EFFECTS OF PLANTING DATE AND LOCATION ON PHENOLOGY, YIELD AND YIELD COMPONENTS AMONG SELECTED COWPEA VARIETIES

BY

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DECLARATION

I declare that the mini-dissertation hereby submitted to the University of Limpopo, for the degree of Master of Science in Agriculture (Crop Science),has not previously been submitted by me for a degree at this or any other university; that it is my work in design and in execution, and that all material contained has been duly acknowledged.

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DEDICATION

Dedicated to my son, Lulama, being a mother to you makes me strive for the best.

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ABSTRACT

Cowpea (*Vigna unguiculata* L. Walp) is one of the important food legumes and a valuable component of the traditional cropping systems. It serves as a source of protein in human diet and plays a major role in animal nutrition. The crop is adaptable to harsh environments including extreme temperatures and water limiting conditions. There is limited information available in cowpea with regards to cultivar selection and performance studies across ranges of environments in South Africa. The objectives of the present study were to 1) determine the influence of different planting dates and locations on phenology, yield and yield components of selected cowpea varieties and 2) determine the relationship of seed yield to environmental conditions such as rainfall and temperature. Ten cowpea genotypes were used for the study, developed by the Agricultural Research Council, Grain Crops Institute, South Africa. The experiment was laid out in a randomized complete block design with three replications. The experiment was carried out at Potchefstroom, Taung (Northwest Province) and Syferkuil (Limpopo Province) during three planting dates viz. 8 Nov. 22 Nov and 6 Dec. 2004. Data collected included the number of days to 50% flowering, number of days to 50% physiological maturity, seed yield, number of branches per plant, number of pods per plant, number of seeds per pod and 100 seed weight. The results showed highly significant differences among cowpea genotypes in each location and across locations for yield and yield components. Planting date one (i.e. 08 November) was better in yield gain over all locations. Potchefstroom was the best location for best yield gain due to high rainfall and relatively favorable low temperatures. The lowest yield was recorded at Syferkuil because of low rainfall and high temperatures. With relatively better performance across locations IT18E-16, CH14 and Pan311 were the best genotypes recommended in these or other similar environments in South Africa.

CHAPTER 1

GENERAL INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp) belongs to the family Fabaceae alt leguminosae. It is one of the important food legumes and a valuable component of the traditional cropping systems in the semi-arid tropics covering Asia, Africa and Central America (Mortimore *et al*., 1997; Van Ek *et al.,* 1997). From the production of this crop, rural families variously derive food, animal feed, and cash. Moreover it will have spillover benefits to their farmlands through, for example, *in situ* decay of root residues, use of animal manures, and ground cover. In addition, because the seed is widely traded out of the major production areas, it provides a cheap and nutritious food for relatively poor urban communities (Singh and Sharma*,* 1997). There is now a common view that cowpea can play a significant role in farming systems where low inputs including animal fertilizer application can be justified.

The climatic requirements of cowpea crop are similar to grain sorghum. On as little as 300 mm rain spread over the growing season, cowpea can produce a yield of up to one-ton seed and six tons of hay (Claufurd *et al.,* 1996). It is ideally suited to tropical lowlands, doing well in hot, dry and humid ecosystems (Nwokolo and Smart, 1996). Cowpea is thus an important seed crop grown throughout Africa and it is popular among the resource-poor farmers in the Limpopo Province of South Africa. Despite the importance of cowpea in sustaining livelihood of the rural communities, seed yield of the crop has always remained low and variable. Poor production practices including choice of cultivar, adaptability as well as lack of information on the right plant planting date has contributed to low cowpea productivity.

There are diverse cowpea genotypes demanding a site specific directed management approach that include, among others, choice of proper planting date, and a selection of best adapted genotypes. With all its different uses and its different advantages, cowpea is a viable and high potential alternative crop. Due to its versatility in yielding high protein and fodder, there is a need to expand production that could be met by growing high yielding varieties (Delacy *et al.,* 1990). Different varieties of cowpea have been bred recently, however, there is no detailed information yet on their specific planting date requirements and site specific adaptations (Coetzee, 1990).

Research on cowpea production, improvement and utilization has been limited in South Africa as cowpea was regarded a rural crop with no industrial use. The lack of high yielding cultivars, which are drought tolerant and resistant to pests and diseases, as well as the unavailability of guaranteed market to dispose excess produce slowly relegated this nutritious pulse. Low seed yields can be attributed to unfavorable agronomic practices by farmers e.g. selection of suitable planting date. These challenge researchers to find the most appropriate planting date using high yielding and early maturing varieties of cowpea (Rachie, 1985).

Improved varieties of cowpea with resistance or tolerance to biotic and abiotic stresses can provide a powerful stimulus for rural development because they enhance the productivity, product quality, profitability and sustainability of farming systems with minimal input. Such varieties especially benefit resource poor farmers that cannot afford inputs such as insecticides and fertilizer (Coetzee, 1990). There is therefore, strong need for genetic improvement and development of cowpea varieties with acceptable traits for exploiting different markets in South Africa.

Varietal requirements of cowpea in terms of plant type, seed colour, maturity date and usage patterns are extremely diverse from region to region, making breeding programs for cowpea more complex than for other crops. No single variety can be suitable for all conditions (Becker, 1988). There is also a need to develop resistance to biotic and abiotic constraints in South Africa. The International Institute of Tropical Agriculture (IITA) has been able to breed cowpea varieties that yields close to four tons/ha. This level of production may be possible in South Africa by improving the overall productivity of cowpea through use of improved varieties and cultural practices. Therefore, the objectives of these studies were: 1) to determine the influence of different planting dates on yield and yield component of selected cowpea varieties and 2) to determine the relationship of seed yield to environmental conditions such as rainfall and temperature.

CHAPTER 2

LITERATURE REVIEW

2.1 Classification of cowpea

Cowpea is often referred to as crowder pea, black-eyed and southern pea and is known internationally with various names including as lubia, niebe, coupe, or frijole. Cowpea (*Vigna unguiculata* L. (Walp)) is a legume crop that belongs to the family Fabaceae alt Leguminosae and is a member of the genus *Vigna*, which belongs to the family Phaseoleae. This family also contains the common bean (*Phaseolus vulgaris* L.) and the mung bean (*Vigna radiata* L.) among other legumes of economic importance. Cowpea belongs to the section of catiang that is fairy simple section of the genus *vigna*, which is characterized by its prominent spur stipulus. This section includes only two distinct species viz. *V. unguiculata* and *V. nervosa* Markotter (Ng and Marachel, 1985).

2.2 Centre of origin and genetic diversity of cowpea

Cowpea is one of the most ancient crops known to man, with its centre of origin and subsequent domestication being closely associated with pearl millet and sorghum in Africa. The precise location of the centre of origin of the species is, however, difficult to determine. Previous speculation on the origin and domestication of cowpea has been based on botanical and cytological evidence, as well as information on its geographical distribution and cultural practices, and historical records (Faris, 1965; Steele and Mehra, 1980; Ng and Marechal, 1985).

Origin and domestication of cowpea occurred in Africa mainly through the African Savannah (Duke, 1981). Probable centres of domestication are thought to be mainly in West Africa, Central Africa and South Africa (Vavilov, 1951). Most primitive of the wild *V. unguiculata* occur in southern Africa in the region encompassing Namibia from the west, across Botswana, Zambia, Zimbabwe, and Mozambique to the east, and the Republic of South Africa. Probably, the Limpopo region of the Republic of South Africa was the centre of speciation of *V. unguiculata*, due to the presence of the most primitive wild varieties i.e. *var*. rhomboidea, *var*. prottracta, *var*. tennis, and *va*r stenophylla (Ng and Marechal, 1985).

2.3 Growth habit

Based on plant types, cowpea can be categorized as erect, semi-erect, prostrate (trailing), or climbing. There is variability in the growth habit within the species, which ranges from indeterminate to determinate with the non-vining types tending to be more determinate (Patel and Hall, 1990). Cowpea is generally taprooted with root depth of up to 95 cm measured eight weeks after sowing. It has trifoliolate leaves that are smooth, dull to shiny, rarely pubescent and developing alternately. Commonly, the terminal leaflet is longer and larger than the lateral leaflets (Davis *et al*., 1991).

2.4 Seed and morphological development

Seed varies from very small up to nearly 2 cm long and the number of seeds per pod ranges from 10 to 20. Seed shape is a major characteristic correlated with seed development in the pod. Seed develop into a kidney shape if not restricted within the pod. However, it becomes progressively more globular when seed growth is restricted by the pod.

The seed coat can be either smooth or wrinkled and of various colors including white, cream, green, buff, red, brown, and black (Saunders, 1960). Seed may also be speckled, mottled, or blotchy and many are also referred to as "eyed" (blackeye, pinkeye purple hull, etc.) where the white colored hilum is surrounded by another color. The cotyledons emerge above the ground indicating epigeal germination (Mutters *et al.,* 1989b). This type of emergence makes cowpea more susceptible to seedling injury, since the plant does not regenerate buds below the cotyledonary node (Davis *et al*., 1991)

2.5 Flowering and pod formation

Cowpea is a day neutral self pollinating plant. Flowers are born in multiple racemes on 8 to 20 cm flower stalks (peduncles) that arise from the leaf axis (Hadley *et al*., 1983). Two or three pods per peduncle are common and often four or more pods are carried on a single peduncle (Adcock and Lawes, 1976). The presence of these long peduncles is a distinguishing feature of cowpea and this characteristic also facilitates harvesting. The open display of flowers above the foliage and the presence of floral nectaries contribute to the attraction of insects. Cowpea pods are smooth, 6 to 10 cm long, cylindrical and generally somewhat curved. Pod colour may be distinctive, most commonly green, yellow or purple. As the seeds dry, pod color of the green and yellow types becomes tan or brown (Davis *et al*., 1991).

2. 6 Economic and nutritional importance

Cowpea is used as human food and livestock fodder. This dual-purpose characteristic makes it an attractive crop where land is limited. It is a drought tolerant warm weather crop, well adapted to the semi arid regions of the tropics where other food legumes do not perform well. This trait is in part explained by the deep rooting habit of some varieties. When grown in dry environments desiccation of cells and tissue is easily avoided in the crop thus neither its biological activity nor survival is threatened (Sinclair and Gardener, 1998).

Cowpea is an important crop for the nutrition and the livelihoods of millions of people in less developed countries. It is consumed in many forms. Young leaves, green pods and green seeds are used as vegetables whereas dry seeds are used in a variety of food preparations (Nout, 1996; Nielsel *et al.,* 1997). The green and dry haulms are fed to livestock, particularly in dry seasons when animal feed is scarce.

Trading of fresh produce and processed cowpea foods and snacks provides rural and urban women with opportunity for earning cash income. Cowpea is also a major source of protein, minerals and vitamins (Bressani, 1985).

Cowpea is very important as a nutritious fodder for livestock (Singh and Tarawali, 1997). Tarawali *et al*. (1997) reviewed the use of cowpea haulms as fodder in different parts of the world. In West Africa, the mature cowpea pods are harvested and the haulms are cut while still green and rolled into bundles containing leaves and vines.

The bundles are stored on roof tops or on tree forks for use and for sale as harawa (feed supplement) in the dry season, making cowpea haulms a key resource in crop-livestock systems (Singh and Tarawali, 1997). In West Africa region on a dry weight basis, the price of cowpea haulms ranges between 50 to 80% of the grain price. Haulms, therefore, constitute an important source of income. The nutritive value of cowpea grain, leaves and haulms is very high. The crude protein ranges from 22 to 30% in the seed and leaves on a dry weight basis (Bressani, 1985; Nielsel *et al*., 1997) and from 13 to 17% in the haulms with a high digestibility value and low fibre level (Tarawali *et al*., 1997).

With all this attributes, cowpea positively influences the nutrition and health of poor people, particularly children. The bulk of the diet of the rural and urban poor Africa consists of starchy foods such as cassava, yams, bananas, millet, sorghum and maize. The addition of even a small amount of cowpea improves the nutritional balance of the diet and enhances protein quality by the synergistic effect of high protein and lysine from cowpea and energy from starchy foods. The nutritional quality of cowpea, particularly the protein, fat and iron content has been improved through breeding (Singh and Ishiyaku, 2000). Cowpea provides an important source of protein (20 to 40%), fat (1.3%), fibre, (1.8%) and carbohydrates (76%). While cowpea seed protein is high in lysine, it is deficient in sulphur containing amino acids and methionine. This is likely to result in an insufficient supply of these amino acids especially when cowpea is consumed with sulfur amino acid deficient starch crops such as cassava (Molvig *et al*., 1997).

Due to its unique ability to fix atmospheric nitrogen through its nodules cowpea grows well in poor soils having more than 85% sand, less than 0.2% organic matter and low levels of phosphorus (Kolawale *et al*., 2000; Sanginga *et al.,* 2000). With these characteristics, the crop does not deplete the naturally low reserves of soil nitrogen. Many experimental findings illustrate that soil N levels increase, following a cowpea crop. Cowpea varies in sensitivity to soil acidity, but it tolerates acid soils under conditions of adequate rainfall (Massey *et al.,* 1998). Cowpea is shade tolerant and, therefore, compatible as an intercrop with maize, millet, sorghum, sugarcane and cotton as well as with several plantation crops (Singh and Emechebe, 1998). Due to its fast growth habit it covers the ground rapidly and, therefore, limits soil erosion.

In situ root decay produces nitrogen-rich residues that improve soil fertility and structure. Due to an awareness of the benefits of crop rotation, farmers grow cowpea in succession to cereals. Hence, the cereal will benefit from the improved soil conditions that resulted from cowpea. Together, these characteristics have made cowpea an important component of subsistence agriculture particularly in dry savannas of the sub Saharan Africa (Mortimore *et al*., 1997; Carsky *et al*., 2001).

2.7 World production and utilization

Reliable statistics on cowpea production and world's planted area are not available as most countries do not maintain separate records on cowpea. The Food and Agricultural Organization (FAO), therefore, suspended formal publication of cowpea production data several years ago (Singh *et al.,* 1997). However, based on the information available from FAO it is estimated that cowpea is now cultivated on at least 12.5 million (m) hectares, with an annual production of over 3 million tons (t) worldwide (Quin, 1997). Subsistence farmers in the semi-arid and subhumid regions of Africa are the major producers and consumers of cowpea. These farmers not only grow cowpea for human consumption and fodder for animal feed, but also utilize the leaves and fruits as vegetables.

Cowpea is widely grown in eastern Africa and southeast Asia primarily as a leafy vegetable. Steele *et al.* (1985) noted that the protein content of the leafy cowpea parts consumed annually in Africa and Asia is equivalent to 5 million t of dry cowpea seeds and that represents as much as 30% of the total food legume production in the lowland tropics. West and central Africa is the leading cowpea-producing region in the world. This region produces 64% of the estimated 3 million t of cowpea seed annually (Quin, 1997). Nigeria is the world's leading cowpea producing country while Ghana, Niger, Senegal, and Cameroon are significant producers.

Outside Africa, the major production areas are Asia and Central and South America. Brazil is the world's second leading producer of cowpea seed, producing 600,000 t annually (Guazzelli, 1988). Cowpea was a major agronomic crop in the United States (US) during the early part of the 20th century, with production peaking at 2.4 million ha in 1937 (Fery, 1980). However, the introduction of newer types of forage crops and the availability of mechanized harvesting equipment for these newer crops resulted in decreased cowpea production to 0.9 million ha in 1964. By the early 1980s, annual cowpea production in the US was estimated at 80,000 t (Fery, 1981).

The cowpea has long been valued in the southern US as a vegetable crop, and an extensive industry currently exists to supply fresh, canned, frozen, and dry-pack products that are marketed nationwide. Additionally, the cowpea has long been a popular item with home gardeners throughout the southern United States.

Presently the crop is not widely grown in South Africa. According to Nell (1990) cowpea production in South Africa amounts to 5,000 tons per annum. Small-scale farming of cowpea is mostly limited to Limpopo Province, Northwest and Kwazulu Natal (Coetzee, 1990). One of the constraints is the transmission of research results to rural farmers in South Africa. Despite the importance of the crop in the national diet and economy, cowpea is still inefficiently produced by local farmers and seed yields are very low and inconsistent. There is limited systematic research on quantitative information of cowpea on which to base the recommendations for cultural practices including, proper planting date.

2. 8 Cultural practices of cowpea

2.8.1 Plant population and spacing

In cowpea, cultivar choice will affect plant population. Cultivars with upright growth forms have a higher plant population than vining or semi vining types, because the upright forms performs much better in narrow rows (Weber *et al*., 1996). Plant population requirement of cowpea with respect to growth type and inter/intra row spacing is summarized in Table 2.1.The environmental potential of the land to be used, will determine the most favourable plant population for cowpea (Coetzee, 1995).

Table 2.1. Growth type, spacing (cm) and plant population of cowpea

Growth type	Inter-row spacing	Intra-row spacing	Plant population/ha
Upright	90	10	111 000
Semi vining	150	10	66 000
Vining	150	10	66 000

2.8.2 Fertilization

Cowpea, like all legumes, forms a symbiotic relationship with a specific soil bacterium (*Rhizobium* sp.), which makes atmospheric nitrogen available to the plant via nitrogen fixation. Fixation occurs in root nodules and the bacteria utilize sugars produced by the plant. Although cowpea *Rhizobium* is normally widespread, seed inoculation with *Rhizobium* specific to cowpea would be beneficial in areas where it is not present. It is, however, important to use *Rhizobium* of the cowpea type (Eaglessham *et al.,* 1977).

Excess nitrogen (N) promotes lush vegetative growth, delays maturity, may reduce seed yield and suppress nitrogen fixation. The plant will perform well under low N conditions due to a high capacity for N fixation. A starter N rate of 27 kg.ha^{-1} is sometimes required for early plant development on low-N soils (Rupela and Saxena, 1987; Bluementhal *et al.,* 1992).

2.8.3 Pests and diseases

Less pest control will be necessary if cowpea is planted early (September) in the growing season rather than late (December). Aphids and bollworm may be problems and can be controlled chemically. Diseases seldom occur, however, it is important not to plant cowpea successively on the same land because of its susceptibility to nematodes (Singh & Singh, 1979).

Several viruses can attack cowpea. A characteristic symptom of the mosaic virus disease is an intermixing of light and dark-green areas. Mottled areas are irregular in outline and may follow the main veins. Infected leaves are generally smaller than healthy ones, and often there is curling of leaf edges. Infected plants usually are more dwarfed and bushy and yields are reduced. Viral diseases can also result in malformed pods. Plants infected during seedling stages may be barren and fail to produce. The best way to prevent large yield losses from virus diseases is to grow tolerant varieties (Emechebe, 1975).

2.8.4 Harvesting

If cowpea is grown for seed yield, harvesting maturing is reached when 90% of the pods have dried off. Harvesting for hay can be done as soon as the pods start to discolour. When cowpea is used as a vegetable, the leaves and young pods can be picked by hand (Nell, 1990).

2.9 Temperature and photoperiod requirements of cowpea

Cowpea is grown between 35^{0}N and 30^{0}S of the equator. Temperature and photoperiod interact with genotype and other aspects of the environment to determine yield potential of seed legumes through their effects on duration of the vegetative and reproductive growth stages (Hadley *et al.*, 1983, Wien and

Summerfield, 1984). High temperature adversely affects productivity of many crops, and these adverse conditions are often influenced by planting date (Hiler *et al.,* 1972, Hall, 1992) In turn, sensitivity to photoperiod can be moderated by temperature. Developing improved germplasm for hot environments requires an understanding of genetic variation for these responses (Patel and Hall, 1990).

Many cowpea genotypes exhibit heat-induced suppression of floral bud development, which results in a two-week delay in flowering when plants are grown in very hot field environments under long days (Warrag and Hall, 1983, 1984a,b; Patel and Hall, 1990). Two weeks or more of consecutive or interrupted hot nights during the first four weeks after germination can cause complete suppression of the development of the first five floral buds on the main stem of sensitive genotypes (Ahmed *et al*., 1992). This damage reduces pod set, number of seeds per pod, and thus seed yield.

Plant or crop development is the progression from sowing to maturity through a series of discrete and clearly defined stages (Squire, 1990). It is modulated primarily by temperature and photoperiod (Roberts and Summerfield, 1987, Squire, 1990). Understanding the environmental influence of development is important. Firstly, because the time from sowing to flowering and maturity determines the duration of biomass accumulation and, second by, the duration of different developmental phases affects the partitioning of the biomass and therefore the ratio of seed to vegetative yield (Mutters *et al*., 1989a).

To maximize biomass accumulation, the life cycle, and particularly the timing of reproductive development and growth, must be timed to match the available resources (Ludlow and Muchow, 1990; Lawn and Imrie, 1991). In the semi-arid environment of South Africa, this means ensuring maximum biomass accumulation when moisture is adequate and temperatures are favorable.

The response to photoperiods may be influenced by temperature with a particular genotype exhibiting different degree of temperature x photoperiod interaction (Miller *et al*., 1958). Breeders of seed legumes, commonly characterize their germplasm into early and medium. For many genotypes, however, these categories are environmentally specific mostly due to different responses to photoperiod and temperature (Huxley and Summerfied, 1996).

Photoperiod effects remain unseen under short daylengths. Most differences in duration of vegetative stage occur under long photoperiods. Genotype specific photoperiod x temperature interaction effects on floral bud development (and hence flowering) further reduce the predictability of flowering date and adaptation from one environment to other (Hadley *et al.,* 1983).

Patel and Hall (1990) indicated that cowpea can yield satisfactorily under greater diversity of climatic, soil, and cultural conditions than other leguminous crops. The factors responsible for the broad adaptation of cowpea are poorly understood (Hall *et al*., 1997). The growing period of cowpea plants is too long to permit its growth for grain where they are not adapted (Russell, 1980). A mean temperature of 27^0C is optimum for good pod formation and seed yield. It performs better in regions with rainfall of 250-1000 mm per annum (Marfo and Hall, 1992). The crop is much more tolerant to high heat and extended drought periods than Phaseolus beans, which are largely confined to higher elevations (Massey *et al*., 1998).

2.10 Genotype x environment interaction

Multi-location evaluation is feasible with relatively few genotypes in the advance stages of a breeding program. Inconsistent genotypic responses to environmental factors such as temperature, soil moisture, soil type, or fertility level from location to location are the function of genotype x environment (G x E) interactions (Kang, 1988).

Genotype x environment interaction has been defined as the failure of genotypes to achieve the relative performance in different environments (Becker, 1988) and the interaction has been widely studied (Crossa *et al*., 1990). Good estimates of genotype x year and genotype x location interactions are necessary in evaluating the efficiency of a testing program and determining the optimum allocation of locations and years. The existence of G x E interactions and their effects on selection process are widely recognized (Berker and Leon, 1988).

Genotypes x year interactions are always of importance in developing improved varieties (Muir *et al*., 1992). Genotype x location interaction is of relatively little importance in selecting material for local adaptation but often assumes a dominant role in selection for wide adaptation (Cooper and Dalecy, 1994). The optimum number of years and locations required for accurate evaluation has not been determined, largely because good estimates of the G x E interactions have not been available (Delacy *et al.,* 1990).

Varietal selection is crucial for improved seed yield and quality. Selection is one of the most important decisions a grower makes annually. Variety selection is the foundation for effective and successful management plan. Although weather conditions cannot be predicted during the growing season, selecting the right variety can help to minimize weather related risks (Patel and Hall,1996). There are many cowpea varieties available, which make selection a challenge. Each variety should have maximum yield potential that is genetically determined. This genetic yield potential is realized only when management and environmental conditions are complementary (Ehlers and Hall, 1996). The performance of a variety may vary from year to year, even within the same field. When varieties are tested over a range of locations and years their performance change, indicating that some varieties are better adapted to a specific environment than others. Selecting a variety with a high and stable yield within a region and across years will more accurately determine the variety performance and stability. To minimize risk, when selecting a variety, one has to look at the variety information obtained from performance trials that are replicated in different locations (Robertsons *et al*., 1985).

2.11 Response of cowpea to drought

Cowpea needs little or no irrigation to produce a successful crop in most years if the pre-plant moisture is adequate. Even in areas with little annual rainfall such as Limpopo Province complete crop failure in cowpea is rare. Earlier studies of cowpea response to drought have produced conflicting results. In field studies, increasing the number of irrigations or the amount of water applied at each irrigation increased seed yield in some experiments (Clark and Hiler, 1973), while it did not show an effect on seed yield in other experiments (Wien *et al.,* 1979, Malik, 1988;). In the study of Wien *et al.,* (1978) cowpea was subjected to drought during the vegetative stage of growth or during flowering, and neither treatment influenced the yield. In contrast, greenhouse studies indicated that seed yield of cowpeas was extremely sensitive to drought during the flowering stage (Hiler *et al*., 1972). According to Huxley and Summerfield (1996), the longer the duration of the growing period, the more pods were produced.

This difference was largely brought about by differences in pod production on branches. Warm days markedly decreased the number of pods per plant (an overall average reduction of 49%) as did warm nights in conjunction with the long days. Under high night temperature, many genotypes do not set fruit even though they produce flowers (Ahmed *et al*., 1992; Warrag and Hall 1984b). Heat injury during pod set was associated with inhibition of proline accumulation in pollen and greater accumulation of proline in anther walls (Mutters *et al*., 1989a; Patel and Hall, 1990). Also percent pod set was greater in hot, short days, compared with hot, long days, but still much lower than under optimal temperatures (Mutters *et al*., 1989b). Cowpea genotypes have been classified with respect to their heat tolerance during different stages of reproductive development and responses to photoperiod (Patel and Hall, 1990; Ehlers and Hall, 1996).

In addition to high daily temperatures, water stress during the reproductive stage causes a sharp decline in flowering and grain filling. Dancete and Hall (1979) have indicated that maximum water requirements of annual crops in one region depended on crop duration. Rachie (1985) emphasized that without fertilizer or irrigation, but with major pest control, a cowpea crop in the semi arid or sub humid tropics can be expected to produce seeds between 1500-3000kg/ha within 85 days. The responses of cowpea to water stress have been studied by various workers (Wien *et al*., 1978; Turk *et al*., 1980).

Plants avoid drought by reductions in leaf area, decreases in stomatal conductance, and changes in leaf orientation (Sharkel and Hall, 1979). Under moderate water stress, cultivars produced close to normal seed yields in spite of stress imposed at flowering because the plants had matured their fruits before the stress became severe (Wien *et al*., 1978). After severe stress was imposed at different intervals during a 35-60 days reproductive period, closure of stomata and reductions in leaf area resulted in limited dry matter production which led to substantial decrease in yield (Turk *et al*., 1980).

2.12 Planting date on cowpea

Research on the effect of planting date on cowpea is limited but soybean (*Phaseolus vulgaris* L.) may serve as a guideline. This is because soybean is also a summer legume and there is documented information on the effect of planting date on soybeans. According to May *et al*. (1989) the yield advantage of early maturing varieties of soybeans over late maturing cultivars did not depend on planting date.

However, delayed planting of early maturing cultivars substantially delayed maturity, eliminating the advantage of early harvest of the early planted and early maturing cultivars (Fatokun *et al*., 2002). Early sowing can result in high grain yields if it enables the crop to escape hot summer weather that can hinder reproductive development (Hall, 1992). If sowing is too early, and soil temperature is cooler than 19^0C, chilling damage can cause slow and incomplete emergence (Ismail *et al*., 1997). Cowpea cultivars that begin flowering early can escape drought in some locations and years resulting high yields.

Planting date is one of the important cultural practices that results in the greatest differences in growth and yield of grain legumes without involving additional costs such as addition of fertilizers. The optimum planting date varies according to cultivar planted. In South Africa the optimal planting time for cowpea in cooler areas is mid-November and in the warmer areas mid-December (Republic of South Africa National Department of Agriculture, 1995). Due to availability of adequate rainfall, planting during this period ensures good seedling establishment, and good flowering and pod filling stages for maximum seed yield. Cowpea can also be planted at the beginning of the rainy season (beginning of October as well as late January). Planting too early could cause poor germination and flower abscission in the flowering period i.e. December/January (Republic of South Africa National Department of Agriculture, 1995).

Planting too late, on the other hand, could cause losses as a result of early frost, or there may not be enough time for the pod formation. This could lead to loss in grain yield and germplasm, and this could affect crude-protein content. If cowpea is planted for green pastures, green manuring or silage, planting can be done early, if the minimum temperature favours germination (Republic of South Africa National Department of Agriculture, 1995).

2.13 Heritability and correlation of traits in cowpea

Miller *et al*. (1958) stated that a breeder designs his/her testing procedures to maximize the genetic effects relative to environmental and interaction effects. Allard (1960) defined heritability as the proportion of the total variability due to genetic causes, or the ratio of the genetic variance to the total variance, and expressed as: $H = \delta^2G/(\delta^2G + \delta^2E)$; where δ^2G is the genetic variance and δ^2E is the environmental variance. Dudley and Moll (1969) defined the total genetic variance as the part of the phenotypic variance which can be attributed to genotypic differences among the phenotypes, and the genotype x environment interaction as part of the phenotypic variance attributable to the failure differences between genotypes to be the same in different environments. They defined this heritability as broad sense heritability. They also went on to say that, if these genotypes are grown in a randomized block experiment that is adequately replicated in time and space, an appropriate data analysis provides a proper test for genetic variability and also provides an estimate of broad sense heritability. From the above concepts, it is clear that heritability estimates for any characteristic can vary greatly, depending on the magnitude of the environmental effects. In this regard, Dudley and Moll (1969) stated that any measure of the genetic variance and broad sense heritability estimates specifically apply only to the population of environments sampled.

Limited information is available on heritability, genotype x environment interaction, phenology, yield and yield components in cowpea. Research results on groundnut (*Arachis hypohaea* L.) indicated that low rainfall and its poor distribution, high temperatures and hot winds during crop maturation compound the environmental effects under these conditions. These environmental effects lead to low heritabilities. The low heritability estimates indicated the difficulty in controlling environmental influence and reducing it so that genetic effects could not be effectively isolated (Sivakumar, 1992).

Some yield components significantly affected seed yield through effects at different stages, from planting to harvest. Therefore, one needs to know more about these traits and how they affect seed yield. Characters with high heritability are easy to select during the earlier segregating populations. However, economic characters like seed yield is polygenic in nature and often influenced by environment and thus have low heritability.

Broad sense heritability is useful information as it provides rough estimates of genetic variability in the breeding materials. Allen (1981) mentioned that broad sense heritability was 61% for the days to 50% flowering in cowpea. Jaisil *et al*. (1976) showed high broad sense heritabilities for number of branches, number of 100 seed weight but rather low broad sense for seed legumes. Singh and_Rachie (1985) reported similar results on high broad sense heritability of 100 seed weight with published estimates averaging 67,8%. Likewise, Allen (1981) indicated high broad sense heritability value of 98, 96% for 100 seed weight. The researchers further indicated that genotype x environment variance components were less than genetic variance components in all characters measured.

The high heritability of hundred seed weight indicates that significant increases in seed yield can be obtained from selection for this trait within the lines. There is a need to explore in greater detail the genetic relationship between seed yield and yield components. Trait such as hundred seed weight may serve as a criterion for indirect selection for seed yield, although a more exhaustive and critical analysis of their correlations is needed.

In cowpea, seed size, usually measured as hundred seed weight, is moderate to highly heritable, with published estimates averaging 67.8 %. The number of seeds per pod is moderately heritable under most environmental conditions; heritability estimates averaging 52.8%. The yields of both the reproductive and the vegetative portions of the cowpea plant are moderately heritable under most environmental conditions. According to Singh and Rachie (1985) heritability for pod number, seed yield, and fresh fodder yield were estimated at 53.1%, 45.0%, and 54.7%, respectively. In cowpea the correlations between many different characters have been estimated, but it is appropriate to give special attention to correlation involving yield components.

CHAPTER 3

3. EFFECTS OF PLANTING DATE AND LOCATION ON PHENOLOGY YIELD AND YIELD COMPONENTS AMONG SELECTED COWPEA GENOTYPES

3. 1 INTRODUCTION

Yield in cowpea is the result of many interacting yield components such as number of pods per plant, number of seeds per pod and mean seed weight. Yield and its components are affected by various factors including phenological development, planting date, genotypic differences and the environment (Gardener *et al*., 1985). Management practices to improve yield components aim to maximize the total yield of grain legumes (Ayaz, 2001). However, interdependent compensatory mechanisms among yield components can create variability (Wilson, 1987) such that large changes of one yield component may affect total yield (Taraweekul, 1999). El-Nadi (1970), Ishag (1973), and Sprent *et al.* (1977), pointed out that yield components may not approximate the estimated or measured yield and often do not follow the same order.

Environmental factors have profound influence on growth and yield of crops (IART, 1991; Agele *et al.,* 1999, 2002). Furthermore, differences in genotypic sensitivity to photoperiod have implication for adaptation of most legumes to growing seasons (Bell and Wright, 1988; Ellis and Robberte*,* 1992). The sensitivity of legumes to the photo thermal effects is a major constraint to the development of a stable management practices, cropping systems and varieties (Silim and Omanga, 2001).

Flowering period is the most important factor influencing genotypic adaptation. It is a particularly important phase in crop development and vulnerable to environmental stresses. Furthermore, it is the timing of this developmental stage that is responsible for determining when a crop will subsequently mature for harvest (Summerfield, 1980). Wilson and Robinson (1995) noted that the time to flowering and duration of growth strongly influence the climatic adaptation and yield potential of a crop. Hence, it is important to determine the factors e.g.

planting dates and sites that affect its development are subsequently responsible for variability in yield and yield components. The initiation of the floral buds and the subsequent development into flowers may require different critical photoperiods (Summerfield, 1980). Various crop species have adaptive features that ensure timely flowering (Wien and Summerfield, 1984).

Yield decreases resulting from drought stress depend both on the phenological timing of the stress and on the degree of yield component compensation. Schou *et al*. (1978) reported that yield is more influenced by changes that occur during flowering to physiological maturity compared with the period from emergence to flowering. Other studies (Johnston and Pendelton 1969; Schou *et al.,* 1978; Egli and Yu, 1991) have indicated that seed number per unit area were responsive to altered environmental conditions during flowering and pod set. Negative effects of stress are particularly important during flowering, seed set and filling (Doss and Thulow, 1974; Sionit and Kramer, 1977; Ashley and Ethridge, 1978).

Yield variability in grain legumes is suggested to be correlated with changes in seed number (Moot, 1993). Furthermore, variations in individual seed weight account for the differences in yield among environments within species, as well as among species in the same environment (Munier-Jolain and Ney, 1998; Ayaz, 2001). Yield components have been used extensively to explain variations in the yield of grain legumes such as *Vicia faba* (Husain *et al.,* 1988), *Phaseolus vulgaris* (Dapaah *et al*., 2000), *Cicer arietinum* (Verghis, 1996) and *Pisum sativum* (Nicholas *et al*., 1985).

Information on the relative importance of various yield components to seed yield remains important. Dhital *et al.* (1997) pointed out that planting dates influenced both yield and yield components. Early planting resulted in highest number of pods per plant (11) and late planting resulted in lowest number of pods per plant (5). Dhital *et al.* (1997) further concluded that the trend of number of seeds per pod followed the trend of pod formation. The number of seeds per pod was 12 in early planting and 6 seeds per pod in late planting. According to Dhital *et al.* (1997) planting date had a highly significant effect on seed yield. Crops from early planting produced high seed yield (1.6 t/ha) and late planting resulted in low yield (0.28 t/ha). Likewise, Weber and Moorthy (1952) and Hodgson and Ayaz (2001) observed that seed yield was significant and positively associated with number of pods per plant and seed weight in soybeans. The researchers further obtained positive and significant correlations between yield and seed weight. Onset of the growing season was associated with growing length, soil moisture regime and possible rapid rise in water level (Akinola, 1986). Spetch and Williams (1984) noted that genotype x environment interactions i.e. a consistent superiority of some genotypes over others in specific environments but an inverse performance rank in other environments, often involved a specific adaptation component.

South Africa has a wide array of climatic conditions and variable rain patterns under which cowpea is produced. The semi arid tropics of South Africa are characterized by more variability in the average date of rain onset than its cessation. Mean daily temperature during the growing season varies from 27-30 ^{0}C with a day length of 12 hours per day. The reproductive growth phase, particularly seed maturity falls into the period of dry spells, which marks the first of the modal rain period. Nevertheless, cropping opportunities exist at the earlier part of the growing rainy season and the dry season falls into the second mode of rainfall distribution (Republic of South Africa National Department of Agriculture, 1995). However, early planting during October is characterized by variable soil temperature and moisture status, while late planting (January), has variable soil moisture, extreme soil temperatures, high irradiance and high atmospheric vapor deficits. Since water is an important climatic condition, the uncertainties about the time of onset and cessation of rains are a crucial factor for predicting the growth and yield performance of rain fed crops. Efforts to expand cowpea production into new cropping systems require understanding of the dynamics of the environment. However, there is a scarce information base from which planting date, the response of flowering and seed yield in warm season legumes can be predicted (Troedson *et al*., 1990; Caryberry *et al*., 1992 and 2001; Craufurd *et al.,* 2001).

It is essential that cowpea breeders in South Africa should collect more information by characterizing various germplasm over a wide range of environments for maximizing yield.

Multi-environmental trials are important procedures in plant breeding for the recommendation and release of superior and stable cultivar(s). Such trials allow comparison of mean yield and stability of genotypes, among other tasks. Consequently, it is possible to select superior cultivars based on greater yield and average stability. Yield and its stability depend on the genetic constitution of the cultivar and the intensity of the environmental constitutions (Bradshaw, 1965; Borojevic, 1990). Thus, to select high yielding and stable cultivars, it is essential to test them under the target production environments in a range of growing conditions. Different stability parameters have been proposed but the choice of any of these methods depends on whether one considers stability over a wide range of environments or the relative stability of a group of cultivars included in a given experiment. The Eberhart-Russel regression analysis (Eberhart and Russel, 1996) and Lin and Binn's superiority parameters of interest are among the commonly used stability models. The parameter of Ebenhart-Russel, (1996) is based on the regression of each genotypic yield on the environmental index (the mean at each environment). According to Eberhart and Russel (1996), a stable cultivar has a regression coefficient close to unity (b=1), with a minimum deviation from regression and high mean yield. Lin and Binns (1988) superiority parameter (Pi) is the squared difference between a cultivar's yield and the maximum yield within each environment, averaged over all the environments. Genotypes with broader adaptation have lower values of this superiority parameter, because they yield closer to the maximum within each environment, relative to genotypes with poor adaptation to the target environments.

Planting date and locations are the major factors responsible for successful cowpea production. Breeders consider these factors to select suitable cowpea cultivars with broader adaptability and yield stability. Limited information is available concerning the effects of planting date and locality on cowpea production in South Africa. Therefore, this study was carried out to investigate the effect of planting dates on yield and yield components among selected cowpea genotypes over three locations in South Africa. This work may contribute to improved understanding of the performance of cowpea lines under these agro-ecological zones for possible wide scale production of the crop.

3.2 MATERIAL AND METHODS

3.2.1 Cowpea lines

Ten cowpea lines namely: PAN 311, ITI8E-16, IT85F-2687, M217, M28, M101, Glenda, Benchuana White, M9 and CH14 were included in the study. Seeds were obtained from the Agricultural Research Council (ARC) Grain Crops Institute at Potchefstroom. Details of the lines are shown in Table 3.1.

Table 3.1 Description of traits of 10 cowpea lines used in the study.

Line	Traits[a]											
	PS	GH	ACB	TL	LGC	FC	PA	PS	PL	SC	SGC	ST
Pan311	1	1	1	1	3	1	3	3	20	3	1	1
IT18E-16	1	1	1	1	3	1	3	3	20	3	1	1
IT185F2687	1	1	1	1	1	1	3	3	14	3	1	1
M217	1	1	1	3	1	1	3	3	16	1	2	1
M28	1	1	1	1	1	7	2	3	12	1	1	1
M101	1	1	7	1	1	2	1	1	9	1	1	1
M9	1	1	5	1	2	2	1	1	10	1	1	1
Glenda	2	1	3	1	2	2	1	1	10	1	1	1
Benchuna white	2	3	1	7	3	1	2	2	13	2	3	1
CH14	2	2	1	1	2	1	3	3	18	1	1	1

[a] **PS=Plant shap**e: 1=dwarf (determinate or semi-determinate), 2=climbing indeterminate; **GH=Growth habit**: 1=erect, 2=indeterminate, 3=creeping, 4=climbing; **ACB=Anthcynanin colouration of branches:** 1= absent, 3=light, 5=medium, 7=dark; **TL=Tendrils**: 1=absent, 3=few, 5=medium, 7=many; **LGC=Leaf green colour**: 3=light, 5=medium, 7=dark, **FC=Flower colour**: 3=light, 5=medium, 7=dark; **PA=Pod altitude**: 1=erect, 2=horizontal, 3=dropping; **PS=Pod shape of curvature**: 1=concave, 2=s-shape, 3=convex; **PL=Pod length**:(in cm), **SC=Seed number in dry stage hilum excluded**: 1=one, 2=two, 3=three or more; **SGC=Seed ground colour**: 1=whitish, 2=grey, 3=brownish, 4=purple, 5=black; **ST=Seed texture of surface of testa**: 1=smooth, 2= wrinkled.

3.2.2 Study sites

Field experiments were conducted under dry land, at three locations of South Africa viz. the University of Limpopo Experimental Farm at Syferkuil in Limpopo Province; Potchefstroom Grain Crops Institute and the Experimental Farm at Taung in North West Province. The study sites are described in Table 3.2.

Table 3.2 Description of the study sites.

Site/location	Soil type	Latitude	Altitude (m)
Syferkuil	Sandy loam, Glenrosa	23ºSouth, 29ºEast	1,261.6
Potchefstroom	Sandy	26ºSouth ,27ºEast	1,345
Taung	Sandy, Hutton	27ºSouth, 24ºEast	1,000

3.2.3 Experimental design and planting

Experiments were carried out using a randomized complete block design in factorial arrangement with three replications in each location. The three factors included 10 cowpea lines, three locations and three planting dates.

Each genotype was sown in four rows in plots 5m long with a 1m inter- row and 25cm intra-row spacing. The three planting dates were 8 November [early planting], 22 November [mid-planting], and 06 December 2004 [late planting] per location.

3.2.4 Data collection

3.2.4.1 Data on phenological traits, seed yield and yield components

The numbers of days to flowering were determined when 50% of the plants per line had flowered. The number of branches per plant and number of pods per plant were counted from eight randomly selected plants from the inner rows. Days to physiological maturity were determined when 50% of individuals per line were physiologically mature. Seed yield was determined during harvest from the two middle rows of each plot. Plot yield was later converted to kg/ha. The weights of 100 seed were determined from randomly selected seed after harvest.

3.2.4.2 Meteorological data

During the cropping season temperature and rainfall were recorded on a daily basis from the nearest meteorological station at each location.

3.2.5 Data analysis

Data on yield components and seed yield of each location were subjected to analysis of variance using Agrobase (2004). When found significant, data of each location were pooled for combined analysis. The LSD procedure at $p=0.05$ level was used for comparison of means. Correlation analysis was carried out to determine association of yield to its components.

To asses stability, Eberhart and Russell's (1996) joint regression model was used and the yields of each genotype were regressed on the mean environmental yields. Accordingly, a cultivar was considered stable when showing regression coefficient (bi) close to unity and a deviation from regression residual variance=$\sum s^2 d_i$ close to zero. To compute the superiority index (Pi) Lin and Binns, 1988) the maximum mean yield among all genotypes was noted at each location. Then for each genotype, the mean square difference between its yield and the maximum yield within each environment averaged over all environments was determined.

3.3 RESULTS

The result from analysis of variance on yield and yield components suggested highly significant differences among genotypes, locations, planting dates and their interactions (Appendix 4.1-4.7).

3.3.1 Days to 50% flowering

Table 3.3 summarizes the response of 10 cowpea lines to the number of days to 50% flowering against planting dates and locations.

At Potchefstroom the average days taken by genotypes to attain 50% flowering was 53 irrespective planting date. Average days to 50% flowering ranged from 48-88 on the first planting date, 36.67-80 (second planting date) and 74-83 (third planting date) (Table 3.3). The maximum number of days to 50% flowering was recorded on the last planting date (08 November). The result indicated that CH14 relatively took the highest number of days to flowering throughout the planting dates, while Pan311 consistently showed relatively less number of days to attain 50% flowering. As the planting dates were delayed, days to 50% flowering of all the genotypes increased except for Benchuana White, which had almost the same number of days to flowering. CH14 had decreased days to flowering as the planting dates were delayed.

At Syferkuil mean days to 50% flowering ranged from 54-70 during the first planting date. Lines showed 45-57 days to flowering during the second planting and 40-60 days on the last planting date (Table 3.3). The minimum number of days to 50% flowering was recorded at the last planting date (06 December). Delayed planting i.e. 22 November and 6 December resulted in reduction in the number of days to attain 50% flowering by 10% and 13%, respectively. The highest number of days to attain flowering were shown by Glenda and Benchuana White on the first plating date, IT85F-2687 on the second planting date and M9 on the last plating date. At this location, the lowest number of days to attain flowering were noted for M101 and M217 at the first two planting dates and Glenda at the last planting dates.

At Taung, days to 50% flowering varied from 49-69 days on the first planting, 40-59 days on the second and from 43-55 days on the last planting date (Table 3.3). Similar to Syferkuil, the last planting date seemed to delay flowering. CH14 took the maximum number of days to attain flowering whereas Pan311 had the minimum number of days. On the second planting date, responses ranged from 44-59 days. M217 and Benchuana White took the maximum number of days to attain 50% flowering.

In general, the second planting date seemed to be the best planting time for cowpea that gave rise to early days to 50 % flowering. Taung was the best location for early flowering. Pan311 was consistently but best in displaying the least number of days to reach 50% flowering.

Table 3.3 Mean response and rank using number of days to 50% flowering among ten cowpea genotypes at Potchefstroom, Syferkuil and Taung during 2004.

	Location and planting date*																	
	Potchefstroom						Syferkuil						Taung					
Line	08 Nov	R	22 Nov	R	06 Dec	R	08 Nov	R	22 Nov	R	06 Dec	R	08 Nov	R	22 Nov	R	06 Dec	R
Pan311	48	9	52	9	74	10	57	7	53	4	43	8	49	10	44	9	43.33	9
IT18E-16	48	10	36.67	10	74	9	58	6	56	2	53	5	51	9	49	7	47	7
IT85F-2687	52	8	54	5	77	8	62	5	57	1	53	4	52	7	57	2	53	4
M217	54	7	56	8	81	4	63	4	45	7	52	6	56	7	59	1	55	2
M28	57	4	57.67	7	81	5	55	9	45	9	58	3	58	5	56	3	54	3
M101	57	5	58.67	6	79	7	54	10	46	10	59	2	57	6	55	5	54	6
M9	57	6	67.67	4	79	6	57	8	49	8	60	1	59	3	56	4	52	5
Glenda	69	3	72.67	3	83	2	70	2	54	3	40	10	63	3	50	8	54	1
Benchuana White	76	2	73	2	81	3	70	1	52	5	42	9	66	2	40	10	43	10
CH14	88	1	80	1	83	1	66	3	52	6	45	7	69	1	54	6	45	8
Mean	60.40		60.73		79.20		61		50.7		50		57.90		51.80		50.03	
LSD	1.2397		11.966		1.3678		1.1940		1.1268		1.4699		1.1135		1.3678		0.6839	
CV	1.45		13.92		1.22		1.38		1.57		2.08		1.36		1.87		0.97	
LSD (L X PD)	1.9429						4.1120						0.1439					
CV (L X PD)	2.11						2.84						0.20					

* LSD(0.05)= Least significant difference, L=line, PD=planting date, CV(%)= Coefficient of variance, R=rank.

3.3.2 Days to physiological maturity

The average time taken to reach for 50% physiological maturity among lines varied from 123-135.47 days at Potchefstroom (Table 3.4). On the first planting date, lines matured from 110-132 days while on the second planting, maturity varied from 116-129 days and 129-142 days at the last planting date. Fewer days to 50% maturity was shown by the second planting date. Early matured genotypes at this location were Pan311 and IT18E-16. The highest numbers of days to attain maturity were noted for CH14 and Benchuana White. There was an increase in the number of days to physiological maturity as the planting date was delayed.

At Syferkuil, early planting resulted in delayed maturity and was significantly higher than the second and the last planting dates. Pan311 and IT18E-16 were fast maturing genotypes while CH14 had delayed maturity at this location (Table 3.4).

The average days to 50% physiological maturity ranged from 111.1-122.7 at Taung. The last planting date took the maximum days to attain physiological maturity and the second planting date took the minimum days to attain physiological maturity. Pan311, IT18E-16, and IT85F-2687 were the fast maturing genotypes at this location (Table 3.4). The two genotypes (i.e.) IT18E-16 and IT85F-2687) consistently showed relatively fewer days to reach maturity across planting dates.

Generally, lines matured earlier at Syferkuil than the other locations. CH14 was consistently the late maturing genotype across all locations in this study.

Table 3.4 Mean response and rank o physiological maturity among ten cowpea genotypes at Potchefstroom, Syferkuil and Taung during 2004.

Line	Location and planting date[*]																	
	Potchefstroom						Syferkuil						Taung					
	08 Nov	R	22 Nov	R	06 Dec	R	08 Nov	R	22 Nov	R	06 Dec	R	08 Nov	R	22 Nov	R	06 Dec	R
Pan311	110	10	120	6	134	8	120	10	92	10	103.33	4	101	8	67	9	96	8
IT18E-16	116	9	122	5	134	9	126	8	96	8	94.67	10	89	9	73	8	94	9
IT85F-2687	118	8	123	4	128	7	123	9	94	9	94.67	9	72	10	65	10	93	10
M217	123	6	124	3	138	3	128	5	102	5	99.33	8	117	6	102	7	99	7
M28	126	5	129	1	136.67	5	127	7	102	6	102	6	126	1	129	1	136	1
M101	126	4	129	2	136	6	127	6	100	7	100.67	7	100	4	126	2	129	2
M9	119	7	119.67	9	136	10	128	4	104	4	102.67	5	120	3	119	3	113	5
Glenda	130	3	116	10	129	2	132	3	112	3	109.33	3	119	7	104	5	112	6
Benchuana White	130	1	119.89	8	141	2	133	2	123	2	119.33	2	116	7	102	6	118	4
CH14	132	2	121	7	142	1	134.	1	126	1	125	1	121	3	117	4	120	3
Mean	123		122.4		135.47		127.8		105.1		105.1		108.1		100.4		111.1	
LSD	1.194		4.1780		1.4850		0.8955		0.8955		6.0720		1.4623		0.7755		1.0658	
CV	0.69		2.41		0.77		0.50		0.60		18.04		0.95		0.58		0.72	
LSD (L X PD)	2.15						5.6318						0.5523					
CV (L X PD)	1.24						3.66						0.4					

[*] LSD(0.05)= Least significant difference, L=line, PD=planting date, CV(%)= Coefficient of variance, R=rank.

3.3.3 Number of branches per plant

Table 3.5 indicates the mean number of branches per plant for the 10 lines. The number of branches per plant ranged from 5-6.53 at Potchefstroom. More number of branches were achieved at the second planting date. The number of branches per plant ranged from 3-11 at the first and the second planting date and 3-7 at the last planting dates (Table 3.5). Glenda produced the highest number of branches per plant at the first planting date (10 branches) followed by CH14 (7 branches) at both the second and last planting dates. M9 and Benchuana White produced the lowest number of branches per plant at the first planting date and Pan311 and IT85F-2687 on the last planting date.

At Syfekruil, average branches per plant ranged from 5.2—6.88. Higher number of branches per plant was recorded at the first planting date (08 November), whereas lower number of branches was recorded at the second planting date (22 November) that was statistically similar to that of the third planting date (06 December). Pan 311 produced the highest number of branches across planting dates. The lowest number of branches was noted for M101 across all the planting dates. A decreasing trend in number of branches per plant was observed as the planting date was delayed at Syferkuil.

At Taung the mean branch number ranged from 5-7. Higher number of branches per plant was produced at the second planting date (22 November). CH14 produced the highest number of branches per plant across planting dates. Fewer branches per plant was recorded for IT85-2687 on the first planting date and IT18E-16 on the last planting date.

Overall, at Syferkuil lines showed the best number of branches than the other locations. When genotypes were ranked across locations CH14, M28 and M9 produced the highest number of branches per plant (Table 3.5).

Table 3.5 Mean number of branches per plant and ranks among ten cowpea genotypes at Potchefstroom, Syferkuil and Taung during 2004.

	Location and planting date[*]																	
	Potchefstroom						Syferkuil						Taung					
Line	08 Nov	R	22 Nov	R	06 Dec	R	08 Nov	R	22 Nov	R	06 Dec	R	08 Nov	R	22 Nov	R	06 Dec	R
Pan311	6	3	4	5	4	4	9	1	7	1	6	1	6.33	5	7	4	6.33	7
IT18E-16	4	5	5	4	5	3	6	8	5	8	4.6	9	5.67	7	5.67	7	6.33	9
IT85F-2687	5	4	4	5	3	5	8	3	6.67	4	6.44	2	5	9	5	9	6.67	6
M217	6	3	5	4	4	4	5	10	4.67	10	4.67	8	6	6	6	6	7.33	5
M28	8.3	2	6	3	4	4	6.7	6	6	6	5	6	7.67	2	7.67	3	6	10
M101	6	3	6	3	5	3	5.67	7	5.33	7	4	10	4	10	6	5	6.33	8
M9	3	6	7	2	6	2	6.67	5	6.67	3	5	5	5.33	8	5	10	8.33	4
Glenda	11	1	7	2	7	1	5.3	9	6	5	5.67	4	6.67	4	5.33	8	8.67	2
Benchuana White	3	6	10.33	4	6	2	7	4	5	9	5	7	7	3	7.67	2	8.33	1
CH14	4	5	11	1	5.67	1	8.67	2	6	2	6	3	7.67	1	7.67	1	8.33	9
Mean	5.63		6.53		4.96		6.83		5.83		5.2		6.13		7		5	
LSD	0.7158		1.4444		1.2216		1.0232		0.7311		1.2576		0.8129		2.6809		1.5269	
CV	8.97		15.69		18.36		10.58		8.85		17.08		9.36		28.69		14.84	
LSD (L X PD)	1.903						0.5062						1.204					
CV (L X PD)	23.63						9.83						13.43					

[*] LSD(0.05)= Least significant difference, L=line, PD=planting date, CV(%)= Coefficient of variance, R=rank.

3.3.4 Number of pods per plant

The mean response on the number of pods per plant at each location is presented in Table 3.6. At Potchefstroom, pods per plant varied from 27-85 at the first planting date, 16.67-101 at the second planting date and 15-39 at the last planting date. Highest numbers of pods was recorded on the second planting date (22 November). A clear decline on the number of pods per plant was observed as the planting dates were delayed. Glenda, M217 and CH14 were relatively best genotypes displaying higher number of pods per plant at the first planting dates. However, their rankings were inconsistent across planting date. Relatively greater number of pods per plant across planting dates was observed in M217. Six out of ten of the genotypes had a decreasing trend in pod number as the planting date was delayed except for IT18E-16, IT85F-2687, Benchuana White and CH14.

At Syferkuil, the variation on average number of pods per plant was from 11.83-16.86 across planting dates. Within the first planting date lines showed mean number of pods that ranged from 13-22,while at the second planting date lines had 9-18 pods per plant and at the last planting date these values ranged from 6-19. Similar to Potchefstroom, the best planting date was 8 November for greater number of pods per plant. Glenda produced the highest number of pods per plant at the first planting date while M28 produced the highest pods per plant at the second planting date. CH14 and Pan311 produced the lowest number of pods per plant at the first and the second planting dates, respectively, (Table 3.6).

At Taung, the average number of pods per plant ranged from 26.73-42.3 across planting dates. At this location, higher numbers of pods was obtained when lines were planted on 08 Nov. Planting date one provided 15.3-64, the second planting date had 21.67-57 pods whereas at the last plating date 16-44.3 pods per plant were harvested (Table 3.6). M9, M217 and CH14 produced the highest number of pods per plant at the first, second and the last planting date, respectively. Benchuana White, CH14 and M9 produced the lowest number of pods per plant at the first, the second and the last planting, respectively.

Table 3.6 Mean number of pods per plant and rank among ten cowpea genotypes at Potchefstroom, Syferkuil and Taung during 2004.

	Location and planting date*																	
	Potchefstroom						Syferkuil						Taung					
Line	08 Nov	R	22 Nov	R	06 Dec	R	08 Nov	R	22 Nov	R	06 Dec	R	08 Nov	R	22 Nov	R	06 Dec	R
Pan311	44	3	62	4	28.33	1	13.67	9	9	10	6	10	42	5	38.33	5	31.67	3
IT18E-16	28.76	5	29	7	33	3	16	6	14	5	11	6	35	7	18.67	9	35.33	2
IT85F-2687	35.67	4	87	2	15.67	5	18	4	16	4	15	5	32	8	23	7	30.33	4
M217	57.33	3	77.33	3	21.67	7	20.33	3	17	3	15	5	60	3	57	1	15.67	8
M28	43	2	47.33	6	39.33	9	19.21	2	18	1	16.33	2	51	4	40	4	22.33	5
M101	43.33	3	39.33	8	15	8	15	8	13.33	7	11	7	62	2	45	2	15.67	8
M9	27	6	18.67	9	21	5	16.1	5	13.67	6	10	8	64	1	44.67	3	17.67	7
Glenda	85.33	1	55.67	5	31.33	4	22	2	18	2	16	3	25	9	25.67	6	19	6
Benchuana White	40.33	6	101	1	22.67	3	15.33	7	13	8	9	9	15.3	10	21.67	8	35.33	2
CH14	46.67	5	16.67	10	18.3	6	13	10	11	9	9	1	37.33	6	15	10	44.33	1
Mean	45.23		53.4		24.64	10	16.86		14.30		11.83		42.36		32..90		26.73	
LSD	3.2459		21.31		7.3525		1.1908		0.5517		1.1846		2.6432		2.0554		7.5399	
CV	5.07		25.90		22.91		4.95		2.73		7.07		4.40		4.41		4.3481	
LSD (L X PD)	4.3914						0.6555						4.4942					
CV (L X PD)	7.83						3.34						9.63					

* LSD(0.05)= Least significant difference, L=line, PD=planting date, CV(%)= Coefficient of variance, R=rank.

In summary, the first planting date showed greater number of pods per plant across locations. There was not much difference in number of pods per plant across locations. Glenda, M28 and M217 were the best lines in terms of number of pods per plant (Table 3.6).

3. 3.5 Number of seeds per pod

The response of lines across locations for mean number of seeds per pod is presented in Table 3.7. At Potchefstroom, the average seed number across planting dates varied from 12.28 -22.63. The mean numbers of seeds per pod on the first planting date ranged from 9-16.7, 9-17 (second plating date) and 14-35 (third planting date) (Table 3.7). The number of seeds per pod was relatively greater during the first and the second planting dates. Pan311 and IT85F-2687 showed better seed set.

At Syferkuil, genotypes produced 7.6-11.8 seeds per pod on average. At this site there were no significant differences among planting dates for seed set (Table 3.7). Pan 311 was the superior line followed by IT85F-2687 for high seed set.

Similar to Syferkuil there was less variation in seed set at Taung (Table 3.7). At Taung, the number of seeds per pod varied from 9.89-11.76. However, there were variations among lines within each planting dates. In both the first and the last planting dates, the highest number of seeds per pod was produced by CH14 (Table 3.7). In the first planting date, Benchuana White had the highest seed set. The lowest number of seeds per pod was produced by M9 in both the first and the second planting dates. Pan 311 was poor in seed set when planted on 06 Dec (last planting date).

Table 3.7 Mean number of seeds per pod and rank among 10 selected cowpea lines at Potchefstroom, Syferkuil and Taung during 2004.

	Location and planting date*																	
	Potchefstroom						Syferkuil						Taung					
Line	08 Nov	R	22Nov	R	06Dec	R	08 Nov	R	22Nov	R	06Dec	R	08 Nov	R	22Nov	R	06Dec	R
Pan311	16.67	1	17	1	28.33	3	14.33	1	12	1	8	1	13.33	3	12.22	3	7.33	10
IT18E-16	14	3	13.67	4	33	2	12.33	3	9	6	7	7	15.33	2	14.33	1	12	2
IT85F-2687	11.67	6	15.67	2	15.33	9	13.67	2	11	3	9	2	12.67	5	9	8	11.67	3
M217	10.67	8	10.67	7	25.33	4	10.67	6	8	8	7	6	12	6	9	9	10	5
M28	9	10	9	8	16.33	8	9.67	8	7	10	7	5	9	8	10.	6	8.3	9
M101	10	9	10	6	14	10	8.67	9	7	9	7	8	8	9	8.3	7	8	8
M9	11.67	5	11.67	10	23	5	9	10	9	5	7	4	7	10	8	10	8	7
Glenda	12	4	12	3	35	1	10	7	9	7	7	9	11.67	8	13.67	2	11	4
Benchuana White	11	7	11	5	17.33	7	11.67	4	12	2	8	3	16.33	1	10.33	5	9	6
CH14	16.16	2	16.33	9	18.67	6	11	5	11	4	9	10	12.33	7	9.90	4	13.67	1
Mean	12.28		12.70		22.63		11.10		9.5		7.6		11.76		10.47		9.89	
LSD	2.0590		1.1592		1.0797		1.1496		1.1940		0.9787		0.6619		0.8913		1.1592	
CV	11.86		6.64		3.36		7.73		8.80		8.75		3.94		5.71		8.27	
LSD (L X PD)	1.3986						0.7133						0.0686					
CV (L X PD)	6.50						5.83						4.59					

* LSD(0.05)= Least Significant difference, L=line, PD=planting date, C.V(%)= Coefficient of variance, R=rank.

In terms of achieving high seed set per pod, the ideal planting date at both Potchefstroom and Syferkuil was the first planting date (08 November), whereas planting on 22 November was found to be better at Taung. Overall, best seed set was observed at Taung. The best performing genotypes for greater seed set sets were Pan311 and IT18E-16 across the study sites.

3.3.6 Hundred seed weight

Table 3.8 represents seed weights from hundred randomly selected seeds of each line. There was low a range (14.1-16.07 g/100 seeds) at Potchefsroom for hundred seed weight among planting dates. However, within each planting date there were significant variations between lines viz. 10-20 g (first planting date), 12-20 g (second planting date) and 10-22 g (third planting date). Heavier seed weight was noted on the first planting date and the lowest on the last planting date. Glenda had the highest hundred seed weight on the first planting date, with CH14 on the second and last planting dates. At Syferkuil, hundred seed weight ranged from 11.6-17.2 g (Table 3.8). At this location across the planting dates, CH14 produced the highest hundred seed weight and M217 the lowest. At Taung, lines had low hundred seed weight as compared to the other locations. The average seed weight varied from 13-14.70 g. CH14 was relatively the best genotype for hundred seed weight at this location. Overall, when genotypes were compared across locations, CH14 produced the highest hundred seed weight, whereas M217 produced the lowest.

The best planting date for maximum seed weight was 22 November at both Syferkuil and Potchefstroom. The hundred seed weight increased as the planting date was delayed in Taung. Generally, lines had better mean seed weight at Syferkuil than on the other sites (Table 3.8).

Table 3.8 Hundred seed weight (g/100 seeds) and rank among 10 selected cowpea lines at Potchefstroom, Syferkuil and Taung during 2004.

	Location and planting date*																	
	Potchefstroom						Syferkuil						Taung					
Line	08 Nov	R	22 Nov	R	06 Dec	R	08 Nov	R	22 Nov	R	06 Dec	R	08 Nov	R	22 Nov	R	06 Dec	R
Pan311	18	2	13	8	16	4	15	7	13.33	7	11	8	13	8	15	7	12	4
IT18E-16	15	5	15	4	14.02	5	16	6	13.67	6	12	7	14	5	16	6	11	5
IT85F-2687	14	7	15	3	10	9	14	8	12.67	8	13	10	16	2	14	8	9.33	9
M217	10	6	12	10	11	7	12	10	10.67	9	11	3	13	6	21	3	8.67	10
M28	11	9	13	7	10.05	10	20	4	19.67	4	21	4	12	9	14	9	10	7
M101	10	1	14	5	11	8	20	3	20.33	3	20	2	10	10	17	5	11	6
M9	11	10	14	6	14	6	21	2	20.67	2	21	6	13	7	12	10	16	1
Glenda	20	1	17	2	16.06	3	14	9	13.67	6	14	5	14	4	20	4	14	2
Benchuana White	10	7	12	9	18	2	17	5	17	5	18	1	16	3	23	1	14	3
CH14	11	8	20	1	22	1	23	1	23	1	23		20	1	18	2	9	8
Mean	16.07		14.10		14.08		17.2		16.46		16.40		13		14.70		11.60	
LSD	0.896		0.5907		0.8955		0.8956		0.8220		1.1940		1.3265		0.2585		3.7440	
CV	4.87		2.84		4.11		3.68		3.53		5.14		6.64		1.07		22.80	
LSD (L X PD)	0.889						0.5546						1.0857					
CV (L X PD)	0.20						2.43						10.21					

* LSD(0.05)= Least significant difference, L=line, PD=planting date, CV(%)= Coefficient of variance, R=rank.

3.3.7 Seed yield

3.3.7.1 Average seed yield response across environments

Table 3.9 summarizes yield response of the genotypes across locations and planting dates. The average seed yield ranged from 3078.90-3363.93 kg/ha at Potchefstroom. Genotypes differed significantly in seed yield in all the planting dates at Potchefstroom, ranging from 2414.81-4959.26 kg/ha at the first planting date, 2527.41-4173.00 kg/ha at the second planting date and 2554.67-4156.67 kg/ha at the last planting date (Table 3.9). The higher mean seed yield was obtained when genotypes were planted on 06 December (4575.741 kg/ha) followed by 08 November (3646.97 kg/ha). CH14 was the highest yielding genotype on the first and the last planting dates with yield measured at 4959.33 and 4155.67 kg/ha, respectively. The genotypes with the lowest yields were M28 on the first planting date, M9 on the second plating date and Glenda at the last plating date (Table 3.9).

At Syferkuil, the mean seed yield varied from 2811.88 -3285.63 kg/ha. Yield ranged from 1466.00-5140 kg/ha at the first planting date, 1743.67-4444.00 kg/ha at the second planting date and 1155.00–4337.00 kg/ha at the last planting date. Higher seed yield was produced at the second planting date (22 November) and low yield at the last planting date (06 December). Benchuana White had a significantly higher yield in both the first and the last planting dates recording 5140 kg/ha and 4337 kg/ha, respectively. M28 produced the lowest yield on the first and the last planting dates. M28 consistently yielded lowest in all the planting dates.

At Taung, mean seed yield ranged from 3531.96-4575.741 kg/ha. During the last planting date, (06 December) genotypes produced significantly higher yields. Low yield was recorded at the second planting date. Similar to Potchefstroom, the seed yield decreased at later planting dates. Seed yield ranged from 1654.00-5932.70 kg/ha at the first planting date, 2125.38-5111.07 kg/ha at the second planting date and 3190.03-6112.33 kg/ha at the last planting date (Table 3.9). Pan311 was the highest yielding genotype at the first plating date followed by IT85F-2687. The lowest yielding genotype across planting dates was M9 which produced 2692.00 kg/ha.

Table 3.9 Yield responses (kg/ha) and rank among 10 selected cowpea lines at Potchefstroom, Syferkuil and Taung during 2004.

	Location and planting date[*]																	
	Potchefstroom						Syferkuil						Taung					
Line	08 Nov	R	22 Nov	R	06 Dec	R	08 Nov	R	22 Nov	R	06 Dec	R	08 Nov	R	22 Nov	R	06 Dec	R
Pan311	3899.26	3	4173.00	1	2640.00	9	3689.67	4	3197.60	3	2900.00	5	5932.59	1	5271.85	1	3427.04	6
IT18E-16	2747.41	7	3440.74	5	2932.67	6	4909.00	2	4444.00	1	3708.89	4	4749.70	2	3285.19	6	4245. 93	7
IT85F-2687	4123.70	2	3581.74	3	3845.33	2	2286.67	8	2705.67	4	2705.92	7	2776.30	7	4955.71	2	3190.37	10
M217	2483.96	9	3205.93	9	3342.33	3	2626.67	6	2420.00	7	2420.33	2	1956.30	8	3368.15	5	4065.93	8
M28	2414.81	10	4043.71	2	2579.33	7	1466.00	10	1739.33	10	1739.33	8	1814.07	9	2146.93	9	5524.45	3
M101	2924.45	6	3491.85	4	2802.00	8	2455.00	7	1743.67	9	1743.70	9	1654.00	10	2125.19	10	4795.55	5
M9	2547.41	8	2527.41	10	3001.33	4	2031.67	9	2554.67	5	2554.81	10	3044.44	6	3045.19	6	6112.26	2
Glenda	3088.89	4	2875.56	8	2554.67	10	3655.00	5	3218.00	2	3217.78	3	3161.48	4	3794.81	4	5247.59	1
Benchuana White	3088.89	5	3064.44	7	2935.67	5	5140.00	1	1898.26	8	4337.04	1	3154.07	5	2394.81	8	5247.41	4
CH14	4959.26	1	3235.56	6	4155.67	1	4596.67	3	2535.00	6	2791.00	6	3217.78	3	4931.85	3	3571.11	9
Mean	3227.67		3363.93		3078.9		3285.63		2645.62		2811.88		3146.073		3531.95		4575.741	
LSD	150.7478		790.4576		574.48		155.42		192.0367		14.31		352.835		162		11.97	
CV	3.30		16.60		13.18		3.71		4.55		0.36		6.83		3.25		770.6974	
LSD (L X PD)	535.6188						135.5528						493.8223					
CV (L X PD)	12.17						3.40						9.62					

[*] LSD(0.05)= Least significant difference, L=line, PD=planting date, CV(%)= Coefficient of variance, R=rank.

3.3.7.2 Yield stability

The overall mean yield of genotypes, joint regression and superiority stability statistics are presented in table 3.10. When compared using mean performance IT18E-16 ranked first followed by Pan311 and M28. The superiority parameter (Table 3.10) also confirmed the ranks of IT18E-16 and Pan311. According to the joint regression stability model the low yielding cultivar M101 and M217 are more stable as indicated by $\sum s^2 d_i$ (Table 3.10).

Table 3.10 Mean yield (kg/ha) 10, joint regression and cultivar superiority stability statistics for comparisons of ten cowpea genotypes tested at nine environments[a].

	Joint regression						Superiority	
Genotype	Mean yield	R	b_i	R	$\sum S^2 d$	R	P_i	R
Pan311	3904.53	2	0.6854	8	1165563.00	8	1804327.53	2
IT18E-16	4384.86	1	0.8747	7	4928800.22	10	846447.93	1
IT185F-2685	3389.14	10	0.2540	6	726890.90	5	4039777.02	6
M217	2816.38	9	0.8537	3	338913.24	2	5302785.70	8
M28	2841.89	3	1.6339	2	1201159.89	9	5746540.12	9
M101	2612.67	8	1.4039	1	599608.67	3	6056534.25	10
M9	2800.33	5	1.8511	4	274354.70	1	4848866.10	7
Glenda	3290.62	4	1.9786	5	682402.47	4	3938008.14	5
Benchuana White	3685.10	7	0.3677	9	1102674.63	7	3331489.59	4
CH14	3775.31	6	0.0970	10	919294.03	6	3300134.84	3

[a] R=rank; b_i=regression coefficient;$\sum s^2 d_i$=sum of deviation from regression; Pi=superiority parameter.

Overall, irrespective of genotype and location during planting date one, there were higher yield produced. Potcheftsroom showed relatively better yield due to higher rainfall and lower temperatures (Tables 3.11 and 3.12). The lowest yield was achieved at Syferkuil. Higher yield performance lines IT18E-16, CH14 and Pan311 were identified as best candidates for production across these environments.

Table 3.11 Maximum and minimum temperatures (^{o}C) for each location of experimentation averaged over 2004-2005.

Month	Taung		Potchefstroom		Syferkuil	
	Max	Min	Max	Min	Max	Min
November	27.72	12.78	34.2	17.3	28.5	12.4
December	30.30	19.29	32.4	17.1	34.1	17.3
January	27.16	17.62	32.2	17.8	34.8	17.2
Febraury	25.17	19.64	32.1	17.6	32.1	16.6
March	26.32	15.37	28.6	14.4	36.7	15.6
Average	27.13	16.4	31.9	16.84	33.16	15.82

Table 3.12 Total rainfall (mm) for each location of experimentation averaged over 2004-2005.

Month	Location		
	Potchefstroom	**Taung**	**Syferkuil**
November	50.8	50.6	59.2
December	117.1	182.2	102.5
January	187.2	92.0	46.4
February	69.3	91.9	56.2
March	56.2	83.9	55.4
Total	480	500.60	319.7

3.4 CORRELATIONS OF YIELD AND YIELD COMPONETS IN COWPEA

Correlation coefficients for pair wise comparison of the degree of relationship between yield and yield components in cowpea at the three locations are presented in Tables 3.13-3.16.

At Potchefstroom (Table 3.13), there were significant negative correlations between seed yield and number of days to flowering, days to physiological maturity and number of pods per plant. This suggests that delayed flowering and maturity as well as presence of pods without seed set had negative effect on seed yield. At this location, seed yield had a weak association with number of seeds per pod, number of branches per plant and hundred seed weight (Table 3.13). There were strong and positive relationships between days to maturity with days to flowering, number of pods per plant and number of branches per plant, and hundred seed weight with number of seeds per pod (Table 3.13).

Table 3.13 Correlation coefficients for pair wise comparison of the relationship between yield and yield components in cowpea at Potchefstoom[a].

	DF	DM	PP	SP	BP	HS
DM	0.33^{*}					
PP	0.12^{NS}	0.24^{*}				
SP	0.05^{NS}	-0.13^{NS}	-0.20^{NS}			
BP	-0.13^{NS}	0.27^{*}	-0.26^{*}	0.06^{NS}		
HS	0.04^{NS}	0.02^{NS}	-0.15^{NS}	0.22^{*}	0.09^{NS}	
SY	-0.25*	-0.25^{*}	-0.37^{**}	0.18^{NS}	0.12^{NS}	-0.08^{NS}

[a] DF=Days to flowering, DM=Days to maturity, BP=Branches per plant, PP=Pods per plant, SP=Seed per pod, HS=Hundred seed weight, SY=Seed yield.
* and ** denote significant correlations at 5% and 1% probability levels, respectively; NS=non significant.

At Syferkuil (Table 3.14), seed yield had a positive strong correlation with number of seed sets per pod and a negative relationship with the number of pods produced per plant. At this site, there were strong and positive correlations among yield components as compared to Potchefstroom.

Table 3.14 Correlation coefficients for pair wise comparison of the relationship between yield and yield components in cowpea at Syferkuil [a].

	DF	DM	PP	SP	BP	HS
DM	0.41^{**}					
PP	0.41^{**}	0.29^{**}				
SP	0.48^{**}	0.46^{**}	0.16^{NS}			
BP	0.27^{*}	0.35^{**}	0.07^{NS}	0.65^{**}		
HS	0.01^{NS}	0.36^{**}	-0.17^{NS}	0.14^{NS}	0.14^{NS}	
SY	-0.01^{NS}	0.14^{NS}	-0.23^{*}	0.38**	0.21^{NS}	-0.13^{NS}

[a] DF=Days to flowering, DM=Days to maturity, BP= Branches per plant, PP=Pods per plant, SP=Seed per pod, HS=Hundred seed weight, SY=Seed yield.
* and ** denote significant correlations at 5% and 1% probability levels, respectively; NS=non significant.

At Taung (Table 3.15), there were poor associations between seed yield and its components. However, there were strong and positive associations among the yield components.

Table 3.15 Correlation coefficients for pair wise comparison of the relationship between yield and yield components in cowpea at Taung[a].

	DF	DM	PP	SP	BP	HS
DM	0.68**					
PP	-0.37**	-0.39^{**}				
SP	0.44**	0.41^{**}	-0.25^{*}			
BP	0.05^{NS}	-0.19^{NS}	0.32^{*}*	-0.30^{**}		
HS	0.21^{*}	0.07^{NS}	-0.09^{NS}	0.18^{NS}	0.32^{**}	
SY	-0.02^{NS}	-0.01^{NS}	0.09^{NS}	-0.09^{NS}	-0.15^{NS}	0.11^{NS}

[a] DF=Days to flowering, DM=Days to maturity, BP= Branches per plant, PP=Pods per plant, SP=Seed per pod, HS=Hundred seed weight, SY=Seed yield.
* and ** denote significant correlations at 5% and 1% probability levels, respectively; NS=non significant.

The correlations of yield and yield components across locations calculated by pooling the mean values of each location are presented in Table3.16. The results show that seed yield had negative and significant correlations with days to maturity and hundred seed weight. Other significant positive correlations were between days to flowering with days to maturity and number of seeds per pod; days to maturity with pods per plant and seeds per pod and hundred seed weight with number of branches per plant Table 3.16.

Table 3.16 Correlation coefficients for pair wise comparison of the relationship between yield and yield components in cowpea across locations[a].

	DF	DM	PP	SP	BP	HS
DM	0.58^{**}					
PP	0.11^{NS}	0.13^{*}				
SP	0.56^{**}	0.37^{**}	0.11^{NS}			
BP	-0.07^{NS}	-0.03^{NS}	0.09^{NS}	-0.18^{**}		
HD	-0.00^{NS}	0.11^{NS}	-0.24^{**}	-0.02^{NS}	0.16^{*}	
SY	-0.11^{NS}	-0.18^{**}	-0.01^{NS}	0.06^{NS}	0.12^{NS}	-0.13^{*}

[a] DF=Days to flowering, DM=Days to maturity, BP= Branches per plant, PP=Pods per plant, SP=Seed per pod, HS=Hundred seed weight, SY=Seed yield.
* and ** denote significant correlations at 5% and 1% probability levels, respectively; NS=non significant.

3.5 DISCUSSION

The present study found significant differences among 10 diverse cowpea germplasm for yield and yield components when tested at three planting dates and three locations in South Africa. The differences were due to genetic variations among lines and environmental factors and climatic conditions, among others.

In this study, there were fewer number of days to 50% flowering at Syferkuil compared to other locations. This might be ascribed to higher temperatures during planting in December and January, which was the onset of flowering (Tables 3.10 and 3.11). Temperature is undoubtedly the dominant factor that affected flowering and maturity (Wallace *et al*. 1995). This has also been reported in navy bean (Husain *et al.*, 1988) and in field beans (Wallace *et al.,* 1995). The authors observed that the rate of development of beans was largely controlled by temperature accounting for 80% of the variation. Marfo and Hall (1992) suggested that the combination of high temperatures and long days can slow down or inhibit floral bud development, thus resulting in few flowers being produced. Their results were also supported by Wien and Summerfield (1984) who mentioned that warmer temperature hasten the appearance of flowers in day-length sensitive genotypes.

In this study cowpea genotypes showed a tremendous variation across planting dates and localities in seed yield and yield components. Lines CH14, IT18E-16 and Pan311 were identified as the best genotypes that can be cultivated across locations for seed yield and yield components. The lines had erect growth habits and medium green leaf color with efficient photosynthesis and high conversion efficiency (Table 3.1). The lines formed more and longer pods with high seed sets that could contribute to a high harvest index. The above mentioned genotypes were determinate in growth, produced many branches because of secondary branching, and large portions of nodes that were reproductive resulted in higher final yield. Further, there was higher seed yield from Benchuana White at Syferkuil both during the first and the last planting dates. This is an indication that growers can successfully plant this genotype either early or late during the growing season. The highest seed yield recorded by CH14 at Pothchefstroom may be partly attributed to its big seed size (Table 3.1). This was also suggested by Razaq (1995) who observed that genotypes differed significantly in the number of seeds per pod. Likewise, Ahmad *et al.* (2001) observed that the genotypic makeup influence number of seeds per pod and yield.

According to Board *et al* (1999), there is often a significant variation in the number of seeds per pod as some plants fail to develop pods. The author further indicated that the response of number of seeds per pod to sowing date was inconsistent. The results differ with those of Thompson and Taylor (1981) where seed number had proved to be the most consistent component of yield. This was to be somewhat surprising because the number of seeds per pod can vary considerably between nodes of the same plant (Ishag, 1973). Usually, fewer seeds per pod are produced at the upper nodes where shriveled ovules are common (Dantuma and Thompson, 1983). Experimental results by Duarte and Adams (1972), Krarup and Davis (1970) indicated that number of seeds per pod is usually considered to be related to yield in a positive manner. Chung and Goulden (1970), however, concluded that both phenotypic expressions are not associated. The number of pods per plant is the most important component in determining yield in several legume crops (Pandey and Gritton, 1975). Generally, variation in the number of pods per plant depends on the type of legumes species. However, the number of pods per plant produced, or maintained to final harvest, depends on environmental conditions and management practices (Knott and Tolukdar, 1971).

Across locations, the first planting date was mostly better in yield performance among genotypes. At Taung, late planting date on average resulted in an increase in yield except for line Pan311. This could indicate that temperature and rainfall were favourable to yield at this planting date.

Among the three locations, Taung was the best to achieve greater yield. This was probably due to higher rainfall and lower temperature conditions during the growing season. These could have been the results of high rainfall and low temperature. The results are in accordance with that of Ahmad *et al.* (2001), who reported that high temperatures experienced during the growing season resulted in low yields and poor pod set. In addition, Steele *et al*. (1985) reported a reduction in seed yield due to hot temperature conditions.

In the present study cowpea lines showed inconsistencies in seed yield. This is an indication of sensitivity to the environment, mainly temperature and rainfall caused interaction between genotypes and environment. The results may suggest that most genotypes had the capacity to yield well depending on the planting date. The poor seed yield in line M28 is an indication of number of pods per plant. There were variations in rank order among genotypes for various yield components at the same or different planting dates or location showing strong the environment had a strong influence. Differences in temperature, moisture, photoperiod for flowering and physiological maturity create variation and instability among yield components of the genotypes. Thus, it is important to identify suitable genotypes to synchronize flowering and physiological maturity with the climatic conditions for maximum yield achievement.

In the present study, there were significant positive correlations between days to flowering with days to maturity and number of seeds per pod. Further, days to maturity had significant strong correlations with pods per plant and number of seeds per pod (Tables 3.13, 3.14, 3.15). This indicated that such traits maybe selected simultaneously in a cowpea improvement program. In general, seed yield had significant negative correlation with number of pods per plant (Tables 3.12, 3.13, 3.15) indicating that production of greater number of pods per plant would not guarantee high seed yield as most pods could be without seed. This, however, is not a disadvantage if a cowpea variety is being selected for fresh fruits. Kumar and Hirochika (2000), however, reported significant and positive correlation between the number of pod per plant and seed yield.

The presence of strong and positive correlations among yield components themselves in this study is in accordance with Tosun *et al.* (1991) and Serene *et al.* (2000). Husain *et al*. (1988), reported that number of pods per plant was consistently and strongly correlated with yield and similar correlations were reported by other workers (Kambal, 1969; Ishag, 1973). The above mentioned authors also observed that number of seeds per pod was considerably variable than the number of pods per plant. According to Chung and Goulden (1970) and Yassim (1973), the correlation of pods per plant and yield have been determined to be positive and significant in seed legumes. Therefore, it would appear as a good characteristic to use for improvement of yield. Furthermore, it is easy to assess and there is considerable variation available in nature to make use of this trait. Kuruvadi and Escobar (1987) observed association between yield and number of pods per plant in common bean. The authors concluded that selection for number of pods per plant, number of seeds per pod and seed weight individually or simultaneously should increase yielding ability of the genotypes.

The present study found negative correlation among number of pods per plant and number of seeds per plant that is contradictory with results reported by Knott and Tolukdar (1971). However, the negative and non-significant correlation between the number of pods and hundred seed weight was in accordance with Adipala *et al.* (1997).The stability analysis indicated that some high yielding a genotypes less stable as shown by the deviation from the joint regression lines, while low yielding genotypes are more stable.

3.6 CONCLUSIONS

The study demonstrated that genotypes, planting date and growing environments significantly influence cowpea yields and yield components. Planting date caused large differences in flowering time among genotype. Planting date should be am important condition when selecting genotypes for specific conditions

Cowpea genotypes performed differently in terms of yield and yield components across locations indicating genotype X environmental conditions.

On average, IT18E-16, CH14 and Pan311 out performed the other genotypes across locations.

The best planting date to produce high seed yield in cowpea was found to be November.

Taung was found to be the best location for the highest yielding cowpea cultivation whereas yield at Syferkuil was relatively lower due to limited rainfall.

Given optimum irrigation, however, higher yields would be possible at Syferkuil since genotypes produced higher number of branches. There was little difference in the number of pods per plant across locations. The highest number of pods per plant was recorded in Glenda, M28 and M217 indicating that they could be suitable for cultivation as a vegetable.

This study was carried out using limited number of germplasm for one year only. It is suggested that the study be extended to include more germplasm collections evaluated at different environment across several years.

3.7 RECOMMENDATIONS

An assessment of adaptation of more cowpea genotypes at different environments across years is recommended. In the current study, results were reported using data from one season. The investigation provided sufficiently evidence to continue with further studies. This study showed that cowpea researchers in Limpopo and Northwest Province should make limited recommendation at different localities. The findings of the study must be regarded as preliminary and need of further confirmation.

The study indicated that early planting dates should be recommended for cowpea at all locations studied. Taung was the higher yielding environment to produce high seed yield in cowpea. The best performing genotypes with relatively stable high and stable yield across locations were IT18E-16, CH14 and Pan311. Genotypes M101 and M217 are more stable as indicated by from regression but produced the lowest mean yield across localities and planting dates.

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5. LIST OF APPENDIX TABLES

Appendix 4.1 Analysis of variance for the number of days to 50% flowering among ten genotypes of cowpea tested at 3 planting dates and 3 locations using 3 replications.

Source	Df	SS	MS	F-comp.	P-value
Line (L)	9	3245.985	360.665	543.24	0.0000
Planting date (Pd)	2	1405.563	702.781	1058.53	0.0000
Locality (Loc)	2	11455.563	5727.781	8627.22	0.0000
L x Pd	18	4097.104	227.617	342.84	0.0000
L x Loc	18	4061.104	225.617	339.83	0.0000
Loc x Pd x L	36	10322.667	286.741	431.89	0.0000
Replication in Loc	6	9.822	1.637	2.47	0.0258
Residual	178	118.178	0.664		
Total	269	34715.985			
Grand mean		R-squared		CV	
58.193		0.9966		1.40%	

Appendix 4.2 Analysis of variance for the number of days taken to physiological maturity among ten genotypes of cowpea tested at 3 planting dates and 3 locations using 3 replications..

Source	Df	SS	MS	F-comp.	P-value
Line (L)	9	16647.481	1849.720	290.85	0.0000
Planting date (Pd)	2	6318.763	3159.381	496.78	0.0000
Locality (Loc)	2	25553.785	12776.893	2009.05	0.0000
L x Pd	18	1848.274	102.682	16.15	0.0000
L x Loc	18	8357.474	464.304	73.01	0.0000
Loc x Pd x L	36	14119.185	392.200	61.67	0.0000
Replication in Loc	6	3.311	0.552	0.09	0.9975
Residual	178	1132.022	6.360		
Total	269	73980.269			
Grand mean		R-squared		CV	
114.296		0.9847		2.21%	

Appendix 4.3. Analysis of variance for seed yield among ten genotypes of cowpea tested at 3 planting dates and 3 locations using 3 replications.

Source	Df	SS	MS	F-comp.	P-value
Line (L)	9	82765298.9	9196144.3	95.74	0.0000
Planting date (Pd)	2	22624.22.5	1131211.2	11.78	0.0000
Locality (Loc)	2	46255938.9	23127969.4	240.77	0.0000
L x Pd	18	7825530.2	4347251.7	45.26	0.0000
L x Loc	18	64675690.2	3593093.9	37.41	0.0000
Loc x Pd x L	36	160301278.2	4452813.3	46.36	0.0000
Replication in Loc	6	443441.6	73906.9	0.77	0.5949
Residual	178	17098361.756	96058.212		
Total	269	452052962.2			
Grand mean		R-squared		CV	
3350.081		0.9622		9.25%	

Appendix 4.4. Analysis of variance for the number of branches per plant among 10 genotypes of cowpea tested at 3 planting dates and 3 locations using 3 replications.

Source	Df	SS	MS	F-comp.	P-value
Line (L)	9	107.837	11.982	33.88	0.0000
Planting date (Pd)	2	12.896	6.448	18.23	0.0000
Locality (Loc)	2	44.985	22.493	63.60	0.0000
L x Pd	18	86.585	4.810	13.60	0.0000
L x Loc	18	102.052	5.670	16.03	0.0000
Loc x Pd x L	36	306.074	8.502	24.04	0.0000
Replication in Loc	6	0.378	0.063	0.18	0.9825
Residual	178	62.956	0.352		
Total	269	723.763			
Grand mean		R-squared		CV	
6.030		0.9130		9.86%	

Appendix.4.5. Analysis of variance for the number of pods per plant among ten genotypes of cowpea tested at 3 planting dates and 3 locations using 3 replications.

Source	Df	SS	MS	F-comp.	P-value
Line (L)	9	100470.300	471.531	67.82	0.0000
Planting date (Pd)	2	4261.781	5863.411	839.82	0.0000
Locality (Loc)	2	34615.822	17307.911	2479.01	0.0000
L x Pd	18	10246.363	569.24	81.53	0.0000
L x Loc	18	12198.030	677.668	97.06	0.0000
Loc x Pd x L	36	26171.481	726.986	104.13	0.0000
Replication in Loc	6	7.244	1.207	0.17	0.9838
Residual	178	1242.756	6.982		
Total	269				
Grand mean		R-squared		CV	
29.00		0.9876		8.84%	

Appendix 4.6. Analysis of variance for the number of seeds per pod among ten genotypes of cowpea tested at 3 planting dates and 3 locations using 3 replications.

Source	Df	SS	MS	F-comp.	P-value
Line (L)	9	842.967	93.663	189.55	0.0000
Planting date (Pd)	2	294.007	147.004	297.50	0.0000
Locality (Loc)	2	1961.252	980.626	1984.54	0.0000
L x Pd	18	362.956	20.164	40.81	0.0000
L x Loc	18	591.933	32.885	66.55	0.0000
Loc x Pd x L	36	2932.148	81.449	164.83	0.0000
Replication in Loc	6	0.711	0.119	0.24	0.9628
Residual	178	87.956	0.494		
Total	269	7073.930			
Grand mean		R-squared		CV	
12.063		0.9876		5.83	

Appendix 4.7. Analysis of variance for 100 seed weight among ten genotypes of cowpea tested at 3 planting dates and 3 locations using 3 replications.

Source	Df	SS	MS	F-comp.	P-value
Line (L)	9	699.022	77.669	98.17	0.0000
Planting date (Pd)	2	132.141	66.070	83.51	0.0000
Locality (Loc)	2	339.785	169.893	214.75	0.0000
L x Pd	18	279.933	15.552	19.66	0.0000
L x Loc	18	1274.289	70.794	89.48	0.0000
Loc x Pd x L	36	1049.926	29.165	36.86	0.0000
Replication in Loc	6	3.178	0.530	0.67	0.6744
Residual	178	140.822	0.791		
Total	269	3919.096			
Grand mean		R-squared		CV	
15.104		0.9641		5.89%	