |
|---|---|---|
| Area planted (hectare) | 750 000 | 1 425 000 |
| Yield (t/ha) | 1.5 | 1.6 |
| Total production t/annum) | 1 125 000 | 2 321 000 |
| Per capita wheat consumption (kg/person/yr) | 33.2 | 75.6 |
| Wheat imports (t/annum) | 700 000 | 400 000 |
| Self-sufficiency (%) | 62 | 85 |
| Area sown to HYV's (%) | 45 | 100 |
| Area irrigated (%) | 1 | 40 |

Adopted from the Ninth Regional Wheat Workshop (1995).

### 2.1.2 Wheat production in Ethiopia

Wheat is grown in only eight of the eighteen major agroecological zones of Ethiopia (Table 2.2). Among cereals, wheat is the fourth most important cereal crop in Ethiopia preceded only by tef, maize and sorghum in both area and production, and is the second largest wheat producer next to South Africa in Sub-Saharan Africa (Payne *et al.,* 1996). About 1 125 000 tons of wheat is produced annually in the country with an annual average consumption, per capita, of about 33.2 kg. The country is about 62% self-sufficient in wheat production. The mean temperatures of the areas where wheat is cultivated in the country ranges from about < 7.5 to 27.5°C and its growing period varies between 61 and 300 days.

It is general practice in most developing countries, including Ethiopia, that farmers plant farm saved seed of improved cultivars. The quality of farm saved seed, when planted year after year for about three to four seasons, deteriorates rapidly resulting in a reduced national average yield. Farmers prefer to plant farm saved seed, mainly due to the high cost of commercial seed as well as transportation.

Table 2.2: Major agroecological zones for growing wheat, faba bean and chickpea in Ethiopia (Ethiopian Agricultural Research Organization, 1998)

| Agroecological zones | Temperature Ranges °C | Length of growing days | Crops grown |
|---|---|---|---|
| Hot to warm sub- moist lowlands | 21 to 27.5 | 61-120 | Wheat, chickpea |
| Tepid to cool sub moist highlands | 11 to 21 | 61-120 | Wheat, chickpea, faba bean |
| Tepid to cool moist mid highlands | 11 to 21 | 121-180 | Wheat, faba bean Chickpea |
| Hot to warm sub-humid lowlands | 21 to 27.5 | 181-240 | Wheat |
| Tepid to cool sub-humid mid highlands | 11 to 21 | 181-240 | Wheat |
| Cold to very cold sub-humid mountain | < 7.5 to 11 | 181-240 | Wheat, faba bean |
| Tepid to cool humid mid highlands | 11 to 21 | 241-300 | Wheat |
| Cold to very cold humid sub-mountain | < 7.5 to 11 | 241-300 | Wheat, faba bean |
| Cold to very cold sub moist mountains | >7.5 to 11 | 61-120 | Faba bean |
| Hot to warm moist lowlands | 21 to 27.5 | 121-180 | Chickpea |
| Tepid to cool moist mid highland | 11 to 21 | 121-180 | Faba bean |

Both durum and bread wheat are the two most important grain crops grown in Ethiopia. The former is indigenous while the latter is a recent introduction. The current total area of production for both durum and bread wheat is about 750 000 ha (Payne *et. al.*, 1995). Both types of wheat occupy proportionately equal areas, that is approximately 375 000 ha each. However, during the past five years bread wheat has steadily increased in acreage by about 34% while durum wheat decreased by 11%. The average yield of wheat in Ethiopia is very low (1.5 tons $ha^{-1}$) as compared to the world wheat yield average (2.69 ton $ha^{-1}$; FAO, 1998).

Bread wheat (*Triticum aestivum* L) is mainly cultivated in the highlands of Ethiopia, with elevations ranging from 1800 to 3000 metres above sea level (masl), where the annual rainfall ranges from 500 to 1200 mm. All but 2% of the bread wheat are grown under rainfed conditions. Both oxen and mechanized farming equipment are used for cultivation of this crop. From approximately 375 000 ha of land, about 675 000 tons of bread wheat is produced annually. Eighty five percent of the area is sown with high yielding varieties and 60% of the bread wheat area is fertilized, though only 23 kg N and 9 kg $P_2O_5.ha^{-1}$ are used (Payne *et al.*, 1995). Bread wheat is cultivated on red, brown and to some extent black clay soils with a pH of above 5.5, and provides flour for cakes, biscuits, pastries, quick breads and snack foods. Gomaa *et al.* (1988) reported that in Egypt, in addition to its use as grain or seed, wheat straw is a source of fodder for animal feed, with the price of straw sometimes exceeding that of the grain. The use of straw for animal feed is also common in Ethiopia.

Moreover, in the bread wheat belt of Ethiopia where wheat is a mono crop practice, the proliferation of grass weeds, including among others noxious weeds of wild oats, is high. Tarekegne *et al.* (1995) reported that wheat cultivated in a continuous cropping system gave 80% lower grain yield than wheat in rotation with faba bean. It is hence essential and also general practice in Ethiopia to rotate wheat crops with legumes for both higher grain and seed production.

At present, faba bean is recommended (Tanner *et al.*, 1999) as the best rotation crop for mainly the bread wheat belt of Ethiopia. Similarly, chickpea is the dominant rotation crop in the tef and durum wheat-growing region of the country. It is clear that, when any seed production scheme is designed, the importance of crop rotation should be considered. It is inter alia with this in mind, that the underlying research project was initiated.

Durum wheat occupies approximately 20-30 million hectares worldwide, is cultivated in many countries and accounts for 8% of the total world wheat production (Lui *et al.*, 1996). The authors also reported that more than half of the total durum wheat is cultivated in the Mediterranean area, including southern Europe, North Africa and southwest Asia, where tetraploid wheat types were domesticated around 10 000 to 15 000 BC. The annual world durum wheat production for the period 1991 to 1993 was estimated at 25.6 - 34.4 million metric tons. It was also reported that the yield level of durum wheat is approximately 80% of that of bread wheat, which has been attributed partly to less favourable crop growing environmental conditions (Liu *et al.,* 1996). However, new high yielding semi dwarf durum wheat cultivars with yield potentials equal or even superior to the highest yielding bread wheat in some areas, have been introduced to Ethiopia. As the price of durum wheat is often higher than that of bread wheat, it is a promising and valuable alternative crop. According to Bozzini (1988), among the tetraploids, T. *tergidum* and T. *durum* are the more advanced types. The basic difference between these two is in their kernel structure with *T. turgidum* being starchy while *T. durum* is vitreous. Besides, *T. durum* is better adapted to semi-arid conditions and *T. turgidum* to a more humid climate.

In Ethiopia, insufficient seed production is a constraint limiting the growth of durum wheat production. Moreover, heights of tall durum wheat varieties are reduced when grown under stress conditions such as water logging, drought and sub-optimal fertilizer inputs. As a result, farmers in such stress areas still prefer to grow medium tall types rather than tall or semi-dwarf cultivars. The former cultivars compete better with weeds than the semi-dwarf types. On the other hand, semi-dwarf wheat cultivars selected from exotic sources require an optimum growing environment and high inputs. At present, the high costs brought about by such practices are only affordable by a few commercial growers and state farms. Commercial farmers multiply the seeds of such semi dwarf wheat on contract basis. The seeds of durum wheat cultivars, however, are simply left for the peasant farming community where seed can only be obtained informally through farmer-to-farmer seed exchange.

Durum wheat is cultivated under rainfed conditions mainly at higher elevations. Oxen are used for plowing. It is grown exclusively by the peasant sector in areas where rainfall ranges from 400 -1200 mm. Traditionally, the crop grows on black clay soils (*vertisols*) of the highlands between 1800 to 2800 masl. These soils badly crack on drying and quickly become waterlogged during heavy rains. Tesemma (1987) reported that, because of its association with such soils, durum wheat is occasionally known as "*Yekoticha Sinde*" meaning wheat of the vertisols. According to Simane (1993), farmers tend to plant durum wheat late in the season. In the northern regions the delay is due to waiting for dependable rainfall whereas in the central regions it is to avoid waterlogging. As a result, durum wheat is exposed to terminal moisture stress during the grain filling period and yields of this crop, grown under such conditions, are poor.

Durum wheat is the class of wheat suitable for the manufacture of pasta products (macaroni, spaghetti, and noodles). According to Dexter and Matsuo (1977) the rheological properties of stiff dough made from durum wheat semolina is well suited for the pasta manufacturing process. In addition, durum wheat generally yields a product which is bright yellow in colour and which when cooked, retains its shape and does not become soft or mushy. The authors further stated that the superior cooking quality of durum wheat pasta has been attributed to the nature of the gluten proteins. The protein content is the major factor that influences both rheological and cooking properties.

However, in Ethiopia, durum wheat also serves for making local bread, *injera*, and other local foods. The most common Ethiopian recipes prepared from durum are "*dabo*" (unleavened bread), "*injera*" (leavened pancake), "*kolo*" (roasted grain), "*dabo-kolo*" (grind, leavened and roasted), "*kinche*" (cracked and porridge), "*chechebsa*" and "*nifro*" (boiled grain). Pasta products made from durum wheat have a greater stability when cooked since it does not tend to disintegrate or become sticky, soft, mushy or starchy when boiled. The flour of durum wheat does not make a satisfactory bread product because the dough is less elastic than that of bread wheat (Tesemma, 1987). Likewise, bread wheat can be used to make pasta products but such products are considered inferior unless flavoured with other ingredients, such as eggs, to increase the protein content and improve the colour as is the case in South Africa (Western Cape). The straw is also used as livestock feed, fuel and as plaster for the construction of local houses (Abebe and Mamo, 1997).

In Ethiopia, a total of 16 durum wheat varieties, out of which 12 varieties were released between 1967 and 1997, are from the National Durum Wheat Program at Debre Zeit. Recommendations on the agronomic practices for cultivating these varieties as well as on the landraces are available. Research information on varieties and their cultural requirements, however, is available only for some areas. Only those farmers located around the main research centres adopt some of the recommended packages. Even in the vicinity of research centers, seeds of improved cultivars for durum wheat are available to farmers and then only through farmer-to-farmer seed exchange. The use of local landraces and poor cultural practices by the majority of the farmers are responsible for the low durum wheat yields. For Ethiopia to become self-sufficient in wheat production, vigorous research programs, effective seed production schemes and competent extension systems are required.

Currently, a number of spaghetti and macaroni producing factories are in the process of being established in some parts of the country. There are indications that such factories are willing to pay higher prices for quality durum wheat. This will certainly encourage farmers to produce more durum wheat, but good seed quality of improved varieties will be essential to establish a viable commercial durum wheat industry.

## 2.2 Chickpea

Chickpea *(Cicer arietinum* L.) is a self-pollinated pulse crop (Poehlman and Sleper, 1995). Pala and Mazid (1991) reported that chickpea is widely grown in West Asia and North Africa (WANA) and primarily in rainfed areas receiving 350 mm to 600 mm annual rain. Chickpea is also widely cultivated in other Asian, African, European, Latin and Central American countries, with India being the leading chickpea producing country of the world as it produces 80% of the total grain (Pandya and Pandey, 1979). Ethiopia is the third largest producer of chickpea, preceeded only by India and Pakistan (Pandya and Pandey, 1979).

Chickpea is an important source of both carbohydrate and protein in the human diet and its straw is highly valued as animal feed. Whole seeds are split into "*dhal*" and consumed or are ground into flour "*besan*" which is used in batters and breads. Quality is critical and "*desi*" types are used for human consumption while the Indian market prefers light brown seeds (Kerr, *et al*., 1997). In Ethiopia and elsewhere, immature green seeds of chickpea are consumed (Geervani, 1991).

Doughton, *et al.* (1993) reported that chickpea is a crop that provides a cash income from grain, requires no N fertilizer owing to its ability to fix atmosphoric N and in rotation can improve the N nutrition and yield of subsequent cereals. For instance, growing chickpea before wheat can lead to useful wheat grain yield and protein increases of around 1% (Doughton, *et al.*, 1993; Pritchard, 1996).

There are two major types of chickpea referred as "*desi*" and "*Kabuli*" types. The "*desi*" (small seeded) type is mainly cultivated around the Indian sub-continent while "*Kabuli*" (larger seeded type) is grown in western Asia and North Africa (Singh *et al.*, 1980). Turkey is currently one of the world's largest exporters of kabuli chickpea (Kerr, *et al.*, 1997). According to Jambunathan and Singh (1990), "*desi*" types are often dark yellow-brown, with thicker husks and a rough surface. It constitutes to about 85% of the total chickpea production in the world while "*kabuli*", which has light-coloured seeds and thin husks, accounts for the remaining 15% (Geervani, 1991). The average seed size for "*desi*" chickpea is determined at >12 g/100 seeds while for "*kabuli*" it is 40 g/100 seeds on average. The seed size can be managed by avoiding sowing seeds in areas with less than 400 mm annual rainfall an by choosing large seeded varieties and by avoiding late sowing as well as shallow and marginal soils. Chickpea should not follow or be preceded by a legume crop and should not be cultivated on the same soil more than once every three years (Kerr, *et al.*, 1997).

In a publication of ICARDA (1993), it was reported that, in the WANA countries, chickpea is traditionally planted in the spring (from late February to May depending on the locality) on mainly black soil types, utilizing residual moisture stored during the winter months (rainy seasons). The most important reason for this is to avoid *Ascochyta* blight, a devastating fungus that strikes chickpea during moist and cool, Mediterranean winters (ICARDA, 1993). However, ICARDA has made some tolerant cultivars available and recommends earlier (winter) planting in WANA countries with the aim of doubling yields.

In general, well-drained and fine textured soils (loams and clays) with pH of 5.5 - 9.0 (in calcium chloride), are suited for chickpea cultivation. However, for the kabuli types, deep free draining soils of medium to fine texture with pH above 6.0 is ideal. Phosphorus (P) is the major nutrient factor influencing nitrogen (N) accumulation as well as partitioning of photosynthate in plants but especially the symbiotic $N_2$-fixation in legumes (Yahiya *et al.*, 1995). The authors also reported that it is necessary to apply between 20 to 40 kg $P_2O_5$ $ha^{-1}$ for the best response regarding leaf area, shoot dry weight, nodule number and shoot N accumulation. Pala and Mazid (1991) performed four season assessment studies in Northern Syria and found that application significantly increased yields of chickpea in the first three seasons, the overall increase being 10%. Pritchard (1996) also suggested that a starter dose of nitrogen (10-15 kg $ha^{-1}$) at seeding time might be useful.

### 2.2.1 Chickpea Production in Ethiopia

Chickpea is amongst Ethiopia's most important cool-season food legumes. It has been under cultivation in the country from time immemorial and 120 000 tons of chickpea is currently produced annually (Bejiga, 1998). The total area under chickpea cultivation in the country is estimated at 147 000 ha in the main rainy season and about 9 550 ha in the short rainy season (CSA, 1997 and 1998). Chickpea is mainly grown on vertisol soils at altitudes between 1400 and 2300 masl where the annual rainfall ranges from 700 to 2000 mm (Bejiga, 1980). Since the crop is very sensitive to waterlogging, it is sown towards the end of the rainy season between August and September and is harvested between November and January. It grows in only four of the eighteen major agroecological zones of Ethiopia (see Table 2.2).

About half of the total chickpea production in Africa is in Ethiopia (Abebe and Mamo, 1997) making Ethiopia one of the most important chickpea producing countries in the world. Yet, the national average yield of this crop has remained very low (<1 ton $ha^{-1}$). This is mainly due to the lack of improved cultivars and poor agronomic practices as well as biotic and abiotic stresses such as diseases, insect pests, drought and waterlogging. In addition, insufficient seed production is still a limiting factor for the production of this crop.

Seed production of improved chickpea cultivars has not kept pace with the varietal development in Ethiopia. Currently, the Ethiopian Seed Enterprise (ESE) is dealing with the seed multiplication of a few cereal crops. Except for seed production of some chickpea cultivars by the National Chickpea Research Coordination Center at Debre Zeit, there is no single seed multiplication farm for chickpea or other pulses. The seed farm at Etaya-Gondie is not ideal for chickpea seed production, because of its *andosol* soils, as chickpea is normally produced on *vertisol* soils in the central highlands. This leads to a persisting misunderstanding between the Ethiopian Seed Enterprise (ESE) and researchers. The ESE reported that improved varieties are not performing well while the real problem, according to researchers, emanates from growing the varieties in an inappropriate environment.

The Debre Zeit Agricultural Research Centre (DZARC) began to coordinate research on this crop at national level in the early seventies. Since then, organized efforts have been made in cooperation with many national institutions such as the former Institute of Agricultural Research (IAR); now known as the Ethiopian Agricultural Research Organization (EARO), the Agricultural Development and Extension Department of the Ministry of Agriculture and the Bio-Diversity Institute. The International Center for Agricultural Research in the Dry Areas (ICARDA) and the International Research Institute for the Semi-arid Tropics (ICRISAT) are also facilitating this work. The program has so far identified many chickpea varieties resistant to wilt and root rots, of which six cultivars were so far, released (Abebe and Mamo, 1997).

### 2.2.2 Chickpea Production in South Africa

In a publication of the Grain Crops Institute of the Agricultural Research Council (ARC) (1999), it has been reported that chickpea is considered as an important human food source because of its high carbohydrate and protein content as well as the fact that it is rich in phosphorus and calcium. In this publication it was also reported that the crop does not tolerate waterlogging and should be planted in well-drained clay to loamy soil with a pH of 5 to 9. The recommended sowing time was also indicated to be during spring (September).

In South Africa this grain is used in the form of Indian "*dahl*" (thick soup used like gravy) but is also used as animal fodder. However, compared to other legume crops, chickpea is not cultivated on a large scale in this country and the land area under chickpea production is uncertain.

## 2.3 Faba beans

Faba beans (*Vicia faba* L.), does not fit neatly in either the self- or cross-pollinated categories (Poehlman and Sleper, 1995). The dry seeds are used as a high protein food by humans but are also utilized as stock feed. In recent years seeds of faba bean produced in Australia have been exported to Egypt for human consumption and to Saudi Arabia for canning (Pritchard, 1996). However, until recently, China has dominated the world faba bean export market. Hence, China is one of the major producers of faba bean (Kerr *et al.*, 1997).

The crop was first considered to be poorly adapted to the low-rainfall environments of southwestern Australia because of its susceptibility to moisture and heat stresses. However, more recent studies have demonstrated that faba bean can produce high bio-mass and seed yields compared to other grain legumes in a range of dry land environments with 300 to 400 mm $yr^{-1}$ average rainfall. But, early sowing and choice of early maturing varieties seem to be critical for high seed yield in such environments (Pritchard, 1996 ; Loss *et al.*, 1997).

Faba beans are canned or consumed as split or whole seed (Kerr *et al.*, 1997), and is therefore considered as a valuable food source for humans and animals. It is rich in protein and particularly the free amino acid lysine, compared to many other legumes, and is consumed in a variety of ways ranging from breakfast food to sophisticated meat extenders. The use of faba beans as an animal feed ingredient continues to expand as ongoing research further verifies their versatility. International research has demonstrated that faba beans can be included in ruminant and mono gastric diets at between 10 to 20% without adverse effects on performance (Kerr *et al.*, 1997). Loss, *et al.* (1997) pointed out that this crop is susceptible to moisture and heat stresses.

### 2.3.1 Faba bean production in Ethiopia

Faba bean is cultivated on 329 310 ha in Ethiopia during the main rainy season and on only 4 020 ha during the short rainy season (CSA, 1997 and 1998). Nevertheless, it has been the leading food legume crop in both acreage and production and is cultivated in six of the eighteen-agro ecological zones of the country (see table 2.2). Although, five improved faba bean cultivars have been released in the country, the production of improved seed as well as the distribution to farmers has been insignificant. However, faba bean remains extremely important as a rotation crop with cereals as well as a major food legume. Therefore, improved seed production of this crop is of prime importance to all farmers. According to Gorfu *et al.* (1996), wheat-dicot rotations exhibited 35% higher soil nitrate levels than cereal-based rotations or continuous wheat production. Wheat-faba bean rotations resulted in a 43% higher soil nitrate level than wheat-rape seed (*Brassica napus* L.) rotations.

Faba beans are well suited for early sowing as they are less prone to frost damage and will pod exceptionally well in a long season. In western Australia it is planted between mid Aprils to the end of May (Pritchard, 1996). According to Loss *et al.* (1997), faba bean is considered poorly adapted to the low-rainfall environments of southwestern Australia because of its susceptibility to moisture and heat stresses. However, the farmer can take advantage of sowing faba beans early as the crop, under these early planting conditions, produces greater seed yields because anthesis lasts longer, more nodes are produced, it has a greater green area index, absorbs more photosynthetically active radiation and shoots with greater peak and final biomass (Loss *et al.,* 1997) result. Hence, more pods are produced in the upper canopy and a larger harvest index is found than when planting is delayed. In Ethiopia, however, although it all depends on the locality, it is mainly sown from late June to the first week of July. Prichard (1996) recommends faba beans to be sown at a depth of 5 – 8 cm for best results, as it increases crop vigour, even though they will still emerge after much deeper sowing. Faba beans are ready for harvest when the leaves, pods and finally the stems turn black (some stems may remain green). This is the normal maturation process and is not caused by disease.

### 2.3.2 Faba bean production in South Africa

Information on the production of faba bean in South Africa is lacking. However, SANSOR (1996) has included this crop in the plant improvement act 53 of 1976.

## 2.4 Parameters of interest to the underlying study

### 2.4.1 Seed size

Bishaw (1994) reported that size is the most prevalent difference among seeds and generally varies from one plant to another in the same field or even within the same plant. Variation from plant to plant results from genetic differences as well as inter-plant competition for light, water and nutrients while the effect of disease can contribute to a wide range of seed sizes within a seed lot. Similarly, Thompson (1979) pointed out that seed size also varies due to the location on an inflorescence, which reflects in flowering time (primary and secondary branches), and nutrition of the developing seeds (basal and apical flowers).

Seed size is the most obvious of the several characteristics influenced by the environment during seed development (Gassim, 1988). The author further stated that, within any seed lot and between lots of the same cultivar, there are variations in size. Nutrition of the mother plant, position on the inflorescence and stage of maturity at harvest may cause variations within a genotype.

Poehlman and Sleper (1995) reported on their classical studies on quantitative inheritance by selecting large and small seeds from a genetically mixed lot of beans. By comparing the weight of each seed with the average weight of seeds harvested from its progeny, they established that the seed weight of individual seeds from the mixed lot contained both a genetic and an environmental component. Seeds originally selected from the mixed lot, varied in seed weight due to inherent differences between seed size and weight as well as environmental factors affecting seed development. In homozygous, pure-breeding lines established by the initial selection, variation for seed weight among seeds from the same plant or plants within the pure line was due to environmental influences only. Variations between the lines were still due to both genetic and environmental influences.

Eser *et al.* (1992) classified seeds of three varieties of chickpea by size into three groups (small, medium and large). The large seeds gave the highest values for seedling emergence $m^{-2}$, time to 50% flowering, plant height, plants $m^{-2}$, biological and grain yields as well as harvest index while the lowest values for these parameters were recorded for small seeds. The large seed group produced, on average, 31.4% greater economic yields than the small seed group.

Cardwell (1984) stated that seed size is positively correlated with seedling vigour among the smaller-seeded species. Among cereal crops, some studies show that heavier seeds produced higher yields than lighter seeds when seeded by number of seeds per area but not when seeded by weight per area. Some data indicate superiority of the intermediate and smaller seed sizes. This failure of large seeds within a seed lot may be associated with their greater mechanical injury during harvesting and processing. High seed density has also been associated with seedling vigour in wheat, cotton and wild rice.

Schillinger *et al.* (1998) reported that semi-dwarf wheat with $Rht_1$ and $Rht_2$ genes produced coleoptile lengths 30 to 40% shorter than did non semi-dwarfs and, hence, had problems in emerging as compared to taller varieties. The authors also claimed that the $Rht_8$ reduced-height gene did not hamper emergence to the extent that $Rht_1$ and $Rht_2$ did. Baalbaki and Copeland (1997) found size but the effects of density and protein content varied from year to year affected that wheat emergence significantly. Small seeds produced significantly lower biological and straw yield than all other treatments in the first year, but second year results varied according to cultivar. Small seeds of both cultivars produced the lowest grain yields.

Saxena and Sheldrake (1980) investigated the effect of graded seed size within a given cultivar on yield of chickpea at three locations in India. Their findings showed that large seed gave larger seedlings, but there was no significant effect on final yield.

### 2.4.2 Seed Treatments

Seed treatments are required for safe emergence, seedling establishment and better crop stands as well as improved yield and quality (FIS, 1999). These treatments complement genetic improvement, function as part of IPM (Integrated Pest Management), are safe and economical in use and reduce personal as well as environmental hazards. Amongst many other benefits, seed treatments can be executed at competitive costs, reduce application efforts and save time as compared to conventional crop protection products. FIS (1999) also indicated that seed treatment is sometimes the only route for the control of certain seed-borne and early season seedling diseases and pests, which without its use would be very difficult to control.

Seed treatment seems feasible in terms of labour time requirement as well as application costs as compared to many foliar or soil applied alternatives. It also reduces the land surface exposed to active ingredients. One can imagine the comparative impact when 10 000 $m^2$ of land is subjected to foliar or soil contact application to that of 58 $m^2$ when seed treatment is employed. Seeds are usually treated with fungicides to provide protection against pests and diseases during germination and seedling emergence. The objective of modern seed treatment is to control certain insects and diseases while improving the establishment of healthy and vigorous plants (FIS, 1999).

According to Batman *et al.* (1986), fungicides could be classified as disinfestants, disinfectants and protectants or as eradicants, protectants and systemics. Disinfestants inactivate organisms that are borne on the surface of the seed. Disinfectants or eradicants limit penetration and therefore are effective against established infections. Protectants protect seed from infection arising from plant debris and from soil organisms. Recently the emphasis has been on systemic fungicides that can be transported from the surface of the seed into the interior. These include fungicides that control internally borne loose smut infections of wheat and barely.

Cardwell (1984) also mentioned three common fungicide seed treatments. Firstly, disinfectants that kill pathogens located under the seed coat, e.g. loose smut (*Ustlago nuda* [Jens.] Rostev) of barley. Secondly, disinfestants effective against seed surface-inhibiting organisms such as covered smuts. Thirdly, protectants that protect the seed after placement in the soil from soil-inhibiting fungi causing seed rot and seedling blights.

Seed treatments with fungicides are used most commonly with species exhibiting hypogeal emergence. The potential for invasion of seedling blight organisms is greater when the food storage structure remains below the soil surface in an environment more uniform in temperature and relative humidity (RH) than the above ground environment. Seed lots seeded into unfavourable environments or those of initial low quality, whether epigeal or hypogeal, show greater responses to seed treatment than do vigorous and high quality seed lots planted at more favourable temperature and moisture conditions (Cardwell, 1984).

In a study conducted in Ethiopia on bread wheat, Zewde *et al.* (1992) reported that application of a fungicide increased the yield of a semi-dwarf wheat cultivar by 4.6% and by 11.3% in another trail under a heavy epidemic of stripe rust (*Puccinia striiformis).* Smiley *et al.* (1996) demonstrated that emergence of winter wheat, planted deeply into stubble-mulch fallow, is often improved when treated with Dividend Fs [active] compared to RTU Vitavax Thiram [active] and, among the systemically translocated triazole fungicides, Dividend Fs is a better choice than Raxil when planting depths exceed 5 cm. Pritchard (1996) reported that seed treatments reduce the risk of introducing diseases from infected seed. Abebe and Mamo (1997) recommended the dressing of chickpea seeds with Benlate (0.25) fungicide for the control of wilt (*Fusarium oxysporum*) and Thiabendazole (0.25) to control ascochyta blight (*Ascochyta rabiei*), as these two are the most important diseases of global importance. These chemicals are widely used for dressing chickpea seeds. Mitter *et al.* (1997), reported that dry seed treatment at 2.5 g/kg of seed with Carbendazim + thiram protected chickpea (cv. JG 62) against its common diseases.

Ahmed and Asaad (1994) reported that Maneb + Mancozeb [active] are used for the control of chocolate spot (B*otrytis fabae*) and rusts of faba bean. The authors also recommended Carboxin (Vitavax), the most widely used seed dressing chemical, as remedy for cereal crops such as wheat diseases caused by mainly common bunt *(Tellitia* spp). However, Celest® XL 035 FS (fludiocsonit/mefenolsam) and Dividend® 030 FS (difenoconazole) were easily available as fungicides for pulses in these experiments. Vitavax Plus® FS (Carboxin/thiram) and Raxil® 15 ES (Tebuconazole) were selected for all wheat experiments in this study.

### 2.4.3 Sowing depth

The rule of thumb for planting depth of many crops is 4 to 5 times the average seed diameter (Cardwell, 1984). For instance, normal depth of seeding for wheat, oats, peanut, rice, rye, sorghum, mungbean and soybean is 4.0 - 5.0 cm. These can, however, also be planted to a depth of 7.5 - 12.5 cm. Corn, cotton, pea and potato can be planted to a depth of 5 - 7.5 cm. The usual maximum depth for emergence of these crops can be from 10.0 - 20.0 cm. (Cardwell, 1984).

Pritchard (1996) reported that in western Australia the optimum depth of seeding for both desi (small seeded) as opposed to kabuli (bold seeded) chickpeas and faba bean is 5 - 8 cm. Sowing depth trials with treatments ranging from 2.5 cm to 10 cm were established at four sites in western Australia. At all sites the plant densities established did not differ significantly among the various sowing depths. Nevertheless, at Three Springs, seeds planted at 2.5 and 5-cm depths produced significantly less grain yield than did the 10-cm planted ones treated with Simazine at 4-litre $ha^{-1}$. At all sites there were no yield penalty with deep sowing. The author also indicated that the recommended seeding rate for chickpeas and faba beans are between 80 - 100 kg $ha^{-1}$ and 120 - 150 kg $ha^{-1}$, respectively.

Other factors influencing seeding depth include type of emergence, i.e., hypogeal or epigeal, soil texture, date of planting and available moisture. Stobbe (1994) studied depth of sowing on wheat in Canada and found that seeds sowed at a shallow depth (2.5 cm) emerged faster than the deeper (5 and 7.5 cm) planted ones. Hence, sowing depth is particularly critical in drought prone environments and its absolute resolution is yet to be addressed for countries like Ethiopia and even South Africa.

In Ethiopia, wheat is planted shallow in some experimental fields. Hence, birds feed on it and the stand of the wheat field remains thin. Moreover, weeds are prevalent in such sparsely populated crop fields. Hence, it was critically important to investigate sowing depth on these crops. For instance, for chickpea, Abebe and Mamo (1997) reported that both optimum sowing depth and seeding rates are not clearly indicated. For chickpea, breeders' recommend different seeding rates of about 65 - 80 kg ha$^{-1}$ as an optimum on the one hand but use doubles this rate (140 kg ha$^{-1}$) for cultivars like Akaki and Mariye. The reason given for this is the large seededness of these cultivars. However, thousand kernel weight of these cultivars is not that much higher than the rest. Using the correct sowing depths could alleviate the problem of lower plant population at reasonable seed rates. In this study, the inclusion of sowing depth trials was considered of prime importance. It is also important to note that information in the literature about sowing depth, as it relates to the four crops included in this study as well as for developing countries, is particularly scarce.

### 2.4.4 Moisture content

Seeds are hygroscopic and therefore lose or gain moisture depending upon the relative humidity of the atmospheric air in which they are stored until equilibrium is established (Bishaw, 1994). In open storage, seed moisture is a function of relative humidity. Each kind of seed attains characteristic moisture content at a given humidity at a particular temperature that is called equilibrium moisture content.

Both Agrawal (1988) and Bishaw (1994), reported that seeds with a high moisture content deteriorate faster and are more susceptible to damage from extreme temperatures, fumigation, fungi, insects, heating and mechanical injury. Seeds with lower moisture content can be stored at higher temperatures or vice versa. According to Harrington (1972), seed life is doubled for every decrease of 5°C in storage temperature when temperature is between 0°C and 50°C, and seed life is doubled with every decrease of 1% in seed moisture content when seed moisture content is between 0 and 14%.

Moisture content is considered as one of the most important quality attributes influencing storability of seed. The lower the moisture content, the longer the period is that seed can be stored without losing viability. The moisture content is calculated as the loss of weight of the sample after drying and is expressed as a percentage of the weight of the original sample (Zulu *et al.*, 1994).

### 2.4.5 Germination percentage

The ultimate objective of testing for germination is to gain information with respect to the field planting value of the seed. Testing germination under field conditions is not a standardized method for assuring the quality of seeds, as results cannot be repeated with reliability. Laboratory methods always ensure those external conditions such as light, water and temperature, are controlled (Zulu *et al.*, 1994).

Thompson (1979) found that the higher the germination capacity, the better the field emergence and in lots with high capacity the establishment rate was close to the germination capacity. The germination capacity, in practice, is the best general indication we have of a seed lot's ability to grow in the field. In other words, high germination capacity is associated with high vigour, and this is the general rule, but it does not follow that seed lots with the same high germination capacity have equal vigour (Thompson, 1979).

Germination of seed in a laboratory test, at most, indicates the potential for field emergence and further development under favourable conditions (ISTA, 1979). It is hardly possible to distinguish the planting value of seeds by simple visual observations. Therefore, proper identification of the planting value of seeds before it is sown is based on scientific knowledge of the seed and on the accumulated experience of seed analysts that is more or less uniformly conducted across the globe. A number of seed specialists have indicated that one of the greatest hazards in plant science is sowing seeds that do not have the capacity to produce an abundant crop (Odiemah and Gomaa, 1988). Subsequently, a standard germination test has been developed to partly alleviate such problems.

### 2.4.6 Coleoptile length

The sheath surrounding and protecting the shoot initial of the embryo, and young seedling of certain monocotyledons (e.g. *Gramineae*), is called the coleoptile and is recognized to be part of the cotyledons (ISTA, 1979). Moreover, the length of the coleoptile of any cereal is a factor determining the degree of protection of the seedling by the sheath while emerging from the soil. In the event of the coleoptile being short, seeds will have to be planted shallow. However, shallow planting is not always possible due to shortage of soil moisture in particularly drought prone areas. As a result, longer coleoptile cultivars are always favoured in drought prone environments.

### 2.4.7 Seedling and root fresh as well as dry masses

Both seedling and root fresh and dry masses are indicators of seedling growth vigour.

### 2.4.8 Hectolitre mass

Hectolitre mass is one of the parameters used to predict flour yield during milling. In South Africa, for example, in wheat a minimum of 76 kg $hl^{-1}$ is graded as suitable for bread making (ARC-Small Grain Institute, 1999). Some researchers (Charles *et al.*, 1996; Finney *et al.*, 1987; Nel *et al.*, 1998) regard hectolitre mass as an indicator of protein content, which is also one of the seed quality parameters, predicting protein flour yield. Higher hectolitre mass is also regarded as indicative of grain plumpness (MacDonald, 1994) following favourable growing conditions during the grain filling period (Evans *et al.*, 1975).

### 2.4.9 Protein content

The protein content in edible seeds of any crop is a major contributor to the nutritional value of foodstuff and is regarded as a quality parameter (Nel *et al.*, 1998). The higher the seed protein contents the greater the commercial value of a crop.

### 2.4.10 Thousand kernels mass (wheat) and hundred kernels mass (pulses)

In South Africa, a thousand kernel mass of more than 40 g and hectolitre mass of 76 kg $hl^{-1}$ is preferable (Mamuya, 2000).

### 2.4.11 Phonological data

Days to heading, days to maturity as well as the length of the grain filling period are regarded as indicative of the adaptability of any crop (or cultivar) to any given environment. Days to heading or flowering were counted from sowing date until 50% of the plants in each plot extruded anthers. Similarly, days to 50% maturity were considered from the sowing date until the sample plants of each plot were physiologically matured. Furthermore, grain filling period was also taken into account as one of the most important parameters for it measures the days from 50% heading to the days to 50% physiological maturity. It is generally believed that the more time a crop cultivar takes to grain fill, the more the grain yield and quality of the product will be. That is the main reason of considering it as one of the parameters of measurement.

### 2.4.12 Grain yield

The overall grain yield performance of any crop cultivar determines its cultivation in organised agriculture on a commercial scale. Due to population growth at an alarming rate, third world countries need to increase their grain yield production. For the time being, quality of grain yield to some third world countries, for example, Ethiopia may not be of prime importance for self-sufficiency in food. Instead, at the moment, quantity of grain yield comes first and quality second (Dagnachew, Personal communication). On the contrary, in developed countries and in South Africa,

both producers and consumers are quality conscious and henceforth do care very much in considering both of these factors (grain yield and quality) in their production systems. As the result, grain yield is considered as of paramount importance for inclusion and be measured as one of the most important parameters.

### 2.4.13 Above ground bio mass

Straw of cereals, legumes and pulses is used for animal feed in many African countries (Payne, *et al.,* 1996). The above ground straw yield potential is therefore often taken as measurement for releasing new crop cultivars. Moreover, greater above ground biomass leads to more crop residue to be utilized as organic fertilizer upon decomposition.

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# CHAPTER 3

# GENERAL MATERIALS AND METHODS

## 3.1 Introduction

All field and laboratory experiments included in this monograph were conducted at the Small Grain Institute, Bethlehem, South Africa in 1999. Field trials were planted on an Avalon soil form (Purchase, *et al.,* 1992) in 1999. Materials and methods applicable to all of the studies outlined in different chapters are described in this chapter. However, materials and methods only applicable to specific chapters are described in the different chapters. The materials and methods used for the two wheat species as well as the two pulse crops were more or less similar.

## 3.2 Plant material

Four different crops and two cultivars per crop (except for three cultivars in the case of durum wheat) were included in this study (table 3.1). Seeds of all crops were obtained from Ethiopia with the exception of one durum wheat cultivar inclusion from South Africa.

Table 3.1: Crops, cultivars and classification used in this study

| Crop | No | Cultivar | Remark |
|---|---|---|---|
| Bread wheat | 1 | Kubsa | Semi-dwarf |
| | 2 | Mitikie | Tall |
| Durum wheat | 1 | Gerardo | Semi-dwarf |
| | 2 | Kilinto | Tall |
| | 3 | Orania* | Semi-dwarf |
| Faba bean | 1 | Kuse | Small seeded |
| | 2 | Cs 20dk | Large seeded |
| Chickpea | 1 | Akaki | Small seeded |
| | 2 | Mariye | Large seeded |

*South African durum wheat cultivar.

**Bread wheat:** Two Ethiopian bread wheat cultivars, namely Kubsa and Mitikie that were released in 1993 and 1994 respectively (IAR KRC, 1997), were introduced and tested in 1999 at the Small Grain Institute, South Africa. Before their release the cultivars were known as HAR 1685 and HAR 1709 respectively. These cultivars were selected for this study as they were released for use on a national scale in Ethiopia (Taa, *et al.*, 1999).

**Durum wheat**: Two Ethiopian durum wheat cultivars, Gerardo and Kilinto, were released in 1976 and 1994 respectively and are currently in production (Bechere *et al.*, 1994). A South African durum wheat cultivar, Orania, was included as a third cultivar to back up Kilinto in case of failure of Kilinto seeds to germinate and grow due to the damage caused by weevils.

**Pulses:** The faba bean cultivar Cs 20dk, a large seeded type, was released in 1976 (IAR KARC, 1997), while cv. Kuse, relatively small seeded, is also a recent release. The chickpea cv. Akaki was released in 1995 while Mariye was released earlier in 1993 (Abebe and Mamo, 1997).

## 3.3 Methods

### 3.3.1 Seedling emergence under field conditions

The number of emerged seedlings was recorded at two-day intervals as soon as emergence commenced on approximately the tenth day for trials that received supplementary irrigation. For non-irrigated experiments, emergence was delayed slightly and recording of seedling emergence started on the fourteenth day after planting. Various formulas have been devised in the past to calculate either germination- or emergence rate (Van de Venter, 1999). However, in this case, the following formula was applied:

$$\text{Mean germination or emergence time (days)} = \frac{\Sigma(Dn)}{\Sigma n}$$

Where n is the number of seeds that emerged on D-day.

### 3.3.2 Thousand kernel mass

About seventy-five to one hundred grams of seeds were randomly sampled from the total of the seed lot for each seed size of each treatment, placed in a Numigral seed counter and counted. Hence, thousand kernels mass of each treatment was determined by weighing the counted kernels.

### 3.3.3 Determination of moisture content in seeds

As the seeds were obtained from Ethiopia, saving the seeds for further investigation was absolutely necessary. Therefore, a non-destructive Sinar Datatec electronic moisture meter (model G6C), which measures moisture in wheat through a di-electric constant method, was employed (Ybema, 1997).

All tests were performed twice. In the event of the difference between the two percentage readings not exceeding 0.5%, the average of the two percentages was recorded as the moisture content. However, when the differences exceeded 0.5%, the tests were repeated on separate quantities of the original sample. The moisture meter was used according to the manufacturer's instructions.

### 3.3.4 Determination of protein content in seeds

The protein content in seeds was determined at standard moisture content of 12%. Milled samples were prepared on a falling number Hammer Mill and protein content determined by near infrared reflection spectroscopy (360 NIRS) using an Infra Alyser (Technicon). The instrument was used according to the manufacturer's instructions.

All tests were performed twice and in the event of the difference between the two values exceeding 0.2%, tests were repeated. Care was taken that the quarts glass was clean, dry and free of scratches and cracks. A soft brush was used to clean the kettle. A spatula was used to transfer the sample to the test cell unit until it overflowed.

Subsequently, the test cell was tapped lightly with the spatula to ensure even spreading of the sample and the surplus material was evenly scraped from the surface without pressing down on the sample. The lid of the test cell unit was screwed on to ensure that the sample was tightly packed each time. The test cell was placed into position and the protein content determined, based on 12% moisture content.

### 3.3.5 Hectoliter mass determination

Hectoliter mass was determined by means of the Funnel Method using a mass meter with an accuracy of 0.1 gram. A container with a volume capacity of 500 ml was used. Care was taken that the seed samples, with moisture content of 12%, were free of dust and other mass bearing particles. A sufficient amount of grain was placed in the hopper until the quart kettle overflowed. The outlet of the hopper was positioned over the kettle, and the grain allowed to flow into the kettle.

The stroker was placed on the kettle and excess grain removed lightly without jarring by stroking the grain with full–length zigzag motions. The grain was subsequently transferred into the weighing pan on the balance and the hectoliter mass recorded (Ybema, 1997; Mamuya, 2000).

### 3.3.6 Thousand kernel mass determination

Seeds from each crop and cultivar were classified beforehand as small, medium and large by using different sieves. Thousand kernels for wheat and 100 for pulses were counted using a Numigral seed counter, model EPL (Falling Number – Stockholm) and the masses determined.

### 3.3.7 Seed treatment

Just before planting, either in the laboratory or the field, an equivalent number of each of the small, medium and large sized seeds were classified using both sieves and precise balances. Each class was again divided into three equal parts for fungicide treatment.

The two fungicides used (as recommended by Mareli, *et al.,* 1996) were, Carboxin/Thiram (Vitavax plus FS) at 25 ml active ingredient $kg^{-1}$ and Tebuconazole (Raxil 15 ES) at 2.5 ml active ingredient $kg^{-1}$. Untreated seed were used as a control. Each fungicide was applied separately as a liquid slurry by hand shaking in a plastic flask shaped bottle for about two minutes until coverage of seeds with the fungicides were complete.

### 3.3.8 Germination percentage and seedling growth measurements in the laboratory

Before germination experiments in the laboratory commenced, the necessary precautions were followed which included disinfecting of containers and working areas with 70% ethanol.

Germination and subsequent seedling growth were measured under controlled conditions in the laboratory using large sized standard germination paper (557x 302 mm). Four sheets of paper were placed on top of each other with the bottom layer protruding approximately 30 mm longitudinally. After placing the paper on a thick glass plate, 100 ml of distilled water was evenly poured onto the substrate layers. Subsequently, the top sheet was removed and one hundred wheat seeds were evenly spaced using a perforated plastic sheet having hundred holes. The top sheet was then carefully replaced and the protruding part of the bottom sheet folded upwards over the top three layers. The four sheets of paper, containing the wheat seeds, were loosely rolled up together longitudinally.

The rolls were placed in polyethylene bags and into a suitable container in a growth chamber. The polyethylene bag was loosely constricted with rubber bands at the open end so that aeration was still possible while the container was closed with a lid preventing unnecessary water loss to the atmosphere. Seeds were allowed to germinate in a growth chamber in the dark at a constant temperature of 20°C. Seedling evaluations were made after eight days in accordance with the International Rules for Seed Testing (ISTA, 1999; NDA, 2000). After the percentage of normal and abnormal seedling as well as dead seeds was calculated, 25 seedlings of each were randomly selected and coleoptile-, root- and total seedling lengths measured. Subsequently, the coleoptiles and roots of seedlings were separated and its fresh weight recorded. The dry mass was also recorded after the plant material was oven dried at 75°C for 48 hours (Salisbury and Ross, 1985).

### 3.3.9 Field experiments

The sowing depth study of all wheat was planted on August 10, 1999. Seeds were planted in rows, using a tractor-mounted planter, together with the fertilizer (see 3.3.11 for statistical layout). The seed size and fungicide treated trial was planted in late August 1999. Fertilizer application to all wheat field trails was the same namely 37.5 kg N, 25 kg P and 12.5 kg K $ha^{-1}$. The fertilizer was band placed in the rows before the seed was sown and incorporated with the soil.

Weeds were mechanically removed once to allow optimal aeration of the roots. All plants and productive spikes of each plot were counted so as to determine the effective tiller $plant^{-1}$ and spikes $m^{-2}$ rates. After harvesting the seeds of ten randomly selected spikes, the number of seed $spike^{-1}$ were calculated by threshing the spikes separately. The number of days to 50% heading and maturity were recorded and the grain filling period determined. Data on yield and yield components were also recorded. Above ground bio-mass of both wheat and pulses was recorded using a pocket (spring balance).

### 3.3.10 Methods applicable to pulses with slight deviation from that for wheat

#### 3.3.10.1 Seed classification

Seeds from each pulse crop and cultivar were classified before hand as small, medium and large by using different analytical and precision balances. Hundred kernels mass was the base for classification of pulses. Seeds of each cultivar were roughly separated into small and large by means of ordinary sieves. Those that fell in between these two groups were individually weighed using an analytical balance and the medium sized seed was separated from the small and large types.

#### 3.3.10.2 Seed treatment

As was the case for wheat, each pulse seed class was again divided into three equal parts for fungicide treatment. Two fungicides Celest® XL 035 FS (fludiocsonit/mefenolsam) and Dividend® 030 FS (difenoconazole), as recommended by Mareli *et al.*, (1996), were selected. The treatment procedures were similar to that followed in wheat. Untreated seed was used as a control.

#### 3.3.10.3 Germination capacity and seedling growth measurements for pulses in the laboratory

Faba bean and chickpea are considered as large seeded compared to wheat. Sand is regarded as the most suitable medium for growing large seeded crops under experimental conditions (ISTA, 1999; National department of Agriculture, 2000). The most appropriate germination sand was obtained from a company in Pretoria, South Africa. Sand and water were mixed in an appropriate proportion in accordance with ISTA (1999) rules at a ratio of 625 ml of water: 10 kg of sand.

Fifty seeds were planted in 2200 ml wet sand in Addis containers (National Department of Agriculture, 2000) after the sand was loosened and leveled off with a small rake. The seeds were placed on top of the prepared sand surface, slight pressure applied to avoid the movement of seeds and covered with 1650 ml of wet sand. The containers were closed and placed into a germination cabinet where seeds were allowed to germinate in 8/16 hrs light/dark respectively at a constant temperature of 20°C. Seedling emergence evaluations were made after eight and 14 days for chickpea and faba bean respectively (ISTA, 1999).

After the percentage of normal and abnormal seedlings, as well as dead seeds, was calculated, 25 seedlings of each were randomly selected, their coleoptile-, root- and total seedling lengths as well as fresh and dry masses measured in the same way as described for wheat (see 3.3.8).

#### 3.3.10.4 Field experiments

All pulse field experiments were planted on November 16, 1999. Fertilizer was band placed in a ratio of 31.8 kg N, 10.6 kg P and 0 kg K $ha^{-1}$ and incorporated into the soil just before the seed was sown. This was based on the recommended rate of other grain legumes grown in the locality (Adrian Botha; personal communication). As pulses are not commonly grown in South Africa, literature on its cultivation is scarce. Consequently, spacing and the average planting depth followed for the two pulse crops were based on Australian literature (Prichard, 1994; Prichard, 1995) as Australia and South Africa share similar environmental conditions. The data collection procedures were similar to that followed for wheat.

Table 3.2: Recommended cultivation practices for pulses in Australia

| Crop | Plants $m^{-2}$ (expected) | Sowing depth in cm |
|---|---|---|
| Faba bean | 25-30 | 5-8 |
| Chickpea | 30-35 | 5-8 |

#### 3.3.10.5 Protein content

The instrument used as well as the procedures followed in determining the protein content of pulse seeds were quite different from that used for wheat seeds. The LECO ® FP-2000 Nitrogen/Protein Analyzer, a non-dispersive, infrared, microcomputer based instrument, designed to measure the nitrogen content in a wide variety of organic compounds was employed. After approximately 15 g of each sample was milled, an aliquot was weighed and placed into the sample holder referred to as a bloat. As part of the analysis procedure, a combustion process converts all nitrogen to elemental $N_2$ and $NO_x$. The equipment was used according to the manufacturer's instructions.

### 3.3.11 Experimental layout and statistical analysis

Experimental designs for both laboratory and field trials were the same wherever seed sizes in combination with fungicide treatment experiments were conducted. However, the layout of the latter bulked laboratory and sowing depth field trials and fungicide treatments for each crop differed from the seed size by seed treatments. In the former laboratory trial and field treatments were identical, in that a three-factor experiment was laid out in a randomized complete block design while four replications were used. In the field trial a split-plot design for cultivar by fungicide interaction was employed where cultivar by sowing depth was taken as main and sowing depth as a sub-plot was used. The laboratory counter parts of each sowing depth field trial were laid out in a two-factor randomized complete block design. Each treatment was replicated four times.

A series of statistical analyses were performed as follows: 1) analysis of variance (ANOVA) was performed on data collected for each trial. The data was subjected to statistical analysis using MSTATC of the micro software program. 2) Mean separation (Tukey's Mean Significant Difference test) was used to separate the means for all measurements with all the interactions that were significant at both 5% and 1% probability levels, 3) correlation matrix analysis was computed, using an AGROBASE micro software program, to identify positive or negative significant relations of the most critical seed quality parameters.

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# CHAPTER 4

# PRELIMINARY SEED CHARACTERIZATION AND SIZE CLASSIFICATION OF ETHIOPIAN BREAD WHEAT, DURUM WHEAT, FABA BEAN AND CHICKPEA CULTIVARS

## 4.1 Introduction

Before seeds were treated or planted at different depths in various trials during this study, seeds obtained from of each crop and cultivar of wheat (bread and durum wheat) were classified according to size and characterized in terms of moisture content, protein content, hectoliter mass and thousand kernel mass. However, pulses (faba bean and chickpea) were classified on the basis of hundred-kernel mass only as the seeds were imported from Ethiopia and the amount of seeds available was insufficient to conduct all the various parameters as for wheat.

Seed size and uniformity are, among others, essential criteria for seed quality. Most of the time seed size varies in the same cultivar due to a number of reasons. Seed size variation occurs due to differences in localities, soil types, sowing date, nutrients, moisture availability, sunlight and climatic differences (mainly temperature). Moreover, in the case of wheat seeds, its position in the spike whether it is in the proximal (basal), central or distal positions during its growing period (Thompson 1979; Calderini *et al.*, 1999) also determines seed size. Thompson (1979) reported that disease infection and attack by pests diminish seed size and, as every plant may not be infected or attacked, differences in seed size may occur. He further stated that flowers on the lateral branches or tillers open later than on the main stem and give rise to seeds that are liable to be harvested while still immature and undersized. Many farmers and scientists (Evans and Bhatt, 1977; Nayeem and Dehpande, 1987; Thompson, 1979) are of the opinion that large seed size is an indication of seed vigour and ultimately of larger and more vigorous seedlings as well as green leaf area capable of increased photosynthesis.

Moreover, if seeds are buried deep in the soil, a large seedling is more likely to reach the surface than smaller ones. Compared to small seeds, larger ones tend to produce seedlings that grow more rapidly in the field and greater proportions of them emerge through the soil surface. Thompson (1979) further commented that shriveled seeds have no practical planting value.

On the other hand, Thompson (1979), Douglas *et al.* (1994) and Usberti and Amaral (1999) all presented some controversial arguments by favouring small and medium sized seeds of the same cultivar to the large ones. They made some rather convincing remarks in this regard after observing that, within the same genotype of wheat as well as in other crops, there were no significant differences in seedling performances of the bigger seeds.

It is important that anyone concerned with the production of seeds or the commercial cultivation of crops has to be familiar with the quality of seeds ahead of planting. Therefore, the primary objective of this preliminary study was to classify the initial seeds of each crop and cultivar of the afore-mentioned four crops into three different seed sizes (small, medium and large) by using different sieve sizes and weight. The overall objective of this study is, therefore, to statistically ascertain the distinction among the laboratory classified seed sizes using known parameters. Such relevant parameters were thousands kernel and hectolitre mass, protein content as well as moisture content in wheat and only hundred kernels mass in pulses were determined. The characterized seeds were used in all follow up trials.

## 4.2 Materials and Methods

The materials and methods applicable to this chapter were described in chapter 3.

## 4.3 Results

### 4.3.1 Bread wheat

#### 4.3.1.1 Cultivar variations

The analysis of variance indicated that the semi-dwarf bread wheat cultivar Kubsa had significantly higher values (at $P \geq 0.01$) than the tall Mitikie with respect to hectoliter mass, thousand kernel mass, protein content and moisture content ($P \geq 0.05$) (Table 4.1).

Table 4.1: Cultivar variations in two Ethiopian bread wheat cultivars on grounds of some seed parameters.

| Cultivar | Parameters | | | |
|---|---|---|---|---|
| | HLM Kg $hl^{-1}$ | TKM (g) | PC % | MC % |
| Kubsa | 75.58A | 32.78A | 8.21A | 10.83A |
| Mitikie | 75.03B | 29.43B | 7.86B | 10.78B |
| P≤ | ** | ** | ** | * |
| Mean | 75.31 | 31.10 | 8.03 | 10.80 |
| C.V. % | 0.15 | 0.52 | 2.77 | 0.58 |

**Abbreviations**:

Ns = non significant; * = significant; ** = highly significant (at $P \leq 0.05$). Any two or more means sharing the same letter are not significantly different at a 5% probability level according to Tukey's mean separation test: HLM= hectolitre mass, TKM= thousand kernel mass, PC= protein content (at 12% MC ; fresh weight), MC= moisture content, HL= hectolitre, g= gram, C.V. = coefficience of variance.

#### 4.3.1.2 Seed size variations

Statistical analysis of the pooled data for both cultivars, revealed that large sized seeds significantly differed (at the $P \leq 0.01$ level) from medium and small sized seeds as well as medium from small in hectoliter mass and thousand kernel mass but showed only a significant difference at the $P \leq 0.05$ level for moisture content. There was no significant difference among seed sizes for percentage protein content (Table 4.2).

Table 4.2: Effect of seed size variations in two Ethiopian bread wheat cultivars.

| Seed Size | Parameters | | | |
|---|---|---|---|---|
| | HLM Kg $hl^{-1}$ | TKM (g) | PC % | MC % |
| Small | 72.30C | 23.55C | 8.05a | 10.75B |
| Medium | 76.15B | 31.92B | 8.06a | 10.82A |
| Large | 77.47A | 37.83A | 7.99a | 10.84A |
| P≤ | ** | ** | Ns | * |

See footnote of Table 4.1.

#### 4.3.1.3 Cultivar by seed size interactions

As far as cultivar by seed size variation was concerned (Table 4.3), highly significant differences (at P≤ 0.01) were observed for hectoliter mass and thousand kernel mass. However, the results indicated non-significant differences for protein and moisture content interactions.

Table 4.3: Effect of cultivar X seed size interactions in two Ethiopian bread wheat cultivars.

| Cultivar X Seed size Slotted sieve (mm) | Parameters | | | |
|---|---|---|---|---|
| | HLM Kg $hl^{-1}$ | TKM (g) | PC % | MC % |
| Kubsa <2.3 x 25 | 71.27 F | 23.27 F | 8.10 a | 10.75 a |
| 2.3 to 2.5 x 25 | 76.97 B | 34.17 C | 8.25 a | 10.90 a |
| >2.5 x 25 | 78.50 A | 40.88 A | 8.28 a | 10.85 a |
| Mitikie 2.2 x 25 | 73.32 E | 23.83 E | 8.00a | 10.75 a |
| >2.2 to 2.3 x 25 | 75.32 D | 29.67 D | 7.88a | 10.75 a |
| >2.3 x 25 | 76.45 C | 34.78 B | 7.70a | 10.83 a |
| P≤ | ** | ** | Ns | Ns |

See footnote of Table 4.1.

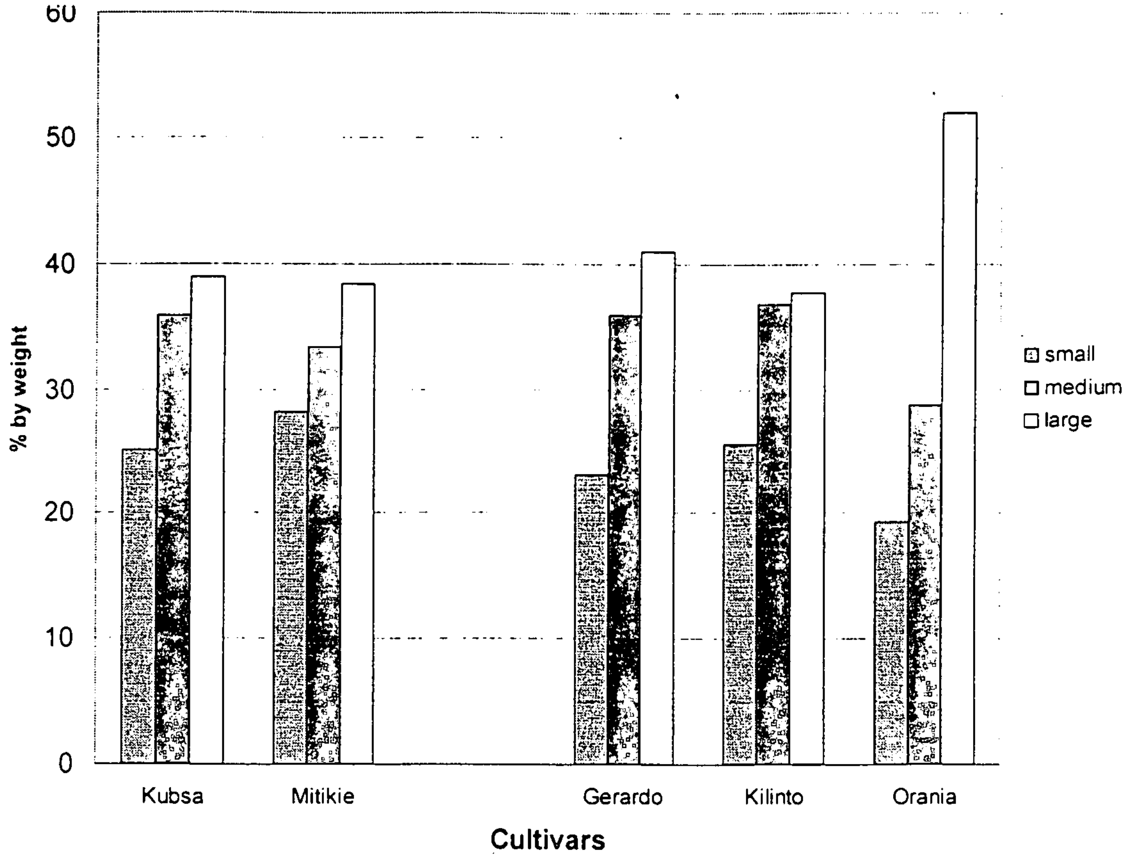


Figure 4.1: The percentage of seed size by fresh weight of two bread wheat (left) and three durum wheat (right) cultivars respectively.

As shown in figure 4.1, the percentage proportion by weight of the three different seed sizes groups for bread wheat was similar. Although masses differed, the seed number was estimated at being close to equal. The size of Orania seeds tended to be more towards the larger group, compared to the other durum wheat cultivars, which is assumed to be indicative of good quality.

### 4.3.2 Durum wheat

#### 4.3.2.1 Cultivar variations

There were highly significant differences among cultivars for all parameters measured (Table 4.4). Orania was found to be superior to others in hectolitre mass while Kilinto measured least of all. However, Kilinto was significantly higher in thousand kernel mass and protein content but did not differ significantly from that of Orania for this parameter. The two Ethiopian cultivars (Kilinto and Gerardo) were found significantly higher in protein content than the South African one (Orania) but somewhat lower in moisture content.

Table 4.4: Durum wheat cultivar variations in terms of fresh mass, protein- and moisture content.

| Cultivar | Parameters | | | |
|---|---|---|---|---|
| | HLM Kg $hl^{-1}$ | TKM (g) | PC % | MC % |
| Gerardo | 79.44B | 46.42C | 9.55A | 11.04B |
| Kilinto, | 75.75C | 55.78A | 9.79A | 10.98B |
| Orania | 83.18A | 48.34B | 8.28B | 11.78A |
| Mean | 79.46 | 50.18 | 9.21 | 11.27 |
| C. V. % | 0.33 | 0.55 | 2.62 | 0.64 |
| P≤ | ** | ** | ** | ** |

See footnote of Table 4.1.

#### 4.3.2.2 The effect of seed size

When the data from the three cultivars were combined and statistically analysed, highly significant differences (at P≤ 0.01) were observed among the three seed size groups for all four parameters measured (Table 4.5). As expected, large seeds measured significantly higher in thousand-kernel mass compared to the medium and small seed size groups. There was no significant difference between the large and medium seed size groups in hectoliter mass. However, both large and medium were superior to small seeded ones for this parameter. Large seed showed a significant reduction in moisture content compared to medium and small seeds.

Table 4.5: Variations in seed size, protein- and moisture content in durum wheat (pooled data for all cultivars )

| Cultivar | Parameters | | | |
|---|---|---|---|---|
| | HLM Kg $hl^{-1}$ | TKM (g) | PC % | MC % |
| Small | 78.59B | 39.96C | 9.43A | 11.29A |
| Medium | 79.85A | 51.39B | 9.01B | 11.32A |
| Large | 79.93A | 59.19A | 9.18B | 11.19B |
| P≤ | ** | ** | ** | ** |

See footnote of Table 4.1.

#### 4.3.2.3 Cultivar X seed size interactions

Highly significant differences (at P≤ 0.01) regarding cultivar by seed size interaction, for the four parameters measured, were observed (Table 4.6). With the exception of moisture content in seeds of the cultivar Orania, variations within and among cultivars were observed for all the parameters measured.

Table 4.6: Cultivar X seed size interactions in durum wheat in terms of seed size, protein and moisture content.

| Cultivar x seed size Slotted sieve (mm) | **Parameters** | | | |
|---|---|---|---|---|
| | HLM Kg $hl^{-1}$ | TKM (g) | PC % | MC % |
| Gerardo 2.3 x 25 | 77.68F | 32.95G | 10.75A | 10.95BC |
| 2.3 to2.8 x 25 | 79.95E | 48.65DE | 9.18CD | 11.10B |
| >2.8 x 25 | 80.70D | 57.65B | 8.73DE | 11.08B |
| Kilinto 2.5 x 25 | 76.15G | 48.13E | 9.63BC | 11.10B |
| >2.5 to3.5 x 25 | 76.20G | 56.33C | 9.56C | 11.02B |
| >3.5x25 | 74.90H | 62.90A | 10.18AB | 10.80C |
| Orania 2.5 x 25 | 81.95C | 38.80F | 7.93F | 11.82A |
| >2.5 to 2.8 x 25 | 83.40B | 49.20D | 8.28EF | 11.82A |
| >2.8 x 25 | 84.20A | 57.03B | 8.63DE | 11.70A |
| P≤ | ** | ** | Ns | Ns |

See footnote of Table 4.1.

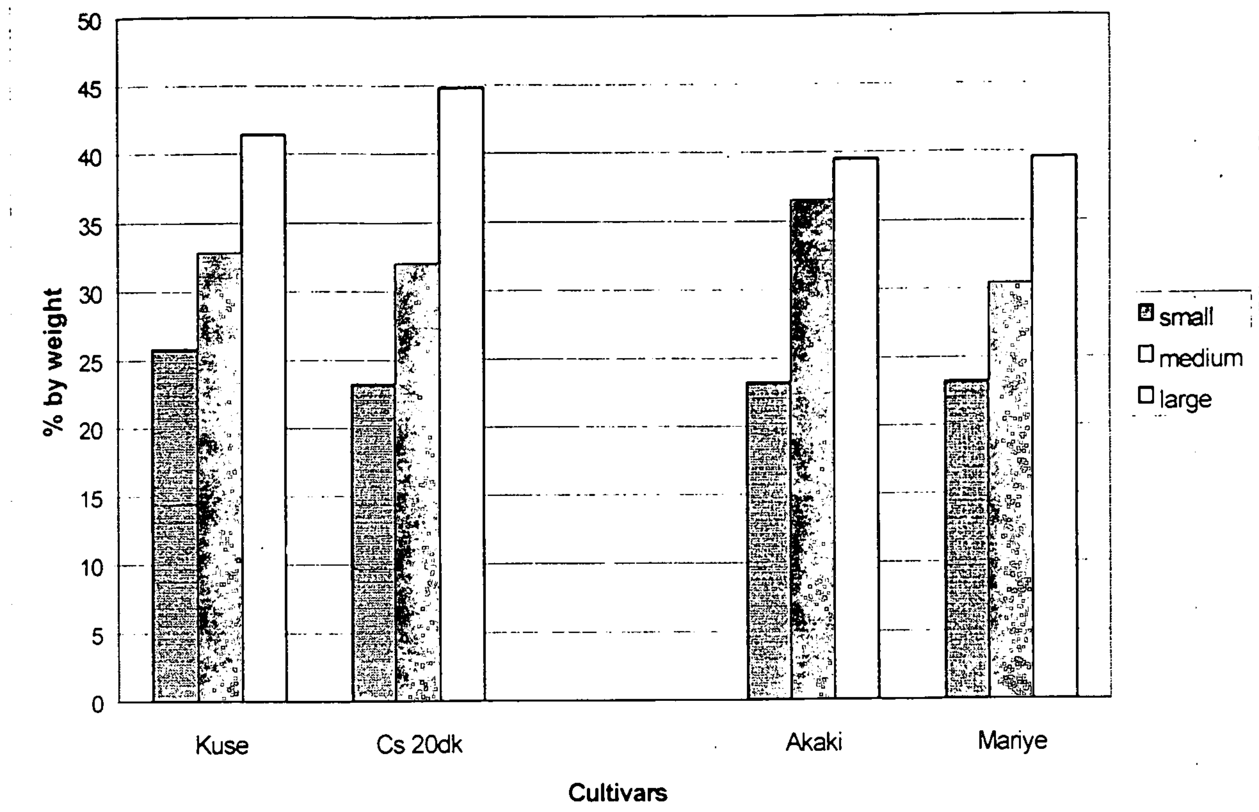


Figure 4.2: Percentage of seed size by weight for faba bean (left) and chickpea (right) side cultivars.

### 4.3.3 Faba bean and chickpea

For faba bean cultivars the percentage proportion of large seed size by weight was greater than that for chickpea (Figure 4.2).

#### 4.3.3.1 Cultivar variations

Statistically, highly significant differences between faba bean cultivars, in 100-kernel mass, were observed (Table 4.7). Cs 20dk is known for its large seediness and hence, the difference from Kuse. In chickpea, Mariye differed significantly from Akaki (table 4.7) with the latter measuring much lower in 100 kernel mass.

Table 4.7: Cultivar variations in terms of hundred kernel mass for (A) Faba bean and (B) chickpea

| **(A) Faba bean** | 100 kernel mass (g) | **(B) Chickpea** | 100 kernel mass (g) |
|---|---|---|---|
| Cultivar | | Cultivar | |
| Kuse | 41.10B | Akaki | 18.69B |
| Cs 20dk | 59.47A | Mariye | 26.57A |
| Mean | 52.79 | Mean | 22.63 |
| C.V. % | 0.27 | C.V. % | 0.64 |
| P≤ | ** | P≤ | ** |

See footnote of Table 4.1.

#### 4.3.3.2 Seed size variations

As was expected, highly significant differences between different seed size groups regarding 100 kernels mass was observed for both crops (Table 4.8) with the large seed groups measuring higher than medium and the medium than the small seeded groups.

Table 4.8: Seed size variations in terms of 100 kernel mass for (A) Faba bean and (B) chickpea

| **(A) faba bean** | 100 kernels mass (g) | **(B) Chickpea** | 100 kernels mass (g) |
|---|---|---|---|
| Seed size | | Seed size | |
| Small | 36.06C | Small | 18.05C |
| Medium | 53.01B | Medium | 22.18B |
| Large | 69.29A | Large | 27.67A |
| P≤ | *, ** | P≤ | *, ** |

See footnote of Table 4.1.

#### 4.3.3.3 Cultivar by seed size interactions

Statistically significant differences in cultivar by seed size interaction were found for both faba bean and chickpea (Table 4.9).

Table 4.9: Cultivar X seed size interactions in terms of 100 kernel mass for (A) Faba bean and (B) chickpea

| **(A) Faba bean** | 100 kernels mass (g) | **(B) Chickpea** | 100 kernels mass (g) |
|---|---|---|---|
| Seed Size g kernel$^{-1}$ | | Seed size g kernel$^{-1}$ | |
| Kuse small <0.35 | 30.26F | Akaki small < 0.16 | 13.86F |
| Medium 0.35 – 0.55 | 47.14D | Medium 0.16– 0.21 | 17.73E |
| Large >0.55 | 60.92B | Large >0.21 | 24.47C |
| Cs 20dk small <0.50 | 41.87E | Mariye small < 0.25 | 22.23D |
| Medium 0.5 - 0.65 | 58.88C | Medium 0.25 – 0.28 | 26.63B |
| Large >0.65 | 77.68A | Large > 0.28 | 30.86A |
| P≤ | ** | | ** |

See footnote of Table 4.1.

## 4.4 Discussion

### Wheat

Bread wheat

In South Africa, wheat grading is mainly based on protein content (PC) and hectolitre mass (HLM) (taken from Ybema, 1996; ARC-SGI, 1999). According to the South African grading rules the PC must be between 9% to ≥ 12% or more and HLM between 74 kg hl$^{-1}$ to ≥ 79 kg hl$^{-1}$ or more to be graded as valuable for human consumption.

Seeds of Ethiopian bread wheat cultivars did not comply with the rules for the classification, grading and packing of wheat in South Africa. This is due to their lower protein contents and hectolitre masses are considered. Hence, cultivars of bread wheat fall under bread wheat low grade two (BL2). As they do not fit to the above criteria, the small and medium sized seeds are graded in the utility (UT) class.

Moisture content

Obviously, the moisture content of seeds for planting must also be within the recommended limit that may have to be compared as relative to the existing parameters. Moisture content of all seed samples up on collection was below 13%. This is acceptable according to the South African grading rules applicable to wheat as per the Rules for the classification, Grading and Packing of wheat 1992 (Ybema, 1996). However, there were significant differences between cultivars and among seed sizes at 5 % probability level. Kubsa had significantly higher moisture content than Mitikie. Among seed sizes, small seed was found drier than either medium or large seed. Kubsa is heavier than Mitikie. Therefore, this investigation reveals that heavier and or larger seeds contain more moisture than the small and lighter.

Durum wheat

In durum wheat, the two Ethiopian durum wheat cultivars were found superior to the South African cultivar, Orania, regarding protein content. As a result, they were found to be at an acceptable range of such a grade. The only impressive criterium for Orania was its yield performance (83.2 kg $hl^{-1}$) which was the best of all cultivars. This cultivar can thus be graded as Grade 1 provided all other criteria are fulfilled. However, due to its inferior protein content Orania was graded in the utility grade. In general, all wheat cultivars showed very low (≥10) in PC. Moreover, according to the South African grading rules the Ethiopian durum wheat cultivars included in this study can be graded as durum low grade one (DL1) (Ybema, 1996; ARC-SGI, 1999).

When all cultivars were taken together, large sized seed groups were significantly better than the medium and small in both PC and HLM parameters. Similarly, highly significant cultivar by seed size interactions were observed for durum wheat indicating that cultivars differ regarding seed size and should probably be treated differently during planting.

In durum wheat unlike bread wheat, small sized seed was superior to medium and large in protein content. The Ethiopian durum wheat cultivars were better than the

South African cultivar Orania for protein content. Otherwise, Orania was found to be superior to the Ethiopia durum wheat cultivars as far as hectoliter mass is concerned.

The moisture content of durum wheat of the two Ethiopian cultivars was also found to be under a similar pattern to that of bread wheat cultivars of the same origin. However, Orania was found to significantly higher than those of the Ethiopian introductions. The moisture content of all was under ideal conditions.

In general, when the two wheat species (bread wheat and durum wheat) are compared, for seed protein content, durum wheat was found to be superior to bread wheat cultivars. The same thing was true for both hectolitre mass and thousand kernels mass. The protein content of durum wheat was much better than that of bread wheat and this is in agreement with the findings of Feillit (1988) who suggested that a high protein content and a "strong" gluten are required to process semolina into a suitable final pasta product.

**Pulses**

As far as pulses are concerned, there were highly significant differences between cultivars, among seed sizes and among their interactions for the measured parameter (hundred kernels mass). Therefore, it was sufficient enough to draw conclusions as the distinct laboratory classification was statistically validated for accuracy.

The proportion of seeds by weight

In general, all cultivars taken together, bread wheat had 26.7, 34.7 and 38.7% of its seed classified as small, medium and large in this order. For durum wheat, the percentage proportion of seed sizes was 22.6, 33.8 and 43.6% for small, medium and large. This indicates that durum wheat seeds were much better than bread wheat as the percentage proportion of medium and large seeds in durum were higher than that of the bread wheat. Similarly, a comparison between faba bean and chickpea was made. On the average, faba bean had 24.5, 32.4 and 43.1% of its seeds as small, medium and large while chickpea as 24.0, 33.5 and 39.6% in this same order. The faba bean is slightly better than chickpea for the same reason explained in wheat. Otherwise, they were almost identical to each other.

In conclusion, the advantage of this approach is in its use as a tool to identify seed sizes and uniformity and qualify their grades for the purpose of boosting seed production. By sampling a minimum amount of about one or two kilograms of a seed lot, seed analysts or any seed technician or the farmer will be able to determine the uniformity of his or her planting material (the seed) before planting. In addition to this, seed researchers or growers can select seed growing environments and or the best sowing dates by comparing and contrasting the sizes of their seed lot grown from the different growing environments using this method. As a result, the best environment, planting date, soil type and or rotation system can be chosen to grow the best quality seed for maximum yield and profit. For example, In Ethiopia, seed sizes and their qualities for a set of cultivars, or even within the same cultivar, vary among farm locations which are less than a kilometer distance from one another. Such variations occur due to differences of soil type (Fufa and Gebeyehu, 1996), drainage (Mitiku *et al.*, 1999), rotation (Wolabu *et al.*, 1996) and soil fertility (Tarekegne *et al.*, 1996). At the end of the day, the more uniform a seed lot will be, the better it will be specifically for the farmer but also for the population at large.

This principle does not involve sophisticated instruments or special training to handle. The implication is that uniform seeds will always have uniform inter plant competition that will in turn provide reasonably more uniform and relatively larger seeds. If seeds are buried deep in the soil, a large seedling is more likely to reach the surface than the small ones. As mentioned in the introduction, compared to small seeds large seeds produce seedlings that grow more rapidly in the field and a greater proportion of them emerge through the soil surface (Thompson, 1979). This principle does not violate the pure seed definition formulated by ISTA rules (ISTA, 1999). Instead, it qualifies it. The seed size classification of all four crops was statistically justified as accurate. The main reason for this is that seed sizes classified in this system significantly differed from one another. This classification method assisted in determining the quality of the seed used in most follow up experiments included in this monograph and supplied a quality assurance methodology to be applied throughout the study.

The overall objective of this study is met in that the laboratory classified seed sizes are statistically verified.

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# CHAPTER 5

# EFFECT OF SEED SIZE AND TREATMENTS ON SEED QUALITY AND YIELD OF ETHIOPIAN BREAD WHEAT CULTIVARS


## Abstract

Two trials, one in the laboratory and its duplicate under field conditions, were conducted at the Small Grain Institute, Bethlehem, South Africa in 1999. A randomized complete block design with four replications was used. Seeds of two selected Ethiopian bread wheat cultivars, Kubsa (semi-dwarf) and Mitikie (tall), were used in the study. The main objectives were to determine germination percentage, field emergence and seed quality by means of different parameters, by comparing fungicide treated and untreated seeds for three different seed sizes of each of the two bread wheat cultivars. An additional goal was to evaluate field performances, such as yield components and other relevant agronomic parameters, of the same material. Significant differences were observed between the treatments tested. In general, Mitikie (93.2% and 66.1%) outperformed Kubsa (84.9% and 56.4%) in laboratory measured germination percentages and field emergence respectively. Among the fungicides used to treat seeds, only Vitavax Plus improved germination percentages as compared to the respective controls. The germination percentage of large size seeds was superior to that of small seeded groups but was not significantly higher than the medium sized seed.



**Key words:** bread wheat, seed size, seed treatments, seed quality, stand establishment


## 5.1 Introduction

Wheat is grown on approximately 100 million hectares in the developing countries of Africa, Asia and Latin America. The semi dwarf cultivars of wheat that launched the green revolution of the 1960's and 1970's doubled to quadrupled production in countries such as India, Pakistan, Turkey, Mexico and Zimbabwe (Singh and Rajaram, 1995). Semi-dwarf cultivars, with short coleoptile lengths, are still amongst the most popular cultivars grown in these areas. However, a more scientific approach for maintaining and improving plant stands and yields from these cultivars has become of primary importance to wheat farmers in developing countries. Moreover, various wheat diseases prevail in these countries and pose a threat to the future production of wheat. For instance in Ethiopia, Kidane (1996) identified six seed-borne fungi of which the control through usage of quality seeds and seed dressing with fungicides, may play a vital role in boosting crop yields.

Moreover, Joshi (1997) reported that plants derived from larger seed classes were taller, showed increased seed bio-mass and subsequent grain yields as well as more leaves, tillers and spikelets than plants derived from smaller seeds of the same genotype. Roy *et al.* (1996) also found a three-fold variation between the smallest and the largest seeds regarding germination rate and seedling vigour index values, suggesting that larger seeds should be selected for good stand establishment in rice. Similarly, in maize larger seeds were suggested to be more advantageous to producers than small or medium ones (Krishnaveni and Vanangamudi, 1989). Gonzalez (1993) reported that *Virola koschnyi* Warb, a forest tree particularly important for reforestation of tropical humid zones on soils with low fertility, produced more vigorous plants from seeds with greater mass.

On the other hand, in some pulse crops such as soybeans and lentils, some authors (Waldia *et al.,* 1988; Bejiga *et al.,* 1995) favoured medium size seeds rather than large or small ones. Similarly, Srimathi *et al.* (1991) found that amongst three seed size groups, medium sized seeds of *Acacia mellifera* gave peak values for viability measured as maximum germination and vigour in terms of root growth and vigour index. The main problem with large seeds of pulses is that they are more liable to mechanical damage during seed processing than the medium or small seed groups. However, most of the investigations so far have dealt with few specific parameters. Therefore, in this study relationships and interactions of several parameters were investigated from several perspectives.

Seed size and fungicide treatments are amongst the seed quality parameters that contribute most towards the planting value of propagating material. There are many causative factors involved (Thompson, 1979) in seed size variations within the same cultivar. One of the main factors is planting date. Ali-Khan (1977) demonstrated that early seeding resulted in higher yields and seed bio-mass in field peas. Similar results were obtained in some cultivated crop production areas (Abebe, *et al.,* 1994; Simane, 1993) in Ethiopia. Early planted seed may escape moisture shortages, dessicating cold winds and cracking of *vertisol* soils that damage roots during the late growing season. Although many seed technologists favour large seeds, the use of seed size as parameter in identifying the best plant propagating material, has remained a controversial issue. The matter of using seed size as parameter for seed quality have been dealt with exhaustively in the developed world but little information on the subject is available on crops cultivated in developing countries, e.g. Ethiopia. The same is true for the use of fungicides as remedy for improving the quality of seeds before planting. Therefore, the main objectives of this study were to investigate the effect of seed size on germination and seedling morphology and to investigate the effect of two fungicides on Ethiopian bread wheat cultivars.

## 5.2 Materials and Methods

### 5.2.1 Materials

Two Ethiopian bread wheat cultivars, viz. Kubsa and Mitikie, were obtained from the Ethiopian National Seed Industry Agency. Unlike other cultivars released mostly at the regional level, these two were released for wider use on a national level in 1993 and 1994 respectively (IAR-KRC, 1997; Taa *et al.*, 1999). Seeds of both cultivars were introduced and tested in the Seed Testing Laboratory of the Small Grain Institute, South Africa, in 1999. The procedures followed were in accordance with the International Rules for Seed Testing (ISTA, 1999) and that of the training manual for seed analysts (National Department of Agriculture, 2000).

**5.2.2 Methods** (see Chapter 3; 3.3)
Treatments for both the laboratory and field trials are shown in table 5.1.

Table 5.1: List of the treatments applied to bread wheat in both laboratory and field trials

| Cultivar | Seed sizes and Slotted sieve size (mm) | Treat . No | Control | Treat . No | Vitavax plus 250 ml/100 kg | Treat . No | Raxil 25 ml/100 kg |
|---|---|---|---|---|---|---|---|
| Kubsa | Small <2.3 x 25 | 1 | " | 4 | " | 7 | " |
| | Medium 2.3 to 2.5 x 25 | 2 | " | 5 | " | 8 | " |
| | Large >2.5 x 25 | 3 | " | 6 | " | 9 | " |
| Mitikie | Small 2.2 x 25 | 10 | " | 13 | " | 16 | " |
| | Medium >2.2 to 2.3.5 x 25 | 11 | " | 14 | " | 17 | " |
| | Large >2.3 x 25 | 12 | " | 15 | " | 18 | " |

## 5.3 Results

### 5.3.1 Data analysis of results obtained under laboratory conditions

#### 5.3.1.1 Cultivar variations (A)

Highly significant differences between the seeds of two bread wheat cultivars, for seven of the ten evaluated parameters, were observed under laboratory conditions (Table 5.2). Mitikie outperformed Kubsa in five of the ten parameters measured. Its germination percentage was significantly higher (93.2% compared to 84.9% for Kubsa) and the percentage abnormal seedlings and dead seeds, for Mitikie, were reduced respectively. Mitikie also showed a significantly longer coleoptile length (88 mm as compared to the 76 mm of Kubsa) as well as significantly higher seedling fresh mass (101 mg as compared to 90 mg for Kubsa). However, Kubsa's two attributes were seedling root length (165 mm) and root dry mass (6.1 mg) which differed significantly from that of Mitikie (158 mm and 5.8 mg respectively).

Table 5.2: Variation in seed and seedling characteristics between two Ethiopian bread wheat cultivars **(A)**

| Cultivar | Ger % | Abs. % | Ds % | CL. mm | SL mm | Srl Mm | Sfm mg | Sdm mg | Srfm mg | Srdm mg |
|---|---|---|---|---|---|---|---|---|---|---|
| Kubsa | **84.9B** | **6.5A** | **8.9A** | **76B** | 123a | **165A** | **90B** | 7.3a | 50a | **6.1A** |
| Mitikie | **93.2A** | **3.4B** | **3.3B** | **88A** | 100a | **158B** | **101A** | 7.3a | 49a | **5.8B** |
| C.V. % | 3.7 | 49.3 | 35.4 | 3.62 | 93.8 | 5.1 | 6.7 | 12.7 | 11.7 | 7.7 |
| Mean | 89.2 | 4.9 | 6.1 | 82 | 111 | 161 | 95 | 7.3 | 49.2 | 6.0 |
| P≥ | ** | ** | ** | ** | Ns | ** | ** | Ns | Ns | ** |

**Abbreviations:**

Ger = germination, Abs = abnormal seedling, Ds = dead seed, CL = coleoptile length, SL = seedling length, Srl = seedling root length, Sfm = seedling fresh mass, Sdm = seedling dry mass, Srdm = seedling root dry mass, mm = millimeter, mg = milligram, LSD = least significant difference, C.V. = coefficient of variance, Ns = Non-significant, * = significant and ** = highly significant at P≤ 0.05 and P≤ 0.01 respectively. Any two or more means sharing the same letter are not significantly different at 5% probability level according to Tukey's mean separation test. Statistically significant differences are indicated in bold and capital letters.

### 5.3.1.2 Variable fungicidal effects (B)

Compared to the control, carboxin/thiram (Vitavax Plus®) highly improved the germination percentages of the two cultivars (Table 5.3). Although this was also the case for the tebuconazole (Raxil®) treatment, no differences between the treatments and the control were observed in this case. The number of abnormal seedlings was also reduced significantly by both of the fungicides. Vitavax Plus® had no effect on seedling fresh mass while Raxil caused a decrease. Moreover, there were no significant differences between the respective controls and treatment with the two fungicides regarding the percentage dead seeds; seedling length, seedling root length, seedling dry- as well as root dry masses.

Table 5.3: Effect of fungicides on variations in bread wheat ; mean of two cultivars **(B)**

| Fungicide | **Ger** % | % **As.** | % Ds | **cl. Mm** | Sl Mm | Srl Mm | **Sfm Mg** | Sdm Mg | **Srfm Mg** | Srdm Mg |
|---|---|---|---|---|---|---|---|---|---|---|
| Control | **87.0B** | **6.5A** | 6.7a | **83A** | 99a | 160a | **95AB** | 7.0a | **49AB** | 5.9a |
| Vitavax plus | **91.0A** | **3.4B** | 5.6a | **84A** | 139a | 163a | **98A** | 7.5a | **46B** | 5.9a |
| Raxil | **90.0AB** | **4.8B** | 6.0a | **79B** | 96a | 162a | **93B** | 7.5a | **53A** | 6.1a |
| P≥ | ** | ** | Ns | ** | Ns | Ns | * | Ns | ** | Ns |

See footnote of Table 5.2

### 5.3.1.3 Cultivar by fungicide interactions (AxB)

Table 5.4 illustrates the statistical analysis of cultivar by fungicide interactions. Except for two parameters namely coleoptile length and seedling root dry mass, no statistically significant cultivar x fungicide interactions were observed in eight of the ten parameters measured. Although not significant, Vitavax Plus® increased the coleoptile length of Kubsa slightly but not that of Mitikie. On the other hand, Raxil® significantly reduced the coleoptile length of Mitikie but not that of Kubsa. However, Raxil® significantly increased the seedling root dry mass of both cultivars while Vitavax Plus® improved that of Kubsa.

Table 5.4: Cultivar X fungicide interactions in bread wheat, in terms of specific parameters **(A X B)**

| Fungicide | Ger % | As. % | Ds % | **Cl. mm** | Sl mm | Srl mm | Sfm mg | Sdm mg | Srfm mg | **Srdm Mg** |
|---|---|---|---|---|---|---|---|---|---|---|
| Kubsa control | 82.2a | 7.8a | 10.3a | **76C** | 97a | 162a | 88a | 7.2a | 48a | **6.0AB** |
| Vitavax Plus® | 87.1a | 4.7a | 8.1a | **78C** | 176a | 169a | 93a | 7.3a | 49a | **6.3A** |
| Raxil® | 85.3a | 6.6a | 8.3a | **75C** | 95a | 163a | 88a | 7.3a | 52a | **6.2A** |
| Mitikie control | 91.8a | 5.2a | 3.1a | **90A** | 101a | 157a | 103a | 6.8a | 50a | **5.8AB** |
| Vitavax Plus® | 94.8a | 2.2a | 3.2a | **90A** | 102a | 157a | 102a | 7.6a | 44a | **5.5B** |
| Raxil® | 93.0a | 2.9a | 3.7a | **83B** | 98a | 160a | 97a | 7.6a | 53a | **6.1A** |
| P≥ | Ns | Ns | Ns | * | Ns | Ns | Ns | Ns | Ns | * |

See footnote of Table 5.2

#### 5.3.1.4 Seed size variation (C)

As shown in Table 5.5, the effect of seed size was statistically very similar to that of cultivar variation. The percentage of small seeds that germinated was highly reduced as compared to medium and large sized seeds. As a result, both abnormal seedlings and percentage dead seeds of the small seed class were respectively higher. The same was observed for coleoptile lengths of seedlings from the small sized seed group that tended to produce significantly shorter coleoptile lengths compared to both the medium and large sized seed groups. During seedling evaluations the number of abnormal, or more spicifically deformed and spindly seedlings, were greater from the small- than from than the medium and large sized seeds groups. The measured seedling- as well as root fresh and dry masses of large sized seeds was significantly higher than for medium sized seeds, which in turn were also significantly higher than that of small sized seeds (Table 5.5).

Table 5.5: Seed size variations in bread wheat in terms of specific parameters ; mean of two cultivars **(C)**

| Fungicide | **Ger %** | % As. | **% Ds** | **cl. Mm** | Sl Mm | Srl Mm | **Sfm Mg** | **Sdm Mg** | **Srfm Mg** | **Srdm Mg** |
|---|---|---|---|---|---|---|---|---|---|---|
| Small | **87.0B** | 5.8a | **7.5A** | **79B** | 133a | 159a | **82C** | **6.2B** | **39C** | **4.8C** |
| Medium | **90.0A** | 4.3a | **5.5B** | **83A** | 100a | 162a | **99B** | **7.6A** | **52B** | **6.2B** |
| Large | **91.2A** | 4.7a | **5.3B** | **84A** | 102a | 163a | **105A** | **8.1A** | **57A** | **6.9A** |
| P≥ | ** | Ns | ** | ** | Ns | Ns | ** | ** | ** | ** |

See footnote of Table 5.1.

#### 5.3.1.5 Cultivar by seed size interactions (A x C)

As shown in Table 5.6, there were statistically significant differences (at the $P \geq 0.05$ level) for cultivar x seed size interactions in only three of the ten parameters measured namely, percentage of dead seeds, seedling root fresh and dry masses. A significantly higher percentage of dead seeds were observed for small sized seeds of Kubsa while the lowest percentage were from large sized seed of Mitikie. Large seeded Kubsa, followed by its medium sized seed group and large seeded Mitikie respectively, showed the highest seedling root fresh and dry masses.

Table 5.6: The effect of cultivar by seed size interactions in bread wheat on specific parameters **(A x C)**

| Fungicide | Ger % | As. % | Ds % | Cl. mm | Sl mm | Srl mm | Sfm mg | Sdm mg | Srfm mg | Srdm Mg |
|---|---|---|---|---|---|---|---|---|---|---|
| Kubsa small | 81.5a | 7.7a | **11.3A** | 72a | 166a | 163a | 76a | 6.0a | **37C** | **4.8D** |
| Medium | 86.7a | 4.9a | **7.7B** | 77a | 99a | 165a | 92a | 7.5a | **52B** | **6.3BC** |
| Large | 86.4a | 6.5a | **7.8B** | 80a | 103a | 167a | 100a | 8.3a | **60A** | **7.3A** |
| Mitikie small | 92.4a | 3.8a | **3.8C** | 85a | 99a | 156a | 87a | 6.4a | **41C** | **4.8D** |
| Medium | 93.3a | 3.6a | **3.3C** | 89a | 101a | 159a | 105a | 7.7a | **52B** | **6.0C** |
| Large | 93.9a | 2.8a | **2.8C** | 89a | 101a | 159a | 110a | 7.9a | **54AB** | **6.6B** |
| P≥ | Ns | Ns | * | Ns | Ns | Ns | Ns | Ns | * | * |

See footnote of Table 5.2.

#### 5.3.1.6 Effect of cultivar by fungicide by seed size interactions (AxBxC)

There was no statistically significant interaction between the three variants namely cultivar, fungicide treatment and seed size.

### 5.3.2 Data analysis of results obtained under field conditions

#### 5.3.2.1 Cultivar variations (A)

Highly significant differences at (P≥ 0.01 level) were observed between the two bread wheat cultivars in ten of the fourteen parameters measured (Table 5.7A and B) under field conditions. Statistically, Mitikie significantly outperformed Kubsa regarding seedling emergence (SE), days to 50% maturity (DM), grain filling period (GFP), plant height (PH), grain yield (GY), protein content (PC), thousand kernel mass (TKM) and hectoliter mass (HLM). However, tillers plant$^{-1}$ and seeds spike$^{-1}$ of Kubsa was significantly higher than that of Mitikie.

Table 5.7A: Effect of cultivar variations in bread wheat under field conditions **(A)**

| Cultivar | % **SE** | RE Days | **TPP** | DH DAYS | **DM DAYS** | **GFP DAYS** | **PH CM** |
|---|---|---|---|---|---|---|---|
| Kubsa | **56.4B** | 15.9a | **6.8A** | 70a | **111.0B** | **41.0B** | **71.1B** |
| Mitikie | **66.1A** | 16.3a | **5.8B** | 69a | **114.5A** | **45.1A** | **81.2A** |
| C.V. % | **14.1** | 11,.8 | **18.0** | 22.0 | **11** | **3.7** | **5.6** |
| Mean | **61.3** | 16.1 | **6.3** | 69.7 | **112.8** | **43.1** | **76.1** |
| P≥ | ** | Ns | ** | Ns | ** | ** | ** |

Table 5.7B: Effect of cultivar variations in bread wheat under field conditions **(A)** (continued)

| Cultivar | SPMS | **KPS** | **GY Kg ha$^{-1}$** | **% PC** | **TKM G** | **HLM Kg hl$^{-1}$** | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Kubsa | 193.2a | **43.1A** | **1197.0B** | **12.9B** | **26.4B** | **55.5B** | 4674a |
| Mitikie | 189.1a | **37.0B** | **1446.9A** | **15.0A** | **28.8A** | **67.6A** | 4956a |
| C.v % | 21.9 | **14.8** | **23.2** | **0.42** | **5.3** | **1.3** | 16.9 |
| Mean | 191.2 | **40.0** | **1321.9** | **14.0** | **27.6** | **61.5** | 4815 |
| P≥ | Ns | ** | ** | ** | ** | ** | Ns |

**Abbreviations:**

SE = seedling emergence; RE = rate of emergence; TPP = tillers per plant; DH = days to 50% heading; DM = days to 50% maturity; GFP = grain filling period; PH = plant height; SPMS = spikes per metre square; KPS = kernels per spike; GY = grain yield; PC = protein content; TKM = thousand kernel mass; HLM = hectolitre mass; AGBM = above ground bio-mass; Cm = centimetre; Ha = hectare; Kg= kilogram; Kub = Kubsa; Mit = Mitikie; g = gram

### 5.3.2.2 Fungicide effects (B)

No significant differences between different fungicide treatments were observed for all parameters measured under field conditions, except in the case of protein content, where Vitavax Plus® significantly improved the protein content of both cultivars as compared to the controls, while Raxil® caused a significant decrease (Table 5.8A and B).

Table 5.8A: Effect of fungicide variations in bread wheat under field conditions **(B)**

| Cultivar | % SE | RE Days | TPP | DH DAYS | DM DAYS | GFP DAYS | PH CM |
|---|---|---|---|---|---|---|---|
| Control | 59.5a | 16.2a | 6.4a | 69.9a | 112.9a | 43.0a | 76.5a |
| Vitavax Pllus® | 63.2a | 15.8a | 6.2a | 69.4a | 112.9a | 43.5a | 76.2a |
| Raxil® | 61.2a | 16.4a | 6.3a | 69.8a | 112.5a | 42.8a | 75.8a |
| P≥ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 5.8B: Effect of fungicide variations in bread wheat under field conditions continued **(B)**

| Cultivar | SPMS | KPS | GY Kg $ha^{-1}$ | % PC | TKM G | HLM Kg $ha^{-1}$ | AGBM Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Control | 195.4a | 39.4a | 1351.5a | **14.2B** | 27.2a | 61.6a | 4945a |
| Vitavax Plus® | 190.0a | 38.9a | 1287.1a | **14.3A** | 27.7a | 61.5a | 4802a |
| Raxil® | 188.0a | 41.8a | 1327.1a | **13.5C** | 28.0a | 61.5a | 4698a |
| P≥ | Ns | Ns | Ns | ** | Ns | Ns | Ns |

See footnote of Table 5.7

### 5.3.2.3 Cultivar by fungicide interaction effects (A x B)

Statistically, no significant cultivar by fungicide interaction was observed for any of the parameters measured except in the case of protein content and hectoliter mass (Tables 5.9A and B). Significantly higher protein content was measured for Mitikie seed treated with Raxil® while the least was from that of Kubsa treated with Raxil®. On the contrary, significantly higher hectoliter mass was obtained from Mitikie treated with Vitavax Plus® while the lowest was from Kubsa treated with Vitavax Plus®.

Table 5.9A: Cultiivar by fungicide interaction in bread wheat under field conditions **(AxB)**

| Variable | % SE | RE Days | TPP | DH DAYS | DM DAYS | GFP DAYS | PH CM |
|---|---|---|---|---|---|---|---|
| Kubsa control | 55.2a | 16.1a | 6.7a | 70.3a | 111.3a | 41.0a | 71.1a |
| Vitavax Plus® | 58.2a | 15.4a | 6.7a | 69.9a | 111.2a | 41.3a | 71.4a |
| Raxil® | 56.0a | 16.2a | 6.9a | 69.8a | 110.7a | 40.8a | 70.8a |
| Mitikie control | 63.8a | 16.3a | 6.1a | 69.6a | 114.6a | 45.0a | 81.8a |
| Vitavax Plus® | 68.2a | 16.1a | 5.6a | 68.9a | 114.6a | 45.7a | 81.0a |
| Raxil® | 66.3a | 16.6a | 5.7a | 69.7a | 114.3a | 44.7a | 80.7a |
| P≥ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 5.9B: Cultivar X fungicide interactions in bread wheat under field conditions **(A x B)**

| Variable | SPMS | KPS | GY Kg $ha^{-1}$ | % **PC** | TKM G | HLM **Kg $hl^{-1}$** | AGBM Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Kubsa control | 199.0a | 41.3a | 1242.1a | **13.5D** | 25.9a | **56.1C** | 4677a |
| Vitavax plus | 189.6a | 42.3a | 1153.9a | **13.5D** | 26.2a | **54.7D** | 4760a |
| Raxil | 191.0a | 45.7a | 1195.0a | **11.8E** | 27.1a | **55.8C** | 4583a |
| Mitikie control | 191.8a | 37.5a | 1461.0a | **14.9C** | 28.5a | **67.1B** | 5213a |
| Vitavax plus | 190.5a | 35.6a | 1420.3a | **15.0B** | 29.1a | **68.3A** | 4844a |
| Raxil | 185.1a | 37.8a | 1459.3a | **15.2A** | 28.8a | **67.3B** | 4813a |
| P≥ | Ns | Ns | Ns | ** | Ns | ** | Ns |

See footnote of Table 5.7.

### 5.3.2.4 Effect of seed size (C)

In both cultivars, large seeds outperformed the small sized seed groups significantly (Table 5.10A and B) and showed better seedling emergence (SE), faster development regarding days to heading (DH), higher thousand kernel mass (TKM), higher grain yield (GY) and above ground bio-mass (AGBM). Differences between large and medium sized seeds were statistically significant in seedling emergence (SE), days to grain filling period (DGP), grain yield (GY) and above ground bio-mass (AGBM) yield.

However, protein content obtained from large sized seed group was found to be lower than small and medium sized seeds.

Table 5.10A: Effect of seed size variations in bread wheat under field conditions on specific parameters **(C)**

| Seed size | % SE | RE Days | TPP | DH DAYS | DM DAYS | GFP DAYS | PH CM |
|---|---|---|---|---|---|---|---|
| Small | **56.5B** | 15.9a | 6.5a | **70.6A** | 113.1a | **42.5B** | 75.9a |
| Medium | **62.2AB** | 16.2a | 6.4a | **69.8A** | 112.8a | **42.9AB** | 76.2a |
| Large | **65.1A** | 16.3a | 5.9a | **68.7B** | 112.4a | **43.8A** | 76.3a |
| P≥ | ** | Ns | Ns | ** | Ns | * | Ns |

Table 5.10B: Effect of seed size variations in bread wheat under field conditions on specific parameters (continued) **(C)**

| Seed size | SPMS | KPS | GY Kg $ha^{-1}$ | % PC | TKM G | HLM Kg $ha^{-1}$ | AGBM Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Small | 190.0a | 39.8a | **1148.8B** | **14.2B** | **27.4AB** | 61.6a | **4500B** |
| Medium | 196.2a | 38.6a | **1341.7AB** | **14.5A** | **27.0B** | 61.4a | **4844AB** |
| Large | 187.3a | 41.8a | **1475.3A** | **13.2C** | **28.4A** | 61.6a | **5101A** |
| P≥ | Ns | Ns | ** | ** | ** | Ns | * |

See footnote of Table 5.7

### 5.3.2.5 Cultivar by seed size interaction effects (AxC)

Results in Table 5.11 and B showed cultivar x seed size interaction effects in only four of the fourteen parameters measured. Highly significant interactions were observed for days to 50% maturity (DM), percent protein content (PC), hectoliter mass (HM) and grain filling period (GFP) at the P≥ 0.05 levels. Plants from small sized seeds of Mitikie were the latest to mature while that from large seeds matured significantly earlier. There was no difference between the three seed sizes of Kubsa with respect to this parameter. As for the grain-filling period (GFP), plants from large sized seeds of Kubsa showed longer days to fill grains than the small and medium ones. The protein content (PC) of medium seed size Mitikie was significantly higher than that of the other two seed size groups.

Table 5.11A: Cultivar X seed size interactions in bread wheat under field conditions **(AxC)**

| Variable | % SE | RE Days | TPP | DH DAYS | **DM DAYS** | **GFP DAYS** | PH CM |
|---|---|---|---|---|---|---|---|
| Kubsa small | 51.8a | 15.9a | 7.0a | 71.3a | **111.2C** | **39.8C** | 70.4a |
| Medium | 56.6a | 15.9a | 7.0a | 69.8a | **110.6C** | **40.8BC** | 71.8a |
| Large | 60.9a | 15.9a. | 6.3a | 68.9a | **111.3C** | **42.4B** | 71.2a |
| Mitikie small | 61.3a | 15.9a | 6.0a | 69.8a | **115.1A** | **45.3A** | 81.4a |
| Medium | 67.8a | 16.5a | 5.8a | 69.9a | **114.9AB** | **45.0A** | 80.6a |
| Large | 69.3a | 16.6a | 5.5a | 68.4a | **113.5B** | **45.1A** | 81.5a |
| P≥ | Ns | Ns | Ns | Ns | ** | * | Ns |

Table 5.11B: Cultivar X seed size interactions in bread wheat under field conditions continued **(AxC)**

| Variable | SPMS | KPS | GY Kg $ha^{-1}$ | % **PC** | TKM G | **HLM Kg $ha^{-1}$** | AGBM Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Kubsa Small | 198.2a | 42.5a | 961.1a | **13.7D** | 26.4a | **55.4C** | 4302a |
| Medium | 196.0a | 40.4a | 1262.2a | **13.2E** | 25.6a | **55.8C** | 4740a |
| Large | 185.4a | 46.3a | 1367.8a | **11.8F** | 27.2a | **55.3C** | 4979a |
| Mitikie Small | 181.8a | 37.0a | 1336.7a | **14.7B** | 28.5a | **67.8AB** | 4698a |
| Medium | 196.4a | 36.8a | 1421.2a | **15.8A** | 28.3a | **67.0B** | 4948a |
| Large | 189.1a | 37.2a | 1582.8a | **14.6C** | 29.7a | **68.0A** | 5223a |
| P≥ | Ns | Ns | Ns | ** | Ns | ** | Ns |

See footnote of table 5.7.

### 5.3.2.6 Fungicide X seed size interactions (BxC)

Statistical analysis of the combined results obtained with the two cultivars revealed a significant fungicide x seed size interaction for both grain yield (GY) (P≥ 0.05) and protein content (PC) (P≥ 0.01). However, no significant interaction was observed for the rest of the twelve parameters measured (Table 5.12).

Plants obtained from both the control and Vitavax Plus® treated large seeds outperformed the plants obtained from medium and small size seeds regarding yield, while the Vitavax Plus® treatment increased the yield significantly compared to the control. For protein content, untreated medium sized seed significantly outperformed all the rest. Seed treatment with both Raxil® and Vitavax Plus® tended to decrease the protein content in all seed size groups (Table 5.12A and B).

Table 5.12A: Fungicide X seed size interactions in bread wheat under field conditions **(BxC)**

| Variable | % SE | RE Days | TPP | DH DAYS | DM DAYS | GFP DAYS | PH CM |
|---|---|---|---|---|---|---|---|
| Control Small | 55.5a | 65.5a | 6.3a | 70.4a | 112.6a | 42.3a | 76.4a |
| Medium | 57.4a | 65.5a | 7.1a | 70.5a | 113.0a | 42.5a | 75.4a |
| Large | 65.6a | 74.6a | 5.8a | 68.9a | 113.1a | 44.3a | 77.6a |
| Vitavax Small | 56.1a | 63.0a | 6.9a | 70.1a | 113.6a | 43.5a | 76.3a |
| Medium | 62.8a | 67.3a | 6.1a | 69.6a | 112.4a | 42.8a | 76.8a |
| Large | 70.6a | 77.4a | 5.5a | 68.5a | 112.6a | 44.1a | 75.6a |
| Raxil Small | 58.0a | 67.3a | 6.4a | 71.3a | 113.1a | 41.9a | 75.1a |
| Medium | 66.4a | 74.0a | 6.0a | 69.4a | 112.9a | 43.5a | 76.4a |
| Large | 59.1a | 65.0a | 6.4a | 68.6a | 111.5a | 42.9a | 75.8a |
| P≥ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 5.12B: Fungicide X seed size interactions in bread wheat under field conditions continued **(BxC)**

| Variable | SPMS | SPS | GY Kg ha$^{-1}$ | % PC | TKM G | HLM Kg ha$^{-1}$ | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Control Small | 197.3a | 38.8a | **1320.1AB** | **14.4C** | 26.9a | 62.0a | 4875a |
| Medium | 200.5a | 39.8a | **1174.4AB** | **14.9A** | 26.6a | 61.2a | 4516a |
| Large | 188.4a | 39.8a | **1560.1A** | **13.2F** | 28.0a | 61.6a | 5444a |
| Vitavax Small | 186.9a | 38.0a | **954.0B** | **14.4C** | 27.6a | 61.5a | 4219a |
| Medium | 189.9a | 36.5a | **1422.6AB** | **14.8B** | 27.1a | 61.5a | 5109a |
| Large | 193.4a | 42.3a | **1484.8A** | **13.7E** | 28.4a | 61.6a | 5078a |
| Raxil Small | 185.9a | 42.5a | **1172.5AB** | **13.9D** | 27.8a | 61.3a | 4406a |
| Medium | 198.3a | 39.5a | **1428.0AB** | **13.9D** | 27.2a | 61.6a | 4906a |
| Large | 180.0a | 43.3a | **1380.9AB** | **12.7G** | 28.9a | 61.8a | 4781a |
| P≥ | Ns | Ns | * | ** | Ns | Ns | Ns |

See footnote of Table 5.7

### 5.3.2.7 Cultivar X fungicide X seed size interaction effects (AxBxC)

By means of analysis of variance (ANOVA) highly significant differences (at the P≥ 0.01 level) were observed in only two of the fourteen parameters measured and only one at the P≥ 0.05 levels (Table 5.13A and B). Cultivar by fungicide by seed size interaction effects was obtained for the grain-filling period (GFP), protein content (PC) and thousand kernels mass (TKM). The statistical differences between the remaining eleven parameters were found to be non significant

Small sized seeds of Mtikie, treated with Vitavax Plus®, took the longest to fill its grains while untreated small sized seeds of Kubsa, as well as Vitavax Plus® treated ones, filled its grains in the shortest time (Table 5.13A). Significantly higher protein content (PC) was measured in medium sized seeds of Mtikie treated with Raxil® while the lowest was from Kubsa (medium size) treated with Raxil. Significantly higher thousand kernels mass (TKM) was obtained from large sized Mtikie seeds while the lowest was from small seeded Kubsa treated with Vitavax Plus®.

Table 5.13A: Cultivar X fungicide X seed size interactions in bread wheat under field conditions **(A x B x C)**

| Variable or Treatments | % SE | RE Days | TPP | DH DAYS | DM DAYS | GFP DAYS | PH CM |
|---|---|---|---|---|---|---|---|
| Kubsa control. Small | 51.5a | 65.3a | 6.5a | 71.0a | 110.8a | **39.8D** | 70.8a |
| Medium | 53.0a | 63.5a | 7.8a | 70.3a | 110.8a | **40.5CD** | 71.0a |
| Large | 61.0a | 73.8a | 5.9a | 69.5a | 112.3a | **42.8BCD** | 71.5a |
| Kubsa Vitavax Small | 46.8a | 56.3a | 7.7a | 72.0a | 111.3a | **39.3D** | 71.3a |
| Medium | 56.5a | 63.0a | 6.8a | 69.5a | 110.5a | **41.0CD** | 71.8a |
| Large | 71.3a | 80.5a | 5.7a | 68.3a | 111.8a | **43.5ABCD** | 71.3a |
| Kubsa Raxil Small | 57.3a | 70.8a | 6.9a | 71.0a | 111.5a | **40.5CD** | 69.3a |
| Medium | 60.3a | 69.5a | 6.5a | 69.5a | 110.5a | **41.0CD** | 72.5a |
| Large | 50.5a | 57.8a | 7.3a | 69.0a | 110.0a | **41.0CD** | 70.8a |
| Mitikie Control Small | 59.5a | 65.8a | 6.1a | 69.8a | 114.5a | **44.8ABC** | 82.0a |
| Medium | 61.8a | 67.5a | 6.4a | 70.8a | 115.3a | **44.5ABC** | 79.8a |
| Large | 70.3a | 75.5a | 5.7a | 68.3a | 114.0a | **45.8AB** | 83.8a |
| Mitikie Vitavax Small | 65.5a | 69.8a | 6.0a | 68.3a | 116.0a | **47.8A** | 81.3a |
| Medium | 69.0a | 71.5a | 5.5a | 69.8a | 114.3a | **44.5ABC** | 81.8a |
| Large | 70.0a | 74.3a | 5.3a | 68.8a | 113.5a | **44.8ABC** | 80.0a |
| Mitikie Raxil Small | 58.8a | 63.8a | 6.0a | 71.5a | 114.8a | **43.3BCD** | 81.0a |
| Medium | 72.5a | 78.5a | 5.6a | 69.3a | 115.3a | **46.0AB** | 80.3a |
| Large | 67.8a | 72.3a | 5.5a | 68.3a | 113.0a | **44.8ABC** | 80.8a |
| P≥ | Ns | Ns | Ns | Ns | Ns | ** | Ns |

See footnote of Table 5.7

Table 5.13B: Cultivar X fungicide X seed size interactions in bread wheat under field conditions **(A x B x C)** continued

| Variable or Treatments | SPMS | KPS | **GY Kg ha$^{-1}$** | **% PC** | **TKM G** | HLM Kg ha$^{-1}$ | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Kubsa control. Small | 217.0a | 40.3a | 1031.0a | **14.1G** | **25.3C** | 56.2a | 4281a |
| Medium | 202.8a | 44.0a | 1242.5a | **14.5F** | **25.6BC** | 56.4a | 4750a |
| Large | 177.3a | 39.8a | 1452.8a | **12.1J** | **26.7ABC** | 55.6a | 5000a |
| Kubsa Vitavax Small | 178.5a | 42.5a | 712.0a | **15.0D** | **25.7BC** | 54.5a | 4250a |
| Medium | 190.5a | 36.3a | 1314.5a | **14.0G** | **25.4C** | 54.9a | 4906a |
| Large | 199.8a | 48.0a | 1435.3a | **11.7L** | **27.6ABC** | 54.8a | 5125a |
| Kubsa Raxil Small | 199.0a | 44.8a | 1140.3a | **12.2J** | **28.2ABC** | 55.5a | 4375a |
| Medium | 194.8a | 41.0a | 1229.5a | **11.3M** | **25.9BC** | 56.2a | 4563a |
| Large | 179.3a | 51.3a | 1215.3a | **11.8K** | **27.4ABC** | 55.6a | 4813a |
| Mitikie Control Small | 177.5a | 37.3a | 16.9.3a | **14.7E** | **28.6ABC** | 67.8a | 5469a |
| Medium | 198.3a | 35.5a | 1106.3a | **15.4C** | **27.6ABC** | 66.0a | 4281a |
| Large | 199.5a | 39.8a | 1667.5a | **14.4F** | **29.3AB** | 67.6a | 5888a |
| Mitikie Vitavax Small | 195.3a | 33.5a | 1196.0a | **13.8H** | **29.4AB** | 68.5a | 4188a |
| Medium | 189.3a | 36.8a | 1530.8a | **15.7B** | **28.8ABC** | 68.2a | 5313a |
| Large | 187.0a | 36.5a | 1534.3a | **15.7B** | **29.2ABC** | 68.4a | 5031a |
| Mitikie Raxil Small | 172.8a | 40.3a | 1204.8a | **15.6B** | **27.4ABC** | 67.2a | 4438a |
| Medium | 201.8a | 38.0a | 1626.5a | **16.4A** | **28.5ABC** | 66.9a | 5250a |
| Large | 180.8a | 35.3a | 1546.5a | **13.6I** | **30.5A** | 68.0a | 4750a |
| P≥ | Ns | Ns | Ns | * | ** | Ns | Ns |

See footnote of Table 5.7

### 5.3.2.8 Correlation Matrix

A correlation matrix was performed to associate all laboratory and field parameters (Table 5.14; see Appendix 1). Correlation values indicate the relative association between two parameters, with 0 indicating absence of correlation and 1 indicating very high or almost identical magnitudes of correlation. The positive and negative signs imply that an increase in one parameter leads to an increase and decrease respectively in another. Values above r=0.2654 (P≥0.05) were found to be significantly correlated and are written in bold. Only some of the most important parameters are briefly discussed.

Grain yield significantly and positively correlated with plant height (r=0.4991), grain filling period (r=0.338), percent seedling emergence (r=0.5976), seedling dry mass (r= 0.3266), seedling fresh mass (r = 0.4366), coleoptile length (r =0.4377) and seed size (r =0. 2879). This implicated that an increase in these parameters would certainly lead to higher grain yield.

However, negative correlation was observed between grain yield and days to 50% heading as well as tillers plant$^{-1}$. Similarly, there was a positive and significant correlation between seed size and seedling length, seedling root dry and fresh masses as well as seedling dry and fresh masses. This illustrated that plants obtained from large seeds were superior to both medium and small. Moreover, coleoptile length positively and significantly correlated with above ground bio-mass, percent protein content, grain yield, plant height, grain filling period, days to 50% maturity and percent seedling emergence. However, it showed a significant negative correlation with kernels per spike, days to 50% heading, tillers per plant and seeding root length.

## 5.4 Discussion

On average, the germination percentages of both cultivars were above 80%, and this is the minimum level for the sales of commercial seed in accordance with the South African Plant Improvement Act, of 1976 (Sansor, 1996), while 85% is required as minimum for certified seed. However, Kubsa (84.9% germination) did not meet the Ethiopian and Kenyan germination percentage standard of 85% and 90% (Alemayehu, *et al.*, 1999; Wayera, 1999) respectively but Mitikie (93.2% germination) did.

In the final analysis, there were sufficient reasons for Mitikie to be considered superior to Kubsa with regard to grain yield, but also with regard to other important parameters. From laboratory results, Mitikie significantly outperformed Kubsa with regard to germination %, coleoptile length and seedling fresh mass. From results obtained in the field, Mitikie was superior to Kubsa regarding percentage seedling emergence, days to

50% maturity, plant height, protein content, thousand kernels mass, hectoliter mass and finally, grain yield. However, the grain filling period was slower for Mtikie.

On the other hand, Kubsa outperformed Mitikie with regard to some of the parameters measured. Data from the laboratory trial showed that Kubsa was significantly superior to Mtikie regarding seedling root length and root dry mass while field data showed an elevated number of tillers plant$^{-1}$ and seeds spike$^{-1}$ in Kubsa. However, Kubsa had smaller grains than Mitikie and in most respects was inferior to the large seeded Mitikie. This is in agreement with findings of Gale and Flintham (1962) who suggested that semi-dwarf cultivars derived from "NORIN 10" and "Tom Thumb" dwarfing genes are associated with an increased number of smaller grains per ear. The authors explained that smaller grain size in certain cultivars is due to competition between tillers and within grains on the same spike. As Kubsa normally has smaller sized seeds compared to Mitikie, the protein content was also much reduced in the former.

As far as the fungicidal effect is concerned, germination percentage and seedling fresh mass as well as coleopitile length were improved by carboxin/thiram (Vitavax Plus®) treatment in both cultivars while treatment with Raxil® (tebuconazole) significantly reduced the coleoptile length of the two cultivars. The latter is in agreement with the findings of Purchase *et al.* (1992) in South African wheat cultivars. However, Raxil® significantly improved the seedling root fresh mass as well as the roots dry mass to a certain extent. Compared to untreated control seeds, the percentage of usually deformed abnormal seedlings were reduced by seed treatment with both fungicides which emphasizes the need of this treatment to at least retain the quality of seeds for planting. Results obtained both in the laboratory under controlled conditions, and in the field, suggest that treatment with especially Vitavax Plus®, appears promising.

Statistically, when data from the two cultivars were combined, large sized seeds were superior to medium and small ones in quite a number of parameters measured. For example, large sized seeds were superior to mostly the small size ones and in some respects to the medium size seeds regarding seedling emergence (SE), grain filling period (GFP), thousand kernels mass (TKM) and finally grain yield (GY) and above ground bio-mass (AGBM). In general, the results obtained are mostly in agreement with published results of (Roy *et al.*, 1996; Baalbaki and Copeland, 1997; Joshi, 1997). All these workers supported the use of reasonably large sized seeds as propagating material.

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# CHAPTER 6

## EFFECT OF SEED TREATMENTS AND SOWING DEPTH ON SEED QUALITY AND YIELD OF ETHIOPIAN BREAD WHEAT CULTIVARS


### Abstract

The effect of two seed treatments and sowing depth on seed quality and yield of two Ethiopian bread wheat cultivars was investigated in the laboratory and under field conditions. In the laboratory, a factorial experiment laid out in a complete randomized block design with four replications, was conducted. In the field trail a split-plot design was used in which cultivars and fungicides were taken as main plot and sowing depth as sub-plots. The main objectives were: (1) to determine the effect of Vitavax Plus ® FS (carboxin/thiram) and Raxil ® ES (tebuconazole), two fungicides, on germination percentage, coleoptile length, seedling length, seedling root length as well as seedling fresh, root fresh and root dry masses, (2) to evaluate emergence, yield components and other related parameters of the same materials when planted at 5 cm and 9 cm deep and (3) to investigate the relationships between laboratory and field performance of two Ethiopian bread wheat cultivars, viz. Kubsa and Mitikie. Significant to highly significant interactions effects were observed among fungicides regarding germination percentage, coleoptile, and seedling lengths. However, differences were non-significant for seedling root length. Shallow planting showed elevated grain and above ground bio-mass yields compared to deep planting. Highly significant differences in protein content, grain yield and above ground bio-mass yields were observed in seeds harvested from plants of which the seeds were initially treated or planted differently.



**Key words**: bread wheat, seed treatments, sowing depth, coleoptile lengths, stand establishment, germination percentage, emergence

## 6.1 Introduction

Poor crop establishment is one of the most important constraints of crop production, particularly in drought prone environments. Radford *et al.* (1989) reported that accurate stand establishment of winter cereals in Queensland, Australia, was so disappointing that crops at times had to be ploughed in due to poor emergence. Similarly, Schillinger *et al.* (1998) reported that stand establishment in the USA is the most important single factor affecting winter wheat grain yield under dry land cultivation conditions. This problem can even be more serious for Sub-Saharan African countries, where soil moisture is in critical shortage and a high evapo-transpiration rate prevails.

About 50% of South African wheat is dryland winter wheat type while 30% is dryland spring wheat. The remaining 20% are from spring wheat under irrigation (Van Niekerk, 1999). The Free State Province, in particular, is the leading wheat production region of South Africa (Purchase 1997; SAGAL, 1998), but is one of the less favourable dryland wheat production regions of the world, as production is associated with several stress factors. According to Ybema (1994), the soil moisture content in the Free State may be low during the planting season (May to August). Residual moisture from summer rains is present and in order to take advantage of the available moisture, the average planting depth is 5.5 cm, as compared to the optimum planting depth of 3 cm under favourable conditions.

Schillinger *et al.* (1998) pointed out that semi-dwarf wheat cultivars are planted deep in dryland areas for sufficient soil moisture contact of the seed to support emergence. This problem can even be more aggravated in farming areas of Ethiopia, where seeds are buried deeper than usual, as it is common practice to use oxen for planting. As a result, an increase in seeding rate (150-200 kg $ha^{-1}$) for wheat is also common practice in Ethiopia. For irrigated spring wheat in South Africa, the optimum seed rate is 100-120 kg $ha^{-1}$ (Purchase, *et al.*, 1999). Seed rate for winter wheat cultivated under rainfed conditions in South Africa is far less and ranges between 15-25 kg $ha^{-1}$.

The use of fungicides is part of modern farming practices. In South Africa, for example, wheat seed needs to be dressed with a registered fungicide before accepted as certified (Sansor, 1996). Various wheat diseases prevail generally in high rainfall wheat growing regions of East Africa and specifically in Ethiopia (Kidane, 1996).

As reported by the Seed Treatment and Environment Committee of the International Seed Trade Federation (FIS, 1999), the use of fungicides to treat seeds in order to retain the quality of seeds, is considered of prime importance. The main aim of this study was to evaluate the effect of fungicidal seed treatments on seed germination and seedling morphology in the laboratory, while seedling emergence and other seed quality related parameters of two Ethiopian bread wheat cultivars planted at two sowing depths (5 cm and 9 cm) were investigated under field conditions.

## 6.2 Materials and Methods

### Laboratory experiment

Refer to the general materials and methods (Chapter 3) for the detailed description of methods followed. However, treatments specific to this chapter are shown in Table 6.1 below.

Table 6.1: List of treatments applied to bread wheat seed under laboratory conditions (2 factor RCBD)

| Cultivar | Treat no | Untreated | Treat no | Vitavax Plus 250 ml 100 $kg^{-1}$ | Treat no | Raxil 25 ml 100 $kg^{-1}$ |
|---|---|---|---|---|---|---|
| Kubsa | 1 | Control | 2 | " | 3 | " |
| Mitikie | 4 | " | 5 | " | 6 | " |

### Field trial

The field trial differed slightly from that described in Chapter 5. It differed in plot size, planting date and design (split plot design with four replications where cultivar x fungicide treatment was taken as main plots and sowing depth as sub- plots). Seeds were planted at the same venue on 10 August, but at two depths (5 cm and 9 cm). Five rows of five meters long were planted with 100 seeds per row. The spacing between rows was 45 cm. From the thirteenth day, when the first seedlings had emerged, emergence was recorded and every two days thereafter until this value leveled off. Treatments of the field trial are tabulated in Table 6.2 below.

Table 6.2: List of treatments applied to bread wheat seeds under field conditions (split-plot) design

| No | Treatment | No | Treatment |
|---|---|---|---|
| 1 | Kubsa control 5 cm | 2 | Kubsa control 9 cm |
| 3 | Kubsa Vitavax Plus® 5 cm | 4 | Kubsa Vitavax Plus® 9 cm |
| 5 | Kubsa Raxil® 5 cm | 6 | Kubsa Raxil® 9 cm |
| 7 | Mitikie control 5 cm | 8 | Mitikie control 9 cm |
| 9 | Mitikie Vitavax Plus® 5 cm | 10 | Mitikie Vitavax Plus® 9 cm |
| 11 | Mitikie Raxil® 5 cm | 12 | Mitikie Raxil® 9 cm |

All plants and productive spikes were counted to determine the number of effective tillers plant$^{-1}$ and spikes m$^{-2}$. After harvesting, the seeds of ten randomly selected spikes per plot were threshed separately in order to compute the number of kernels per spike.

## 6.3 Results

### 6.3.1 Data analysis of results obtained under laboratory conditions

Sowing depth data, obtained from this laboratory experiment, was pooled with the laboratory seed size data obtained from Chapter 5 for each cultivar, and analyzed statistically. No significant planting depth x seed size interaction was observed (results not shown). Where necessary, previous findings (Chapter 5) are referred to in the discussion of this chapter.

### 6.3.2 Data analysis of results obtained under field conditions

#### 6.3.2.1 Cultivar variations (A)

Highly significant differences were observed between cultivars for days to 50% maturity, the grain filling period (GFP) and seed protein content (PC) (Table 6.3A and B). Under all conditions Mitikie was superior to Kubsa for these parameters. As was expected, a significant difference in plant height (PH) between cultivars occurred. In all cases, Mitikie outperformed Kubsa in this regard. The rest of the nine parameters were found not to differ significantly.

Table 6.3A: Variation between two Ethiopian bread wheat cultivars in terms of specific parameters measured under field conditions **(A)**

| Variable | % SE | RE Days | TPP | HD DAYS | **MD Days** | **GFP Days** | **PH Cm** |
|---|---|---|---|---|---|---|---|
| Kubsa | 21.4a | 17.8a | 3.0a | 82.0a | **123.1B** | **41.0B** | **57.5B** |
| Mitikie | 22.8a | 17.4a | 3.1a | 82.5a | **126.8A** | **44.4A** | **60.7A** |
| Mean | 22.1 | 17.6 | 3.1 | 82.3 | **125.0** | **42.7** | **59.1** |
| P≥ | Ns | Ns | Ns | Ns | ** | ** | * |

Table 6.3B: Variation between two Ethiopian bread wheat cultivars in terms of soecific parameters measured under field conditions **(A)** (continued)

| Variable | SPMS | KPS | GY Kg $ha^{-1}$ | % **PC** | TKM G | AGBM Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|
| Kubsa | 23.7a | 36.7a | 322.4a | **12.6B** | 30.1a | 1093a |
| Mitikie | 24.0a | 37.3a | 283.5a | **14.6A** | 30.6a | 1045a |
| Mean | 23.8 | 37.0 | 303.0 | **13.6** | 30.4 | 1067 |
| P≥ | Ns | Ns | Ns | ** | Ns | Ns |

Abbreviations:

SE = seedling emergence; RE = rate of emergence; TPP = tillers per plant; DH = days to 50% heading; DM = days to 50% maturity; GFP = grain filling period; PH = plant height; SPMS = spikes per metre square; KPS = kernels per spike; GY = grain yield; PC = protein content; TKM = thousand kernel mass; HLM = hectolitre mass; AGBM = above ground bio-mass; Cm = centimetre; Ha = hectare; Kg= kilogram; G = gram; Kub = Kubsa; Mit = Mitikie ; Ns, *, and ** = none significant, significant and highly significant at (P≤ 0.05) and (P≤ 0.01) respectively. Any two or more means sharing the same letter are not

### 6.3.2.2 Fungicidal effects

Untreated seeds were significantly higher (at p≤ 0.001) in protein content (PC) than both of the fungicide treated ones. No significant differences were observed among the seeds treated with different fungicides for the rest of the twelve parameters studied (Table 6.4 and B).

Table 6.4A: Fungicide effects on bread wheat seeds ; mean of two cultivars **(B)**

| Variable | % SE | RE Days | TPP | HD DAYS | MD DAYS | GFP Days | PH cm |
|---|---|---|---|---|---|---|---|
| Control | 22.0a | 17.6a | 3.3a | 81.8a | 124.9a | 43.1a | 60.3a |
| Vitavax Plus® | 22.0a | 17.4a | 3.0a | 83.0a | 125.0a | 42.0a | 57.5a |
| Raxil® | 22.4a | 17.7a | 2.9a | 82.0a | 125.0a | 43.0a | 59.6a |
| P≥ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 6.4B: Fungicide effects on bread wheat seeds ; mean of two cultivars (continued) **(B)**

| Variable | SPMS | KPS | GY Kg ha$^{-1}$ | % **PC** | TKM G | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|
| Control | 23.7a | 38.8a | 353.6a | **13.8A** | 30.8a | 1134a |
| Viitavax Plus® | 23.1a | 34.0a | 278.1a | **13.5B** | 29.9a | 1007a |
| Raxil® | 24.7a | 38.1a | 277.3a | **13.5B** | 30.4a | 1065a |
| P≥ | Ns | Ns | Ns | ** | Ns | Ns |

See footnote of Table 6.3

### 6.3.2.3 Cultivar by fungicide interactions (AxB)

The cultivar x fungicide interaction was significant for spike m$^{-2}$ (SPMS) (at p≤ 0.05) and highly significant for protein content (PC) (at p≤ 0.01). The highest spike m$^{-2}$ (SPMS) was obtained from Kubsa treated with Raxil®. Untreated Mitikie seeds (control) showed the highest protein content (PC) while the lowest protein content was observed in Kubsa seeds treated with Vitavax Plus®. However, no significant cultivar x fungicide interaction was observed for the rest of the eleven parameters measured (Tables 6.5A and B).

Table 6.5A: Cultivar X fungicide interactions in bread wheat **(A X B)**

| Variable | % SE | RE Days | TPP | DH Days | MD Days | GFP Days | PH cm |
|---|---|---|---|---|---|---|---|
| Kubsa control | 22.9a | 17.4a | 3.1a | 81.6a | 122.8a | 41.1a | 59.4a |
| Vitavax Plus® | 19.0a | 17.9a | 2.9a | 83.3a | 123.5a | 40.3a | 57.0a |
| Raxil ® | 22.4a | 17.9a | 3.1a | 81.3a | 123.0a | 41.8a | 56.3a |
| Mit control | 21.1a | 17.8a | 3.6a | 81.9a | 127.0a | 45.1a | 61.1a |
| Vitavax Plus® | 25.0a | 17.0a | 3.1a | 82.8a | 126.5a | 43.8a | 58.0a |
| Raxil ® | 22.4a | 17.4a | 2.8a | 82.8a | 127.0a | 44.3a | 63.0a |
| P≥ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 6.5B: Cultivar X Fungicide interactions in bread wheat (continued) **(A X B)**

| Variable | **SPMS** | KPS | GY Kg ha$^{-1}$ | % **PC** | TKM G | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|
| Kubsa control | **24.2AB** | 40.3a | 481.9a | **12.5E** | 30.1a | 1246a |
| Vitavax Plus® | **17.95B** | 33.1a | 179.9a | **12.4F** | 29.4a | 815a |
| Raxil ® | **29.0A** | 36.6a | 305.4a | **12.9D** | 30.9a | 1218a |
| Mitikie control | **23.19AB** | 37.3a | 225.3a | **15.0A** | 31.5a | 1023a |
| Vitavax Pus® | **28.32AB** | 34.9a | 376.3a | **14.7B** | 30.4a | 1199a |
| Raxil ® | **20.39AB** | 39.7a | 249.1a | **14.1C** | 30.0a | 912a |
| P≥ | * | Ns | Ns | ** | Ns | Ns |

See footnote of Table 6.3

### 6.3.2.4 Effect of sowing depth (C)

Highly significant differences (at p≤ 0.01) between sowing depth and seedling emergence (SE), productive tiller plant$^{-1}$ (TPP), days to 50% heading (DH), days to 50% maturity (DM), plant height (PH) and protein content (PC) were observed (Tables 6.6A and B). The percentage seedling emergence (SE) was significantly higher at the shallower planting depth (5 cm) than at the deep (9 cm) planting. Although not significant, higher grain yields (GY) and above ground bio-mass (AGBM) were measured for shallow planted seeds. However, tillers plant$^{-1}$ (TPP), days to 50%

heading (DH), days to 50% maturity (DM), plant height (PH) and protein content (PC) significantly increased when seeds were planted deeper.

Table 6.6A: Effect of sowing depth on different measured parameters in bread wheat **(C)**

| Variable | % **SE** | RE Days | **TPP** | **DH Days** | **MD Days** | GFP Days | PH Cm |
|---|---|---|---|---|---|---|---|
| 5 cm | **30.3A** | 17.3a | **1.9B** | **80.9B** | **123.5B** | 42.6a | 57.2B |
| 9 cm | **13.9B** | 17.8a | **4.2A** | **83.6A** | **126.4A** | 42.8a | 61.0A |
| P≥ | ** | Ns | ** | ** | ** | Ns | Ns |

Table 6.6B: Effect of sowing depth on different measured parameters in bread wheat (continued) **(C)**

| Variable | SPMS | KPS | GY Kg ha$^{-1}$ | % **PC** | TKM G | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|
| 5 cm | 25.1a | 35.1a | 329.5a | **13.1B** | 30.8a | 957a |
| 9 cm | 22.5a | 38.9a | 276.4a | **14.1A** | 29.9a | 1181a |
| P≥ | Ns | Ns | Ns | ** | Ns | Ns |

See footnote of Table 6.3

### 6.3.2.5 Cultivar x sowing depth interactions (AxC)

Statistically significant interactions at ($p \leq 0.05$) were observed between sowing depth and seedling emergence (SE) where the highest emergence came form shallow planted seeds (Tables 6.7A and B). Grain yield (GY) variation between cultivars was found interesting as deeply planted Kubsa significantly outperformed the shallow planted one in grain yield while the opposite was true for Mitikie.

Moreover, significantly higher cultivar x sowing depth variation at ($p \leq 0.01$) was observed for protein content (PC) where Mitikie at a deeper planting depth was found to be significantly superior to Kubsa and all other treatments. The other ten parameters did not differ significantly.

Table 6.7A Cultivar X sowing depth interactions in bread wheat **(A X C)**

| Variable | % SE | RE Days | TPP | DH Days | DM Days | GFP Days | PH Cm |
|---|---|---|---|---|---|---|---|
| Kub 5 cm | **27.2A** | 17.5a | 1.9a | 81.2a | 121.7a | 40.5a | 55.3a |
| 9 cm | **15.7B** | 18.0a | 4.1a | 82.9a | 124.5a | 41.6a | 59.8a |
| Mit 5 cm | **33.5A** | 17.1a | 2.0a | 80.7a | 125.3a | 44.7a | 59.1a |
| 9 cm | **12.2B** | 17.7a | 4.3a | 84.3a | 128.3a | 44.1a | 62.3a |
| P≥ | * | Ns | Ns | Ns | Ns | Ns | Ns |

Table 6.7B: Cultivar X sowing depth interactions in bread wheat continued (A X C)

| Variable | SPMS | KPS | **GY Kg ha$^{-1}$** | **% PC** | TKM G | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|
| Kubsa 5 cm | 23.0a | 33.9a | **250.5AB** | **12.3D** | 30.8a | 861a |
| 9 cm | 24.4a | 39.5a | **394.3A** | **13.0C** | 29.5a | 1324a |
| Mitikie 5 cm | 27.4a | 36.3a | **408.5A** | **14.0B** | 30.9a | 1053a |
| 9 cm | 20.6a | 38.3a | **158.6B** | **15.2A** | 30.3a | 1037a |
| P≥ | Ns | Ns | * | ** | Ns | Ns |

See footnote of Table 6.3

### 6.3.2.6 Fungicide by sowing depth interaction (BXC)

Significantly higher fungicide x sowing depth variation was obtained for days to 50% heading (DH) and protein content (PC) (Tables 6.8A and B). Untreated control, at 5 cm sowing depth, was the earliest to head (DH) but showed the lowest protein content (PC). On the contrary, deeply planted control seeds headed (DH) later and had the highest protein content (PC). The analysis of variance revealed non-significant differences for the remaining eleven parameters.

Table 6.8A: Fungicide X sowing depth interactions in bread wheat **(B X C)**

| Variable | % SE | RE Days | TPP | **DH Days** | DM Days | GFP Days | PH cm |
|---|---|---|---|---|---|---|---|
| Con 5 cm | 30.6a | 17.3a | 2.2a | **79.3C** | 123.3a | 44.0a | 58.5a |
| Con 9 cm | 13.4a | 17.9a | 4.4a | **84.3A** | 126.5a | 42.3a | 62.0a |
| Vit Plus 5 cm | 30.8a | 17.2a | 2.0a | **82.4AB** | 123.8a | 41.4a | 54.4a |
| Vit Plus 9 cm | 13.3a | 17.6a | 4.0a | **83.6AB** | 126.3a | 42.6a | 60.6a |
| Rax 5 cm | 29.6a | 17.3a | 1.7a | **81.1BC** | 123.5a | 42.4a | 58.8a |
| Rax 10 cm | 15.1a | 18.0a | 4.2a | **82.9AB** | 126.5a | 43.6a | 60.5a |
| P≥ | Ns | Ns | Ns | ** | Ns | Ns | Ns |

Table 6.8B: Fungicide X sowing depth interactions bread wheat **(B x C)** continued

| Variable | SPMS | KPS | GY Kg $ha^{-1}$ | % **PC** | TKM G | AGBM Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|
| Con 5 cm | 27.6a | 36.9a | 312.9a | **12.8F** | 31.5a | 1060a |
| Con 9 cm | 19.8a | 40.7a | 394.3a | **14.7A** | 30.1a | 1209a |
| Vit Plus 5 cm | 26.1a | 29.1a | 364.9a | **13.1E** | 30.3a | 940a |
| Vit Plus 9 cm | 20.2a | 38.9a | 191.3a | **13.9B** | 29.5a | 1074a |
| Rax 5 cm | 21.8a | 39.3a | 310.8a | **13.5D** | 30.8a | 871a |
| Rax 10 cm | 27.6a | 37.0a | 243.8a | **13.5C** | 30.1a | 1259a |
| P≥ | Ns | Ns | Ns | ** | Ns | Ns |

See footnote of table 6.3

### 6.3.2.7 Cultivar x fungicide x sowing depth interaction (A x B x C)

With the exception of protein content (PC), no cultivar X fungicide X sowing depth interactions were observed for the parameters measured (Tables 6.9A and B). The highest protein content (PC) was obtained from deeply planted Mitikie control while the least was from shallow planted Kubsa control.

Table 6.9A: Cultivar x fungicide x sowing depth interactions on bread wheat **(A x B x C)**

| Variable | % SE | RE Days | TPP | DH Days | DM Days | GFP Days | PH Cm |
|---|---|---|---|---|---|---|---|
| Kubsa control 5 cm | 27.3a | 17.3a | 2.2a | 79.8a | 121.0a | 41.3a | 56.0a |
| 9 cm | 18.5a | 17.6a | 4.0a | 83.5a | 124.5a | 41.0a | 62.8a |
| Kubsa Vitavax Plus 5 cm | 27.3a | 17.5a | 1.7a | 83.3a | 122.0a | 38.8a | 54.8a |
| Kubsa Vitavax Plus 9 cm | 10.8a | 18.2a | 4.2a | 83.3a | 125.0a | 41.8a | 59.3a |
| Kubsa Raxil 5 cm | 27.0a | 17.6a | 1.9a | 80.5a | 122.0a | 41.5a | 55.3a |
| 9 cm | 17.8a | 18.3a | 4.2a | 82.0a | 124.0a | 42.0a | 57.3a |
| Mitikie control 5 cm | 34.0a | 17.3a | 2.2a | 78.8a | 125.5a | 46.8a | 61.0a |
| 9 cm | 8.3a | 18.2a | 4.9a | 85.0a | 128.5a | 43.5a | 61.3a |
| Mitikie Vitavax Plus 5 cm | 34.3a | 17.0a | 2.3a | 81.5a | 125.5a | 44.0a | 54.0a |
| Mitikie Vitavax Plus 9 cm | 15.8a | 17.1a | 3.9a | 84.0a | 127.5a | 43.5a | 62.0a |
| Mitikie Raxil 5 cm | 32.3a | 17.1a | 1.4a | 81.8a | 125.0a | 43.3a | 62.3a |
| 9 cm | 12.5a | 17.8a | 4.2a | 83.8a | 129.0a | 45.3a | 63.8a |
| P≥ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 6.9B: Cultivar X fungicide X sowing depth interactions on bread wheat **(A X B X C)**

| Variable | SPMS | KPS | GY Kg ha$^{-1}$ | % PC | TKM G | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|
| Kubsa control 5 cm | 25.1a | 38.6a | 303.8a | **11.7K** | 31.0a | 1000a |
| Kububsa control 9 cm | 23.3a | 42.0a | 660.0a | **13.4F** | 29.3a | 1491a |
| Kubsa Vitavax Plus 5 cm | 19.2a | 27.6a | 177.3a | **12.1J** | 29.3a | 713a |
| Kubsa Vitavax Plus 9 cm | 16.7a | 38.6a | 182.5a | **12.7I** | 29.5a | 917a |
| Kubsa Raxil 5 cm | 24.7a | 35.4a | 270.5a | **13.0G** | 32.0a | 871a |
| Kubsa Raxil 9 cm | 33.3a | 37.8a | 340.3a | **12.8H** | 29.8a | 1565a |
| Mitikie control 5 cm | 30.2a | 35.2a | 322.0a | **13.9E** | 32.0a | 1120a |
| Mitikie control 9 cm | 16.2a | 39.5a | 128.5a | **16.1A** | 31.0a | 926a |
| Mitikie Vitavax Plus 5 cm | 33.0a | 30.6a | 552.5a | **14.1D** | 31.3a | 1167a |
| Mitikie Vitavax Plus 9 cm | 23.7a | 39.2a | 200.0a | **15.2B** | 29.5a | 1232a |
| Mitikie Raxil 5 cm | 18.9a | 43.3a | 351.0a | **13.9E** | 29.5a | 871a |
| Mitikie Raxil 9 cm | 21.9a | 36.1a | 147.3a | **14.3C** | 30.5a | 954a |
| P≥ | Ns | Ns | Ns | ** | Ns | Ns |

See footnote of tabe 6.3

### 6.3.2.8 Correlation matrix

The statistical correlation matrix for all interactions is shown in Table 6.10 (Appendix 2). The correlation matrix between grain yield and seed spike$^{-1}$ (R=0.3706), between grain yield and spikes m$^{-2}$ (r=0.6088), between grain yield and emergence (r= 0.5296), were all positive and highly significant (P≥0.01). Correlation between yield and plant height (r=0.3327) was significant only at the 5% probability level. However, grain yield showed negative associations with days to 50% heading and days to 50% maturity at 1% and 5% probability levels respectively.

Among the most important factors considered, sowing depth significantly and positively correlated (r=0.4268) with days to 50% maturity, days to 50% heading (r=0.4907) and tiller plant$^{-1}$ (0=7461). Similarly, positive correlation between grain yield and plant height (r=0.3710) with sowing depth was observed but, only at the 5% probability level.

Significant and positive correlation between protein content and germination (r=0.6403), coleoptile length (r=0.7213), seedling fresh mass (r=0.6459) and days to maturity (r=0.6771) were observed. The increase in one parameter led to the prediction of an increase in another.

## 6.4 Discussion

It is commonly believed that, in dry land areas, tall-straw cultivars are preferred to short-straw ones. Findings in this study clearly demonstrated that the taller cultivar, Mitikie, outperformed the semi-dwarf cultivar Kubsa in most of the parameters measured. Plant heights measured in this trial were reduced by an unusual severe drought that prevailed in the Free State during October to November 1999. This is in agreement with the report of Kinyua *et al.* (1999), where droughts were also found to affect plant height.

Statistical analysis of the means for the two cultivars resulted in Vitavax Plus® leading to significantly increased coleoptile and seedling lengths compared to the other treatments. Vitavax Plus® also significantly increased the germination percentage as was reflected in the emergence of seedlings in the field. Seed treated with Raxil® did not improve the germination percentage and this is in agreement with the findings in Kenya by Wanyera (1999). Raxil®, however, had a distinct improving effect on seedling root length. Vitavax Plus® therefore seems to have a positive influence on germination as well as seedling development of the two tested Ethiopian bread wheat cultivars with no phytotoxic effects. The different ways in which Raxil and Vitavax Plus influenced the seeds of different cultivars is difficult to explain but might be associated with the different active substances of the two fungicides.

In general, poor emergence can be attributed to a combination of several factors, e.g. lack of soil moisture, planting time and planting depth. Moreover, short coleoptile length was considered one of the main factors responsible for the poor emergence of spring and winter wheat by Schillinger *et al.* (1998). According to the authors, coleoptile length in turn is controlled by several factors of which the genetic constitution is considered the main one. Unlike the finding of Whan (1976), where he elucidated a very close association between mature plant height and coleoptile length within the semi-dwarf wheat studied (r=0.90), our results did not show any significant correlation at all.

The cultivar Mitikie, having significantly longer coleoptile lengths, performed better than the semi-dwarf cultivar Kubsa, with the shorter coleoptile lengths. However, during field emergence, the coleoptile lengths of Kubsa seedlings were found to be much shorter than expected (compared to laboratory results). A number of environmental factors could have been responsible for the shortening of Kubsa coleoptiles, e.g. contact of seeds with fertilizer (personal communication with a South African farmer, 1999), shortage of moisture and high temperature regimes (Smiley *et al.*, 1996). Age of seeds can also play a role where coleoptiles of old seeds tend to be shorter than that from fresh seed (Smiley *et al.*, 1996).

Although it did not bring about significantly higher grain yield increases, shallow planting increased seedling emergence, caused faster heading and hence maturity in both cultivars. In contrast, the number of tillers plant$^{-1}$, plant height, days to 50% maturity and days to 50% heading as well as the protein content were increased by planting deeper (9 cm). According to Ybema (1994) deep planting is preferred to shallow by most farmers in Eastern Free State, South Africa, especially during low frost seasons, to exploit the residual moisture in order to improve seedling emergence and hence crop stand. On the other hand, due to the availability of ample soil moisture during planting in winter rainfall areas, shallow planting (2.5 cm) is practiced in the South Western Cape Province.

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# CHAPTER 7

# EFFECT OF SEED SIZE AND TREATMENTS ON SEED QUALITY AND YIELD OF ONE SOUTH AFRICAN AND TWO ETHIOPIAN DURUM WHEAT CULTIVARS


**Abstract**

Two identical studies on durum wheat, one in the laboratory under controlled conditions and the other under field conditions, were conducted at the Small Grain Institute, Bethlehem, South Africa in 1999. The main aims were to examine the effects of seed size and fungicide treatments on germination, seedling emergence, seed quality parameters, yield and its components. A randomized complete block design with four replications was used. Two Ethiopian durum wheat cultivars, Gerardo (semi-dwarf) and Kilinto (tall), and one South African cultivar, Orania (semi-dwarf), were included in the study. In the laboratory trial, Orania, with 94.5% seed germination, outperformed both Gerardo (87.2%) and Kilinto (56.3%). However, Kilinto showed the longest coleoptile and seedling lengths as well as the highest fresh and dry seedling masses. A marked improvement in seed germination was observed after treatment with both Carboxin/thiram® (Vitavax Plus) and Teruconazole® (Raxil) fungicides. Coleoptile and seedling lengths as well as seedling fresh and dry masses, were highly increased in all cultivars, as compared to the medium and small sized ones, by fungicide treatments. In the field trial, the highest grain yield, seed protein content, hectolitre mass and aboveground biomass was obtained from Gerardo after treating seeds with fungicides. Orania outperformed the two Ethiopian cultivars in emergence. Compared to untreated control seeds, treatment with Vitavax Plus significantly improved seedling emergence. Statistical analysis of combined data for all cultivars, revealed significant increases in grain yield, seed protein content and hectoltre mass from large sized seeds.



**Key words:** durum wheat, seed size, fungicide, seed treatments, coleoptile length and seedling emergence

## 7.1 Introduction

The rheological properties of stiff dough, produced from durum wheat semolina, are especially suitable for the manufacturing of pasta products such as macaroni, spaghetti, and noodles (Dexter and Masuo, 1977). According to Blanco *et al.* (1988), durum wheat occupies about 20 million hectares worldwide, spread over many countries. More than half of the total land under durum wheat cultivation lies in the Mediterranean regions of southern Europe, North Africa and southwestern Asia with an estimated annual production of approximately 27.5 million tons.

Joshi (1997) reported that wheat plants derived from large seeds were taller, produced higher grain yields as well as more leaves, tillers and spikelets than plants derived from smaller seeds of the same genotype. Roy *et al.* (1996) also found a threefold difference between the smallest and the largest planted seeds regarding germination rate and seedling vigour index values in rice. Similarly, in maize, larger seeds were suggested as more advantageous to producers than small or medium ones (Krishnaveni and Vanangamudi, 1989). From these studies it became clear that larger seeds within a genotype should be selected for good stand establishment in cultivated plants.

Seed size, as quality parameter, and fungicide treatment for retaining seed quality, might have been dealt with exhaustively in the developed world but information on this subject is scarce in developing countries. Particularly the rejection of durum wheat seed on grounds of quality in many certification laboratories (Grass and Tourkmani, 1999) is frequently reported. Treatment of seeds with fungicides is also frequently used as a remedy in retaining the quality of seeds for planting (Crosier, 1966).

Various wheat diseases prevail in mostly highland high rainfall wheat growing in East African countries. Amongst Ethiopian cultivars, Kidane (1996) identified six seed-borne fungi of which the control through usage of quality seeds and seed dressing with fungicides may play a vital role. Therefore, the main objectives of this study were to identify the best seed size in terms of seed quality and to investigate the effectiveness of two common fungicides on quality improvement in seeds of one South African and two Ethiopian durum wheat cultivars.

## 7.2 Materials and Methods

### 7.2.1 Materials

See Chapter 3.

### 7.2.2 Methods

Treatments for both the laboratory and field trials are shown in table 7.1.

Table 7.1: List of treatments applied to durum wheat in laboratory and field trials

| Cultivar | Seed sizes and Slotted sieve size (mm) | Treat No. | Control | Treat . No | Vitavax plus 250 ml/100 kg | Treat . No | Raxil 25 ml/100 kg |
|---|---|---|---|---|---|---|---|
| Gerardo | Small <2.3 x 25 | 1 | " | 4 | " | 7 | " |
| | Medium 2.3 to 2.8 x 25 | 2 | " | 5 | " | 8 | " |
| | Large >2.8 x 25 | 3 | " | 6 | " | 9 | " |
| Kilinto | Small 2.5 x 25 | 10 | " | 13 | " | 16 | " |
| | Medium >2.5 to 3.5 x 25 | 11 | " | 14 | " | 17 | " |
| | Large >3.5 x 25 | 12 | " | 15 | " | 18 | " |
| Orania | Small 2.5 x 25 | 19 | " | 22 | " | 25 | " |
| | Medium >2.5 to 2.8 x 25 | 20 | " | 23 | " | 26 | " |
| | Large >2.8 x 25 | 21 | " | 24 | " | 27 | " |

The field trial was conducted at the Small Grain Institute, South Africa on an Avalon soil form (Purchase, *et al.*, 1992). The trial was planted in late August 1999 and was fertilized at the rate of 37.5 kg N, 25 kg P and 12.5 kg K $ha^{-1}$. The fertilizer was band placed in the rows before the seed was sown and incorporated with the soil. Hundred seeds per plot were planted by hand with spacing of 5 cm between seeds in a row of 5 m long and 40 cm wide. As the moisture in the soil was depleted in August, supplementary irrigation was supplied to ensure and facilitate emergence (see chapter 3 for a detailed description of methods applied).

## 7.3 Results

### 7.3.1 Data analysis of results obtained under laboratory conditions

#### 7.3.1.1 Cultivar variations (A)

Results in table 7.2 revealed highly significant differences among cultivars for the ten parameters tested. Orania seeds (94.5%) outperformed that of Gerardo (87.2%) and Kilinto (56.3%) in terms of germination percentage. The poor performance of Kilinto could be ascribed to damage of seeds by weevil's prior to test. For this reason Orania was included in the study. The percentages of abnormal seedlings (ABS) and dead seeds (DS) were also very much reduced for the best germinating cultivars. Compared to Kilinto, the seedling roots length (SRL) and seedling root fresh masses (SRFM) of the best two performing cultivars were also significantly higher. However, Kilinto showed significantly longer coleoptile lengths (CL) and seedling lengths (SL) as well as higher seedling fresh- (SFM) and dry (SDM) as well as seedling root dry masses (SRDM).

Table 7.2: Cultivar variations in durum wheat, and in terms of specific parameters measured under laboratory conditions **(A)**

| Variable | Ger % | Abs. % | Ds % | cl. mm | Sl mm | Srl mm | Sfm mg | Sdm mg | Srfm mg | Srdm Mg |
|---|---|---|---|---|---|---|---|---|---|---|
| Gerardo | 87.22B | 7.33B | 5.42B | 83.62B | 109.0B | 175.92A | 129.2B | 10.34B | 85.25A | 9.79B |
| Kilinto | 56.25C | 16.67A | 27.33A | 110.3A | 130.4A | 154.3B | 181.1A | 14.10A | 73.08B | 10.21A |
| Orania | 94.53A | 4.31C | 1.81C | 75.57C | 102.1C | 174.1A | 103.1C | 9.17C | 85.36A | 9.92AB |
| C.v. % | 4.36 | 34.0 | 27.2 | 6.87 | 5.21 | 5.93 | 6.87 | 8.1 | 8.6 | 6.94 |
| Mean | 79.33 | 9.44 | 11.52 | 89.84 | 113.83 | 168.11 | 137.78 | 11.20 | 81.23 | 9.97 |
| P≤ | ** | ** | ** | ** | ** | ** | ** | ** | ** | * |

**Abbreviations:**

Ns = Non-significant, * = significant and ** = highly significant at P≤ 0.05 and P≤ 0.01 respectively. Any two or more means sharing the same letter are not significantly different at 5% probability level according to Tukey's mean separatin. Ger = germination Abs = abnormal seedling Ds = dead seed Cl = coleoptile length Sl = seedling length Srl = seedling root length Sfm = seedling fresh mass Sdm = seedling dry mass Srdm = seedling dry mass Mm = millimeter mg = milligram C.v. = coefficient of variance

#### 7.3.1.2 Fungicide variations (B)

Fungicide treatment had marked effects on eight of the ten parameters measured (table 7.3). Carboxin/thiram (Vitavax plus) caused a significant increase in the germination % (GER), seedling lengths (SL) and seedling fresh mass (SFM) in all cultivars compared to the untreated control seeds. However, treatment with Vitavax Plus was not significantly higher in terms of germination % (GER) compared to the Tebuconazole (Raxil) treatment and of coleoptile length compared to untreated control.

Although the percentage abnormal seedlings (ABS) obtained from treated seeds were not statistically different from the controls, the highest score was recorded from Raxil treatments. Moreover, the percentage dead seeds (DS) recorded was much higher in the untreated control than in the two fungicide treatments. Raxil also highly reduced the coleoptile length (CL), had little effect on seedling fresh mass (SFM) but tended to cause an increase in both fresh- (SRFM) and dry root masses (SRDM).

Table 7.3: Effect of different fungicides, in terms of different paramaters measured (mean of three cultivars) under laboratory conditions **(B)**, on durum wheat seeds

| Variable | **Ger %** | **% Abs.** | **% Ds** | **cl. Mm** | **Sl Mm** | Srl Mm | **Sfm Mg** | Sdm Mg | **Srfm Mg** | **Srdm Mg** |
|---|---|---|---|---|---|---|---|---|---|---|
| Control | 77.08B | 9.44AB | 13.50A | 90.41A | 113.0B | 166.34a | 135.6B | 11.00a | 80.11B | 9.96AB |
| Vitavax plus | 81.08A | 8.33B | 10.69B | 93.25A | 118.2A | 169.32a | 143.6A | 11.43a | 78.36B | 9.63B |
| Raxil | 79.83A | 10.53A | 10.36B | 85.86B | 110.3B | 168.66a | 134.1B | 11.18a | 85.22A | 10.33A |
| P≤ | ** | * | ** | ** | ** | Ns | ** | Ns | ** | ** |

See footnote of table 7.2

#### 7.3.1.3 Cultivar X fungicide interactions (AxB)

Significant cultivar by fungicide interaction, in terms of differences, was observed in three of the ten parameters considered (Table 7.4) namely germination % (GER), % dead seeds (DS) and seedling lengths (SL), when the respective controls were compared to fungicide treatments. Albeit not in a spectacular fashion, both Vitavax Plus and Raxil tended to increase the germination % in seeds of Kilinto and Orania. Vitavax plus tended to decrease the % dead seeds of Kilinto, but had no significant effect on the other two cultivars. Raxil decreased the seedling length (SL) of Gerardo and Kilinto but had no effect on Orania.

Table 7.4: Cultivar X fungicide interactions under laboratory conditions **(AxB)**

| Variable | Ger % | % Abs. | % **Ds** | cl. Mm | **Sl Mm** | Srl Mm | Sfm Mg | Sdm Mg | Srfm Mg | Srdm Mg |
|---|---|---|---|---|---|---|---|---|---|---|
| Gerardo Control | **87.0B** | 7.8a | **5.1CD** | 82.4a | **107CD** | 173.9a | 124.8a | 10.2a | 83.9a | 9.7a |
| Vitavax plus | **88.1B** | 6.3a | **5.6C** | 87.6a | **114C** | 175.2a | 135.8a | 10.7a | 82.3a | 9.4a |
| Raxil | **86.6B** | 7.8a | **5.6C** | 80.9a | **106D** | 178.7a | 126.9a | 10.1a | 89.6a | 10.3a |
| Kilinto control | **50.5D** | 16.1a | **33.5A** | 112.1a | **131A** | 150.5a | 178.1a | 13.8a | 70.0a | 10.2a |
| Vitavax plus | **59.8C** | 16.1a | **24.3B** | 115.3a | **137A** | 157.7a | 190.9a | 14.5a | 71.2a | 9.9a |
| Raxil | **58.4C** | 17.8a | **24.3B** | 103.6a | **123B** | 154.6a | 174.3a | 14.5a | 78.2a | 10.6a |
| Orania control | **93.8A** | 4.4a | **1.9CD** | 76.8a | **101D** | 174.7a | 104.0a | 9.0a | 86.4a | 10.1a |
| Vitavax plus | **95.3A** | 2.6a | **2.3CD** | 76.8a | **103D** | 175.0a | 104.0a | 9.1a | 81.8a | 9.6a |
| Raxil | **94.5A** | 5.9a | **1.3D** | 73.1a | **102D** | 172.7a | 101.7a | 9.4a | 87.9a | 10.2a |
| P≤ | ** | Ns | ** | Ns | ** | Ns | Ns | Ns | Ns | Ns |

See footnote of Table 7.2

### 7.3.1.4 Seed size variation (C)

Comparison among the three seed size classes showed highly significant differences in five and a significant difference in one of the ten parameters measured (table 7.5). Coleoptile length (CL) and total seedling length (SL) of seedlings from small sized seed was significantly shorter compared to that of both medium and large sized ones. Seedlings from large sized seeds were also significantly better than that from medium and small sized seeds in terms of seedling fresh mass (SFM), seedling dry mass (SDM), seedling root fresh (SRFM) and dry masses (SRDM).

Table 7.5: Effect of seed size in durum wheat in terms of specific parameters measured under laboratory conditions ; mean of three cultivars **(C)**

| Variable | Ger % | % Abs. | % Ds | **cl. Mm** | **Sl Mm** | Srl Mm | **Sfm Mg** | **Sdm Mg** | **Srfm Mg** | **Srdm Mg** |
|---|---|---|---|---|---|---|---|---|---|---|
| Small | 79.1a | 10.4a | 11.33 | **86.9B** | **112B** | 167.0a | **122C** | **9.94C** | **66.3C** | **7.98C** |
| Medium | 80.1a | 8.7a | 11.1a | **91.7A** | **115AB** | 168.7a | **141B** | **11.34B** | **82.8B** | **10.22B** |
| Large | 78.8a | 9.2a | 12.1a | **90.9A** | **115A** | 168.6a | **150A** | **12.33A** | **94.6A** | **11.73A** |
| P≤ | Ns | Ns | Ns | ** | * | Ns | ** | ** | ** | ** |

See footnote of table 7.2

### 7.3.1.5 Cultivar x seed size interactions (AxC)

Cultivar by seed size interactions was observed in only four of the ten parameters studied. Statistical analysis of combined data revealed highly significant cultivar differences in the percentage dead seeds (DS), seedling root fresh (SRFM) and dry masses (SRDM) while it was only significant for seedling length (SL). In general, large seeded Orania showed a significantly lower percentage dead seeds (DS) while large seeded Kilinto measured the highest for this parameter. The opposite was true for seedling dry mass (SDM). Moreover, Kilinto outperformed the other cultivars in seedling root fresh (SRFM) and dry masses (SRDM). Results are presented (Table 7.6)

Table 7.6: Cultivar X seed size variation under laboratory conditions (AxC)

| Variable | Ger % | % Abs. | % **Ds** | cl. Mm | Sl Mm | Srl Mm | Sfm Mg | **Sdm Mg** | **Srfm Mg** | **Srdm Mg** |
|---|---|---|---|---|---|---|---|---|---|---|
| Gerardo small | 86.4a | 8.17a | **5.42C** | 80.88a | 106..03a | 176.21a | 111.08a | **8.62EF** | **66.08E** | **7.22D** |
| Medium | 87.67a | 6.33a | **5.92C** | 85.63a | 111.33a | 176.10a | 133.75a | **10.63CD** | **86.08B** | **10.09B** |
| Large | 87.58a | 7.50a | **4.92CD** | 84.36a | 109.68a | 175.46a | 142.67a | **11.77C** | **103.6A** | **12.06A** |
| Kilinto small | 56.92a | 18.00a | **26..00B** | 102.38a | 127.48a | 153.56a | 165.67a | **13.30B** | **64.25E** | **8.74C** |
| Medium | 57.67a | 16.50a | **25.67B** | 114.16a | 131.25a | 156.23a | 186.25a | **13.84B** | **75.42CD** | **10.45B** |
| Large | 54.17a | 15.50a | **30.33A** | 110.48a | 132.33a | 153.02a | 191.42a | **15.16A** | **79.58BC** | **11.45A** |
| Orania small | 93.92a | 5.08a | **2.58CD** | 73.48a | 101.02a | 171.20a | 90.42a | **7.89F** | **68.42DE** | **7.98CD** |
| Medium | 95.08a | 3.17a | **1.83CD** | 75.48a | 102.00a | 173.77a | 104.17a | **9.57DE** | **86.928** | **10.11B** |
| Large | 94.58a | 4.67a | **1.00D** | 77.76a | 103.36 | 177.44a | 114.58a | **10.05D** | **100.8A** | **11.67A** |
| P≤ | Ns | Ns | ** | Ns | Ns | Ns | Ns | * | ** | ** |

See footnote of table 7.2

### 7.3. 1. 6 Cultivar x fungicide treatment x seed size interactions (AxBxC)

No significant cultivars x fungicide treatment x seed size interactions were revealed statistically (results not shown).

### 7.3.2 Data analysis of results obtained under field conditions

### 7.3.2.1 Cultivar variations (A)

The analysis of variance (ANOVA) of combined results for the three cultivars (table 7.7A and B) revealed highly significant variation among cultivars in twelve of the fifteen parameters measured. The South African cultivar, Orania, followed by Gerardo, outperformed Kilinto in seedling emergence (SE). Although, not significantly different from Kilinto, Orania was the latest to head (DH) while Gerardo was the earliest. However, in terms of tillers plant$^{-1}$ (TPP), Kilinto measured significantly higher than the other two, took the longest days to mature (DM) and possessed the largest thousand kernels mass (TKM). In contrast, seedling emergence (SE) of Kilinto was slowest and the number of spikes m$^{-2}$ (SPMS) was significantly lower than that of the other two cultivars. Moreover, Kilinto took more days to grain fill (GFP) while this period was significantly reduced in Orania. Orania was also the shortest grower (PH).

The two semi-dwarf cultivars performed almost similar in terms of number of spikes m$^{-2}$ (SPMS) and total grain yield (GY). Although it did not differ significantly from Orania, Gerardo performed the best in total grain yield (GY) and above ground biomass yield (AGBM). In addition to this, Gerardo outperformed the other two in seed protein content (CP). Orania measured least in terms of thousand kernels mass (TKM) but, outperformed the other two cultivars in terms of number of kernels spike$^{-1}$ (KPS).

Table 7. 7A: Cultivar variations in durum wheat in terms of specific parameters measured under field conditions **(A)**

| Variable | % SE | % SE of Germinated | ER Days | TPP | DH DAYS | DM DAYS | GFP DAYS | PH CM |
|---|---|---|---|---|---|---|---|---|
| Gerardo | **68.94B** | 79.22a | 15.87a | **5.042B** | **67.14B** | **103.4B** | **36.31B** | **70.08B** |
| Kilinto | **47.33C** | 84.42a | 16.59a | **6.811A** | **70.00A** | **113.8A** | **41.75A** | **85.39A** |
| Orania | **78.06A** | 82.47a | 15.96a | **4.581C** | **72.53A** | **102.1C** | **29.39C** | **56.00C** |
| C.v. % | 15.1 | 18.22 | 11.2 | **16.3** | 3.0 | 1.84 | **7.34** | 5.56 |
| Mean | 64.78 | 84.04 | 16.1 | **5.48** | 70.56 | 106.44 | **35.82** | 70.49 |
| P≤ | ** | Ns | Ns | ** | ** | ** | ** | ** |

Table 7. 7B: Cultivar variations in durum wheat in terms of specific parameters measured under field conditions **(A)**

| Variable | SPMS | KPS | GY KG HA$^{-1}$ | % PC | TKM G | HLM KG HL$^{-1}$ | ABGB Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Gerardo | **171.9A** | **40.28B** | **1817A** | **16.40A** | **38.50B** | **68.91A** | **5219A** |
| Kilinto | **155.2B** | **29.13C** | **934B** | **15.50B** | **42.28A** | **69.07A** | **4233B** |
| Orania | **176.5A** | **45.24A** | **1643A** | **14.50C** | **28.29C** | **64.34B** | **5097A** |
| C.v. % | 15.49 | **20.23** | 32.71 | **0.27** | **11.93** | 2.42 | 20.0 |
| Mean | 167.88 | **38.22** | 1464.68 | **15.47** | **36.36** | 67.44 | 4849.54 |
| P≤ | ** | ** | ** | ** | ** | ** | ** |

**Abreviations:**

ABGB = above ground bio-mass, PC = protein content, TKM = thousand kernel mass, GY = grain yield, KPS = kernels per spike, SPMS = seeds per meter square PH = plant height, GFP = Grain filling period, DM = days to 50% maturity DH = days to 50% heading, TPL = tillers per plant, ER= emergence rate (mean days), ES = emergence seedlings, SS = seed size, HLM = hectolitre mass

### 7.3.2.2 Fungicide variations (B)

Highly significant differences among fungicides were observed for two parameters and a significant difference for one of the fifteen parameters considered (table 7.8A and B). Vitavax Plus treatment highly improved seedling emergence (SE), compared to the Raxil treatment and untreated controls while the protein content (PC) in Raxil treated seeds was significantly higher than in both Vitavax Plus treated and control seeds. However, the control was statistically superior to seeds treated with both fungicides in terms of tillers plant$^{-1}$ (TPP).

Table 7.8A: Effect of different fungicides on durum wheat seeds in terms of specific parameters measured under field conditions ; mean of three cultivars **(B)**

| Variable | % SE | % SE of Germinated | RE Days | **TPP** | DH DAYS | DM DAYS | GFP DAYS | PH CM |
|---|---|---|---|---|---|---|---|---|
| Control | **60.58B** | 79.36a | 16.36a | **5.800A** | 70.86a | 106.7a | 35.72a | 70.75a |
| Vitavax plus | **69.00A** | 85.61a | 15.75a | **5.333B** | 70.50a | 106.2a | 35.75a | 70.33a |
| Raxil | **64.75AB** | 81.14a | 16.31a | **5.300B** | 70.31a | 106.4a | 35.97a | 70.37a |
| P≤ | ** | Ns | Ns | * | Ns | Ns | Ns | Ns |

Table 7.8B: Effect of different fungicides on durum wheat seeds in terms of specific parameters measured under field conditions ; mean of three cultivars (continued) **(B)**

| Variable | SPMS | KPS | GY Kg ha$^{-1}$ | % **PC** | TKM G | HLM Kg hl$^{-1}$ | ABGB Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Control | 161.72a | 38.60a | 1379a | **15.30C** | 37.09a | 67.73a | 4743a |
| Vp plus | 176.3a | 38.44a | 1611a | **15.43B** | 36.29a | 67.37a | 5101a |
| Raxil | 165.6a | 37.62a | 1404a | **15.67A** | 35.68a | 67.22a | 4705a |
| P≤ | Ns | Ns | Ns | ** | Ns | Ns | Ns |

See footnote of table 7.7

### 7.3.2.3 Cultivar x fungicide interactions (AxB)

With the exception of a highly significant improvement in protein content (PC) caused by Raxil treatment, no significant cultivar by fungicide treatment interactions were observed for any of the other parameters measured (Tables 7.9A and B).

Table 7.9A: Cultivar X fungicide interactions in durum wheat under field conditions **(AxB)**

| Variable | % SE | % SE of Germinated | RE Days | Tpp | DH DAYS | DM DAYS | GFP DAYS | PH CM |
|---|---|---|---|---|---|---|---|---|
| Gerardo control | 65.58a | 75.50a | 15.43a | 5.242a | 67.08a | 103.2a | 36.08a | 69.17a |
| Vitavax plus | 73.25a | 83.42a | 16.00a | 5.067a | 67.50a | 103.8a | 36.33a | 70.92a |
| Raxil | 68.00a | 78.75a | 16.19a | 4.817a | 66.83a | 103.3a | 36.50a | 70.17a |
| Kilinto control | 41.33a | 82.67a | 17.68a | 7.383a | 73.00a | 114.7a | 41.67a | 85.08a |
| Vitavax plus | 52.83a | 88.67a | 15.65a | 6.400a | 71.17a | 112.7a | 41.58a | 85.25a |
| Raxil | 47.83a | 81.92a | 16.45a | 6.650a | 71.83a | 114.1a | 42.00a | 85.83a |
| Orania con | 74.83a | 79.92a | 15.97a | 4.775a | 72.50a | 102.3a | 29.42a | 58.00a |
| Vitavax plus | 80.92a | 84.75a | 15.62a | 4.533a | 72.83a | 102.2a | 29.33a | 54.83a |
| Raxil | 78.42a | 82.75a | 16.30a | 4.433a | 72.25a | 101.7a | 29.42a | 55.17a |
| P≤ | Ns | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 7.9B: Cultivar X fungicide interactions in durum wheat under field conditions continued **(AxB)**

| Variable | SPMS | KPS | GY KG $HA^{-1}$ | % **PC** | TKM Gm | HLM KG $HL^{-1}$ | ABGB Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Gerardo control | 170.0a | 42.23a | 1778a | **15.68C** | 38.11a | 68.73a | 5240a |
| Vitavax plus | 183.8a | 38.36a | 2008a | **16.53B** | 38.33a | 69.10a | 5729a |
| Raxil | 161.9a | 40.26a | 1664a | **16.98A** | 39.05a | 68.88a | 4688a |
| Kilinto control | 138.9a | 27.72a | 728.2a | **15.67C** | 44.93a | 69.93a | 3948a |
| Vitavax plus | 164.6a | 31.20a | 1095a | **15.28E** | 42.14a | 68.38a | 4583a |
| Raxil | 162.2a | 28.47a | 978.3a | **15.55D** | 39.77a | 68.90a | 4167a |
| Orania con | 176.3a | 45.85a | 1632a | **14.56F** | 28.22a | 64.53a | 5042a |
| Vitavax plus | 180.7a | 45.75a | 1730a | **14.47G** | 28.41a | 64.62a | 4990a |
| Raxil | 172.7a | 44.13a | 1568a | **14.48G** | 28.23a | 63.88a | 5260a |
| P≤ | Ns | Ns | Ns | ** | Ns | Ns | Ns |

### 7.3.2.4 Seed size variation (C)

Statistically, four of the measured parameters differed significantly and an additional one highly significantly, in terms of seed size variation (Tables 7.10A and B). Seedlings from large sized seeds emerged significantly earlier (RE) than from both small and medium sized seed groups. Although, not statistically different from the medium seed size, large seed also ultimately produced seeds with higher protein content (PC). Statistically, plants from small seeds took significantly longer than those from the other seed size groups to reach the 50% heading stage (DH).

Seeds harvested from plants obtained from both medium and large seed size groups measured significantly higher in hectolitre mass (HLM) while a significantly higher grain yield (GY) was harvested from plants grown from large sized seeds. Although, not statistically different from each other, the above ground bio mass (AGBM) yield was also slightly higher in plants grown from large sized seeds. Similar values, with no significant variation, were measured for the rest of the parameters considered.

Table 7.10A: The efect of seed size in durum wheat in terms of specific parameters measured under field conditions ; mean of three cultivars **(C)**

| Variable | % SE | % SE of Germinated | **RE Days** | TPP | **DH DAYS** | DM DAYS | GFP DAYS | PH CM |
|---|---|---|---|---|---|---|---|---|
| Small | 62.61a | 80.36a | **16.44A** | 5.442a | **71.42A** | 106.6a | 35.19a | 70.31a |
| Medium | 65.58a | 81.72a | **16.46A** | 5.358a | **70.11B** | 106.5a | 36.58a | 70.81a |
| Large | 66.14a | 84.03a | **15.52B** | 5.633a | **70.14B** | 106.1a | 35.67a | 70.36a |
| P≤ | Ns | Ns | * | Ns | * | Ns | Ns | Ns |

Table 7.10B: The efect of seed size in durum wheat in terms of specific parameters measured under field conditions ; mean of three cultivars (continued) **(C)**

| Variable | SPMS | KPS | **GY Kg ha$^{-1}$** | **% PC** | TKM G | **HLM Kg hl$^{-1}$** | ABGB Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Small | 164.8a | 37.13a | **1388B** | **15.46B** | 36.12a | **66.71B** | 4715a |
| Medium | 168.3a | 37.56a | **1374B** | **15.47AB** | 37.01a | **67.96A** | 4795a |
| Large | 170.6a | 39.97a | **1632A** | **15.48A** | 35.93a | **67.66A** | 5038a |
| P≤ | Ns | Ns | * | * | Ns | ** | Ns |

See footnote of table 7.7

#### 7.3.2.5 Cultivar x seed size interactions (AxC)

Results shown in table 7.11A and B indicate statistically significant to highly significant cultivar by seed size interaction in terms of tillers plant$^{-1}$ (TPP) and seed protein content (PC) respectively. The highest number of tillers plant$^{-1}$ (TPP) was recorded for Kilinto while the highest seed protein content (PC) was measured in harvested seeds from Gerardo. Kilinto seeds measured higher in protein content than Orania.

Table 7.11A: Cultivar X seed size interactions in durum wheat under field conditions **(AxC)**

| Variable | % SE | % SE of Germinated | RE Days | **TPP** | DH DAYS | DM DAYS | GFP DAYS | PH CM |
|---|---|---|---|---|---|---|---|---|
| Gerardo Small | 65.83a | 76.33a | 15.83a | **5.208B** | 68.08a | 104.1a | 35.83a | 70.75a |
| Gerardo Medium | 69.50a | 79.67a | 16.38a | **4.983B** | 66.33a | 103.8a | 37.50a | 70.00a |
| Gerardo Large | 71.50a | 81.67a | 15.40a | **4.933B** | 67.00a | 102.4a | 35.58a | 69.50a |
| Kilinto Small | 49.08a | 87.17a | 16.90a | **6.425A** | 73.08a | 114.3a | 41.75a | 84.92a |
| Kilinto Medium | 47.42a | 81.58a | 16.88a | **6.500A** | 71.67a | 113.5a | 42.33a | 85.42a |
| Kilinto Large | 45.50a | 84.50a | 16.00a | **7.508A** | 71.25a | 113.6a | 41.17a | 85.83a |
| Orania small | 72.92a | 77.58a | 16.60a | **4.692B** | 73.08a | 101.5a | 28.00a | 55.25a |
| Orania medium | 79.83a | 83.92a | 16.13a | **4.592B** | 72.33a | 102.3a | 29.92a | 57.00a |
| Orania large | 81.42a | 85.92a | 15.16a | **4.458B** | 72.17a | 102.4a | 30.25a | 55.75a |
| P≤ | Ns | Ns | Ns | * | Ns | Ns | Ns | Ns |

Table 7.11B: Cultivar X seed size interactions in durum wheat under field conditions continued **(AxC)**

| Variable | SPMS | KPS | GY KG HA$^{-1}$ | **% PC** | TKM Gm | HLM KG HL$^{-1}$ | ABGB Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Gerardo Small | 169.3a | 38.80a | 1663a | **16.33B** | 36.28a | 67.67a | 5010a |
| Gerardo Medium | 170.8a | 39.80a | 1816a | **16.32B** | 40.34a | 69.58a | 5260a |
| Gerardo Large | 175.7a | 42.24a | 1972a | **16.55A** | 38.87a | 69.47a | 5385a |
| Kilinto Small | 155.8a | 29.01a | 922.9a | **15.49CD** | 43.98a | 68.55a | 4323a |
| Kilinto Medium | 153.2a | 29.01a | 7.93.3a | **15.55C** | 42.79a | 69.37a | 4104a |
| Kilinto Large | 156.8a | 29.37a | 1085a | **15.45D** | 40.07a | 69.30a | 4271a |
| Orania small | 169.3a | 43.57a | 1577a | **14.55E** | 28.10a | 63.90a | 4813a |
| Orania medium | 180.9a | 43.86a | 1514a | **14.52E** | 27.90a | 64.93a | 5021a |
| Orania large | 179.4a | 48.30a | 1839a | **14.44F** | 28.86a | 64.20a | 5458a |
| P≤ | Ns | Ns | Ns | ** | Ns | Ns | Ns |

See footnote of table 7.7

### 7.3.2.6 Fungicide x seed size interactions (Bx C)

Fungicide x seed size interaction (Table 7.12A and B) was highly significant for only seed protein content (PC). All other parameters were similar and revealed no clear variations in terms of fungicide treatment or seed size. In general, the highest protein content (PC) was recorded from harvests of Raxil treated seeds followed by Vitavax Plus.

Table 7.12A: Fungicide X seed size interactions (mean of three cultivars) on durum wheat under field conditions **(BxC)**

| Variable | % SE | % SE of Germinated | RE Days | TPP | DH DAYS | DM DAYS | GFP DAYS | PH CM |
|---|---|---|---|---|---|---|---|---|
| Control small | 59.83a | 80.92a | 16.64a | 5.558a | 71.83a | 106.7a | 34.42a | 71.00a |
| Control medium | 59.67a | 75.17a | 16.28a | 5.658a | 69.92a | 106.8a | 36.92a | 70.92a |
| Control large | 62.25a | 82.00a | 16.14a | 6.183a | 70.83a | 106.7a | 35.83a | 70.33a |
| VitavaxPlus small | 65.17a | 82.08a | 16.57a | 5.200a | 72.00a | 106.3a | 34.92a | 69.00a |
| Vitavax Plus medium | 70.75a | 87.42a | 16.08a | 5.358a | 70.25a | 106.5a | 36.42a | 71.17a |
| Vitavax Plus large | 71.08a | 87.33a | 14.61a | 5.442a | 69.25a | 105.8a | 35.92a | 70.83a |
| Raxil. Small | 62.83a | 78.08a | 16.12a | 5.567a | 70.42a | 106.9a | 36.25a | 70.92a |
| Raxil. Medium | 66.33a | 82.58a | 17.02a | 5.058a | 70.17a | 106.3a | 36.42a | 70.33a |
| Raxil. Large | 65.08a | 82.75a | 15.81a | 5.275a | 70.33a | 105.9a | 35.25a | 69.92a |
| P≤ | Ns | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 7.12B: Fungicide X seed size interactions (mean of three cultivars) on durum wheat under field condition continued **(BxC)**

| Variable | SPMS | KPS | GY KG HA$^{-1}$ | % PC | TKM Gm | HLM KG HL$^{-1}$ | ABGB Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Control small | 162.8a | 37.78a | 1332a | **15.27F** | 36.76a | 67.27a | 4635a |
| Control medium | 152.6a | 37.22a | 1264a | **15.36E** | 39.06a | 68.40a | 4635a |
| Control large | 169.8a | 40.80a | 1543a | **15.28F** | 35.44a | 67.53a | 4958a |
| VitavaxPlus small | 165.3a | 38.19a | 1388a | **15.29F** | 36.54a | 66.62a | 4656a |
| Vitavax Plus medium | 185.4a | 36.78a | 1610a | **15.44D** | 37.00a | 67.95a | 5333a |
| Vitavax Plus large | 178.3a | 40.34a | 1836a | **15.54C** | 35.33a | 67.53a | 5313a |
| Raxil. Small | 166.2a | 35.41a | 1443a | **15.81A** | 15.07a | 66.23a | 4854a |
| Raxil. Medium | 166.8a | 38.68a | 1249a | **15.58BC** | 34.97a | 67.53a | 4417a |
| Raxil. Large | 163.8a | 38.77a | 1518a | **15.62B** | 37.02a | 57.90a | 4844a |
| P≤ | Ns | Ns | Ns | ** | Ns | Ns | Ns |

See footnote of table 7.7

#### 7.3.2.7 Cultivar x fungicide x seed size interactions (AxBxC)

Statistically, cultivar x fungicide x seed variation was clearest in terms of seed protein content and also highly significantly. Seeds harvested from plants obtained from small seeded Gerardo, and treated with Raxil, measured highest in protein content (PC) and was followed by seeds harvested from plants obtained from medium and large seeds of the same cultivar, but treated with Vitavax Plus.

Plants grown from large sized control Kilinto seeds tillered best while Gerardo control plants from medium sized seeds tillered poorly. Orania plants from large seeds, treated with Vitavax Plus, and those from medium and large seeds treated with Raxil, had the lowest tiller plant$^{-1}$ count (TPP). Untreated control plants from large seeded Gerardo and small seeded Orania, as well as large seeded and medium seeded Orania treated with both Vitavax Plus and Raxil, had the lowest number of seeds spike$^{-1}$ (SPS). Results are presented in tables (7.13A and B).

Table 7.13A: Cultivar X fungicide X seed size interactions under field conditions (AxBxC)

| Variable | % SE | % SE of Germinated | RE Days | TPP | DH DAYS | DM DAYS | GFP DAYS | PH CM |
|---|---|---|---|---|---|---|---|---|
| Geardo Control Small | 58.50a | 67.00a | 15.63a | **5.875BCDEF** | 68.50a | 103.0a | 34.50a | 70.75a |
| Gerardo control medium | 65.25a | 75.75a | 15.68a | **4.400F** | 65.50a | 104.0a | 38.50a | 69.00a |
| Gerardo control Large | 73.00a | 83.75a | 14.98a | **5.450BCDEF** | 67.25a | 102.5a | 35.25a | 67.75a |
| Gererdo Vitavax small | 70.75a | 81.25a | 15.95a | **4.900CDEF** | 68.75a | 104.5a | 35.75a | 70.25a |
| Gerardo Vitavax medium | 73.25a | 83.00a | 16.90a | **5.525BCDEF** | 67.75a | 104.0a | 36.25a | 71.00a |
| Gerardo Vitavax large | 75.75a | 86.00a | 15.13a | **4.775CDEF** | 66.00a | 103.0a | 37.00a | 71.50a |
| Gerardo Raxil small | 68.25a | 80.75a | 15.90a | **4.850CDEF** | 67.00a | 104.8a | 37.25a | 71.25a |
| Gerardo Raxil Medium | 70.00a | 80.25a | 16.58a | **5.025CDEF** | 65.75a | 103.5a | 37.75a | 70.00a |
| Gerardo.Raxil large | 65.75a | 75.25a | 16.10a | **4.575EF** | 67.75a | 101.8a | 34.50a | 69.25a |
| Kilinto control small | 46.50a | 95.75a | 18.35a | **6.125ABCDEF** | 74.25a | 115.0a | 40.75a | 85.00a |
| Kilinto control medium | 39.75a | 71.50a | 17.55a | **7.650AB** | 72.25a | 114.0a | 41.75a | 85.00a |
| Kilinto control large | 37.75a | 80.75a | 17.13a | **8.375A** | 72.50a | 115.0a | 42.50a | 85.25a |
| Kilinto Vitavax small | 54.50a | 91.00a | 15.85a | **5.950ABCDEF** | 73.00a | 113.5a | 42.25a | 84.50a |
| Kilinto Vitavax medium | 55.75a | 92.00a | 16.00a | **6.000ABCDEF** | 70.50a | 113.0a | 43.00a | 85.25a |
| Kilinto Vitavax large | 48.25a | 83.00a | 15.10a | **7.250ABC** | 70.00a | 111.5a | 39.50a | 86.00a |
| Kilinto Raxil small | 46.25a | 74.75a | 16.50a | **7.200ABCD** | 72.00a | 114.5a | 42.50a | 85.25a |
| Kilinto Raxil medium | 46.75a | 81.25a | 17.08a | **5.850BCDEF** | 72.25a | 113.5a | 42.25a | 86.00a |
| Kilinto Raxil large | 50.50a | 89.75a | 15.78a | **6.900ABCDE** | 71.25a | 114.3a | 41.50a | 86.25a |
| Orania control small | 74.50a | 80.00a | 15.95a | **4.675EF** | 72.75a | 102.0a | 28.00a | 57.25a |
| Orania control medium | 74.00a | 78.25a | 15.63a | **4.925CDEF** | 72.00a | 102.5a | 30.50a | 58.75a |
| Orania control large | 76.00a | 81.50a | 16.33a | **4.725DEF** | 72.75a | 102.5a | 29.75a | 58.00a |
| Orania Vitavax small | 70.25a | 74.00a | 17.90a | **4.750DEF** | 74.25a | 101.0a | 26.75a | 52.25a |
| Orania Vitavax medium | 83.25a | 87.25a | 15.35a | **4.550EF** | 72.50a | 102.5a | 30.00a | 57.25a |
| Orania Vitavax large | 89.25a | 93.00a | 13.60a | **4.300F** | 71.75a | 103.0a | 31.25a | 55.00a |
| Orania Raxil small | 74.00a | 78.75a | 15.95a | **4.650EF** | 72.25a | 101.5a | 29.25a | 56.25a |
| Orania Raxil mediu | 82.25a | 86.25a | 17.40a | **4.300F** | 72.50a | 101.8a | 29.25a | 55.00a |
| Orania Raxil large | 79.00a | 83.25a | 15.55a | **4.350F** | 72.00a | 101.8a | 29.75a | 54.25a |
| P≤ | Ns | Ns | Ns | * | Ns | Ns | Ns | Ns |

Table 7.13B: Cultivar X fungicide X seed size interactions in durum wheat under field conditions continued **(AxBxC)**

| Variable | SPMS | **KPS** | GY Kg $ha^{-1}$ | % **PC** | TKM Gm | HLM Kg $hl^{-1}$ | ABGB Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Geardo Control Small | 174.3a | **35.42ABC** | 1588a | **15.90E** | 37.10a | 68.45a | 4938a |
| Gerardo control medium | 137.5a | **41.08ABC** | 1465a | **15.35J** | 39.63a | 69.20a | 4625a |
| Gerardo control Large | 198.3a | **50.18A** | 2283a | **15.80EF** | 37.60a | 68.55a | 6156a |
| Gererdo Vitavax small | 170.3a | **38.75ABC** | 1765a | **15.85EF** | 36.80a | 67.30a | 5406a |
| Gerardo Vitavax medium | 200.8a | **38.33ABC** | 2175a | **17.05B** | 40.25a | 70.15a | 6125a |
| Gerardo Vitavax large | 180.0a | **38.00ABC** | 2085a | **16.70C** | 37.95a | 69.85a | 5656a |
| Gerardo Raxil small | 163.0a | **42.23ABC** | 1636a | **17.23A** | 34.95a | 67.25a | 4688a |
| Gerardo Raxil Medium | 174.0a | **40.00ABC** | 1808a | **16.55D** | 41.15a | 69.40a | 5031a |
| Gerardo.Raxil large | 148.8a | **38.55ABC** | 1549a | **17.15AB** | 41.05a | 70.00a | 4344a |
| Kilinto control small | 140.8a | **28.75ABC** | 795a | **15.75F** | 45.18a | 70.10a | 4250a |
| Kilinto control medium | 142.5a | **29.38ABC** | 876a | **15.77F** | 49.53a | 69.50a | 4063a |
| Kilinto control large | 133.5a | **25.03C** | 514a | **15.48HI** | 40.10a | 70.20a | 3531a |
| Kilinto Vitavax small | 162.0a | **29.20ABC** | 953a | **15.18K** | 44.33a | 68.10a | 4531a |
| Kilinto Vitavax medium | 167.5a | **31.20ABC** | 973a | **15.27JK** | 42.95a | 69.10a | 4625a |
| Kilinto Vitavax large | 164.3a | **33.20ABC** | 1359a | **15.38IJ** | 39.15a | 67.95a | 4594a |
| Kilinto Raxil small | 164.5a | **29.08ABC** | 1021a | **15.55GH** | 42.45a | 67.45a | 4188a |
| Kilinto Raxil medium | 149.5a | **26.45BC** | 531a | **15.60G** | 35.90a | 69.50a | 3625a |
| Kilinto Raxil large | 172.5a | **29.88ABC** | 1383a | **15.50GH** | 40.95a | 69.75a | 4688a |
| Orania control small | 173.3a | **49.15A** | 1613a | **14.15N** | 28.00a | 63.25a | 4719a |
| Orania control medium | 177.8a | **41.20ABC** | 1451a | **14.95L** | 28.03a | 66.50a | 5219a |
| Orania control large | 177.8a | **47.20AB** | 1831a | **14.58M** | 28.63a | 63.85a | 5188a |
| Orania Vitavax small | 163.5a | **46.23ABC** | 1445a | **14.85L** | 28.50a | 64.45a | 4031a |
| Orania Vitavax medium | 188.0a | **40.80ABC** | 1683a | **14.00O** | 27.83a | 64.60a | 5250a |
| Orania Vitavax large | 190.5a | **49.83A** | 2064a | **14.55M** | 28.90a | 64.80a | 5688a |
| Orania Raxil small | 171.0a | **34.93ABC** | 1673a | **14.65M** | 27.80a | 64.00a | 5688a |
| Orania Raxil medium | 177.0a | **49.58A** | 1409a | **14.60M** | 27.85a | 63.70a | 4594a |
| Orania Raxil large | 170.0a | **47.88AB** | 1623a | **14.20N** | 29.05a | 63.95a | 5500a |
| P≤ | Ns | * | Ns | ** | Ns | Ns | Ns |

See footnote of table 7.7

### 7.3.2. 8 Correlation Matrix

Table 7.14 (appendix 3) represents a statistical correlation matrix for all measured parameters and for the three-durum wheat cultivars in terms of relationships between and within laboratory and field data. It shows that the above ground biomass correlated positively and significantly with both grain yield and number of spikes $m^{-2}$. Similarly, protein content correlated positively and significantly with thousand kernel and hectolitre masses. The same correlation between hectolitre mass and seedling fresh and dry masses, grain filling period, plant height and thousand kernels mass was observed.

Moreover, thousand kernel mass was also positively and significantly correlated with coleoptile length, seedling fresh and dry masses, days to 50% maturity, grain filling period and plant height. Grain yield correlated with germination percentage, seedling root length, seedling emergence, spikes $m^{-2}$ and kernels $spike^{-1}$. Kemels $spike^{-1}$ was also positively and significantly correlated with germination %, seedling root length, seedling emergence and spikes $m^{-2}$. Finally, plant height positively and highly significantly correlated with coleoptile and seedling lengths, seedling fresh and dry masses, tillers $plant^{-1}$, days to 50% maturity and with grain filling period.

On the other hand, protein content strongly but negatively correlated with days to 50% maturity while both hectolitre and thousand kernel masses correlated similarly with germination %. Grain yield negatively correlated with abnormal seedlings, coleoptile and seedling lengths as well as with days to 50% maturity. Number of kernels $spike^{-1}$ also negatively correlated with % abnormal seedlings, % dead seeds, coleoptile length, seedling length, seedling fresh mass, days to 50% maturity, grain filling period and plant height. Plant height in turn also negatively correlated with germination %, seedling root length and % emerged seedlings.

The grain filling period was negatively correlated with % germination and emerged seedlings. Days to 50% maturity very strongly and negatively correlated (-0.9328) with germination %, seedling root length and % seedling emergence.

## 7.4 Discussion

Seeds of the durum wheat cultivars, Orania and Gerardo, showed germination percentages of >80% and this is an acceptable level for commercial seed in accordance with the South African plant improvement act 1953 of 1976 (Sansor, 1996). Both of these cultivars also comply with the Ethiopian germination standards 85% for certified seeds (Ensermu *et al.*, 1999). However, Gerardo will not comply with the Kenyan germination standard of 90% (Wayera, 1999) while Orania will. The germination percentage of Kilinto seed was too low to meet any of the standards. This is due to weevil's damage for which Orania was included as a backup in case it totally failed to perform. Nevertheless, the performances of the three cultivars were further compared, under both controlled laboratory and field conditions, by using a number of parameters. Interestingly, the laboratory data corresponded well with the results obtained under field conditions, and this was probably a reflection of the genetic potential of the cultivars.

Although the germination capacity of Kilinto seeds was unacceptably low (56%), seedlings had the longest coleoptiles, compared to the other two cultivars. This is considered an attribute for seedlings to emerge from the soil with ease and those seeds that germinated performed well in this regard. Schillinger *et al.* (1998) reported that, in general, semi-dwarf wheat produced coleoptile lengths 30 to 40% shorter than did non semi-dwarfs and, hence, had problems in emerging particularly if planted deep as compared to taller varieties. However, despite the relatively long coleoptiles and probably because of the low germination percentage, Kilinto also measured low in terms of seedling emergence, and eventually total yield, which might leave a distorted impression of the genetic potential of this cultivar. The poor germination performance of Kilinto was most probably due to damage by weevils during storage and for this reason a South African cultivar, Orania, was included in the study. What is important to note, however, is that plants that were obtained from the seeds that germinated, measured significantly lower in terms of the number of seeds spike$^{-1}$, compared to the other two cultivars. This cannot be attributed to poor germination or emergence and must be considered as important when the commercial potential of the cultivar is finally evaluated.

The South African durum wheat cultivar, Orania, performed better than Gerardo in terms of both seed germination and seedling emergence. From this it was expected that it should also perform best in terms of final grain yield, but this was not the case. Moreover, Orania plants were the shortest of all and both the grain filling period and measured days to 50% maturity was shorter than that for Gerardo. However, the grains of Orania were the smallest and it also measured as the lowest in thousand kernels mass, compared to Gerardo. This is in agreement with the findings of Gale and Flintham (1962) who suggested that semi-dwarf cultivars derived from NORIN 10 and tom-thumb dwarfing genes are associated with an increased number of smaller grains per ear. The authors speculated that grain size is inter alia determined by the competition for nitrogen between tillers and also within grains on the same spike. The same explanation is given for differences in grain protein content that measured much lower in Orania grains compared to that of the larger grains of Gerardo. The most important factor to be noted here is the grain filling period. Orania did not have sufficient time to fill its grains and was unable to compete in yield with its counter part Gerardo. As a result, its grain size was significantly lower than the other two cultivars. Consequently, its thousand kernel mass was recorded far below the acceptable level of the South African standard grain size of about 40 grams (Mamuya, 2000). Kilinto was the only cultivar that meets to such a standard grain size. Gerardo was also superior to Orania in terms of hectolitre mass and performed as the highest of all in protein content.

In the Free State Province of South Africa, planting of spring wheat cultivars is always delayed to escape frost damage. On the other hand, delayed planting can be risky as residual soil moisture can be depleted at the later planting stage. As a result, the wheat crop can be exposed to very high spring or summer temperatures that may cause high yield losses (Labuschagne and Van Deventer, 1999). The temperature effect is even much more critical when it occurs just before or just after anthesis and the effect is more pronounced in small seeded (e.g. Orania) than large seeded (e.g. Gerardo) cultivars (Calderin *et al.*, 1999).

In general, taking all valuable measurements into account, Gerardo may deserve to be considered as one of the best durum wheat cultivars for the Bethlehem (Eastern Free State) area of the Republic of South Africa. Therefore, it is worthy of further investigation in terms of other yield limiting factors such as planting dates and seed rates, etc.

As far as the fungicide treatment effect is concerned, carboxin/thiram (Vitavax Plus) proved to be the best for it significantly improved seed germination, coleoptile length and fresh mass of seedlings in all durum wheat cultivars. This is in agreement with the findings of Purchase, *et al.* (1992) and also supports the fact that Vitavax Plus is one of the recommended fungicides for seed treatment in both Ethiopia and South Africa. However, tebuconazole (Raxil) highly reduced the coleoptile length of seedlings in all durum wheat cultivars. Some authors (Kollmorgen and Ballinger, 1975; Murrey and Kuiper, 1988) reported that certain fungicides have negative effects on the quality of seed when treated, and usage of the appropriate fungicide, as well as the rate at which it is administered, is critically important. Otherwise, the use of registered fungicide for seed treatment in wheat is a compulsory activity, for example, in South Africa (SANSOR, 1996).

It has been reported in the past that seed size is positively correlated with seedling vigour, especially among smaller-seeded cultivars (Cardwell, 1984), and that larger seeds produced higher yields than medium or small ones. However, other reports to the contrary have been published where claims were made that intermediate and smaller seed sizes were superior to the larger ones in this regard (Saxena *et al.*, 1980). Baalkai and Copeland (1997) found that wheat emergence was affected significantly by seed size but the protein content varied from year to year. No clear pattern is obvious which emphasizes the fact that each crop and even each cultivar considered for commercial production should be evaluated in terms of seed size.

Large sized seeds, from all durum wheat cultivars included in this study, were superior in terms of most of the parameters measured under both laboratory and field conditions. The most significant indications of the superiority of large seeds over medium and small ones were in terms of seedling emergence, seedling growth and root development (highest fresh and dry masses), short period to maturity and significantly higher grain yield. Small sized seeds were found significantly inferior to both medium and large sized seeds in quite large numbers of parameters measured. According to Thompson (1979), it is advisable to avoid small sized seeds as a propagating material. Instead there are possibilities of harvesting quality seeds mostly from early and timely planting (Alikhan, 1977). Early planting is a measure to escape drought conditions (Simane, 1993), also considered as a curative factor for producing small sized seeds. In addition to other possible farm management practices such as adequate soil drainage, especially in *vertisols* (Abebe *et al.*, 1994), suggested the selection of fertile soil and appropriate crop rotation systems are some of the best remedies that enable seed growers to produce large and plumb seeds.

When a number of variables were interacted, for instance, for cultivar by seed size interaction, there was no variation observed with in cultivar but only between cultivars for tillers per plant. However, this was not true for % protein content where large seeded Gerardo was superior to both other cultivars and seed sizes of its own type. On the contrary, large seeded Orania was the lowest of all with regard to this parameter (protein content). From the interaction of all three variables, untreated large seeded Kilinto tillered the best of all. However, the results were not clearly indicative in the case of kernels per spike. Obviously, there were distinctions of cultivar by seed size by fungicide interactions observed for protein content. Moreover, Gerardo seed treated with Raxil produced significantly higher protein content than all other treatments in the fungicide by seed size interaction variable. In this regard untreated large seeded Orania performed as the lowest of all in protein content.

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# CHAPTER 8

# EFFECT OF SEED TREATMENTS AND SOWING DEPTH ON SEED QUALITY AND YIELD OF TWO ETHIOPIAN AND ONE SOUTH AFRICAN DURUM WHEAT CULTIVARS


## Abstract

The effects of seed treatment and sowing depth on seed quality of different durum wheat cultivars were investigated under laboratory and field conditions. In the laboratory, a factorial experiment in randomized complete block design, with four replications, was used while in the field a split-plot design, where cultivars and fungicides were considered as main and sowing depth as sub-plots, was laid out. The aims of this study were: (1) to evaluate the effects of two fungicides viz. Vitavax Plus ® FS (carboxin/thiram) and Raxil ® ES (tebuconazole), as initial seed treatments, on seed quality and (2) determine the effect of planting at different depths, on emergence, yield and yield components. Orania, Gerardo and Kilinto seeds germinated at 94.5%, 87.2% and 56.3% respectively while seedling emergence was measured at 35.25%, 34.42% and 18.83%. Kilinto had significantly longer coleoptile and seedling lengths compared to the two semi-dwarfs. However, semi-dwarf cultivars produced significantly longer seedling roots while the root fresh mass was significantly higher than that of Kilinto. Vitavax Plus significantly improved germination percentage, seedling lengths, seedling fresh mass and seed protein content compared to untreated and Raxil treated seeds. Shallow planting at 5 cm performed significantly better than deep planting in terms of emergence, grain yield and above ground biomass. A highly significant difference in seed protein content was observed between treatments for all factors and interactions.



**Key words**: durum wheat, seed treatments, sowing depth, coleoptile, seed quality, germination and emergence

## 8.1 Introduction

Inadequate crop emergence remains a global constraint. Radford *et al.*, (1989) reported that establishment of winter cereals in Queensland, Australia, was so disappointing due to poor emergence that crops had to be ploughed in. More recently, Schillinger *et al.* (1998) reported that crop stand establishment under rainfed conditions is the most single important factor affecting winter wheat grain yield. This problem is much more accentuated in Sub Saharan African countries where soil moisture is in critical shortage accompanied by a very high evapo-transpiration rate. The Free State Province of South Africa is one of the leading wheat production regions in the country (Purchase, 1997). However, it is one of the less favourable dry land wheat production regions in the world, due to moisture stress factors. The soil moisture content in this region can be very low during the planting season (May to August ; Ybema, 1994) when only residual moisture from the summer rains is present. In order to take advantage of the available soil moisture, the average planting depth of wheat is forced to be as deep as 5.5 cm compared to the optimum planting depth of 3 cm for wheat under favourable conditions.

Schillinger *et al.* (1998) pointed out that semi-dwarf wheat cultivars have 30 to 40 percent shorter coleoptile lengths than tall types. Moreover, such cultivars are planted deep in dry land areas for sufficient soil moisture utilization. This problem is even more accentuated in farming areas of Ethiopia, where seeds are buried deeper than usual due to oxen ploughing and thick soil covering. As a result, seeding rate (150-200 kg $ha^{-1}$) for wheat is exceptionally high and compared with the seeding rate of 100-120 kg $ha^{-1}$ irrigated spring wheat in South Africa (Purchase *et al.*, 1992). The seeding rate for winter wheat cultivation under rainfed conditions in this country is even far less than this and ranges between 15-25 kg $ha^{-1}$.

In recent years the cultivation of semi-dwarf durum wheat cultivars have become popular (Singh and Rajaram, 1996). Mostly, semi-dwarf cultivars are associated with shorter coleoptile lengths (Allan *et al.*, 1962; Cornish, 1986). Consequently, seedling emergence is one of the constraints that wheat producers have to deal with.

In South Africa, wheat seed need to be treated with registered fungicides before it is certified (Sansor, 1996). Various fungal diseases are also problematic in high rainfall wheat growing regions of East Africa, including Ethiopia (Kidane, 1996) and their control through usage of high quality seeds and seed dressing with systemic fungicides is equally important.

In this study, the effects of two fungicides on seed germination, seedling emergence, yield and its components were evaluated in durum wheat cultivars at two sowing depths (5 cm and 9 cm).

## 8.2 Materials and Methods

Refer to chapter 3. Treatments for laboratory and field experiments are summarized in tables 8.1 and 8.2 respectively,

Table 8.1: List of treatments for durum wheat under laboratory conditiond (two factor RCBD)

| Cultivar | Treat no | Untreated | Treat no | Vitavax Plus 250 ml 100 kg$^{-1}$ | Treat no | Raxil 25 ml 100 kg$^{-1}$ |
|---|---|---|---|---|---|---|
| Gerardo | 1 | Control | 2 | " | 3 | " |
| Kilinto | 4 | " | 5 | " | 6 | " |
| Orania | 7 | " | 8 | " | 9 | " |

Table 8.2: List of treatments for durum wheat under field conditiond (split-plot) design

| No | Treatment | No | Treatment |
|---|---|---|---|
| 1 | Gerardo Control 5 cm | 2 | Gerardo control 9 cm |
| 3 | Gerardo Vitavax 5 cm | 4 | Gerardo Vitavax 9 cm |
| 5 | Gerardo Raxil 5 cm | 6 | Gerardo Raxil 9 cm |
| 7 | Kilinto control 5 cm | 8 | Kilinto control 9 cm |
| 9 | Kilinto Vitavax 5 cm | 10 | Kilinto Vitavax 9 cm |
| 11 | Kilinto Raxil 5 cm | 12 | Kilinto Raxil 9 cm |
| 13 | Orania control 5 cm | 14 | Orania control 9 cm |
| 15 | Orania Vitavax 5 cm | 16 | Orania Vitavax 9 cm |
| 17 | Orania Raxil 5 cm | 18 | Orania Raxil 9 cm |

## 8.3 Results

### 8.3.1 Data analysis of results obtained under laboratory conditions

Laboratory results obtained in this follow-up experiment were discussed in chapter seven. Therefore, results are neither presented nor discussed in the chapter to avoid redundancy. However, the tendencies identified in the previous trial will be considered in the discussion of this chapter.

### 8.3.2 Data analysis of results obtained under field conditions

### 8.3.2 Cultivar variations (A)

Statistical analysis of results revealed significant variation among cultivars for ten of the fourteen parameters measured under field conditions (Table 8.3A and B). Highly significant differences (at the p≤ 0.01 level) were observed for nine and significant differences (at p≤ 0.05) for one of the parameters. The highest yielding (GY) cultivar, Gerardo, was significantly earlier in seedling emergence rate (ER) and days to 50% heading (DH) compared to the other two cultivars. Significantly higher protein content (PC) was also measured for Gerardo than for Kilinto and Kilinto than for Orania. Moreover, Gerardo was also at equal level with Orania and superior to Kilinto in terms of emergence (SE), days to 50% maturity (DM) and number of spike $m^{-2}$ (SPMS). Although, seedlings of Orania emerged (SE) at almost the same rate as did the outstanding cultivar Gerardo, its performance in both grains yield (GY) and above ground bio mass (AGBM) was relatively lower than that of the two Ethiopian cultivars. It also measured as the lowest for most of the other parameters used to evaluate its field performance.

Table 8.3A: Cultivar variations in durum wheat under field conditions **(A)**

| Variable | % SE | % SE of Germinated | ER Days | TPP | DH DAYS | DM DAYS | GFP DAYS |
|---|---|---|---|---|---|---|---|
| Gerardo | **35.25A** | 40.50a | **15.52B** | **2.43B** | **77.92C** | **121.4B** | **43.50A** |
| Kilinto | **18.83B** | 34.25a | **16.55AB** | **3.31A** | **83.42A** | **126.3A** | **44.00A** |
| Orania | **34.42A** | 36.54a | **17.17A** | **2.39B** | **80.38B** | **119.8B** | **39.21B** |
| C.v. % | 50.16 | 48.8 | 7.8 | 54.2 | 3.8 | 1.94 | 7.97 |
| Mean | 29.5 | 37.1 | 16.4 | 2.71 | 80.6 | 125.5 | 42.2 |
| P≤ | ** | Ns | ** | * | ** | ** | ** |

Table 8.3B: Cultivar variations in durum wheat under field conditions continued **(A)**

| Variable | **PH** | SPMS | **KPS** | GY Kg $ha^{-1}$ | **% PC** | **TKM g** | AGBM Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Gerardo | **57.83B** | 30.13a | **36.67A** | 424.6a | **17.15A** | **33.71A** | 1739a |
| Kilinto | **66.96A** | 27.00a | **29.67B** | 368.0a | **16.21B** | **36.79A** | 1369a |
| Orania | **48.58C** | 25.21a | **38.58A** | 314.2a | **14.96C** | **26.17B** | 1351a |
| C.v. % | 9.5 | 63.5 | 25.9 | 84.51 | 0.8 | 13.1 | 65.6 |
| Mean | 57.4 | 27.4 | 37.97 | 368.9 | 16.1 | 32.2 | 1486.2 |
| P≤ | ** | Ns | ** | Ns | ** | ** | Ns |

**Abbreviations:** Ns = Non-significant, * = significant and ** = highly significant at P≤ 0.05 and P≤ 0.01 respectively. Any two or more means sharing the same letter are not significantly different at 5% probability level according to Tukey's mean separatin. ABGM= above ground bio mass; PC= protein content; TKM= thousand kernel mass; GY= grain yield; KPS= kernels per spike; SPMS=Seeds per meter square; PH = plant height; GFP =Grain filling period; DM = days to 50% maturity; DH = days to 50% heading; TPP= tillers per plant; ER = Emergence rate; ES = emereged seedlings; HLM = hectoliter mass

### 8.3.2. 2 Fungicide variations (B)

Statistical analysis of pooled data for all the different cultivars revealed, with the exception of seed protein content (PC), no significant differences in thirteen of the fourteen parameters (Tables 8.4A and B). Significantly higher protein content (PC) was measured in seeds harvested from plants grown from Vitavax Plus treated seeds. The protein content in seeds from plants grown from Raxil treated seeds did not differ from that of control. Although the statistical programme did not reveal significant differences between the final yield outcome of seeds initially treated with Vitavax and Raxil, the latter treatment reduced the yield by 34% on average.

Table 8.4A: Fungicide variations in durum wheat under field conditions **(B)**

| Variable | % SE | % SE of Germinated | ER Days | TPP | DH DAYS | DM DAYS | GFP DAYS |
|---|---|---|---|---|---|---|---|
| Control | 31.83a | 41.29a | 16.12a | 2.43a | 80.29a | 122.6a | 42.29a |
| Vitavax. Plus | 29.25a | 35.50a | 16.47a | 2.71a | 80.79a | 122.3a | 41.46a |
| Raxil | 27.42a | 34.50a | 16.65a | 3.00a. | 80.63a | 122.6a | 42.96a |
| P≤ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 8.4B: Fungicide variations in durum wheat under field conditions continued **(B)**

| Variable | PH | SPMS | KPS | GY Kg $ha^{-1}$ | **% PC** | TKM g | AGBM Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Control | 56.58a | 24.46a | 33.83a | 396.6a | **15.85B** | 32.67a | 1617a |
| Vitavax. Plus | 58.71a | 28.50a | 35.79a | 428.4a | **16.56A** | 31.75a | 1247a |
| Raxil | 58.08a | 29.38a | 35.29a | 281.8a | **15.90B** | 32.25a | 1594a |
| P≤ | Ns | Ns | Ns | Ns | ** | Ns | Ns |

See footnote of table 8.3

### 8.2.2.3 Cultivar x fungicide interactions (AxB)

Highly significant cultivar by fungicide interaction was also observed only for protein content (PC) (Tables 8.5A and B). Significantly higher seed protein content was obtained from Gerardo, initially treated with Vitavax plus and Raxil, while the lowest of all was from Orania, treated with Raxil. Seeds obtained from plants grown from Vitavax Plus and from Raxil treated Gerardo seeds showed a significant increase in protein content. In the case of Kilinto, Vitavax Plus treatment contributed to a slight increase in seed protein content while Raxil treated resulted in a decrease. The same tendency was observed in the South African durum wheat cultivar Orania, except that seed protein content improvement by Vitavax Plus was not as marked as for the Ethiopian cultivars. Once again the initial Raxil seed treatment decreased the final yield slightly in both Kilinto and Orania but the statistical programme considered this cultivar x fungicide interaction as non-significant.

Table 8.5A: Cultivar x fungicide interactions in durum wheat under field conditions **(AxB)**

| Variable | % SE | % SE of Germinated | ER Days | TPP | DH DAYS | DM DAYS | GFP DAYS |
|---|---|---|---|---|---|---|---|
| Gerardo Control | 34.13a | 39.13a | 15.79a | 2.10a | 77.88a | 121.5a | 43.62a |
| Gerardo Vitavax | 36.75a | 41.50a | 15.18a | 2.51a | 78.38a | 120.5a | 42.13a |
| Gerardo Raxil | 34.88a | 40.88a | 15.60a | 2.68a | 77.50a | 122.3a | 44.75a |
| Kilinto Control | 20.88a | 41.50a | 15.73a | 3.18a | 82.88a | 126.8a | 43.88a |
| Kilinto Vitavax | 16.50a | 28.63a | 17.53a | 3.10a | 84.13a | 126.5a | 42.63a |
| Kilinto Raxil | 19.13a | 32.63a | 16.41a | 3.66a | 83.25a | 125.8a | 45.50a |
| Orania control | 40.50a | 43.25a | 16.85a | 2.03a | 80.13a | 119.5a | 39.38a |
| Orania Vitavax | 34.50a | 36.38a | 16.70a | 2.51a | 79.88a | 120.0a | 39.63a |
| Orania Raxil | 28.25a | 30.00a | 17.95a | 2.64a | 81.13a | 119.8a | 38.63a |
| P≤ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 8.5B: Cultivar x fungicide interactions in durum wheat under field conditions **(AxB)**

| Variable | PH | SPMS | KPS | GY Kg $ha^{-1}$ | % PC | TKM G | AGBM Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Gerardo Control | 55.25a | 27.00a | 35.75a | 326.3a | **16.26C** | 36.38a | 2333a |
| Gerardo Vitavax | 60.50a | 31.13a | 37.00a | 453.6a | **17.55A** | 32.25a | 1389a |
| Gerardo Raxil | 57.75a | 32.25a | 37.25a | 494.0a | **17.63A** | 32.50a | 1496a |
| Kilinto Control | 66.63a | 29.25a | 30.25a | 513.4a | **16.17C** | 36.63a | 1347a |
| Kilinto Vitavax | 64.75a | 21.63a | 28.25a | 428.8a | **16.96B** | 36.88a | 958a |
| Kilinto Raxil | 69.50a | 30.13a | 30.50a | 161.9a | **15.49D** | 36.88a | 1801a |
| Orania control | 47.88a | 17.13a | 35.50a | 350.3a | **15.11E** | 25.00a | 1172a |
| Orania Vitavax | 50.88a | 32.75a | 42.13a | 402.8a | **15.16E** | 26.13a | 1394a |
| Orania Raxil | 47.00a | 25.75a | 38.13a | 189.5a | **14.60F** | 27.38a | 1486a |
| P≤ | Ns | Ns | Ns | Ns | ** | Ns | Ns |

See footnote of table 8.3

### 8.2.2.4 Sowing depth variations (C)

At different sowing depths, highly significant differences were observed for % seedling emergence (SE), emergence rate (ER), number of productive tillers plant$^{-1}$ (TPP), seed protein content (PC) and grain yield (GY) (Tables 8.6A and B) from statistical analysis of pooled data for all cultivars. However, protein content (PC) was significantly improved by deep rather than shallow planting. Planting seeds shallow (5 cm), significantly increased seedling emergence and subsequent grain yield. However, the protein content of seeds harvested from plants raised from seeds that were initially deep planted (9 cm), were significantly higher than those obtained from shallow planted ones.

Table 8.6A: Effect of sowing depth on specific parameters in durum wheat under field conditions **(C)**

| Variable | **% SE** | **% SE of Germinated** | **ER Days** | **TPP** | HD DAYS | MD DAYS | GFP DAYS |
|---|---|---|---|---|---|---|---|
| 5 cm | **38.72A** | **48.39A** | **15.67B** | **2.19B** | 80.08a | 122.2a | 42.58a |
| 9 cm | **20.28B** | **25.81B** | **17.16A** | **3.23A** | 81.06a | 122.8a | 41.89a |
| P≤ | ** | ** | ** | ** | Ns | Ns | Ns |

Table 8.6B: Effect of sowing depth on specific parameters in durum wheat under field conditions **(C)**

| Variable | PH CM | SPMS | SPS | **GY Kg ha$^{-1}$** | **% PC** | TKM g | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| 5 cm | 57.08a | 30.36a | 33.89a | **459.6A** | **15.79B** | 33.17a | 1410a |
| 9 cm | 58.50a | 24.53a | 36.06a | **278.3B** | **16.41A** | 31.28a | 1563a |
| P≤ | Ns | Ns | Ns | * | * | Ns | Ns |

See footnote of table 8.3

### 8.2.2.5 Cultivar x sowing depth interaction (AxC)

Statistically, highly significant cultivar by sowing depth interactions were only observed for protein content (PC), plant height and grain yield. The protein content of Gerardo seeds harvested from plants raised from shallow planted seeds was higher ($p \geq 0.01$) compared to the case where plants were raised from deep planted sesds. However, in the other two cultivars the protein content (PC) in seeds from deep planting was significantly higher than that from shallow planting. Interestingly, in the case of both Gerardo and Orania, plants from deeply planted seeds grew taller than the shallow planted ones. Shallow planting significantly reduced the final yield.

Table 8.7A: Cultivar x sowing depth interactions in durum wheat under field conditions **(AxB)**

| Variable | % SE | % SE of Germinated | ER Days | TPP | DH DAYS | DM DAYS | GFP DAYS |
|---|---|---|---|---|---|---|---|
| Gerardo 5 cm | 43.83a | 50.58a | 14.67a | 2.00a | 78.25a | 121.2a | 42.92a |
| Gerardo 9 cm | 26.67a | 30.42a | 16.38a | 2.86a | 77.58a | 121.7a | 44.08a |
| Kiliinto 5 cm | 23.83a | 43.00a | 15.83a | 2.88a | 82.75a | 126.0a | 44.75a |
| Kilinto 9 cm | 13.83a | 25.50a | 17.28a | 3.74a | 84.08a | 126.7a | 43.25a |
| Orania 5cm | 48.50a | 51.58a | 16.51a | 1.700a | 79.25a | 119.3a | 40.08a |
| Orania 9cm | 20.33a | 21.50a | 17.83a | 3.08a | 81.50a | 120.2a | 38.33a |
| P≤ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 8.7B: Cultivar x sowing depth interactions in durum wheat under field conditions **(AxB)**

| Variable | **PH** | SPMS | SPS | GY Kg ha$^{-1}$ | % **PC** | TKM G | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Gerardo 5 cm | **55.25CD** | 31.33a | 35.00a | 421.8a | **17.24A** | 33.75a | 1364a |
| Gerardo 9 cm | **60.42BC** | 28.92a | 38.33a | 427.5a | **17.05B** | 33.67a | 2114a |
| Kiliinto 5 cm | **68.50A** | 29.33a | 27.75a | 598.2a | **15.58D** | 39.17a | 1454a |
| Kilinto 9 cm | **65.42AB** | 24.67a | 31.58a | 137.8a | **16.83C** | 34.42a | 1284a |
| Orania 5cm | **47.50E** | 30.42a | 38.92a | 358.9a | **14.56F** | 26.58a | 1411a |
| Orania 9cm | **49.67DE** | 20.00a | 38.25a | 269.4a | **15.36E** | 25.75a | 1290a |
| P≤ | * | Ns | Ns | Ns | ** | Ns | Ns |

See footnote of table 8.3

### 8.2.2.6 Fungicide x sowing depth interactions (BxC)

Significant fungicide by sowing depth interaction was only observed for protein content (PC) (Tables 8.8A and B) where deeply planted seeds treated with Vitavax Plus and Raxil produced plants with higher seed protein than seeds obtained from the shallow planted ones. Although, statistically, final yield differences were not significant, highest yields were obtained from Vitavax Plus treated and shallow planted seeds compared to untreated controls and Raxil treated seeds.

Table 8.8A: Fungicide x sowing depth interactions in durum wheat under field conditions **(BxC)**

| Variable | % SE | % SE of Germinated | ER Days | TPP | HD DAYS | MD DAYS | GFP DAYS |
|---|---|---|---|---|---|---|---|
| Control 5 cm | 43.17a | 54.58a | 15.28a | 2.13a | 79.67a | 121.7a | 42.00a |
| Control 9 cm | 20.50a | 28.00a | 16.97a | 2.74a | 80.92a | 123.5a | 42.58a |
| Viitavax 5 cm | 37.08a | 44.75a | 15.68a | 2.23a | 80.17a | 122.3a | 42.17a |
| Vitavax 9 cm | 21.42a | 26.25a | 17.25a | 3.18a | 81.42a | 122.3a | 40.75a |
| Raxil 5 cm | 35.92a | 45.83a | 16.05a | 2.23a | 80.42a | 122.5a | 43.58a |
| Raxil 9 cm | 18.92a | 23.17a | 17.26a | 3.76a | 80.83a | 122.7a | 42.33a |
| P≤ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 8.8B: Fungicide x sowing depth interactions in durum wheat under field conditions **(BxC)**

| Variable | PH CM | SPMS | SPS | GY Kg ha$^{-1}$ | **% PC** | TKM G | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Control 5 cm | 57.17a | 30.67a | 33.33a | 492.5a | **16.23C** | 34.50a | 1210a |
| Control 9 cm | 56.00a | 18.25a | 34.33a | 300.8a | **15.47E** | 30.83a | 2024a |
| Viitavax 5 cm | 56.75a | 29.42a | 34.58a | 573.8a | **15.91D** | 32.50a | 1293a |
| Vitavax 9 cm | 60.67a | 27.58a | 37.00a | 282.9a | **17.21A** | 31.00a | 1201a |
| Raxil 5 cm | 57.33a | 31.00a | 33.75a | 312.5a | **15.24F** | 32.50a | 1725a |
| Raxil 9 cm | 58.83a | 27.75a | 36.83a | 251.1a | **16.57B** | 32.00a | 1463a |
| P≤ | Ns | Ns | Ns | Ns | ** | Ns | Ns |

See footnote of table 8.3

### 8.2.2.7 Cultivar x fungicide x sowing depth interactions (AxBxC)

According to the statistical analysis of variance procedure, significant cultivar by fungicide by sowing depth interaction was only apparent in terms of seed protein content (Tables 8.9A and B). Initial Raxil treatment tended to increase the protein content in seeds harvested from both Gerardo and Orania plants grown from deep planted seeds. This was not true for Kilinto. Vitavax Plus treatments had a similar effect as Raxil in seeds obtained from shallow planted Kilinto.

Table 8.9A: Cultivar x fungicide x sowing depth interactions in durum wheat under field conditions **(AxBxC)**

| Variable | % SE | % SE of Germinated | RE Days | TPP | HD DAYS | MD DAYS | GFP DAYS |
|---|---|---|---|---|---|---|---|
| Gerardo control 5 cm | 44.75a | 51.25a | 14.73a | 2.23a | 78.75a | 121.0a | 42.25a |
| Gerardo control 9 cm | 23.50a | 27.00a | 16.85a | 1.98a | 77.00a | 122.0a | 45.00a |
| Gerardo Vitavax 5 cm | 44.50a | 50.75a | 14.30a | 1.70a | 78.25a | 120.5a | 42.25a |
| Gerardo Vitavax 9cm | 29.00a | 32.25a | 16.05a | 3.33a | 78.50a | 120.5a | 42.00a |
| Gerardo Raxil 5 cm | 42.25a | 49.75a | 14.98a | 2..08a | 77.75a | 122.0a | 44.25a |
| Gerardo Raxil 9 cm | 27.50a | 32.00a | 16.23a | 3.28a | 77.25a | 122.5a | 45.25a |
| Kilinto control 5 cm | 24.00a | 47.50a | 15.20a | 3.30a | 82.25a | 125.5a | 43.25a |
| Kilinto control 9 cm | 17.75a | 35.50a | 16.25a | 3.05a | 83.50a | 128.0a | 44.50a |
| Kilinto Vitavax 5 cm | 19.50a | 33.75a | 16.78a | 2.65a | 83.50a | 126.5a | 43.00a |
| Kilinto Vitavax 9 cm | 13.50a | 23.50a | 18.28a | 3.55a | 84.75a | 126.5a | 42.25a |
| Kilinto Raxil 5 cm | 28.00a | 47.75a | 15.53a | 2.70a | 82.50a | 126.0a | 48.00a |
| Kilinto Raxil 9 cm | 10.25a | 17.50a | 17.30a | 4.63a | 84.00a | 125.5a | 43.00a |
| Orania control 5cm | 60.75a | 65.00a | 15.90a | 0.85a | 78.00a | 118.5a | 40.50a |
| Orania control 9cm | 20.25a | 21.50a | 17.80a | 3.20a | 82.25a | 120.5a | 38.25a |
| Orania Vitavax 5cm | 47.25a | 49.75a | 15.98a | 2.35a | 78.75a | 120.0a | 41.25a |
| Orania Vitavax 9cm | 21.75a | 23.00a | 17.43a | 2.68a | 81.00a | 120.0a | 38.00a |
| Orania Raxil 5cm | 37.50a | 40.00a | 17.65a | 1.90a | 81.00a | 119.5a | 38.50a |
| Orania Raxil 9cm | 19.00a | 20.00a | 18.25a | 3.38a | 81.25a | 120.0a | 38.75a |
| P≤ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 8.9B: Cultivar x fungicide x sowing depth interactions in durum wheat under field conditions **(AxBxC)** continued

| Variable | PH CM | SPMS | SPS | GY KG HA$^{-1}$ | % PC | TKM G | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Gerardo control 5 cm | 55.75a | 35.50a | 34.75a | 321.5a | **17.35B** | 39.25a | 1213a |
| Gerardo control 9 cm | 54.75a | 18.50a | 36.75a | 331.0a | **15.18FG** | 33.50a | 3453a |
| Gerardo Vitavax 5 cm | 57.25a | 27.75a | 34.00a | 402.8a | **17.40B** | 31.50a | 1287a |
| Gerardo Vitavax 9cm | 63.75a | 34.50a | 40.00a | 504.5a | **17.70B** | 33.00a | 1491a |
| Gerardo Raxil 5 cm | 52.75a | 30.75a | 36.25 | 541.0a | **16.98C** | 30.50a | 1593a |
| Gerardo Raxil 9 cm | 62.75a | 33.75a | 38.25a | 447.0a | **18.27A** | 34.50a | 1398a |
| Kilinto control 5 cm | 69.50a | 34.75a | 28.25a | 784.5a | **15.48F** | 39.25a | 1389a |
| Kilinto control 9 cm | 63.75a | 23.75a | 32.25a | 242.3a | **16.88C** | 34.00a | 1306a |
| Kilinto Vitavax 5 cm | 64.25a | 21.25a | 22.50a | 757.0a | **16.27D** | 40.25a | 1000a |
| Kilinto Vitavax 9 cm | 65.25a | 22.00a | 34.00a | 100.0a | **17.65B** | 33.50a | 917a |
| Kilinto Raxil 5 cm | 71.75a | 32.00a | 32.50a | 253.0a | **15.00G** | 38.00a | 1972a |
| Kilinto Raxil 9 cm | 67.25a | 28.25a | 28.50a | 70.8a | **15.98DE** | 35.75a | 1630a |
| Orania control 5cm | 46.25a | 21.75a | 37.00a | 371.5a | **15.88E** | 25.00a | 1029a |
| Orania control 9cm | 49.50a | 12.50a | 34.00a | 329.0a | **14.35H** | 25.00a | 1315a |
| Orania Vitavax 5cm | 48.75a | 39.25a | 47.25a | 561.8a | **14.05HI** | 25.75a | 1593a |
| Orania Vitavax 9cm | 53.00a | 26.25a | 37.00a | 243.8a | **16.27D** | 26.50a | 1194a |
| Orania Raxil 5cm | 47.50a | 30.25a | 32.50a | 143.5a | **13.75I** | 29.00a | 1611a |
| Orania Raxil 9cm | 46.50a | 21.25a | 43.75a | 235.5a | **15.45F** | 25.75a | 1361a |
| P≤ | Ns | Ns | Ns | Ns | ** | Ns | Ns |

See footnote of table 8.3

### 8.2.2.8 Correlation matrix

The statistical correlations of all parameter combinations are shown in a correlation matrix (Table 8.10; see Appendix). Grain yield showed positive but poor correlation for kernels spike$^{-1}$ (R=0.3208), spikes m$^{-2}$ (r=0.3353) and emergence (r= 0.3495). Coleoptile length showed positive and slight correlation with thousand kernel mass (r=0.5246) and plant height (r=0.6775) and significant correlation with days to 50% maturity (r=0.7358) while corelation with seedling dry mass (r=0.9447), seedling fresh mass (r=0.9846) and seedling length (r=0.9352) was highly significant. However, coleoptile length negatively correlated with seedling root fresh mass (r=-0.6605) and seedling root length (r=-0.7832). Seed size correlated poorly with emergence rate (r=0.4519), tillers plant$^{-1}$ (r=0.3717) and protein content (r=0.2414).

Among the most important factors considered, germination showed significant and strong positive correlation with seedling root fresh mass (r=0.7344) and with seedling root length (r=0.8545). Above ground biomass showed no relationship with any of the parameters.

## 8.4 Discussion

Although deep planting is commonly preferred to shallow planting in dry areas (Ybema, 1994), due to better utilization of soil moisture, this study presented contradicting results. Deeply planted seeds of the tall cultivar, Kilinto, produced plants that did not out-yield the semi-dwarf cultivar Gerardo. As the germination capacity of Kilinto seeds were very low due to weevil damage prior to fungicide treatment, not much must be read into this observation. Subsequently, the South African cultivar, Orania, was included as additional study material. Deep planting had a similar, albeit not as marked, yield reducing effect in the latter cultivar. No distinct effect of deep planting on plant heights was observed notwithstanding the fact that a severe drought was experienced in the Free State during October/November 1999.

Among the fungicides, Vitavax Plus highly increased germination percentage of seeds as well as coleoptile and seedling lengths, seedling fresh mass and the protein content of finally harvested seeds, although the differences were not significant compared to the Raxil treated seeds. Consequently, the Vitavax Plus treatment increased grain yields while the Raxil treatment decreased the final yield markedly in both Kilinto and Orania. However, the statistical programme used to analyse pooled data did not reveal this as significant. The latter is difficult to explain but probably shows that the statistical analysis of pooled data should be interpreted with caution. For example, when actual yield differences of 34% and even 60% are encountered, while this is not regarded as statistically significant in terms of statistical variation, one should caution when making recommendations. When the statistical programme compares data in terms of variation or interaction, differences that seem significant when directly compared as raw data might appear to be different but, statistically, and in terms of interaction, is not.

Coleoptile length is controlled by several factors of which the hereditory or genetic factor (Schillinger *et al.*, 1998) is regarded as the most important. Kilinto, for instance, was characterized by its significantly longer coleoptiles compared to that of the other two semi-dwarf cultivars. Coleoptile length can also be affected by a number of environmental factors. For example, the length of the coleoptile can be shortened when the seed is in direct contact with fertilizer at planting, by a shortage of soil moisture and by high temperature regimes (Smiley, *et al.*, 1996). Age of the seed can also determine the coleoptile length whereby old seeds produce seedlings with shorter coleoptiles compared to that from fresh seed. Moreover, some fungicides (e.g. Mancozeb) can have a shortening effect on coleoptile length as well as reduce and delay seedling emergence, even within the same planting season (Kollmorgen and Ballinger, 1975). **Similarly, Ybema (1994) also reported the application of fungicides like Baytan and Vicit led to shorter shoot lengths, lower emergence rates and lower final emergence percentages as well as an increase in phytotoxic symptoms.** Such problems arise and are aggravated when high dosages of fungicide is used for treating seeds and especially at high temperature regimes accompanied with moisture stress during planting time (Purchase *et al.*, 1999).

Shallow planting (5 cm) of durum wheat improved both seedling emergence and final yield, compared to deep planting. This is in contrast with the findings of Pritchard (1996) who reported that, in western Australia, chickpea seeds planted at 2.5 and 5 cm depths produced significantly less grain yield than did the 10 cm planted ones. It is clear that planting depth should be optimized for a specific crop and also for a specific region.

However, deep planting (9 cm) resulted in higher protein content in seeds at final harvest. According to Dexter *et al.* (1977), seed protein content in durum wheat is the major factor influencing cooking properties and for this reason improvement of seed protein content must be considered as important when optimizing cultivation practices. Although it is difficult to explain the correlation between sowing depth and protein content in seeds at harvest, it can be speculated that seedling roots from deep planted seeds should have had better access to the fertilizer banded below the seed at planting and probably also soil moisture. This could have at least contributed to the establishment of strong seedlings and a healthy plant, in which normal metabolism was optimized.

Despite the improvement of protein content in seeds harvested from plants obtained from deep planted seeds in this study, the average planting depth for wheat in the Free State region is about 5.5 cm (Ybema, 1994). From a yield perspective, it appears that farmers in this part of the world should stick to the shallower planting depth. For Ethiopian farmers, planting depth should be optimized under local conditions and in the different regions where durum wheat is cultivated. Results from this study at least indicated that planting depth is an important factor that should be considered when optimizing cultivation practices for Ethiopian durum wheat cultivars.

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# CHAPTER 9

# EFFECT OF SEED SIZE AND TREATMENTS ON SEED QUALITY AND YIELD OF ETHIOPIAN FABA BEAN CULTIVARS


## Abstract

The main objective of this study was to evaluate the performance of different seed sizes of two selected Ethiopian faba bean cultivars, namely Kuse (small seed sized) and Cs 20dk (large seed sized), also treated with different fungicides, by applying seed quality parameters under laboratory and field conditions. A three-factor randomized complete block design, with four replications, was used. Laboratory and field trials were conducted at the Small Grain Institute, Bethlehem, South Africa in 1999/2000. Significant differences between cultivars were observed and both medium and large seeds of Kuse were superior to that of Cs 20dk in terms of germination capacity, seedling fresh and root dry masses but inferior with regard to epicotyl length. Generally, large sized seeds outperformed small sized ones in terms of a number of quality parameters, under field conditions. Germination percentage, after treatment with the fungicide Dividend, was significantly improved compared to treatment with Celest. Moreover, field performance was predictable from laboratory results.



**Key words:** faba beans, seed size, seed treatments, seed quality, germination, emergence yields and yields components


## 9.1 Introduction

Faba bean is a valuable protein-rich food that has sustained large human populations in the past and provides an alternative to soybean meal for animal feed in temperate regions (Bond *et al.*, 1994). According to the authors, the area under faba bean cultivation in the world has declined and this is partly ascribed to unreliable yields. Seed treatment with fungicides protects the seedlings from seed borne and soils borne fungal pathogens and is seen as the only possible way to circumvent the problem of low yields.

Seed size is an important factor that should be considered when optimizing cultivation practices for faba bean. Small sized lupine seeds, planted at the same plant density in drier regions of western Australia, was reported to produce lower yields than large sized ones (Jarvis, 1996). Similarly, Elemey (1993) reported that the dry weight of seedlings obtained from larger faba bean seeds were higher than from smaller ones. On the other hand, in some pulse crops such as soybeans and lentils, some authors (Waldia *et al.*, 1988; Bejiga, *et al.*, 1995) favoured medium size seeds to large or small ones. Similarly, Srimathi *et al.* (1991) found that amongst three seed size groups, medium sized seeds of *Acacia mellifera* gave peak values for viability measured as maximum germination and vigour in terms of root growth and vigour index.

Stelling *et al.* (1994) reported that production of high quality seed from large seeded, white flowered *V. faba* cultivars, remained problematic. It is also the contention of some seed specialists that large sized seeds are liable to more mechanical damage than medium or small ones during harvesting and seed processing. This study was initiated to evaluate the quality of seeds harvested from plants of two faba bean cultivars, obtained from three different seed sizes and additionally treated with fungicides.

## 9.2 Materials and Methods

### 9.2.1 Materials

Two of the Ethiopian faba bean cultivars, viz. Kuse and Cs 20dk, were obtained from the Ethiopian National Seed Industry Agency.

### 9.2.2 Methods

Procedures followed were in accordance with the International Rules for Seed Testing (ISTA, 1999) and that of the training manual for seed analysts, National Department of Agriculture (2000). Germination and subsequent seedling measurements were taken under controlled conditions in the laboratory using sand as the medium for growth. Please refer to chapter 3, section 3.2.2, for the details. Treatments that are specific to this chapter were similar under both laboratory and field conditions and is shown in Table 9.1.

Table 9.1 List of faba bean treatments for both laboratory and field experiments

| Cultivar | Seed size mean Mass/seed (g) | Treat. No | Control | Treat. No | Celest Xl 030 FS 200 ml 100 $kg^{-1}$ | Treat. No | Dividend 035 FS 200 ml 100 $kg^{-1}$ |
|---|---|---|---|---|---|---|---|
| Kuse | Small <0.35 | 1 | " | 2 | " | 3 | " |
| | Medium 0.35 to 0.55 | 4 | " | 5 | " | 6 | " |
| | Large >0.55 | 7 | " | 8 | " | 9 | " |
| Cs 20dk | Small < 0.5 | 10 | " | 11 | " | 12 | " |
| | Medium 0.5 to 0.65 | 13 | " | 14 | " | 15 | " |
| | Large > 0.65 | 16 | " | 17 | " | 18 | " |

## 9.3 Results

### 9.3.1 Analysis of data obtained under laboratory conditions

#### 9.3.1.1 Cultivar variations (A)

Highly significant differences between the two cultivars were observed for epicotyl length (EL) and seedling lengths (SL) at $P \leq 0.01$ and seedling fresh mass (SFM) at $P \leq 0.05$. Kuse significantly outperformed Cs 20dk for these three parameters measured (Table 9.2).

Table 9.2: Efect of cultivar variation in faba bean on specific parameters under laboratory conditions **(A)**

| Variable | Ger % | % Abs. | **El mm** | **Sl mm** | Srl mm | **Sfm mg** | Sdm mg | Srfm mg | Srdm Mg |
|---|---|---|---|---|---|---|---|---|---|
| Kuse | 96.6a | 2.7a | **181A** | **203A** | 143a | **1112A** | 112a | 618a | 142a |
| Cs 20dk | 97.1a | 2.2a | **151B** | **173B** | 139a | **1037B** | 112a | 655a | 138a |
| C.v. % | 2.08 | 72.01 | **11.19** | **10.49** | 6.8 | **14.7** | 13.0 | 17.5 | 21.4 |
| Mean | 96.8 | 2.44 | **166** | **188** | 141 | **1074** | 112 | 637 | 140 |
| P≥ | Ns | Ns | ** | ** | Ns | * | Ns | Ns | Ns |

**Abbreviations:**

Ns = Non-significant, * = significant and ** = highly significant at $P \leq 0.05$ and $P \leq 0.01$ respectively. Any two or more means sharing the same letter are not significantly different at 5% probability level according to Tukey's mean separation test. Statistically significant differences are indicated in bold and capital letters. Ger = germination; Abs = abnormal seedling; El = Epicotyl length ; Sl = seedling length ; Srl = seedling root length ; Sfm = seedling fresh mass ; Sdm = seedling dry mass ; Srdm = seedling dry mass ; mm = millimeter ; mg = milligram ; Lsd = least significant difference ; C.v. = coefficient of variance

### 9.3.1.2 Seed size variation (B)

For pooled data of both cultivars, the germination (GER) percentage of large and medium sized seeds was significantly higher than that of the small seeds. As a result, the percentage of abnormal seedlings (ABS) from large and medium sized seeds was significantly reduced. Similarly, the seedling drymass (SDM) and seedling root dry mass (SRDM) of seedlings grown from large sized seeds were statistically higher than that from medium and small sized seed. However, the epicotyl length (EL) and seedling length (SL) of seedlings grown from small sized seeds were significantly longer than that from medium and large sized seeds. Results were non-significant for the rest of the parameters measured (Table 9.3).

Table 9.3 Effect of seed size variations in faba bean on specific parameters (mean of two cultivars) **(B)**

| Variable | **Ger %** | % **Abs.** | **El mm** | **Sl mm** | Srl mm | Sfm mg | **Sdm mg** | Srfm mg | **Srdm Mg** |
|---|---|---|---|---|---|---|---|---|---|
| Smalll | **94.8B** | **3.83A** | **186A** | **210A** | 143a | 1067a | **98C** | 618a | **123B** |
| Medium | **98.0A** | **1.83B** | **165B** | **186B** | 142a | 1052a | **112B** | 620a | **142AB** |
| Large | **97.8A** | **1.67B** | **147C** | **170C** | 140a | 1103a | **125A** | 672a | **154A** |
| P≥ | * | * | ** | ** | Ns | Ns | ** | Ns | ** |

See footnote of table 9.2

### 9.3.1.3 Cultivar x seed size interactions (AxB)

Statistically significant cultivar x seed size variation was only found in one of the nine parameters measured, namely seedling root dry mass (SRDM) (Table 9.4). Significantly lower root mass (SRDM) was obtained in seedlings grown from small sized seeds and for both cultivars.

Table 9.4 Cultivar x seed size interactions in faba bean mean of two cultivars **(AxB)**

| Variable | Ger % | % Abs. | El Mm | Sl Mm | Srl Mm | Sfm mg | Sdm Mg | Srfm mg | **Srdm Mg** |
|---|---|---|---|---|---|---|---|---|---|
| Kuse small | 94.7a | 4.17a | 198a | 224a | 143a | 1097a | 95a | 606a | **119B** |
| Medium | 98.2a | 1.67a | 185a | 205a | 146a | 1130a | 115a | 616a | **157A** |
| Large | 96.8a | 2.33a | 159a | 181a | 141a | 1110a | 125a | 636a | **150AB** |
| Cs20dk small | 94.8a | 3.50a | 173a | 196a | 142a | 1038a | 100a | 630a | **128AB** |
| Medium | 97.8a | 2.00a | 144a | 166a | 138a | 975a | 110a | 626a | **127AB** |
| Large | 98.7a | 1.00a | 135a | 158a | 1138a | 1097a | 125a | 708a | **158A** |
| P≥ | Ns | Ns | Ns | Ns | Ns | Ns | Ns | Ns | * |

See footnote of table 9.2

### 9.3.1.4 Fungicide variations (C)

Fungicidal variations were observed for only seed germination (GER) and abnormal seedlings (ABS). Compared to seed treatment with Celest, Dividend treatment significantly improved germination (GER) percentage at the P≥0.05 level when data for the two cultivars was pooled. However, more abnormal seedlings (ABS) were observed for the untreated control than for the two fungicide treatments (Table 9.5).

Table 9.5 Effect of fungicide treatment on specific parameters in faba bean (mean of two cultivars) **(C)**

| Variable | Ger % | % Abs. | El mm | Sl mm | Srl mm | Sfm mg | Sdm mg | Srfm mg | Srdm Mg |
|---|---|---|---|---|---|---|---|---|---|
| Control | **96.7AB** | **7.5A** | 167a | 189a | 138a | 1084a | 111a | 660a | 146a |
| Celest | **96.1B** | **5.5B** | 163a | 186a | 144a | 1044a | 109a | 599a | 129a |
| Dividend | **97.8A** | **5.3B** | 167a | 189a | 142a | 1094a | 115a | 650a | 144a |
| P≥ | * | * | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

See footnote of table 9.2

### 9.3.1.5 Cultivar x fungicide and seed size X fungicide interactions (AxB)

No statistically significant cultivar x fungicide or seed size x fungicide interactions were observed (results not shown)

### 9.3.1.6 Cultivar x fungicide x seed size interactions (A x B x C)

Statistically significant differences, at the $P \leq 0.05$ level, were observed for two of the nine parameters measured (Table 9.6) indicating at least some cultivar x fungicide x seed size interaction. Statistically, longer seedlings (SL), or for that matter larger seedlings, were obtained from untreated small sized seeds of Kuse. Large sized and Dividend treated seeds of Cs 20dk produced the smallest seedlings. As could be expected, the same tendency was observed for seedling fresh mass.

Table 9.6: Cultivar x fungicide x seed size interactions on faba bean under laboratory conditions **(A x B x C)**

| Treatments | Ger % | % Abs. | El Mm | **Sl Mm** | Srl Mm | **Sfm Mg** | Sdm mg | Srfm mg | **Srdm Mg** |
|---|---|---|---|---|---|---|---|---|---|
| Kuse small control | 93.5a | 5.00a | 208a | **236A** | 143a | **1189AB** | 98a | 634a | 109a |
| Kuse small celest | 95.0a | 4.00a | 194a | **221AB** | 148a | **1099ABCD** | 94a | 616a | 118a |
| Kuse small Dividend | 95.5a | 3.50a | 193a | **215ABC** | 140a | **1001BCD** | 95a | 568a | 132a |
| Kuse medi control | 98.0a | 1.50a | 191a | **213ABC** | 142a | **1154AB** | 115a | 638a | 163a |
| Kuse medi celest | 99.0a | 1.50a | 190a | **209ABCD** | 145a | **1139ABC** | 116a | 607a | 160a |
| Kuse medium dividend | 97.5a | 2.00a | 174a | **195ABCDE** | 150a | **1096ABCD** | 115a | 593a | 149a |
| Kuse large control | 97.5a | 2.00a | 151a | **172BCDE** | 134a | **1016BCD** | 119a | 589a | 157a |
| Kuse large celest | 95.0a | 3.50a | 156a | **175BCDE** | 145a | **1031BCD** | 119a | 548a | 125a |
| Kuse larg dividend | 98.0a | 1.50a | 170a | **198ABCDE** | 145a | **1283A** | 137a | 772a | 168a |
| Cs 20dk small conl | 95.5a | 3.00a | 175a | **199ABCDE** | 135a | **1050BCD** | 100a | 645a | 127a |
| Cs 20dk small celest | 93.5a | 4.50a | 175a | **196ABCDE** | 151a | **1012BCD** | 97a | 612a | 131a |
| Cs 20dk small dividend | 95.5a | 3.00a | 169a | **192ABCDE** | 140a | **1054BCD** | 102a | 633a | 125a |
| Cs 20dk medicontrol | 97.5a | 2.50a | 134a | **154E** | 137a | **901D** | 104a | 659a | 149a |
| Cs 20dk medium celest | 96.0a | 3.50a | 136a | **159DE** | 138a | **920CD** | 106a | 588a | 112a |
| Cs 20dk medium dividend | 100.0a | 0.00a | 163a | **184ABCDE** | 141a | **1104ABCD** | 119a | 633a | 122a |
| Cs 20dk large control | 98.0a | 1.50a | 142a | **163CDE** | 138a | **1197AB** | 133a | 797a | 174a |
| Cs 20dk large celest | 98.0a | 1.50a | 130a | **158DE** | 139a | **1061ABCD** | 122a | 624a | 128a |
| Cs 20dk large dividend | 100.0a | 0.00a | 134a | **153E** | 139a | **1032BCD** | 122a | 704a | 172a |
| P≥ | Ns | Ns | Ns | * | Ns | * | Ns | Ns | Ns |

See footnote of table 9.2

### 9.3.2 Analysis of data obtained under field conditions

#### 9.3.2.1 Cultivar variations (A)

The field performance of the two-faba bean cultivars was evaluated using eighteen parameters. Statistically significant differences between cultivars were observed for only six of the eighteen parameters measured (Table 9.7A and B). Kuse was significantly superior to Cs 20dk in terms of number of seedlings that emerged (ES), plants $m^{-2}$ (PPMS), grain yield (GY) and above ground bio mass (AGBM). However, Cs 20dk plants tended to form significantly more branch $plant^{-1}$ (BPP) than did Kuse.

Table 9.7A: Effect of cultivar variations in faba bean on specific cultivars in terms of seed size and fungicide treatments under field conditions **(A)**

| Variable | % ES | % EG | PPMS | RE Days | DF DAYS | DM DAYS | GFP | PH Cm |
|---|---|---|---|---|---|---|---|---|
| Kuse | **79.11A** | **81.83A** | **21.97A** | 21.68a | 53.72a | 110.94a | 57.22a | 53.72a |
| Cs 20dk | **53.94B** | **55.42B** | **14.94B** | 21.70a | 54.72a | 111.31a | 56.56a | 54.72a |
| P≥ | ** | ** | ** | Ns | Ns | Ns | Ns | Ns |
| C.v. % | 16.35 | 16.87 | 16.34 | 2.80 | 4.46 | 2.57 | 5.99 | 4.46 |
| Mean | 66.53 | 68.63 | 18.46 | 21.69 | 54.22 | 111.13 | 56.89 | 54.22 |

Table 9.7B: Effect of cultivar variations in faba bean on specific cultivars in terms of seed size and fungicide treatments under field conditions (contibued) **(A)**

| Variable | **BPP** | PPP | SPP | **GY Kg $ha^{-1}$** | % PC | HKM g | **AGBM Kg $ha^{-1}$** |
|---|---|---|---|---|---|---|---|
| Kuse | **1.25B** | 3.172a | 2.115a | **663A** | 20.27a | 44.23a | **3766A** |
| Cs 20dk | **1.500A** | 2.947a | 2.103a | **404B** | 19.73a | 44.73a | **2678B** |
| P≥ | ** | Ns | Ns | ** | Ns | Ns | * |
| C.v % | 17.86 | 61.29 | 27.11 | 76.42 | 13.19 | 15.02 | 59.14 |
| Mean | 1.377 | 3.060 | 2.109 | 533.611 | 20.00 | 44.48 | 3222 |

**Abbreviations:** ES =emerged seedlings; EG =emerged seedlings of germinated seeds; RE =rate of emergence; PPMS =plants per meter square; DF =days to 50% flowering; DM =days to 50% maturity; GFP =grain filling period; PH =plant height; BPP =branches per plant; PPP =pods per plant; GY =grain yield; PC =protein content; HKM =hundred kernel mass; AGBM = above ground bio-mass; SPP =seeds per pod; cm = centimetre, ha = hectare; Kg= kilogram; g = gram.

#### 9.3.2.2 Seed size variation (B)

Statistical analysis of pooled data of the two cultivars revealed that plants grown from large seeds outperformed those from small sized seeds in terms of % emerged seedlings (ES) and plants $m^{-2}$ (PPMS) (Table 9.8A and B). Moreover, these plants flowered earlier (DF), were slower to fill grains (GFP), but produced seeds with higher hundred kernels mass (HKM). Although not significantly, large sized seeds outperformed medium and small sized ones in terms of the final grain yield (GY) harvested as well as above ground bio mass yield (AGBM).

Table 9.8A: Effect of seed size variations on specific parameters in faba bean under field conditions **(B)**

| Variable | **% ES** | % EG | **PPMS** | RE Days | **DF DAYS** | DM DAYS | **GFP** | **PH Cm** |
|---|---|---|---|---|---|---|---|---|
| Small | **61.50B** | **65.04B** | **17.08B** | 21.61a | **55.08A** | 110.25a | **55.13B** | **55.08A** |
| Medium | **65.58AB** | **66.83AB** | **18.21AB** | 21.71a | **54.33AB** | 11.58a | **57.25AB** | **54.33AB** |
| Large | **72.50A** | **74.00A** | **20.08A** | 21.76a | **53.25B** | 111.54a | **58.29A** | **53.25B** |
| P≥ | ** | * | ** | Ns | * | Ns | ** | * |

Table 9.8B: Effect of seed size variations on specific parameters in faba bean under field conditions **(B)** (continued)

| Variable | BPP | PPP | SPP | GY K $ha^{-1}$ | % PC | **HKM g** | AGBM Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Small | 1.314a | 2.758a | 2.197a | 437.6a | 19.95a | **40.97B** | 2721a |
| Medium | 1.413a | 3.217a | 2.012a | 536.9a | 20.11a | **45.62AB** | 3183a |
| Large | 1.404a | 3.204a | 2.117a | 626.3a | 19.93a | **46.85A** | 3762a |
| P≥ | Ns | Ns | Ns | Ns | Ns | * | Ns |

See footnote of table 9.7

#### 9.3.2.3 Cultivar x seed size interactions (A x B)

Statistical analysis revealed significant cultivar x seed size variation in terms of seedling emergence (ES), plants $m^{-2}$ (PPMS) and seeds $pod^{-1}$ (SPP) (Tables 9.9A and B). The large sized seeds of Cs 20dk significantly outperformed both medium and small sized seeds of this cultivar with regard to the mentioned parameters, except for seeds $pod^{-1}$ where small seeds developed into plants having more seeds per pod. Contrary to these results, small sized seeds of the cultivar Kuse performed better than medium and large sized seeds in terms of the first two parameters mentioned above, but not for number of seeds pod$^{-1}$, where plants grown from large seeds produced more seeds per pod.

Table 9.9A: Cultivar x seed size interactions in faba bean under field conditions (A x B)

| Variable | % ES | % EG | PPMS | RE Days | DF DAYS | DM DAYS | GFP | PH Cm |
|---|---|---|---|---|---|---|---|---|
| Kuse small | **78.67AB** | **83.33A** | **21.83AB** | 21.38a | 54.42a | 109.75a | 55.33a | 54.42a |
| Medium | **80.17A** | **81.58A** | **22.33A** | 21.77a | 53.08a | 110.83a | 57.75a | 53.08a |
| Large | **78.50AB** | **80.58AB** | **21.75AB** | 21.90a | 53.67a | 112.25a | 58.58a | 53.67a |
| Cs 20dk Sml | **44.33C** | **46.75C** | **12.33C** | 21.84a | 55.75a | 110.75a | 54.92a | 55.75a |
| Medium | **51.00C** | **52.08C** | **14.08C** | 21.65a | 55.58a | 112.33a | 56.75a | 55.58a |
| Large | **66.50B** | **67.42B** | **18.42B** | 21.62a | 52.83a | 110.83a | 58.00a | 52.83a |
| P≥ | ** | ** | * | Ns | Ns | Ns | Ns | Ns |

Table 9.9B: Cultivar x seed size interactions in faba bean under field conditions (A x B)

| Variable | BPP | PPP | SPP | GY K ha$^{-1}$ | % PC | HKM g | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Kuse small | 1.145a | 2.525a | **2.019AB** | 464.0a | 19.73a | 39.18a | 2766a |
| Medium | 1.250a | 3.783a | **1.950AB** | 719.8a | 20.08a | 45.31a | 4074a |
| Large | 1.367a | 3.208a | **2.375A** | 804.5a | 20.99a | 48.20a | 4456a |
| Cs 20dk small | 1.483a | 2.992a | **2.375A** | 411.3a | 20.18a | 42.76a | 2676a |
| Medium | 1.575a | 2.650a | **2.075AB** | 353.9a | 20.14a | 45.93a | 2292a |
| Large | 1.442a | 3.200a | **1.858B** | 448.2a | 18.87a | 45.49a | 3067a |
| P≥ | Ns | Ns | * | Ns | Ns | Ns | Ns |

See footnote of table 9.7

### 9.3.2.4 Fungicide variations (C)

There was no significant variation among the fungicides (results not shown).

### 9.3.2.5 Cultivar x fungicide interaction (A x C)

Significant cultivar x fungicide variation (at $P \leq 0.05$) was observed for only three of the eighteen parameters measured (Table 9.10A and B). Celest significantly prolonged the flowering period (DF) of Cs 20dk and increased its plant height (PH). Celest treatment also significantly prolonged the grain-filling period (GFP) of Kuse. Dividend treatment had no significant effect on the performance of seeds from different cultivars.

Table 9.10A: Cultivar x fungicide interactions in faba bean under field conditions **(A x C)**

| Variable | % ES | % EG | PPMS | RE Days | **DF DAYS** | DM DAYS | **GFP** | **PH Cm** |
|---|---|---|---|---|---|---|---|---|
| Kuse control | 78.67a | 81.67a | 21.83a | 21.84a | **54.83AB** | 111.00a | **56.17AB** | **54.83AB** |
| Celest | 76.17a | 78.58a | 21.17a | 21.73a | **53.17B** | 111.75a | **58.58A** | **53.17B** |
| Dividend | 82.50a | 85.25a | 22.92a | 21.48a | **53.17B** | 110.08a | **56.92AB** | **53.17B** |
| Cs 20dk control | 55.67a | 57.33a | 15.42a | 21.68a | **53.83B** | 111.25a | **57.42AB** | **53.83B** |
| Celest | 48.67a | 50.58a | 13.58a | 22.01a | **56.00A** | 111.00a | **54.92B** | **56.00A** |
| Dividend | 57.50a | 58.33a | 15.83a | 21.43a | **54.33AB** | 111.67a | **57.33AB** | **54.33AB** |
| P≥ | Ns | Ns | Ns | Ns | * | Ns | * | * |

Table 9.10B: Cultivar x fungicide interactions in faba bean under field conditions **(A x C)**

| Variable | BPP | PPP | SPP | GY K $ha^{-1}$ | % PC | HKM g | AGBMKg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Kuse control | 1.287a | 3.425a | 2.153a | 721.2a | 20.65a | 45.31a | 4271a |
| Celest | 1.258a | 3.358a | 2.175a | 590.8a | 20.54a | 44.65a | 3715a |
| Dividend | 1.217a | 2.733a | 2.017a | 676.4a | 19.60a | 42.73a | 3310a |
| Cs 20dk contr | 1.533a | 2.950a | 2.092a | 455.7a | 20.13a | 45.18a | 2986a |
| Celest | 1.475a | 2.858a | 2.000a | 276.8a | 19.62a | 43.99a | 1736a |
| Dividend | 1.492a | 3.033a | 2.217a | 480.8a | 19.44a | 45.02a | 3312a |
| P≥ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

See footnote of table 9.7

### 9.3.2.6 Seed size x fungicide variation (B x C)

No significant seed size x fungicide interaction was observed (results not shown).

### 9.3.2.7 Cultivar x fungicide x seed size variation (A x B x C)

Some, rather weak, cultivar x fungicide x seed size variation was observed (Table 9.11A and B). Small sized Cs 20dk seeds, treated with Celest, produced taller plants (PH) but which showed a slight delay in flowering. On the other hand, medium sized Kuse seeds, treated with Dividend, produced shorter plants which flowered earlier. No real pattern was apparent. Plants grown from large sized Kuse seeds, treated with Celest, showed delayed maturity- (DM) as well as grain filling periods (GFP) while small sized seeds treated with Dividend tended to experience shortened periods during the maturity phase.

Table 9.11A: Cultivar X fungicide X seed size interactions in faba bean under field conditions **(A X B X C)**

| Variable or treatments | % ES | % EG | PPMS | RE Days | DF DAYS | DM DAYS | GFP | PH Cm |
|---|---|---|---|---|---|---|---|---|
| Kuse small control | 78.00a | 83.50a | 21.50a | 21.37a | **54.75AB** | **112.5AB** | 57.75ABC | **54.75AB** |
| Kuse small celest | 82.00a | 86.50a | 22.75a | 21.56a | **52.75AB** | **109.3BC** | 56.50ABCDE | **52.75AB** |
| Kuse small dividend | 76.00a | 80.00a | 21.25a | 21.20a | **55.75AB** | **107.5C** | 51.75E | **55.75AB** |
| Kuse medium control | 78.50a | 79.75a | 22.00a | 22.01a | **55.75AB** | **109.8ABC** | 54.00CDE | **55.75AB** |
| Kuse medium celest | 76.50a | 77.25a | 21.25a | 21.80a | **52.75AB** | **112.3AB** | 59.50A | **52.75AB** |
| Kuse medium dividend | 85.50a | 87.75a | 23.75a | 21.50a | **50.75B** | **110.5ABC** | 59.75A | **50.75B** |
| Kuse large control | 79.50a | 81.75a | 22.00a | 22.15a | **54.00AB** | **110.8ABC** | 56.75ABCD | **54.00AB** |
| Kuse large celest | 70.00a | 72.00a | 19.50a | 21.82a | **54.00AB** | **113.8A** | 59.75A | **54.00AB** |
| Kuse large dividend | 86.00a | 88.00a | 23.75a | 21.73a | **53.00AB** | **112.3AB** | 59.25AB | **53.00AB** |
| Cs 20dk Small control | 49.50a | 51.75a | 13.75a | 21.90a | **54.50AB** | **109.0BC** | 54.50BCDE | **54.50AB** |
| Cs 20dk Small celest | 33.00a | 35.50a | 9.25a | 22.20a | **58.00A** | **110.8ABC** | 52.50DE | **58.00A** |
| Cs 20dk Small dividend | 50.50a | 53.00a | 14.00a | 21.43a | **54.75AB** | **112.5AB** | 57.75ABC | **54.75AB** |
| Cs20dkmedium control | 53.00a | 54.25a | 14.50a | 21.50a | **54.00AB** | **112.8AB** | 58.75ABC | **54.00AB** |
| Cs 20dk medium celest | 45.50a | 47.50a | 12.75a | 22.23a | **56.25AB** | **112.3AB** | 56.00ABCDE | **56.25AB** |
| Cs 20dk medium dividend | 54.50a | 54.50a | 15.00a | 21.23a | **56.50AB** | **112.0AB** | 55.50ABCDE | **56.50AB** |
| Cs 20dk large Control | 64.50a | 66.00a | 18.00a | 21.63a | **53.00AB** | **112.0AB** | 59.00AB | **53.00AB** |
| Cs 20dk large Celest | 67.50a | 68.75a | 18.75a | 21.60a | **53.75AB** | **110.0ABC** | 56.25ABCDE | **53.75AB** |
| Cs 20dk large Dividend | 67.50a | 67.50a | 18.50a | 21.63a | **51.75AB** | **110.5ABC** | 58.75ABC | **51.75AB** |
| P≥ | Ns | Ns | Ns | Ns | * | * | ** | * |

Table 9.11B: Cultivar X fungicide X seed size interactions in faba bean under field conditions **(A X B X C)**

| Variable or Treatments | BPP | PPP | SPP | GY K $ha^{-1}$ | % PC | HKM g | AGBM Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Kuse small control | 1.185a | 4.050a | 2.032a | 820.8a | 21.40a | 44.93a | 4445a |
| Kuse small celest | 1.050a | 1.875a | 2.400a | 372.5a | 20.38a | 38.45a | 2049a |
| Kuse small dividend | 1.200a | 1.650a | 1.625a | 198.8a | 17.40a | 34.15a | 1806a |
| Kuse medium control | 1.325a | 3.275a | 1.675a | 457.0a | 18.84a | 42.78a | 3195a |
| Kuse medium celest | 1.250a | 4.625a | 1.975a | 654.8a | 20.10a | 45.45a | 4792a |
| Kuse medium dividend | 1.175a | 3.450a | 2.200a | 1047.8a | 21.30a | 47.70a | 4236a |
| Kuse large control | 1.350a | 2.950a | 2.750a | 885.8a | 21.73a | 48.23a | 5174a |
| Kuse large celest | 1.475a | 3.575a | 2.150a | 745.0a | 21.15a | 50.05a | 4306a |
| Kuse large dividend | 1.275a | 3.100a | 2.225a | 782.8a | 20.10a | 46.33a | 3889a |
| Cs 20dk small control | 1.600a | 3.225a | 2.225a | 474.3a | 19.55a | 40.48a | 2465a |
| Cs 20dk small celest | 1.400a | 2.400a | 2.250a | 198.3a | 19.78a | 41.20a | 1285a |
| Cs 20dk small dividend | 1.450a | 3.350a | 2.650a | 561.3a | 21.23a | 46.60a | 4278a |
| Cs 20dk medium control | 1.400a | 2.675a | 2.200a | 428.8a | 19.95a | 46.70a | 2882a |
| Cs 20dk medium celest | 1.725a | 2.750a | 1.850a | 277.0a | 21.10a | 48.10a | 1701a |
| Cs 20dk medium dividend | 1.600a | 2.525a | 2.175a | 356.0a | 19.38a | 43.00a | 2292a |
| Cs 20dk large control | 1.600a | 2.950a | 1.850a | 464.0a | 20.90a | 48.35a | 3611a |
| Cs 20dk large celest | 1.300a | 3.425a | 1.900a | 355.3a | 17.98a | 42.68a | 2222a |
| Cs 20dk large dividend | 1.425a | 3.225a | 1.825a | 525.3a | 17.73a | 45.45a | 3368a |
| P≥ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

See footnote of table 9.7

### 9.3.2.8 Correlation Matrix

A correlation matrix (Table 9.12; Appendix 5) was performed to investigate the association of all laboratory and field parameters. Significantly correlated figures are written in bold. Although correlation was rather weak in most instances, some of the parameters which correlated highest (>0.5) are mentioned.

Different sized faba bean seeds showed some positive correlation in terms of their field performance with regard to dry mass of seedlings produced (r=0.5347). However, negative correlation was observed for epicotyl length (r= -0.5001) in seedlings. Grain yield positively correlated with days to maturity (r=0.5348), the grain filling period (r=0.6173), number of pods $plant^{-1}$ (r=0.7703), hundred seed mass (r=0.6536), protein content (r=0.5742) and above ground bio-mass (r=0.8246).

## 9.4 Discussion

Seeds of both cultivars were of good quality and showed high germination capacity of above 96%, which were higher than the minimum requirement (70%) as prescribed for the the Republic of South Africa (SANSOR, 1996). High germination capacity, as predicted in the laboratory, is associated with high seed vigour and field emergence potential (Bishaw, 1994; ISTA, 1999, Van De Venter, 1999).

Interestingly, the small sized seeds of both Cs 20dk and Kuse produced seedlings with longer epicotyls as compared to the seedlings from medium and large seeds. However, in both cultivars, the dry mass of seedlings grown from large seeds was higher, implicating larger seedlings, and this was in accordance with the findings of Elemey (1993). Plants that developed to maturity from the latter seedlings also produced higher yields.

As far as seed size variation is concerned, laboratory and field performances of seeds from both cultivars resulted in similar trends. Germination and emergence was significantly higher for the large sized seed than for the medium and small. The same was true for seedling mass and the final yield, in terms of hundred seed mass, for large sized seeds. Germination capacity (ISTA, 1999), as measured in the laboratory, was found to be the best predictor for field performance of seeds from both faba bean cultivars. However, in most cases, the performance of large and medium sized seed was close to each other. In general, albeit not statistically significant in all cases, seed and above ground bio-mass yields were found to be relatively higher for plants grown from large sized seed as compared to that from medium and small seeds. This is in agreement with the findings of Arafa (1987) who reported on wheat that grain and straw yields were slightly higher for plants grown from larger seeds than from medium and small ones. However, this observation regarding the field performance of large sized faba bean seeds is in contrast with the findings of Saxena *et al.* (1980) on chickpea who reported that large seeds produced larger seedlings, but there was no significant effect on final yield.

Among the fungicide treatments, significantly higher germination percentage was recorded from seeds treated with Dividend than that treated with Celest. Although Hussien *et al.* (1991) reported significantly higher seed (+39.8%) and straw yields (+44.9%) from faba bean plants grown from seeds treated with Quinolate [Oxine-copper], no other clear similar fungicidal effects were observed in this study from fungicide treated faba bean seeds. The effect of seed size was greater than that of fungicide treatments.

It seems from this study that, for obtaining quality faba bean seed, special attention should be given to sort large sized seed from medium and small ones prior to planting and use only the larger ones in a seed production programme. Seed size variation of crops in general, and in faba beans in particular, is most probably genetically related and breeding programmes for attaining faba bean cultivars with predominantly large sized seeds, might seem worthwhile in future. However, the effect of environmental factors on the size of seeds ultimately harvested can not be ignored and special projects, to elucidate the possible metabolic mechanism underlying this effect in faba beans, should be planned for the future. The latter factors to be considered might include variations in planting date (Mohamed, 1986; Dhingra *et al.*, 1990), soil fertility (Caballero, 1988, Abdulsalam, *et al.*, 1996), temperature (Elemery, 1993), moisture regime (Newton and Hill, 1987; Al Abdusalam *et al.*, 1996), population per unit area (El Tuhami and Hussien, 1986; Salem and El Massri, 1986; Kahnt *et al.*, 1988) and plant health (Gorfu, 1997).

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# CHAPTER 10

## EFFECT OF SEED TREATMENTS AND SOWING DEPTH ON SEED QUALITY AND YIELD OF ETHIOPIAN FABA BEAN CULTIVARS


### Abstract

Trials were conducted under controlled laboratory and field conditions to investigate the effect of seed treatments and sowing depths on seed quality using various parameters. The main objective of the laboratory trial was to examine the effect of two fungicides, Celest® XL 035 FS (fludiocsonit/mefenolsam) and Dividend® 030 FS (difenoconazole), as seed treatments on germination capacity, epicotyl-, seedling- and seedling root lengths in two faba bean cultivars, viz. Kuse and Cs 20dk. In the laboratory, a factorial experiment laid out in a randomnized complete block design, with four replications, was used. Kuse proved to be superior to Cs 20dk in epicotyl length, seedling length and seedling fresh mass. None of the two fungicides seemed to have a significant effect on seed quality as compared to the untreated control. In the field a split-plot design was used whereby cultivars and fungicides were taken as main-, and sowing depth as sub-plots. The main aim of the field trial was to evaluate fungicide treated seed at two different sowing depths in terms of emergence, yield and yield components as well as other related parameters, and to evaluate the relationship between laboratory and field performances. In the field, Kuse outperformed Cs 20dk regarding emerged seedlings and number of plants established per $m^2$. However, harvested seeds Cs 20dk was significantly higher than that of Kuse in kernel mass. In general, both cultivars performed better when grown from deep planted than from shallow planted seed. The effects of fungicides were insignificant.



**Key words**: faba bean, seed treatments, sowing depth, epicotyl length, seedling root lengths, germination, emergence, yield and yield components

## 10.1 Introduction

Pulses, such as faba bean, are not only important sources of vegetable protein in the human diet, but also possess the unique ability of fixing atmospheric nitrogen into the soil through *Rhizobia* present in the nodules on their roots (Hussain *et al.*, 1994). However, in spite of their importance, pulses have not received the necessary research attention in seed production programmes that they deserve. Consequently, yields are generally low and have been almost static over the past three decades.

Faba bean, as most pulses or grain legumes, are generally considered as hard crops and are mostly grown on marginal soils under low fertility and moisture conditions (Hussain *et al.*, 1994). An optimal plant population must be maintained in order to achieve the required target yield (Radford *et al.,* 1989) and is the most important single factor affecting yield. This remains a problem in Sub-Saharan African countries where soil moisture is critically low and is accompanied by a high evapo-transpiration rate.

Moreover, Diekmann (1988) reported on the disease problem associated with faba bean production. This is probably due to the fact that faba beans require growth conditions that are also favourable for pathogen development, i.e. warm temperature, high rainfall or irrigation. Seeds transmit most of the pathogens, including a number of viruses. Among these are *Ascochyta* spp., *Botrytis faba*, *B. cinerea*, bean yellow mosaic virus, broad bean stain virus, true broad bean mosaic virus, pea seed-borne mosaic virus and *Ditylenchus dipsaci* (Diekmann, 1988). Seed treatment with chemicals prior to planting is therefore of prime importance.

Generally, in dry land areas, faba bean seeds are planted deep in order to utilize the available soil moisture and to support seedling emergence. This is especially true for most drought-prone environments of Sub-Saharan Africa. In Ethiopia deep planting is common practice, but the use of oxen adds another dimension namely covering of seeds with thick soil sods which forces seeds deeper than usual. As a result, the seeding rate (150-250 kg $ha^{-1}$) for faba bean is exceptionally high in Ethiopia.

The main aims of this study were to evaluate the performance of faba bean plants grown from fungicide treated and untreated as well as deep planted (12 cm) and shallow planted (6 cm) seeds in two cultivars, by using different parameters. This was performed under laboratory and field conditions in order to determine the correlation and the predictability of field performance with laboratory data.

## 10.2 Materials and Methods

Laboratory and field treatments are shown in Tables 10.1 and 10.2. Refer to chapter 3, section 3.2.2, for details.

Table 10.1: List of faba bean treatments (laboratory trial ; two factor RCBD)

| Cultivar | Treat no | Control | Treat no | Celest XI 030 FS 2 ml $kg^{-1}$ | Treat. No | Dividend 035 FS 2 ml $kg^{-1}$ |
|---|---|---|---|---|---|---|
| Kuse | 1 | " | 2 | " | 3 | " |
| Cs 20dk | 4 | " | 5 | " | 6 | " |

Table 10.2: List of faba bean treatments (field trial ; split-plot design)

| Cultivar | Sowing depth | Treat. No | Control | Treat. No | Celest XI 030 FS 2 ml $kg^{-1}$ | Treat . No | Dividend 035 FS 2 ml $kg^{-1}$ |
|---|---|---|---|---|---|---|---|
| Kuse | 6 cm | 1 | " | 3 | " | 5 | " |
| | 12 cm | 2 | " | 4 | " | 6 | " |
| Cs 20dk | 6 cm | 7 | " | 9 | " | 11 | " |
| | 12 cm | 8 | " | 10 | " | 12 | " |

## 10.3 Results

### 10. 3.1 Analysis of data obtained under laboratory conditions

Laboratory results were similar to those presented and discussed in the preceding chapter (chapter 9). As planting at different depths in the laboratory showed no significant effects, data is neither presented nor discussed further in this chapter.

### 10.3.2 Analysis of data obtained under field conditions

#### 10.3.2.1 Cultivar variations (A)

Statistically significant cultivar variation was only observed in terms of seedling emergence (SE) and number of plants established per $m^2$ (PPMS) where Kuse outperformed Cs 20dk. However, Cs 20dk showed more branches plant$^{-1}$ (BPP) and measured significantly higher in hundred kernel mass (HKM) (Tables 10.3A and B).

Table 10.3A: Effect of cultivar variation on specific parameters in faba bean under field conditions **(A)**

| Variable | % ES | % EG | PPMS | RE days | DF Days | DM days | GFP | PH Cm |
|---|---|---|---|---|---|---|---|---|
| Kuse | **85.2A** | **86.7A** | **23.7A** | 20.6a | 53.6a | 108.5a | 55.2a | 51.2a |
| Cs 20dk | **61.3B** | **63.1B** | **17.1B** | 20.1a | 54.8a | 109.3a | 54.5a | 51.5a |
| P≤ | ** | ** | ** | Ns | Ns | Ns | Ns | Ns |

Table 10.3B: Effect of cultivar variations on specific parameters in faba bean under field conditions **(A)** (continued)

| Variable | BPP | PPP | SPP | GY Kg ha$^{-1}$ | % PC | HKM g | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Kuse | **1.19B** | 3.90a | 1.87a | 584a | 19.01a | **39.74B** | 2623a |
| Cs 20dk | **1.51A** | 4.25a | 1.65a | 610a | 18.85a | **45.68A** | 2542a |
| P≤ | ** | Ns | Ns | Ns | Ns | ** | Ns |

**Abbreviations:** ES =emerged seedlings ; EG =emerged % from germinated seeds ; RE =rate of emergence ; ppms =plants per meter square ; DF =days to 50% flowering ; DM =days to 50% maturity ; GFP =grain filling period ; PH =plant height ; BPP =branches per plant ; PPP =pods per plant ; GY =grain yield ; PC =protein content ; HKM =hundred kernel mass ; AGBM = above ground bio-mass ; SPP =seeds per plant ; cm = centimetre ; Ha = hectare ; Kg= kilogram

#### 10.3.2.2 Fungicide variations (B)

No significant variation in seed treatment with different fungicides was observed (results not shown).

#### 10.3.2.3 Cultivar x fungicide interactions (A x B)

No significant cultivar x fungicide interaction was observed (results not shown).

#### 10.3.2.4 Sowing depth variations (C)

Albeit not highly significant in all cases, deep planting (12 cm) seemed to have had more of a benificial effect on the field performance of seeds as compared to shallow planted ones (Table 10.4A and B). More seedlings emerged (ES) and more plants established per $m^2$ (PPMS) when seeds were planted deep. Moreover, the rate of seedling emergence (RE) were higher, these plants tended to flower earlier (DF) and harvested seeds measured significantly higher in hectolitre mass (HKM) and final yield.

Table 10.4A: Effect of sowing depth on specific parameters in faba bean under field conditions **(C)**

| Variable | % ES | % EG | PPMS | RE days | DF DAYS | DM DAYS | GFP | PH Cm |
|---|---|---|---|---|---|---|---|---|
| 6 cm | **71.9B** | **73.8B** | **20.0B** | **21.8A** | **55.5A** | 108.8a | **53.5B** | 50.6a |
| **12 cm** | **74.6A** | **76.0A** | **20.8A** | **19.0B** | **52.9B** | 109.1a | **56.2A** | 52.1a |
| **P≤** | ** | ** | ** | ** | * | Ns | * | Ns |

Table 10.4B: Effect of sowing depth on specific parameters in faba bean under field conditions (C) (continued)

| Variable | **BPP** | PPP | SPP | GY Kg $ha^{-1}$ | % PC | HKM g | AGBM Kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| 6 cm | 1.32a | 3.52a | 1.82a | 540a | 18.68a | **41.07B** | 2337a |
| **12 cm** | 1.39a | **4.62a** | 1.70a | **655a** | 19.18a | **44.35A** | **2828a** |
| **P≤** | Ns | Ns | Ns | Ns | Ns | ** | Ns |

Abbreviations: see footnote of table 10.3

### 10.3.2.5 Cultivar x fungicide x sowing depth interactions (A x B x C)

Although no statistically significant cultivar x fungicide x sowing depth interaction was observed, the results are presented in table 10.5A and B.

Table 10.5A: Cultivar x fungicide x sowing depth interactions in faba bean under field conditions **(A x B x C)**

| Variable | % ES | % EG | PPMS | RE Days | DF DAYS | DM DAYS | GFP | PH Cm |
|---|---|---|---|---|---|---|---|---|
| Kuse con 6 cm | 85.0a | 86.8a | 23.8a | 21.6a | 56.0a | 110.8a | 54.8a | 53.3a |
| Con 12 cm | 73.8a | 76.5a | 20.5a | 20.1a | 54.5a | 110.3a | 55.8a | 55.0a |
| Kuse Celest 6 cm | 86.3a | 88.3a | 23.8a | 21.4a | 53.0a | 106.0a | 53.0a | 47.0a |
| Celest 12 cm | 96.3a | 96.5a | 26.8a | 19.0a | 51.5a | 108.5a | 57.0a | 52.3a |
| Kuse dividend 6 cm | 82.5a | 85.0a | 22.8a | 21.9a | 54.5a | 106.8a | 53.5a | 49.3a |
| Divdend 12 cm | 87.5a | 87.0a | 24.5a | 19.8a | 52.0a | 109.0a | 57.0a | 50.3a |
| Cs 20dk con 6 cm | 65.0a | 66.5a | 18.3a | 22.2a | 56.3a | 108.5a | 52.3a | 51.3a |
| Con 12 con | 63.8a | 65.8a | 17.8a | 18.7a | 53.3a | 110.5a | 57.3a | 49.8a |
| Cs 20dk celest 6 cm | 58.8a | 61.5a | 16.5a | 21.0a | 55.0a | 111.3a | 56.3a | 54.8a |
| Celest 12 cm | 67.5a | 70.8a | 19.0a | 17.7a | 53.3a | 107.3a | 54.0a | 51.5a |
| Cs 20dk dividend 6 cm | 53.8a | 54.8a | 15.0a | 22.5a | 58.0a | 109.3a | 51.3a | 48.0a |
| Dividend 12 cm | 58.8a | 59.8a | 16.3a | 18.8a | 52.8a | 109.0a | 56.3a | 54.0a |
| P≤ | Ns | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Table 10.5B: Cultivar x fungicide x sowing depth interactions in faba bean under field conditions **(Á x B x C)** continued

| Variable | BPP | PPP | SPP | GY Kg ha$^{-1}$ | % PC | HKM g | AGBM Kg ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Kuse con 6 cm | 1.25a | 3.18 | 2.08a | 725a | 20.90a | 40.85a | 2816a |
| Con 12 cm | 1.25a | 4.18 | 1.75a | 573a | 18.48a | 42.55a | 2813a |
| Kuse Celest 6 cm | 1.10a | 2.35 | 1.85a | 345a | 16.35a | 35.45a | 2191a |
| Celest 12 cm | 1.13a | 3.28 | 2.15a | 647a | 20.78a | 41.43a | 2889a |
| Kuse dividend 6 cm | 1.20a | 4.05 | 2.05a | 502a | 19.23a | 36.13a | 2285a |
| Divdend 12 cm | 1.23a | 6.35 | 1.33a | 715a | 18.35a | 42.05a | 2743a |
| Cs 20dk con 6 cm | 1.20a | 4.50 | 1.38a | 412a | 19.13a | 43.53a | 2261a |
| Con 12 con | 1.50a | 3.05 | 2.05a | 644a | 19.35a | 47.25a | 2774a |
| Cs 20dk celest 6 cm | 1.70a | 4.08 | 2.13a | 854a | 18.83a | 44.98a | 2288a |
| Celest 12 cm | 1.45a | 5.85 | 1.23a | 559a | 18.65a | 45.95a | 2677a |
| Cs 20dk dividend 6 cm | 1.45a | 2.95 | 1.43a | 401a | 17.68a | 45.50a | 2181a |
| Dividend 12 cm | 1.78a | 5.05 | 1.68a | 792a | 19.45a | 46.85a | 3070a |
| P≤ | Ns | Ns | Ns | Ns | Ns | Ns | Ns |

Abbreviations see footnote table10.3

#### 10.3.2.6 Correlation matrix

Albeit not spectacular, some positive correlation between sowing depth and seedling emergence rate (r=0.7898) and above ground bio mass (r=0.7692) was observed (Table 10.8 ; Appendix 6). Epicotyl length also correlated positively with seedling dry mass (r=0.6248). However, sowing depth negatively but weakly correlated with emergence rate (r=-0. 4739) and days to flowering (r=-0.3410).

### 10.4 Discussion

Untreated seeds of Cs 20dk tended to germinate slightly better than that of Kuse. However, seedlings of Kuse were superior in epicotyl length, resulting in better field emergence. Moreover, Kuse seedlings appeared healthy because of their size (higher fresh mass). It can be speculated that seeds of some cultivars decline faster during storage than others and, although the germination percentage may remain high, the seed's capacity to produce healthy seedlings may be still be low. Based on the the better performance of Kuse seeds under both laboratory and field conditions, as compared to that of Cs 20dk, it seems that epicotyl length and seedling fresh mass, measured under laboratory conditions, could be used as indicators to predict field performance. In this study, treatment with fungicides (recommended by Pritchard, 1995) had no significant effect on any of the quality parameters used to evaluate the field performance of faba bean seeds. Nevertheless, one is hesitant to derive from this that treatment of faba beans with registered fungicides is unnecessary. Local conditions should always be taken into consideration and practices such as crop rotation or chemical treatments should be considered.

In the literature cited, both early and deep planting of faba bean seeds were found to be positively correlated with the final yield outcome (Pritchard, 1995; Loss *et al.*, 1996: Mohamed, 1986; Dhingra *et al.*, 1990). Early sowing is general practice in low rainfall areas and most probably makes the plants less prone to frost damage and subsequent pod abscission. As the area where trials were conducted in this study was also subjected to quite a lengthy drought period, but deep planting (12 cm) of seeds produced plants with the highest yields, it appears that this is in accordance with previous findings and no change in this recommendation is valid. According to Pritchard (1995), seedlings from deep planted faba bean seeds emerges without difficulty, probably because of its hypogeal germination pattern, and he recommends a planting depth of 6-8 cm under optimum soil moisture conditions during planting. Results in this study indicate that even a planting depth of 12 cm will not reduce the productivity potential of faba beans.

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# CHAPTER 11

# EFFECT OF SEED SIZE, TREATMENTS AND SOWING DEPTH ON SEED QUALITY OF ETHIOPIAN CHICKPEA CULTIVARS

**Abstract**

A study was undertaken on chickpea 1) To assess the performance of two chickpea cultivars with three different seed sizes and fungicide treatments for seed quality parameters as tested under laboratory and field conditions. 2) To evaluate emergence and emergence rate of bulked (unclassified) seeds of the two same cultivars when planted at 5 cm and 10-cm depth. 3) Quality parameters in the laboratory were employed to predictable field emergence. Seeds of two selected chickpea cultivars, viz. Akaki relatively (small seed sized) and Mariye (large seed sized) were used. Four experiments were conducted. In seed treatments and size study a three factor randomized complete block design with four replications was used both in the laboratory and field. However, the designs of the two coupled laboratory and field studies) involving bulked seed treatments and sowing depth differed where a split-plot design was used in the field and a two factor in the laboratory. The trials were conducted at the Small Grain Institute, Bethlehem, South Africa in 1999/2000. Significant differences between cultivars for quite a number of parameters were obtained. Under both laboratory and field conditions Cv. Akaki was superior to Mariye in germination (GER) percentage and percentage of emerged seedling (ES). Seedling root length and all other seedling masses of large sized seeds were significantly higher than the medium and small sized seed groups. However, epicotyl (El) and seedling lengths (Sl) of small seeded were statistically longer than the medium and large seeded. Seedling root length (SRL) of Dividend treated seed was significantly shorter than untreated and Celest treated fungicide. Planting chickpea deep at 10 cm brought about significantly higher emerged seedling (ES) than the shallow (5-cm). In general, this showed that the prediction of emergence could be made from seed quality laboratory parameters.

**Key words:** chickpea, seed size, treatments, seed quality, germination, emergence yield and yield components

### 11.1 Introduction

Chickpea is cultivated on about 8.7 million hectares worldwide. It accounts for about 13% of the world area of pulse (Pala and Mazid, 1991). Chickpea forms an important dietary component in those countries in which it is a major crop. Although most of the world's chickpea production and consumption is in India (>70%), the crop is also important in other countries of mainly West Asia, North Africa, Mediterranean Europe, and Latin America (Jambunathan and Singh, 1990). Malhotra & Singh, (1991) reported that this crop is grown in diverse conditions of crop management, and biotic stresses. Within these environments, it is cultivated primarily in rain fed areas receiving 350 mm to 600 mm average annual precipitation.

Chickpea is a good source of carbohydrates and proteins and the crude protein content of chickpea varies from 12.4 to 31.5% (Geervani, 1991). Besides, chickpea like any other pulse also plays a big role in improving soil fertility mainly by nitrogen enrichment, which in turn improves crop yields and protein content, decreases diseases and minimizes weeds and other pests of the preceding cereal crops when used in rotation (ARC-Small Grain Institute, 1999).

Modern farmers generally believe in this system, but sometimes complain that large sized seeds of grain legumes are more liable to mechanical damage than medium or small during harvesting and seed processing. Nijhawan *et al.* (1990) evaluated the effects of three different grades in four cultivars of chickpea in India. Their findings revealed that there were significant yield differences among cultivars and not among grades. On the other hand, Murray and Auld (1987), reported that in the USA sowing seed 14% smaller than the largest sized seed in seed lots, reduced sowing costs by 30% without sacrificing seed yield and 1000-seed wt. This is with the provision that repeated screening of seed lots, to obtain smaller seed for sowing, should be limited to a few cycles to prevent production of seed with lower average 1000-seed wt. than that in the original seed lot. Similarly, Eser *et al.* (1991) pointed out that a large seed group the production systems. The planting of cultivars using the appropriate sowing depth, is among the cultural practices that should play great role in all crop production systems. Therefore, this study was undertaken to determine some seed quality parameters of chickpea seeds of two cultivars using three different seed sizes and by applying fungicide treatments under laboratory and field conditions. This was also done in order to examine the application potential of laboratory seed quality tests to predict the outcome under field conditions.

## 11.2 Materials and Methods

### 11.2.1 Materials

Two of the Ethiopian chickpea cultivars, namely Akaki and Mariye, were selected and obtained from the Ethiopian National Seed Industry Agency. Mariye, which is a large seeded type was released in 1985 while CV. Akaki, that is relatively small seeded, was also a recent release of 1995 (Abebe and Mamo, 1997). Seeds of both cultivars were introduced from Ethiopia and tested in the Small Grain Institute, Bethlehem, South Africa in 1999/2000. The procedures followed in the laboratory test was in accordance with the International Rules for Seed Testing (ISTA, 1999) and that of the training manual for seed analysts, National Department of Agriculture (2000).

### 11.2.2 Methods

The procedures followed are described in the general materials and methods (please refer to chapter 3) of this monograph.

Table 11.1 List of treatments for laboratory and field experiments (three factor RCBD design)

| Cultivar | Seed size mean Mass/seed (g) | Treat. No | Control | Treat. No | Celest Xl 030 FS 2 ml $kg^{-1}$ | Treat. No | Dividend 035 FS 2 ml $kg^{-1}$ |
|---|---|---|---|---|---|---|---|
| Akaki | Small <0.16 | 1 | " | 2 | " | 3 | " |
| | Medium 0.16 to 0.21 | 4 | " | 5 | " | 6 | " |
| | Large >0.21 | 7 | " | 8 | " | 9 | " |
| Mariye | Small < 0.25 | 10 | " | 11 | " | 12 | " |
| | Medium 0.25 to 0.28 | 13 | " | 14 | " | 15 | " |
| | Large > 0.28 | 16 | " | 17 | " | 18 | " |

Table 11.2: List of treatments for a second laboratory trial (two factor RCBD design)

| Cultivar | Treat no | Control | Treat no | Celest Xl 030 FS 2 ml kg$^{-1}$ | Treat . No | Dividend 035 FS 2 ml kg$^{-1}$ |
|---|---|---|---|---|---|---|
| Akaki | 1 | " | 2 | " | 3 | " |
| Mariye | 4 | " | 5 | " | 6 | " |

Table 11.3: Sowing depth treatments under field conditions (split-plot design)

| Lcultivar | Sowing depth | Treat. No | Control | Treat. No | Celest Xl 030 FS 2 ml kg$^{-1}$ | Treat . No | Dividend 035 FS 2 ml kg$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Akaki | 5 cm | 1 | " | 3 | " | 5 | " |
| | 10 cm | 2 | " | 4 | " | 6 | " |
| Mariye | 5 cm | 7 | " | 9 | " | 11 | " |
| | 10 cm | 8 | " | 10 | " | 12 | " |

Please refer to general materials and methods (chapter 3) for the details.

## 11. 3 Results

### 11. 3. 1 Analysis of data on the effect of seed size and fungicide treatments under laboratory and field conditions

#### 11. 3.1.1 Cultivar variations (A)

Highly significant differences between the two cultivars were observed for germination (Ger) percentage, abnormal seedlings (Abs), epicotyl length (EL), seedling length (SL), seedling root length (srl), seedling fresh mass (sfm), seedling root fresh mass (Srfm) at ($P \leq 0.01$) and percent of emerged seedling (Es) at ($P \leq 0.05$). In most cases the recently released Cv Akaki outperformed Mariye. However, Mariye showed significantly higher seedling root length (Srl) and seedling root fresh mass (srfm) than Akaki. There was no significant difference between cultivars for the rest two parameters for seedling dry mass (Sdm) and seedling root dry mass (Srdm). Field performance was evaluated for only two parameters where statistically significant difference between cultivars was obtained in one of the two parameters measured. Akaki performed significantly higher at (P≤0.05) than Mariye in percentage of emerged seedling (Es). All relevant results are presented in table 11.4 below.

Table 11.4: Effect of cultivar and seed size variations in chickpea under laboratory and field conditions (A)

| Variable | Ger % | % Abs. | El Mm | Sl Mm | Srl Mm | Sfm Mg | Sdm Mg | Srfm Mg | Srdm Mg | % ES | ER Days |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Akaki | 96.9A | 2.3B | 92.8A | 121.7A | 125.8B | 257A | 26.2a | 282B | 32.1a | **67.44A** | 21.94a |
| Mariye | 93.9B | 5.4A | 73.1B | 103B | 144.2A | 234B | 26.7a | 345A | 33.7a | **61.06B** | 22.19a |
| C.v. % | 4.1 | 85.7 | 8.7 | 7.07 | 9.13 | 9.14 | 7.44 | 20.13 | 24.85 | 19.09 | 10.43 |
| Mean | 95.4 | 3.9 | 83 | 112.3 | 135 | 245 | 26.42 | 314 | 32.9 | 64.25 | 22.06 |
| P≥ | ** | ** | ** | ** | ** | ** | Ns | ** | Ns | * | Ns |

**Abbreviations:** Ns = Non-significant, * = significant and ** = highly significant at P≤ 0.05 and P≤ 0.01 respectively. Any two or more means sharing the same letter are not significantly different at 5% probability level according to Tukey's mean separation test. Statistically significant differences are indicated in bold and capital letters;Ger = germination Abs = abnormal seedling seed El = Epicotyl length Sl = seedling length Srl = seedling root length Sfm = seedling fresh mass Sdm = seedling dry mass Srdm = seedling dry mass Mm = millimeter Mg = milligram Lsd = least significant difference C.v. = coefficient of variance

### 11.3.1.2. Seed size variation (B)

When the mean of the two cultivars were taken into account, there was no significant difference observed among seed sized groups for germination (GER) percentage and abnormal seedling (ABS). The remaining eight and one of the eleven parameters measured were found to be highly significant at (P≤0.01) and (P≤0.01) level respectively (Table 11.5). The epicotyl (EL) and seedling lengths (SL) were found to be longer from the small sized seeds compared to both medium and large sized seeds. However, the seedling fresh (Sfm) and seedling root fresh masses (Srfm) of small sized seed groups were significantly lower than that of medium and the medium than that of the large sized seed group. In general, large seeded groups were significantly higher than small seeded groups for seedling root length (Srl), seedling fresh mass (Sfm), seedling dry mass (Sdm), seedling root fresh (Srfm) and dry masses (Srdm) as well as in percentage of emerged seedling (Es). The results are presented in table 11.5.

Table 11.5: Effect of seed size variations on specific parameters in chickpea (mean of two cultivars) **(B)**

| Variable | Ger % | % Abs. | **El Mm** | **Sl Mm** | **Srl Mm** | Sfm Mg | Sdm Mg | **Srfm Mg** | **Srdm Mg** | **% ES** | ER Days |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Smalll | 95.3a | 4.00a | **88.7A** | **117A** | **128B** | **233C** | **23.3B** | **284C** | **29.6B** | **60.50B** | 21.85a |
| Medium | 95.2a | 3.92a | **82.0B** | **111B** | **133B** | **142B** | **26.0AB** | **294B** | **30.2B** | **62.92AB** | 22.82a |
| Large | 95.8a | 3.75a | **78.2B** | **109B** | **144A** | **262A** | **29.9A** | **362A** | **38.9A** | **69.33A** | 21.52a |
| P≥ | Ns | Ns | ** | ** | * * | ** | ** | ** | ** | ** | NS |

See footnote of table 11.4.

### 11.3.1.1.3 Cultivar x seed size interactions (A X B)

Table 11.6 shows the results of cultivar x seed size interactions for the eleven parameters measured. Significant differences at ($p \leq 0.05$) were observed for only three of the eleven parameters. The seedling root fresh mass (Srfm) of large seeded Mariye was significantly higher than the rest of all other treatments. On the other hand, large seeded Akaki showed significantly higher seedling root dry mass (Srdm) than all other treatments while the least same masses were recorded from the small seeded of the this same cultivar. The results are presented in table 11.6.

Table 11.6: Cultivar x seed size interactions mean of two cultivars **(A X B)**

| Variable | Ger % | % Abs. | El Mm | Sl Mm | Srl Mm | Sfm Mg | Sdm Mg | **Srfm Mg** | **Srdm Mg** | **% ES** | ER Days |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Akaki small | 95.8a | 2.8a | 101a | 127a | 118a | 239a | 22.6a | **223E** | **25.3C** | **58.50B** | 22.13a |
| Medium | 97.0a | 2.2a | 91a | 120a | 124a | 254a | 25.9a | **284D** | **30.3BC** | **68.00AB** | 22.53a |
| Large | 98.0a | 2.0a | 87a | 118a | 136a | 276a | 30.0a | **340B** | **40.7A** | **75.83A** | 21.17a |
| Mariye small | 94.7a | 5.2a | 77a | 106a | 138a | 225a | 24.1a | **345B** | **33.9ABC** | **62.50AB** | 21.58a |
| Medium | 93.3a | 5.7a | 74a | 102a | 142a | 230a | 26.1a | **305C** | **30.1BC** | **57.83B** | 23.11a |
| Large | 93.7a | 5.5a | 69a | 100a | 153a | 247a | 29.8a | **385A** | **37.2AB** | **62.83AB** | 21.88a |
| P≥ | Ns | Ns | Ns | Ns | Ns | Ns | Ns | * | * | * | Ns |

See footnote of table 11.4.

### 11.3.1.4 Fungicide variations (C)

Significant difference was observed for fungicidal variations at (P≥0.05) level for only one of the eleven parameters measured. The seedling root length (Srl) of Divided treated seeds was significantly lower than both Celest and untreated. Celest improved the seedling root length more than that of the untreated lot but not significantly. The results of all the parameters measured are presented below in table 11.7

Table 11.7: Effect of fungicide variations on specific parameters in chickpea (mean of two cultivars) **(C)**

| Variable | Ger % | % Abs. | El Mm | Sl Mm | **Srl Mm** | Sfm Mg | Sdm Mg | Srfm Mg | Srdm Mg | % ES | ER Days |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 95.8a | 2.92a | 84a | 113a | **136A** | 250a | 26.9a | 330a | 31.6a | 64.17a | 22.64a |
| Celest | 95.0a | 4.33a | 82a | 111a | **139A** | 239a | 25.8a | 295a | 34.3a | 67.83a | 22.01a |
| Dividend | 95.4a | 4.42a | 83a | 112a | **129B** | 248a | 26.5a | 316a | 32.8a | 60.75a | 21.54a |
| P≥ | Ns | Ns | Ns | Ns | * | Ns | Ns | Ns | Ns | Ns | Ns |

See footnote of table 11.4

### 11.3.1.5 Cultivar X Fungicide interactions (A X C)

Under both laboratory and field conditions, there was no significant effect observed between cultivars for cultivar x fungicide interactions. Therefore, results are neither tabulated nor discussed.

### 11.3.1.6 Cultivar X Fungicide interactions (B X C)

Under both laboratory and field conditions, there was no significant effect observed between cultivars for seed size x fungicide interactions. Therefore, results are neither tabulated nor discussed.

### 11.3.1.7 Cultivar x seed size x fungicide interactions (A x B X C)

Cultivar by seed size by fungicide variation was observed in only one of the eleven parameters measured. Such a variation was observed in seedling root length (Srl) where large seeded Mariye outperformed the rest of the treatments. Statistically longer seedling root length (Srl) than the rest of the treatments was obtained from large seeded Mariye. Moreover, statistically shorter seedling root length was obtained from small seeded Akaki compared to the rest of the treatments. Results were non-significant for the remaining ten parameters measured (Table 11.8).

Table 11. 8: Cultivar x seed size x fungicide interactions on chickpea under laboratory condition **(A X B X C)**

| Variable | Ger % | % Abs. | El mm | Sl Mm | Srl Mm | Sfm mg | Sdm Mg | Srfm Mg | Srdm mg | % ES | ER Days |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Akaki small con. | 94.5a | 3.5a | 98a | 127a | **117GFH** | 235a | 23.0a | 226a | 23.8a | 78.00a | 83.50a |
| Akaki small Cel | 97.0a | 1.0a | 99a | 126a | **130DEFG** | 228a | 22.0a | 233a | 27.3a | 82.00a | 86.50a |
| Akaki small Div. | 96.0a | 4.0a | 105a | 128a | **109H** | 256a | 22.8a | 211a | 24.8a | 76.00a | 80.00a |
| Akaki med Con | 97.0a | 0.5a | 98a | 127a | **131DEFG** | 274a | 26.3a | 290a | 29.8a | 78.50a | 79.75a |
| Akaki med cel | 97.5a | 2.5a | 88a | 117a | **114GH** | 245a | 25.5a | 260a | 31.0a | 76.50a | 77.25a |
| Akaki med Div | 96.5a | 3.5a | 86a | 116a | **127EFGH** | 243a | 26.0a | 301a | 30.3a | 85.50a | 87.75a |
| Akaki lar con | 99.0a | 1.0a | 91a | 120a | **136CDEF** | 283a | 30.0a | 345a | 38.3a | 79.50a | 81.75a |
| Akaki lar cel | 98.0a | 2.0a | 87a | 119a | **159AB** | 274a | 28.8a | 350a | 48.3a | 70.00a | 72.00a |
| Akaki lar Div | 97.0a | 3.0a | 83a | 115a | **112GH** | 274a | 31.3a | 325a | 35.5a | 86.00a | 88.00a |
| Mariye small con | 95.0a | 4.5a | 74a | 106a | **141BCDE** | 223a | 25.8a | 436a | 35.8a | 49.50a | 51.75a |
| Mariye small cel | 95.5a | 4.5a | 79a | 107a | **135CDEF** | 225a | 23.5a | 271a | 32.3a | 33.00a | 35.50a |
| Mariye small Div | 93.5a | 6.5a | 77a | 107a | **138CDE** | 230a | 23.0a | 329a | 33.8a | 50.50a | 53.00a |
| Mariye med con | 95.5a | 3.0a | 73a | 100a | **134CDEF** | 227a | 25.8a | 296a | 26.3a | 53.00a | 54.25a |
| Mariye med cel | 88.5a | 10.5a | 71a | 98a | **151ABC** | 217a | 25.3a | 292a | 32.3a | 45.50a | 47.50a |
| Makiye med Div | 96.0a | 3.5a | 76a | 107a | **140BCDE** | 246a | 27.3a | 327a | 31.8a | 54.50a | 54.50a |
| Mariye lar con | 94.0a | 5.0a | 71a | 102a | **163A** | 257a | 30.8a | 384a | 35.8a | 64.50a | 66.00a |
| Mariye lar cel | 93.5a | 5.5a | 69a | 109a | **146ABCD** | 244a | 29.8a | 364a | 35.0a | 67.50a | 68.75a |
| Mariye lar Div | 93.5a | 6.0a | 68a | 99a | **150ABC** | 240a | 29.0a | 406a | 40.8a | 67.50a | 67.50a |
| P≥ | Ns | Ns | Ns | Ns | * | Ns | Ns | Ns | Ns | Ns | Ns |

See footnote of table 11.4. con = control; cel = celest; Div = Dividend; lar = large med = medium

### 11.3.1.8 Correlation Matrix

Table 11.9 shows the results of correlation matrix. Correlation matrix was performed to associate all data drawn from laboratory and to the field parameters measured. Correlation indicates the relative association between two parameters, with zero indicating absence of correlation, whereas. one being has very highly correlated or almost identical magnitudes. The positive and negative signs imply that an increase in one parameter leads to an increase and decrease respectively in another. Only some of the most important parameters are briefly discussed.

Chickpea seed size showed positive and significant correlation with % emerged seedlings (ES) (r=0.2668), seedling root dry mass (Srdm) (r=0.3683), seedling dry mass (Sdm) (r=0.6903), seedling root fresh mass (Srfm) (r=0.3893), seedling fresh mass (Sfm) (r=0.3917), seedling root length (Srl) (r=0.3458). However, seed size was negatively and significantly correlated with seedling (Sl) (r= -0.2404) and epicotyl lengths (El) (r=-0.3262).

Germination (Ger) percentage was significant and positively associated with epicotyl (El) (r=0.3546) and seedling lengths (Sl) (r=0.3172) as well as with seedling fresh mass (Sfm) (r=0.3845).

Table 11.9 correlation matrix for chickpea cultivars on seeds size by fungicides

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GP | 0.0533 | | | | | | | | | | |
| | 0.6610 | | | | | | | | | | |
| AS | -0.0252 | -0.9457 | | | | | | | | | |
| | 0.8359 | 0.0000 | | | | | | | | | |
| EL | -0.3262 | 0.3546 | -0.3618 | | | | | | | | |
| | 0.0059 | 0.0026 | 0.0021 | | | | | | | | |
| SL | -0.2404 | 0.3172 | -0.3210 | 0.9231 | | | | | | | |
| | 0.0450 | 0.0075 | 0.0067 | 0.0000 | | | | | | | |
| SRL | 0.3458 | -0.0555 | 0.0662 | -0.4206 | -0.3974 | | | | | | |
| | 0.0034 | 0.6479 | 0.5862 | 0.0003 | 0.0007 | | | | | | |
| SFM | 0.3917 | 0.3845 | -0.3338 | 0.5170 | 0.6401 | 0.0622 | | | | | |
| | 0.0008 | 0.0010 | 0.0047 | 0.0000 | 0.0000 | 0.6092 | | | | | |
| SRFM | 0.3893 | 0.0342 | 0.0071 | -0.3632 | -0.2202 | 0.5534 | 0.2821 | | | | |
| | 0.0009 | 0.7785 | 0.9532 | 0.0020 | 0.0670 | 0.0000 | 0.0180 | | | | |
| SDM | 0.6903 | -0.0963 | 0.1508 | -0.2839 | -0.1640 | 0.1970 | 0.2465 | 0.2573 | | | |
| | 0.0000 | 0.4279 | 0.2126 | 0.0172 | 0.1749 | 0.1021 | 0.0397 | 0.0315 | | | |
| SRDM | 0.3683 | 0.1551 | -0.1359 | -0.1954 | -0.2650 | 0.4291 | 0.0613 | 0.3949 | 0.0820 | | |
| | 0.0017 | 0.1998 | 0.2620 | 0.1051 | 0.0266 | 0.0002 | 0.6141 | 0.0007 | 0.4996 | | |
| ES | 0.2668 | 0.1390 | -0.0991 | 0.1318 | 0.0920 | -0.0813 | 0.2027 | -0.1162 | 0.1831 | 0.1693 | |
| | 0.0256 | 0.2512 | 0.4144 | 0.2767 | 0.4489 | 0.5033 | 0.0924 | 0.3381 | 0.1293 | 0.1612 | |
| ER | -0.0593 | 0.1309 | -0.1250 | 0.0071 | -0.0965 | -0.0146 | -0.1295 | -0.1531 | -0.1761 | -0.0492 | 0.1764 |
| | 0.6261 | 0.2803 | 0.3025 | 0.9536 | 0.4266 | 0.9042 | 0.2855 | 0.2059 | 0.1448 | 0.6857 | 0.1440 |
| | SS | GP | AS | EL | SL | SRL | SFM | SRFM | SDM | SRDM | ES |

See footnote of table 11.4.

### 11. 3. 2 Analysis of data on the effect of seed treatments and sowing depth obtained under laboratory and field conditions

#### 11.3.2.1 Cultivar variations (A)

Highly significant differences at ($P \leq 0.05$) between the two cultivars were observed for seven of the eleven parameters measured. These were germination (Ger) percentage, percent of abnormal seedlings (Abs), epicotyl (EL), seedling lengths (SL), seedling root length (Srl), seedling fresh mass (SFM) and seedling root fresh mass (Srfm). With the exception of parameters like seedling root length (Srl) and seedling root fresh mass (Srfm) where Mariye performed higher than Akaki, the latter significantly outperformed the former (Mariye) in the rest of the parameters measured. The results are shown in table 11.10.

Table 11.10: Effect of cultivar variations on specific parameters in chickpea under laboratory and field conditions in terms of sowing depth **(A)**

| Variable | **Ger %** | % **Abs.** | **El mm** | **Sl mm** | **Srl mm** | **Sfm** mg | Sdm Mg | **Srfm mg** | Srdm mg | % ES | ER Days |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Akaki | **97A** | **2.8B** | **93A** | **122A** | **126B** | **257A** | 26.2a | **283B** | 32.3a | 64.6a | 22.58a |
| Mariye | **94B** | **5.3A** | **73B** | **103B** | **143A** | **237B** | 26.7a | **332A** | 33.8a | 62.6a | 22.32a |
| C.v. % | 2.05 | 40.8 | 5.3 | 4.35 | 4.9 | 6.27 | 4.92 | 8.12 | 10.25 | 19.70 | 8.64 |
| Mean | 95.6 | 4.04 | 83 | 112 | 134 | 247 | 26.42 | 308 | 33.00 | 63.60 | 22.45 |
| P≥ | ** | ** | ** | ** | ** | ** | Ns | ** | Ns | Ns | Ns |

See footnote of table 11.4.

### 1.3.2.2 Fungicide variations (B)

When the two cultivars were taken into account, the germination (GER) percent of large and medium sized seeds was significantly higher than the small. As the result, percent of abnormal seedlings (ABS) of large and medium sized seeds was significantly reduced compared to the small seed group. Similarly, the seedling dry mass (SDM) and seedling root dry mass (SRDM) of the large sized seed was statistically higher than medium and the medium than small sized seed. However, contrary to this and unexpectedly, the epicotyl length (EL) and seedling length (SL) of small sized seed were significantly longer than medium and the medium than the large sized seeds. Results were non-significant for the rest of the parameters measured (table 11.11).

Table 11.11: Effect of fungicide treatment on specific parameters in chickpea (mean of two cultivars) **(B)**

| Variable | Ger % | % Abs. | El mm | Sl mm | Srl mm | Sfm Mg | Sdm mg | Srfm mg | Srdm mg | % ES | ER Days |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 96.4a | 3.38a | 83.8 | 114a | **135AB** | 247a | 27.0a | 309a | 31.6a | 59.3a | 22.26a |
| Celest | 95.0a | 4.38a | 82.4 | 111a | **139A** | 146a | 25.9a | 295a | 34.6a | 63.4a | 22.53a |
| Dividend | 95.4a | 4.38a | 82.5 | 112a | **129B** | 248a | 26.4a | 318a | 32.8a | 68.1a | 22.56a |
| P≥ | Ns | Ns | Ns | Ns | * | Ns | Ns | Ns | Ns | Ns | Ns |

See footnote of table 11.4.

### 11.3.2.3 Cultivar x fungicide interaction (A X B)

Table 11.12 shows variations for cultivar x seed size interactions. Out of the eleven parameters measured, significant difference at ($P \leq 0.05$) was observed in only seedling root length (Srl). The longest seedling root length was obtained from Mariye treated with Celest while the shortest was Akaki seed treated with Dividend. The results of all treatments and parameters measured are shown in table 11.12 below.

Table 11.12 Cultivar x fungicide interactions in chickpea **(A X B)**

| Variable | Ger % | % Abs | El mm | Sl Mm | **Srl Mm** | Sfm Mg | Sdm. Mg | Srfm Mg | Srdm Mg | % ES | ER Days |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Akaki control | 97.5a | 2.8a | 94.8a | 125a | **128BC** | 264a | 26.5a | 287a | 30.5a | 60.75a | 22.04a |
| Celest | 97.5a | 2.0a | 91.5a | 121a | **134AB** | 248a | 25.5a | 281a | 36.0a | 67.75a | 22.55a |
| Dividend | 96.3a | 3.5a | 91.5a | 120a | **116C** | 258a | 26.5a | 283a | 30.3a | 65.38a | 23.16a |
| Mariye control | 95.3a | 4.0a | 72.8a | 103a | **142AB** | 231a | 27.5a | 332a | 32.8a | 57.75a | 22.49a |
| Celest | 92.5a | 6.8a | 73.3a | 102a | **144A** | 242a | 26.3a | 309a | 33.3a | 59.13a | 22.51a |
| Dividend | 94.5a | 5.3a | 73.5a | 104a | **143AB** | 239a | 26.3a | 354a | 35.3a | 70.88a | 21.95a |
| P≥ | Ns | Ns | Ns | Ns | * | Ns | Ns | Ns | Ns | Ns | Ns |

See footnote of table 11.4.

### 11.3.2.4 Sowing depth variations (C)

Due to the late arrival of the rains to the location where this study was conducted, soil moisture content was critically low during planting. As a result, percentage of emerged seedling (ES) from deeply planted (10-cm) soil horizon was significantly higher than from shallow planting (5 cm). Most of the seeds (80.32%) emerged from deep planting compared to only 52.74% of the shallow planted ones. Although not significantly, seeds from the deeper planting soil horizon emerged faster than from the shallow horizon. The faster emergence rate from the deep planting soil horizon could possibly be attributed to a better seed and soil moisture contact after planting in the deeper soil horizon than in the shallow horizon. The results are shown in table 11. 13.

Table11.13: Effect of sowing depth on specific parameters in chickpea (mean of two cultivars) **(C)**

| Variable | **% Emerged seedling** | % emerged seedlings | Emergence rate (mean days) |
|---|---|---|---|
| 5 cm | **50.42B** | 52.74 | 23.01a |
| 10 cm | **76.79A** | **80.32** | 21.89a |
| Mean | 63.60 | 66.53 | 22.45 |
| C.v % | 19.70 | - | 8.64 |
| P≥ | ** | - | Ns |

See footnote of table 11.4.

### 11.3.2.5 Cultivar x sowing depth interactions under field conditions (A X C)

Under field conditions there was no significant variation observed among cultivar x sowing depth interactions. Therefore, results are not tabulated nor discussed.

### 11.3.2.6 Fungicide X sowing depth interactions under field conditions (B X C)

Under field conditions there was no significant variation observed among fungicide X sowing depth. Therefore, results are not tabulated nor discussed.

### 11.3.2.7 Cultivar x fungicide interaction under field conditions (A X B X C)

Under field conditions there was no significant variation observed among cultivar x fungicide X sowing depth interactions. Therefore, results are not tabulated nor discussed.

## 11.4 Discussion

On average, seeds of the two cultivars showed high germination capacity (above 95% germination). This indicates that seeds were of high quality and the germination percentage of both cultivars certainly met the minimum requirement for seed vigour. High germination capacity is believed to be closely associated with high vigour and serves as a prediction for field emergence (Bishaw, 1994; ISTA, 1999; van De Venter, 1999).

Seeds of the cultivar, Akaki, was not only slightly better than that of Mariye in terms of germination capacity but also in seedling emergence, indicating that in this case germination capacity could perhaps be used to at least predict field emergence capacity. The main reasons for Akaki seed outperforming that of Mariye appeared to be due to the longer epicotyls of its seedlings as well as the fact that it produced larger and healthier seedlings. Interestingly, the relatively smaller sized seeds of Akaki produced larger seedlings, also with longer epicotyls, than the larger sized seeds of Mariye. The latter was also statistically confirmed when pooled data for the two cultivars was analysed.

However, statistical analysis of the pooled data for the two cultivars revealed that seedling root length, seedling fresh and dry masses as well as seedling root fresh and dry masses obtained from the large sized seeds were significantly higher than that from medium and small sized seed groups. The latter also reflected in higher seedling emergence, stand establishment and final yield. From cultivar by seed size interaction analysis it appeared that large sized seed of Akaki produced the highest plant population in the field. It therefore seems advisable to plant large sized seeds of any of the cultivars tested in this study. This is in agreement with the findings of Saxena and Sheldrake (1980) who reported that the use of graded large sized chickpea seeds in India produced larger seedlings.

Seed treatment with the fungicide, Dividend, had a negative effect on root development in the sense that it reduced seedling root length. For this reason, Dividend should be used with caution or may even have to be avoided.

Sowing of chickpea seeds at different depths had an interesting effect on its field performance. Sowing seeds as deep as 10 cm actually improved seedling emergence. The effect of sowing depth on seedling emergence is generally believed to be dependent on a complex of factors among which the soil type as well as the availability of soil moisture are considered the most important. After extensive trials on the effect of sowing depth on desi type chickpea in Australia, Pritchard (1996) suggested to sow chickpea at a depth of between 5 and 8 cm. This is more or less in line with findings in this study, except that a depth of 10 cm under South African conditions in an Avalon soil type can even be recommended.

In summary, the improvement observed in planting large sized chickpea seeds at a depth of 10 cm, may oblige one to recommend the latter as standing practice for chickpea cultivation in the Eastern Free State province of South Africa.

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# CHAPTER 12

## GENERAL DISCUSSION AND CONCLUSION

This study dealt with four major Ethiopian crops namely bread wheat, durum wheat, faba bean and chickpea. Information regarding the effect of seed size, seed treatments with fungicides and sowing depth on seed quality on these crops is particularly scarce in Ethiopia. If it is considered that these four crops are cultivated on an estimated area of over 1.3 million hectares (CSA, 1997; 1998), then the importance of information on crop management for these crops become apparent. Due to inadequate production of quality seed as well as poor cultural practices in Ethiopia, the amount of seed sowed per hectare for each of these crops is ever increasing which also increases cost to the farmer. Even in a country like South Africa, where organized agriculture is in an advanced developmental state, problems related to poor quality wheat seed are regularly encountered (Ybema, 1994). In this light, the need to build up a data bank for especially the Ethiopian seed industry was heartfelt and prompted this study.

Regarding bread wheat cultivars, although the opposite was initially observed during preliminary trials, Mitikie proved to be superior to Kubsa in both yield potential and seed protein content in the final trials. This could be attributed to the most vigorous (high germination %) and viable (strong seedling) seeds of Mitikie. Moreover, Mitikie showed the inherent genetic ability to produce seedlings with long coleoptiles, which is closely associated with plant height (Schillinger *et al.*, 1998) and a successful vegetative growth stage. The, latter was especially true for plants grown from large seeds. These plants outperformed those obtained from medium and small seeds in terms of all the yield components (viz. final grain mass and above ground biomass) and this is in agreement with the findings of Joshi (1997), Roy *et al.* (1996) and Gonzalez (1993).

The effect of treating bread wheat seeds with fungicides prior to planting was less pronounced compared to the differences observed between plants obtained from seeds of different sizes. However, both fungicides tested, significantly improved the germination capacity of seeds from both bread wheat cultivars. Especially the Vitavax plus treatment contributed to an increase in the protein content of seeds ultimately harvested, and no phytotoxic effects were observed, as was the case in Raxil treated seeds. It might be advisable for Ethiopian bread wheat farmers to treat the latter fungicide with caution.

The number of emerged seedlings from shallow planted bread wheat was significantly higher and produced plants that were faster to head and reach maturity than did plants from deep sown seeds. However, significant yield improvement was not statistically confirmed. The main reason for this could be due to the fact that deeply planted seeds produced plants with a significantly higher number of tillers plant$^{-1}$ but not necessarily with higher biomass. Moreover, seeds harvested from plants that were deep sown initially were significantly higher in protein content. It is difficult to speculate on reasons for the latter, but it might be associated with better access of roots to fertilizer placed in a band below the seed at planting, especially during the early stages of seedling development. It is known that seedlings utilize much energy during their early development to build up resistance against inter alia pathogens (Friebe *et al.*, 1999). According to the authors, highly resistant seedlings stand a better chance to develop fully during the vegetative growth stage and allows adult plants to enter the reproductive phase with more zest. The metabolic activities of these plants, including the process of protein synthesis, will most probably be on an optimal level.

The results obtained from durum wheat were similar to that from bread wheat in the sense that the medium tall cultivar, Gerardo, performed better than the semi-dwarf cultivar, Orania, under conditions prevailing in the Eastern Free State Province of South Africa. Reasons for this could be many and are difficult to list and prioritize, but seeds of the taller cultivar produced larger seedlings with clearly longer coleoptiles, compared to that of the semi-dwarf cultivar, and emerged quite easily from deeper sowing depths. Larger seedlings, with long coleoptiles, were also obtained from seeds of the tall cultivar, Kilinto, and this is in accordance with the findings of Schillinger *et al.* (1996). However, it was out-yielded by the medium tall cultivar, Gerardo.

Moreover, plants produced from large sized durum wheat seeds were superior to those produced from medium and small ones in some respects, of which higher grain yield and seed protein content were the most important. A similar statement could not be made with the same conviction for seed treatment with fungicides as no clear tendency was observed. For instance, treatment of seeds with Vitavax Plus improved the germination percentage, seedling emergence and seedling fresh mass while Raxil improved the seed protein content as well as seedling root development. Although untreated control seeds produced plants with more tillers, Vitavax Plus treatment contributed to a slight improvement in grain yield. Probably for the latter reason, treatment with Vitavax Plus must be preferred to Raxil treatment in accordance with the findings of Purchase *et al.* (1992). According to the Wheat Seed Unit of CIMMYT, Vitavax Plus is also the most preferred fungicide. In South Africa, Vitavax plus and Raxil are currently registered fungicides for the control of loose smut and stinking smut in wheat (Boshoff and van Niekerk, 2000).

However, fungicide treatment of seeds should be administered with caution when deep sowing is to be exercised. Shillinger *et al.* (1996) reported the tendency of durum wheat coleoptiles to shorten when seeds were treated with fungicides. This problem is particularly aggravated if the soil temperature is higher or lower than normal at the time of planting. Due to unexpected heavy rain during harvesting of the durum wheat trial, no reliable conclusions could be made on the effect of sowing depth on the final yield outcome and seed quality. During this time, reports by the milling and baking industry in a local agricultural magazine (Farmer's weekly, 1999) stated that only about 30% of the South African wheat was of acceptable grade. Unwanted discoloration of especially durum wheat is caused by cool, wet weather conditions or frost during seed development, that can delay ripening (Fernandez *et al.*, 2000). Discoloration reduces the commercial grade of wheat and is usually more severe under irrigated than rainfed wheat crops.

Everything considered, from this study it appears that Gerardo might be the best option for possible cultivation in the Eastern Free State Province of South Africa However, it might be advisable to compare it with other South African cultivars over a number of seasons. It might also be worthwhile to consider selecting, through cross breeding, better cultivars from Ethiopian and South African ones. In this respect, for instance, the abundance of kernels per spike observed in the South African cultivar, Orania could be combined with the desirable kernel size of Kilinto and or Gerardo. In this study, Orania showed a rather short grain filling period. According to Calderini *et al.* (1999), a short grain filling period could be associated with high temperature occurring at pre- or post anthesis affecting kernel size and grain yield, and is not necessarily related to the genetic make-up of a cultivar. The latter emphasizes the importance of optimum agronomic conditions when cultivar selections are planned.

In the study of faba bean, the cultivar Kuse was superior to Cs 20dk with regard to almost all parameters measured under both laboratory and field conditions. Moreover, in the laboratory large sized faba bean seeds performed best in terms of most of the parameters used to evaluate seed performance. Similarly, these results were confirmed under field conditions and were in accordance with the findings of Joshi (1997) as well as Krishnaveni and Vanangamudi (1989) who reported on the the advantages of large sized faba bean seeds as a propagating material.

Treatment of faba bean seeds with the fungicide, Dividend, improved seed germination while treatment with Celest significantly reduced the development of seedling roots under field conditions. No yield advantages were observed from fungicide treatments. Mareli *et al.* (1996) warned that treating faba bean seeds with fungicides should be done with caution and we have to agree with this.

From results obtained in this study, deep planting of faba bean seeds is preferred to shallow planting for a number of reasons. Our data suggests that faba bean seeds can even be planted as deep as 12 cm, particularly under low soil moisture conditions, with no yield penalty. Pritchard (1995) planted faba bean seeds at 2.5 and 5 cm in Australia and reported the latter to have produced plants with significantly higher yields than the former. His planting depth recommendation for Australia was 5 to 8 cm.

In general, and the same as was encountered with faba bean, the recently released chickpea cultivar, Akaki, outperformed the relatively older cultivar, Mariye, in terms of most of the parameters used to measure its performance under laboratory and field conditions. Moreover, with the exception of epicotyl length and seedling length, where seedlings grown from small sized chickpea seeds were superior to that from both medium and large sized seeds, the latter seeds outperformed small and medium sized seeds in almost all respects. This corresponded with the findings of Bhor *et al.* (1988) on chickpea in India. Eser *et al.* (1991) also reported that, on average, 31.4% higher yields were possible from plants grown from large sized chickpea seeds compared to small ones.

In chickpea, none of the fungicide treatments contributed to improvement of seed performance as compared to the untreated controls. Contrary to the results obtained with faba bean, the registered fungicide, Dividend, significantly reduced seedling length compared to other treatments.

This investigation also showed that deep sowing of chickpea seeds (10 cm) improved seedling emergence, compared to shallow planted (5 cm) ones. As a result, stand establishment improved by 27.6% but, surprisingly, this did not reflect in higher yields from plants grown from deep-planted seeds. However, this information is valuable, particularly for semi-arid regions where soil moisture in the upper layers can be in critical shortage during planting time. As pointed out by Pritchard (1995), the cotyledons of chickpea remain below the soil surface (unlike lupins) during germination, with only the emerging shoot growing towards the soil surface, allowing the seed of chickpea and the like to be sown deep, with no reduction in emergence and yields. Pritchard (1995) recommended a planting depth of 5 - 8 cm for chickpea but speculated that a planting depth of 10 cm would not lead to yield reduction. Results obtained during this study confirmed the latter speculation to be valid.

In summary, some workers (Duczmal and Minicka, 1989; Egli and Tekrony, 1995) are of the opinion that the relationship between laboratory- and field performance tests on seed is complex and the ability of laboratory tests to predict field emergence is variable and strongly depends on the field environment. In this light it seems worthwhile to briefly comment on the major variables observed during this study.

The seed protein content of any crop is a major contributor to the nutritional quality of foodstuff prepared from it and the higher the seed protein content the higher the commercial value of any seed crop. Pritchard (1995) reported that by disease prevention, due to rotation of cereals with legumes, Australian farmers have experienced increased yields of up to 400 kg $ha^{-1}$, concomitant with an increase in seed protein content of between 1.5 and 2.0%, compared to wheat on wheat cultivation. Moreover, according to Bulisani and Warner (1980), a higher protein content in seeds sowed the following season contributed to larger and healthier seedlings, regardless of whether seeds were small or large. Their findings also demonstrated that small seeds with a higher protein content produced heavier seedlings, with better-developed roots, than the subsequent weight class with a low percentage protein. According to Barnard (2000), seed protein content in wheat was shown to be genetically controlled and significant genotypes or varietal differences for this characteristic have been noticed.

However, she also reported that grain seed protein content is strongly affected by environmental factors and agricultural practices but that grain yield and grain protein content can be negatively correlated (Barnard, 2000).

In this study, and for all four crops studied, it was found that the best performing cultivars were those of which the seed protein content were highest during the initial planting of trials. This indicates that, especially for seed production, laboratory seed protein content tests can be used as a parameter for predicting the field performance of seeds. Moreover, as thousand-kernel mass, or hundred-kernel mass in the case of pulses, is related to seed size and most probably seed protein content, this can also be used to predict the field performance of seeds. In this study, and without exception, larger seeds proved to be superior to medium and small ones in terms of most of the parameters measured for all four crops studied. In South Africa a thousand kernel mass of more than 40 g, and a hectolitre mass of 76 kg $hl^{-1}$ in wheat, is used as an indicator for seed quality (Mamuya, 2000). From this study, indications are that this criterion can also be applied to Ethiopian cultivars. According to Pretorius (1983), thousand kernels mass still remains one of the reliable criteria for yield loss or gain.

Hectolitre mass is one of the important measurements employed in cereals for the identification of flour milling qualities (Dick and Matsuo, 1988) and represents the mass of wheat grain per volume. Fully matured and plump kernels, undamaged by diseases or the environment, are high in test weight and pack more uniformly in containers, giving rise to a higher hectolitre mass. Small kernels on the other hand, are usually more elongated and pack more randomly to give a lower hectolitre mass (Dick and Matsuo, 1980; Barnard, 2000). In this study, the bread wheat cultivar with highest hectolitre mass statistically outperformed the other. Similarly, in durum wheat, the cultivar Gerardo outperformed Orania in many respects, while the former measured highest in hectolitre mass. Comparing the two wheat species, durum wheat (67.4-kg $hl^{-1}$) outperformed bread wheat (61.5-kg $hl^{-1}$) in this and some other respects. Moreover, seeds harvested from plants grown from small sized seeds were found inferior to those grown from medium and large sized seeds. This is thus confirming the high value placed on seed plumpness as reflected in hectolitre mass.

As both wheat and pulse straw is primarily used as fodder for livestock in Sub-Saharan countries, the above ground biomass has become additionally important as parameter for measuring successful cultivation of these crops (Gomma, 1988; Payne *et al.*, 1996). The authors also reported that the price of wheat straw sometimes exceeds that of grain. The crops investigated in this study are all valuable sources of animal fodder in Ethiopia, known to sustain of the largest livestock populations in Africa (Debele, 1986). Therefore, crops that produce both good grain and above ground biomass yields are desired. With this in mind, above ground biomass was considered as parameter in this study. From the results obtained with the four crops in question it seemed that good grain yields also correlated with high above ground biomass yields. Moreover, relatively higher above ground biomass yields were obtained from plants grown from large sized seeds as well as from deep planted seeds.

Uniformity in seed size is very important for mechanical planting with precision planters. Agrawal (1988) and Bishaw (1994) reported that in general, small seeds escape mechanical injury whereas large seeds are more likely to be damaged during planting and spherical seeds are more protected against mechanical damage than flat or irregularly shaped seeds. However, larger seeds of all crops evaluated in the study, were shown to produce seedlings with higher vigour, which could be associated with more seed reserves available to the axes during germination compared to small and medium seeds. The impact of seed damage during planting, therefore, seemed to have been of less importance than the properties of large seeds.

Because of seed borne diseases, seed treatment with recommended fungicides is still considered to be an important practice as preventive measure. Line (undated) from the Internet reported that in most regions of the world, spores on the seed are the major source of inoculum. He further explained that the spores germinate and infect the plant before the wheat seedlings emerge. The fungus grows within the plant and infects the normal wheat kernel. Bowden (undated) or from internet, an extension specialist, as well as Batmann *et al.* (1986), pointed out the several uses of seed treatments. They included the control of seed- and soil-borne diseases, improvement of germination rate and stand establishment, suppression of root rot disease and the control of foliar diseases such as powdery mildew, leaf rust and leaf blotch. Batmann *et al.* (1986) also stated that for the farmer the main objective of using seed treated with fungicides is to increase yield and to prevent loss of quality (by infection of wheat with bunt, for example).

It must, however, be realized that fungicides can be harmful to seeds, humans or animals alike when the correct dosages are not applied. For example, as reported by Kollmorgen and Ballinger (1975) seed dressing with mancozeb was found to be responsible for the poor emergence of wheat and barley. In this study, Vitavax Plus significantly improved the field performance of both bread and durum wheat seeds while Raxil treatment showed the opposite. For faba beans seeds it was treatment with Dividend that had an improving effect while Celest tended to reduce the overall performance of plants grown from these seeds. However, for chickpea exactly the opposite was observed indicating that seed treatment with fungicides should be optimized for each crop separately.

In conclusion, the production of high quality seed and the development of new cultivars in many developing countries, specifically in Sub-Saharan Africa, have not kept pace with the rest of the world (van Gastel and Kerley, 1988; Grisley, 1993). Moreover, the benefits of improved cultivars will not be realized until sufficient and high quality seed is available to the producers. In Ethiopia some recent releases of new cultivars were experienced but distribution of these cultivars, to be grown on a commercial scale, has not yet taken off. Characterization of the latter in terms of its potential, compared to existing cultivars, was one of the reasons for this study. Secondly, on ground roots level, farmers in some developing countries complain about the seed quality of particularly self-pollinated crops supplied to them by large seed enterprises. Moreover, farmers are sometimes reluctant to buy seed from these companies, mostly because of its low quality, and because of low yields harvested from this seed (Zeven, 1999).

The state of affairs outlined above can be avoided, especially with the availability of modern techniques to test for seed quality. Growers are becoming more aware of the importance of high quality seed that is capable of rapid and uniform emergence under a wide range of environmental conditions, and may demand that seed is certified by seed companies in future before it is sold to farmers. This study showed that rather cheap and fast techniques, such as seed size, seed protein content and germination capacity, can be applied to predict the field performance of seeds and to certify seed quality. Poor seed quality, in terms of any one of these factors, can result in predicting reduced yield quality or even total crop failure (Bishaw, 1994). Moreover, information on optimal planting depth and seed treatment for Ethiopian crop cultivars should be more readily available to farmers and this will need more extensive research.

Due to the alarming rate at which the population of third world countries grow, grain yield production needs to be increased and the approach outlined above will need special attention. At this point in time, grain quantity is still regarded as more important than quality in Ethiopia (Dagnachew, personal communication). However, due to gradual involvement of the private sector, quality consciousness has improved. In more developed countries, such as South Africa, both producers and consumers have been quality conscious for many years. As a result, grain quality is measured frequently and is considered of paramount importance as a parameter.

Finally, development of high yielding cultivars that also produce high quality seed, should remain a priority in breeding programmes in Ethiopia. Ensermu *et al.* (1999) and Beyene *et al.* (1999) have reported that the average wheat varietal turnover in Ethiopia was 13 years. As opposed to this, the average for wheat variety turnover in one of the most effective wheat production regions, namely the Yaqui valley in Mexico, is less than four years while the world average is seven years (Beyene *et al.*, 1999). Therefore, improved varieties need to be released faster in Ethiopia and the poor performance of "older" faba bean and chickpea varieties encountered during this study support this statement. However, releasing new cultivars will come to nothing unless supported by sound multiplication schemes of seeds with high quality and a sound extension programme to capture farmers' attention and provide them with the scientific information necessary for the successful cultivation of crops.

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# SUMMARY


This study was undertaken in an attempt to obtain information on the quality of seed produced by some of the important crops grown in Ethiopia. Bread and durum wheat was chosen amongst cereals while chickpea and faba bean represented pulses. For all crops two cultivars were included except in the case of durum wheat where a third South African cultivar was additionally investigated. All experiments were carried out at the Small Grain Institute, Bethlehem, South Africa under laboratory and field conditions.

The main objectives of this study were 1) to classify seeds of each crop into three different sizes (small, medium and large) and to characterize seeds in terms of kernel mass, hectolitre mass, moisture content and protein content where applicable, 2) to determine the differences in germination potential of untreated seeds and seeds treated with different fungicides under laboratory and field conditions, 3) to evaluate the field performances of different seedlots, including yield components, by means of agronomic parameters, 4) to investigate the effect of two different sowing depths on emergence, seed yield and other yield components and 5) to statistically determine cultivar, seed size, fungicide treatment and sowing depth interactions in a variety of ways.

Of the two Ethiopian bread wheat cultivars, Mitikie outperformed Kubsa under laboratory and field conditions for most of the seed quality parameters evaluated. The main reason appeared to be the fact that deeper planted seeds performed well, probably due to longer coleoptile lengths of seedlings, which in turn was positively associated with strong and taller plants. When soil moisture is minimal, as is the case in semi-arid regions, it is possible to plant seeds of this variety deeper than normal in order to utilize soil moisture better.

On average, small sized bread wheat seeds performed worst of all and large sized seeds best in terms of most of the measured parameters. Large seeds contributed to a 13.8% increase in seedling emergence and produced plants with a 22.1% higher yield as well as 11.8% increase in above ground biomass. The effect of fungicides on the field performance of bread wheat seeds was less pronounced as compared to that of seed size.

Seedling emergence from shallow planted (5 cm) bread wheat seeds was much better than from deep planted (9 cm) ones. However, although the seed protein content of seeds harvested from plants grown from deep planted seeds were higher than that from shallow planted ones, shallow planting is still recommended for the Eastern Free State area on grounds of the overall performance of these seeds observed in this study.

Durum wheat cultivars performed in a similar fashion as bread wheat. Seedlings of semi-dwarf durum wheat cultivars, as was the case for semi-dwarf bread wheat cultivars, showed longer root lengths than did the tall cultivars. Moreover, seeds from the semi-dwarf cultivar, Gerardo, produced taller plants than Orania and outyielded both other cultivars. Some weevil damage was observed in seeds of Kilinto and therefore its true performance could not be evaluated properly.

Large sized durum wheat seeds outperformed the medium and small ones in most respects. Fungicide treatments also had an improving effect on seed performance compared to untreated control seeds. Seedling emergence was also greatly improved by shallow planting and this was reflected in significantly higher yields. The seed protein content, as was the case in bread wheat, were significantly higher in seeds harvested from plants grown from deep-planted seeds except in the case of Gerardo. Seed treatment with Vitavax Plus, together with deep planting, had the most significant increasing effect on the protein content in durum wheat seeds.

In comparing the two faba bean cultivars, it was clear that Kuse outperformed Cs 20dk in terms of most of the evaluated parameters under both laboratory and field conditions. Similar to the previous two crops, large sized seeds appeared to outperform the other two seed size groups in most respects. However, surprisingly the small sized seeds produced seedlings with longer epicotyls but this had no real effect on the other quality parameters. Moreover, the fungicide Dividend also had some improving effect on the germination of faba bean seeds. Celest, however, significantly reduced the root length of seedlings compared to the other treatments, and also on grounds of the outcome observed by means of other parameters, Celest is not recommended for treatment of faba bean seeds. Deep planted (10-12 cm) faba bean seeds outperformed the shallow planted ones in many respects and deep planting is therefore recommended.

In chickpea, none of the fungicide treatments improved the field performance of seeds. Dividend treatment rather reduced seedling root length. As in the case of bean, deep-planted seeds (10 cm) performed better than shallow planted ones (5 cm).

In general, and in most respects, laboratory and field data correlated well. Moreover, recently released cultivars of all crops investigated, outperformed the older ones. This emphasises the need for replacing older cultivars with newer ones on a larger scale in Ethiopia. Large sized seeds are preferred to medium and the medium to small ones for all the crops investigated. Shallow planting for Ethiopian wheat cultivars, but deep planting for pulse cultivars, is recommended. Seed treatment with fungicides is imperative in wheat crops but is not as critical in pulse crops.

# OPSOMMING

Hierdie studie is onderneem om inligting oor die kwaliteit van saad vir belangrike gewasse wat in Etiopië geproduseer word te verkry. Brood- en durumkoring stel die graangewasse voor terwyl akkerboon ("chickpea") en fababoon die peulgewasse verteenwoordig. Vir al die gewasse is twee cultivars ingesluit behalwe vir die durumkoring waar 'n derde Suid-Afrikaanse cultivar addisioneel bestudeer is. Alle proewe is by die Kleingraaninstituut, Bethlehem, Suid-Afrika uitgevoer onder laboratorium en veld toestande.

Die hoofdoel van die studie was 1) om die saad van elke gewas in drie groottes te klassifiseer (klein, middelmatig en groot) en om die saad te karakteriseer in terme van korrelmassa, hektoliter-massa, persentasie vog en persentasie proteïen, 2) om die ontkiemingspotensiaal van onbehandelde- en swamdoderbehandelde saad onder laboratorium- en veldtoestande te bepaal, 3) om onder veldtoestande die potensiaal van verskeie saadlotte te bepaal, 4) om die invloed van twee saaidieptes op opkoms, opbrengs en ander opbrengs-parameters te ondersoek en 5) om statisties die cultivar, saadgrootte, saadbehandelingsmiddels en saaidiepte-interaksies te ondersoek.

Van die twee Etiopiese broodkoring cultivars het Mitikie beter gevaar as Kubsa in die laboratorium sowel as onder veldtoestande vir meeste van die kwaliteitsparameters wat geëvalueer is. Die hoofrede hiervoor blyk dat saad wat dieper geplant was, beter gevaar het omrede die saailinge langer koleoptiellengtes gehad het, en dit aan die anderkant positief geassosieer is met langer plante. As grondvog minimaal is, soos die geval is in die semi-ariede streke, is dit dus moontlik om saad van hierdie cultivar dieper as normaal te plant om die vog beter te kan benut.

Oor die algemeen het die kleiner broodkoring-saad die slegste gevaar terwyl die groter saad die beste in terme van meeste van die parameters gevaar het. Die groot saadgrootte het 'n 13.8% opkoms van saailinge gehad en die plante het 'n 22.1% hoër opbrengs gelewer sowel as 'n 11.8% toename in die bogrondse bio-massa. Die invloed van swamdodersaadbehandelingsmiddels op die veldproef was minder duidelik as wat die invloed van saadgrootte was.

Saailing-opkoms by 'n vlakker plantdiepte (5 cm) vir broodkoring was baie beter as by die dieper plantdiepte (9 cm) en die proteïeninhoud van die dieper plantdiepte was hoër as dié van die vlakker plantdiepte. Volgens die resultate verkry uit die proewe, het dit egter geblyk dat die vlakker plantdiepte vir die Oos-Vrystaat aanbeveel kan word.

Durumkoring cultivars het baie soos die broodkoring gereageer. Saailinge van die semi-dwerg durumkoring cultivar, soos in die geval van die semi-dwerg broodkoring, het langer wortellengtes gehad as die lang-strooi cultivars. Ook het die semi-dwerg, Gerardo, oor die algemeen langer plante tot gevolg gehad as Orania en het die beste opbrengs vir die durums gelewer. Insekskade is opgemerk by saad van Kilinto en daarom kon die cultivar nie ten volle geëvalueer word nie.

Groot durumsaad het beter gevaar as die medium en klein saad groepe in meeste aspekte. Swamdoder-behandelde saad het ook beter gevaar as onbehandelde kontrole saad. Saailingopkoms was beter by die vlakker plantdiepte, wat weerspieël is in beter opbrengste. Die geoeste sade se proteïeninhoud, soos in die geval van broodkoring, was betekenisvol hoër vir plante wat die dieper geplante sade voortgekom het, behalwe in die geval van Gerardo. Vitavax Plus behandelde saad wat diep geplant is, het opbrengste gelewer wat die betekenisvolste verhoging in die proteïeninhoud van durumkoring gehad het.

As die twee fababoon cultivars vergelyk word, is dit duidelik dat Kuse beter gevaar het as Cs 20dk vir meeste van die parameters wat in die laboratorium- en veldproewe geëvalueer is. Soos die vorige twee gewasse, het die groot saad beter gevaar as die ander twee saadgroottes. Kleiner sade het saailinge met verrassend langer epikotiele gelewer, maar geen beduidende uitwerking is op die kwaliteit waargeneem nie.

Saadbehandeling met Dividend het ook 'n verbeterde ontkieming van die fababoontjies teweegebring. Celest aan die ander kant, het die wortellengte van die saailinge verkort. Op grond van die uitslae van die ander gemete parameters, word Celest nie vir gebruik op fababoontjies aanbeveel nie. Die fababone wat diep geplant is, het beter gevaar in verskeie aspekte as met die vlakker plantdiepte, en daarom word die dieper plantdiepte aanbeveel.

In die geval van akkerbone het nie een van die saadbehandelingsmiddels tot 'n verbetering onder veldtoedstande gelei nie. Dividend het inderwaarheid die saailing-wortellengte verkort. Soos in die geval van die fababone het die dieper plantdiepte (10 cm) beter resultate gelewer as die vlakker plantdiepte (5 cm).

Oor die algemeen het die laboratorium- en velddata goed gekorreleer. Ook het die nuwer vrygestelde cultivars beter as die ouer cultivars gevaar. Dit beklemtoon die feit dat ouer cultivars tot 'n groot mate vervang moet word met nuwe cultivars in Etiopië. Groter saadgroottes word verkies bo die klein saadgroottes in al die gewasse wat ondersoek is. Vlakker plantdieptes word aanbeveel vir Etiopiese koringcultivars, en dieper plantdieptes vir die peulgewasse. Saadbehandelingsmiddels met swamdoders is noodsaaklik vir koringgewasse maar is nie van kritiese belang vir die peulgewasse nie.

## Appendices:

## Appendix 1

**Table 5.13:** Correlation Matrix on seed size and treatments of laboratory and field parameters no bread wheat

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PPC | 0.0737 | | | | | | | | | | | | | | | | | | | | | | | |
| HLM | 0.1375 | 0.6508 | | | | | | | | | | | | | | | | | | | | | | |
| TKM | 0.3796 | 0.1663 | 0.5658 | | | | | | | | | | | | | | | | | | | | | |
| GY | 0.8322 | 0.0861 | 0.2810 | 0.5700 | | | | | | | | | | | | | | | | | | | | |
| KPS | 0.1101 | -0.3873 | -0.4450 | -0.2088 | 0.0533 | | | | | | | | | | | | | | | | | | | |
| Spms | 0.2654 | 0.0076 | -0.0490 | 0.0222 | 0.1615 | -0.1584 | | | | | | | | | | | | | | | | | | |
| PH | 0.4407 | 0.4935 | 0.7064 | 0.5244 | 0.4991 | -0.2903 | 0.1006 | | | | | | | | | | | | | | | | | |
| GFP | 0.0552 | 0.3091 | 0.6971 | 0.5801 | 0.3338 | -0.3339 | 0.0643 | 0.5129 | | | | | | | | | | | | | | | | |
| MD | -0.1990 | 0.5038 | 0.7265 | 0.3099 | -0.0576 | -0.4801 | -0.1154 | 0.4430 | 0.7432 | | | | | | | | | | | | | | | |
| HD | -0.3185 | 0.1374 | -0.1763 | -0.4965 | -0.5657 | -0.0723 | -0.2327 | -0.2383 | -0.6078 | 0.0796 | | | | | | | | | | | | | | |
| TPL | -0.1047 | -0.1330 | -0.3858 | -0.3696 | -0.2958 | 0.1713 | 0.4088 | -0.3130 | -0.3802 | -0.3415 | 0.1612 | | | | | | | | | | | | | |
| ER | -0.0227 | 0.0166 | 0.1409 | -0.0217 | 0.0108 | -0.0012 | -0.1170 | 0.1771 | -0.0390 | 0.1598 | 0.2477 | -0.1352 | | | | | | | | | | | | |
| PSE | 0.4478 | 0.1416 | 0.4126 | 0.5283 | 0.5976 | -0.2179 | 0.2594 | 0.4477 | 0.5769 | 0.2785 | -0.5290 | -0.6265 | 0.0657 | | | | | | | | | | | |
| RDM | 0.1291 | -0.3969 | -0.1810 | -0.0209 | 0.1943 | 0.2120 | 0.0122 | -0.0229 | 0.0362 | -0.2128 | -0.3065 | -0.0827 | 0.0672 | 0.1984 | | | | | | | | | | |
| SRFM | -0.0380 | -0.2854 | -0.0544 | -0.0127 | 0.0060 | 0.1042 | -0.0254 | -0.0572 | 0.1486 | 0.0225 | -0.1946 | -0.0665 | 0.0765 | 0.1592 | 0.7544 | | | | | | | | | |
| SDM | 0.1676 | -0.1793 | 0.0118 | 0.2232 | 0.3266 | 0.1210 | 0.0491 | 0.1895 | 0.3073 | 0.0078 | -0.4487 | -0.2186 | -0.1284 | 0.3604 | 0.6387 | 0.4899 | | | | | | | | |
| SFM | 0.3322 | 0.1181 | 0.4095 | 0.4477 | 0.4366 | -0.1432 | 0.1040 | 0.4822 | 0.4783 | 0.2177 | -0.4541 | -0.2474 | 0.0967 | 0.4857 | 0.5930 | 0.5493 | 0.5810 | | | | | | | |
| SRL | -0.0524 | -0.3034 | -0.4692 | -0.3334 | -0.1166 | 0.0839 | -0.0465 | -0.2431 | -0.3312 | -0.2721 | 0.1706 | 0.0946 | 0.0917 | -0.1373 | 0.3129 | 0.2990 | 0.1663 | -0.0077 | | | | | | |
| SL | 0.0850 | 0.0583 | 0.0749 | -0.0709 | 0.0298 | -0.1133 | 0.0718 | 0.1082 | 0.1476 | 0.1395 | -0.0543 | -0.0560 | 0.0110 | 0.1670 | 0.4422 | 0.4645 | 0.4240 | 0.4545 | 0.2270 | | | | | |
| CL | 0.3463 | 0.5021 | 0.7594 | 0.5562 | 0.4377 | -0.3791 | 0.0846 | 0.6986 | 0.6541 | 0.5288 | -0.3470 | -0.3305 | 0.0679 | 0.5157 | 0.0774 | 0.0392 | 0.2460 | 0.6555 | -0.3665 | 0.3775 | | | | |
| PDS | -0.1379 | -0.4014 | -0.7404 | -0.5029 | -0.2261 | 0.4034 | 0.1286 | -0.5409 | -0.5752 | -0.5820 | 0.1662 | 0.3719 | -0.0546 | -0.3890 | -0.0974 | -0.2197 | -0.1882 | -0.5503 | 0.1978 | -0.2467 | -0.6741 | | | |
| PAS | -0.0560 | -0.2428 | -0.4917 | -0.2687 | -0.1109 | 0.1506 | 0.1558 | -0.3507 | -0.3379 | -0.3554 | 0.0816 | 0.2022 | -0.1474 | -0.2402 | -0.1257 | -0.2127 | -0.1920 | -0.3482 | -0.0137 | -0.3918 | -0.4225 | 0.4179 | | |
| GP | 0.0905 | 0.3942 | 0.7294 | 0.4304 | 0.1738 | -0.3114 | -0.2062 | 0.5351 | 0.5173 | 0.5530 | -0.1143 | -0.3669 | 0.0977 | 0.3525 | 0.1070 | 0.2350 | 0.2136 | 0.5126 | -0.1243 | 0.3550 | 0.6416 | -0.8342 | -0.8197 | |
| SS | 0.2167 | -0.2687 | 0.0039 | 0.1915 | 0.2879 | 0.1285 | -0.0286 | 0.1123 | 0.1699 | -0.1251 | -0.4016 | -0.2096 | 0.0935 | 0.3317 | 0.8871 | 0.6955 | 0.6807 | 0.7366 | 0.1543 | 0.4563 | 0.2793 | -0.2553 | -0.1715 | 0.2273 |
| | AGBM | PPC | HLM | TKM | GY | KPS | Spms | PH | GFP | MD | HD | TPL | ER | PSE | SRDM | SRFM | SDM | SFM | SRL | SL | CL | PDS | PAS | GP |

**Abbreviations:**

ABGB = above ground bio-mass, PPC = Percent protein content, HLM = hectoliter mass, TKM = thousand kernel mass, GY = grain yield, KPS = kernels per spike, SPMS = seeds per meter square PH = plant height, GFP = Grain filling period, MD = days to 50% maturity, HD = days to 50% heading, TPL = tillers per plant, ER= emergence rate (mean days), PSE = percent seedling emergence SRFM = seedling root fresh mass, SRFM = seedling root fresh mass, SDM = seedling dry mass, SFM = seedling fresh mass, SRL = seedling root length, SL = Seedling length, CL = coleoptile length

PDS = percent dead SL = Seedling length SL = Seedling length SL = Seedling length seeds, PAS = percent of abnormal seedlings, GP = germination percentage, SS = seed size

## Appendix 2

**Table:6.10:** Correlation Matrix for bread wheat sowing depth study

| | AGBM | PC | GY | TKM | KPS | SPMS | PH | GFP | DM | DH | TPP | ER | SE | SRDM | SRFM | SDM | SFM | SRL | SL | CL | DS | AS | PG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PC | 0.2013 | | | | | | | | | | | | | | | | | | | | | | |
| GY | 0.2107 | -0.0639 | | | | | | | | | | | | | | | | | | | | | |
| TKM | 0.0235 | 0.1234 | 0.2249 | | | | | | | | | | | | | | | | | | | | |
| KPS | 0.2887 | 0.1088 | **0.3706** | 0.1361 | | | | | | | | | | | | | | | | | | | |
| SPMS | 0.1106 | -0.0597 | **0.6088** | **0.3192** | 0.2752 | | | | | | | | | | | | | | | | | | |
| PH | 0.2585 | 0.3299 | **0.3327** | -0.0152 | **0.5484** | 0.1446 | | | | | | | | | | | | | | | | | |
| GFP | 0.0114 | **0.4132** | 0.0423 | 0.0545 | 0.0774 | 0.2653 | 0.2046 | | | | | | | | | | | | | | | | |
| DM | -0.0037 | **0.6771** | **-0.3603** | -0.2514 | -0.1343 | -0.2847 | 0.2120 | **0.5356** | | | | | | | | | | | | | | | |
| DH | -0.0156 | **0.2930** | **-0.4232** | **-0.3208** | -0.2206 | **-0.5708** | 0.0150 | **-0.4544** | **0.5089** | | | | | | | | | | | | | | |
| TPP | 0.0007 | **0.3759** | -0.1158 | 0.0527 | 0.1912 | 0.1530 | **0.3668** | 0.0307 | **0.3169** | **0.3030** | | | | | | | | | | | | | |
| ER | -0.0264 | -0.0086 | -0.2743 | 0.1837 | -0.0490 | -0.1765 | -0.1457 | -0.1711 | 0.0632 | 0.2411 | **0.3143** | | | | | | | | | | | | |
| SE | 0.0200 | -0.2768 | **0.5296** | 0.1125 | 0.0579 | **0.5349** | -0.1339 | 0.1954 | **-0.4348** | **-0.6578** | **-0.6562** | **-0.4595** | | | | | | | | | | | |
| SRDM | -0.1949 | **-0.5700** | 0.0641 | 0.0170 | 0.1802 | 0.1397 | 0.0965 | **-0.3944** | **-0.4213** | -0.0424 | 0.1150 | 0.0435 | 0.0321 | | | | | | | | | | |
| SRFM | -0.2274 | -0.0783 | 0.2207 | **0.5259** | 0.1422 | 0.2559 | 0.0072 | 0.1225 | -0.1497 | -0.2828 | -0.0015 | 0.1018 | 0.1277 | **0.3450** | | | | | | | | | |
| SDM | -0.0928 | -0.0350 | -0.0109 | -0.0295 | -0.0036 | 0.0002 | 0.1202 | -0.0495 | -0.0126 | 0.0372 | -0.0137 | -0.0262 | -0.0209 | 0.0303 | -0.0646 | | | | | | | | |
| SFM | 0.0161 | **0.6459** | -0.1994 | -0.0130 | -0.2073 | -0.1320 | 0.1167 | **0.2982** | 0.5606 | 0.2874 | 0.0942 | -0.1478 | -0.1349 | **-0.5431** | -0.1947 | 0.0769 | | | | | | | |
| SRL | -0.0936 | **-0.5593** | -0.0103 | -0.0209 | -0.0697 | 0.0711 | -0.0633 | **-0.4688** | **-0.3812** | 0.0758 | 0.0485 | 0.1381 | -0.0410 | 0.6175 | 0.2146 | 0.0431 | **-0.4679** | | | | | | |
| SL | 0.0242 | 0.2588 | -0.1564 | 0.1615 | **-0.3064** | -0.0743 | -0.1672 | 0.0507 | 0.1926 | 0.1515 | 0.0312 | -0.0428 | -0.0890 | **-0.4572** | 0.0600 | 0.0563 | **0.4987** | 0.1094 | | | | | |
| CL | 0.0821 | **0.7213** | -0.2216 | -0.0528 | -0.1901 | -0.1776 | 0.0815 | **0.3891** | **0.5940** | 0.2299 | 0.0384 | -0.1857 | -0.0823 | **-0.7727** | **-0.3413** | 0.0590 | **0.8564** | **-0.5949** | **0.5225** | | | | |
| DS | -0.1733 | **-0.7134** | 0.1002 | -0.1262 | 0.0055 | -0.0513 | -0.1956 | **-0.5148** | **-0.5700** | -0.0764 | -0.0297 | 0.1045 | -0.0268 | **0.5260** | -0.0415 | 0.0649 | **-0.7563** | **0.4175** | **-0.4089** | **-0.7514** | | | |
| AS | -0.0429 | **-0.4047** | -0.0294 | -0.1618 | 0.1541 | -0.0405 | -0.0561 | -0.2860 | **-0.3595** | -0.0876 | 0.0391 | 0.2800 | -0.0694 | **0.3901** | -0.1375 | 0.0296 | **-0.5486** | 0.1072 | **-0.5577** | **-0.5153** | **0.6467** | | |
| PG | 0.1211 | **0.6403** | -0.0224 | 0.1784 | -0.0706 | 0.0750 | 0.1514 | **0.4716** | **0.5300** | 0.0783 | -0.0002 | -0.1854 | 0.0527 | **-0.5274** | 0.1386 | -0.0518 | **0.7300** | -0.2880 | 0.5233 | **0.7001** | **-0.9158** | **-0.8730** | |
| SP | 0.1823 | **0.4268** | -0.0820 | -0.0694 | 0.2460 | -0.1061 | **0.3710** | 0.0435 | **0.4907** | **0.4733** | **0.7461** | 0.2890 | **-0.6957** | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -0.0067 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

**Abreviations:**

ABGB = above ground biomass, PC = protein content, TKM = thousand kernel mass, GY = grain yield, KPS = kernels per spike, SPMS = seeds per meter square PH = plant height, GFP = Grain filling period, DM = days to 50% maturity, DH = days to 50% heading, TPL = tillers per plant, ER= emergence rate (mean days), SE = seedling emergence SRFM = seedling root fresh mass, SRFM = seedling root fresh mass, SDM = seedling dry mass, SFM = seedling fresh mass, SRL = seedling root length, SL = Seedling length, CL = coleoptile length DS = dead seed, SL = Seedling length Srl = Seedling root length , AS = abnormal seedling, GP = germination percentage, SS = seed size

Appendix 3

**Table 7.14**: Correlation Matrix of seed size and treatments on durum wheat laboratory and field trials

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PC | -0.0206 | | | | | | | | | | | | | | | | | | | | | | | |
| HLM | 0.0182 | 0.6369 | | | | | | | | | | | | | | | | | | | | | | |
| TKM | -0.0770 | 0.5076 | 0.6991 | | | | | | | | | | | | | | | | | | | | | |
| GY | 0.7720 | 0.0610 | -0.0344 | -0.1846 | | | | | | | | | | | | | | | | | | | | |
| kPS | 0.3091 | -0.2194 | -0.4676 | -0.4660 | 0.5139 | | | | | | | | | | | | | | | | | | | |
| SPMS | 0.6728 | -0.0812 | -0.1534 | -0.1965 | 0.5880 | 0.2735 | | | | | | | | | | | | | | | | | | |
| PH | -0.1709 | 0.4139 | 0.6909 | 0.7408 | -0.3820 | -0.6218 | -0.2416 | | | | | | | | | | | | | | | | | |
| GFP | -0.1517 | 0.4304 | 0.7305 | 0.7244 | -0.2935 | -0.5388 | -0.2225 | 0.8738 | | | | | | | | | | | | | | | | |
| DM | -0.3127 | 0.1138 | 0.4714 | 0.5855 | -0.5584 | -0.6487 | -0.3140 | 0.8446 | 0.8259 | | | | | | | | | | | | | | | |
| DH | -0.2210 | -0.5189 | -0.4146 | -0.2342 | -0.4244 | -0.1644 | -0.1426 | -0.0920 | -0.2698 | 0.2646 | | | | | | | | | | | | | | |
| TPP | -0.0912 | 0.1409 | 0.4044 | 0.4632 | -0.2911 | -0.4622 | -0.0536 | 0.6962 | 0.5939 | 0.6942 | 0.1106 | | | | | | | | | | | | | |
| ER | -0.4863 | 0.0894 | -0.1070 | -0.0328 | -0.4340 | -0.1427 | -0.2558 | 0.0268 | -0.0981 | 0.1555 | 0.4127 | -0.0541 | | | | | | | | | | | | |
| ES | 0.4360 | -0.2298 | -0.4611 | -0.5448 | 0.5835 | 0.5821 | 0.5504 | -0.7607 | -0.6558 | -0.7816 | -0.1748 | -0.7925 | -0.1338 | | | | | | | | | | | |
| SRDM | 0.0102 | 0.0220 | 0.1388 | 0.0366 | 0.0225 | 0.0397 | 0.0291 | 0.0415 | 0.0507 | 0.0565 | 0.0231 | 0.0530 | 0.0160 | 0.0216 | | | | | | | | | | |
| SRFM | 0.1829 | 0.0080 | -0.0254 | -0.2346 | 0.3230 | 0.3212 | 0.1903 | -0.3296 | -0.2117 | -0.3554 | -0.2101 | -0.2787 | -0.1546 | 0.3843 | 0.7898 | | | | | | | | | |
| SDM | -0.2708 | 0.2018 | 0.4888 | 0.5404 | -0.4184 | -0.4798 | -0.2263 | 0.7606 | 0.6677 | 0.7553 | 0.0954 | 0.5544 | 0.1978 | -0.5848 | 0.4747 | 0.0109 | | | | | | | | |
| SFM | -0.3100 | 0.2902 | 0.5672 | 0.5943 | -0.4460 | -0.5498 | -0.2818 | 0.8225 | 0.7357 | 0.7830 | 0.0352 | 0.5628 | 0.2024 | -0.6325 | 0.3912 | -0.0571 | 0.9281 | | | | | | | |
| SRL | 0.3183 | 0.0236 | -0.2816 | -0.3362 | 0.5211 | 0.4996 | 0.3109 | -0.5742 | -0.4704 | -0.6711 | -0.2819 | -0.4628 | -0.2452 | 0.5663 | 0.0494 | 0.4139 | -0.6225 | -0.6006 | | | | | | |
| SL | -0.4312 | 0.2085 | 0.3203 | 0.4500 | -0.5535 | -0.5199 | -0.2721 | 0.6427 | 0.5374 | 0.6798 | 0.1999 | 0.3982 | 0.3866 | -0.5005 | 0.2067 | -0.2068 | 0.7521 | 0.8381 | -0.5007 | | | | | |
| CL | -0.3676 | 0.2151 | 0.4744 | 0.5867 | -0.5264 | -0.5641 | -0.3251 | 0.8061 | 0.7136 | 0.8333 | 0.1593 | 0.5465 | 0.2830 | -0.6505 | 0.1849 | -0.2693 | 0.8669 | 0.9424 | -0.6627 | 0.8792 | | | | |
| DS | -0.3564 | 0.1430 | 0.4900 | 0.6039 | -0.5807 | -0.6617 | -0.3572 | 0.8331 | 0.7292 | 0.9052 | 0.2347 | 0.7227 | 0.1554 | -0.7819 | 0.0988 | -0.3713 | 0.7775 | 0.8091 | -0.6810 | 0.6967 | 0.8374 | | | |
| AS | -0.2880 | 0.2084 | 0.4938 | 0.5702 | -0.5092 | -0.5859 | -0.3260 | 0.8140 | 0.7026 | 0.8020 | 0.1417 | 0.4886 | 0.1533 | -0.6498 | 0.0634 | -0.3187 | 0.6784 | 0.7337 | -0.6227 | 0.6411 | 0.7494 | 0.7579 | | |
| GP | 0.3444 | -0.1859 | -0.5369 | -0.6332 | 0.5801 | 0.6735 | 0.3615 | -0.8850 | -0.7788 | -0.9328 | -0.2103 | -0.6923 | -0.1550 | 0.7918 | -0.1073 | 0.3617 | -0.8060 | -0.8426 | 0.6976 | -0.7208 | -0.8634 | -0.9776 | -0.8563 | |
| SS | 0.0989 | 0.0115 | 0.1381 | -0.0099 | 0.1524 | 0.1135 | 0.0838 | -0.0072 | 0.0336 | -0.0366 | -0.1331 | 0.0563 | -0.1586 | 0.0884 | 0.8574 | 0.7505 | 0.3867 | 0.2991 | 0.0493 | 0.0588 | 0.1003 | 0.0236 | -0.0790 | -0073 |
| | AGBM | PC | HLM | TKM | GY | KPS | SPMS | PH | GFP | MD | DH | TPP | ER | ES | SRDM | SRFM | SDM | SFM | SRL | SL | CL | DS | AS | GP |

**Abbreviations** used for the table of **correlation matrix:**

ABGB = above ground bio-mass, PC = protein content, TKM = thousand kernel mass, GY = grain yield, KPS = kernels per spike, SPMS = seeds per meter square PH = plant height, GFP = Grain filling period, DM = days to 50% maturity DH = days to 50% heading, TPL = tillers per plant, ER= emergence rate (mean days), ES = emergence seedlings SRFM = seedling root fresh mass, SRFM = seedling root fresh mass, SDM = seedling dry mass, SFM = seedling fresh mass, SRL = seedling root length, SL = Seedling length, CL = coleoptile length DS = dead seed SL = Seedling length, AS = abnormal seedlings, GP = germination percent, SS = seed size, HLM = hectolitre mass

NB: Significant differences at 5% probability level are shown in bold

## Appendix 4

**Table 8.13 Correlation Matrix for laboratory and field parameters on durum wheat sowing depth study**

| | SS | GP | AS | DS | CL | SL | SRL | SFM | SDM | SRFM | SRDM | ES | ER | TPP | DH | HM | GFP | PH | KPS | SPMS | GY | TKM | PC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GP | 0.0000 | | | | | | | | | | | | | | | | | | | | | | |
| AS | 0.0000 | **-0.9331** | | | | | | | | | | | | | | | | | | | | | |
| DS | 0.0000 | **-0.9876** | **0.8777** | | | | | | | | | | | | | | | | | | | | |
| CL | 0.0000 | -0.9049 | 0.8475 | 0.8890 | | | | | | | | | | | | | | | | | | | |
| SL | 0.0000 | -0.7750 | 0.7233 | 0.7541 | 0.9352 | | | | | | | | | | | | | | | | | | |
| SRL | 0.0000 | **0.8545** | **-0.8353** | **-0.8395** | **-0.7832** | **-0.6718** | | | | | | | | | | | | | | | | | |
| SFM | 0.0000 | **-0.9096** | **0.8746** | **0.8800** | **0.9846** | **0.9174** | **-0.7768** | | | | | | | | | | | | | | | | |
| SDM | 0.0000 | **-0.9362** | **0.9250** | **0.9039** | **0.9447** | **0.8686** | **-0.8535** | **0.9550** | | | | | | | | | | | | | | | |
| SRFM | 0.0000 | **0.7344** | **-0.5861** | **-0.7652** | **-0.6605** | **-0.5410** | **0.6089** | **-0.6223** | **-0.6662** | | | | | | | | | | | | | | |
| SRDM | 0.0000 | **-0.2560** | **0.3548** | 0.2033 | **0.2951** | **0.4290** | -0.1635 | **0.3186** | **0.3177** | 0.0982 | | | | | | | | | | | | | |
| ES | **-0.5323** | **0.4087** | **-0.4002** | **-0.3962** | **-0.3569** | **-0.2831** | **0.4058** | **-0.3671** | **-0.4079** | **0.3957** | -0.0890 | | | | | | | | | | | | |
| ER | **0.4519** | 0.0443 | -0.0405 | -0.0459 | -0.0821 | -0.1287 | -0.0680 | -0.1022 | -0.0321 | -0.1231 | -0.0785 | **-0.5911** | | | | | | | | | | | |
| TPP | **0.3717** | **-0.3015** | **0.3025** | **0.2909** | **0.2516** | 0.2027 | -0.2197 | **0.2691** | **0.2679** | -0.2208 | 0.1135 | **-0.4662** | 0.2328 | | | | | | | | | | |
| HD | 0.1434 | **-0.5057** | **0.4684** | **0.5131** | **0.4946** | **0.4023** | **-0.5727** | **0.4576** | **0.5015** | **-0.4312** | 0.1367 | **-0.6905** | **0.4566** | **0.4086** | | | | | | | | | |
| MD | 0.1010 | **-0.7786** | **0.7318** | **0.7601** | **0.7358** | **0.6386** | **-0.6714** | **0.7383** | **0.7518** | **-0.5931** | 0.1870 | -0.4200 | 0.0908 | **0.4047** | **0.4932** | | | | | | | | |
| GFP | -0.0899 | **-0.3961** | **0.4088** | **0.3571** | **0.3519** | **0.3328** | **-0.2378** | **0.4043** | **0.3927** | -0.1854 | 0.1625 | 0.1988 | **-0.3648** | 0.0370 | -0.3530 | 0.5909 | | | | | | | |
| PH | 0.0740 | -0.7101 | 0.6617 | 0.6991 | 0.6775 | 0.5297 | -0.5971 | 0.6987 | 0.6711 | -0.4911 | -0.0237 | **-0.3310** | -0.1194 | **0.3325** | **0.3420** | **0.5810** | **0.3515** | | | | | | |
| KPS | 0.1124 | **0.4134** | **-0.4286** | **-0.3846** | **-0.4004** | **-0.3816** | **0.3889** | **-0.4142** | **-0.4262** | 0.2527 | **-0.2488** | 0.2315 | -0.0086 | 0.0706 | **-0.2525** | **-0.3089** | -0.1037 | -0.1445 | | | | | |
| SPMS | -0.2020 | 0.0001 | -0.0246 | 0.0007 | 0.0003 | 0.0048 | 0.0648 | 0.0278 | -0.0433 | 0.1029 | -0.0043 | **0.4327** | **-0.3939** | **0.3208** | -0.1919 | 0.0719 | **0.2815** | 0.1650 | **0.3003** | | | | |
| GY | -0.2039 | 0.0748 | -0.1768 | -0.0374 | -0.0471 | -0.0485 | 0.1570 | -0.0591 | -0.1590 | 0.0785 | -0.1275 | **0.3495** | **-0.3825** | -0.0192 | **-0.2938** | -0.1832 | 0.0295 | 0.1428 | **0.3208** | **0.3353** | | | |
| TKM | -0.1556 | **-0.5955** | **0.5583** | **0.5678** | **0.5246** | **0.4365** | **-0.4401** | **0.5606** | **0.5645** | **-0.4302** | -0.0680 | -0.1040 | **-0.2576** | 0.1084 | 0.1082 | **0.4058** | **0.3576** | **0.6631** | **-0.2639** | 0.0942 | 0.1148 | | |
| PC | **0.2414** | -0.1703 | 0.1511 | 0.1478 | **0.2642** | **0.2525** | 0.0418 | **0.3130** | 0.1867 | -0.1189 | -0.0474 | -0.0440 | -0.1905 | 0.0966 | -0.1148 | 0.1937 | 0.2218 | **0.3363** | -0.0362 | 0.0755 | 0.0335 | 0.2878 | |
| AGBM | 0.1438 | 0.1049 | -0.1147 | -0.1046 | -0.1789 | -0.1806 | 0.1173 | -0.1744 | -0.1262 | -0.0329 | -0.0882 | -0.0003 | 0.1491 | 0.1696 | -0.1251 | -0.1326 | -0.0161 | -0.1143 | 0.1587 | 0.0750 | 0.1001 | -0.0578 | -0.1414 |

**Abbreviations:**

ABGB = above ground bio-mass, PC = protein content, TKM = thousand kernel mass, GY = grain yield, KPS = kernels per spike, SPMS = seeds per meter square PH = plant height, GFP = Grain filling period, DM = days to 50% maturity DH = days to 50% heading, TPL = tillers per plant, ER= emergence rate (mean days), ES = emerged seedlings

SRFM = seedling root fresh mass, SRFM = seedling root fresh mass, SDM = seedling dry mass, SFM = seedling fresh mass, SRL = seedling root length, SL = Seedling length, CL = coleoptile length DS = dead seed SL = Seedling length, AS = abnormal seedlings, GP = germination percent, SS = seed size

NB: All significant differences at 5% probability level are written in bold while none significance is not

## Appendix 5

**Table 9.12: Correlation matrix on faba bean in the laboratory and field experiments in relation to seed size & treatments**

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GER | 0.4676 | | | | | | | | | | | | | | | | | | | | | |
| AS | -0.4133 | -0.8688 | | | | | | | | | | | | | | | | | | | | |
| EL | -0.5001 | -0.2954 | 0.1939 | | | | | | | | | | | | | | | | | | | |
| SL | -0.4654 | -0.2633 | 0.1534 | 0.9689 | | | | | | | | | | | | | | | | | | |
| SRL | -0.1113 | -0.1331 | 0.0016 | 0.3063 | 0.3614 | | | | | | | | | | | | | | | | | |
| SFM | 0.0617 | 0.0919 | -0.2023 | 0.6571 | 0.7469 | 0.4093 | | | | | | | | | | | | | | | | |
| SRFM | 0.1725 | 0.2420 | -0.3402 | 0.1648 | 0.2845 | 0.3340 | 0.6788 | | | | | | | | | | | | | | | |
| SDM | 0.5347 | 0.3466 | -0.4074 | 0.2030 | 0.2687 | 0.1985 | 0.7754 | 0.5470 | | | | | | | | | | | | | | |
| SRDM | 0.3578 | 0.3831 | -0.4148 | 0.0145 | 0.0210 | 0.0019 | 0.2949 | 0.5455 | 0.4998 | | | | | | | | | | | | | |
| ES | 0.2480 | 0.0446 | -0.0061 | 0.3342 | 0.3242 | 0.2120 | 0.3059 | 0.0928 | 0.2580 | 0.2086 | | | | | | | | | | | | |
| ER | 0.0933 | 0.0051 | -0.0425 | 0.0563 | 0.1147 | 0.2218 | 0.2251 | 0.2085 | 0.1669 | 0.1439 | -0.1439 | | | | | | | | | | | |
| BPP | 0.1357 | 0.2134 | -0.1694 | -0.4546 | -0.4694 | -0.3177 | -0.3126 | -0.1163 | -0.0500 | -0.0693 | -0.5881 | -0.0002 | | | | | | | | | | |
| DH | -0.2609 | -0.1466 | 0.2463 | 0.0219 | 0.0425 | 0.0179 | -0.0989 | -0.1154 | -0.2259 | -0.2814 | -0.3889 | 0.1927 | 0.1159 | | | | | | | | | |
| DM | 0.1806 | 0.1208 | -0.0845 | -0.1819 | -0.1594 | 0.0725 | -0.0067 | -0.0132 | 0.1005 | -0.0417 | -0.1058 | 0.1078 | 0.3385 | 0.0929 | | | | | | | | |
| GFP | 0.3303 | 0.2041 | -0.2494 | -0.1499 | -0.1489 | 0.0387 | 0.0710 | 0.0765 | 0.2438 | 0.1764 | 0.2129 | -0.0637 | 0.1673 | -0.6683 | 0.6781 | | | | | | | |
| PH | -0.1557 | -0.2234 | 0.2063 | 0.0693 | 0.0610 | 0.4262 | 0.0380 | -0.0998 | -0.0642 | -0.1444 | -0.1767 | 0.3045 | -0.0267 | 0.2409 | 0.1601 | -0.0569 | | | | | | |
| PPP | 0.1052 | 0.1958 | -0.2113 | -0.0587 | -0.0996 | -0.0415 | -0.0632 | -0.0861 | 0.0610 | 0.1587 | -0.0243 | -0.0711 | 0.2980 | -0.2052 | 0.5230 | 0.5419 | -0.0805 | | | | | |
| SPP | -0.0411 | -0.0330 | 0.0448 | -0.1696 | -0.1656 | -0.0316 | -0.1886 | -0.2016 | -0.1311 | -0.2237 | -0.2243 | 0.0759 | 0.2704 | 0.0485 | 0.1166 | 0.0502 | 0.0630 | -0.1146 | | | | |
| GY | 0.1714 | 0.1873 | -0.1562 | 0.0127 | -0.0117 | 0.0542 | 0.0266 | -0.1032 | 0.1541 | 0.1337 | 0.2928 | -0.0529 | 0.1142 | -0.2942 | 0.5348 | 0.6173 | -0.0900 | 0.7703 | 0.2250 | | | |
| HSM | 0.3390 | 0.1740 | -0.1866 | -0.2305 | -0.2221 | 0.0440 | 0.0164 | -0.0311 | 0.2388 | 0.0679 | -0.0229 | 0.0592 | 0.3719 | -0.1360 | 0.7633 | 0.6708 | 0.0141 | 0.5917 | 0.1675 | 0.6536 | | |
| PC | -0.0033 | -0.0273 | -0.0772 | 0.0767 | 0.1025 | 0.2438 | 0.1723 | 0.0495 | 0.1623 | -0.0634 | 0.1126 | 0.0791 | 0.1652 | -0.0426 | 0.6288 | 0.4979 | 0.0481 | 0.4325 | 0.1105 | 0.5742 | 0.7326 | |
| AGBM | 0.2071 | 0.2324 | -0.2135 | 0.0649 | 0.0680 | 0.0299 | 0.1524 | 0.0245 | 0.2209 | 0.1860 | 0.3064 | 0.0695 | 0.1138 | -0.2371 | 0.6530 | 0.6648 | -0.0600 | 0.6507 | 0.1228 | 0.8246 | 0.6914 | 0.6134 |
| | SS | GER | AS | EL | SL | SRL | SFM | SRFM | SDM | SRDM | ES | ER | BPP | DH | DM | GFP | PH | PPP | SPP | GY | HSM | PC |

## Abbreviations used in tables

ES =emerged seedling, EG =emerged of germinated, RE =rate of emergence, PPMS =plants per meter square, DF =days to 50% flowering, DM =days to 50% maturity, GFP =grain filling period, PH =plant height BPP =branches per plant, PPP =pods per plant, GY =grain yield, PC =protein content, HKM =hundred kernels mass, AGBM = above ground bi-mass, SPP =seeds per plant, CM = centimetre, HA = hactare, KG= kilogram

# Appendix 6

**Table 10.8: Correlation matrix for laboratory and field trials on faba bean in relation to sowing depth study**

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GER | 0.0000 | | | | | | | | | | | | | | | | | | | | | |
| AS | 0.0000 | **-0.7319** | | | | | | | | | | | | | | | | | | | | |
| EL | 0.0000 | 0.0445 | -0.1205 | | | | | | | | | | | | | | | | | | | |
| SL | 0.0000 | 0.0690 | -0.1151 | **0.9723** | | | | | | | | | | | | | | | | | | |
| SRL | 0.0000 | -0.2716 | 0.0951 | **0.5270** | **0.5312** | | | | | | | | | | | | | | | | | |
| SFM | -0.1493 | 0.0565 | 0.0168 | -0.1128 | -0.0844 | -0.1216 | | | | | | | | | | | | | | | | |
| SRFM | -0.0070 | **0.3365** | **-0.3572** | **0.3989** | **0.4973** | **0.3607** | 0.1062 | | | | | | | | | | | | | | | |
| SDM | 0.0000 | 0.1598 | -0.2741 | **0.6248** | **0.7026** | **0.6031** | -0.0465 | **0.6704** | | | | | | | | | | | | | | |
| SRDM | 0.0000 | **0.4637** | **-0.3672** | **0.3966** | **0.4178** | 0.0727 | 0.2372 | **0.6091** | **0.4128** | | | | | | | | | | | | | |
| ES | 0.0707 | -0.1461 | 0.2088 | **0.4927** | **0.4693** | 0.2137 | 0.0605 | -0.1372 | 0.1937 | 0.2121 | | | | | | | | | | | | |
| ER | **-0.4739** | 0.0365 | 0.0017 | -0.1552 | -0.2417 | -0.2030 | 0.0126 | -0.2272 | **-0.3837** | -0.0524 | **-0.3706** | | | | | | | | | | | |
| BPP | 0.0812 | 0.1314 | -0.1160 | **-0.5567** | **-0.5307** | -0.2150 | -0.1482 | -0.0598 | -0.2771 | -0.2896 | **-0.7854** | 0.1490 | | | | | | | | | | |
| DF | **-0.3410** | -0.0055 | 0.1012 | **-0.4208** | **-0.4904** | **-0.3918** | 0.0517 | -0.2828 | **-0.5441** | -0.1740 | **-0.5686** | **0.7898** | **0.4051** | | | | | | | | | |
| DM | 0.0000 | -0.2024 | 0.1901 | **-0.4473** | **-0.5247** | **-0.4099** | -0.0637 | **-0.4678** | **-0.5329** | -0.2742 | -0.1936 | **0.3922** | **0.3003** | **0.5922** | | | | | | | | |
| GFP | **0.3837** | -0.1672 | 0.0366 | -0.1067 | -0.1194 | -0.0252 | -0.1492 | -0.1892 | -0.0530 | -0.0484 | **0.3150** | **-0.3874** | 0.0300 | **-0.3846** | **0.4522** | | | | | | | |
| PH | 0.1112 | -0.0988 | 0.0550 | 0.1955 | 0.2650 | 0.1050 | 0.0324 | 0.1806 | **0.3011** | 0.0890 | 0.0424 | -0.1901 | 0.1110 | -0.1753 | 0.0977 | **0.3053** | | | | | | |
| PPP | 0.2252 | -0.0101 | -0.1170 | 0.0293 | 0.1101 | 0.0378 | 0.0498 | 0.1214 | 0.2475 | 0.1075 | -0.0132 | -0.2807 | 0.1402 | -0.2550 | 0.1089 | **0.4083** | **0.4831** | | | | | |
| SPP | -0.0930 | -0.1441 | 0.2830 | -0.0579 | -0.0921 | -0.2137 | -0.2178 | **-0.3780** | -0.2770 | -0.2242 | 0.1671 | 0.1387 | -0.0490 | 0.1351 | 0.1338 | 0.0281 | -0.0919 | **-0.4988** | | | | |
| GY | 0.1544 | -0.0431 | 0.0014 | -0.0051 | 0.0569 | -0.0441 | -0.0630 | -0.0664 | 0.1452 | 0.0830 | 0.1817 | -0.3210 | 0.1804 | -0.2609 | 0.2839 | **0.6447** | **0.6169** | **0.6729** | 0.0938 | | | |
| HSM | 0.2658 | -0.0184 | -0.0871 | -0.2840 | -0.2607 | -0.0382 | -0.0517 | 0.1015 | 0.0747 | -0.0764 | **-0.4237** | -0.0952 | **0.4585** | 0.0831 | 0.2587 | 0.2605 | 0.2094 | **0.3212** | -0.1658 | **0.3384** | | |
| PC | 0.0872 | -0.1767 | 0.1205 | 0.1300 | 0.1516 | 0.2022 | 0.0235 | 0.0945 | 0.2228 | 0.0130 | 0.1504 | -0.1575 | -0.0231 | -0.1626 | 0.1291 | **0.3296** | **0.3326** | **0.3054** | -0.0709 | **0.3975** | **0.5199** | |
| AGBM | **0.3262** | 0.0355 | -0.1344 | 0.0854 | 0.0647 | -0.0681 | -0.1085 | -0.0361 | 0.0683 | 0.1582 | 0.0561 | -0.1721 | 0.2478 | -0.1477 | **0.2929** | **0.5694** | **0.5957** | **0.5681** | -0.0135 | **0.7692** | **0.4526** | **0.3952** |
| | SD | GER | AS | EL | SL | SRL | SFM | SRFM | SDM | SRDM | ES | ER | BPP | DF | DM | GFP | PH | PPP | SPP | GY | HSM | PC |

**Abbreviations:**

GP =germination percentage AS= abnormal seedlings EL= epicotyl length SL= seedling length SRL=SEEDLING ROOT LENGTH SFM= seedling fresh mass SRFM= seedling root fresh mass SDM= seedling dry mass SRDM= seedling root dry mass ES= emerged seedlings ER= emergence rate BPP= branches per plant DF= days to 50% flowering DM= days to 50% maturity GP= germination percentage PH= plant height PPP= pods per plant SPP= seeds per plant GY= grain yield HSM= hundred seeds mass PC= protein content AGBM= above ground bio-mass SD= sowing depth