# SORGHUM-COWPEA INTERCROPPING: INFLUENCE OF LEGUME VARIETY ON SYSTEM PRODUCTIVITY AND INSECT PEST INFESTATION

BY

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## DECLARATION

I hereby declare that the work herein submitted as a thesis for the Master of Science in Agriculture resulted from my own investigation, and that it has neither wholly nor partially been presented as a thesis for degree in this University or elsewhere.

Work by other authors which served as sources of information have duly been acknowledged by reference to the authors.

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## DEDICATION

This work is dedicated to my parents, the late George Mphosi and Anna Mphosi for their support in giving me education, despite lacking formal education.

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# CHAPTER 1

## INTRODUCTION AND LITERATURE REVIEW

Intercropping is the practice of growing two or more crops on the same area of land during a growing season. Other suggested definitions are (a) any form of cropping system in which there is a significant amount of intercrop competition and (b) the growing of two or more crops in different but proximate rows. Common characteristics of different forms of intercropping are that they have the effect of intensifying crop production and a more efficient exploitation of environments with limiting or potentially limiting growth resources.

Under the general category of intercropping, there are four subcategories namely,: mixed, row, strip and relay (Vandemeer, 1992). Mixed intercropping implies growing component crops simultaneously with no distinct row arrangement and is commonly used in labour-intensive subsistence farming systems. Row intercropping involves growing component crops simultaneously in different rows. This is used in mechanized agriculture because it permits crop specific operations. Strip intercropping implies growing component crops simultaneously in different strips to permit the independent cultivation of each crop. Relay intercropping is the growing component of crops in relay, so that growth cycles overlap (Ofori and Stern, 1987).

Intercropping is an ancient practice and has continued to be popular in the developing world (Vandemeer, 1992). The continuous popularity of intercropping is due to several reported advantages of the system compared to the sole cultures. Such advantages include increased soil erosion control, spreading labour requirement and harvesting more evenly throughout the season, insurance against crop failure (Rao *et al*. 1980), facilitating production of many commodities in a limited area, efficient utilization of growth resources by plants with different growth duration, heights, rooting systems and nutrient requirements. Other advantages include controlling the spread of diseases and pests (Vandemeer, 1992, Skovgard and Pats, 1996;. Itulya and Aguyoh, 1998). Under most circumstances, however, it is unlikely that intercropping row crops on the same field should be of great interest unless there is a biological advantage to growing the different species together. Other advantages of on-farm crop diversity (such as diversification of economic risk and allocation of labour requirements) could be met in most cases without intercropping.

## INTERCROP PRODUCTIVITY

The biological advantage or disadvantage of intercrop systems has been measured in a number of ways. Different indices have been proposed for evaluating the efficiency per unit area of land of cereal-legume intercrop systems. These include comparisons of absolute yields, protein yields, caloric equivalent, and in economic terms, gross returns from intercrops and sole crops. But the commonly used indices are relative yield total (RYT), land equivalent ratio(LER), Area time equivalent ratio (ATER) and staple land equivalent ratio (Ofori and Stern, 1978).

**Relative Yield Total**

The mixture of a component crop expressed as a proportion of its yield as a sole crop from the same replacement series is the relative yield of the crop. The sum of the relative yields of component crops is called Relative Yield Total and is denoted by RYT. When the RYT is equal to or less than one, there is no advantage to intercropping. Although the calculation of RYT was originally based on the replacement series in competition studies, where proportions of the components in binary mixtures are varied but the overall crop densities remain constant, the calculation can in fact be applied to any density situation in intercropping (Ofori and Stern, 1987; Mead and Willey, 1980).

**Land Equivalent Ratio**

The most common method is the use of indices such as the land equivalent ratio (LER) as reported by Mead and Wiley (1980). The LER indicates the amount of land planted to sole monocrop to require obtaining the same economic or biological yield as the intercrop.

The mathematical model by which the LER is calculated is : LER=(Yij/Yii)+(Yji+Yjj), where Y is the yield per unit area, Yii and Yjj are sole crop yields of the component crops i and j, and Yij and Yji are intercrop yields (Mead and Willey, 1980). The partial LER values, Li and Lj, represent the ratios of the yields of crops i and j when grown as intercrops, relative to sole crops. Thus, Li=(Yij/Yii) and Lj=(Yji/Yjj) and therefore LER is the sum of the two partial land equivalent ratios so that LER=Li+Lj. When LER=1, there is no advantage to intercropping in comparison with sole cropping. When LER>1, a larger area of land is needed to produce the same yield of sole crop of each component than with an intercropping mixture.

Although this measurement has been widely used as an estimation of intercrop advantage and the degree of intercropping competition, it does not clarify mechanisms of inter-species interaction.

**Area Time Equivalent ratio**

Hiebsch (1980) proposed the Area Time Equivalent Ratio (ATER) as a modification to land equivalent ratio (LER). It takes into account the duration of the crop and also permits an evaluation of crops on a yield-per-day basis as described by Hiebsch and McCollum (1987).

The mathematical model for the ATER is as follows:

ATER=(Liti+Ljtj)/T,

where Li and Lj are relative yields or partial LERs of component crops i and j, ti and tj are the durations(days) for i and j, and T is the duration (days) of the whole intercrop system.

**Staple Land Equivalent Ratio**

In situations where the primary objective is to produce a fixed quality of one component (staple) crop, usually the cereal, and some yield of the legume, Reddy and Chetty (1984) proposed the concept of the Staple Land Equivalent Ratio (SLER) as an extension of LER. It is based on assumption of the basic requirement for minimum supply of a major staple crop such as the cereal. It is estimated as SLER=(Yi/Yii)+Pij (Yji/Yjj), where Yi/Yii is "standardized yield" of staple i, Pij is the proportion of land devoted to intercropping, and Yji/Yii is the relative yield of crop. This index is peculiar to India and does not appear to have been used widely there either.

Two theoretical principles for understanding mechanisms for yield advantages in intercrops have been proposed (Vandemeer, 1992). These are derived from well-known concepts in ecology that have been used to explain the structure of natural plant and animal communities. The first is the "Competitive production principle" which states that an intercrop may be successful if the resource requirements of the two species are sufficiently distinct. Less competition for the resources of light, water, or nutrients may occur in an intercrop than occurs in sole crops, which may lead to intercrop yield advantages.

This principle of niche differentiation may be operative in the dimensions of either time or space. Willey (1979) described this principle in the following manner: intercrop advantages occur when the sum of the inter-crop competition is less than the sum of the intra-crop competition. Example of the competitive production principle include differential rooting depths to minimize competition for water. The efficiency of soil water uptake by the root system is therefore a key factor in determining the rate of transpiration and tolerance to drought.

Water uptake by the root is a complex parameter which depends on root structure, root anatomy, and the pattern by which different parts of the root contribute to overall water transport (Zaffaroni and Schneiter, 1989 ; Salih *et al.*, 1999); differential demands on soil N by legumes and nonlegumes (Ahmed & Rao, 1982; ; Francis, *et al.*1982 ; Clark & Francis,1985, Francis,1982 and Akintoye *et al.*,1990): staggered maturities, which maximize dry matter production per unit of photosynthetically active radiation (PAR) absorbed over time and earlier canopy cover or occupation of different canopy positions, thereby increasing light Interception or efficiency (Clark and Francis,1985; Marshall and Willey, 1983 and Gibson, *et al.*,1992).

The second principle has been termed the "facilitative production principle" or simply "facilitation" (Vandemeer, 1992). This occurs when one species benefits directly from modification of the growth environment by the other species in an intercrop. A common example is the transfer of N from legumes to nonlegumes within a growing season (Ofori and Stern, 1987 and Siame and Willey, 1998). This mechanism is distinct from the competitive production principle wherein legumes and nonlegumes may be compatible because they do not compete for the same resource namely soil N, (Doyle and Fischer, 1979, Ahmed and Rao, 1982 and Francis, 1982). Other examples include: the beneficial effects of shade in hot environment (Willey, 1979 and Trenbath, 1993); windbreaks in windy environments and tall plants to climbing plants (Willey 1979 and Francis *et al.*,1982 Vandemeer, 1992).

Economic crop production is the conversion of three natural resources (light, water and nutrient) into usable products by the plant community. The efficiency by which these resources can be used is influenced in part by crop management. Three management decisions that can influence the production of a crop are cultivar selection, plant population and row spacing or arrangement (Zaffaroni and Schneiter, 1989 ; Jameison and Ewert, 1999).

A fundamental understanding of the mechanisms of how intercrops capture and use resources would provide a more scientific basis for recommending appropriate combinations of species and planting arrangements for intercropping at different locations (Putnam and Allan, 1992 ; Salih, *et al*., 1999).

A strong and persistent interest among agricultural ecologists and entomologists during the last decades has been directed towards the mechanisms involved in suppression of herbivores (Root, 1973).

Two generally accepted working hypotheses were proposed to explain differences in herbivore populations in simple and different habitats. The resource concentration hypothesis predicts that oligophagous herbivores will locate and build up populations in monoculture, because the host plants are concentrated in time and place (Willey, 1979; Trenbath 1993 and Skovgard and Pats, 1996). When resource concentration is adapted to consider the effects of intercrops on specialist insect pests, it states that pests will: (1) be less able to find their hosts because of visual and olfactory interference with their search pattern, (2) tend to stay for less time because of the disruptive effect of landing on non-host plants, and (3) have lowered survival and fecundity.

The natural hypothesis postulates a greater functional and numerical response by predators and parasitoids in different habitats due to a supply of alternate prey and food leading to a reduction in the herbivore populations. These two hypotheses imply that suppression of oligophagous herbivores will increase with habitat diversification, and effective natural enemies are more likely to be generalists than specialists (Kennedy *et al*., 1994). These hypotheses may not be mutually exclusive, but subordinate to each other.

Although multiple cropping systems were the first types of organized agriculture in relation to monoculture which is a relatively recent invention (Francis, 1982), their biological complexity has deterred scientists from analyzing their productivity, particularly in relation to the capture and uses of physical resources. Nevertheless, there is substantial agronomic evidence that the yields of many intercrops may exceed the combined yields of their component species grown as sole crops (Willey and Rao, 1981; Ahmed and Rao, 1982). Despite the reported advantages of intercropping, it is also clearly evident that improper set up of intercropping system can result in poorer productivity of the intercrops relative to sole culture of component crops. An important management consideration that may significantly impact on intercrop performance is choice of cultivar in this cropping practice. Unfortunately, the significance of crop cultivars in intercrop productivity is lacking and almost non-existent in sorghum intercrop system under local conditions. Such information will be essential for maximum productivity and recommendations that relate to intercropping systems.

Grain sorghum (*Sorghum bicolor*) and Cowpea (*Vigna unguiculata*) are popular crops in South

Africa especially among resource poor farmers in the Northern Province due to ability to withstand drought conditions unsuitable for maize and many other field crops. Sorghum has prolific root systems, ability to maintain stomatal opening at low leaf water potentials and high osmotic adjustment which permit it to achieve economic and stable yields under drought environments.

Cowpea is a major source of protein in human diets in rural communities in addition to its role as soil fertility builder through symbiotic N-fixation. Sorghum and cowpea have traditionally been studied as sole cultures rather than as intercrops despite the widespread practice of intercropping among resource poor farmers and the reported benefit of intercropping in general. Understanding the mechanisms of growth resource use, especially nitrogen and water, will assist in management practices for maximum productivity in the sorghum-cowpea intercrops.

The objectives of the study were:

1. To assess the impact of intercropping on insect pest population of African Bollworm, (*Helicoverpa armigera*), Aphids, *Melanaphis sacchari, R.maidis* and stem-borers, *Chilo partellus* and *Busseola fusca.*
2. To assess patterns of dry matter partitioning and light interception in sorghum and Cowpea intercropping systems.
3. To determine the significance of cowpea and nitrogen fertilizer on dry matter accumulation and grain yield in a sorghum and cowpea intercropping system.

# CHAPTER 2

## Incidence of Insect Pest Infestation in Sorghum-Cowpea Intercrops


### ABSTRACT

The presence of legumes in cereals intercropped, leads to attack escape from insect pests under some conditions. The increase in crop production potential due to the enhanced diversity by intercropping systems to control insect pests is an inevitable pillar in sorghum-cowpea intercropping among the small scale farmers of the Northern Province of South Africa. Dwarf sorghum (Macia) was intercropped with four cultivars of cowpeas under rainfed conditions of the northen Province. A randomized complete block design in a split plot arrangement was used with two levels of nitrogen assigned as the main treatments and nine cropping systems as subplots with three replications in three locations namely Syferkuil, Tompi Seleka and Zebediela. The two levels of nitrogen were 0 kg N and 120 kg N $ha^{-1}$ and intercropping systems were, sole sorghum, sole Pan 311, sole Pan 326, sole Bechuana white and sole Agrinawa, sorghum-Pan 311, sorghum-Pan 326, sorghum-Bechuana white and sorghum-Agrinawa.Aphid abundance was scored for Sorghum aphid (Honeydew aphid), *Melanaphis sacchari* and Maize aphid (Whorl aphid) *R maidis* from the two middle rows of plants per plot, Bollworm data was scored using the bucket method and Stalk borers infestation of , *Chilo partellus* and *Busseola fusca* was recorded through determining the exit, entry, deadheart and whorl damage. Significant reduction of the insect pests was observed in all insect pests monitored.



**Keywords**: Intercropping systems, *Chilo partellus*, *Busseola fusca*, *Melanaphis sacchari*, and *Rhopalsiphum maidis* and *Helicoverpa armigera*

## INTRODUCTION

Intercropping, the practice of growing two or more crops simultaneously on the same field in a growing season, is an ancient practice and has continued to be popular in the developing world (Vandermeer, 1992). Small scale farmers have often shown preference for this system as it provides an opportunity to grow different crops, reduces risks of the total crop failure in unfavourable seasons, employs family labour more gainfully and often reduces insect pest populations (Trenbath, 1993).

Research into the impact of intercropping on the levels of infestation of stem-borers in sorghum has been pursued but results have remained unpublished in Southern African countries (Flattery, 1982). There are no reports done in South Africa on intercropping as a potential cultural method to control stem-borers. Amoako-Atta and Omolo (1983) reported a significant insect pest reduction in Kenya by intercropping in Maize as a potential cultural method. Ebenebe (1998) in Lesotho reported that intercropping reduces the incidence of infestation by stalk borers in maize.

Grain sorghum, *Sorghum bicolor* (L.) Moench is an important grain crop grown by commercial and small-scale farmers in South Africa (Wenzel *et al*. 1997). Small-scale farmers grow it mostly as a mixture with or without maize and with Cowpeas and watermelons during the summer growing seasons.

Among the important pests of sorghum in South Africa are *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae) and *Busseola fusca* Fuller (Lepidoptera: Noctuidae) (Van Hamburg, 1980; Van Rensburg and Van den Berg, 1992). Van den Berg (1994) reported 58% estimated yield loss on Sorghum in South Africa due to *C. partellus* attack while Annecke and Moran (1982) reported 5 to 72% on maize due to *B. fusca* damage.

Aphids are the most important pests of grain sorghum in South Africa, especially in the warm dry land sorghum of Northern Province (Van Rensburg 1973; Annecke and Moran, 1982). Aphids that may be found on Sorghum are *Melanaphis sacchari*, Zehntner (Homoptera: Aphididae); *Rhodopalsiphum maidis*, Fitch (Homoptera: Aphididae) and *Schizaphis graminum*, Rondani (Homoptera: Aphididae). The whorl aphids *R. maidis* and the sorghum aphid *M. sacchari* are mainly leaf feeders, but are known to infest sorghum heads also. Both aphids suck sap from sorghum leaves and head parts (Teetes *et al*, 1983). The importance of whorl aphids is questionable especially during the seedling to whorl stage and no clear yield reduction has been observed.

Population buildup of the *M.sacchari* begins 3 weeks after crop germination (Van Rensburg, 1973) and in South Africa, very high populations have been observed after the flag leaf stage. The main impact on yield loss occurs from the flag leaf stage (Van Rensburg, 1973) and panicle infestation is probably of less importance in grain yield reduction, although it increases threshing difficulties. Yield loss estimates in Botswana (Flattery, 1982) and Zimbabwe (*Page et al.* 1985) range between 46 and 78% annually without insecticide control. The potential increase of sugarcane aphid is high in newly released sorghum cultivars which in most cases are susceptible to this insect pest (Manthe, 1992).

Flattery (1982) and Van Rensburg (1973) reported that high plant density promotes low plant vigour but reduces aphid infestation and population buildup.Van Rensburg (1979) reported crop losses of between 46 and 80 % due to uncontrolled sorghum aphid populations. Annecke and Moran (1982) have reported 60% sorghum grain yield reduction due to aphids' infestation in South Africa.

Currently, insecticide application is the only measure used for the control of aphids (Teetes *et al* 1983). Intercropping has been reported to be a potential cultural method to combat insect pests due to its enhanced crop diversity (Root, 1973).

Sorghum panicles are infested by a wide range of insect pests from anthesis to grain maturity, of which only a few species cause severe damage. Compared to shoot pest damage, panicle pests can cause both quantitative and qualitative losses, which generally cannot be compensated for by further plant growth and recovery. Although fragmentary data are available on pest incidences, information is lacking on the actual crop losses sustained in farmers' fields, where intercropping is commonly practices.

Over 100 sorghum insect pest species have been recorded in Africa, of which more than 40 are panicle- feeding pests (Nwanze, 1985 and Seshu Reddy, 1991). African bollworm, *Helicoverpa armigera*, Hubner (Lepidoptera: Noctuidae) is a major pest of several crops in the Old World semi-arid tropics and in Southern Africa, it is considered an important panicle insect pests (Dennis, 1983). However it is still of low importance in small-scale farmers' fields. Sorghum panicle insect pests are of low economic importance for the following reasons: (1) traditional cultivars are long-duration types (150 days to maturity) and flower and set seed late in the season under declining rainfall conditions and (2) loose heads of traditional cultivars harbor fewer head bugs (Flattery, 1982).

This characterizes traditional small-scale farming with low-input systems with low yields (± 600 kg ha-1), but stable production. Mostly traditional land races are grown, and crop protection measures against sorghum insects are seldom or never practiced. However, this is not the case with large and commercial sorghum producers who grow newly developed high-yielding cultivars. Introduction of new cultivars to subsistence farmers makes *H. armigera* a pest of potential economic importance in South Africa and southern African countries. A considerable damage due to *H. armigera* in cowpea and sorghum grains was reported in South Africa (Annecke and Moran, 1982)

The objective of the study was to assess the impact of nitrogen and sorghum-cowpea intercropping systems on insect pest populations of African Bollworm, (*Helicoverpa armigera*), Aphids, *Melanaphis sacchari, Rhopalsiphum maidis* and stem-borers, *Chilo partellus* and *Busseola fusca.*

## MATERIAL AND METHODS

Three field trials were conducted at the University of the North's experimental farm at Syferkuil, Zebediela and Tompi Seleka during the 1999-2000 growing season in the Northern Province of South Africa. All locations receive an annual rainfall of approximately 500 mm and consist of mainly a sandy loam soil of Hutton form.

A randomized complete block design in a split plot arrangement was used with two levels of nitrogen assigned as the main treatments and sorghum intercrop involving four cowpea cultivars of varying morphology as subplots. They include Pan 311, Pan 326,and Bechuana white and Agrinawa. Pan 311, Pan 326 and Bechuana White are commercially marketed varieties whereas Agrinawa represent a landrace collected from different locations in Southern Africa and improved by the Agricultural Research Council. The experiment was replicated three times. The two levels of nitrogen were 0 kg N and 120 kg N $ha^{-1}$ and intercropping systems were, sole sorghum, sole Pan 311, sole Pan 326, sole Bechuana white and sole Agrinawa, sorghum-Pan 311, sorghum-Pan 326, sorghum-Bechuana white and sorghum-Agrinawa. Grain sorghum cultivar, Macia was used in the experiment. Sorghum and cowpea varieties were arranged in alternate intercropping pattern in which alternate single rows of sorghum and cowpea spaced 0.90 m apart between the sorghum and cowpea rows with an intra-row spacing of 0.15 m in all component crops. Seeds were planted by hands in November 1999 at three locations and were later thinned out to the desired population.

The sorghum population was kept at 74074 plants per hectare while cowpea population was also 74074 plants per hectare. The plot intercrop size was 5m (length) x 3.6 m (wide) with each plot consisting of eight rows and of which the middle four rows were designated for dry matter sampling and grain yield determination.

Nitrogen was applied as banded to all plots in the form of urea at the rate of 120 kg N $ha^{-1}$and all plots received 50 kg P $ha^{-1}$ as superphosphate at planting. Weeds were frequently controlled manually during the growing season.

### Stalk borers

The incidence of Leaf feeding damage and deadheart symptoms caused by *C. partellus* and *B. fusca* in the whorl of sorghum plants was monitored. The number of damaged, entry and exit holes caused by larvae and pupae were determined in intercropped and sole crops. This was done by dissecting ten plants per plot.

### Aphids

Aphid abundance was scored for Sorghum aphid (Honeydew aphid), *Melanaphis sacchari* and Maize aphid (Whorl aphid) *R maidis* from the two middle rows of plants per plot. A scale of one to six, representing the mean percentage of plant leaves covered by aphids was used, where: 1=0-10%, 2=11-25%, 3=26-50%, 4=51-70%, 5=71-90%, and 6= 91-100% of plant tissue covered by aphids from seedling emergence to physiological maturity (Manthe, 1992). Aphid abundance for all species was scored using the same scale method. The maize aphid were sampled at whorl stage once after 4 weeks while the honey dew aphids were mostly sampled at flowering or after.

**Bollworm**

Ten plants were sampled from each plot between 08h00 and 11h00 using the modified Bucket method (Steward, *et al* .1991). A clear plastic bag (20.3 x 7.6 x 38.1cm) was carefully placed over the panicle and was held firmly around the peduncle, 20 cm from the bottom of the panicle. The peduncle was cut and the bag was tied up and transported to the laboratory. The panicle was carefully placed over and down inside the bucket. The peduncle was placed between the palms of the sampler's hands and rotated rapidly (twirled) for 15 seconds. The twirling of the panicle caused the inhabitating arthropods and flowering structures (anthers) to be more evenly dispersed in the bottom of the bucket and they were thoroughly examined under a microscope. After each sample, the bucket was wiped clean with cloth to avoid contamination.

Data on the number of moth exit holes per stalk were subjected to analysis of variance.

Brown paper bags were placed on the panicles to prevent bird damage around late February 2000.

Analysis of variance was done using the statistical package, called Statistix and Fisher's protected LSD determined differences between means of treatments.

## RESULTS AND DISCUSSION

### Sorghum stem borer

Nitrogen did not influence the infestation levels of *C. partellus* at Zebediela and Tompi Seleka. . Nitrogen significantly decreased *C. partellus* infestation by 8.4% under nitrogen fertilized conditions (Table 1, 2 and 3) and this has been attributed to heavy rainfall that caused leaching and uneven localized nitrogen fertilizer distribution through running water that resulted in nitrogen toxicity and inadequacy to targeted plants (Buckman and Brady,1969). The Infestation levels of *C. partellus* was higher than that of *B. fusca* at all location. *C. partellus*, larvae constituted 80.8, 88.8 and 66.5% of the stem borer population at Syferkuil, Tompi Seleka and Zebediela respectively (tables1,2 and 3). Infestation levels of C.partellus were reduced by 36, 56, 56 and 60% in sorghum-Pan 311, sorghum-Pan326,sorghum-Bechuana white and sorghum-agrinawa patterns, respectively at Syferkuil. *C.partellus,* infestation level percentage reduction at Tompi Seleka ranged from 15% in sorghum-pan 311 to 23% in sorghum-agrinawa (table 2).

The sorghum stalk borer, *C. partellus*, infestation responded significantly ($P \leq 0.05$) within the intercropping systems at Zebediela. The number of C.partellus larvae was significantly reduced in sorghum in the intercropped treatments at Zebediela (sorghum-pan326). Although not significant, a similar tendency was observed at Syferkuil (sorghum-pan311). At Zebediela, intercropping sorghum with Agrinawa resulted in 58.3% reduction in *C.partellus* numbers in sorghum. Intercropping systems reduced *C.partellus* infestation by 44% compared to sole cultures (Ebenebe, 1998).

Although not significant, intercropping reduced *C. partellus* infestation by 44% and 10.25% at Syferkuil and Tompi Seleka (table 1 and 2), respectively. Ebenebe (1998) and Amoako-Atta (1983) observed similar results in Lesotho and Kenya.

The low infestation of *C.partellus* in most intercropping systems was due to the canopy coverage by cowpea leaves in the early crop stages, and less oviposition by *C. partellus* moths (Amoako-Atta *et al*, (1983).

## Maize stalk borer

The effect of nitrogen application was non-significant at all locations, studied (table 1,2 and 3). Although, nitrogen application was non-significant, numerically the tendency of high infestation was observed under nitrogen fertilized conditions (table 1,2 and 3). *B.fusca* infestation was increased by 25% and 15.2% under N fertilized compared to unfertilized at Tompi Seleka and Zebediela, respectively (table 2 and 3) The increase in *B. fusca* under increased nitrogen levels may be due to the attractiveness of crops due to the compensatory growth rate attributed by nitrogen as a fertilizer (Amoako-Atta, 1983)

A significant difference in *B. fusca* infestation was observed between the intercropping systems at Syferkuil (table 1). The number of *B. fusca* larvae was reduced by 62.4% in intercropping systems relative to sole culture at Syferkuil (table 1). Although not significant, intercropping at Tompi Seleka and Zebediela reduced *B.fusca* infestation by 72.7% and 23.5%, respectively.

*B.fusca,* infestation level percentage reduction at Tompi Seleka ranged from 55% in sorghum-pan 326 to 81% in sorghum-Pan 311 and sorghum-agrinawa (table 2).

The low incidence of *B.fusca* damage on sorghum under intercropping conditions was probably due to canopy coverage formed by leaves of cowpea varieties in the early crop stages. Amoako-Atta *et al*. (1983) suggested that cowpea and sorghum are of similar height in their early stages which would reduce the visual stimuli that attract the borer moth to sorghum for oviposition. Intercropping systems had a disruptive effect on entrance of *B. fusca* into the crop and its establishment and colonization as reported by Mumford and Balidda (1983) and also on resource concentration that may affected the efficiency of *B.fusca* in exploiting sorghum as the host crop (Root, 1973).

**Entry holes**

The effect of nitrogen application on mean entry number of holes per sorghum stem was not significantly at locations (table 1,2 and 3). The most striking significant differences ($p<0.05$) were observed within the intercropping systems at Syferkuil and Zebediela while the effect was not significant at Tompi Seleka (Table1, 2 and 3). Mean entry holes were significantly ($p<0.05$) decreased by 57% and 30% in sorghum-Agrinawa cropping systems relative to sole cultures at both Syferkuil and Zebediela respectively (Table1 and 3). Sorghum-agrinawa reduced mean entry holes by 57% and 30% at Syferkuil and Zebediela, respectively while Tompi Seleka mean entry holes were reduced by 30% under sorghum-agrinawa The reduction caused by sorghum-agrinawa combination is probably due to its massive leaf production that enhanced disruptive effects on the stalk borers through high crop diversity that might have contributed to poor colonization and numerical decrease of stalk borer population (Mumford and Balidda, 1983; Trenbath, 1992 and Vandemeer, 1992).

## Exit holes

The effect of nitrogen application on mean entry number of holes per sorghum stem was not significant at all locations (table 1,2 and 3). Cropping systems only at Syferkuil and not in the other locations influenced mean exit holes per stem. At Syferkuil, sole culture had significantly higher exit holes, 3.8 compared to an average of 2.01 across the intercrop treatments. Although not significant, intercropping treatments increased the mean number of exit holes per stem by 33.3% at Tompi Seleka and reduced it by 20.2% at Zebediela with Sorghum-Agrinawa performance being the best relative to sole cultures and other intercropping treatments.

## Whorl damage

Nitrogen did not influence the incidence of whorl damage at any of the locations (table 1,2,3). Significant differences in the incidence of whorl damage were observed between the intercropping treatments at Syferkuil (table 1). The incidence of whorl damage in sorghum grown as pure crop was significantly higher (73.3%) than the average of the intercrop. When intercropped with cowpea the incidence of whorl damage was 50% (Sorghum-Pan 311), 56%(Sorghum-Pan326), 53.3%(Sorghum-Bechuana White) and 48.3%(Sorghum /Agrinawa systems) at Syferkuil, respectively. Intercropping reduced whorl damage by 40.6% at and Zebediela. The whorl damage at Tompi Seleka was 100% irrespective of whether sorghum was intercropped or in a sole culture (table 2).

## Deadheart

Nitrogen application did not influence the incidence of deadheart at any location (table 1,2 and 3). Significant differences in dead heart incidence were observed between intercropping treatments ($P<0.05$) at Zebediela and Tompi Seleka but not at Syferkuil (table 1,2 and 3). Intercropping treatments reduced deadheart at Tompi Seleka and Syferkuil by 80.4% and 36.3%, respectively (table 1 and 2). A decrease of deadheart by 97.2% by intercropping treatments was observed in Sorghum-Pan 311 while and Sorghum-Pan 326 and sorghum-Agrinawa treatments reduced deadheart by 94.4% at Zebediela. Although not significant, intercropping treatments decreased deadheart by 45% relative to sole cultures and sorghum-Agrinawa reduced deadheart by 69.9% compared to sole culture. Mohyuddon and Attique (1978) observed that yield reduction in maize caused by *C. partellus* was due to deadheart and stunting but not tunneling or stalk breakage.

## African bollworm

Nitrogen did not influence the infestation of *H.armigera* at all location (table 1,2 and 3). Intercropping had a significant effect on *H. armigera* infestation at Syferkuil and Tompi Seleka. Intercropping reduced *H. armigera* infestation by 58.9% and 45% compared to sole cultures respectively (table 1 and 2). Although not significant, intercropping reduced *H. armigera* infestation by 34.2% compared to sole cultures. Intercropping sorghum with Pan 311 treatments at Syferkuil reduced *H. armigera* by 85% relative to sole sorghum cultures. T3 also reduced *H.armigera* by 71% at Syferkuil while 36% and 43% reduction was observed in T4 and T5. The reduction was probably due to the morphology and phytochemicals produced by cowpea genotypes as reported by Root (1973) and Mumford and Baliddawa (1983).

## APHIDS

Nitrogen did not have an effect on sorghum and maize aphid abundance at both locations. This is contrary to what Heathcote (1974) reported probably because in that study irrigation was controlled whereas in the present study, heavy rainfall enhanced leaching of Nitrogen fertilizers.

Sorghum aphid, *M. sacchari*, abundance score was significantly (P>0.05)) reduced in sorghum intercropped with cowpeas at both locations except where sorghum was intercropped with variety Pan 311(early maturing variety) relative to sole cultures. Intercropping reduced sorghum aphid infestation by 48.9% and 45.6% across all intercropping systems at Syferkuil and Zebediela respectively (Table 4 and 5). A reduction of 43.2% and 39,2% of plants with aphids was observed at Zebediela and Syferkuil respectively compared to sole culture (Table 4 and 5).

Maize aphid, *R.maidis*, abundance score was significantly ($P<0.05$) affected by intercropping systems. Significantly lower aphid abundance scores were recorded in intercropped than in sole cultures (Table 1 and 2). Intercropped sorghum reduced R. *maidis* abundance by 52.4% and 34.8% (Table 1 and 2) at Syferkuil and Zebediela respectively. A reduction in the number of plants with maize aphid in intercropping was observed at both locations respectively. Intercropped sorghum reduced the number of plants with maize aphid by 37.7% and 36.8% at Zebediela and Syferkuil respectively (Table 4 and 5).

The reduction in both sorghum and maize aphid abundance in intercropped plots might have been due to the disruptive effect imposed by cowpeas intercropped with sorghum and rain storms (Trenbath, 1993).

Mumford and Baliddawa (1983) and Root (1973) reported that the disruptive effect through phytochemicals produced by Non-host crops lowers the survival and fecundity of specialist insect pests.

## Incidence of *M.sacchari* infested plants

Nitrogen did not influence the incidence of sorghum aphid, *M.sacchar*i at all locations. The number of plants observed to be infested with sorghum aphids was significantly reduced in intercropping treatments compared to sole cultures. On average intercropping reduced the number of plants found with aphids by 51% at Zebediela, whereas at Syferkuil 39% reduction was observed. Although sorghum-Pan 311 was significantly different from sole culture, many plants with sorghum aphids were observed in it compared significantly to other cropping systems (table 4 and 5). The sorghum-Agrinawa system reduced the number of plants found having sorghum aphids by 55% and 51% at

Syferkuil and Zebediela, respectively.

The number of plants observed to be infested with *R .maidis* was not significantly influenced by the intercropping treatments or nitrogen level. Nitrogen application had no significant effect on R. maidis infestation levels. Intercropping, on average reduced the number of plants with maize aphids by 37% and 38% compared to sole cultures at Syferkuil and Zebediela, respectively (table 4 and 5).

The reduction is probably due to the disruptive influence imposed by the massive morphological structure, attributed by its high total dry matter and stover yield.

## CONCLUSION

Nitrogen did not influence entry and exit holes, whorl damage, deadheart, *Busseola fusca* larvae, *Chilo partellus*, *Melanaphis sacchari* and *Rhopalsiphum maidis* abundance. Intercropping sorghum with cowpea significantly reduced stem borer infestation at all locations. The intercropping treatments had pronounced effects on entry, exit holes per stem, whorl damage, deadheart, *C.partellus*, *B.fusc*a and *H.armigera* infestations at different locations. Infestation levels of *C.partellus* were higher than that of B. fusca at all sites. *C. partellus*, larvae constituted 80.8%,88.8% and 66.5% of stem borer population at Syferkuil, Tompi Seleka and Zebediela respectively (table1, 2 and 3).

Sorghum-Agrinawa treatment reduced *C.partellus* population by 58% at Zebediela compared to 40% and 15% reduction observed at Syferkuil and Tompi Seleka (Table1,2 and 3). The number of *B. fusca* larvae was reduced by 62.4% in intercropping treatments relative to sole culture at Syferkuil (Table1). Although not significant, intercropping reduced *B.fusca* infestation by 72.7 and 24% at Tompi seleka and Zebediela.

Sorghum-Agrinawa treatment reduced mean entry holes by 57% and 30% at Syferkuil and Zebediela respectively, while at Tompi Seleka, mean exit holes were reduced by 30% by sorghum-Pan311.sorghum-Agrinawa treatment reduced exit by 66% and 26% at Syferkuil and Zebediela, respectively (table1 and 3). The incidence of whorl damage in sorghum grown as pure crop was significantly higher (90.3%) than other treatments. When intercropped with cowpea the incidence of whorl damage was 50%(sorghum-Pan311),56%(sorghum-Pan326),53.3%(sorghum-Bechuana White),48.3%(sorghum-Agrinawa) at Syferkuil, respectively.

Sorghum-Pan311 reduced deadheart by 97% while sorghum-Pan326 and sorghum-Agrinawa treatments reduced deadheart by 94% at Zebediela.

Intercropping treatments reduced *H.armigera* infestation significantly at Syferkuil and Tompi Seleka. Sorghum-Pan 311 reduced the number *of H. armigera* larvae by 85% compared to sole cultures. Sorghum aphid, *M.sacchari* abundance score was reduced by 43.2% and 39.2% in all intercropping treatments at Syferkuil and Zebediela. Intercropping significantly reduced *R. maidis* abundance score by 52.4% and 34.8% at Syferkuil and Zebediela respectively compared to sole cultures. The sorghum-Agrinawa intercropping treatment showed the most promising cropping system relative to sole. Intercropped sorghum reduced the number of plants with maize aphid by 37.7% and 36.8% at Zebediela and Syferkuil. The study shows that intercropping is a potential insect pest cultural method in reducing insect pest infestation level.

# CHAPTER 3

# SORGHUM-COWPEA INTERCROPPING SYSTEM: LIGHT INTERCEPTION AND DRY MATTER PARTITIONING.

## ABSTRACT

Management of intercrops to maximize their complementarity and synergism and to minimise competition between has been demonstrated with sorghum intercropped with four cowpea varieties. The objectives were to assess the influence of nitrogen on light interception and dry matter partitioning of sorghum and cowpea.

A randomised complete block design in a split arrangement was used with two levels of nitrogen assigned as the main treatment and nine cropping systems. The experiment was replicated three times. Sorghum and cowpea varieties were arranged in alternate intercropping pattern in which alternate single rows of sorghum and cowpea spaced 0.9 cm apart between the sorghum and cowpea with an inter-row of 0.15 in all component crops. Light interception attributed, 72 and 92 % to total cowpea dry matter accumulation. Dry matter partitioning to the leaves ranged from 78.8-g $m^{-2}$ to 177.8 g $m^{-2}$ under intercropping across all locations. Agrinawa produced the highest stover (6348-kg $ha^{-1}$ compared to other cowpea varieties. Light interception attributed 64 and 93% to sorghum dry matter accumulation. Intercropping increased sorghum dry matter accumulation by 16% on average and stover yield by 18% on average across all locations. Cropping patterns influenced light interception and dry matter partitioning during the growing period of sorghum and cowpea.

**Keywords:** Light interception, leaf, shoot, root dry matter and stover yield

# INTRODUCTION

Economic crop production is the conversion of three natural resources (light, water and nutrient) into usable products by the plant community. The efficiency by which these resources can be used is influenced in part by crop management. Three management decisions that can influence the production of a crop are cultivar selection, plant population and row spacing or arrangement (Jameison and Ewert, 1999; Zaffaroni, 1989). A more-efficient use of resource is a major reason advanced for the advantage of intercropping over alternative cropping systems (Keating and Carberry 1993). Solar radiation is the energy that drives crop productivity by the process of photosynthesis; it also determines water use by processes involved in evaporation and transpiration. Improved productivity per unit incident radiation can result from adoption of a cropping system that either increases the interception of solar radiation and /or maintains higher radiation -use efficiency (Keating and Carberry, 1993). Minimizing the proportion of radiant energy reaching the ground will ensure efficient utilization of incident solar radiation. Crop yield is closely related to assimilate production during the reproduction period of crop growth, However, it is difficult to relate yield directly to solar radiation because of other factors that influence the relative contributions of assimilate produced in pre-anthesis and post-anthesis periods. Mumford and Baliddawa (1983) reported that where the competition of an intercrop is directly for light, increased total biomass production by the intercrop could result in improved yields.

Great diversity in intercrop canopies is possible, resulting from the various combinations in space and time of planting and spatial distribution, leaf size, shape, orientation, and plant height. Willey (1979) and Francis (1982) found it useful to consider resource capture in terms of temporal and spatial dimensions. Although not strictly independent, this distinction provides a convenient means of the structuring of radiation capture. Planting patterns that do not effectively exploit the available space at any time within the duration of the cropping season will result in incomplete radiation interception and, in cases where other resources are not limiting, lost production (Ofori and Stern, 1993). The two major components of light interception over time are the duration of the crop cycle and the rate of leaf area development between emergence and the attainment of an adequate leaf area indexes to intercept most light (Ofori and Stern, 1993).

Water is a most important soil factor in semi-arid and subtropical regions, where intercropping is extensively practiced in dryland farming systems and inadequate rainfall may frequently limit crop production (Ofori and Stern, 1987). The differences in root systems, depth of rooting, lateral root spread, and root densities are factors that affect competition for water between component crops. The use of different parts of the soil profile by root systems of different crop species minimizes the degree of competition for water (Natarajan, et al.,1985). When component crops compete for available water, in an intercrop involving cereals, with its higher growth rate and more extensive root system, is generally favoured (Shackel and Hall, 1984).

Nitrogen (N) is the major limiting nutrient for most plant species (Ofori and Stern, 1989). Nitrogen in the soil falls into five categories:(1) nitrogen in organic matter;(2) mineral nitrogen in the soil solution and exchange sites; (3) nitrogen in plant residues in the soil; (4) ammonium fixed in clay minerals; and (5) gaseous nitrogen in the soil's atmosphere.

Acquisition and assimilation of N is second in importance only to photosynthesis for plant growth and development. Vandemeer (1992) reported that the decrease in photosynthesis from decreasing carbon dioxide concentration around the shoot of hydrated plants has the same effect on $N_2$ fixation as decreasing photosynthesis by dehydration.

One of the most primary factors contributing to improved crop yields in both leguminous and non-leguminous crops is the increased availability of N during critical stages of plant growth (Ofori and Stern, 1987). Production of high-quality, protein-rich foods in adequate amounts to feed an increasing world population is extremely dependent on the availability of sufficient nitrogen (Putnam and Allan, 1992). Nitrogen circulates through an ecosystem and needs to be present at a certain minimum level to sustain that ecosystem (Vandemeer, 1992). Nitrogen, in intercropping systems that consists of legumes growing in association with another crop, is consisted in terms of fixation, release, transformation, and gains and losses from the system. The success of intercrop farming system depends initially on effective nitrogen fixation and more importantly, on subsequent transfer of nitrogen to the non-legume (Ofori and Stern, 1993).

Final yield depends on total biomass production and partitioning among plant parts. Crop biomass at maturity is the integral of crop growth rate (CGR) over the total duration of growth, and biomass production is often studied by relating CGR to plant and environmental factors. When a particular resource is limiting growth, dry matter accumulation may most meaningfully be analyzed in relation to the capture of that resource and the efficiency with which it is converted to biomass (Ofori and Stern, 1993).

Assimilation partitioning is another important process determining crop yield. Higher assimilate partitioning to leaves will maximize light interception whereas higher partitioning to roots will assist the plants to utilize soil resources more thoroughly (Francis, *et al.*, 1978)

Another important partitioning process is that involving the harvested organ, and a measure of the partitioning process occurring through the growth period is harvest index (HI), the ratio of yield to total biomass at maturity. In cereals, harvest index (HI) is commonly about equal to the amount of assimilate produced during grain filling expressed as a fraction of the total biomass production (Ofori and Stern, 1987).

Ofori and Stern, (1993) reported that the goodness of the match between pattern of phenological development of a crop and available growing season is an important determinant of yield in both sole cropping and intercropping. In intercropping, modification of growth environment and also competition with other component crops may alter (commonly delay, in additive intercropping) phenological development of the crop.

A fundamental understanding of the mechanisms of how intercrops capture and use resources would provide a more scientific basis for recommending appropriate combinations of species and planting arrangements for intercropping at different locations (Salih, *et al.*,1999 ; Putnam and Allan, 1992).

The objective of the study was to determine the influence of nitrogen and cowpea variety on light interception and dry matter partitioning during growth in sorghum-cowpea intercrops.

## MATERIAL AND METHODS

The quantity of energy potentially available for photosynthesis that is captured by a crop canopy is defined as absorbed Photosynthetically active radiation (PAR) and is the irradiance occurring in the 400 to 700 nm wavelengths (Gallo and Daughty, 1986). PAR was recorded using Sun Scanner model between 11:hr and 13:00hr. Measurements were taken by recording the PAR above the crop canopy in a plot. The instrument was then placed at ground surface diagonally to two centre rows in the middle of the same plot. The mathematical model by which the PAR is calculated is : PARi = (1-PARb/PARa) x100 where PARi stands for light intercepted and PARb is for below canopy and PARa for above canopy readings as indicated by Carr et al (1992) and Gallo and Daughty (1986). Brown paper bags were placed on the panicles of the plants during the early milk stage of growth to prevent bird damage (Chapter 2). Leaves, shoot, roots, were collected during the flowering stage at all locations and oven dried at 60 ° C. Stover yield was collected at physiological maturity and analysed.

Analysis of variance was done using the statistical package, called Statistix and Fisher's protected LSD and Duncan Multiple range test to determine differences between treatment means.

## RESULTS AND DISCUSSION

### Cowpea dry matter distribution

### Total dry matter

The effect of nitrogen was non significant for total biomass production at all locations. The most striking significant differences were observed within the cropping patterns at ($P \leq 0.05$). Total dry matter accumulation at Syferkuil ranged from 246.95 g $m^{-2}$ to 596.38 g $m^{-2}$ , at Tompi Seleka from 142.2 g $m^{-2}$ to 645.5 g $m^{-2}$ and while at Zebediela total dry matter accumulation ranged from 264.08 g $m^{-2}$ to 553.43 g $m^{-2}$ respectively. Total dry matter accumulation was increased by 0.08%, 4.41% and 0.25% at Zebediela, Tompi Seleka and Syferkuil under intercropping conditions relative to sole cultures. Agrinawa was superior in dry matter accumulation in both sole and intercrop among the variety systems except at Syferkuil where intercrop out yielded sole cultures (Table 9 and 10). Light interception attributed 92,72 and 88% to total cowpea dry matter accumulation at Syferkuil, Tompi Seleka and Zebediela respectively (Figure 4, 5and 6). High total dry matter accumulation was modulated by optimal resource use (Ofori and Stern,1987).

### Leaves

Crop biomass at maturity is the integral of crop growth rate (CGR) over the whole crop duration, and biomass production is often examined by relating CGR to plant and environmental factors (Francis, et al., 1978). The effect of nitrogen was not significant on leaf dry matter accumulation at all locations. Dry matter partitioning to the leaves differed significantly ($P<0.05$) across the cropping systems. Dry matter partitioning to the leaves at Syferkuil ranged from 78.8 g $m^{-2}$ to 172.4 g $m^{-2}$, ranged from 48.5 g $m^{-2}$ to 155.6 g $m^{-2}$ at Tompi Seleka and while at Zebediela, dry matter partitioning to the leaves ranged from 94.4 g $m^{-2}$ to 177.8 g $m^{-2}$ intercropping increased dry matter partitioning to the leaves by 10.2%, and 2% at Tompi seleka and Syferkuil while at Zebediela leaf dry matter accumulation was decreased by 3.7% respectively(Table 9,10 and 11). The difference in the partitioning of dry matter to the leaves depended on the genotype and the environment (Kang, 1998; Terao *et al*, 1997). Late maturing variety, Agrinawa produced the highest leaf dry matter while Pan 311 was the lowest (Table 9,10 and 11).

## Stems

The effect of nitrogen was not significant in stem production at all locations (Table 9,10,11). Stem production differed ($p<0.05$) significantly across cropping systems. Agrinawa produced more stems (424 g $m^{-2}$) compared to other cowpea genotypes (Table 9,10 and 11). Stem dry matter production ranged from 74.5 g/$m^2$ to 424.9 g $m^{-2}$ (Table 9,10,and 11) on average during the growing season. Stem dry matter production at Syferkuil ranged from 136.83 g $m^{-2}$ to 362.5 g $m^{-2}$, at Tompi Seleka it ranged from 74.5 g $m^{-2}$ to 460.13 g $m^{-2}$, while at Zebediela Stem dry matter production ranged from 134.63 g $m^{-2}$ to 424.9 g $m^{-2}$. Agrinawa partitioned its photosynthates to stem development rather than to grain production. This has been reported by other authors attributed mainly due to the genotypic constitution of the crop (Terao, *et al*., 1997). Pan 311, as an early maturing variety partitions its photosynthates to grain seed production. This makes Pan 311 not to be a good forage legume crop for animal production compared to Agrinawa and Bechuana white.

## Roots

The effect of nitrogen was not significant for root dry matter accumulation at location (Table 9,10 and 11). However, root dry matter accumulation differed ($P<0.05$) significantly across cropping patterns. Root dry matter accumulation ranged from 19.2 $g/m^2$ to 63 $g/m^2$ (Table 9,10 and 11) on average during the growing season. Root dry matter accumulation was increased by 9.81%, 6.35 and 0.5% under intercropping systems at Tompi Seleka, Syferkuil and Zebediela respectively. Root dry matter accumulation at Syferkuil ranged from 31.33 g $m^{-2}$ to 63.48 g $m^{-2}$, at Tompi Seleka it ranged from 19.18 g $m^{-2}$ to 45.62 g $m^{-2}$, while at Zebediela Root dry matter accumulation ranged from 30.4 g $m^{-2}$ to 60.4 g $m^{-2}$. Root dry matter partition differed with location that influenced the genotypic variation of the cowpea crops.

### Stover yield

The effect of nitrogen was not significant for stover yield at all locations. Stover yield was significantly different ($P<0.05$) among the intercropping systems, ranging from 2554 kg $ha^{-1}$ to 6349 kg $ha^{-1}$ (Table 9,10 and 11). Pan 311 produced the lowest stover yield compared to the other three cowpea genotypes, Agrinawa, Bechuana White and Pan 326 under the intercropping and sole culture conditions (Table 9,10 and 11). Agrinawa produced the highest stover yield (6348 kg $ha^{-1}$) compared to other cowpea varieties (Table 9). Stover yield was increased by 0.8%,1.46% and 7.35% under intercropping conditions compared to sole cultures (Table 9,10 and 11).

## Sorghum

### Dry matter accumulation

The effect of nitrogen on sorghum dry matter accumulation was not significantly different at all location. Sorghum dry matter accumulation responded significantly ($P<0.05$) to cropping system. Dry matter accumulation was high for sorghum intercrop than in sole culture, irrespective of cowpea genotype. The dry matter accumulation ranged from 277.8 g to 473.4g across the cropping treatments (Table16,17 and 18). Intercropping systems increased sorghum dry matter accumulation by 13.9%, 20.4% and 14.09% at Syferkuil, Tompi Seleka and Zebediela when compared with the sole cultures. Dry matter accumulation was high at Syferkuil and Zebediela and low at Tompi Seleka (Table Table16,17 and 18). High dry matter accumulation at Syferkuil and Zebediela might probably be due to maximum utilization of resources with a minimized inter-specific competition (Fukai and Trenbath, 1993).

## Stover yield

The effect of nitrogen on sorghum stover yield was not significant at all locations. Sorghum-Pan 311 cropping system increased stover yield at Syferkuil by 17.9% (Table 16) and at Tompi seleka by 23.8% (Table16) compared to the sole cultures. Sorghum-Pan 326, sorghum-Bechuana white and sorghum- Agrinawa were not significantly different to sole cultures, sole sorghum (Table 16). There was significant increase of stover yield due to intercropping,of 21.3%, 15.6% and 16% at Tompi Seleka, Syferkuil and Zebediela, respectively compared to sole cultures (Table16, 17and 18). Stover yield ranged from 4300 kg $ha^{-1}$ to 6894 kg $ha^{-1}$ (Table 16,17 and 18). Early variety, Pan 311 modified the environmental resources for the sorghum to use the resources optimally.

## Light Interception

Solar radiation is the energy that drives crop productivity by the process of photosynthesis(Keating and Carberry,1993). Minimizing the proportion of radiant energy reaching the ground is a simple means of promoting efficient utilization of incident solar radiation (Keating and Carberry,1993). The effect of nitrogen on light interception was not significantly different at all location. Light interception differed ($P<0.05$) significantly across all cropping systems. More light was intercepted at Syferkuil and Zebediela and less light was intercepted at Tompi seleka.. Light interception depended mostly on the phenological development of the crop, The more longer the vegetative stage the more light intercepted and vice versa ( Figure 1,2 and 3). Light interception attributed 93%,64% and 92% to sorghum dry matter accumulation at Syferkuil, Tompi Seleka and Zebediela respectively (Figure.7,8 and 9).

## CONCLUSION

Assimilation partitioning is another important process determining crop yield in intercropping and monocropping conditions. Assimilation partitioning differed across the cowpea varieties incorporated in the cropping patterns due to their different phenological developmental patterns. Agrinawa produced the highest in leaf (177.8 g $m^{-2)}$, shoot (424 g $m^{-2}$) and root (63 g $m^{-2}$) dry matter accumulation, with Pan 311 producing less compared to the other cowpea varieties in both intercropping and sole culture conditions. Total dry matter ranged from 142.2 kg $ha^{-1}$ to 596.38 kg $ha^{-1}$ with Agrinawa producing more compared to other legumes. Stover yield highest in Agrinawa (6348.5 kg $ha^{-1}$), with Pan 311 having the least (2553.8 kg $ha^{-1}$). Sorghum dry matter accumulation ranged from 277.8 g $m^{-2}$ to 473,4 g $m^{-2}$. Intercropping increased sorghum dry matter by an average percentage of 18%. Light interception depended mostly on the phenological development of the crop, The longer the vegetative stage the more light intercepted and vice versa (Figure 1,2 and 3). Cropping patterns influenced light interception and dry matter partitioning during the growing period of sorghum and cowpea.

# CHAPTER 4

# SORGHUM-COWPEA INTERCROPPING: THE INFLUENCE OF NITROGEN AND COWPEA VARIETIES ON GRAIN YIELD AND YIELD COMPONENT


## ABSTRACT

This study was conducted in the field during the 1999-2000 cropping season to assess important yield components and to estimate LER as a measure of overall system productivity at three locations in the sorghum growing areas of Northern Province namely; Syferkuil, Zebediela and Tompi seleka. The experiments were carried out using randomised complete block design in a split plot arrangement. Two levels of nitrogen were assigned as the main treatments and nine intercropping systems as the subplots. Sorghum, Macia (dwarf) was intercropped with four cowpea genotypes Pan 311, Pan 326, Bechuana white and Agrinawa. Cowpea grain yield ranged from 396.4 kg $ha^{-1}$ to 2031 kg $ha^{-1}$ while in sorghum grain yield was increased by 19 to 23% under intercropping compared to sole cultures. The harvest index of cowpea ranged from 6 to 46% while HI of sorghum ranged from 15 to 27% across all locations. Land Equivalent Ratio values indicated a land use efficiency of 6 and 35% under intercropping patterns compared to the sole cultures. The inverse productivity between intercropping and sole cultures indicated lack of adequate resources to maintain the numerous pods produced by intercropped plant, probably due to competitive pressure from sorghum. Number of pods, seeds per pod and 100 seed mass, weight per panicle, seeds per panicle and 1000 seed mass are important yield components and have a high impact on grain yield in cowpea and sorghum.



**Keyword:** Cowpea, Land equivalent ratio, grain yield, yields component

# INTRODUCTION

Intercropping is defined as growing two or more crops simultaneously on the same field (Andrews and Kassam, 1976)and it is a common traditional practice among the resource-poor farmers throughout the Northern Province of South Africa. Sorghum is predominantly grown in intercropping systems with pumpkin, watermelon and cowpea in the Province (Liphadzi, 1998). Small scale farmers have shown preference for this system as it provides an opportunity to grow different crops, reduces risk of crop failure in unfavourable seasons, and employs family labour more gainfully.

Kass (1978) reported that the practice of intercropping is common to farmers throughout the semi-arid tropics and many studies have demonstrated substantial increases in intercrop productivity compared to sole cultures. Studies by Andrews (1972) and Reddy et al: (1980) with sorghum and cowpea have demonstrated that these two crops can be successfully combined to produce both legume and cereal more efficiently than growing them separately.

Cowpea is an important grain legume in South Africa. Alghali (1991) reported that cowpea provides an inexpensive source of protein for the rural poor and is valued for its flavour and short cooking time. The plant is especially favoured by farmers because of its ability to maintain soil fertility through symbiotic nitrogen fixation (Blade,*et al* 1992). Cowpea is generally grown as the understorey crop in a system based on cereals and is useful because it establishes rapidly. This results in less soil erosion, a reduction in soil temperature, and lowers weed pressure (Vandemeer. 1992). Intercropping provides a useful basis for interpreting the three basic interspecies relationships: mutual inhibition, mutual co-operation and compensation. When mutual inhibition occurs, both crops in the mixture yield less than their potential (expected) yields in sole. In the case of mutual cooperation, both crops in the mixture yield more than expected, but if compensation occurs, the yield of one species surpasses the other and makes up for the inferior performance of the component crop.

The potential for overyielding indicates that resources are maximized in an intercropping system (Vandemeer, 1992). Research has indicated that growing two or more species at the same time can have advantages in light interception, water use, and nutrient uptake (Vandemeer, 1992). Ofori and Stern (1993) reported that intercropping productivity depends on genetic constitution of component crops, growth environment (atmospheric and soil) and agronomic manipulations of micro environment. The interaction of these factors should be optimized so that the limiting resource is utilized more effectively in the intercrop (Ofori and Stern, 1993). An understanding of the sharing of resources among component crops will help identify more appropriate agronomic manipulations and cultivars for intercrops. Wiley (1979) and Vandemeer (1992) reported that a yield advantage of intercropping occurs because component crops differ in their use of growth resources in such a way that when they are grown in combination they are able to complement each other and so, make better overall use of resources than when grown separately. Wiley (1979) observed that it is possible to have a sparse canopy, say tall cereals for the high light intensities at the top of the canopy and a more dense canopy say a compact legume for the lower intensities.

Intercropping grain sorghum and legumes is a common practice in the tropics, but the effects of nitrogen application in this intercropping system have not yet been fully studied. Intercropping with legumes is used to avoid application of expensive nitrogen fertilizers and may be one possible way to increasing land productivity (Allen and Obura, 1983). Bandyopadhyay and DE, 1986) observed an increased yield and nitrogen fixation by the intercropped legumes and improved nutrient-uptake efficiency from soil and N fertilizers (Elmore and Jacobs, 1986) as some of the advantages of intercropping.

There is limited information on intercropping sorghum (*Sorghum bicolor* L) and cowpea (*Vigna unguiculata*) and data on the efficiency of intercropping sorghum and legumes with or without nitrogen fertilization. Such information could provide an alternate and sustainable production system for many resource-poor farms in the Northern Province of South Africa.

Sorghum and cowpea are very important field crops in South Africa and are mostly grown by resource- poor farmers as intercrops. Despite the popularity of these crops, yield levels from production fields of the small-scale farmers remain low to marginal due to poor availability of growth resources. Agronomic practices that will increase seed yields per unit area without substantial chemical input is essential to assisting resource poor farmers in these regions. Recent attempts to improve sorghum productivity among resource-poor farmers have been through the introduction of new varieties said to be high yielding. Though crop yield in intercropping is an end product of many plant growth processes that interact with the environment, is often limited by lack of adequate resources, and is mostly determined by how efficiently the crop can utilize the available resources.

The creation of favourable growing conditions for the less competitive legume crop in intercropping is important in ensuring overall increase in productivity (Vandemeer, 1992). Faris *et al* (1983) and Carr et al (1992) found that yield of sorghum can be enhanced by intercropping with legumes, possibly because biologically fixed N is transferred from legume to sorghum plant (Elmore and Jacobs, 1986). One of the reasons put forward for these higher yields is that the component crops complement each other and make better overall use of resources when growing together than when growing separately (Vandemeer, 1992).

Putnam *et al* (1986) concluded that intercropping increased protein content of forages. Though there seems to be a convincing trend of high yield in intercropping relative to sole cultures, Trenbath (1993) concluded that only a minority of binary mixtures resulted in increased yields and that the margin of yield increase was usually statistically insignificant and very sensitive to environmental conditions.

The objectives of the study were to:

(i) Identify important yield components which have high impact on grain yield in sorghum - cowpea intercrops.

(ii) Estimate Land Equivalent Ratio as a measure of overall system productivity.

## MATERIAL AND METHODS

The plot size was 5m (length) x 3.6 m (wide) with each plot consisting of eight rows and of which the middle four rows were designated for dry matter sampling and grain yield determination. Seed yields of individual rows of all treatments were measured at maturity and sole crop yields were obtained from centre rows (mid plot) of the sole crop plots. Seed yields of component crops were harvested in all treatments at physiological maturity and dry matter at flowering. More details can be obtained from chapter 2 .

The land equivalent ratio (LER) was calculated according to the method of Mead and Willey (1980) to determine overall system productivity. The LER is defined as the amount of land planted to sole crops required to attain the same yield as in the intercrop. LER values significantly greater than 1.0 indicate an intercrop advantage relative to sole crop; LER values less than 1.0 indicate an intercrop disadvantage; and an LER equal to 1.0 implies no difference between the intercrop and sole crop. LERs were calculated as

$$LER = (Yab/Yaa) + (Yba/Ybb)$$

where Yaa and Ybb are the sole crop yields of crops a and b, respectively, Yab is the intercrop yield of crop a, and Yba is the intercrop yield of crop b. Physiological maturity of cowpeas was recorded when 90% of the plants in a plot had reached pod rattling. Harvest index, Yield components, and physiological maturity were also determined.

The data was pooled across all locations before analysis, since N did not influence component crop productivity. Heavy rainfall enhanced N leaching (Buckman and Brady,1969) and for this reason nitrogen data was disregarded and only cropping systems were considered. Statistical analyses were performed using the statistical package, STATISTIX and differences between means were compared using LSD.

## RESULTS AND DISCUSSION

## Cowpea

### Grain Seed Yield

The effect of nitrogen on cowpea grain seed yield was not significantly different at all location. The most striking significant differences were observed within the cropping patterns. Grain yield produced ranged from 396.4 kg $ha^{-1}$ to 2031.7 kg $ha^{-1}$ (Table 11). On average more grain yield was produced at Syferkuil and followed by Zebediela, with Tompi seleka produced the lowest. Pan 311, an early maturing genotype, produced the highest yield compared to other cowpea genotypes under intercropping and sole cropping conditions (Table12). Comparing average intercrop yields with sole cultures, Intercropping treatments increased grain yield by 6.5%,5.0% at Syferkuil and Tompi Seleka, respectively. However, at Zebediela, reduction of 3.2% in grain yield was observed.

### Harvest index

Harvest index reflects the ratio of economic yield (grain) to the total biological productivity of a crop and it gives an indication of how plants partition dry matter into reproductive organs relative to vegetative parts. The effect of nitrogen on harvest index was non-significant at all locations. The striking significant differences in harvest index were observed among the cropping patterns at all location. Pan 311 was superior (44%) in both sole cultures and intercrop compared to Agrinawa with the HI of 8% (Table16). At Tompi Seleka, Harvest index ranged from 5.7% to 46% (Table 16) with Zebediela scoring the lowest compared to other locations. The HI in

Zebediela ranged from 9% to 37% for Pan 311 and Agrinawa, respectively.

## Yield component

The effect of nitrogen on yield component was not significantly different. Number of pods per plant differed ($P<0.05$) significantly among the cropping systems at Syferkuil, Tompi Seleka and Zebediela. Sole Pan 311 and sorghum-Pan311 among all cropping systems (Table 6,7 and 8) produced the highest numbers of pods.

Intercropping increased number of pod per plant by 3.3%,9.1% and 8.9% at Syferkuil, Tompi Seleka and Zebediela, compared to sole cultures, respectively.

Seed per pod differed significantly ($P<0.05$) across all cropping systems at all location (Table 6,7 and 8). Intercropping systems increased seed per pod by 1.9%, 10.8% and 10.5% at Syferkuil, Tompi Seleka and Zebediela compared to sole cultures, respectively (Table 6,7 and 8). Same trend was observed in 100 seed mass that differed significantly ($P<0.05$) at all locations. Intercropping increased 100 seed mass by 3.9%, 3.5% and 4.6% at Syferkuil, Tompi Seleka and Zebediela compared to sole cultures, respectively. The higher grain yield recorded in Pan311 was partly modulated through increased number of pod per plant and larger seeds. The inverse productivity between intercropping and sole cultures indicates lack of adequate resources to maintain the numerous pod produced by the intercropped plant, probably due to competitive pressure from sorghum.

## Flowering and physiological maturity

The effect of nitrogen on flowering and physiological maturity was significantly different at all location. Intercropping systems had significant effect on flowering and physiological maturity at all locations (Table13,14 and 15). The early flowering varieties, Pan 311 and Pan 326 flowered between 47. and 56 days after emergence whereas Bechuana white and Agrinawa were the slowest in floral appearance, occurring about 69 to 73 days after emergence(Table 13,14 and 15). Intercropping increased flowering by 5% and 5.3% at both Tompi Seleka and Zebediela, respectively (Table 13,14 and 15) compared to sole cultures. At Syferkuil flowering was decreased by 3.5% compared to sole cultures (Table 13).

Days to physiological maturity also differed across the cropping systems with Pan 311 exhibiting the earliest maturity. Trend in maturity across the cropping systems did not appear to be similar to that of flowering (Table 13,14 and15). Intercropping increased physiological maturity by 7%,5.1%and 5% at Suferkuil, Tompi Seleka and Zebediela, respectively (Table 13,14 and 15). Flowering and physiological maturity attributed 48 and 19% to grain seed yield production at Syferkuil. At Zebediela flowering and physiological maturity attributed 12 and 6%, respectively whereas at Tompi Seleka physiological maturity attributed 10% and flowering 1% to grain seed yield.

## Sorghum

### Seed Yield

Nitrogen effect was not significantly different on seed yield at all location. Highly significant ($P \leq 0.05$) grain yield response in sorghum was observed among all cropping systems at all locations (Table 16,17 and 18). Grain seed yield at Syferkuil was increased by 22 and 19% under Sorghum-Pan 311 and Sorghum-Pan326, Sorghum-Bechuana white and Sorghum-Agrinawa intercrop respectively. At Tompi seleka, 25,22,21 and 23% increase under Sorghum-Pan311, Sorghum-Pan326, Sorghum-Bechuana white and Sorghum-Agrinawa intercrop respectively was observed while Sorghum- Pan311 combination was also high with the % increase of 23%. The reason for high grain seed yield in sorghum under Sorghum-Pan311 was due reduced nutrient competition and enhanced micro environmental modifications effected by Pan 311 as an early variety (Ofori and Stern,1987 and Fukai,1993). Intercropping, on average increased sorghum grain yield by 19.,23 and 20% at Syferkuil, Tompi Seleka and Zebediela respectively compared to sole culture.

### Yield Component

The nitrogen effect on sorghum yield component was not significantly different at all locations. There was a significant effect of cropping patterns ($P \leq 0.05$) on sorghum panicle weight. Compared to sole cultures, intercropping systems increased weight per panicle by 40.5,45.6 and 36.1% at Syferkuil, Tompi Seleka and Zebediela, respectively. The weight per panicle ranged from 59.0 g to 103.6g across all locations (Table 13, 14 and 15).

The trend of seeds per panicle followed the trend of weight per panicle, where intercropping produced 26.8, 27.2 and 23.8% increase at Syferkuil, Tompi seleka and Zebediela, compared to sole culture, respectively (Table 13, 14 and 15**).** Seed per panicle was ranging from 61.0 g to 91.0 g in cropping pattern. Cropping systems had a significant effect on 1000 seed mass. Intercropping systems increased 1000 seed mass by 66.0,72.0 and 44.4% at Syferkuil, Tompi Seleka and Zebediela compared sole culture (Table 13,14 and 15). Increase grain yield resulting from greater seed mass has previously been reported for soybean (Slater et al, 1991)

**Flowering and Physiological Maturity**

The effect of nitrogen on sorghum flowering and physiological maturity was not significantly different all location. Significant differences were observed in physiological maturity among the cropping systems only at Syferkuil and Zebediela (Table 13, 14 and 15). Days to 50% flowering at Syferkuil ranged from 59 to 61%. At Tompi seleka, flowering ranged from 55 to 58% compared to flowering at Zebediela that had similar trend to Syferkuil. Early and late cowpea varieties intercropped with sorghum did not influence flowering and physiological maturity of sorghum.

## Harvest Index

Harvest index reflects the ratio of economic yield (grain) to the total biological productivity of a crop and it gives an indication of how plants partition dry matter into reproductive organs relative to vegetative parts. Harvest index did not differ ($P<0.05$) significantly across the cropping systems. Although not significant, numerically harvest index ranged from 15 to 27% across locations. The variation in harvest index has been reported to be also dependant to crop interaction with environment (Donald and Hamblin,1976)

## Land equivalent Ratio

The LER ratio is defined as the amount of land planted to sole crops required to attain the same yield as in the intercrop. LER values significantly greater than 1.0 indicate an intercrop advantage relative to sole crop; LER values less than 1.0 indicate an intercrop disadvantage; and an LER equal to 1.0 implies no difference between the intercrop and sole crop. The positive LER resulting from cropping systems appears to be a function of resource niche differentiation in both time and space(Ofori and Stern,1987 and Fukai, 1993). The higher LER was probably due to the creation of regions of greater resource abundance than in the sole crops(Midmore,1993). Partial LER of Sorghum ranged from 0.59 to 0.63 (Table19,20 and 21) while in cowpea ranged from 0.45 to 0.75 (Table 19,20 and 21). The total Land equivalent ratio ranged from 1.06 to 1.35 (Table 19,20 and 21). The results indicate a land use efficiency of 6 and 35% under intercropping systems relative to the sole cultures (Mead and willey,1983). Schultz et al (1973) and Midmore (1993) attributed high LER values to optimal irrigation during the growing seasons of the components crops. and believed that optimal irrigation therefore apparently could relieve the effect of overcrowding, hence mitigating inter-specific competition for resources.

# CONCLUSION

Pan 311 produced the highest seed yield of 2031.7 kg $ha^{-1}$ compared to other cowpea intercropped and in sole cultures. The high seed yield of Pan 311 intercropped and sole cultures was partly attributed to its higher harvest index, higher number of pods per plant and heavier seeds relative to other cowpea varieties.

The lowest yield was observed in Agrinawa with an average yield of 396.4 kg $ha^{-1}$ attributable to low harvest index in both intercropping and sole cultures conditions.

Sorghum grain yield ranged from 1521 kg $ha^{-1}$ to 2159.2 kg $ha^{-1}$. High grain yield of sorghum was observed under intercropping systems than under sole cropping and was attributable to its high weight per panicle, seed per panicle and thousand seed weight. Intercropping enhanced high complementarity through optimal use of resources within the component crops. Intercropping enhanced land use efficiency.

**SUMMARY**

Management of intercrops to maximize their complementarity and synergism and to minimise competition has been demonstrated with sorghum intercropped with four cowpea varieties. A randomized complete block design in a split arrangement was used with two levels of nitrogen assigned as the main treatment and nine cropping systems as subplots. The experiment was replicated three times. Sorghum and cowpea varieties were arranged in alternate intercropping pattern in which alternate single rows of sorghum and cowpea spaced 0.9 cm apart between the sorghum and cowpea with an inter-row of 0.15 in all component crops. The objectives of the study were to (1) determine the significance of cowpea and nitrogen fertilizer on dry matter accumulation and grain yield in sorghum and cowpea intercrop, (2) assess patterns of dry matter partitioning and light interception in sorghum and cowpea intercropping and (3) assess the impact of intercropping on insect pest population of african Bollworm, *Helicoverpa armigera*; sorghum aphid, *Melanaphis sacchari*; maize aphid, *Rhopalsiphum maidis* and stem borers, *Chilo partellus* and *Busseola fusca*

An infestation level of *C.partellus* was higher than that of *B. fusca* at all sites. *C. partellus*, larvae constituted 80.8,88.8 and 66.5% of stem borer population at Syferkuil, Tompi Seleka and Zebediela respectively. Sorghum-Agrinawa treatment reduced *C.partellus* population by 58% at Zebediela compared to 40 and 15% reduction observed at Syferkuil and Tompi Seleka. The number of *B. fusca* larvae was reduced by 62.4% in intercropping treatments relative to sole culture at Syferkuil . Although not significant, intercropping reduced *B.fusca* infestation by 72.7 and 24% at Tompi seleka and Zebediela. Sorghum-Agrinawa treatment reduced mean entry holes by 57 and 30% at Syferkuil

and Zebediela respectively, while at Tompi Seleka, mean exit holes were reduced by 30% by sorghum-Pan311.

Sorghum-Agrinawa treatment reduced exit by 66 and 26% at Syferkuil and Zebediela, respectively. The incidence of whorl damage in sorghum grown as pure crop was significantly higher (90.3%) than other treatments. When intercropped with cowpea the incidence of whorl damage was 50%(sorghum-Pan311), 56(sorghum-Pan 326), 53.3(sorghum-Bechuana White), 48.3% (sorghum-Agrinawa) at Syferkuil, respectively. sorghum-Pan311 reduced deadheart by 97% while sorghum-Pan326 and sorghum-Agrinawa treatments reduced deadheart by 94% at Zebediela.

Intercropping treatments reduced *H. armigera* infestation significantly at Syferkuil and Tompi Seleka. Sorghum-Pan 311 reduced the number *of H. armigera* larvae by 85% compared to sole cultures.

Sorghum aphid, *M.sacchari* abundance score was reduced by 43.2 and 39.2% in all intercropping treatments at Syferkuil and Zebediela. Intercropping significantly reduced *R. maidis* abundance score by 52.4 and 34.8% at Syferkuil and Zebediela respectively compared to sole cultures. The sorghum-Agrinawa intercropping treatment showed the most promising cropping system relative to sole. Intercropped sorghum reduced the number of plants with maize aphid by 37.7 and 36.8% at Zebediela and Syferkuil.

Total dry matter accumulation at Syferkuil ranged from 246.95g $m^{-2}$ to 596.38g $m^{-2}$, at Tompi Seleka ranged from 142.2 g $m^{-2}$ to 645.5 g $m^{-2}$ and while at Zebediela total dry matter accumulation ranged from 264.08 g $m^{-2}$ to 553.43 g $m^{-2}$. Light interception attributed 92, 72 and 88% to total cowpea dry matter accumulation at Syferkuil, Tompi Seleka and Zebediela respectively. Dry matter partitioning to the leaves at Syferkuil ranged from 78.78 g $m^{-2}$. to 172.4 g $m^{-2}$., at Tompi Seleka ranged from 48.5 g $m^{-2}$. to 155.6 g $m^{-2}$. and while at Zebediela dry matter partitioning to the leaves ranged from 94.4 g $m^{-2}$. to 177.8 g $m^{-2}$.. Intercropping systems increased stem dry matter production by 10%, 6% and 1% at Zebediela, Tompi Seleka and Syferkuil.

Root dry matter accumulation at Syferkuil ranged from 31.33 g $m^{-2}$ to 63.48 g $m^{-2}$, at Tompi Seleka ranged from 19.18 g $m^{-2}$. to 45.62 g $m^{-2}$. and while at Zebediela Root dry matter accumulation ranged from 30.4 g $m^{-2}$. to 60.4 g $m^{-2}$., respectively.

Cowpea stover yield ranged from 2554 to 6349 kg $ha^{-1}$. Pan 311 produced the lowest stover yield compared to the three cowpea genotypes, Agrinawa, Bechuana White and Pan 326 under the intercropping and sole culture conditions

Intercropping treatments increased sorghum dry matter accumulation by 13.9, 20.4 and 14.09% at Syferkuil, Tompi Seleka and Zebediela when compared with the sole cultures. Light interception attributed 93, 64 and 92% to sorghum dry matter accumulation at Syferkuil, Tompi Seleka and Zebediela respectively. A significant sorghum stover yield increase due to intercropping treatments was 21.3, 15.6 and 16% at Tompi Seleka, Syferkuil and Zebediela, respectively compared to sole cultures.

Cowpea grain yield produced ranged from 396.4 to 2031.7 kg $ha^{-1}$. Pan 311 as an early maturing genotype produced the highest yield compared to other cowpea genotype under intercropping and monocropping conditions. Cowpea harvest index ranged from 5.7 to 45.9%, respectively. Sole Pan 311 and sorghum-Pan311 produced the highest number of pods were across all cropping systems. The early flowering varieties, Pan 311 and Pan 326 flowered between 47 and 56 days after emergence whereas Bechuana white and Agrinawa were the slowest in floral appearance, occurring about 69 to 73 days after emergence.

Intercropping increased sorghum grain yield by 19.3, 22.8 and 20% at Syferkuil, Tompi Seleka and Zebediela respectively compared to sole culture. The trend of seeds per panicle followed the trend of weight per panicle, where intercropping produced 26.8, 27.2 and 23.8% increase at Syferkuil, Tompi seleka and Zebediela, compared to sole culture, respectively. Intercropping treatments increased 1000 seed mass by 66, 72 and 44.4% at Syferkuil, Tompi Seleka and Zebediela compared sole culture. The total Land equivalent ratio ranged from 1.06 to 1.35. The results indicated a land use efficiency of 6 to 35% under intercropping systems relative to the sole cultures. The study suggests that intercropping has a potential in improving crop management under resource poor farming conditions of the Northern Province.

## TABLES AND GRAPHS

Table 1. Mean number of entry and exit holes, incidence of whorl damage and dead heart symptoms, and the number of *Chilo partellus* and *Busseola fusca* larvae per plant under different intercropping systems at Syferkuil in the Northern Province

| Cropping patterns φ | *C. partellus* $Plant^{-1}$ | *B. fusca* $Plant^{-1}$ | Mean no of entry holes per stem | Mean no of exit holes per stem | Whorl damage % | Deadheart % | *H. armigera* $Panicle^{-1}$ |
|---|---|---|---|---|---|---|---|
| T1 | 2.5 | 0.8a | 6.8a | 3.8a | 90.3a | 55.6 | 1.4a |
| T2 | 1.6 | 0.2b | 4.3b | 2.5ab | 50b | 33.3 | 0.2d |
| T3 | 1.4 | 0.3b | 3.8b | 2.4b | 56.1b | 22.2 | 0.4cd |
| T4 | 1.4 | 0.4ab | 3.6b | 2.1b | 53.3b | 50.0 | 0.9b |
| T5 | 1.5 | 0.3b | 2.9b | 1.3b | 48.3 | 16.7 | 0.8bc |
| $LSD_{0.05}$ | ns | 0.4091 | 1.8407 | 1.2453 | 23.753 | ns | 0.3909 |
| Nitrogen | | | | | | | |
| 0 kg N | 1.66 | 0.4 | 4.5 | 2.6 | 59.2 | 50.1 | 0.7 |
| 120 kg N | 1.8 | 0.4 | 4.2 | 2.3 | 60 | 20 | 0.7 |
| $LSD_{0.05}$ | 0.2 | ns | ns | ns | ns | ns | ns |

Means followed by the same letters in a column are not significantly different ($P \leq 0.05$;Least significance differences test). φ = T1=sole sorghum, T2=sorghum- Pan 311, T3=sorghum-Pan 326, T4=sorghum- Bechuana white, T5=sorghum- Agrinawa. ns = non significant.

Table 2. Mean number of entry and exit holes, incidence of whorl damage and dead heart symptoms, and the number of *Chilo partellus* and *Busseola fusca* larvae per plant under different intercropping systems at Tompi Seleka in the Northern Province.

| Cropping systems φ | *C.partellus* $Plant^{-1}$ | *B. fusca* $Plant^{-1}$ | Mean no of entry holes per stem | Mean no of exit holes per stem | Whorl damage % [1] | Deadheart % | *H. armigera* $panicle^{-1}$ |
|---|---|---|---|---|---|---|---|
| T1 | 3.9 | 1.1 | 5.6 | 0.9 | 100 | 43.8a | 0.5a |
| T2 | 3.0 | 0.2 | 3.8 | 0.9 | 100 | 33.3ab | 0.3b |
| T3 | 3.9 | 0.5 | 5.1 | 1.1 | 100 | 23.3b | 0.3b |
| T4 | 4.1 | 0.3 | 5.1 | 1.2 | *100* | 26.7b | 0.3b |
| T5 | 3.3 | 0.2 | 4.3 | 1.9 | *100* | 28.3b | 0.2 |
| $LSD_{0.05}$ | ns | ns | ns | ns | ns | 14.738 | 0.0981 |
| Nitrogen | | | | | | | |
| 0 kg N | 3.32 | 0.4 | 4.7 | 1.4 | 100 | 30.8 | 0.3 |
| 120 kg N | *3.98* | 0.5 | 4.9 | 0.9 | 100 | 31.3 | 0.3 |
| $LSD_{0.05}$ | ns | ns | ns | ns | ns | ns | ns |

Means followed by the same letters in a column are not significantly different ($P \leq 0.05$;Least significance differences test). φ=T1=sole sorghum, T2=sorghum- Pan 311,T3=sorghum-Pan 326,T4=sorghum- Bechuana white,T5=sorghum-Agrinawa. ns = non significant.

Table 3. Mean number of entry and exit holes, incidence of whorl damage and dead heart symptoms, and the number of *Chilo partellus* and *Busseola fusca* larvae per plant under different intercropping systems at Zebediela in the Northern Province.

| Cropping patterns φ | *C.partellus* $Plant^{-1}$ | *B. fusca* $Plant^{-1}$ | Mean no of entry holes per stem | Mean no of exit holes per stem | Whorl damage % | Deadheart % | H. armigera $Panicle^{-1}$ |
|---|---|---|---|---|---|---|---|
| T1 | 4.8a | 1.7 | 13.2a | 7.4 | 64.2 | 17.9a | 2.8 |
| T2 | 3.0b | 1.8 | 10.6b | 5.9 | 30.5 | 0.5b | 2.4 |
| T3 | 2.7b | 1.3 | 9.8b | 5.8 | 36.1 | 1.0b | 1.5 |
| T4 | 2.8b | 0.7 | 10.b | 6.5 | 52.8 | 11.6ab | 1.7 |
| T5 | 2.0b | 1.7 | 9.2b | 5.5 | 33.3 | 1.0b | 2.0 |
| $LSD_{0.05}$ | 1.0653 | ns | 2.369 | ns | ns | 13.018 | ns |
| Nitrogen | | | | | | | |
| 0 kg N | 3.4 | 1.3 | 10.7 | 6.2 | 31.2 | 5.0 | 2.16 |
| 120 kg N | 2.7 | 1.5 | 10.5 | 6.3 | 55.6 | 7.4 | 2.0 |
| $LSD_{0.05}$ | ns | ns | ns | ns | ns | ns | ns |

Means followed by the same letters in a column are not significantly different ($P \leq 0.05$; Least significance differences test).φ=T1=Sole sorghum, T2=- Pan311,T3=sorghum-Pan 326,T4=sorghum-Bechuana white, T5=sorghum-Agrinawa). ns = non significant

Table 4. Mean rating of number of plants for *Melanaphis sacchari* and *Rhopalsiphum maidis* abundance under different intercropping patterns at Syferkuil experimental farm in the Northern Province.

| Cropping patterns φ | No of plants in $m^2$ | No. of Plants with *M.sacchari* | *M.sacchari* abundance | No.of plants with *R.maidis* | *R.maidis* abundance |
|---|---|---|---|---|---|
| T1 | 4.5 | 5.6a | 4.6a | 9.1a | 4.2a |
| T2 | 4.4 | 4.7a | 3.8a | 5.8b | 2.5b |
| T3 | 4.3 | 3.2b | 2.1b | 5.9b | 2.6b |
| T4 | 5.1 | 3.2b | 2.0b | 5.0b | 1.8 |
| T5 | 4.4 | 2.5b | 2.2b | 6.3b | 1.2d |
| $LSD_{0.05}$ | ns | 1.0932 | 0.8573 | 1.4110 | 0.6201 |
| Nitrogen | | | | | |
| 0 kg N | 4.4 | 3.8 | 2.7 | 6.8 | 2.8 |
| 120 kg N | 4.5 | 3.7 | 3.1 | 6.4 | 2.1 |
| $LSD_{0.05}$ | ns | ns | ns | ns | ns |

Means followed by the same letters in a column are not significantly different ($P \leq 0.05$; Least significance differences test). φ= T1=sole sorghum, T2=sorghum-Pan 311, T3=sorghum-Pan 326, T4=sorghum-Bechuana white, T5=sorghum- Agrinawa. ns = non significant.

Table 5. Mean rating of number of plants for sorghum aphids, *Melanaphis sacchari* and *Rhopalsiphum maidis* abundance under different intercropping systems at Zebediela in Northern Province.

| Cropping patterns φ | No of plants in $m^2$ | No. of Plants with *M.sacchari* | *M.sacchari* abundance | No. of plants with *R.maidis* | *R.maidis* abundance |
|---|---|---|---|---|---|
| T1 | 3.6 | 3.7a | 3.9a | 6.1a | 4.3a |
| T2 | 2.5 | 3.0b | 3.3b | 4.2b | 3.2b |
| T3 | 2.7 | 1.7c | 1.8c | 3.7b | 2.8b |
| T4 | 2.9 | 2.0c | 1.5c | 3.5b | 2.8b |
| T5 | 2.7 | 1.8c | 1.5c | 3.8b | 2.5b |
| $LSD_{0.05}$ | ns | 0.6617 | 0.4896 | 1.3068 | 0.9624 |
| Nitrogen | | | | | |
| 0 kg N | 3.1 | 2.6 | 2.4 | 3.7 | 3.2 |
| 120 kg N | 2.5 | 2.3 | 2.4 | 4.8 | 3.1 |
| $LSD_{0.05}$ | ns | ns | ns | ns | ns |

Means followed by the same letters in a column are not significantly different ($P \leq 0.05$;Least significance differences test). φ = T1=sole sorghum, T2=sorghum- Pan 311,T3=sorghum-Pan 326,T4=sorghum- Bechuana white,T5=sorghum-Agrinawa. ns = Non significant.

Table 6. Flowering, maturity and yield component of different cowpea cultivars grown under intercropping systems at Syferkuil in the Northern Province.

| Cropping patterns φ | Days to 50% flowering | Physiological maturity (days) | Yield Component | | |
|---|---|---|---|---|---|
| | | | Pod plant $^{-1}$ | Seed pod$^{-1}$ | 100 seeds mass |
| | | | No | No | g |
| T1 | 54.67b | 71.83c | 44.8a | 17.033a | 11.673ab |
| T2 | 55.3b | 75.66c | 31.08bc | 14.467ab | 9.990bc |
| T3 | 67.67a | 92.16ab | 32.83bc | 15.900a | 10.773ab |
| T4 | 73.83a | 108.33a | 21.28d | 12.617b | 7.723d |
| T5 | 53.17b | 68.5c | 46.58a | 17.167a | 12.39a |
| T6 | 55.67b | 79.33bc | 38.05ab | 15.250ab | 10.490ab |
| T7 | 66.00a | 93.83ab | 29.33bcd | 16.217a | 10.790ab |
| T8 | 73.83a | 98.67a | 23.82cd | 12.550b | 8.190dc |
| CV (%) | 12.27 | 14.77 | 21.66 | 16.48 | 17.27 |

Means within columns followed by different letters differ significantly ($P \leq 0.05$: Duncan Multiple range test). DAE =Days after emergence. φ= T1=sole Pan 311,T2=sole Pan 326, T3=sole Bechuana white,T4 =sole Agrinawa,T5=sorghum-Pan311,T6=sorghum-Pan326 T7=sorghum-Bechuana white and T8=sorghum-Agrinawa.

Table 7. Flowering, maturity and yield component of different cowpea cultivars grown under intercropping systems at Tompi Seleka in the Northern Province.

| Cropping systems φ | Days to 50% flowering | Physiological maturity | Yield Component | | |
|---|---|---|---|---|---|
| | | | Pod plant $^{-1}$ | Seed pod$^{-1}$ | 100 seeds mass |
| | | | No | No | g |
| T1 | 47.2c | 59.3f | 36.5b | 9.8bc | 7.78b |
| T2 | 52.7c | 75.3d | 23d | 8.9c | 6.85c |
| T3 | 60.3b | 85b | 17.4e | 10.9b | 7.83b |
| T4 | 71.2a | 100.3ab | 8.7f | 5.5d | 3.72d |
| T5 | 50.7c | 66.3ef | 41.a | 13.2a | 10.07a |
| T6 | 52.3c | 71.7ed | 25.8c | 9.2bc | 6.6c |
| T7 | 68a | 93b | 15.7e | 11b | 7.13bc |
| T8 | 72a | 105.3a | 10.9f | 5.5d | 3.32d |
| CV (%) | 7.3 | 8.14 | 9.7 | 13.1 | 10.32 |

ns= non significant difference among varieties under intercropping and sole systems. Means within columns followed by different letters differ significantly at $P \leq 0.05$: Duncan multiple range test. DAE = Days after emergence. φ= T1=sole Pan 311,T2=sole Pan 326, T3=sole Bechuana white, T4=sole Agrinawa, T5=sorghum-Pan 311, T6=sorghum-Pan326,T7=sorghum-Bechuana white and T8=sorghum-Agrinawa.

Table 8. Flowering, maturity and yield component of different cowpea cultivars grown under intercropping patterns at Zebediela in the Northern Province.

| Cropping patterns φ | Days to 50% flowering | Physiological maturity | Yield Component Pod plant $^{-1}$ | Seed pod$^{-1}$ | 100 seeds mass |
|---|---|---|---|---|---|
| | | | ......No...... | ........No.... | g |
| T1 | 47.2c | 59.3f | 36.47b | 9.83bc | 7.78b |
| T2 | 52.7c | 75.3d | 23.01d | 8.89c | 6.85c |
| T3 | 60.3b | 85c | 17.42e | 10.87b | 7.83b |
| T4 | 71.17a | 100.3ab | 8.78f | 5.53d | 3.71d |
| T5 | 50.67c | 66.3ef | 41a | 13.17a | 10.06a |
| T6 | 52.33c | 71.67de | 25.77c | 9.15c | 6.6c |
| T7 | 68a | 93b | 15.65e | 11.1b | 7.13bc |
| T8 | 72.5a | 105.3a | 10.87f | 5.47d | 3.32d |
| CV (%) | 7.35 | 8.14 | 9.67 | 13.62 | 10.32 |

Means within columns followed by different letters differ significantly at $P \leq 0.05$: Duncan Multiple range test. DAE = Days after emergence. φ=T1=sole Pan 311,T2=sole Pan 326, T3=Sole Bechuana white,T4=Sole agrinawa, T5=-Pan 311, T6=sorghum-Pan326, T7=sorghum-Bechuana white and T8=sorghum-Agrinawa.

Table 9. Leaves, shoots, roots, total dry matter and Stover yield of different cowpea cultivars and sorghum-cowpea intercropping systems at Syferkuil in the Northern Province.

| Cropping patterns φ | Leaves | shoots | roots | Total dry matter | Stover Yield |
|---|---|---|---|---|---|
| | $gm^{-2}$ | $gm^{-2}$ | $gm^{-2}$ | $gm^{-2}$ | Kg $ha^{-1}$ |
| T1 | 78.78e | 136.83f | 31.33f | 246.95f | 4465.7c |
| T2 | 86.90d | 160.53e | 39.09d | 286.50e | 3714.3 |
| T3 | 140.80d | 296.50c | 45.07c | 482.32c | 5461.2b |
| T4 | 172.40a | 362.50a | 63.48a | 598.38a | 6348.5a |
| T5 | 79.00e | 138.98f | 34.72e | 252.70f | 4558.7c |
| T6 | 90.17d | 176.82d | 42.73c | 309.72d | 3942.4b |
| T7 | 133.95c | 309.14c | 50.23b | 493.32c | 5611.4b |
| T8 | 158.12b | 341.77b | 62.62a | 562.50b | 6168.3a |
| CV (%) | 5.1 | 5.2 | 5.7 | 3.73 | 5.2 |

Means within columns followed by different letters differ significantly ($P \leq 0.05$: Duncan Multiple range test). φ =T1=sole Pan 311,T2=sole Pan 326, T3=sole Bechuana white,T4=sole Agrinawa, T5=sorghum-Pan 311, T6=sorghum-Pan326, T7=sorghum-Bechuana white and T8=sorghum-Agrinawa.

Table 10. Leaves, shoots, roots, total dry matter and Stover yield of different cowpea cultivars and sorghum-cowpea intercropping systems at Tompi Seleka in the Northern Province.

| Cropping patterns φ | Leaves | shoots | roots | Total dry matter | Stover yield |
|---|---|---|---|---|---|
| | ……………………g $m^{-2}$ | ………………… | | $g\ m^{-2}$ | $kg\ ha^{-1}$ |
| T1 | 48.53e | 74.50d | 19.18d | 142.22d | 2553.8e |
| T2 | 65.73d | 93.80cd | 28.95b | 188.48c | 2560.e |
| T3 | 89.67c | 358.25c | 31.43b | 497.37b | 3451.6c |
| T4 | 146.57d | 453.22a | 45.62a | 645.50a | 4810.5 |
| T5 | 59.97d | 90.78cd | 26.02c | 176.77c | 3031.8d |
| T6 | 68.03d | 113.13c | 27.38b | 208.55c | 2594.1d |
| T7 | 102.80b | 350.73b | 42.32a | 495.85b | 3762.4b |
| T8 | 155.57a | 460.13a | 41.72a | 657.42a | 4970.8a |
| CV (%) | 8.37 | 17.06 | 10.03 | 9.17 | 7.32 |

Means within columns followed by different letters differ significantly ($P \leq 0.05$: Duncan Multiple range test). φ=T1=sole Pan 311,T2=sole Pan 326, T3=sole Bechuana white,T4=sole Agrinawa, T5=Sorghum-Pan 311, T6=sorghum-Pan326, T7=sorghum-Bechuana white and T8=sorghum-Agrinawa.

Table 11. Leaves, shoots, roots, total dry matter and Stover yield of different cowpea cultivars and sorghum-cowpea intercropping systems at Tompi seleka in the Northern Province.

| Cropping systems φ | Leaves | shoots | roots | Total dry matter | Stover Yield |
|---|---|---|---|---|---|
| ........................ | ................ | .........g $m^{-2}$..... | ................ | g $m^{-2}$ | kg $ha^{-1}$ |
| T1 | 94.865d | 137.12 | 32.00c | 264.08d | 3987.9c |
| T2 | 118.50c | 174.88d | 30.433c | 323.82c | 4128.8c |
| T3 | 141.17b | 280.22c | 48.88b | 478.93b | 5530.5b |
| T4 | 169.25a | 340.83b | 54.44ab | 538.70a | 5938.2a |
| T5 | 94.433d | 134.63 | 26.28c | 255.35d | 4034.1c |
| T6 | 121.40c | 175.62d | 31.35c | 328.37c | 4174.1c |
| T7 | 140.83b | 293.27c | 48.60b | 467.03b | 5465.7b |
| T8 | 177.77a | 424.87a | 60.42a | 553.43a | 6068.3a |
| CV (%) | 8.4 | 17.01 | 10.03 | 9.17 | 7.32 |

Means within columns followed by different letters differ significantly($P \leq 0.05$: Duncan Multiple range test). φ=T1=sole Pan 311,T2=sole Pan 326, T3=sole Bechuana white, T4=sole Agrinawa, T5=-Pan 311, T6=sorghum-Pan326, T7=sorghum-Bechuana white and T8=sorghum-Agrinawa.

Table 12. Seed yield and harvest index of different cowpea varieties under different cropping systems at Syferkuil, Tompi seleka and Zebediela in the Northern Province.

| Cropping patterns φ | Syferkuil | | Tompi Seleka | | Zebediela | |
|---|---|---|---|---|---|---|
| | Seed yield | HI | Seed Yield | HI | Seed Yield | HI |
| | Kg $ha^{-1}$ | % | Kg $ha^{-1}$ | % | Kg $ha^{-1}$ | % |
| T1 | 1996.2a | 44.63a | 1209.6b | 45.9a | 1480.6b | 33.78a |
| T2 | 849.3b | 22.90b | 753.17c | 28.6c | 890.67c | 21.59c |
| T3 | 637.5b | 11.6c | 623.73d | 11.6d | 761.23d | 13.78d |
| T4 | 364.6d | 5.73d | 413.7e | 6.2e | 551.17e | 9.30e |
| T5 | 2031.7a | 44.53a | 1343.1a | 43.27b | 1347.1a | 36.72b |
| T6 | 845.2b | 21.45b | 752.93c | 26.64c | 890.43c | 21.35c |
| T7 | 678.2b | 12.09c | 657.90d | 11.73d | 795.40d | 14.65d |
| T8 | 543.3d | 8.41d | 396.43e | 5.7e | 533.93e | 8.82e |
| CV (%) | 5.87 | 6.9 | 5.04 | 6.54 | 5 | 6.5 |

Means within columns followed by different letters differ significantly ($P \leq 0.05$:Duncan Multiple range test). φ= Province.whereT1=sole Pan 311,T2=sole Pan 326, T3=sole Bechuana white,T4=sole Agrinawa, T5=Sorghum-Pan 311, T6=sorghum-Pan326, T7=sorghum-Bechuana white and T8=sorghum-Agrinawa.

Table 13. Flowering, maturity and yield component of sorghum grown under different cropping systems at Syferkuil in the Northern Province.

| Cropping patterns φ | Days to 50% flowering | Days Physiological maturity | Yield Weight panicle$^{-1}$ | Component Seeds panicle$^{-1}$ | 1000 seed mass |
|---|---|---|---|---|---|
| | | | g | No | g |
| T5 | 61 | 76b | 84.3b | 77.4c | 24.09a |
| T6 | 59 | 80ab | 88.9ab | 83.1a | 23.27a |
| T7 | 61 | 82a | 83.9b | 79.2ab | 22.96a |
| T8 | 59 | 80ab | 91.8a | 78.4b | 24.93a |
| T9 | 59 | 81ab | 61.8c | 62.7c | 14.341b |
| $LSD_{0.05}$ | ns | 4.8742 | 5.5035 | 4.3830 | 3.6183 |
| CV (%) | 4.08 | 4.97 | 13.51 | 9.8 | 20.66 |

ns= non significant difference among varieties under intercropping and sole systems. Means within columns followed by different letters differ significantly at $P \leq 0.05$: Least significance difference test. φ= T5=-Pan 311, T6=-Pan326,T7=-Bechuana white , T8=-Agrinawa and T9=Sole sorghum.

Table 14. Flowering, maturity and yield component of sorghum grown under different cropping patterns at Tompi Seleka in the Northern Province.

| Cropping patterns φ | Days to 50% flowering | Physiological maturity | Yield Component | | |
|---|---|---|---|---|---|
| | | | Weight panicle$^{-1}$ | Seeds panicle$^{-1}$ | 1000 seed mass |
| | | | g | No | g |
| T5 | 56 | 75 | 82.45b | 76.14b | 23.59a |
| T6 | 55 | 77 | 88.96a | 80.97a | 22.42a |
| T7 | 58 | 81 | 82.12b | 77.93ab | 22.03a |
| T8 | 57 | 79 | 90.09a | 77.10ab | 24.00a |
| T9 | 56 | 79 | 59c | 61.35c | 13.41b |
| $LSD_{0.05}$ | ns | ns | 5.8662 | 4.34 | 3.4631 |
| CV (%) | 4.64 | 5.51 | 5.77 | 4.68 | 13.24 |

ns= non significant difference among varieties under intercropping and sole systems. Means within columns followed by different letters differ significantly ($P \leq 0.05$: Least Significance difference test). φ = T5=-Pan 311, T6=-Pan326, T7=-Bechuana white , T8=-Agrinawa and T9=Sole sorghum.

Table 15. Flowering, maturity and yield component of sorghum grown under different cropping systems at Zebediela in the Northern Province.

| Cropping patterns φ | Days to flowering | Days Physiological maturity | Yield Component | | |
|---|---|---|---|---|---|
| | | | Weight panicle$^{-1}$ | Seeds panicle$^{-1}$ | 1000 seed mass |
| | | | g | No | g |
| T5 | 60 | 79b | 95.62b | 85.73b | 31.05a |
| T6 | 61 | 83ab | 100.66b | 91.35a | 30.24a |
| T7 | 63 | 85a | 95.62b | 87.53ab | 29.93a |
| T8 | 61 | 83ab | 103.60a | 86.70b | 31.9a |
| T9 | 60 | 83ab | 72.63c | 70.95c | 21.31b |
| $LSD_{0.05}$ | ns | 4.874 | 5.4127 | 4.3830 | 3.6182 |
| CV (%) | 4 | 4.7 | 4.62 | 4.14 | 10 |

ns= non significant difference among varieties under intercropping and sole systems. Means within columns followed by different letters differ significantly at $P \leq 0.05$: Least Significance difference test. φ=T5=sorghum-Pan 311, T6=sorghum-Pan326, T7=sorghum-Bechuana white , T8=sorghum- Agrinawa and T9=Sole sorghum.

Table 16. Dry matter, stover yield, Seed yield, harvest index and Land equivalent ratio under different cropping systems at Syferkuil in the Northern Province.

| Cropping patterns φ | Dry matter | Stover yield | Seed yield | Harvest index | LER |
|---|---|---|---|---|---|
| | $g\ m^{-2}$ | $kg\ ha^{-1}$ | $kg\ ha^{-1}$ | % | |
| T5 | 473.4a | 6894.0a | 2159.2a | 23.9 | 0.61 |
| T6 | 458.2a | 6676.7b | 2095.0a | 23.9 | 0.59 |
| T7 | 456.5a | 6661.7b | 2096.8a | 23.9 | 0.59 |
| T8 | 468.6a | 6804.4b | 2118.1a | 23.7 | 0.6 |
| T9 | 407.4b | 5849.5b | 1775.0b | 23.3 | - |
| LSD 0.05 | 18.47 | 191.40 | 77.89 | ns | ns |
| CV (%) | 3.27 | 2.33 | 3.03 | 3.24 | 3.04 |

ns= non significant difference among varieties under intercropping and sole systems. Means within columns followed by different letters differ significantly at $P \leq 0.05$: Least significant difference test. φ=T5=sorghum-Pan 311, T6=sorghum-Pan326,T7=sorghum-Bechuana white , T8=sorghum- Agrinawa and T9= Sole sorghum.

Table 17. Dry matter, stover yield, Seed yield, harvest index and Land equivalent ratio under different cropping systems at Tompi Seleka in the Northern Province.

| Cropping patterns φ | Dry matter | Stover yield | Seed yield | Harvest index | LER |
|---|---|---|---|---|---|
| | $g\ m^{-2}$ | $kg\ ha^{-1}$ | $kg\ ha^{-1}$ | % | |
| T5 | 343.89a | 5344.3a | 1905.5a | 26 | 0.63 |
| T6 | 328.38a | 5144.5b | 1860.79b | 27 | 0.61 |
| T7 | 326.88a | 5111.8b | 1843.2a | 26.5 | 0.61 |
| T8 | 339.03a | 5254.7ab | 1864.3a | 15.1 | 0.61 |
| T9 | 277.86b | 4299.8c | 1521.3b | 26 | - |
| LSD0.05 | 17.670 | 184.86 | 79.59 | 1.69 | ns |
| CV (%) | 4.04 | 2.94 | 3.56 | 3.83 | 3.56 |

ns= non significant difference among varieties under intercropping and sole patterns.
Means within columns followed by different letters differ significantly at $P \leq 0.05$: Least significant difference test. φ= T5=sorghum-Pan 311, T6=sorghum-Pan326,T7=sorghum-Bechuana white , T8=sorghum-Agrinawa and T9=Sole sorghum.

Table 18. Sorghum dry matter, stover yield, Seed yield, harvest index and land equivalent ratio under different cropping patterns at Zebediela in the Northern.

| Cropping systems φ | Dry matter | Stover yield | Seed yield | Harvest index | LER |
|---|---|---|---|---|---|
| | g $m^{-2}$ | kg $ha^{-1}$ | kg $ha^{-1}$ | % | |
| T5 | 468.69a | 6780.2a | 2093.3a | 23.6 | 0.61 |
| T6 | 453.36a | 6562.9b | 2029.2a | 23.6 | 0.59 |
| T7 | 451.68a | 6547.8b | 2031.0a | 23.7 | 0.59 |
| T8 | 463.83a | 6690.6ab | 2052.3a | 23.5 | 0.6 |
| T9 | 402.66b | 5735.7c | 1709.2b | 22.9 | - |
| LSD | 18.47 | 191.40 | 77.89 | ns | ns |
| CV (%) | 3.3 | 2.37 | 3.14 | 3.34 | 3.14 |

ns= non significant difference among varieties under intercropping and sole systems. Means within columns followed by different letters differ significantly at $P \leq 0.05$: Least significant difference test. φ=Province.T5=sorghum-Pan311,T6=sorghum-Pan326,T7=sorghum-Bechuana white, T8=sorghum- Agrinawa and T9=Sole sorghum.

Table 19. Partial and total Land equivalent ratio (LER) under different cropping patterns at Tompi Seleka in the Northern Province.

| Cropping systems φ | Sorghum | Cowpea | Total |
|---|---|---|---|
| | Partial LER | | LER |
| T5 | 0.63 | 0.55 | 1.18 |
| T6 | 0.61 | 0.5 | 1.11 |
| T7 | 0.61 | 0.53 | 1.14 |
| T8 | 0.61 | 0.48 | 1.09 |

φ = T5=sorghum-Pan 311, T6=sorghum-Pan326, T7=sorghum-Bechuana white and T8=sorghum-Agrinawa.

Table 20. Partial and total Land equivalent ratio (LER) under different cropping systems at Syferkuil in the Northern Province.

| Cropping patterns φ | Sorghum | Cowpea | |
|---|---|---|---|
| | Partial LER | | Total LER |
| T5 | 0.61 | 0.51 | 1.12 |
| T6 | 0.59 | 0.5 | 1.09 |
| T7 | 0.59 | 0.53 | 1.12 |
| T8 | 0.6 | 0.75 | 1.35 |

φ =T5=Sorghum-Pan311, T6=sorghum-Pan326,T7=sorghum-Bechauna white and T8=sorghum-Agrinawa.

Table 21. Partial and total Land equivalent ratio (LER) under different cropping systems at Zebediela in the Northern Province.

| Cropping Patterns φ | Sorghum | Cowpea | |
|---|---|---|---|
| | Partial LER | | Total LER |
| T5 | 0.61 | 0.45 | 1.06 |
| T6 | 0.59 | 0.5 | 1.09 |
| T7 | 0.59 | 0.52 | 1.11 |
| T8 | 0.6 | 0.48 | 1.08 |

φ =T5=sorghum-Pan 311, T6=sorghum-Pan326, T7=sorghum-Bechauna white and T8=sorghum-Agrinawa.

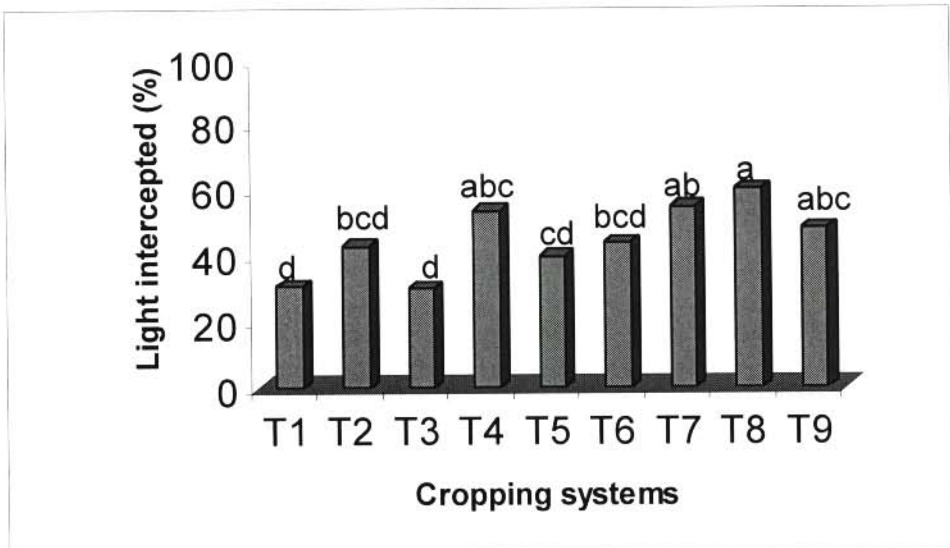


Figure 1. Light intercepted under intercropping and monocropping conditions at Tompi Seleka in the Northern Province,whereT1=sole Pan 311,T2=sole Pan 326, T3=sole Bechuana white, T4=sole Agrinawa,T5=sorghum-Pan 311,T6=sorghum-Pan326, T7=sorghum-Bechuana white and T8=sorghum-Agrinawa and T9=sole sorghum.

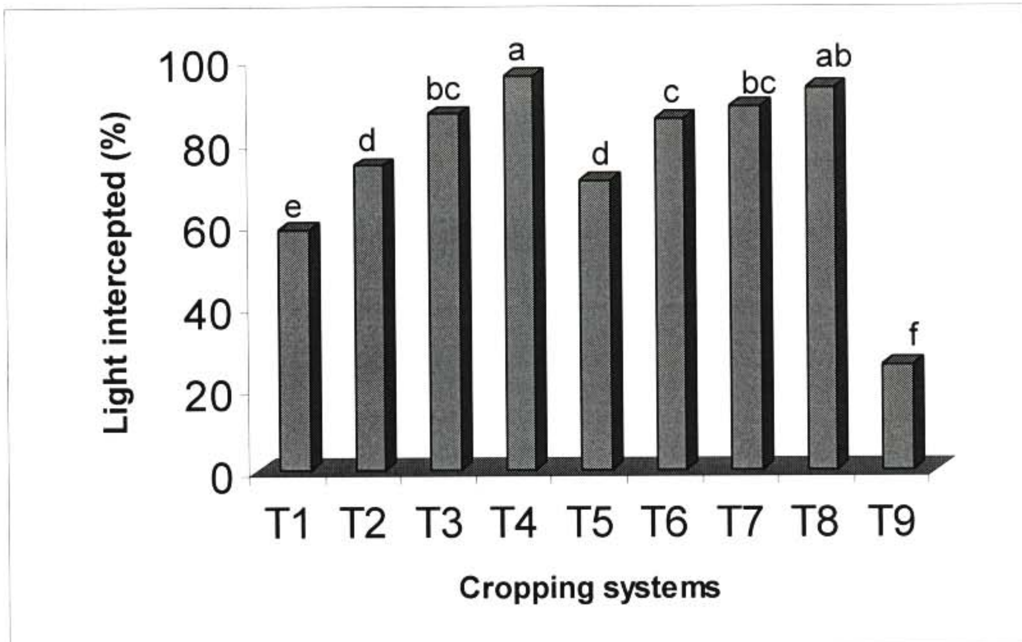


Figure 2. Light intercepted under intercropping and monocropping conditions at Zebediela in the Northern Province,whereT1=sole Pan 311,T2=sole Pan 326, T3=sole Bechuana white, T4=sole Agrinawa, T5=sorghum-Pan 311, T6=sorghum-Pan326, T7=sorghum-Bechuana white and T8=sorghum-Agrinawa and T9=sole sorghum.

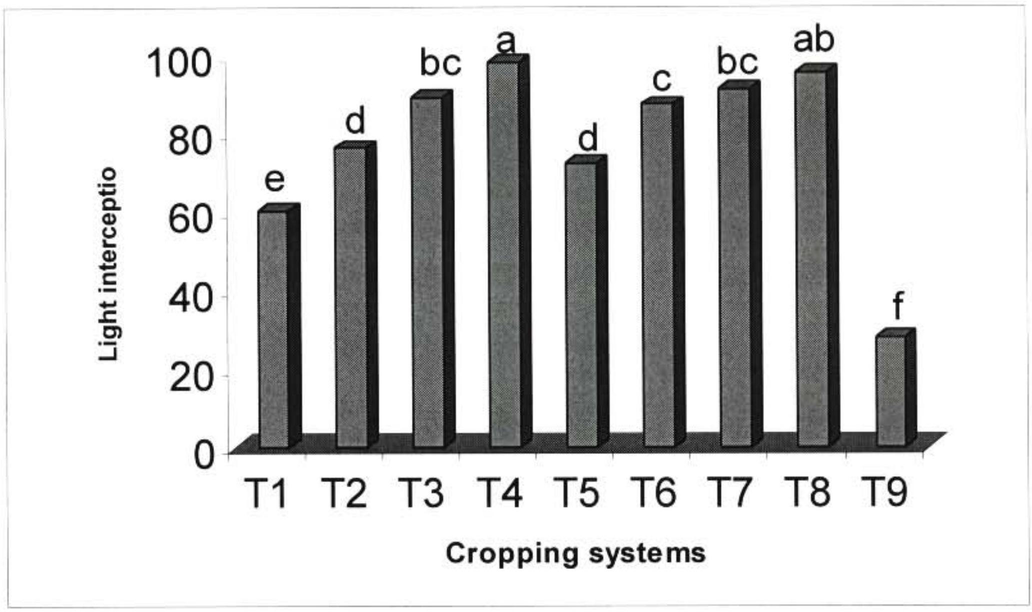


Figure 3. Light intercepted under intercropping and monocropping conditions at Syferkuil in the Northern Province,whereT1=sole Pan 311,T2=sole Pan 326, T3=sole Bechuana white, T4=sole Agrinawa, T5=sorghum-Pan 311, T6=sorghum-Pan326, T7=sorghum-Bechuana white , T8=sorghum-Agrinawa and T9=sole sorghum.

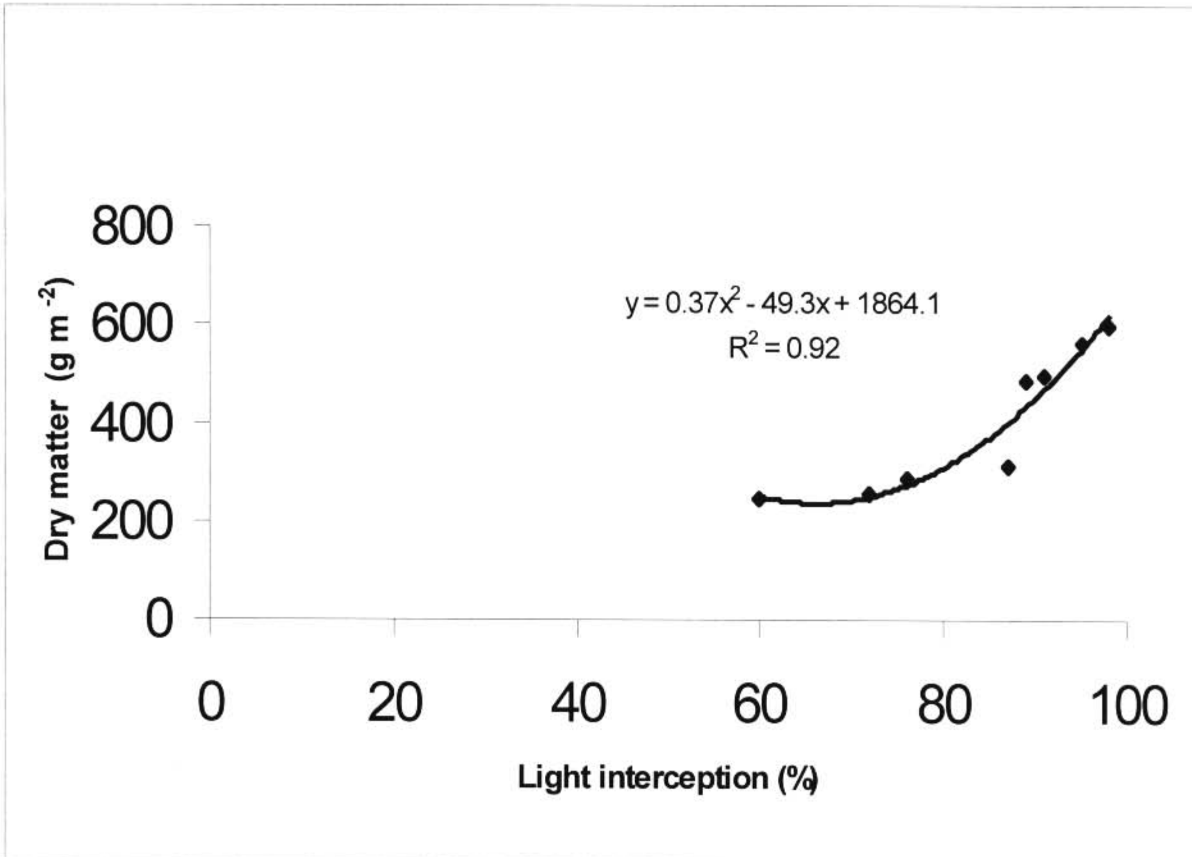


Figure 4. Relationship between total dry matter accumulation and light interception of four cowpea varieties intercropped with sorghum at Syferkuil in the Northern Province.

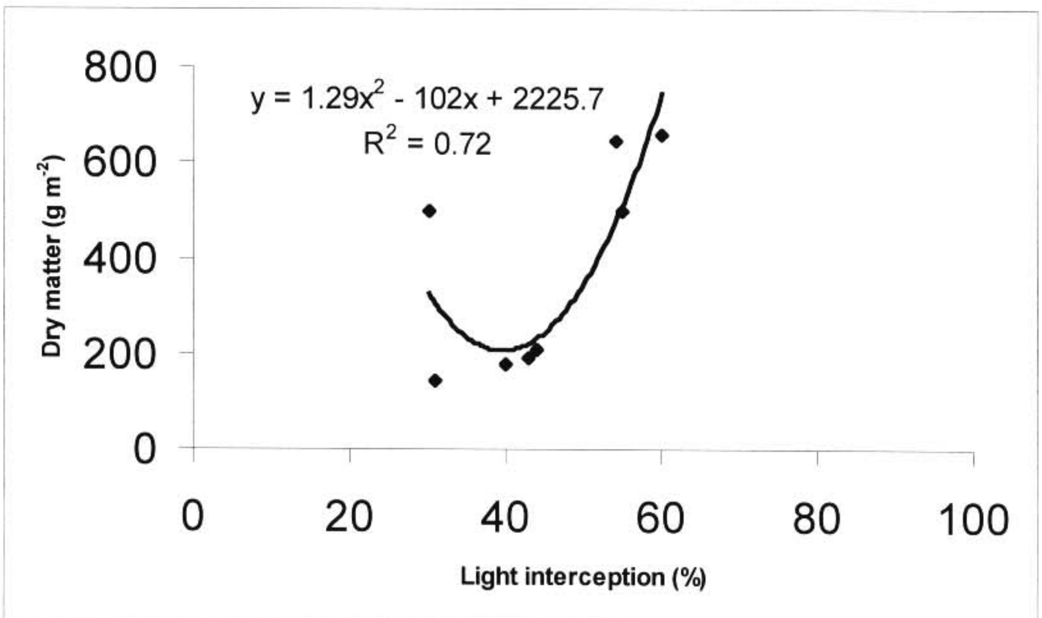


Figure 5. Relationship between total dry matter accumulation and light interception of four cowpea varieties intercropped with sorghum at Tompi Seleka in the Northern Province.

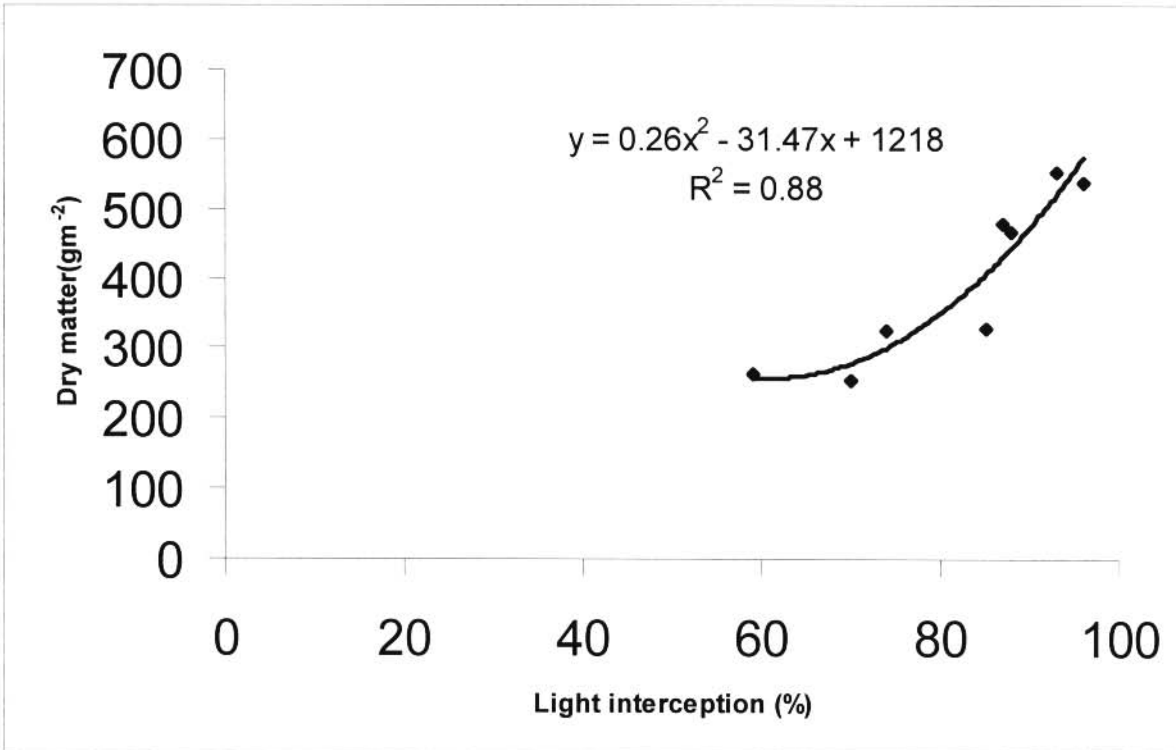


Figure 6. Relationship between total dry matter accumulation and light interception of four cowpea varieties intercropped with sorghum at Zebediela in the Northern Province.

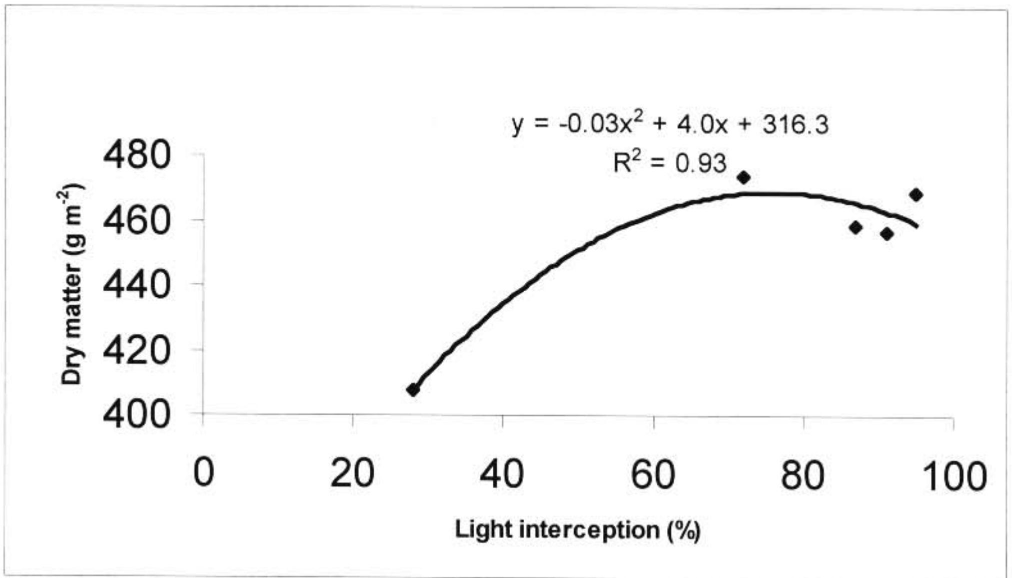


Figure 7. Relationship between sorghum dry matter accumulation and light interception at Syferkuil in the Northern Province.

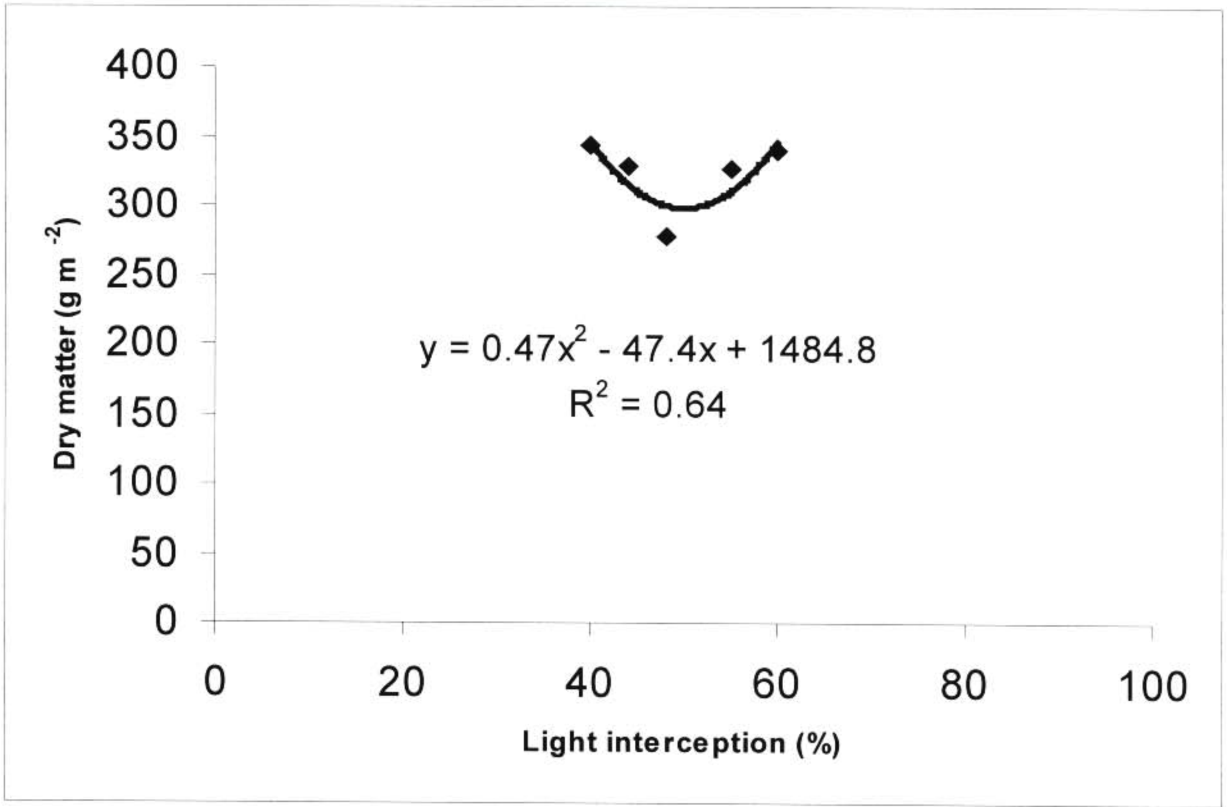


Figure 8. Relationship between sorghum dry matter accumulation and light interception at Tompi Seleka in the Northern Province.

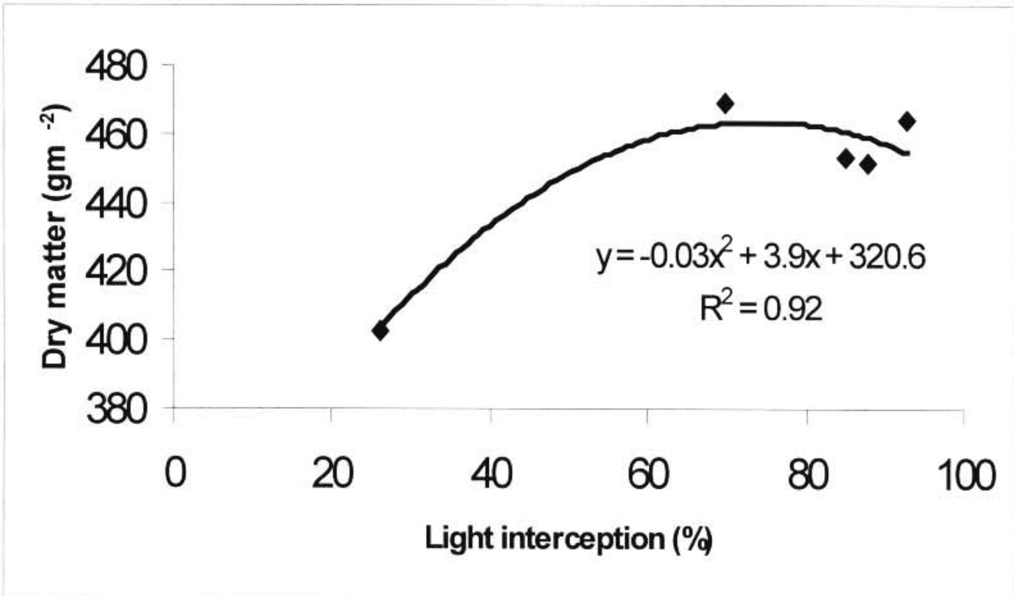


Figure 9. Relationship between sorghum dry matter accumulation and light interception at Zebediela in the Northern Province.

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