EVALUATION OF IRRIGATED COTTON CULTIVARS IN SOUTH AFRICA.

by

M. M. PRETORIUS

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Department of Soil, Crop and Climate Sciences
Faculty of Natural and Agricultural Sciences
University of the Free State
BLOEMFONTEIN.

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SUPERVISOR: Dr J. Allemann.

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DECLARATION

I declare that this dissertation is my own unaided work. It is being submitted for the degree of M.Sc (Agric) in the Faculty of Natural and Agricultural Sciences, University of the Free State, Bloemfontein, RSA. It has not been submitted before for any degree or examination in any other University.

Signed on the ________________ day of _______________ 2010

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ABSTRACT

Cotton (*Gossypium hirsutum*) is a globally important fibre crop. The cottonseed has a high oil and protein content and is used for human and animal consumption. Innumerable commodities are made from cotton. Annual cultivar evaluations are essential to compare the yield and quality obtained in different production areas, to obtain experimental data to recommend the most suitable cultivar for a production area. The objective of this study was to evaluate the performance of different cotton cultivars under irrigation in South Africa. The cultivars planted from the 2003/2004 season up to the 2005/2006 season were NuOPAL, DeltaOPAL, DeltaOpal RR, LS9219 and SZ9314. The localities were Loskop (Mpumalanga Province), Makhathini (KwaZulu-Natal), Rustenburg (North-West Province), Vaalharts and Upington (Northern Cape) and Weipe (Limpopo Province). The Additive Main Effects and Multiplicative Interaction (AMMI) statistical model was used to describe the effect of cultivar x environment interaction on the yield of cotton planted under irrigated conditions. It is recommended that cotton producers should plant NuOPAL, since it was selected by the AMMI model as the best performer in respect of seed cotton yield and fibre yield (kg ha^{-1}) in fifteen out of eighteen environments.

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CHAPTER 1

INTRODUCTION

Upland cotton (*Gossypium hirsutum* L.), a member of the Malvaceae family, is believed to have originated in tropical America (Purseglove, 1974). It is considered to be the most important textile fibre crop in the world (Zumba, 2004), providing roughly half of the global fibre requirement (Myers and Stolton, 1999). Fibre from various species within this genus has been used for several thousand years to produce clothing and other textiles in places such as India, the Nile valley and Peru (Myers and Stolton, 1999). Cotton has long been valued in the clothing industry because of the comfort of clothing produced from its fibre (Orr, 1977).

Cotton is regarded as one of the most versatile agricultural products in the world and is used in the manufacture of more than 1 000 major products (Broodryk, 1997). It has been viewed as the world's most important cash crop for many years (Cantrell *et al*, 2003). Not only is the fibre important, but the seed is also of economic importance, because it is used for planting and as an oilseed (Broodryk, 1997). After soya bean, cotton is the second most important oilseed crop in the world (Zumba, 2004). Edible oil is produced by pressing the seed to extract the oil, and removing the toxic compound, gossypol, during the refining process (Cotton SA, 2008). The resulting oilcake is also an important source of protein in the animal feed industry (Purseglove, 1974).

In South Africa cotton is an important crop because of its agricultural value and potential to create employment. The fibre has a variety of uses in the textile industry and is also used in the armament industry (Le Roux, 1988). Cotton has been produced in this country since 1846, although large-scale production virtually ceased after 1870 (CottonSA, 2008). From a small planting of 12 to 14 ha in 1904, the cotton industry expanded to become an important agricultural industry in South

Africa, with plantings of close on 100 000 ha in the 1999/2000 season (CottonSA, 2008).

The total area planted to dry land cotton has steadily decreased from a high of 69 578 ha in the 1998/99 season to 2 863 ha in the 2007/08 season, while at the same time the average yield of seed cotton has decreased from 580 to 541 kg ha^{-1}. Production under irrigation has shown a similar decrease (20 361 to 7 700 ha), but yields have steadily increased from 2720 to 3640 kg ha^{-1} over the same period (CottonSA, 2008). This decrease in cotton production is related to the poor price of South African cotton on the international market. The low price results in a decrease in income for both small-scale and commercial producers and makes other cash crops more attractive (Bruwer, 2007).

The increase in yield in the RSA can be ascribed to the cotton-breeding programme that has evolved over the past 77 years. This evolution has resulted in four distinct breeding programmes located in the Upington, Vaalharts, Loskop and Rustenburg production areas. Each of these programmes has its own objective, based on the specific potential and agricultural situation encountered in that specific area (Greeff, 1986).

Leafhoppers or jassids (*Jacobiella fascialis*) can cause considerable damage to cotton foliage, while *Verticillium* wilt also causes economic losses. Jassid-resistant lines (Cornelissen, 2002) and *Verticillium*-tolerant lines (Theron, 2007) have been evaluated in the breeding programme of the Agricultural Research Council – Institute for Industrial Crops, in order to find high-yielding cultivars tolerant to these two pests. The use of such cultivars will contribute to increased profitability. The introduction of transgenic cotton in the USA in 1995 brought significant changes to the cotton industry. Resistance to bollworm and the herbicide glyphosate was introduced and production costs were thereby significantly reduced (Jordan *et al*, 2003). Consequently, the number of transgenic cotton varieties planted as well as the area planted to transgenic cotton throughout the cotton-producing countries of the world has increased significantly (Jordan *et al*, 2003).

The correct choice of cultivar is very important in cotton production as this contributes to the reduction of risk while optimizing yield and quality, which in turn affects income. A wide range of cultivars are presently available on the international market and also in the RSA, all of which differ regarding their adaptability, yield potential, agronomic characteristics and disease susceptibility. It is important that producers should be aware of both the superior and poor characteristics of each cultivar so that this genetic diversity can be fully utilized throughout the wide range of agro-ecologies found in South Africa.

To enable breeders and agronomists to make good recommendations, it is also imperative that they continually evaluate both current and newly developed cultivars, as well as newly imported cultivars that were bred in other countries, for their adaptability under both dry land and irrigated conditions in the various production areas found in South Africa. Furthermore, it is important to import or breed cultivars with a short growing season, since several cotton-production areas in the Republic of South Africa are subject to shorter growing seasons due to temperatures, availability of moisture and crop rotation.

The aim of this study was to evaluate the performance of different cultivars under irrigation in South Africa.

CHAPTER 2

LITERATURE STUDY

2.1 History of cotton

2.1.1 Origin and species

Cotton has been cultivated since prehistoric times and was used as clothing in Brazil, Peru and Mexico long before the discovery of America by Europeans (Poehlman, 1987). Cotton plants originated as tropical scrubs and developed through the ages to become the source of the most important textile fibre. Archaeological discoveries showed that cotton was in use in western Pakistan as early as 3000 B.C. (Anonymous, 1979)

Cotton belongs to the genus *Gossypium* of which four of the 43 *Gossypium* species are considered to be of major agricultural importance. They produce spinnable lint that is of great value to the spinning and textile industries (Areke, 1999). Cultivated cotton species are important in that they produce fibres that are spinnable whereas wild relatives produce seeds without fibres, or very short fibres. However, wild relatives are also useful in that they contribute some useful traits for the improvement of cultivated cultivars (Meredith *et al*, 1996). Worldwide all cotton produced belongs to one of the following four species *Gossypium hirsutum* L., G. *barbadence* L., G. *herbaceum* L., and G. *arboreum* L. More than 90 % of all cotton produced is *Gossypium hirsutum* L. (Kaynak, 2007)

In 1516, Portuguese explorers in South Africa came across natives who had planted and used cotton for making garments (Scherffius & Oosthuizen, 1924). Cotton was planted in the Western Cape as early as 1690 and was reintroduced in 1846 by Dr Adams of the American Mission (van Heerden, 1988a). Cotton was planted on a large scale in KwaZulu-Natal and the Cape colony during 1860 to 1870 due to increased demand as a result of the American Civil War (de Kock, 1994).

A cotton gin was erected in the Tzaneen area, where cotton was ginned and baled mechanically. The co-operative movement with regard to cotton had its origins in 1922 when a co-operative and ginnery was established at Barberton. By 1969 about 80% of the total crop was being produced in the irrigation areas of Loskop, Vaalharts and Upington (Anonymous, 1979).

2.2 Botany of Cotton

2.2.1 Taxonomy

The botanical classification of cotton according to de Kock (1994), is as follows:

Division	: Angiospermae
Class	: Dicotyledonae
Subclass	: Dilleniidae
Order	: Malvales
Family	: Malvaceae
Tribe	: Gossypieae
Genus	: Gossypium

According to the classification of Wolfe & Kipps (1959), cotton belongs to the family Malvaceae. There are eight commonly recognized species of cotton, namely:

1 *Gossypium barbadense*, the long-staple Barbadoes, Sea Island, Egyptian, and Peruvian varieties.
2 *Gossypium herbaceum*, the varieties of India, Thailand, China, and Italy.
3 *Gossypium hirsutum*, the American Upland varieties.
4 *Gossypium arboreum*, found in Ceylon, Arabia, and South America.
5 *Gossypium peruvianum,* the native varieties of Peru

6 *Gossypium purpurascens*, found widely distributed on islands in the Atlantic, Indian, and Pacific Oceans.

7 *Gossypium braziliense*, found in Brazil and other parts of South America. Perennial shrub or small tree.

8 *Gossypium nanking*, Chinese or Thailand cotton.

2.2.2 Morphology

Rehm & Espig (1991) stated that all cotton species are potentially perennial, even though they are normally grown for only one year in modern agriculture. The cotton seedling, with its fast-growing radicle and gland-studded stem (hypocotyls), which lifts the two big cotyledons and the growing point out of the soil, develops from the seed (van Heerden, 1978). Cotton plants form a strong taproot, which develops even at the seedling stage, and which can reach a depth of 3 m (Rehm & Espig, 1991).

A cotton plant has a single ascending main stem that bears a leaf at each node and usually has one branch. Vegetative branches (monopodia) tend to be produced lower down on the plant, while reproductive (sympodia) branches are produced higher up or on the monopodia (Figure 2.1). Sympodia are generally short and terminate in a flower bud (Bennett, 1991).

Cotton leaves are large, palmately lobed (three, five or seven lobed) and covered with multicellular stellate hairs (Kochhar, 1981). Plants in the genus Gossypium have showy flowers, each with five sepals united into a cuplike calyx and five petals of whitish or yellowish color that often turn pink with age (Wolfe & Kipps, 1959).

Pollination usually occurs in the early afternoon. By late afternoon the corolla begins to change colour, first becoming a faint pink and later a deep red-mauve. At the same time, the bracts (calyx) close around the ovary. At this stage, the bud is termed a square. As the square develops, the fruit increases in size and protrudes beyond the bracts. The fruit or boll is a 3 to 5-locular, dehiscent capsule, each locule containing approximately nine seeds (Figure 2.2). These seeds produce the lint fibres as well as the short fuzz (Bennett, 1991).

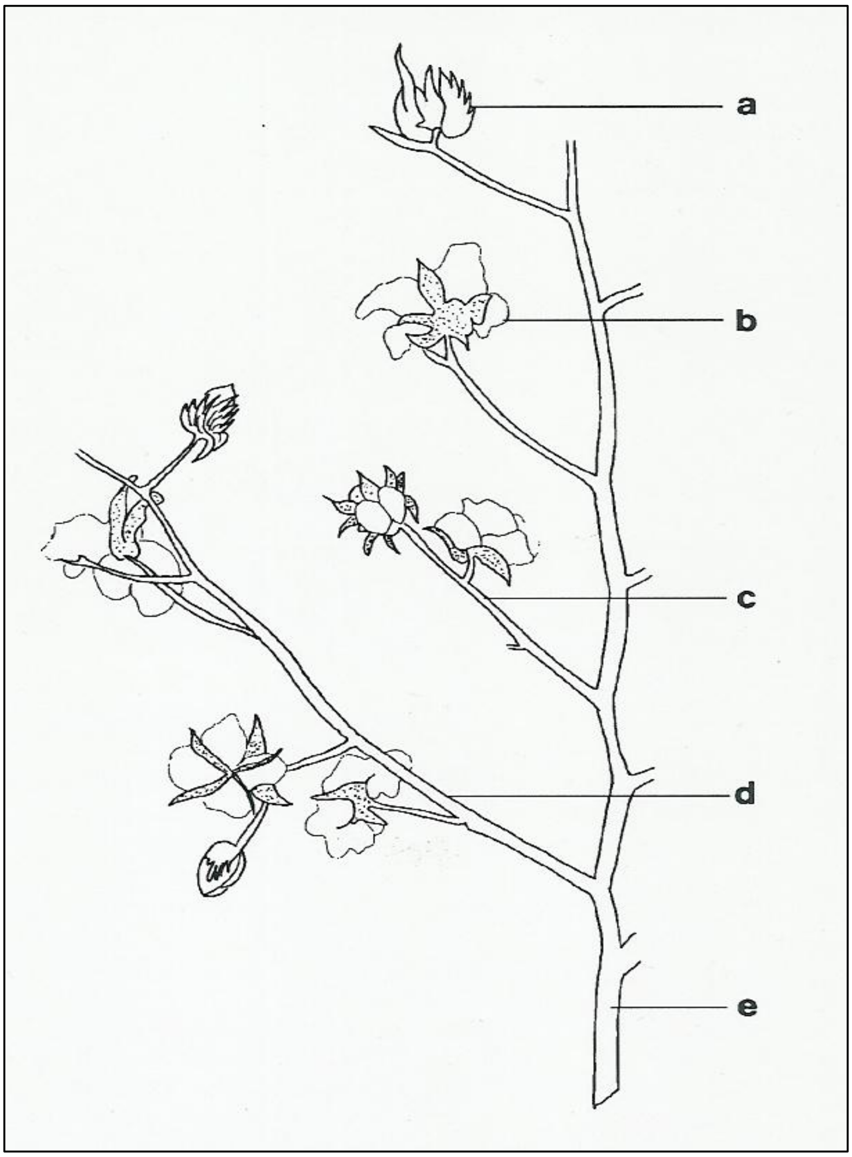


Figure 2.1. Morphology of the cotton plant (Bennett, 1991)

a - square

b - burst boll

c - sympodium

d - monopodium

e - main stem

Figure 2.2 Fruit formation: a. Flower bud; b. Flowers; c. Unripe boll; d. Mature boll

Cotton fibres represent epidermal prolongations of seed coat cells. Differentiation of such hairy growths occurs on the epidermal surface of ovules even before pollination, but proceeds quite rapidly after pollination, reaching maturity in 45 to 50 days. The fibres reach their full length during the first twenty-five days of boll development, after which they start to increase in thickness (Kochhar, 1981).

2.3 Uses of cotton

The first step in the processing of the cotton picking is taken at the gin, where the fibre, about 36 % of the mass, is separated from the seed. The fibre, which is the most important product, consists mainly of cellulose. The various products derived from cotton are illustrated in Figure 2.3 (Schröder, 1990a). Cotton lint is the most important vegetable fibre in the world today and is woven into fabrics, either alone or combined with other fibres (Purseglove, 1974). Cotton is used as an input in more than fifty industrial sectors from the textile, food, and film industries to the war industry. Cotton production has changed considerably to keep pace with the increases in world population and the socio-economic needs of societies (Kaynak, 2007).

2.3.1 Fibre

Lint is the most important industrial raw material for which cotton is widely cultivated (Areke, 1999). Cotton fibre serves for approximately half of all domestic textile uses. Cotton has unique basic qualities, which accounts for it being the leading fibre in terms of quantities consumed (Berger, 1969).

2.3.2 Seed

According to de Kock (1994) cottonseed production and processing ranks second among the five major oilseeds in the world market (soybean, cotton, sunflower, peanut and rape). Oil can be extracted from cottonseed and purified into edible oil or used in the processing of products such as soap, cosmetics, pharmaceuticals, lubricants and also culinary products (Areke, 1999). Cotton seed oil is one of the most important of the world's semi-drying oils and is primarily a food product, used in making cooking and salad oil, mayonnaise, margarine and various other products (Berger, 1969).

2.4 World situation.

Cotton is ranked high among the world's economically important crops. This is due to the numerous products that are processed from cotton, as well as the ever-increasing demand for such products (Areke, 1999).

Cotton plays an important role in everyday life and is of economic importance. Certain factors, such as the increasing population, the demand for natural fibre, and the improvement in the quality of life, have led to higher demand for cotton fibre.

Only a limited number of countries are suitable for cotton production and 80 % of the cotton in the world is produced in China, the USA, India, Pakistan, Uzbekistan, Brazil, and Turkey. The world cotton area, yield, production, imports, consumption and exports are presented in Table 2.1 (ICAC, 2006).

Table 2.1 World cotton area, yield, production, imports, consumption and exports (ICAC, 2006)

Marketing year	**Area (1000ha)**	**Yield (kg ha^{-1})**	**Production (Mt)**	**Imports (MR)**	**Consumption (Mt)**	**Exports (Mt)**
1995/1996	36.1	564	20.3	5.805	18.4	6.0
1996/1997	34.1	575	19.6	6.134	19.0	6.0
1997/1998	33.8	594	20.1	5.756	19.0	6.0
1998/1999	32.8	569	18.7	5.405	18.5	5.5
1999/2000	32.1	595	19.1	6.068	19.6	6.1
2000/2001	31.8	612	19.5	5.755	19.9	5.9
2001/2002	33.4	644	21.5	6.195	20.1	6.4
2002/2003	29.9	646	19.3	6.586	20.9	6.6
2003/2004	32.1	645	20.7	7.261	21.3	7.2
2004/2005	35.2	747	26.3	7.326	23.4	7.8

2.4.1 Production and consumption

The latest estimates from the International Cotton Advisory Committee (ICAC), showed that 23.7 million tons of cotton was produced during 2008/2009, compared with 26.2 million tons in 2007/2008. This decrease in production is contributed to decreasing cotton returns, more attractive prices for competing crops, and difficulties in financing inputs (ICAC, 2009).

SEED COTTON	SEED	PULP	Cake and meal - Flour - bread, cake, biscuits - Feed - Cattle and sheep - Fertilizer Crude oil - Refined oil - salad and cooking oil, mayonnaise, margarine Sediment oil - Soap - Glycerine, explosives, pharmaceuticals, cosmetics - Fatty acids - rubber, plastics, insecticides, fungicides
		HULLS	Feed for beef and dairy cattle Fertilizer - mulch Bran - livestock feed Furfural - synthetic rubber
		SEED COTTON	Pulp - Viscose, Cellulose nitrate, Paper Absorbent cotton
		LINTERS	Yarn - Lamp and candle wick, twine, rugs Felts - Automotive upholstery, pads, cushions, mattresses
		PLANTING PURPOSES	
	LINT	CLOTHING	Clothes, underwear, gloves, mackintoshes, etc Linings for tyres, bags, rope, tents, medical bandages, etc Sheets, towels, bedspreads, curtains

Figure 2.3. Uses of cotton (Schröder, 1990a)

2.5 Production of cotton in South Africa

Cotton production in South Africa provides employment for 100 000 people. In 2003, the textile industry's local sales fetched R12.4 billion (a further R13 billion was obtained from the sale of garments/textile) and exports totaled R3.8 billion (Anonymous, 2005)

South African cotton is produced under both irrigated and dry land conditions. The second estimate for the 2008/2009 production year shows a total cotton harvest of 42 042 bales of fibre (Cotton SA, 2008). The estimated harvest will be the smallest in 40 years. This is mainly due to the perception that cotton farming is no longer a viable option, especially in the light of the favourable prices of other competitive summer crops. Cotton is getting strong competition from other crops, such as maize and sunflower, whose prices skyrocketed. These crops not only give farmers higher prices, but also need lower inputs (Cotton SA, 2008). Table 2.2 shows the hectares planted and yield for South Africa.

2.6 Soil and climatic requirements

2.6.1 Soil

Cotton is grown on a large variety of soils, but it does best on a deep, crumbly soil with a good humus supply and favourable moisture-holding capacity. Sandy loams, loams and well-granulated clay loams are considered best, with optimum pH ranges of between 5.2 and 7 (Berger 1969). Cotton grows well on moderately fertile soils. Soils in the cotton regions range from sands to very heavy clays with acidity levels ranging from pH 5.2 to pH 8+ (Martin & Leonard, 1976).

Table 2.2 Areas planted and yield in the Republic of South Africa (Cotton SA, 2008)

Marketing year	Irrigation (ha)	Dry land (ha)	Total (ha)	Yield (Kg ha^{-1}) Irrigation	Dryland	Average
1997/98	15954	67017	82971	2189	403	746
1998/99	20361	69578	89939	2724	580	1065
1999/00	31263	67356	98619	2680	545	1222
2000/01	10486	40282	50768	3107	777	1258
2001/02	18539	38153	56692	3455	593	1529
2002/03	9791	28897	38688	3538	515	1280
2003/04	10322	12252	22574	3482	475	1850
2004/05	18269	17450	35719	3455	492	2007
2005/06	12897	8866	21763	3791	521	2459
2006/07	9720	8394	18114	3633	485	2174
2007/08**	7920	3443	11363	3700	541	2844

* Seed cotton

** Estimates

2.6.2 Climate

Kochhar (1981) describes that cotton is essentially a tropical crop, but its cultivation now extends from 37° N to 32° S in the New World and from 47° N in the Ukraine to 30° S in the Old World. Martin & Leonard (1976) explains that climatic conditions are favorable for cotton production where summer temperatures are not lower than 25°C. The cotton-production zone lies between 37° north and 32° south latitude, except in the Russian Ukraine, where cotton is grown at up to 47° north latitude.

2.6.3 Temperature

Cotton needs warm days and relatively warm nights for ideal growth and development (Greeff, 1988). Cotton is a long-season plant, requiring a minimum of 180 to 200 frost-free days, as well as uniformly high temperatures during the growing season (Berger, 1969). Martin, (1976), describes three climatic essentials for cotton cultivation are freedom from frost for a minimum growing and ripening season, an adequate supply of moisture, and abundant sunshine. Cotton requires high temperatures, abundant sunshine, low humidity, especially during picking time, and a long frost-free growing season of about seven months for optimum development (Serfontein 1970).

2.6.4 Light

Abundant sunlight is essential for normal growth processes of cotton plants, because large quantities of carbohydrates have to be building up before cotton plants reached picking maturity. Sufficient sunlight during the long period of boll formation is essential, as long periods of cloudy weather can cause abscission (van Heerden, 1978). Adequate sunshine is important during periods of early growth and full bloom for the proper development of cotton plants. Insufficient sunshine will prevent ripening of the boll to full maturity (Berger, 1969).

2.7 Production areas

Cornish-Bowden (1979) explains that the ideal cotton areas are the irrigated Upington/Prieska areas in the West, the hot Limpopo/Letaba valleys in the North, the Eastern Lowveld areas running down the Mozambique boundary into the Swaziland Lowveld and Northern Natal's low lying country. Despite certain climatically limitations, cotton has moved out of the classical areas into other areas. The most notable examples of such areas are the Loskop/Rust-de-Winter irrigation areas and the Northern Cape irrigation area of Douglas, Vaalharts and Modderriver.

Ehlers & van Heerden (1976) cited by Dippenaar (1988) drew charts describing the then existing plus potential new cotton-production areas of South Africa. Three temperature areas were described, namely:

a) Favourable areas where both day and night temperatures are optimal from December to February.

b) Less favourable areas where either day or night temperature is optimum for the growth of cotton.

c) Marginal areas where both temperatures are too low for optimal growth.

Although the three cotton areas depicted on the charts have 200 frost free-days per season, it is impossible to deduce the length of the active flower and boll set periods or the main limiting climate factor from the charts. The intermittent sharp decline in night temperatures in the Central Transvaal and the cotton areas in the Northern Cape is a limiting factor that is detrimental to cotton production and fibre quality during some seasons (Dippenaar, 1988).

In South Africa, the Lowveld, central Transvaal and areas further north are usually warm enough in early spring to ensure emergence and good stands. In Griqualand West early season temperatures, until the end of October, are too low for rapid growth of cotton. Increases in minimum air temperature during early spring are more pronounced in the cooler cotton areas than in the warm Lowveld. Early planting of cotton is therefore recommended in most areas to make the best use of the available growing season (Dippenaar & Human, 1991). Only 1600 to 1900 DGb (available degree days) are available to set a crop potential in the central Transvaal, western Transvaal-Vryburg area and Griqualand West. On the contrary, more than 2400 to 3000 DGb are available to produce a yield in the Lowveld and Limpopo Valley (Dippenaar & Human, 1992).

Cotton production takes place in all the different provinces of South Africa, whereof only the Limpopo Province, Mpumalanga, the Northern Cape and Kwa-Zulu Natal, and to a lesser extend the North West Province is known as cotton production regions. These regions are illustrated in Figure 2.4 (Bennett-Nel, 2007).

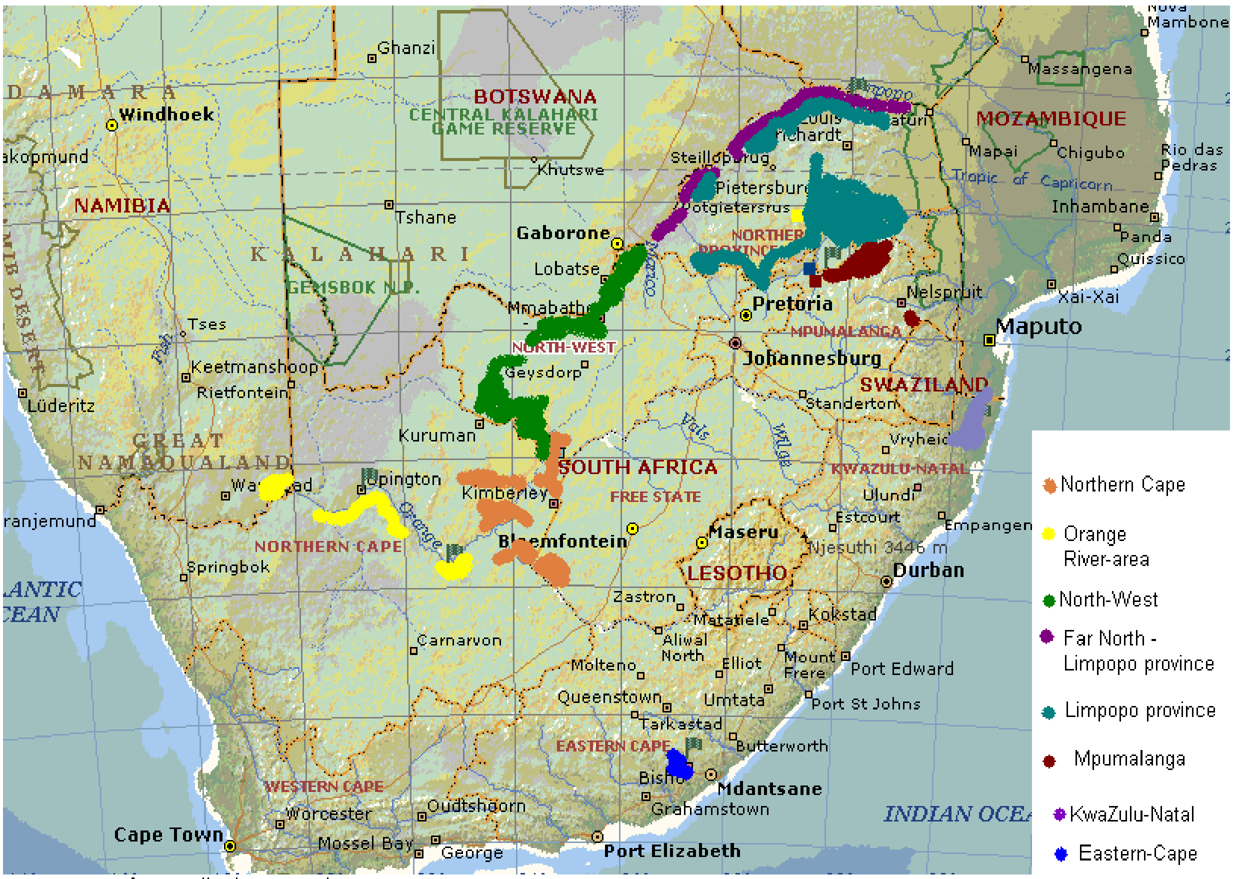


Figure 2.4 Cotton production areas of the Republic of South Africa

2.8 Production practices

2.8.1 Seedbed

The purpose of primary cultivations is to aerate the seedbed, improve penetration of irrigation and incorporate large quantities of plant residues in the soil. The soil water status should be favorable for efficient and cost effective cultivation. Soil that is too wet or too dry when cultivation takes place may result in breaking of the soil structure. Moldboard ploughs should be used with caution since they require high tractive power and can cause a plough sole in certain soils. Chisel implements are just as effective for primary cultivation (ARC, 2004).

2.8.2 Fertilization

2.8.2.1 Nitrogen

Nitrogen has the greatest influence on yield. Cotton requires 112 kg N ha^{-1} for a 4-ton crop. This implies an application of 140 kg N ha^{-1} if the efficiency factor of 80% for a sandy soil is taken into consideration. Fertilizer applications must be complemented by good irrigation to keep the effective soil in the 0,9 m deep root zone at field capacity. Sandy soils that are inclined to leach should receive split applications of nitrogen. Half of the N can be applied at planting, with the second application at 7 to 8 weeks after planting (FSSA, 1989). Rochester *et al*, (1998) stated that irrigated cotton requires up to 200 kg nitrogen N ha^{-1} to achieve maximum yield.

2.8.2.2 Phosphate

Phosphate fertilization will stimulate more even boll splitting, and also improve fibre quality. The P (Bray 1) in the top 30 cm of soil should be 20 to 30 mg P kg^{-1}. On the slightly alkaline soils often associated with irrigation areas, the efficiency factor on a build-up soil (20 to 30mg P/kg) may be as high as 80% (FSSA, 1989).

2.8.2.3 Potassium

Potassium plays an important role in respiration, protein synthesis and carbohydrate metabolism. No potassium is normally applied when soils have concentrations of higher than 80, 100 and 120 mg K kg^{-1} respectively for sand, loam and clay soils (ARC, 2004). Potassium uptake can be prevented or decreased by poorly aerated soil, compaction layers, or a high calcium or magnesium content of irrigated soils (FSSA, 1989).

2.9 Planting method

Various mechanical planters are available in South Africa for cotton planting. Precision planters which space seeds in groups of three to four at desired intra-row spacing are also on the market. Planting to stand is only advisable under conditions that are extremely favorable for germination. Plant the seed about 20 mm deep in clayey soil, or to a maximum of 30 mm in sandy soil for the development of a strong, healthy seedling (ARC, 2004).

2.9.1 Planting date

Soil temperature is one of the most important factors determining planting time. Cotton should not be planted before the topsoil has maintained a temperature of 16 to 18°C or higher for approximately 10 successive days. The second half of October to mid-November can be considered the best time to plant cotton in all the cotton-production areas (ARC, 2004).

2.9.2 Plant spacing and density

Plant populations of approximately 70 000 plants ha^{-1} under irrigated conditions and 30 000 plants ha^{-1} under dry land conditions, are recommended. Plant populations can also be manipulated to reduce the detrimental effect of a very late planting date. Under these circumstances a high plant population with a resulting competition effect forces the plants to grow faster and achieve higher yields (ARC, 2004).

2.9.3 Irrigation

Van Heerden (1964) states that 635 mm of irrigation is adequate for cotton to obtain maximum yield. The topsoil must contain sufficient water for the germination of cottonseeds. Soils should be at field capacity to a depth of at least 100 cm at planting time. A light irrigation (15 to 20 mm) immediately after planting is sufficient to replenish the soil water and ensure good contact between the seed and the soil. Applications of 20 to 25 mm of irrigation per week are usually sufficient. Cotton develops a full leaf canopy between 80 to 100 days after planting. At this stage the water consumption of cotton plants is equal to the evaporation, as measured by the American A-pan, of water from an open surface of water. This stage also coincides with the peaks of flowering and boll setting. Cotton is very sensitive to water stress at this stage (ARC, 2004).

Crop factors for the various cotton producing areas change during the course of the growing season (Figure 2.5). The rate at which the crop factor increases is closely related to the growth rate of the cotton plant (Dippenaar, 1990b). A bigger crop factor is reached much sooner in very hot areas than in the more temperate regions due to the faster growth rates achieved under these conditions. The largest leaf area is also found when the crop factor is at its peak, at which stage the plant has also reached the maximum effective root depth, for supplying the necessary water requirement.

2.10 Weed control

Weeds that germinate early in the season (six to eight weeks after planting) compete with young cotton plants for space, water, sunlight and nutrients. Pre-emergence herbicides can be used at the time of planting. The type of herbicide will depend upon the type of weed that holds the greatest threat (ARC, 2004).

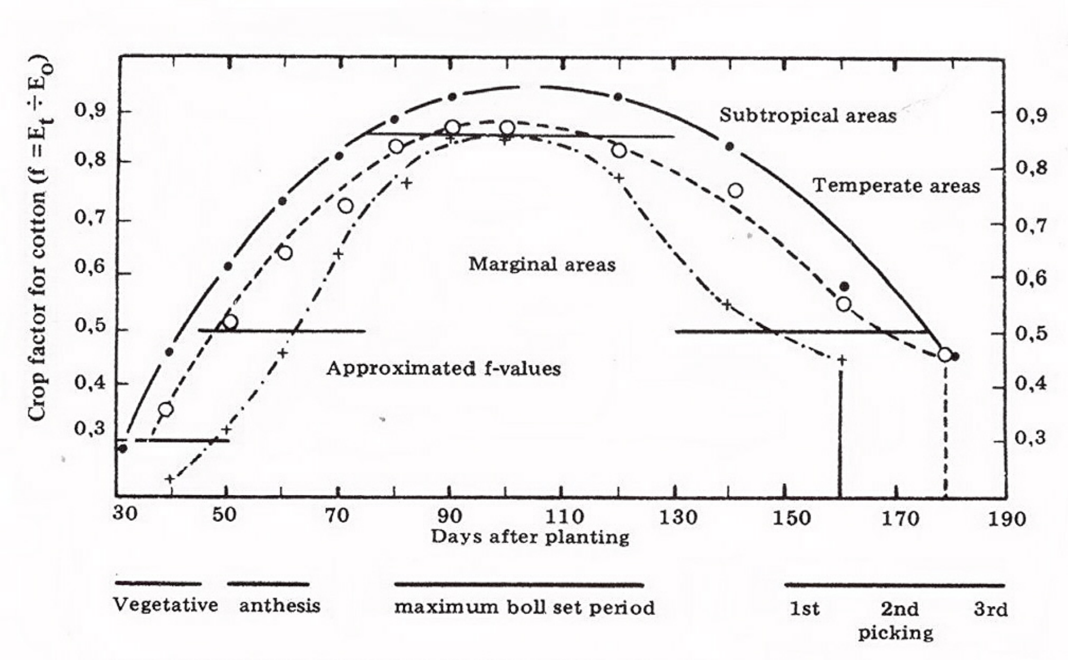


Figure 2.5 Crop factors for cotton in different climatic regions

2.11 Harvesting

Cotton can be hand picked or harvested mechanically. Practically all the cotton produced in the USA is harvested by machine (Munro, 1987). Harvesting begins about six months after planting and is the most expensive operation of cotton cultivation. Cotton is picked as soon as the boll opens. If left in the field for a longer period it may fall out or be damaged by rain. Hand picking is continued over a period of two months or more because all the bolls do not ripen at the same time. It is desirable to pick dry cotton free from trash. In general, hand picking produces considerably cleaner cotton when compared with mechanical harvesting (Kochhar, 1981).

2.12 Quality and grading

New spinning technologies have an impact on cotton fiber properties and therefore there is an increasing need for finer, stronger, and cleaner cottons. The changing emphasis in fiber selection has already had, and will continue to have a far-reaching impact on breeding, farming, ginning, and merchandising cotton. Cotton is classed to determine the grade, staple and character which indicates to a large extend the spinning utility and hence the market value of each bale. There is three factors that determines grade, namely: Colour, leaf residue (impurities) and preparation (The degree of smoothness or coarseness of the cotton lint after ginning (Schröder, 2006). The High volume instrument is the established instrument for determining fibre quality for cotton. Measurements obtained by the USTER HVI Classing include: Length and length uniformity, strength and elongation, micronaire and maturity, color and trash, and short fiber index (Uster ® HVI Classing, 2004).

2.12.1 Lint Length.

Length and length uniformity are two of the most important cotton fiber properties. Without sufficient fiber length, a fine yarn count cannot be spinned. Fiber length should be distributed evenly to produce a yarn at a high level of production efficiency. This is why fibre length (or "staple length") was established as one of the first parameters in the cotton supply chain, determining the value of cotton. Acceptable fibre lengths are 26.9 to 29+ (Uster ® HVI Classing, 2004).

2.12.2 Lint Strength

Cotton fibres need to have certain strength to withstand the strain put on them during the opening, cleaning, and spinning processes. Fibre strength and elongation are directly correlated to yarn strengths and elongation. Fibre strength is a parameter that is being recognized in buying and selling cotton worldwide. Acceptable strengths is > 27 g tex^{-1} (Uster ® HVI Classing, 2004)

2.12.3 Micronaire and maturity

In order to achieve a certain yarn count, a specific number of fibres are required per cross-section. The micronaire value, along with the fibre length, determines to a large extend what yarn can be spun from the cotton. Micronaire in combination with maturity has a strong effect on the dyeing ability of the yarn and fabric. Micronaire is also recognized as an important property in the international cotton trade. Acceptable micronaire values are 3.5 – 4.9 (Uster ® HVI Classing, 2004).

2.13 Factors affecting yield and quality

Shedding of squares or young bolls can have a detrimental affect on the yield of cotton. Dippenaar (1990b) describes that excessive shedding (35%) may be related to one or more of the following conditions:

Water. Any large fluctuation in the availability of soil water. Drought is the major cause of abscission.

Light. Prolonged periods of overcast weather can increase shedding.

Temperature. Abnormally high temperatures and cold periods favour shedding.

Mineral nutrition. Deficiency of any element will result in an abnormal amount of shedding of squares and bolls and correcting the deficiency will reduce this loss.

Plant population. An increase in plant population will cause an increase in shedding percentage. This indicates that besides root competition, shading may also play an important role in this regard.

Pests. Damage (puncturing followed by necrotic patches) done by insects can result in shedding.

2.13.1 Environmental stresses

When plants are subjected to environmental stress conditions such as temperature extremes, drought, herbicide treatment or mineral deficiencies, the balance between the production of reactive oxygen species and the quenching activity of the antioxidants is upset, often resulting in oxidative damage. Plants with high levels of antioxidants (constitutive or induced) have been reported to have greater resistance to this oxidative damage (Gossett *et al*, 1994). Growth rate of leaf area and internode length increased as temperature increased to 27 to 30°C, then decreased at higher temperatures (Reddy *et al*, 1997).

2.13.2 Water stress

Water stress adversely affects both yield and fibre quality of cotton and any improvement of water use efficiency (WUE) would be expected to partially reduce these adverse affects (Stiller *et al*, 2005). Water is one of the most important limiting factors in profitable cotton production (Whitaker *et al*, 2008). Water causes major variation in cotton yield (Gerik *et al*, 1994). Plant water stress during square formation and early flowering resulted in fewer bolls to reach maturity, but this detrimental affect is mitigated by the development of bigger bolls due to greater lint growth. Moisture stress during ripening of the cotton crop, advanced boll opening, increased lint and boll development and consequently enhanced yields (de Kock *et al*, 1990). Cotton is often exposed to drought, which adversely affects both yield and quality (Saranga *et al*, 1998). In South Africa, where drought is a severe problem, the tolerance of economically important crops to drought-stress is of great value. Six South African cultivars were evaluated for changes in protein profiles during osmotic stress. Drought-related protein synthesis was found in the cultivars Lido, Delta Pine, Acala 1517-70 and OR3, while drought-related proteins were not observed in the cultivars Selati and Letaba. It would appear that drought-related protein synthesis was cultivar specific (van der Mescht & Ronde, 1993). Drip irrigation can promote cotton yield and earliness (Chu *et al*, 1995). Any large fluctuation in the availability of soil water can result in increased shedding, and subsequently a decrease in yield (Dippenaar, 1990a).

2.13.3 Nutrient deficiencies

Cotton yields have greatly increased since 1935, because of better crop management and the use of improved cultivars. One major management factor that greatly impacts yield of cotton is nitrogen fertilization (Meredith *et al*, 1997). The mineral nutrition of cotton depends on both the cotton root's ability to explore the soil, and on the soil's ability to supply N, P and K nutrients. Cotton has an indeterminate growth habit and some sensitivity to adverse environmental conditions that can result in excess fruit abscission (Bisson *et al*, 1994).

2.13.4 Pests

Insects and diseases have a great effect on the rate of abscission and shedding. Directly after squares or bolls has been damaged by an insect, (even if only punctured, a necrotic patch forms, followed by abscission (Dippenaar, 1990a). *Heliothis* spp. is major pests in many cotton-producing countries of the world. Cotton breeders are attempting to develop cultivars that have useful levels of field resistance or tolerance to tobacco budworm (Jenkins & Mcarty, 1994). Young cotton crops host a range of insect pests, including thrips (Thysanoptera). Leaf distortion, reduced leaf area and plant height, and growth delay are often observed in thrips-damaged cotton and, in cases of severe infestation, loss of vegetative buds and branching after release of apical dominance have been reported. Because of these effects, thrips have the potential to reduce yield and delay the maturity of cotton crops (Sadras & Wilson, 1998). The nectariless and okra-leaf traits confer low levels of resistance in cotton *Gossypium hirsutum* L., to pink bollworm, *Pectinophora gossypiella* (Wilson, 1989).

2.13.5 Growth hormones

Yield in cotton is often associated with the number of bolls produced per unit area. Boll retention is an important process that affects lint yield. Many biotic stresses have been reported to have a direct influence on boll retention. The concentration of important plant growth substances such as IAA (Indole acictic acid) and ABA (absitic acid) must be maintained or supplied at critical levels if a boll is to be retained (Heitholt & Schmidt, 1994). As an indeterminate perennial, cotton is susceptible to excessive vegetative growth during conditions of high temperature, water supply and soil fertility. With more intensive crop management and higher yielding cotton varieties, the practice of early stress has been replaced with the use of a growth regulator to restrict excessive vegetative growth (Constable, 1994).

2.13.6 Variety

In South Africa, Bt-technology (Genetically Modified Cotton) has proved to be not only effective against the target pests, which are the African bollworms on cotton, but it is also beneficial to farmers in the form of a higher yield production and improved crop protection (Bennett-Nel, 2007). Quality of cotton is directly linked to price, which is indirectly linked to yield. By comparing fibre quality parameters (strength, length, length uniformity and micronaire) across different technology types, i.e. single gene introduction (Bt-cotton or RR-cotton) (Jordan & Wakelyn, 2003) found that fibre quality is just as likely to have been improved as not. In South Africa no significant differences in length and strength between Bt- and non-Bt-cotton under irrigated and rain-fed conditions, although the micronaire was found to be lower in both Bt- and non-Bt-cotton under rain fed conditions (Joubert *et al*, 2001). Joubert *et al* (2001) cited by Bennett-Nel, 2007 found Gin out Turn (GOT) to be higher in the case of Bt-cotton when compared to non-Bt-cotton. Fibre properties of Bt-cotton were found to be more acceptable than those of non-Bt-cotton during studies in South Africa performed in the 1999 to 2001 seasons (Joubert *et al*, 2001).

Braden & Smith (2004) found that breeding for long staple cultivars has been successful, resulting in lines that possess improved yield and fibre quality but without unduly delaying crop maturity. Over the years, breeders have selected earlier maturing cultivars so that growers could maximize early season moisture, avoid late season build-up of insects, optimise their opportunity to recover from in-season stresses, and avoid crop damage due to inclement weather during the harvest season (Braden & Smith, 2004). Genetic diversity among cultivars reduces vulnerability of the crop to a disease or insect pathogen. In cotton, diversity is important for long-term improvement in lint yield and fibre quality (May *et al*, 1995). In trying to increase the yield of upland cotton, breeders have indirectly selected more for increases in harvest index than in photosynthesis. Future cotton yield advances may need increases in both harvest index plus photosynthesis (Pettigrew & Meredith, 1994). Previous research has shown that tropical accessions have useful genetic variability for insect and disease resistance and fibre quality (McCarthy *et al*, 1996). Cotton with alternative leaf morphologies, such as the cleft-shaped okra-leaf types, offers production advantages such as earlier maturity.

Cotton cultivars that mature early without sacrificing yield can reduce production costs (Heitholt & Meredith, 1998). The genetic improvement of cotton fibre quality and yield is imperative under the situation of increasing consumption and rapid development of textile technology. Previous researchers did identification of stress response genes expressed in cotton. Major stress factors in cotton included the wilt pathogens *Verticillium dahliae*, *Fusarium oxysporum* f. sp. *vasinfectum,* bacterial blight, root-knot nematode, drought, and salt stress. A few genes related to the biosynthesis of gossypol, other sesquiterpene phytoalexins and the major seed oil fatty acids were isolated from cotton (Liu & Zhang, 2008).

2.14 Breeding

2.14.1 Early breeding history in South Africa (1920 – 1990)

Breeding from as early as in the 1920's were done in South Africa, where hairy cotton varieties were developed at Barberton and exploited for their resistance to leafhoppers. (Annecke & Moran, 1982).

In 1970 the South African textile industry favored an increase of fibre length and micronaire index of lint from certain areas. Emphasis later shifted to improvement of fibre tenacity, and with the increased importance of rotor spinning, a lower micronaire index became increasingly desirable (van Heerden *et al*, 1987).

Greeff (1986) explains that the breeding programme (1986) for Upland cotton in South Africa has evolved over a period of 77 years. It was done in four distinct breeding programmes located at Upington, Vaalharts, Loskop and Rustenburg. These programmes were co-coordinated from the TCRI (Tobacco and Cotton research Institute).

In many parts of the world, an important aim of cotton breeding is earliness of crop maturity. Subsequently the TCRI (Tobacco and Cotton Research Institute) initiated a breeding project in 1986 for the development of cotton cultivars adapted to a short growing season. The study investigated cultivar-environment interactions involving 15 short-season cultivars used in a programme at three different localities namely, Loskop, Vaalharts and Rustenburg (de Kock, 1994).

In the breeding programme of 1987, the cultivar Acala 1517-70 was considered the standard as far as fibre characteristics were concerned. Acala 1517-70 then produced a better quality fibre than the other cultivars grown in South Africa but had a low yield potential. In the Vaalharts and Loskop programmes improved yield and fibre properties equal to those of Acala 1517-70, were the breeding objectives. Resistance to *Xanthomonas* spp and *Altenaria* spp formed part of the screening process. In the Upington area, a prerequisite was resistance to *Verticilium* wilt, resistance to the physiological disorder called red leaf disease, and improvement of the spin ability of the locally grown OR3 (van Heerden *et al*, 1987).

According to van Heerden (1988b) the national breeding program of South Africa was carried out at Groblersdal, Vaalharts and Upington. Evaluation of breeding lines and cultivars in the three areas over various seasons supplied information of importance to breeders, ginners and spinners. Van Heerden (1988b) states that preliminary results from breeding trials indicated a finer but more mature fibre at Vaalharts.

2.14.2 Breeding after 1990

The Agricultural Research Council undertook cotton breeding for yield and quality improvement, at the Institute for Industrial Crops (ARC-IIC), in the North-West Province. The Plant Breeding Division at the Institute was responsible for developing new cultivars that will produce more efficiently under existing or potential environmental conditions, through manipulation of gene frequencies (Swanepoel, 2004). This division had various programmes aimed at improving genotypic backgrounds for improved production in dry land conditions, irrigation conditions and short growing season conditions, resistance to verticilium wilt and nematodes. The germplasm consists of 1726 accessions.

Cornellissen (2002) describes a program to develop jassid resistant varieties through incorporation of hairiness to adapted cultivars or breeding lines to address the problems of limited resource farmers in the Republic of South Africa.

CHAPTER 3

MATERIALS AND METHODS

3.1 Trial sites

Trials to evaluate the performance of a number of cotton cultivars under irrigation were conducted at Loskop, Makhathini, Rustenburg, Upington, Vaalharts and Weipe (Figure 3.1). These sites are representative of production areas 1 to 8, namely:

Area 1: the Lower Orange River area (irrigation).
Area 2: Griqualand West (irrigation).
Area 3: North-West, Vryburg.
Area 4: North-West, Rustenburg.
Area 5: the Limpopo Valley (irrigation).
Area 6: Loskop - Springbok Flats.
Area 7: Mpumalanga (irrigation).
Area 8: KwaZulu- Natal.

3.2 General trial procedure

At each trial site the trial was planted on a soil type that was representative of the soils on which cotton is produced in that area (Table 3.1). Conventional soil preparation practices were followed, and fertilizers were applied according to the soil analysis and the yield potential for each site.

CottonSA recommended all the cultivars for planting during the 2003 to 2006 seasons, in the different cotton producing areas of South Africa. The two imported cultivars that were evaluated in the trials are from Zimbabwe and are long staple cultivars with longer fibres. Spinners need more uniform fibre, and therefore cotton cultivars decreased during the past decade.

The following five cultivars were evaluated using a randomized complete-block trial design, replicated three times, at each site, namely:

DeltaOPAL - a conventional cultivar from Delta Pine. This was used as the control treatment against which the others were evaluated:

NuOPAL - a cultivar from Delta Pine containing the Bollgard™ gene;

DeltaOpal RR - a Delta Pine cultivar containing the Roundup Ready™ gene;

SZ9314 and LS219 - two cultivars from Quton Cotton in Zimbabwe.

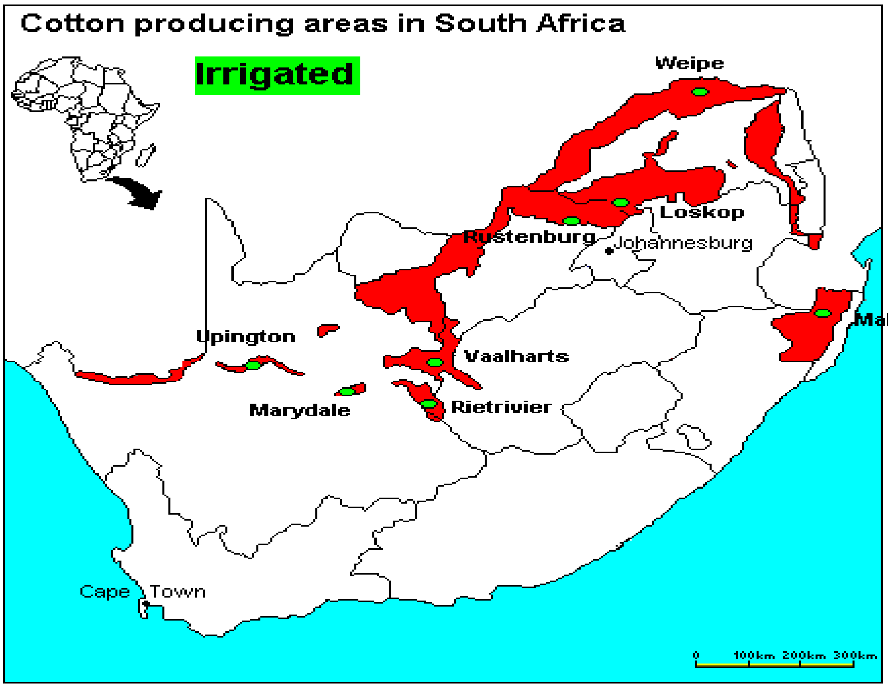


Figure 3.1 Localities in the different irrigated cotton-production areas in South Africa, showing trial sites

Plots were 4 x 9 m in size and contained four rows spaced 1 m apart, with plants spaced 0.15 m apart in the row. Two seeds were planted by hand at each planting station and the seedlings were thinned out to a single plant per station when they were approximately 15 cm tall. Thinning was completed within three weeks of emergence. This resulted in a plant population of 70 000 plants ha^{-1}, the recommended plant population for cotton under irrigation. Data were collected from a net plot of 2 x 8.7

m. Only the two centre rows were harvested and the first and last plants from those rows were excluded to eliminate side effects.

3.3 Fertilization

Fertilizer was applied according to the soil analysis done for each site (Tables 3.7, 3.9, 3.11, 3.13 and 3.15) and the yield potentials at each site. The fertilizer (N, P, K) application rates to achieve optimum yields at each site are given in Table 3.1. At Loskop, N was given in the form of LAN (28), P as Superphosphate (10.5) and K as K_2SO_4. Fertilizer at Makhathini was applied in the form of 2:3:4 (33) at planting and two top dressing applications of LAN (28) at 4 and 8 weeks after planting. At Rustenburg, fertilizers were applied in the form of 2:3:4 (33) at planting and two LAN (28) top dressings at 4 and 8 weeks after planting. At Upington, fertilizer was applied in the form of 2:3:4 (30) at planting and two ASN top dressings were applied at 4 and 8 weeks after planting. At Vaalharts, fertilizer was applied in the form of 2:3:4 (33) at planting and three top dressing applications of LAN (28) at 4, 7 and 9 weeks. At Weipe the farmer gave 70 kg ha^{-1} N and no P and K (Table 3.2).

Table 3.1 The different amounts of nutrients required by the aboveground parts of the cotton plant for the production of different yields

Seed cotton yield (kg ha^{-1})	N	P	K
		(kg ha^{-1})	
1000	90	15	60
1500	140	18	65
2000	180	20	70
2500	215	28	85
3000	230	30	100
3500	240	30	115
4000	245	30	130
4500	250	30	140

Source: ARC, 2004.

3.4 Irrigation

The cotton was irrigated accordingly to the water requirements of the crop. Irrigation was applied via overhead irrigation, at all sites, with the exception of Weipe, where drip irrigation was used.

Table 3.2 Soil form, fertilization amounts and rainfall during different seasons at different localities

Locality	**Season**	**Soil form***	**Fertilization (kg ha^{-1})**			**Rainfall**
			N	**P**	**K**	**(mm)**
Loskop	2003/2004	Hutton	140	70	40	134.7
	2004/2005	Hutton	140	70	40	315.8
	2005/2006	Hutton	140	70	40	436.1
Makhathini	2003/2004	Hutton	150	40	80	275.2
	2004/2005	Hutton	150	40	80	585.2
	2005/2006	Hutton	150	40	80	401.8
Rustenburg	2003/2004	Arcadia	140	30	80	710.8
	2004/2005	Arcadia	170	30	80	513.4
	2005/2006	Arcadia	150	30	80	636.3
Upington	2003/2004	Hutton	150	30	40	303.1
	2004/2005	Hutton	150	30	40	196.1
	2005/2006	Hutton	150	30	40	356.8
Vaalharts	2003/2004	Hutton	220	50	70	334.8
	2004/2005	Hutton	220	50	70	295.7
	2005/2006	Hutton	260	50	70	212.3
Weipe	2003/2004	Hutton	70	0	0	295.4
	2004/2005	Hutton	70	0	0	165.9
	2005/2006	Hutton	70	0	0	93.1

* Grond klassifikasie, 1977

3.5 Weed control

Weed control practices differed between the various sites depending on the weed spectrum that was found. Both monocotyledonous (grasses and sedges), and broadleaf weeds were controlled by pre- and post emergence herbicides. The herbicides used at each site are given in Table 3.3 and are registered for use on Cotton

(Directorate of Agricultural Information, 1988). Hand hoeing was also done to keep trials weed free for the duration of the season.

Table 3.3 Herbicides used to control weeds at the various trial sites

Site	Chemical application Active ingredient	Concentration (g ℓ$^{-1}$)	Application rate	Time of application
Loskop	Trifluralin	480	1.5 ℓha^{-1}	Pre-emergence
Rustenburg	S-metolachlor	915	4.0 ℓha^{-1}	Pre-emergence
	Fluometuron / prometryn	250/250	1.3 ℓha^{-1}	Pre-emergence
Makhathini	S-metolachlor	915	3.0 ℓha^{-1}	Pre-emergence
	Fluometuron / prometryn	250/250	0.6 ℓha^{-1}	Pre-emergence
Vaalharts	Trifluralin	480	1.0 - 1.5 ℓha^{-1}	Pre-emergence
Upington	Glyphosate	360	300 mℓ/15 ℓ H_2O	Post-emergence
	MSMA	720	375 mℓ/15 ℓ H_2O	Post-emergence
Weipe	S-metolachlor	915	0.6 ℓha^{-1}	Pre-emergence
	Fluometuron / prometryn	250/250	3.0 ℓha^{-1}	Pre-emergence

3.6 Insect control

Cotton fields were scouted for insects in such a way that the observations were representative of the specific field. A minimum sample of 24 plants were randomly chosen in each plot and investigated for pests, except for spider mite that requires a sample of 48 plants. The whole plant including the young bolls and squares should be examined. Control thresholds for important cotton pests are summarized in Table 3.4. Pesticides applied at the different localities are summarized in Tables 3.6, 3.8, 3.10, 3. 12, 3.14 and 3.16.

3.7 Harvesting and measurements

Defoliation was left to occur naturally and no chemical defoliation was done on the trials. All harvesting was carried out by hand to ensure that the different treatments was harvested and weighed accurately. The first harvest at all the localities was carried out at the beginning of April when approximately 60 - 70 % of the bolls were opened. The remainder of the cotton was picked during the first or second week of May, depending on the trial site.

After harvesting, the following yield and quality parameters were determined:

a) *Yield*
   - Total seed cotton yield (kg ha^{-1})
   - Fibre percentage (fibre was removed from seeds with a mini gin)
   - Fibre yield (kg ha^{-1})

b) *Quality*

   The fibre laboratory at Cotton SA, Pretoria, determined fibre qualities.
   - Average fibre length (mm)
   - Fibre strength (g tex-1)
   - Micronaire (Fibre fineness)

3.8 Statistical analysis

After collection, the data were subjected to statistical analysis using the GenStat® (Payne *et al*., 2007) statistical program. Treatment means that were significant at the 5% level of significance were separated using Tukey's Least Significant Difference test (LSD_T) as described by Snedecor (1980). AMMI analysis was done using the GenStat® AMMI procedure. The Additive Main effects and Multiplicative Interaction, or AMMI, technique is primarily used for exploring cultivar x environment data.

Table 3.4 Control thresholds for important cotton pests (ARC, 2004)

Pest	**Control threshold** **Conventional + herbicide tolerant**	**Control threshold** **Bollworm resistant cotton**
American bollworm	5 larvae / 24 plants	More than 5 plants with one or more bollworm / 24 plants
Red bollworm	6 eggs / 24 plants or 2 larvae / 24 plants	More than 2 plants with one or more red bollworm / 24 plants
Spiny bollworm	2 larvae / 24 plants	More than 2 plants with one or more spiny bollworm/ 24 plants
Bollworm complex	5 larvae / 24 plants	More than 5 plants with one or more bollworm / 24 plants
Spider mite	When mites appear in localized spots, apply control to these spots only. When mites are distributed throughout the block, apply a blanket spray when the following thresholds are reached. Up to week 10: 0,5: From week 11: Add 0,125 to 0,5 for each week after week 10. Control must be aimed at keeping the mite population below the threshold, until first boll burst or until 20 weeks after plant emergence	Same as for conventional cotton
Aphids	Control when honeydew is found on plants	Same as for conventional cotton
Whitefly	Control as soon as 10 whiteflies / leaf are found or when leaf edges turn yellow and curl around	Same as for conventional cotton
Leafhoppers	Control when 2 leafhoppers per leaf are found or when leaf edges turn yellow and turn around	Control when 3 or more leafhoppers per plant are found.
Thrips	Control only when leaf damage occurs early in the season	
Stainers	Control as soon as the first colonies appear	Control when 6 or more colonies are found per 24 plants

Table 3.5 Soil analysis during the 2003 to 2006 seasons at Loskop

Description	2003/2004	2004/2005	2005/2006
pH	6.15	6.9	6.23
Resistance	389	415	538
mg kg^{-1}			
N	12	3	3
P	10	6	5
K	219	214	205
Ca	1397	1903	1360
Mg	693	879	699
Na	60	81	34
S-values	13.5	17.7	13.3
Ca %	51.6	53.6	51.4
Mg %	42.2	40.8	43.3
K %	4.2	3.6	4.1
Na %	1.9	1.9	1.2
% Sand	54	57	56
% Loam	9	7	8
% Clay	37	36	36

Table 3.6 Insect control during the 2003 to 2006 seasons at Loskop

Season	**Pest**	**Product**	**Times applied**	**Application rate**
2003/2004	Bollworms	Endosulfan	7	1 litre ha^{-1}
		Cypermethrin	7	75 ml ha^{-1}
	Jassids	Acetamiprid	3	50 g ha^{-1}
	Red Spider Mite	Abamectin	2	300 ml ha^{-1}
		Mineral oil	2	2 litres ha^{-1}
2004/2005	Bollworms	Endosulfan	7	1 litre ha^{-1}
		Cypermethrin	7	75 ml ha^{-1}
	Jassids	Acetamiprid	4	50 g ha^{-1}
	Red Spider Mite	Abamectin	2	300 ml ha^{-1}
		Mineral oil	2	2 litres ha^{-1}
2005/2006	Bollworms	Endosulfan	9	1 litre ha^{-1}
		Alpha-cypermethrin	9	75 ml ha^{-1}
	Jassids	Acetamiprid	4	50 g ha^{-1}
	Red Spider Mite	Abamectin	2	300 ml ha^{-1}
		Mineral oil	1	2 litres ha^{-1}
	Mirids	Profenofos	1	1 litre ha^{-1}

Table 3.7 Soil analysis during the 2003 to 2006 seasons at Makhathini

Description	2003/2004	2004/2005	2005/2006
pH	6.62	6.93	5.5
Resistance	669	600	968
mg kg^{-1}			
N	6	7	9
P	29	30	24
K	400	510	304
Ca	838	1445	476
Mg	268	388	158
Na	83	108	53
S-values	7.8	12.2	4.68
Ca %	53.8	59.4	50.6
Mg %	28.4	26.1	27.8
K %	13.2	10.8	16.6
Na %	4.7	3.8	4.95
% Sand	58	58	55
% Loam	10	11	10
% Clay	32	31	35

Table 3.8 Insect control during the 2003 to 2006 seasons at Makhathini

Season	Pest	Product	Times applied	Application rate
2003/2004	Bollworms, Aphids, Red spider mite	Decis	3	200 ml ha^{-1}
		Mospilan	1	75 gr ha^{-1}
		Abamectin	1	400 ml ha^{-1}
2004/2005	Bollworms, Aphids, Red spider mite	Decis	3	200 ml ha^{-1}
		Mospilan	1	75 gr ha^{-1}
		Abamectin	1	400 ml ha^{-1}
2005/2006	Bollworms, Aphids, Red spider mite	Decis	3	200 ml ha^{-1}
		Mospilan	1	75 gr ha^{-1}
		Abamectin	1	400 ml ha^{-1}

Table 3.9 Soil analysis during the 2003 to 2006 seasons at Rustenburg

Description	2003/2004	2004/2005	2005/2006
pH	7.5	6.72	7.25
Resistance	268	388	268
mg kg^{-1}			
N	1	4	5
P	5	4	12
K	101	103	115
Ca	4312	2840	4500
Mg	3496	2440	2890
Na	78	53	58
S-values	51.0	34.9	46.931
Ca %	42.3	40.7	47.9
Mg %	56.5	57.8	50.9
K %	0.5	0.8	0.6
Na %	0.6	0.7	0.5
% Sand	28	30	28
% Loam	16	15	14
% Clay	56	55	58

Table 3.10 Insect control during the 2003 to 2006 seasons at Rustenburg

Season	Pest	Product	Times applied	Applicatio n rate
2003/2004	Bollworms, aphids, thrips, beetles, foliar-feeding larvae, tarsonemid mites, borers, cutworms, bollworms, bugs, whiteflies and leafhoppers.	Endosulfan	7	1 litre ha^{-1}
2004/2005	Bollworms, aphids, thrips, beetles, foliar-feeding larvae, tarsonemid mites, borers, cutworms, bollworms, bugs, whiteflies and leafhoppers.	Endosulfan	9	1 litre ha^{-1}
2005/2006	Bollworms, aphids, thrips, beetles, foliar-feeding larvae, tarsonemid mites, borers, cutworms, bollworms, bugs, whiteflies and leafhoppers.	Endosulfan	8	1 litre ha^{-1}

Table 3.11 Soil analysis during the 2003 to 2006 seasons at Upington

Description	2003/2004	2004/2005	2005/2006
pH	7.27	7.89	7.17
Resistance	1020	633	910
mg kg^{-1}			
N	7	2	7
P	36	75	71
K	88	235	143
Ca	1760	2680	1400
Mg	413	425	343
Na	50	65	38
S-values	12.7	17.8	10.4
Ca %	69.5	75.3	67.5
Mg %	27.0	19.7	27.3
K %	1.8	3.4	3.5
Na %	1.7	1.6	1.6
% Sand	76	78	84
% Loam	12	12	6
% Clay	12	10	10

Table 3.12 Insect control during the 2003 to 2006 seasons at Upington

Season	Pest	Product	Times applied	Application rate
2003/2004	Bollworms	Endosulfan	2	1 litre ha^{-1}
		Endosulfan	2	1.5 litre ha^{-1}
2004/2005	Bollworms	Endosulfan	1	1 litre ha^{-1}
		Endosulfan	2	1.5 litre ha^{-1}
2005/2006	Bollworms	Endosulfan	2	1 litre ha^{-1}
		Endosulfan	2	1.5 litre ha^{-1}

Table 3.13 Soil analysis during the 2003 to 2006 seasons at Vaalharts

Description	2003/2004	2004/2005	2005/2006
pH	6.14	6.15	6.75
Resistance	1920	1340	1440
mg kg^{-1}			
N	4	10	8
P	76	120	35
K	75	160	105
Ca	350	445	108
Mg	115	163	153
Na	20	28	15
S-values	2.980	4.104	3.639
Ca %	58.7	54.2	56.1
Mg %	31.9	32.8	34.7
K %	6.5	10	7.4
Na %	2.9	3	1.8
% Sand	90	90	93
% Loam	3	2	0
% Clay	7	8	7

Table 3.14 Insect control during the 2003 to 2006 seasons at Vaalharts

Season	Pest	Product	Times applied	Application rate
2003/2004	Bollworms	Endosulfan	2	1 litre ha^{-1}
		Endosulfan	2	1.5 litre ha^{-1}
2004/2005	Bollworms	Endosulfan	1	1 litre ha^{-1}
		Endosulfan	2	1.5 litre ha^{-1}
2005/2006	Bollworms	Endosulfan	2	1 litre ha^{-1}
		Endosulfan	2	1.5 litre ha^{-1}

Table 3.15 Soil analysis during the 2003 to 2006 seasons at Weipe

Description	2003/2004
pH	-
Resistance	-
mg kg^{-1}	
N	-
P	70
Fe	200
Mn	94
S	148
Zn	26
Cu	3.3
B	0.7
S-values	
Ca %	63
Mg %	22
K %	8.9
Na %	3%
% Sand	84
% Loam	6
% Clay	10

Table 3.16 Insect control during the 2003 to 2006 seasons at Weipe

Season	Pest	Product	Times applied	Application rate
2003/2004	Jassids and stainers	Mospilan	2	50gr/ha
2004/2005	Jassids and stainers	Mospilan	2	50gr/ha
2005/2006	Jassids and stainers	Mospilan	2	50gr/ha

CHAPTER 4

LOCALITY ANALYSIS

4.1 Introduction

The yield and fibre quality results obtained for each locality were analysed separately in order to determine which cultivar would be the best for that specific locality. This was done so that recommendations regarding the best cultivar could be made to farmers in each irrigation scheme. These results are presented in this chapter.

4.2 Loskop

Yield parameters

Cultivar had a significant effect ($P<0.05$) on all three yield parameters (seed cotton yield, fibre percentage and fibre yield) in the 2003/04 and 2004/05 seasons. In the 2005/06 season, however, the cultivar effect was only significant for the fibre percentage (Table 4.1).

From table 4.1 it can be seen that the cultivar, LS9219, produced the lowest seed cotton yield during the 2003/04 and 2004/05 seasons, while the yield of NuOPAL was better in both the 2004/05 and 2005/06 seasons. During the 2003/04 season, DeltaOPAL produced the highest yield of 3 515 hg ha^{-1}, but this was not significantly better than the yield produced by NuOPAL, DeltaOpal RR or SZ9314. The yield of the latter cultivar also did not differ significantly from that of LS9219. A slightly different picture was obtained during the 2004/05 season when NuOPAL produced the highest seed cotton yield (3 757 kg ha^{-1}). This yield was significantly higher than that of LS9219 (2 805 kg ha^{-1}), but the yields of the other cultivars did not differ significantly from those of the two mentioned cultivars.

Although the average seed cotton yield obtained during the 2004/05 season was higher than that obtained during the 2003/04 season, the fibre percentage realised was approximately 3% lower (Table 4.1). During the 2003/04 season, it was found that DeltaOPAL produced the highest fibre percentage of (43.7%) and that it significantly outperformed all the other cultivars. DeltaOPAL was followed by NuOPAL (41.7%), while DeltaOpal RR (39.7%) produced the lowest fibre percentage. During the 2004/05 and 2005/06 seasons, the cultivar effect differed from that found during 2003/04 season, but showed the same tendency in both years. During these seasons, it was found that the fibre percentages produced by DeltaOPAL, NuOPAL and DeltaOpal RR and SZ9314 did not differ significantly from each other, but they were all significantly higher than the fibre percentage produced by LS9219 (Table 4.1).

Table 4.1 Yield data for the various cotton cultivars, planted at Loskop during the 2003 to 2006 seasons

Season Parameter	Cultivar					Average
	DeltaOPAL	NuOPAL	DeltaOpal RR	LS9219	SZ9314	
2003/04						
Seed cotton yield (kg ha^{-1})	3 515 a	3 425 a	3 245 a	2 140 b	2 736 ab	3 012
Fibre %	43.7 a	41.7 b	39.7 c	41.0 bc	40.3 bc	41.3
Fibre yield (kg ha^{-1})	1 534 a	1 427 a	1 287 ab	876 b	1 105 ab	1 246
$LSD_{T(0.05)}$	SCY = 1 075	F = 1.71	FY = 467.9			
2004/05						
Seed cotton yield (kg ha^{-1})	3 526 ab	3 757 a	3 611 ab	2 805 b	3 252 ab	3 390
Fibre %	38.8 a	39.2 a	39.1 a	33.6 b	40.1 a	38.2
Fibre yield (kg ha^{-1})	1 371 a	1 472 a	1 412 a	943 b	1 305 ab	1 301
$LSD_{T(0.05)}$	SCY = 889.0	F = 2.869	FY = 367.5			
2005/06						
Seed cotton yield (kg ha^{-1})	2 524	3 875	2 817	3 014	2 833	3 013
Fibre %	39.7 a	39.7 a	39.0 a	34.7 b	40.3 a	38.7
Fibre yield (kg ha^{-1})	999	1 536	1 094	1 046	1 142	1 163
$LSD_{T(0.05)}$	SCY = ns	F = 3.114	FY = ns			

Figures in the row followed by the same letter do not differ significantly from each other

ns – not significant at the 5% level

During the 2003/04 and 2004/05 seasons, the fibre yields showed a similar pattern, with no statistically significant differences between DeltaOPAL, NuOPAL, DeltaOpal RR and SZ9314. During the 2003/04 season, DeltaOPAL (1 534 kg ha^{-1}) and

NuOPAL (1 437 kg ha^{-1}) produced significantly more fibre than LS9219 (876 kg ha^{-1}). The fibre yields of DeltaOpal RR (1 278 kg ha^{-1}) and SZ9314 (1 105 kg ha^{-1}) were not significantly different from those produced by any of the other cultivars. A slight difference was observed in the results obtained during the 2004/05 season in that NuOPAL (1 472 kg ha^{-1}), DeltaOPAL (1 371 kg ha^{-1}) and DeltaOpal RR (1 412 kg ha^{-1}) produced significantly more fibre than LS9219 (943 kg ha^{-1}). The fibre yield produced by SZ9314 (1 305 kg ha^{-1}) did not differ significantly from that produced by any of the other cultivars. No statistically significant differences in the fibre yield obtained from any of the cultivars tested were noted during the 2005/06 season, possibly due to larger variation that occurred during that season.

Not one of the four cultivars evaluated during the 2003/04, 2004/05 and 2005/06 seasons outperformed the standard cultivar, DeltaOPAL, significantly in respect of seed cotton yield and fibre yield. DeltaOPAL (43.7%) gave the highest seed cotton yield, fibre percentage and fibre yield during the 2003/04 season. Although SZ9314 gave the highest fibre percentages in the 2004/05 and 2005/06 seasons, NuOPAL gave the highest seed cotton and fibre yields. Both DeltaOPAL and NuOPAL can be recommended for planting in the Loskop area. However, the cultivar, LS9219, cannot be recommended for planting in this area, because its performance was consistently poorer than that of the standard (DeltaOPAL).

Quality parameters

When the quality parameters (fibre length, fibre strength and micronaire) were analysed, a different picture emerged from that obtained with yield. Fibre length was significantly affected by cultivar in all three seasons evaluated (Table 4.2).

From the data presented in Table 4.2 it can be seen that the results obtained in respect of fibre length were almost the opposite of those obtained in respect of the total seed cotton yield in both the 2003/04 and 2004/05 seasons. The cultivar, LS9219, produced the longest fibre (32.8 and 32.3 mm). This cultivar also produced the longest fibre during the 2005/06 season (32.0 mm). In all of the seasons evaluated, the fibre produced by this cultivar was significantly ($P<0.05$) longer than that produced by DeltaOPAL (28.3, 29.0 and 27.7 mm), NuOPAL (29.1, 28.7 and 27.3 mm) and DeltaOpal RR (28.2, 29.0 and 27.7 mm). The fibre length produced by SZ9314 during the 2003/04 season was also significantly shorter than that of LS9219 while it did not differ significantly from that of LS9219 during either the 2004/05 season (32.3 mm) or the 2005/06 season (30.7 mm). During the last two seasons the length of the fibre produced by SZ9314 was significantly longer than that produced by the other three cultivars (DeltaOPAL, NuOPAL and DeltaOpal RR).

Table 4.2 Quality data for the various cotton cultivars planted at Loskop, during the 2003 to 2006 seasons

Season Parameter	Cultivar					Average
	DeltaOPAL	NuOPAL	DeltaOpal RR	LS9219	SZ9314	
2003/04						
Length (mm)	28.3 b	29.1 b	28.2 b	32.8 a	29.6 b	29.6
Strength (g tex^{-1})	32.4 ab	31.4 ab	30.7 b	35.2 a	31.3 b	32.2
Micronaire	4.7	4.4	4.5	4.3	4.8	4.5
$LSD_{T(0.05)}$	L = 1.697	S = 3.814	M = ns			
2004/05						
Length (mm)	29.0 b	28.7 b	29.0 b	32.3 a	32.3 a	30.3
Strength (g tex^{-1})	29.9	32.2	32.5	33.5	32.1	32.0
Micronaire	4.7	4.4	4.5	4.3	4.8	4.5
$LSD_{T(0.05)}$	L = 2.418	S = ns	M = ns			
2005/06						
Length (mm)	27.7 b	27.3 b	27.7 b	32.0 a	30.7 a	29.1
Strength (g tex^{-1})	30.5 ab	29.9 b	29.4 b	33.8 a	30.1 ab	30.7
Micronaire	4.3	4.2	4.4	3.9	4.4	4.2
$LSD_{T(0.05)}$	L = 1.71	S = 3.777	M = ns			

Figures in the row followed by the same letter do not differ significantly from each other
ns – not significant at the 5% level

LS9219 (35.2, 33.5 and 33.8 g tex^{-1}) also produced the strongest fibre in comparison with all the other cultivars evaluated during the 2003/04, 2004/05 and 2005/06 seasons, although the differences were not statistically significant ($P<0.05$) during the 2004/05 season (Table 4.2). The prime micronaire range lies between 3.8 and 4.2, and acceptable values are between 3.5 to 4.7. During 2003/04 all micronaire values were higher than the prime micronaire range. Spinners do not accept micronaire values of above 4.7, but will still buy it at a discount price to mix with other cotton. During the 2003/04 and 2005/06 season DeltaOPAL had the highest micronaire value of 4.7. Other micronaire values evaluated during the three seasons were between 3.9 and 4.5.

All five cultivars evaluated during the three seasons produced fibre of the quality required by the textile industry. As a result, the cultivar recommended for this area would be the one that gave the highest yield and, seeing that DeltaOPAL and NuOPAL produced higher seed cotton and fibre yields than the other cultivars, they are recommended for planting in this area.

4.3 Makhathini

Yield parameters

Cultivar had a significant effect ($P<0.05$) on all three yield parameters (seed cotton yield, fibre percentage and fibre yield) in the 2003/04 and 2005/06 seasons. In the 2004/05 season, however, the cultivar effect was only significant for seed cotton yield (Table 4.3).

From Table 4.3 it can be seen that the cultivar, NuOPAL, produced the highest seed cotton yield (5 476, 3 969 and 3 574 kg ha^{-1}) during the 2003/04, 2004/05 and 2005/06 seasons. During the 2003/04 season this was significantly higher than that produced by DeltaOPAL (4 298 kg ha^{-1}), DeltaOpal RR (4 078 kg ha^{-1}), LS9219 (3 165 kg ha^{-1}) and SZ9314 (3 169 kg ha^{-1}). During the 2004/05 season this was only significantly higher than that produced by DeltaOpal RR (2 907 kg ha^{-1}), LS9219 (2 350 kg ha^{-1}) and SZ9314 (2 406 kg ha^{-1}), not significantly higher than DeltaOPAL (3 145 kg ha^{-1}). During the 2005/06 season NuOPAL (3 574 kg ha^{-1}) produced significantly higher seed cotton yields than that produced by LS9219 (1 879 kg ha^{-1}) and SZ9314 (2 500 kg ha^{-1}), not significantly higher than DeltaOPAL (2 675 kg ha^{-1}) and DeltaOpal RR (2 722 kg ha^{-1}).

Table 4.3 Yield data for the various cotton cultivars planted at Makhathini, during the 2003 to 2006 seasons

Season Parameter	Cultivar					Average
	DeltaOPAL	NuOPAL	DeltaOpal RR	LS9219	SZ9314	
2003/04						
Seed cotton yield (kg ha^{-1})	4 298 b	5 476 a	4 078 b	3 165 c	3 169 c	4 037
Fibre %	36.4 a	37.1 a	35.8 a	31.1 b	36.0 a	35.3
Fibre yield (kg ha^{-1})	1 566 b	2 036 a	1 436 b	986 c	1 142 c	1 438
$LSD_{T(0.05)}$	SCY = 619.5	F = 1.653	FY = 253.2			
2004/05						
Seed cotton yield (kg ha^{-1})	3 145 a	3 969 a	2 907 b	2 350 b	2 406 b	2 955
Fibre %	38.0	40.5	44.0	44.7	43.7	42.2
Fibre yield (kg ha^{-1})	1 384	1 661	1 275	1 052	1 045	1 284
$LSD_{T(0.05)}$	SCY = 960.0	F = ns	FY = ns			
2005/06						
Seed cotton yield (kg ha^{-1})	2 675 ab	3 574 a	2 722 ab	1 879 b	2 500 b	2 670
Fibre %	37.2 ab	35.8 bc	36.2 bc	33.9 c	39.3 a	36.5
Fibre yield (kg ha^{-1})	995 ab	1 282 a	985 ab	635 b	982 ab	976
$LSD_{T(0.05)}$	SCY = 1016	F = 2.358	FY = 368.1			

Figures in the row followed by the same letter do not differ significantly from each other
ns – not significant at the 5% level

During the 2003/04 season, it was found that NuOPAL produced the highest fibre percentage of (37.1%) and that it significantly outperformed only LS9219 (31.1%). NuOPAL was followed by DeltaOPAL (36.4%), SZ9314 (36.0 %), and DeltaOpal RR (35.8 %). During the 2004/05 season LS9219 gave the highest fibre percentage of 44.7%. During the 2005/06 season, the highest fibre percentage was produced by SZ9314 (39.3%), and it significantly outperformed NuOPAL (35.8 %), DeltaOpal RR (36.2) and LS9219 (33.9), but not DeltaOPAL (37.2%).

During the 2003/04, 2004/05 and 2005/06 seasons NuOPAL (2 036, 1 661 and 1 282 kg ha^{-1}) had the highest fibre yield. This differed significantly from DeltaOPAL (1 566 kg ha^{-1}), DeltaOpal RR (1 436 kg ha^{-1}), LS9219 (986 kg ha^{-1}) and SZ9314 (1 142 kg ha^{-1}) during the first season. During the 2005/06 season NuOPAL (1 282 kg ha^{-1}) produced significantly more fibre than only LS9219 (635 kg ha^{-1}), not more than DeltaOPAL (995 kg ha^{-1}), DeltaOpal RR (965 kg ha^{-1}) or SZ9314 (982 kg ha^{-1}).

NuOPAL outperformed the standard cultivar, DeltaOPAL, significantly regarding seed cotton yield and fibre yield during the 2003/04 season, and although not significant, also more yield than DeltaOPAL during the 2004/05 and 2005/06 seasons. NuOPAL gave higher fibre percentages during the first season. NuOPAL can be recommended for planting in the Makhathini area. The cultivars, LS9219 and SZ9314, both did poor during all three season evaluated, and cannot be recommended for planting in this area.

Quality parameters

When the quality parameters (fibre length, fibre strength and micronaire) were analysed, a different picture emerged from that obtained with yield. Fibre length showed significant differences between cultivar in the 2003/04, 2004/05 and 2005/06 seasons (Table 4.4).

From the data presented in Table 4.4 it can be seen that the results obtained in respect of fibre length were almost the opposite of those obtained for the total seed cotton yield in the 2003/04, 2004/05 and 2005/06 seasons. The cultivar, LS9219, produced the longest fibre (33.3, 33.3 and 31.7 mm). The fibre produced by this cultivar, was significantly ($P<0.05$) longer than those produced by DeltaOPAL (29.3, 30.3 and 29.0 mm), NuOPAL (29.0, 30.7 and 30.0 mm), DeltaOpal RR (29.3, 29.3 and 29.0 mm), and SZ9314 (30.7 mm both) in 2003/04 and 2004/05. The fibre length produced by LS9219 (31.7 mm) did not differ significantly from that of SZ9314 (31.3 mm) during the 2005/06 season.

During the 2003/04 season a low micronaire value of 3.4 was obtained at both LS9219 and SZ9314. Micronnaire values of the other cultivars were acceptable during this first season. During the last two seasons acceptable values of between 3.5 to 4.5 were obtained.

All five cultivars tested produced fibre of the quality required by the textile industry except for the relatively low micronaire value of 3.4 during the first season obtained from the cultivars, LS9219 and SZ9314. As a result, the cultivar recommended for this area would be the one that gave the highest yield and, seeing that NuOPAL produced significantly higher seed cotton and fibre yield it is recommended for planting in this area.

Table 4.4 Quality data for the various cotton cultivars planted at Makhathini, during the2003 to 2006 seasons

Season Parameter	Cultivar					Average
	DeltaOPAL	NuOPAL	DeltaOpal RR	LS9219	SZ9314	
2003/04						
Length (mm)	29.3 b	29.0 b	29.3 b	33.3 a	30.7 b	30.3
Strength (g tex^{-1})	31.4	31.2	30.6	34.7	32.0	32.0
Micronaire	3.6	3.8	3.5	3.4	3.4	3.5
$LSD_{T(0.05)}$	L = 2.551	S = ns	M = ns			
2004/05						
Length (mm)	30.3 b	30.7 b	29.3 b	33.3 a	30.7 b	30.9
Strength (g tex^{-1})	33.3	33.0	34.8	33.2	33.1	33.5
Micronaire	4.1	3.8	4.2	3.7	3.9	3.9
$LSD_{T(0.05)}$	L = 1.786	S = ns	M = ns			
2005/06						
Length (mm)	29.0 b	30.0 b	29.0 b	31.7 a	31.3 a	30.2
Strength (g tex^{-1})	33.8	34.5	33.1	35.9	34.3	34.3
Micronaire	4.5	3.9	4.2	4.2	4.5	4.3
$LSD_{T(0.05)}$	L = 1.153	S = ns	M = ns			

Figures in the row followed by the same letter do not differ significantly from each other
ns – not significant at the 5% level

4.4 Rustenburg

Yield parameters

Cultivar had a significant effect ($P<0.05$) on fibre percentage in the 2004/05 and 2005/06 seasons (Table 4.5).

Although not statistically significant ($P<0.05$) the cultivar, DeltaOpal RR (2 897 and 1 920 kg ha^{-1}) produced the lowest seed cotton yield during the 2003/04 and 2005/06 seasons, while LS9219 (2 619 kg ha^{-1}) produced the lowest yield during the 2004/05 season. The yield of NuOPAL (4 273, 4 107 and 2 365 kg ha^{-1}) was the highest in all three seasons.

Table 4.5 Yield data for the various cotton cultivars planted at Rustenburg, during the 2003 to 2006 seasons

Season Parameter	Cultivar					Average
	DeltaOPAL	NuOPAL	DeltaOpal RR	LS9219	SZ9314	
2003/04						
Seed cotton yield (kg ha^{-1})	3 417	4 273	2 897	3 235	3 601	3 485
Fibre %	44.4	42.7	42.0	43.7	44.8	43.5
Fibre yield (kg ha^{-1})	1 677	2 380	1 582	1 522	1 904	1 813
$LSD_{T(0.05)}$	SCY = ns	F = ns	FY = ns			
2004/05						
Seed cotton yield (kg ha^{-1})	3 068	4 107	3 194	2 619	3 145	3 227
Fibre %	43.0 b	42.3 b	41.7 b	37.7 c	45.3 a	42.0
Fibre yield (kg ha^{-1})	1 320	1 731	1 339	984	1 419	1 359
$LSD_{T(0.05)}$	SCY = ns	F = 1.503	FY = ns			
2005/06						
Seed cotton yield (kg ha^{-1})	2 092	2 365	1 920	2 121	2 088	2 117
Fibre %	39.7 a	39.7 a	39.0 a	34.7 b	40.3 a	38.7
Fibre yield (kg ha^{-1})	834	942	751	734	844	821
$LSD_{T(0.05)}$	SCY = ns	F = 3.114	FY = ns			

Figures in the row followed by the same letter do not differ significantly from each other

ns – not significant at the 5% level

During the 2004/05 and 2005/06 seasons, it was found that SZ9314 produced the highest fibre percentages of 45.3 and 40.3%. During 2004/05 this was significantly higher than all the other cultivars namely DeltaOPAL (43.0 %), NuOPAL (42.3 %), DeltaOpal RR (41.7 %) and LS9219 (37.7 %), but in 2005/06 this was only significantly higher than LS9219 (34.7%), not higher than DeltaOPAL (39.7 %), NuOPAL (39.7%) and DeltaOpal RR (34.7%).

Although not statistically significant ($P<0.05$), the cultivar, NuOPAL, produced the highest fibre yields of 2 380, 1 731 and 942 kg ha^{-1} during the three seasons evaluated. LS9219 resulted in the lowest fibre yields of 1 522, 984 and 734 kg ha^{-1} respectively for the 2003/04, 2004/05 and 2005/06 seasons. The only significant difference regarding yield parameters was during the 2004/05 season, where fibre percentage was the highest at SZ9314. Although not statistically significant (P<0.05), NuOPAL gave the highest seed cotton and fibre yield and is therefore recommended for planting in the Rustenburg area. However, the cultivar, LS9219, cannot be recommended for planting in this area, because its performance was consistently poorer than that of the standard (DeltaOPAL).

Quality parameters

When the quality parameters (fibre length, fibre strength and micronaire) were analysed a different picture again emerged from that obtained with yield. Fibre length was significantly affected by cultivar in the 2003/04, 2004/05 and 2005/06 seasons. Fibre strength was significantly affected by cultivar in the 2005/06 season (Table 4.6).

From Table 4.6 it can be seen that the cultivar, LS9219, produced the longest fibre (32.6, 32.0 and 31.3mm). In all the seasons evaluated, the fibre produced by this cultivar was significantly (P<0.05) longer than those produced by DeltaOPAL (28.8, 27.3 and 27.0 mm), NuOPAL (28.2, 28.3 and 27.0 mm) and DeltaOpal RR (28.6, 27.7 and 27.7 mm). The fibre length produced by SZ9314 (31.8 and 29.7 mm) during the 2003/04 and 2004/05 seasons was not significantly shorter than that of LS9219 (32.6 and 32.0 mm), but during the 2004/05 season LS9219 (32.0 mm) gave significantly longer fibre than SZ9314 (29.7 mm).

LS9219 (35.5 and 38.5 g tex^{-1}) also produced the strongest fibre in comparison with all the other cultivars evaluated during the 2003/04 and 2004/05 seasons, although the differences were not statistically significant (P<0.05). During the 2005/06 season, LS9219 (37.1 g tex^{-1}) significantly outperformed NuOPAL (29.9 g tex^{-1}) and SZ9314 (33.1 g tex^{-1}) but not DeltaOPAL (31.5 gtex^{-1}) and DeltaOpal RR (32.3 g tex^{-1}).

Although not statistically significant (P<0.05), during the 2003/04 season all micronaire values were too high, ranging from 4.8 to 5.0. During 2004/05 all micronaire values were acceptable except for DeltaOpal RR with a value of 3.4.

During the 2005/06 season LS9219 and SZ9314 had low micronaire values of 3.0 and 3.4 (Table 4.6).

Table 4.6 Quality data for the various cotton cultivars planted at Rustenburg, during the 2003 to 2006 seasons

Season Parameter	Cultivar					Average
	DeltaOPAL	NuOPAL	DeltaOpal RR	LS9219	SZ9314	
2003/04						
Length (mm)	28.8 b	28.2 b	28.6 b	32.6 a	31.8 a	30.0
Strength (g tex^{-1})	32.0	30.5	32.0	35.5	33.9	32.8
Micronaire	4.8	5.0	5.0	4.8	5.0	4.9
$LSD_{T(0.05)}$	L = 2.575	S = ns	M = ns			
2004/05						
Length (mm)	27.3 c	28.3 bc	27.7 c	32.0 a	29.7 b	29.0
Strength (g tex^{-1})	32.9	33.9	34.6	38.5	38.5	35.7
Micronaire	3.9	3.7	3.4	3.7	3.9	3.7
$LSD_{T(0.05)}$	L = 1.748	S = ns	M = ns			
2005/06						
Length (mm)	27.0 b	27.0 b	27.7 b	31.3 a	29.7 ab	28.5
Strength (g tex^{-1})	31.5 ab	29.9 c	32.3 ab	37.1 a	33.1 b	32.9
Micronaire	3.6	3.7	3.6	3.0	3.4	3.6
$LSD_{T(0.05)}$	L = 3.260	S = 2.728	M = ns			

Figures in the row followed by the same letter do not differ significantly from each other
ns – not significant at the 5% level

Although LS9219 consistently gave significantly longer and stronger fibre than the other cultivars, it could be planted for special fibre purposes in selected areas and under proper cultivation practices. The cultivar recommended for this area should be the one that gave the highest yield and, seeing that none of the cultivars evaluated produced a significantly higher yield than the standard (DeltaOPAL), no change in the cultivar recommended for this area will be made based on these results. NuOPAL produced the highest seed cotton and fibre yields and is recommended for planting in the Rustenburg area.

4.5 Upington

Yield parameters

Cultivar only had a significant effect ($P<0.05$) on fibre percentage and fibre yield in the 2003/04 season (Table 4.7).

During the 2003/04 season, SZ9314 (7 927 kg ha^{-1}) gave the highest seed cotton yield followed by DeltaOPAL with 7 809 kg ha$^{-1)}$. During the 2004/05 season the cultivars, LS9219 (8 750 kg ha^{-1}) followed by NuOPAL (8 653) gave the highest seed cotton yield. During the 2005/06 season NuOPAL (6 103 kg ha^{-1}) and DeltaOPAL (5 989 kg ha^{-1}) gave the highest seed cotton yield.

From Table 4.7 it can be seen that the cultivar, NuOPAL, produced the highest fibre percentage (45.0 %) during the 2003/04 season. This was not significantly higher than that produced by DeltaOPAL (44.7%), DeltaOpal RR (44.3%) and SZ9314 (43.7%). It only differed significantly from LS9219 (38.7%). LS9219 gave the highest fibre percentage of 43.2 % in 2004/05 and SZ9314 and NuOPAL (both 41 %) gave the highest fibre percentages in 2005/06.

From Table 4.7 it can be seen that the cultivars, SZ9314, (3 478 kg ha^{-1}) and DeltaOPAL, (3 471 kg ha^{-1}) produced significantly more fibre than LS9219 (2 577 kg ha^{-1}) during the 2003/04 season. During the 2004/05 season LS9219 (3 780 kg ha^{-1}) and NuOPAL (3 589 kg ha^{-1}) produced more fibre. NuOPAL (2 494 kg ha^{-1}) and DeltaOPAL (2 406 kg ha^{-1}) produced the highest fibre yield in the 2005/06 season. This did not differ significantly from NuOPAL (3 403 kg ha^{-1}) or DeltaOpal RR (3 144 kg ha^{-1}). The cultivar, SZ9314, followed by DeltaOPAL, could be recommended for planting in Upington, if climatically conditions similar than that of the 2003/04 season would occur. The same recommendation can be make for LS9219, followed by NuOPAL, that can be planted in Upington, if similar climatically conditions than that of 2004/05 occurs. NuOPAL did the best regarding seed cotton yield in the 2005/06 season, and can be recommended for planting in the Upington area.

Quality parameters

When the quality parameters (fibre length, fibre strength and micronaire) were analysed, cultivar had no significant effect (P<0.05) on any of the quality parameters (Table 4.8).

Table 4.7 Yield data for the various cotton cultivars planted at Upington, during the 2003 to 2006 seasons

Season Parameter	Cultivar					Average
	DeltaOPAL	NuOPAL	DeltaOpal RR	LS9219	SZ9314	
2003/04						
Seed cotton yield (kg ha^{-1})	7 809	7 632	7 157	6 697	7 927	7 445
Fibre %	44.7 a	45.0 a	44.3 a	38.7 b	43.7 a	43.3
Fibre yield (kg ha^{-1})	3 471 a	3 403 a	3 144 a	2 577 b	3 478 a	3 215
$LSD_{T(0.05)}$	SCY = ns F = 2.847 FY = 558.3					
2004/05						
Seed cotton yield (kg ha^{-1})	8 334	8 653	8 336	8 750	8 268	8 468
Fibre %	42.1	41.5	41.6	43.2	42.0	42.1
Fibre yield (kg ha^{-1})	3 508	3 589	3 470	3 780	3 477	3 565
$LSD_{T(0.05)}$	SCY = ns F = ns FY = ns					
2005/06						
Seed cotton yield (kg ha^{-1})	5 989	6 103	5 815	5 535	5 247	5 738
Fibre %	40.3	41.0	40.7	36.3	41.0	39.9
Fibre yield (kg ha^{-1})	2 406	2 494	2 362	2 026	2 148	2 287
$LSD_{T(0.05)}$	SCY = ns F = ns FY = ns					

Figures in the row followed by the same letter do not differ significantly from each other

ns – not significant at the 5% level

Although not statistically significant (P<0.05) the cultivar, LS9219 (31.9 mm) produced the longest fibre during the 2003/04 season, and SZ9314 (31.0 mm) during the 2004/05 season. During the 2005/06 season LS9219 (32.3 mm) produced significantly longer fibre that DeltaOPAL (30.0 mm) and DeltaOpal RR (29.7 mm), but not significantly longer than NuOPAL (30.3 mm) and SZ9314 (31.3 mm).

LS9219 (32.8 and 34.6 g tex^{-1}) also produced the strongest fibre in comparison with all the other cultivars evaluated during the 2003/04 and 2005/06 seasons. The strongest fibre during the 2004/05 season was produced by SZ9314 (35.0 g tex^{-1}). During all three seasons evaluated, acceptable micronaire values were produced by all the cultivars. All five cultivars tested produced fibre of the quality required by the textile industry. The same picture emerged at Upington than at Loskop, with the cultivar, LS9219 that produced significantly longer fibre than NuOPAL in 2003/04 and DeltaOPAL and DeltaOpal RR in 2005/06. LS9219 did however, only produced the highest seed cotton and fibre yield in 2004/05 and therefore DeltaOPAL and NuOPAL are also recommended for planting in the Upington area, since it produced the highest seed cotton and fibre yield in the 2003/04 and 2005/06 seasons

Table 4.8 Quality data for the various cotton cultivars planted at Upington, during the 2003 to 2006 seasons

Season Parameter	Cultivar					Average
	DeltaOPAL	NuOPAL	DeltaOpal RR	LS9219	SZ9314	
2003/04						
Length (mm)	29.1	28.7	29.0	31.9	30.7	29.9
Strength (g tex^{-1})	32.7	30.1	31.0	32.8	32.7	31.8
Micronaire	4.2	4.1	4.4	3.7	4.3	4.2
$LSD_{T(0.05)}$	L = ns	S = ns	M = ns			
2004/05						
Length (mm)	29.7	30.0	30.0	30.7	31.0	30.3
Strength (g tex^{-1})	34.0	33.0	33.3	33.3	35.0	33.7
Micronaire	4.1	3.9	4.0	4.2	4.5	4.1
$LSD_{T(0.05)}$	L = ns	S = ns	M = ns			
2005/06						
Length (mm)	30.0 b	30.3 ab	29.7 b	32.3 a	31.3 ab	30.7
Strength (g tex^{-1})	34.3	32.9	34.0	34.6	33.1	33.8
Micronaire	3.9	4.0	3.7	4.3	4.6	4.1
$LSD_{T(0.05)}$	L = 2.029	S = ns	M = ns			

Figures in the row followed by the same ltter do not differ significantly from each other
ns – not significant at the 5% level

4.6 Vaalharts

Yield parameters

Cultivar had a significant effect (P<0.05) on all three yield parameters (seed cotton yield, fibre percentage and fibre yield) in the 2004/05 and 2005/06 seasons (Table 9). In the 2003/04 season, however, the cultivar effect was only significant for the fibre percentage and fibre yield (Table 4.9).

From Table 4.9 it can be seen, that during 2003/04, the cultivar, SZ9314, produced the lowest seed cotton yield (4 360 kg ha^{-1}), while the yield of DeltaOPAL tended to be higher (6 062 kg ha^{-1}) than all the other cultivars. During the 2004/05 season, NuOPAL (6 887 kg ha^{-1}) produced the highest seed cotton yield, significantly outperforming only SZ9314 (3 393 kg ha^{-1}), not DeltaOPAL (6 150 kg ha^{-1}), DeltaOpal RR (5 222 kg ha^{-1}) or LS9219 (4 802 kg ha^{-1}). During 2005/06, NuOPAL (3 847 kg ha^{-1}) produced significantly higher yield than DeltaOpal RR (2 298 kg ha^{-1}), LS9219 (1 388 kg ha^{-1}) and SZ9314 (1 736 kg ha^{-1}), not significantly higher than DeltaOPAL (2 726 kg ha^{-1}).

From table 4.9 it can be seen that during the 2003/04 to 2005/06 seasons, SZ9314 (45.4, 42.3 and 41.0 %) had the highest fibre percentages. This did not differ significantly from DeltaOPAL (45.3, 40.0 and 40.3) during the 2003/04, 2004/05 and 2005/06 seasons. It differed significantly from LS9219 (38.6 and 35.0 %) in the 2003/04 and 2005/06 seasons, and from NuOPAL (39.3 %) and DeltaOpal RR (39.3 %) during the 2004/05 season.

During the 2003/04 season, DeltaOPAL (2 747 kg ha^{-1}) gave the highest fibre yield, while SZ9314 gave the lowest fibre yield of 1981 kg ha^{-1}. During 2004/05, NuOPAL (2 720 kg ha^{-1}) gave the highest fibre yield, while SZ9314 again gave the lowest yield of 1 432 kg ha^{-1}. During the 2005/06 season, NuOPAL (1 557 kg ha^{-1}) produced significantly more fibre than DeltaOpal RR (923 kg ha^{-1}), LS9219 (487 kg ha^{-1}) and SZ9314 (710 kg ha^{-1}) not significantly more than that produced by DeltaOPAL (1 100 kg ha^{-1}) (Table 4.9).

NuOPAL significantly outperformed DeltaOpal RR, LS9219 and SZ9314, but not DeltaOPAL during the 2005/06 season. NuOPAL also obtained the highest yield during the 2004/05 season. DeltaOPAL realised the highest yield in the 2003/04 season. Both NuOPAL and DeltaOPAL are recommended for planting in the Vaalharts area.

Quality parameters

When the quality parameters (fibre length, fibre strength and micronaire) were analysed a different picture emerged from that obtained with yield. Fibre length was significantly affected by cultivar in 2003/04 and 2005/06, while fibre strength showed significant differences between cultivars in the 2003/04 and 2005/06 seasons. Micronaire was significantly affected by cultivar in the 2003/04 and 2004/05 seasons (Table 4.10).

Table 4.9 Yield data for the various cotton cultivars planted at Vaalharts, during the 2003 to 2006 seasons

Season Parameter	Cultivar					Average
	DeltaOPAL	NuOPAL	DeltaOpal RR	LS9219	SZ9314	
2003/04						
Seed cotton yield (kg ha^{-1})	6 062	5 878	4 907	5 541	4 360	5 350
Fibre %	45.3 a	45.0 a	44.6 a	38.6 b	45.4 a	43.8
Fibre yield (kg ha^{-1})	2 747 a	2 643 ab	2 186 ab	2 133 ab	1 981 b	2 338
$LSD_{T(0.05)}$	SCY = ns	F = 3.172	FY = 764.2			
2004/05						
Seed cotton yield (kg ha^{-1})	6 150 a	6 887 a	5 222 ab	4 802 ab	3 393 b	5 291
Fibre %	40.0 ab	39.3 b	39.3 b	42.0 a	42.3 a	40.6
Fibre yield (kg ha^{-1})	2 444 ab	2 720 a	2 060 ab	2 016 ab	1 432 b	2 134
$LSD_{T(0.05)}$	SCY = 2671	F = 2.362	FY = 1109			
2005/06						
Seed cotton yield (kg ha^{-1})	2 726 ab	3 847 a	2 298 bc	1 388 c	1 736 bc	2399
Fibre %	40.3 a	40.3 a	40.0 a	35.0 b	41.0 a	39.3
Fibre yield (kg ha^{-1})	1 100 ab	1557 a	923 bc	487 c	710 bc	956
$LSD_{T(0.05)}$	SCY = 1280	F = 1.670	FY = 518.4			

Figures in the row followed by the same letter do not differ significantly from each other
ns – not significant at the 5% level

The cultivar LS9219 produced the longest fibre (32.6 and 34.3 mm) during the 2003/04 and 2005/06 seasons. In both of the mentioned seasons evaluated, the fibre produced by this cultivar was significantly ($P<0.05$) longer than that produced by DeltaOPAL (29.2 and 30.0 mm), NuOPAL (29.1 and 30.7 mm) and DeltaOpal RR (28.5 and 29.0 mm). The fibre length produced by SZ9314 did not differ significantly from that of LS9219 during either the 2003/04 season (30.3 mm) or the 2005/06 season (32.0 mm).

During 2003/04, the fibre produced by LS9219 (35.4 g tex^{-1}) and SZ9314 (32.4 g tex^{-1}) were significantly stronger than DeltaOPAL (31.7 g tex^{-1}), NuOPAL (30.6 g tex^{-}1), and DeltaOpal RR (31.3 g tex^{-}1), but not SZ9314 (32.4 g tex^{-1}) (Table 4.10). Although the differences were not statistically significant ($P<0.05$) during the 2004/05 season, the cultivar, SZ9314, had the strongest fibre of 33.9 g tex^{-1}. During 2005/06, LS9219 (33.8 g tex^{-1}) gave significantly stronger fibre than DeltaOPAL (30.3 g tex^{-1}), NuOPAL (30.6 g tex^{-1}), DeltaOpal RR (29.9 g tex^{-1}), and SZ9314 (30.4 g tex^{-1}).

Table 4.10 Quality data for the various cotton cultivars planted at Vaalharts, during the 2003 to 2006 seasons

Season Parameter	Cultivar					Average
	DeltaOPAL	NuOPAL	DeltaOpal RR	LS9219	SZ9314	
2003/04						
Length (mm)	29.2 b	29.1 b	28.5 b	32.6 a	30.3 a	29.9
Strength (g tex^{-1})	31.7 b	30.6 b	31.3 b	35.4 a	32.4 ab	32.3
Micronaire	4.4 ab	4.1 c	4.3 bc	4.3 bc	4.7 a	4.3
$LSD_{T(0.05)}$	L = 0.901	S = 3.303	M = 0.348			
2004/05						
Length (mm)	29.3	29.3	29.3	29.0	29.7	29.3
Strength (g tex^{-1})	33.6	31.9	33.4	30.9	33.9	32.7
Micronaire	4.5 ab	4.0 b	4.5 ab	4.4 ab	4.8 a	4.4
$LSD_{T(0.05)}$	L = ns	S = ns	M = 0.765			
2005/06						
Length (mm)	30.0 bc	30.7 bc	29.0 c	34.3 a	32.0 ab	31.2
Strength (g tex^{-1})	30.3 b	30.6 b	29.9 b	33.8 a	30.4 b	31.0
Micronaire	4.2	4.1	4.4	4.2	4.4	4.2
$LSD_{T(0.05)}$	L = 2.551	S = 2.475	M = ns			

Figures in the row followed by the same letter do not differ significantly from each other

ns – not significant at the 5% level

During the 2003/04 and 2004/05 seasons, the cultivar, SZ9314, (4.7 and 4.8) gave significantly higher micronaire values (coarser fibre). The other cultivars had values of between 4.0 to 4.5 that fell within the acceptable limits for fibre quality. Although LS9219 gave significantly longer fibres during two seasons, and the strongest fibres during all three seasons evaluated, the cultivar recommended for this area would be the one which gave the highest yield, and seeing that DeltaOPAL during 2003/04 and

NuOPAL during the 2004/05 and 2005/06 seasons produced the highest seed cotton and fibre yield they are recommended for planting in the Vaalharts area.

4.7 Weipe

Yield parameters

Cultivar had a significant effect ($P<0.05$) on all three yield parameters (seed cotton yield, fibre percentage and fibre yield) in the 2003/04 and 2005/06 seasons. In the 2005/06 season, however, the cultivar effect was only significant for the fibre percentage (Table 4.11).

From table 4.11 it can be seen that the cultivar, LS9219, (3 835 and 3 389 kg ha^{-1}), produced the lowest seed cotton yield in 2003/04 and 2005/06 while the yield of NuOPAL (5 785 kg ha^{-1}) was the highest in the 2003/04 season, but only significantly outperforming LS9219, not DeltaOPAL, DeltaOpal RR or SZ9314. During 2005/06 the yield of DeltaOPAL (4 336 kg ha^{-1}) was the highest, but this was not significantly better than the yield of NuOPAL, DeltaOpal RR or SZ9314.

During the 2003/04 season, it was found that the cultivar, NuOPAL, produced the highest fibre percentage of (43.0%), significantly outperforming only LS9219 (38.7 %). During the 2004/05 season, the cultivar SZ9314 produced the highest fibre percentage of 43.5 %, significantly outperforming all the other cultivars except DeltaOPAL (42.8%). During 2005/06, the cultivar NuOPAL (41.3 %) produced the highest fibre percentage, significantly outperforming only LS9219 (35.3%), not DeltaOPAL (40.7 %), DeltaOpal RR (38.3 %) or SZ9314 (39.3%).

From Table 4.11 it can be seen the cultivar, NuOPAL, (2 487 kg ha^{-1}) had the highest fibre yield, significantly higher than only LS9219 (1 484 kg ha^{-1}) during the 2003/04 season. During the 2004/05 season, DeltaOpal RR (2 380 kg ha^{-1}) produced the highest fibre yield. During the 2005/06 season, DeltaOPAL (1 760 kg ha^{-1})

significantly outperformed only LS9219 (1 205 kg ha^{-1}), not NuOPAL (1 608 kg ha^{-1}), DeltaOpal RR (1 511 kg ha^{-1}), LS9219 (1 205 kg ha^{-1}) or SZ9314 (1 505 kg ha^{-1}).

NuOPAL, DeltaOpal RR and DeltaOPAL resulted in the highest seed cotton and fibre yield during the 2003/04, 2004/05 and 2005/06 seasons respectively, and any of the three cultivars can be recommended for planting in the Weipe area, depending on the producer's choice of cultivar. LS9219 cannot be recommended for planting in this area, because its performance was consistently poorer than that of the standard cultivar (DeltaOPAL).

Table 4.11 Yield data for the various cotton cultivars planted at Weipe, during the 2003 to 2006 seasons

Season Parameter	Cultivar					Average
	DeltaOPAL	NuOPAL	DeltaOpal RR	LS9219	SZ9314	
2003/04						
Seed cotton yield (kg ha^{-1})	5 172 ab	5 785 a	4 977 ab	3 835 b	4 929 ab	4 939
Fibre %	42.7 a	43.0 a	42.3 a	38.7 b	42.7 a	41.9
Fibre yield (kg ha^{-1})	2 207 a	2 487 a	2 107 ab	1 484 b	2 108 ab	2 079
$LSD_{T(0.05)}$	SCY = 1439	F = 2.916	FY = 677.3			
2004/05						
Seed cotton yield (kg ha^{-1})	5 282	4 845	5 845	4 622	5 387	5 196
Fibre %	42.8 ab	41.4 bc	40.8 c	37.6 d	43.5 a	41.2
Fibre yield (kg ha^{-1})	2 261	2 008	2 380	1 734	2 346	2 146
$LSD_{T(0.05)}$	SCY = ns	F = 1.763	FY = ns			
2005/06						
Seed cotton yield (kg ha^{-1})	4 336 a	3 914 ab	3 914 ab	3 389 b	3 816 ab	3 874
Fibre %	40.7 a	41.3 a	38.3 ab	35.3 b	39.3 ab	39.0
Fibre yield (kg ha^{-1})	1 760 a	1 608 a	1 511 ab	1 205 b	1 505 ab	1 518
$LSD_{T(0.05)}$	SCY = 708.3	F = 5.180	FY = 348.1			

Figures in the row followed by the same letter do not differ significantly from each other

ns – not significant at the 5% level

Quality parameters

When the quality parameters (fibre length, fibre strength and micronaire) were analysed a different picture emerged from that obtained with yield. Fibre length, strength and micronaire were significantly affected by cultivar in the 2003/04 and 2004/05 seasons (Table 4.12).

During the first two seasons, the cultivar LS9219 produced the longest fibre (33.0 and 32.7 mm). The fibre produced by this cultivar was significantly ($P<0.05$) longer than that produced by DeltaOPAL (both 29.3 mm), NuOPAL (29.7 and 29.0 mm) and DeltaOpal RR (29.0 and 29.3 mm). The fibre length produced by SZ9314 (29.3 mm) during the 2003/04 season was also significantly shorter than those of LS9219 (33.0 mm), while SZ9314 (31.0 mm) did not differ significantly in length from that of LS9219 (32.7 mm) during the 2004/05 season. LS9219 (34.6 g tex^{-1}), also gave the strongest fibre of all the cultivars evaluated during the 2003/04 season significantly outperforming DeltaOpal RR (28.7 g tex^{-1}), not DeltaOPAL ((29.9 g tex^{-1}), NuOPAL (31.2 g tex^{-1}) or SZ9314 (32.1 g tex^{-1}). Although not statistically significant ($P<0.05$), NuOPAL (35.4 g tex^{-1}) gave the strongest fibre during the 2005/06 season.

Table 4.12 Quality data for the various cotton cultivars planted at Weipe, during the 2003 to 2006 seasons

Season Parameter	Cultivar					Average
	DeltaOPAL	NuOPAL	DeltaOpal RR	LS9219	SZ9314	
2003/04						
Length (mm)	29.3 b	29.7 b	29.0 b	33.0 a	29.3 b	30.1
Strength (g tex^{-1})	29.9 ab	31.2 ab	28.7 b	34.6 a	32.1 ab	31.3
Micronaire	3.8 ab	4.2 a	4.0 a	3.3 b	4.0 a	3.8
$LSD_{T(0.05)}$	L = 2.062	S = 5.631	M = 0.5936			
2004/05						
Length (mm)	29.3 b	29.0 b	29.3 b	32.7 a	31.0 a	30.3
Strength (g tex^{-1})	32.4	32.1	31.8	33.7	32.4	32.5
Micronaire	4.9 a	4.8 a	4.6 ab	4.3 b	4.6 ab	4.6
$LSD_{T(0.05)}$	L = 1.364	S = ns	M = 0.349			
2005/06						
Length (mm)	31.0	31.3	30.7	32.3	32.0	31.5
Strength (g tex^{-1})	34.8	35.4	34.1	34.1	35.2	34.7
Micronaire	4.3	4.0	4.2	4.0	4.3	4.2
$LSD_{T(0.05)}$	L = ns	S = ns	M = ns			

Figures in the row followed by the same letter do not differ significantly from each other
ns – not significant at the 5% level

During the 2003/04 season the micronaire value of the cultivar, LS9219 (3.3) was too low. The other cultivars had values of between 3.8 and 4.2, which were within acceptable limits. During the 2004/05 season, the cultivars, DeltaOPAL (4.9) and NuOPAL (4.8) resulted in too high values (coarse fibre).

Although LS9219 gave significantly longer fibres and the strongest fibre in the 2004/05 season, the yield of the cultivar is the lowest of all the cultivars tested in the three seasons, and can therefore not be recommended for planting in the Weipe area. As a result, the cultivar recommended for this area would be the one that gave the highest yield and, seeing that DeltaOPAL and NuOPAL produced the highest seed cotton and fibre yield they are recommended for planting in the Weipe area.

CHAPTER 5

CULTIVAR ADAPTABILITY

5.1 The AMMI model.

Various statistical techniques are available to describe cultivar x environment interaction, but there are certain statistical and biological considerations to be taken into account. The trend has been to apply multivariate analysis techniques to provide information on the real multivariate response of cultivars to environments, rather than the previously popular joint linear regression techniques (Purchase *et al*, 2000). Through multivariate analysis, cultivars with similar responses can be clustered, hypotheses generated and later tested, and the data can be summarized and analyzed more easily. One such multivariate technique is widely known as the AMMI model, which combines analysis of variance of cultivar and environment main effects with principal components analysis of the cultivar x environment interaction into a unified approach. The results can be graphically represented in an easily interpretable and informative bi-plot that shows both main effects and cultivar x environment interactions. The AMMI model has been used extensively and with success over the past few years to analyze and understand various crop cultivar x environment interactions.

The effect of cultivar and environment interactions in the interpretation of results of yield trials, are well known. A combined analysis of variance can quantify the interactions, but as an additive statistical model describes only the main effects. The classical ANOVA does little to help understand or interpret the interactions. That is why for stability analysis, various forms of joint linear regression, and related cultivar and environment statistical procedures can be deficient in defining main effects, incorrectly declaring interactions insignificantly, or explaining too little of the interaction variance. AMMI offers a more appropriate first statistical analysis of yield trials that may have a meaningful cultivar and environment interaction. (Ma'ali *et al*, 2007).

The Additive Main effects and Multiplicative Interaction, or AMMI, technique is primarily used for exploring cultivar x environment data. This technique combines the additive main effects model for the ANOVA and the multiplicative model for the principal components analysis (PCA). The PCA model is fitted to the residuals from the ANOVA and the resulting scores are called the I (for interaction) PCA scores to distinguish them from the well-known PCA scores. These IPCA scores are calculated for both the cultivars and the environments and graphs are produced of the first IPCA scores versus the cultivar and environment means, from which the stability of both can be seen (those with the lowest scores – closest to zero – are more stable or less sensitive), as well as which are most similar in yield and score (stability) (Smith & Smith, 1992).

AMMI calculations proceeds in two steps. First, ANOVA partitions the treatments into the row effects, column effects and row-by-column interactions. Second, PCA is applied to the interaction means, partitioning it into a number of IPCA components. In practice just the first few components are of interest, while the higher components are relegated to the residual. A choice is required of how many components to include in the model before relegating the rest to the residual. Hence, AMMI actually constitutes a model family. The model retaining 0 IPCA is denoted AMMI0, that with one component is AMMI1, and so on, until finally the full model retaining all IPCA1 is denoted AMMIF (Smith & Smith, 1992).

5.2 Research procedure.

Five cultivars namely DeltaOPAL, NuOPAL, DeltaOpal RR, LS9219 and SZ9314 were tested at six localities namely, Loskop, Makhathini, Rustenburg, Upington, Vaalharts and Weipe, for three successive seasons (2003/2004, 2004/2005, 2005/2006) in randomized complete block design trials under irrigation conditions.

Due to different planting dates, agronomic practices and different weather conditions, the eighteen trials were considered to represent eighteen environments. The AMMI statistical model was used to describe the cultivar x environment interaction of the various cultivars. Standard and scientifically acceptable procedures for the National Cotton Cultivar Trials were used and are described in chapter 3. Seed cotton yield (kg ha^{-1}), fibre percentage (%), fibre yield (kg ha^{-1}), fibre length (mm), fibre strength (g tex^{-1}) and micronaire data were statistically analyzed and are presented in the form of the AMMI2 model and AMMI yield stability values.

Figure 1 in Addendum 2, shows an example of the AMMI model's classification of the adaptability and stability characteristics of sorghum cultivars. If the letters A to E represent cultivars the following conclusions could be made. Cultivar A is very good adapted towards high potential conditions but is not stable. Therefore, under poor prevailing conditions this cultivar may yield poorly. Cultivars B and C are stable for most environmental potential conditions although their yields will be lower compared to cultivar A under high potential conditions. Cultivar C is more stable than cultivar B because it is lying closer to the IPCA value of zero. Cultivar D is also considered stable, but only for low potential environments. Cultivar E is unstable and only adapted to low potential environments. In general, cultivars that fall between IPCA values of 1 and –1 are considered stable, but their adaptabilities can range between low and high potential environments (Ma'ali *et al*, 2007).

5.3 Seed cotton yield (kg ha^{-1}).

The combined analysis of variance (ANOVA) of the five cultivars over 18 environments, according to the AMMI 2 model are presented in Table 1 (Addendum 1). From this table it can be seen that environment, cultivar and the GE interaction had a highly significant effect ($P<0.001$) on seed cotton yield. Variance components of the sum of squares, ranged from 4,7% for cultivars, 83,6 % for environments and from 5 % for cultivar x environment interaction. This indicates the overwhelming influence of the environment on the seed cotton yield produced by the cultivars evaluated in the respective cotton producing areas of South Africa.

Tables 5.1 and 5.2 give the IPCA scores for cultivars and environments respectively. The sign of the IPCA score does not reflect a negative or positive interaction effect on yield, but simply shows that cultivars will perform better in environments with similar signs, and worse in environments with opposite signs.

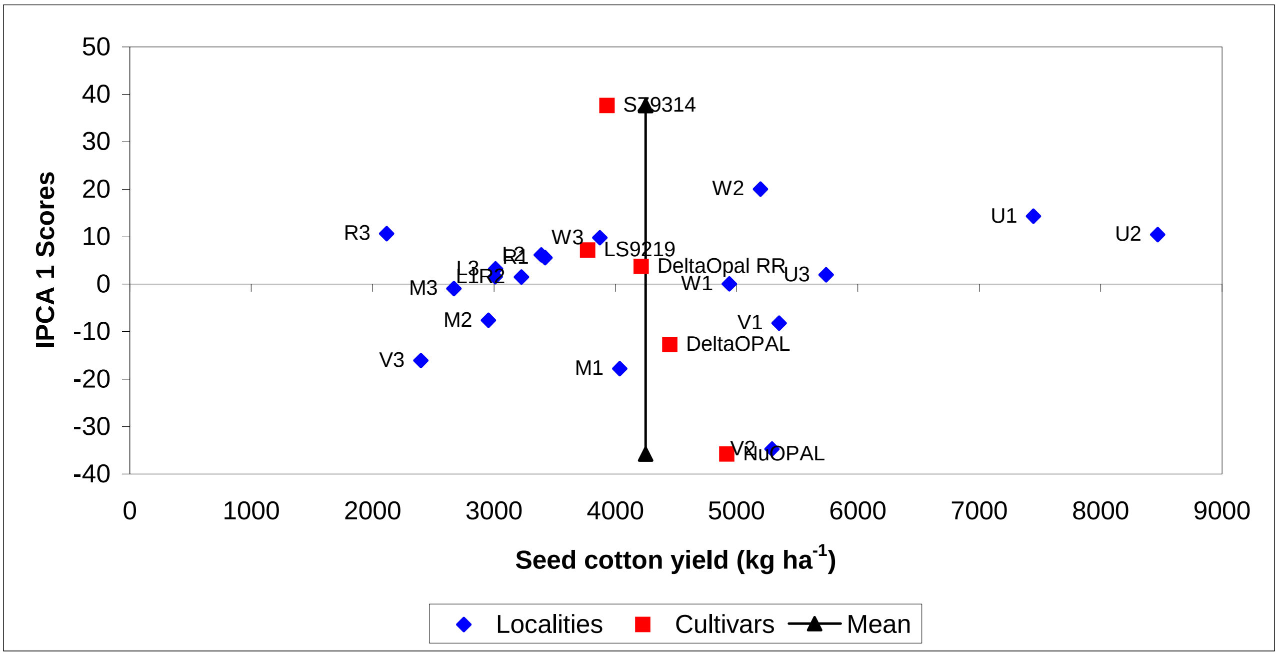
Table 5.1 Summary of the mean seed cotton yields and Genotypic IPCA scores for the 5 cultivars, together with a classification of cultivars based of length of growing period

Cultivar	Mean yield (kg ha^{-1})	IPCA1	IPCA2	Classification
DeltaOPAL	4451	-12.741	-1.022	Medium / Long season
NuOPAL	4919	-35.795	10.975	Medium / Long season
DeltaOpal RR	4215	3.756	11.115	Medium / Long season
LS9219	3772	7.141	-37.086	Medium / Long season
SZ9314	3933	37.639	16.018	Medium / Long season

Table 5.2 Summary of the mean seed cotton yields and environmental IPCA scores for the 18 environments

Environment	Mean	IPCA1	IPCA2
Loskop 2004	3012	1.571	8.121
Loskop 2005	3390	6.198	3.498
Loskop 2006	3013	3.225	-7.680
Makhathini 2004	4037	-17.797	8.073
Makhathini 2005	2955	-7.642	2.534
Makhathini 2006	2670	-0.939	9.491
Rustenburg 2004	3421	5.608	-3.483
Rustenburg 2005	3227	1.539	6.093
Rustenburg 2006	2117	10.654	-10.308
Upington 2004	7445	14.330	7.822
Upington 2005	8468	10.472	-17.163
Upington 2006	5738	1.933	-7.983
Vaalharts 2004	5350	-8.199	-22.413
Vaalharts 2005	5291	-34.775	-8.340
Vaalharts 2006	2399	-16.074	11.751
Weipe 2004	4939	0.056	16.508
Weipe 2005	5196	20.017	4.445
Weipe 2006	3874	9.823	-0.967

The biplot of the IPCA1 scores versus the cultivar and environment mean for seed cotton yield can be seen in Figure 5.1. The IPCA 1 score of the cultivar, DeltaOpal RR (3.756), indicate clearly that it is specifically adapted to most environments, as is LS9219 (7.141) but to a lesser extent. DeltaOPAL (-12.741) and NuOPAL (-35.795) are sensitive cultivars that indicate specific adaptation to higher yielding environments. SZ9314 (37.639) is a sensitive cultivar that is specifically adapted to lower potential or more unfavourable conditions and gave below average seed cotton yields. By just considering the IPCA 1 scores, DeltaOpal RR appear to be the least sensitive cultivar over the range of environments.



Key for Graphs: Localities, L - Loskop, M - Makhathini, R - Rustenburg, U - Upington, V - Vaalharts and W - Weipe. Years 1 - 3: Years of the experiment.

Figure 5.1 AMMI model 2 bi-plot for five cotton cultivars and 18 environments for the duration 2003-2006

5.4 Fibre percentage.

The combined analysis of variance (ANOVA) of the five cultivars over 18 environments, according to the AMMI 2 model are presented in Table 2 (Addendum 1). From this table it can be seen that environment, cultivar and the cultivar x environment interaction had a highly significant effect (P<0.001) on fibre percentage.

Variance components of the sum of squares, ranged from 17.8% for cultivars, 51.5 % for environments and from 21.5 % for cultivar x environment interaction. This indicates the overwhelming influence of the environment on percentage fibre produced by the cotton cultivars evaluated in the respective cotton producing areas of South Africa. The IPCA scores for cultivars and environments are given in Tables 5.3 and 5.4 respectively.

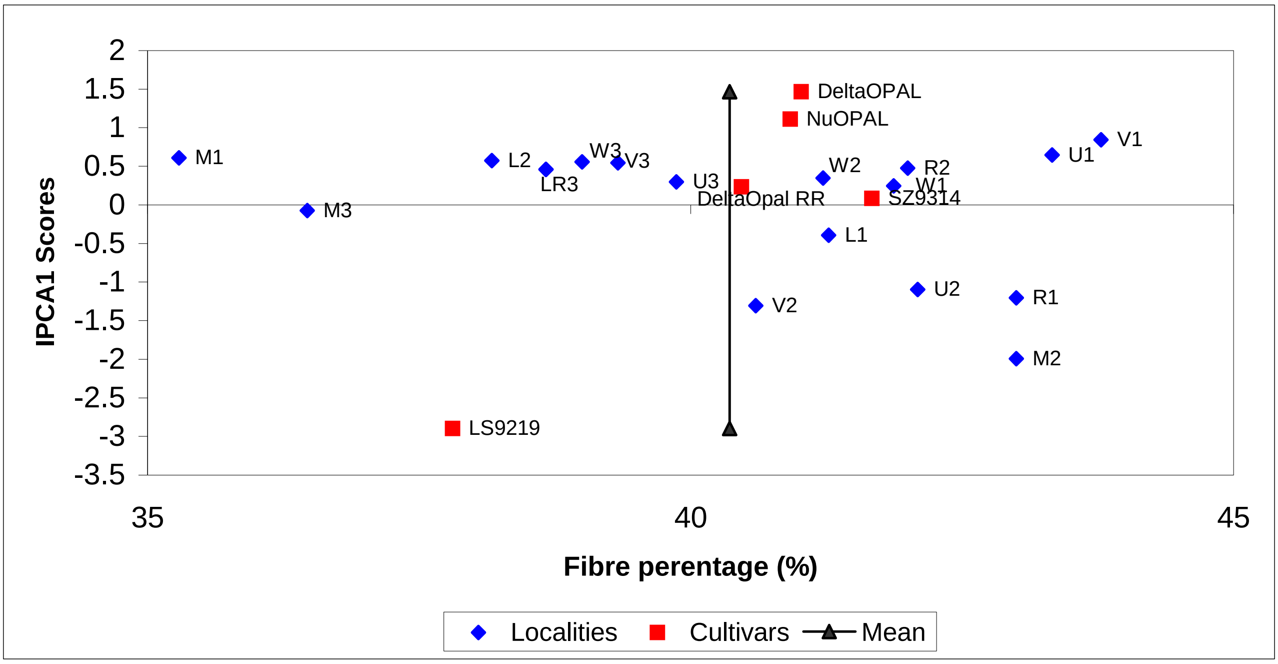
Table 5.3 Summary of the mean fibre percentages and Genotypic IPCA scores for the 5 cultivars, together with a classification of cultivars based of length of growing period

Cultivar	Mean fibre %	IPCA1	IPCA2	Classification
DeltaOPAL	41.0	1.467	-1.368	Medium / Long season
NuOPAL	40.9	1.110	-0.382	Medium / Long season
DeltaOpal RR	40.5	0.235	1.063	Medium / Long season
LS9219	37.8	-2.897	-0.713	Medium / Long season
SZ9314	41.7	0.084	1.400	Medium / Long season

Table 5.4 Summary of the mean fibre percentages and environmental IPCA scores for the 18 environments

Environment	Mean	IPCA1	IPCA2
Loskop 2004	41.3	-0.394	-1.628
Loskop 2005	38.2	0.574	0.489
Loskop 2006	38.7	0.459	0.160
Makhathini 2004	35.3	0.608	-0.111
Makhathini 2005	43.0	-1.993	1.018
Makhathini 2006	36.5	-0.073	0.315
Rustenburg 2004	43.0	-1.204	0.220
Rustenburg 2005	42.0	0.477	0.537
Rustenburg 2006	38.7	0.459	0.160
Upington 2004	43.3	0.648	-0.130
Upington 2005	42.1	-1.095	-0.710
Upington 2006	39.9	0.297	0.177
Vaalharts 2004	43.8	0.844	0.241
Vaalharts 2005	40.6	-1.304	-0.267
Vaalharts 2006	39.3	0.547	0.266
Weipe 2004	41.9	0.248	-0.092
Weipe 2005	41.2	0.346	0.010
Weipe 2006	39.0	0.556	-0.657

The biplot of the IPCA1 scores versus the cultivar and environment mean for fibre percentage can be seen in Figure 5.2. The IPCA 1 score of the cultivar, SZ9314 (0.084), indicate clearly that it is specifically adapted to most environments, as is DeltaOpal RR (0.235) but to a lesser extent. DeltaOPAL (1.467) and NuOPAL (1.110) are sensitive cultivars that indicate specific adaptation to higher yielding environments. LS9219 (-2.897) is a sensitive cultivar, specifically adapted to lower potential or more unfavourable conditions and gave below average fibre percentages. By just considering the IPCA 1 scores, SZ9314 appear to be the least sensitive cultivar over the range of environments, with above average fibre percentages.



Key for Graphs: Localities, L - Loskop, M - Makhathini, R - Rustenburg, U - Upington, V - Vaalharts and W - Weipe. Years 1 - 3: Years of the experiment.

Figure 5.2 AMMI model 2 bi-plot for five cotton cultivars and 18 environments for the duration 2003-2006

5.5 Fibre yield (kg ha^{-1}).

The combined analysis of variance (ANOVA) of the five cultivars over 18 environments, according to the AMMI 2 model are presented in Table 3 (Addendum 1). From this table it can be seen that environment, cultivar and the cultivar x environment interaction had a highly significant effect (P<0.001) on fibre yield. Variance components of the sum of squares, ranged from 6.0 % for cultivars, 83.1 % for environments and from 4.8 % for cultivar x environment interaction. This indicates the overwhelming influence of the environment on fibre yield produced by the cotton cultivars evaluated in the respective cotton producing areas of South Africa. Tables 5.5 and 5.6 give the IPCA scores for cultivars and environments respectively.

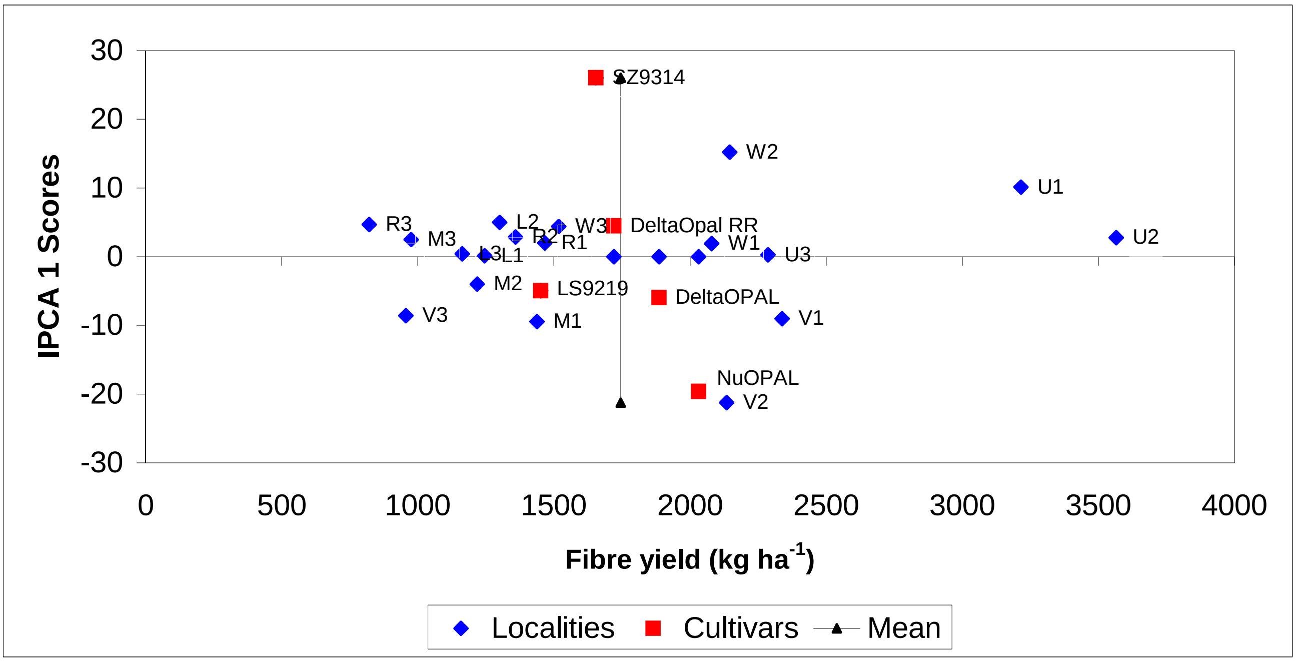
Table 5.5 Summary of the mean fibre yields and Genotypic IPCA scores for the 5 cultivars, together with a classification of cultivars based of length of growing period

Cultivar	Mean fibre yield (kg ha^{-1})	IPCA1	IPCA2	Classification
DeltaOPAL	1886	-5.967	9.075	Medium / Long season
NuOPAL	2032	-19.587	9.352	Medium / Long season
DeltaOpal RR	1720	4.472	5.666	Medium / Long season
LS9219	1451	-4.954	-27.082	Medium / Long season
SZ9314	1654	26.037	2.989	Medium / Long season

Table 5.6 Summary of the mean fibre yields and environmental IPCA scores for the 18 environments

Environment	Mean	IPCA1	IPCA2
Loskop 2004	1246	0.146	3.246
Loskop 2005	1301	4.977	1.611
Loskop 2006	1163	0.418	-6.721
Makhathini 2004	1438	-9.425	7.606
Makhathini 2005	1218	-3.999	-2.861
Makhathini 2006	976	2.507	1.336
Rustenburg 2004	1466	2.008	-7.725
Rustenburg 2005	1359	2.845	2.426
Rustenburg 2006	821	4.683	-8.235
Upington 2004	3215	10.128	11.297
Upington 2005	3565	2.770	-19.045
Upington 2006	2287	0.265	-1.014
Vaalharts 2004	2338	-9.018	-0.937
Vaalharts 2005	2134	-21.256	-2.217
Vaalharts 2006	956	-8.570	8.094
Weipe 2004	2079	1.886	10.881
Weipe 2005	2146	15.219	1.878
Weipe 2006	1518	4.415	0.381

The biplot of the IPCA1 scores versus the cultivar and environment mean for fibre yield can be seen in Figure 5.3. The IPCA 1 score of the cultivar, DeltaOpal RR (4.472), indicate clearly that it is a sensitive cultivar, specifically adapted to most environments, as is LS9219 (-4.954) but to a lesser extent. DeltaOPAL (-5.967) and NuOPAL (-19.587) are sensitive cultivars that indicate specific adaptation to higher yielding environments. SZ9314 (26.037) is specifically adapted to lower potential or more unfavourable conditions and gave below average fibre yields.



Key for Graphs: Localities, L - Loskop, M - Makhathini, R - Rustenburg, U - Upington, V - Vaalharts and W - Weipe. Years 1 - 3: Years of the experiment.

Figure 5.3 AMMI model 2 bi-plot for five cotton cultivars and 18 environments for the duration 2003-2006

5.6 Fibre length (mm).

The combined analysis of variance (ANOVA) of the five cultivars over 18 environments, according to the AMMI 2 model are presented in Table 4 (Addendum 1). From this table it can be seen that environment, cultivar and the cultivar x environment interaction had a highly significant effect ($P<0.001$) on fibre lengths. Variance components of the sum of squares, ranged from 53.6 % for cultivars, 18.1 % for environments and from 14.3 % for cultivar x environment interaction. This indicates the overwhelming influence of the cultivars on fibre length (mm) produced by the cotton cultivars evaluated in the respective cotton producing areas of South Africa. Tables 5.7 and 5.8 give the IPCA scores for cultivars and environments respectively.

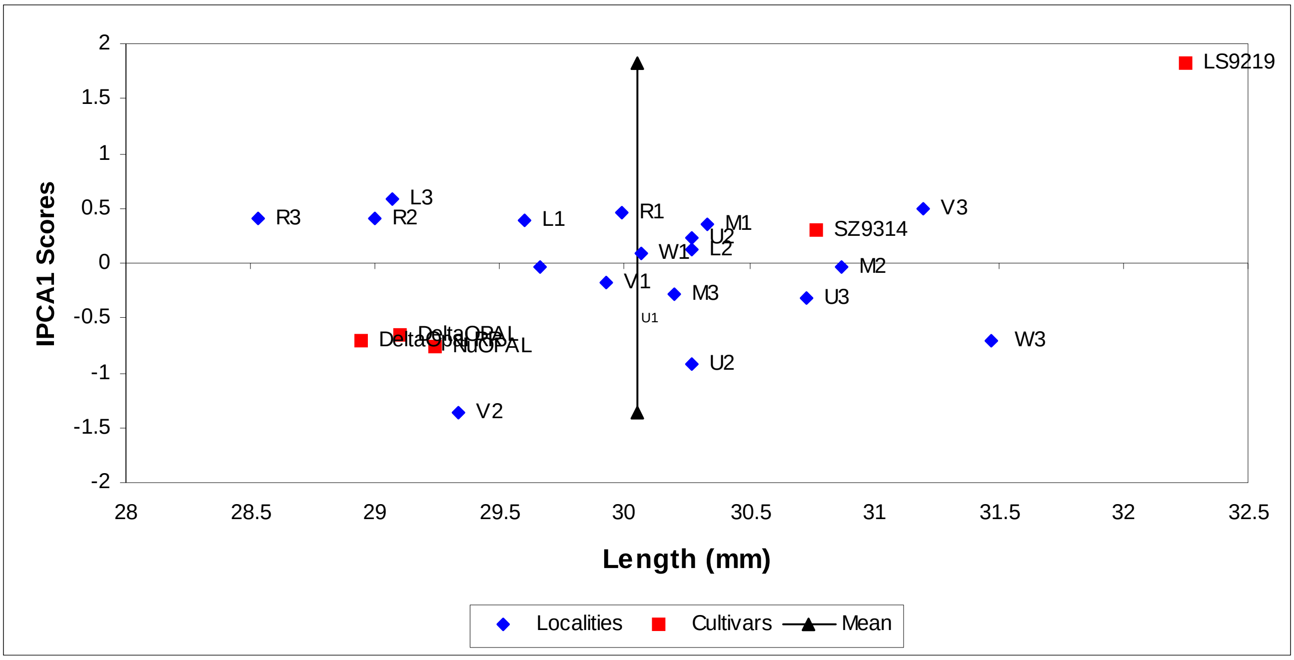
Table 5.7 Summary of the mean fibre length and Genotypic IPCA scores for the 5 cultivars together with a classification of cultivars based of length of growing period

Cultivar	Mean Length (mm)	IPCA1	IPCA2	Classification
DeltaOPAL	29.1	-0.647	0.252	Medium / Long season
NuOPAL	29.2	-0.768	0.840	Medium / Long season
DeltaOpal RR	28.9	-0.710	-0.228	Medium / Long season
LS9219	32.3	1.818	0.604	Medium / Long season
SZ9314	30.8	0.307	-1.468	Medium / Long season

Table 5.8 Summary of the mean fibre lengths and environmental IPCA scores for the 18 environments

Environment	Mean	IPCA1	IPCA2
Loskop 2004	29.6	0.392	0.559
Loskop 2005	30.3	0.226	-0.828
Loskop 2006	29.1	0.576	-0.501
Makhathini 2004	30.3	0.348	0.171
Makhathini 2005	30.9	-0.044	0.666
Makhathini 2006	30.2	-0.291	-0.174
Rustenburg 2004	30.0	0.454	-0.659
Rustenburg 2005	29.0	0.401	0.165
Rustenburg 2006	28.5	0.406	-0.316
Upington 2004	29.7	-0.034	-0.174
Upington 2005	30.3	-0.914	-0.226
Upington 2006	30.7	-0.325	0.061
Vaalharts 2004	29.9	0.182	0.268
Vaalharts 2005	29.3	-1.370	-0.088
Vaalharts 2006	31.2	0.501	0.258
Weipe 2004	30.1	0.085	0.887
Weipe 2005	30.3	0.122	-0.096
Weipe 2006	31.5	-0.716	0.026

The biplot of the IPCA1 scores versus the cultivar and environment mean for fibre length can be seen in Figure 5.4. The IPCA 1 score of the cultivar, SZ9314 (0.307), indicate clearly that it is specifically adapted to most environments. LS9219 (1.818) is a sensitive cultivar specifically adapted to higher yielding environments. DeltaOPAL (-0.647), NuOPAL (-0.768) and DeltaOpal RR are less sensitive cultivars specifically adapted to lower yielding environments and resulted in below average lengths. By just considering the IPCA 1 scores, SZ9314 appear to be the least sensitive cultivar over the range of environments.



Key for Graphs: Localities, L - Loskop, M - Makhathini, R - Rustenburg, U - Upington, V - Vaalharts and W - Weipe. Years 1 - 3: Years of the experiment.

Figure 5.4. AMMI model 2 bi-plot for five cotton cultivars and 18 environments for the duration 2003-2006

5.7 Fibre strength (g tex^{-1}).

The combined analysis of variance (ANOVA) of the five cultivars over 18 environments, according to the AMMI 2 model are presented in Table 5 (Addendum 1). From this table it can be seen that environment, cultivar and the cultivar x environment interaction had a highly significant effect (P<0.001) on fibre strength. Variance components of the sum of squares, ranged from 16.9 % for cultivars, 30.6 %

for environments and from 22.4 % for cultivar x environment interaction. This indicates the overwhelming influence of the environment on fibre strength produced by the cotton cultivars evaluated in the respective cotton producing areas of South Africa. Tables 5.9 and 5.10 give the IPCA scores for cultivars and environments respectively.

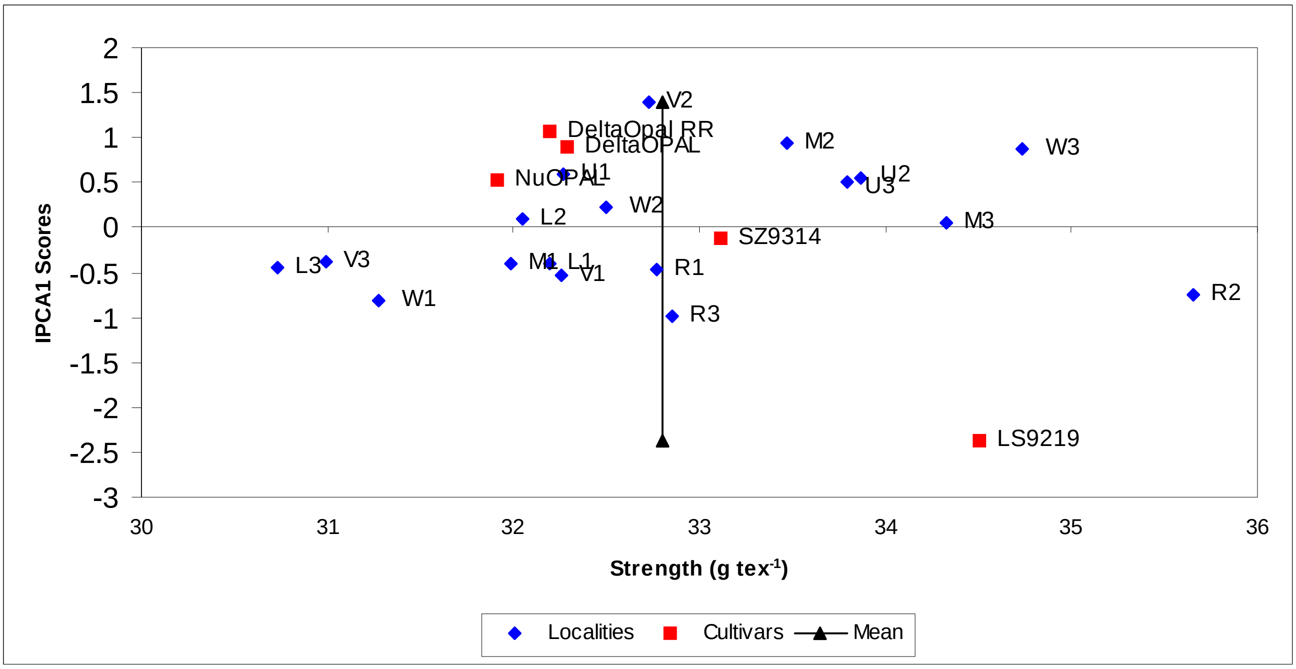
Table 5.9 Summary of the mean strengths and Genotypic IPCA scores for the 5 cultivars, together with a classification of cultivars based on length of growing period

Cultivar	**Mean strength (g tex^{-1})**	**IPCA1**	**Classification**
DeltaOPAL	32.3	0.906	Medium / Long season
NuOPAL	31.9	0.531	Medium / Long season
DeltaOpal RR	32.2	1.066	Medium / Long season
LS9219	34.5	-2.376	Medium / Long season
SZ9314	33.1	-0.127	Medium / Long season

Table 5.10 Summary of the mean strengths and environmental IPCA scores for the 18 environments

Environment	**EM**	**IPCA1**
Loskop 2004	32.2	-0.400
Loskop 2005	32.1	0.100
Loskop 2006	30.7	-0.450
Makhathini 2004	32.0	-0.401
Makhathini 2005	33.5	0.940
Makhathini 2006	34.3	0.050
Rustenburg 2004	32.8	-0.470
Rustenburg 2005	35.7	-0.756
Rustenburg 2006	32.9	-0.987
Upington 2004	32.3	0.585
Upington 2005	33.9	0.547
Upington 2006	33.8	0.505
Vaalharts 2004	32.3	-0.539
Vaalharts 2005	32.7	1.385
Vaalharts 2006	31.0	-0.375
Weipe 2004	31.3	-0.819
Weipe 2005	32.5	0.220
Weipe 2006	34.7	0.866

The biplot of the IPCA1 scores versus the cultivar and environment mean for fibre strength can be seen in Figure 5.5. The IPCA 1 score of the cultivar, SZ9314 (-0.127), indicate clearly that it is specifically adapted to most environments, as is NuOPAL (0.531) but to a lesser extent. DeltaOPAL (0.906) and DeltaOpal RR (1.066) indicate specific adaptation to lower yielding environments. DeltaOPAL is less sensitive than DeltaOpal RR as its IPCA 1 score is closer to zero. LS9219 (-2.376) is a sensitive cultivar, specifically adapted to higher yielding environments and gave above average strengths. By just considering the IPCA 1 scores, SZ9314 appear to be the least sensitive cultivar over the range of environments.



Key for Graphs: Localities, L - Loskop, M - Makhathini, R - Rustenburg, U - Upington, V - Vaalharts and W - Weipe. Years 1 - 3: Years of the experiment.

Figure 5.5 AMMI model 2 bi-plot for five cotton cultivars and 18 environments for the duration 2003-2006

5.8 Micronaire.

The combined analysis of variance (ANOVA) of the five cultivars over 18 environments, according to the AMMI 2 model are presented in Table 6 (Addendum environment interaction had a highly significant effect (P<0.001) on micronaire. Variance components of the sum of squares, ranged from 4 % for cultivars, 59 % for environments and from 15 % for cultivar x environment interaction. This indicates the overwhelming influence of the environment on micronaire produced by the cotton cultivars evaluated in the respective cotton producing areas of South Africa. Tables 5.11 and 5.12 give the IPCA 1 scores for cultivars and environments respectively.

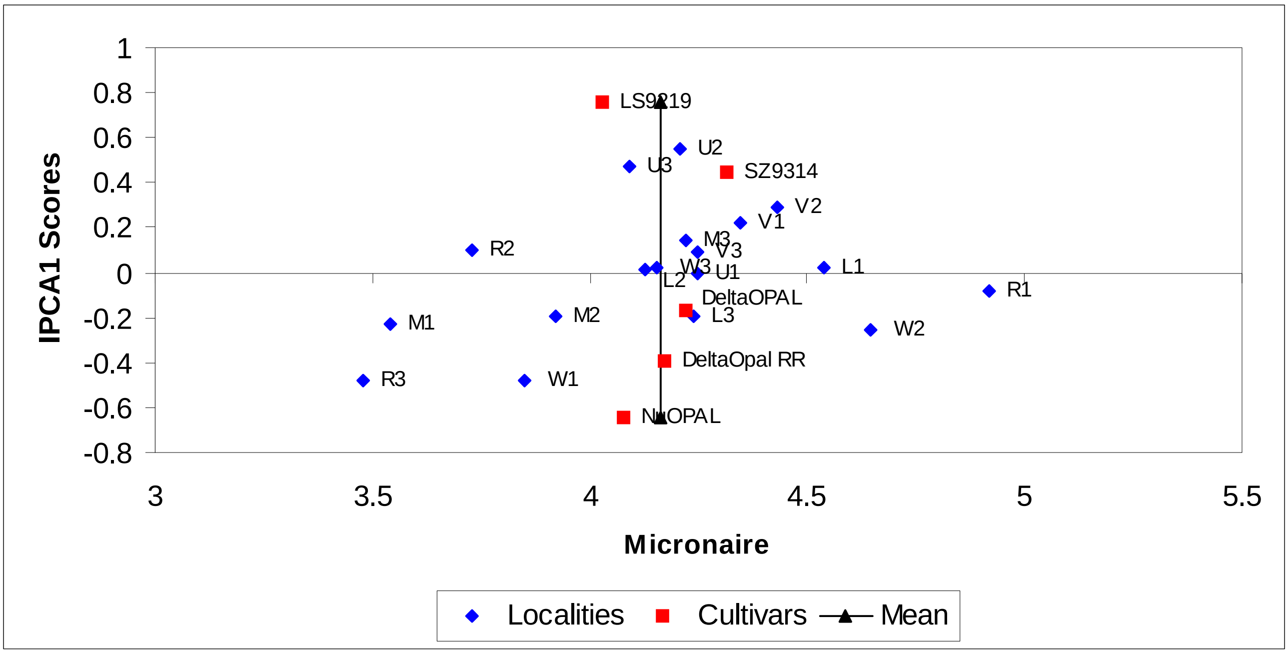
Table 5.11 Summary of the mean micronaires and Genotypic IPCA scores for the 5 cultivars, together with a classification of cultivars based of length of growing period

Cultivar	Mean micronaire	IPCA1	Classification
DeltaOPAL	4.2	-0.169	Medium / Long season
NuOPAL	4.1	-0.641	Medium / Long season
DeltaOpal RR	4.2	-0.392	Medium / Long season
LS9219	4.0	0.755	Medium / Long season
SZ9314	4.3	0.446	Medium / Long season

Table 5.12 Summary of the mean micronaires and environmental IPCA scores for the 18 environments

Environment	Mean	IPCA1
Loskop 2004	4.5	0.024
Loskop 2005	4.1	0.010
Loskop 2006	4.2	-0.192
Makhathini 2004	3.5	-0.227
Makhathini 2005	3.9	-0.195
Makhathini 2006	4.2	0.139
Rustenburg 2004	4.9	-0.086
Rustenburg 2005	3.7	0.104
Rustenburg 2006	3.5	-0.481
Upington 2004	4.2	-0.001
Upington 2005	4.2	0.552
Upington 2006	4.1	0.471
Vaalharts 2004	4.3	0.217
Vaalharts 2005	4.4	0.291
Vaalharts 2006	4.2	0.089
Weipe 2004	3.8	-0.482
Weipe 2005	4.6	-0.259
Weipe 2006	4.2	0.026

The biplot of the IPCA1 scores versus the cultivar and environment mean for micronaire can be seen in Figure 5.6. The IPCA 1 score of the cultivar, DeltaOPAL (-0.169) indicate clearly that it is specifically adapted to most environments, as is DeltaOpal RR (-0.392)) but to a lesser extent. NuOPAL (-0.641) and LS9219 (0.755) are less sensitive cultivars that indicate specific adaptation to lower yielding environments. NuOPAL is less sensitive than LS9219 as its IPCA 1 score is closer to zero. SZ9314 (0.446) is specifically adapted to most environments. By just considering the IPCA 1 scores, DeltaOPAL appear to be the least sensitive cultivar over the range of environments.



Key for Graphs: Localities, L - Loskop, M - Makhathini, R - Rustenburg, U - Upington, V - Vaalharts and W - Weipe. Years 1 - 3: Years of the experiment.

Figure 5.6 AMMI model 2 bi-plot for five cotton cultivars and 18 environments for the duration 2003-2006

CHAPTER 6

DISCUSSION AND RECOMMENDATIONS

6.1 Introduction

Before any recommendations can be made for future commercialization, it is extremely important that multi-location trials should be conducted to select the best cultivars for specific environments. Cultivars react differently to environmental factors due to cultivar x environment interaction. Breeders and farmers both want a stable cultivar that always produces the highest yield every year. Such a cultivar would be the ideal cultivar, but because the interaction is nearly always sizeable and significant, the ideal cultivar will never exist. Consequently, the selection of cultivars depends on the approach to risk management and risk avoidance. If the environment could be sufficiently and accurately predicted, certain cultivars could be recommended for certain environments, thereby managing the risks. Because the environments of specific localities and efficacy of applied cultivation practices change from year to year and because the cultivar recommendation is based on environments, not locations, there is always a chance that the selected cultivar will not perform as intended. With the knowledge currently available, environments can be classified and described, but not predicted accurately, risk avoidance should, therefore, rather be practiced. Risks can be avoided by selecting the cultivar that performs well most of the time in most environments. The first three best cultivars recommended, based on estimated yields across all three seasons and trial localities, are given for each environment in Tables 6.1, 6.2, 6.3, 6.4, 6.5 and 6.6.

6.2 Seed cotton yield (t ha^{-1})

The results of the environments in ranked score order and the three cultivars with the highest seed cotton yields for each environment are shown in Table 6.1. This table gives valuable information regarding cultivar performance and adaptation. From this it becomes evident that NuOPAL was the first recommendation 15 out of 18 times, the second 2 out of 18 times, and the third in 1 out of 18 times, which means that it was one of the top three recommendations 18 out of 18 times. SZ9314 was the first recommendation 2 out of 18 times and the third 1 out of 18 times. LS9219 was the first recommendation 1 out of 18 times and the third 1 out of 18 times. No other cultivar matched the performance of NuOPAL.

6.3 Fibre percentage (%)

SZ9314 was the first recommendation 12 out of 18 times, the second 2 out of 18 times, and the third 2 out of 18 times, which means that it was one of the top three recommendations 16 out of 18 times (Table 6.2).

DeltaOPAL was the first recommendation 3 out of 18 times, the second 7 out of 18 times, and the third 2 out of 18 times, which means that it was one of the top three recommendations 12 out of 18 times. The cultivar, NuOPAL, was the third recommendation 8 out of 18 times, and DeltaOpal RR was the second recommendation 1 out of 18 times and the third 4 out of 18 times. LS9219 was the first recommendation 2 out of 18 times, the second 2 out of 18 times and the third recommendation in respect of fibre yield 2 out of 18 times.

6.4 Fibre yield (t ha^{-1})

NuOPAL was the first recommendation 15 out of 18 times, the second 2 out of 18 times, which means that it was one of the top three recommendations in respect of fibre yield 17 out of 18 times (Table 6.3).

The cultivar, SZ9314, was the first recommendation 2 out of 18 times and the third 3 out of 18 times. The cultivar, LS9219, was the first recommendation 1 out of 18 times and the third 1 out of 18 times.

Table 6.1 The AMMI models best three cultivar selections for mean seed cotton yield (t ha^{-1}) in relation to the 18 environments evaluated

Environment	**Average yield (t ha^{-1})**	**AMMI cultivar recommendations Mean seed cotton yield (t ha^{-1})**		
Weipe 2005	5.2	SZ9314	DeltaOpal RR	NuOPAL
		5.7	5.3	5.2
Upington 2004	7.4	SZ9314	NuOPAL	DeltaOpal RR
		7.8	7.7	7.5
Rustenburg 2006	2.1	NuOPAL	DeltaOPAL	LS9219
		2.3	2.2	2.1
Upington 2005	8.5	LS9219	NuOPAL	DeltaOPAL
		8.7	8.6	8.5
Weipe 2006	3.9	NuOPAL	DeltaOPAL	SZ9314
		4.2	3.9	3.9
Loskop 2005	3.4	NuOPAL	DeltaOPAL	DeltaOpal RR
		3.9	3.5	3.4
Rustenburg 2004	3.4	NuOPAL	DeltaOPAL	DeltaOpal RR
		3.8	3.5	3.4
Loskop 2006	3.0	NuOPAL	DeltaOPAL	DeltaOpal RR
		3.5	3.2	2.9
Upington 2006	5.7	NuOPAL	DeltaOPAL	DeltaOpal RR
		6.2	5.9	5.6
Loskop 2004	3.0	NuOPAL	DeltaOPAL	DeltaOpal RR
		3.7	3.2	3.1
Rustenburg 2005	3.2	NuOPAL	DeltaOPAL	DeltaOpal RR
		3.9	3.4	3.3
Weipe 2004	4.9	NuOPAL	DeltaOPAL	DeltaOpal RR
		5.8	5.1	5.1
Makhathini 2006	2.7	NuOPAL	DeltaOPAL	DeltaOpal RR
		3.5	2.9	2.7
Makhathini 2005	3.0	NuOPAL	DeltaOPAL	DeltaOpal RR
		3.9	3.2	2.9
Vaalharts 2004	5.4	NuOPAL	DeltaOPAL	LS9219
		6.1	5.7	5.6
Vaalharts 20 06	2.4	NuOPAL	DeltaOPAL	DeltaOpal RR
		3.8	2.8	2.4
Makhathini 20 04	4.0	NuOPAL	DeltaOPAL	DeltaOpal RR
		5.4	4.5	4.0
Vaalharts 2005	5.3	NuOPAL	DeltaOPAL	DeltaOpal RR
		7.1	5.9	5.0

Table 6.2 The AMMI model's best three cultivar selections for mean fibre percentage in relation to the 18 environments evaluated

Environment	**Average Fibre %**	**AMMI cultivar recommendations Fibre %**		
Vaalharts 2004	43.8	SZ9314	DeltaOPAL	NuOPAL
		45.5	45.4	45.2
Upington 2004	43.3	DeltaOPAL	NuOPAL	SZ9314
		45.1	44.7	44.5
Makhathini 2004	35.3	DeltaOPAL	NuOPAL	SZ9314
		37.0	36.6	36.5
Loskop 2005	38.2	SZ9314	NuOPAL	DeltaOPAL
		40.2	39.2	39.0
Weipe 2006	39.0	DeltaOPAL	NuOPAL	LS9219
		41.4	40.4	39.4
Vaalharts 2006	39.3	SZ9314	DeltaOPAL	NuOPAL
		41.1	40.4	40.4
Rustenburg 2005	42.0	SZ9314	NuOPAL	DeltaOpal RR
		44.1	42.9	42.6
Loskop 2006	38.7	SZ9314	DeltaOPAL	NuOPAL
		40.2	39.8	39.7
Rustenburg 2006	38.7	SZ9314	DeltaOPAL	NuOPAL
		40.2	39.8	39.7
Weipe 2005	41.2	SZ9314	DeltaOPAL	NuOPAL
		42.6	42.4	42.2
Upington 2006	39.9	SZ9314	DeltaOPAL	NuOPAL
		41.5	40.7	40.7
Weipe 2004	41.9	SZ9314	DeltaOPAL	NuOPAL
		43.1	43.0	42.7
Makhathini 2006	36.5	SZ9314	DeltaOpal RR	NuOPAL
		38.2	36.9	36.8
Loskop 2004	41.3	DeltaOPAL	NuOPAL	LS9219
		43.6	42.0	41.0
Upington 2005	42.1	LS9219	SZ9314	DeltaOPAL
		43.2	42.3	42.1
Rustenburg 2004	43.0	SZ9314	LS9219	DeltaOpal RR
		44.5	43.8	43.1
Vaalharts 2005	40.6	LS9219	SZ9314	DeltaOpal RR
		42.0	41.4	40.1
Makhathini 2005	43.0	SZ9314	LS9219	DeltaOpal RR
		45.6	45.5	43.7

Table 6.3 The AMMI model's best three cultivar selections for fibre yield (t ha^{-1}) in relation to the 18 environments evaluated

Environment	**Average fibre yield (t ha^{-1})**	**AMMI cultivar recommendations Fibre yield (t ha^{-1})**		
Weipe 2005	2.1	SZ9314	DeltaOPAL	DeltaOpal RR
		2.5	2.2	2.2
Upington 2004	3.2	SZ9314	NUOPAL	DeltaOPAL
		3.4	3.4	3.4
Loskop 2005	1.3	NUOPAL	DeltaOPAL	SZ9314
		1.5	1.4	1.3
Rustenburg 2006	0.8	NUOPAL	DeltaOPAL	SZ9314
		0.940	0.86	0.827
Weipe 2006	1.5	NUOPAL	DeltaOPAL	SZ9314
		1.7	1.6	1.5
Rustenburg 2005	1.4	NUOPAL	DeltaOPAL	DeltaOpal RR
		1.6	1.5	1.4
Upington 2005	3.6	LS9219	NuOPAL	DeltaOPAL
		3.8	3.6	3.5
Makhathini 2006	1.0	NUOPAL	DeltaOPAL	DeltaOpal RR
		1.2	1.1	0.97
Rustenburg 2004	1.5	NUOPAL	DeltaOPAL	DeltaOpal RR
		1.6	1.5	1.4
Weipe 2004	2.8	NUOPAL	DeltaOPAL	DeltaOpal RR
		2.4	2.3	2.1
Loskop 2006	1.2	NUOPAL	DeltaOPAL	DeltaOpal RR
		1.4	1.2	1.1
Upington 2006	2.3	NUOPAL	DeltaOPAL	DeltaOpal RR
		2.6	2.4	2.3
Loskop 2004	1.2	NUOPAL	DeltaOPAL	DeltaOpal RR
		1.5	1.4	1.2
Makhathini 2005	1.2	NUOPAL	DeltaOPAL	DeltaOpal RR
		1.6	1.4	1.2
Vaalharts 2006	1.0	NUOPAL	DeltaOPAL	DeltaOpal RR
		1.5	1.2	0.94
Vaalharts 2004	2.3	NUOPAL	DeltaOPAL	DeltaOpal RR
		2.8	2.5	2.3
Makhathini 2004	1.4	NUOPAL	DeltaOPAL	DeltaOpal RR
		2.0	1.7	1.4
Vaalharts 2005	2.1	NUOPAL	DeltaOPAL	LS9219
		2.8	2.4	2.0

6.5 Fibre length (mm)

LS9219 was the first recommendation 16 out of 18 times and the second 1 out of 18 times, which means that it was one of the top three recommendations in respect of fibre length 17 out of 18 times. No other cultivar matched the performance of LS9219 in respect of fibre length. The other cultivar that was the first recommendation 2 out of 18 times was SZ9314. SZ9314 was also second 14 out of 18 times and third 2 out of 18 times. NuOPAL was the second recommendation 3 out of 18 times and the third 11 out of 18 times (Table 6.4).

6.6 Fibre strength (g tex^{-1})

LS9219 was the first recommendation in respect of fibre strength 15 out of 18 times. SZ9314 was the second recommendation 15 out of 18 times and the third 3 out of 18 times. LS9219 was one of the top three recommendations 15 out of 18 times. DeltaOpal RR was the first recommendation 3 out of 18 times and the third 2 out of 18 times (Table 6.5).

6.7 Micronaire

The prime micronaire range lies between 3.8 and 4.20

DeltaOPAL was the first recommendation 1 out of 18 times, the second 3 out of 18 times and the third 3 out of 18 times. NuOPAL was also the first recommendation 1 out of 18 times. DeltaOpal RR was the second recommendation 5 out of 18 times and the third 5 out of 18 times. SZ9314 gave the highest micronaire values in 12 of the 18 environments, which means that the fibre may be too coarse in some instances and that it will be bought at a discount price to be blended with other cotton (Table 6.6).

Table 6.4 The AMMI model's best three cultivar selections for mean length (mm) in relation to the 18 environments evaluated

Environment	**Average length (mm)**	**AMMI cultivar recommendations Length (mm)**		
Loskop 2006	29.1	LS9219	SZ9314	DeltaOpal RR
		32.0	30.7	27.7
Vaalharts 2006	31.2	LS9219	SZ9314	NuOPAL
		34.5	31.7	30.2
Rustenburg 2004	30.0	LS9219	SZ9314	DeltaOpal RR
		32.6	31.8	28.7
Rustenburg 2006	28.5	LS9219	SZ9314	DeltaOPAL
		31.3	29.8	27.2
Rustenburg 2005	29.0	LS9219	SZ9314	NuOPAL
		32.0	29.6	28.0
Loskop 2004	29.6	LS9219	SZ9314	NuOPAL
		32.9	29.6	29.0
Makhathini 2004	30.3	LS9219	SZ9314	NuOPAL
		33.3	30.9	29.4
Loskop 2005	30.3	LS9219	SZ9314	DeltaOpal RR
		32.4	32.3	29.2
Vaalharts 2004	29.9	LS9219	SZ9314	NuOPAL
		32.6	30.3	29.2
Weipe 2005	30.3	LS9219	SZ9314	NuOPAL
		32.6	31.2	29.3
Weipe 2004	30.1	LS9219	NuOPAL	SZ9314
		33.0	29.9	29.5
Upington 2004	29.7	LS9219	SZ9314	NuOPAL
		31.7	30.6	28.7
Makhathini 2005	30.9	LS9219	NuOPAL	SZ9314
		33.4	30.7	30.6
Makhathini 2006	30.2	LS9219	SZ9314	NuOPAL
		31.8	31.1	29.5
Upington 2006	30.7	LS9219	SZ9314	NuOPAL
		32.4	31.3	30.2
Weipe 2006	31.5	LS9219	SZ9314	NuOPAL
		32.4	31.9	31.2
Upington 2005	30.3	SZ9314	LS9219	NuOPAL
		31.0	30.7	30.0
Vaalharts 2005	29.3	SZ9314	NuOPAL	DeltaOPAL
		29.8	29.5	29.3

Table 6.5 The AMMI model's best three cultivar selections for mean strength (g tex^{-1}) in relation to the 18 environments evaluated

Environment	**Average strength (g tex-1)**	**AMMI cultivar recommendations Strength (g tex^{-1})**		
Vaalharts 2005	32.7	DeltaOpal RR	DeltaOPAL	SZ9314
		33.6	33.5	32.9
Makhathini 2005	33.5	DeltaOpal RR	DeltaOPAL	SZ9314
		33.9	33.8	33.7
Weipe 2006	34.7	DeltaOpal RR	DeltaOPAL	SZ9314
		35.1	35.0	34.9
Upington 2004	32.3	LS9219	SZ9314	DeltaOpal RR
		32.6	32.5	32.3
Upington 2005	33.9	LS9219	SZ9314	DeltaOpal RR
		34.3	34.1	33.9
Upington 2006	33.8	LS9219	SZ9314	DeltaOPAL
		34.3	34.0	33.7
Weipe 2005	32.5	LS9219	SZ9314	DeltaOPAL
		33.7	32.8	32.2
Loskop 2005	32.1	LS9219	SZ9314	DeltaOPAL
		33.5	32.4	31.6
Makhathini 2006	34.3	LS9219	SZ9314	DeltaOPAL
		35.9	34.6	33.9
Vaalharts 2006	31.0	LS9219	SZ9314	DeltaOPAL
		33.6	31.3	30.1
Loskop 2004	32.2	LS9219	SZ9314	DeltaOPAL
		34.9	32.6	31.3
Makhathini 2004	32.0	LS9219	SZ9314	DeltaOPAL
		34.7	32.4	31.1
Loskop 2006	30.7	LS9219	SZ9314	DeltaOPAL
		33.5	31.1	29.8
Rustenburg 2004	32.8	LS9219	SZ9314	DeltaOPAL
		35.6	33.1	31.8
Vaalharts 2004	32.3	LS9219	SZ9314	DeltaOPAL
		35.3	32.6	31.3
Rustenburg 2005	35.7	LS9219	SZ9314	DeltaOPAL
		39.2	36.1	34.5
Weipe 2004	31.3	LS9219	SZ9314	DeltaOPAL
		34.9	31.7	30.0
Rustenburg 2006	32.9	LS9219	SZ9314	DeltaOPAL
		36.9	33.3	31.4

Table 6.6 The AMMI model's best three cultivar selections for mean micronaire in relation to the 18 environments evaluated

Environment	**Average micronaire**	**AMMI cultivar recommendations micronaire**		
Upington 2005	4.2	SZ9314	LS9219	DeltaOPAL
		4.6	4.5	4.2
Upington 2006	4.1	SZ9314	LS9219	DeltaOPAL
		4.5	4.3	4.1
Vaalharts 2005	4.4	SZ9314	LS9219	DeltaOPAL
		4.7	4.5	4.4
Vaalharts 2004	4.3	SZ9314	LS9219	DeltaOPAL
		4.6	4.4	4.4
Makhathini 2006	4.2	SZ9314	DeltaOPAL	LS9219
		4.4	4.3	4.2
Rustenburg 2005	3.7	SZ9314	DeltaOPAL	DeltaOpal RR
		3.9	3.8	3.7
Vaalharts 2006	4.2	SZ9314	DeltaOPAL	DeltaOpal RR
		4.4	4.3	4.2
Weipe 2006	4.2	SZ9314	DeltaOPAL	DeltaOpal RR
		4.3	4.2	4.2
Loskop 2004	4.5	SZ9314	DeltaOPAL	DeltaOpal RR
		4.7	4.6	4.5
Loskop 2005	4.1	SZ9314	DeltaOPAL	DeltaOpal RR
		4.3	4.2	4.1
Upington 2004	4.2	SZ9314	DeltaOPAL	DeltaOpal RR
		4.4	4.3	4.3
Rustenburg 2004	4.9	SZ9314	DeltaOPAL	DeltaOpal RR
		5.0	5.0	5.0
Loskop 2006	4.2	DeltaOPAL	DeltaOpal RR	SZ9314
		4.3	4.3	4.3
Makhathini 2005	3.9	DeltaOPAL	DeltaOpal RR	SZ9314
		4.0	4.0	4.0
Makhathini 2004	3.5	DeltaOPAL	DeltaOpal RR	NuOPAL
		3.6	3.6	3.6
Weipe 2005	4.6	DeltaOpal RR	DeltaOPAL	NuOPAL
		4.8	4.7	4.7
Rustenburg 2006	3.5	NuOPAL	DeltaOpal RR	DeltaOPAL
		3.7	3.7	3.6
Weipe 2004	3.8	NuOPAL	DeltaOpal RR	DeltaOPAL
		4.1	4.0	4.0

6.8 Final recommendation

Since no other cultivar matched the performance of NuOPAL in respect of seed cotton or fibre yield, NuOPAL is recommended for planting in all of the different cotton-production areas of South Africa. The cultivar, LS9219, outperformed NuOPAL with regard to fibre length and fibre strength, but was second to NuOPAL in respect of seed cotton and fibre yields. Consequently, LS9219 cannot be recommended for planting in the different cotton-production areas of South Africa, with the exception of Upington, when environmental conditions (temperature, heat units and rainfall) similar to those of the 2004/05 season at Upington are expected. SZ9314 could be recommended for planting in the Weipe and Upington areas, but only if similar conditions to those of the 2004/05 and 2003/04 seasons are expected.

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ADDENDUM 1

Anova Tables for AMMI Analysis

Table 1 The analysis of variance table, for seed cotton yield (t ha^{-1}), of the five cotton cultivars tested over 18 environments, according to the AMMI model

Source	DF	SS	MS	F_probability
Environment	17	774660131	45568243	<0.001
Block	36	27825820	772939	<0.001
Cultivar	4	43486780	10871695	<0.001
Interaction	68	46525977	684206	<0.001
IPCA1	20	25694109	1284705	<0.001
IPCA2	18	10577398	587633	<0.001
Residual	30	10254470	341816	0.09
Error	143	34681731	242530	
Total	269	927180438	3446767	

DF = Degree of freedom, SS = Sums of squares, MS = Means of squares

Table 2 The analysis of variance table, for fibre (%), of five cultivars over 18 environments according to the AMMI model

Source	DF	SS	MS	F_probability
Environment	17	1408.5	82.86	<0.001
Block	36	80.0	2.22	0.01
Cultivar	4	485.9	121.48	<0.001
Interaction	68	589.1	8.66	<0.001
IPCA1	20	429.2	21.46	<0.001
IPCA2	18	96.6	5.37	<0.001
Residual	30	63.3	2.11	0.02
Error	138	173.4	1.26	
Total	269	2737.0	10.17	

DF = Degree of freedom, SS = Sums of squares, MS = Means of squares

Table 3 The combined analysis of variance (ANOVA) for fibre yield (t ha^{-1}) of five cultivars over 18 environments according to the AMMI model

Source	DF	SS	MS	F probability
Environment	17	149676773	8804516	<0.001
Block	36	4010206	111395	<0.001
Cultivar	4	9915737	2478934	<0.001
Interaction	68	8476395	124653	<0.001
IPCA1	20	3910975	195549	<0.001
IPCA2	18	2675161	148620	<0.001
Residual	30	1890259	63009	0.09
Error	137	6260389	45696	
Total	269	178339500	662972	

DF = Degree of freedom, SS = Sums of squares, MS = Means of squares

Table 4 The analysis of variance table, for length (mm) of five cultivars over 18 environments according to the AMMI model

Source	DF	SS	MS	F_probability
Environment	17	147.5	8.68	<0.001
Block	36	32.5	0.90	<0.001
Cultivar	4	437.4	109.35	<0.001
Interaction	68	117.1	1.72	<0.001
IPCA1	20	72.4	3.62	<0.001
IPCA2	18	33.5	1.86	<0.001
Residual	30	11.3	0.38	0.09
Error	141	81.6	0.58	
Total	269	816.1	3.03	

DF = Degree of freedom, SS = Sums of squares, MS = Means of squares

Table 5 The analysis of variance table, for strength (g tex^{-1}) of five cultivars over 18 environments according to the AMMI model

Source	DF	SS	MS	F_probability
Environment	17	433.8	25.52	<0.001
Block	36	87.4	2.43	0.036
Cultivar	4	240.3	60.07	<0.001
Interaction	68	318.2	4.68	<0.001
IPCA1	20	87.2	9.36	<0.001
Residual	30	131.0	2.73	0.915
Error	141	339.4	2.36	
Total	269	1419.1	5.28	

DF = Degree of freedom, SS = Sums of squares, MS = Means of squares

Table 6 The analysis of variance table for micronaire of five cultivars over 18 environments according to the AMMI model

Source	DF	SS	MS	F_probability
Environment	17	34.26	2.0155	<0.001
Block	36	2.34	0.0649	0.494
Cultivar	4	2.77	0.6923	<0.001
Interaction	68	8.95	0.1317	<0.001
IPCA1	20	5.57	0.2785	<0.001
IPCA2	18	3.38	0.0705	<0.001
Residual	48	3.38	0.0705	0.365
Error	143	9.45	0.0656	
Total	269	57.77	0.2148	

DF = Degree of freedom, SS = Sums of squares, MS = Means of squares

ADDENDUM 2

AMMI model biplot

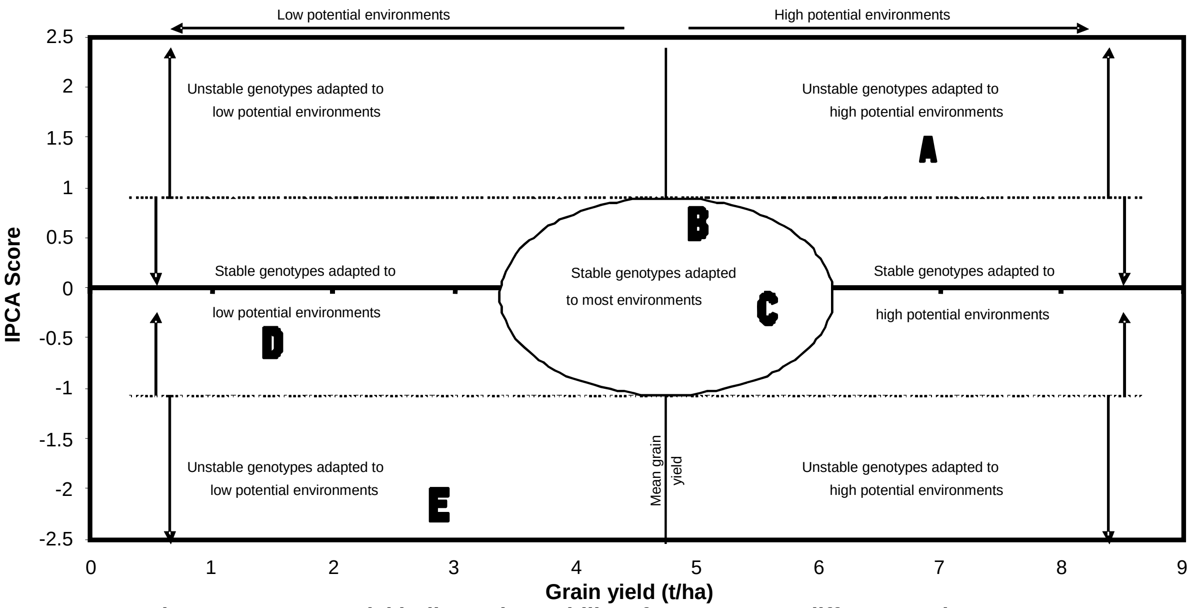

Figure 1. AMMI model indicate the stability of genotypes at different environments

(MA'ALI *et al*, 2007).

SUMMARY

Cotton is regarded as one of the most versatile agricultural products in the world. In South Africa, relatively low prices, high input costs, exchange rates, cheap import of cotton fibre and international subsidies are all factors affecting cotton production negatively. To get optimum yields when planting cotton instead of grain, cultivar selection is the most important aspect that the cotton grower has to take into consideration. Whereas a herbicide or insecticide that has been chosen can be changed during the season, cultivar selection is done only once and the selected cultivar dictates field management for the entire season. In order to give cotton producers recommendations regarding the adaptability and stability of cultivars, five cotton cultivars were planted at 6 sites in South Africa over the period 2003 to 2006. Seed cotton yield, fibre percentage, fibre yield and fibre qualities were determined and cultivars were evaluated for performance and yield stability in the eight cotton production regions. The cultivars planted under irrigated conditions were NuOPAL, DeltaOPAL, DeltaOpal RR, LS9219 and SZ9314. The localities were Loskop (Mpumalanga Province), Makhathini (KwaZulu-Natal), Rustenburg (North-West Province), Vaalharts and Upington (Northern Cape) and Weipe (Limpopo Province). The combined analysis of variance, according to the Additive Mean Effects and Multiplicative Interaction (AMMI) model was performed using the GENSTAT package. To give a graphical explanation of the Cultivar x Environment Interaction and the adaptation of the cultivars to the environment, the AMMI model 2 bi-plot was used where the IPCA 1 scores (Principle Component Interaction Analysis) were plotted against the mean parameters. The IPCA scores of cultivars in the AMMI analysis is an indication of the stability of a cultivar over environments. Although the cultivar, LS9219, outperformed NuOPAL with regard to fibre length and strength, it was second to NuOPAL in terms of seed cotton and fibre yields. Since no other cultivar matched the performance of NuOPAL regarding seed cotton or fibre yield (it was selected by the AMMI model as the best performer in respect of seed cotton yield and fibre yield (kg ha^{-1}) in fifteen out of eighteen environments), NuOPAL is recommended for planting in all of the different cotton-production areas of South Africa.

OPSOMMING

Katoen is bekend as een van die mees veelsydige landbouprodukte in die wêreld. In Suid-Afrika word katoenaanplantings negatief beinvloed deur relatiewe lae pryse, hoë insetkoste, wisselkoerse, goedkoop invoere van katoenvesel en internasionale subsidies. Cultivar keuse is die belangrikste besluit wat gemaak word om optimum opbrengste te verseker. Anders as onkruid- of insekdoder keuses wat deur die seisoen aangepas of verander kan word, word cultivar keuse slegs een maal per seisoen gedoen en die besluit wat geneem word, bepaal die verbouiingsbestuur vir die hele seisoen. Ten einde aanbevelings aan produsente te verskaf aangaande die aanpasbaarheid en stabiliteit van verskillende cultivars, is vyf cultivars geplant op ses lokaliteite gedurende die periode 2003 tot 2006. Saadkatoenopbrengs, veselpersentasie, veselopbrengs en veselkwaliteite is bepaal en cultivars is geëvalueer vir prestasie en opbrengs stabiliteit in die agt veskillende katoen produserende areas. Die cultivars wat geplant is onder besproeiingstoestande, is NuOPAL, DeltaOPAL, DeltaOpal RR, LS9219 en SZ9314. Die lokaliteite was Loskop, (Mpumalanga Provinsie), Makhathini (KwaZulu-Natal Provinsie), Rustenburg (Noord-Wes Provinsie) Vaalharts en Upington (Noord-Kaap Provinsie) en Weipe (Limpopo Provinsie). Die gekombineerde variansie volgens die "Additive Mean Effective And Multiplicative Interaction (AMMI)" model is uitgevoer met die GENSTAT program en is gebruik om die effek van cultivar x omgewing interaksie te bepaal op die parameters gemeet. Om grafies die cultivar x omgewings interaksie en aanpasbaarheid van cultivars ten opsigte van omgewings te beskryf, is die AMMI model 2 XY-grafiek gebruik waar 'n IPCA-waarde (Die "Principle Component Interaction Analysis") geplot is teen die gemiddelde opbrengs. Die IPCA waardes van cultivars in die AMMI analise gee 'n aanduiding van die cultivar se stabiliteit oor verskillende omgewings. Alhoewel die cultivar, LS9219, NuOPAL oortref het wat vesellengte en veselsterkte aanbetref, het dit tweede gekom na NuOPAL wat saadkatoen- en veselopbrengs aanbetref. Aangesien geen ander cultivar NuOPAL se prestasie oortref het aangaande saadkatoen- of veselopbrengs nie (gekies deur AMMI as die beste presteerder in vyftien uit die agtien omgewings aangaande saadkatoen- en

veselopbrengs), word NuOPAL aanbeveel vir planting in al die verskillende katoenproduserende areas van Suid-Afrika.