EFFECT OF INTERCROPPING PATTERN ON THE INCIDENCE OF STRIGA AND YIELD OF SORGHUM (*Sorghum vulgare* L)

BY

ROBLE DAUDI ROBLE MATARY

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE (AGRICULTURE) OF SOKOINE UNIVERSITY OF AGRICULTURE MOROGORO, TANZANIA

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ABSTRACT

Two field experiments were conducted to evaluate the effect of different sorghum/groundnut and sorghum/bambara groundnuts intercrops grown in eight cropping patterns at two locations (Bihawana and Hombolo) at Dodoma, Tanzania. The experimental design was a randomized Complete Block Design with three replications. Eight cropping patterns were treatments (ABR=Alternate between rows, DR=Double rows, AWR - Alternate within rows, SH = same hill, AWRABR= Alternate between rows and alternate within rows, RP = Random planting, S= Monocrop groundnuts, G= Monocrop sorghum, BG= Monocrop bambara groundnuts). The rainfall pattern was not satisfactory at both sites. The continuous rainfall (January, February, March and April = 884 mm) at Bihawana affected the *Striga* germination due to wet dormancy. The rainfall at Hombolo was low (463.8 mm) and erratic such that the dry spell at stages of plant growth adversely affected *Striga* and crop growth patterns, thus affecting yield and yield attributes for sorghum. The infestation of *Otheca benningsenii* in groundnuts and bambara groundnuts, *Calidea dregae* and stalkborers (*Sesamia calamistis*) in sorghum for both sites had a detrimental effect on all crops respectively. In both sorghum/ groundnuts and sorghum/ bambara groundnuts at Bihawana there was no *Striga* observed in the trial. At Hombolo, however, in sorghum/ groundnuts and sorghum/ bambara groundnuts intercrops *Striga* was higher in monocrop sorghum (6.8) compared to other cropping patterns. The results showed that at Bihawana, in sorghum similar results were realised in sorghum grain yield per hectare in both sorghum/groundnuts and sorghum/bambara groundnuts intercrop respectively. In sorghum/ groundnuts intercrop at Bihawana higher

groundnuts yield was observed in monocrop groundnuts and DR intercrop (600 kg/ha and 580 kg/ha) compared to AWR and SH intercrops (350 kg/ha and 160 kg/ha), while in sorghum/ bambara groundnuts higher yield was realized in monocrop bambara groundnuts (G= 510 kg/ha) compared to mixtures (DR and ABRAWR intercrops = 200 kg/ha and 190 kg/ha)). In sorghum/ groundnuts intercrops at Hombolo, higher groundnuts yield was observed in mixture (AWR intercrop) as compared to mixtures (ABR and DR intercrops), while in sorghum/ bambara groundnuts intercrop higher bambara groundnuts yield was observed in mixture (SH, AWRABR and AWR intercrops= 560 kg/ha, 510 kg/ha and 480 kg/ha) compared to other cropping patterns. In view of the wide scale of *Striga* damage worldwide interest has to be focused on the use of intercropping as a control measure, which is meaningful and economical way of controlling the parasitic weed within the reach of poor resource farmers. At Bihawana, in sorghum/ groundnuts intercrop, sorghum grain yield was higher in monocrop sorghum (1900 kg/ha) as compared to other cropping patterns, while greater groundnuts grain yield was observed in monocrop groundnuts (600 kg/ha). In case of sorghum in sorghum/ bambara groundnuts intercrop, higher sorghum grain yield was observed in RP intercrop (2240 kg/ha), whereas in bambara groundnuts higher yield was realised in monocrop bambara groundnuts (510 kg/ha). In sorghum/ groundnuts intercrop at Hombolo, ABRAWR intercrop gave higher yield of sorghum (1500 kg/ha), whereas AWR intercrop (600 kg/ha) gave higher yield in groundnuts as compared to other cropping patterns. In case of sorghum/ bambara groundnuts intercrop, higher yield of sorghum was obtained in ABRAWR intercrop (1180 kg/ha), while in bambara groundnuts higher yield was realised in SH intercrop (560 kg/ha). This has indicated that mixtures can enhance grain yield of sorghum although at Hombolo, *Striga* infestation was high in both sorghum/ groundnuts and sorghum/ bambara groundnuts intercrops.

DECLARATION

I Roble Daudi Roble Matary do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work and to the best of my knowledge it has not been submitted for a degree award in any other university.

Signature.......................................

Roble Daudi Roble Matary

Date 13th SEPT. 2001

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DEDICATION

This dissertation is dedicated to my beloved deceased father Mr. Daudi Matary, my mother Mwatumu Ally and my deceased guardian Mr. Ally Feruzi who are the worriors of my academic success.

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LIST OF SYMBOLS AND ABBREVIATIONS

ABR	Alternate between rows
ABRAWR	Alternate between rows and alternate within rows
AWR	Alternative within rows
BG	Monocrop bambara groundnuts
CAN	Calcium Ammonium Nitrate
°C	Centigrade degree
Ca	Calcium
CO_2	Carbondioxide
Cm	centimetre
CEC	Cation exchange capacity
DR	Double rows
DAP	Days after planting
DAs	Days after sowing
e.g.	That is
FAO	Food and Agriculture Organization of United Nations
G	Monocrop groundnuts
ICRISAT	International Crops Research Institute of Semi-arid Tropics
IDRC	International Development Research Centre
IITA	International Institute for Tropical Agriculture
LSD	Least Significant Difference
Mm	millimetre
Mg	milligram

N	Nitrogen
NS	North South
NW	North West
P_2O_5	Phosphorus pentoxide
ppm	parts per milliono
RP	Random planting
RIDEP	Regional Integrated Development Programme
S	Monocrop sorghum
SH	Same hill
SSA	Sub-Saharan Africa
SW	South West
TSP	Triple super phosphate
WAP	Weeks after planting

CHAPTER ONE

1.0 INTRODUCTION

Dryland cereals occupy around 80-85% of the planted area in semi-arid areas of central Tanzania especially Dodoma (Hotland, 1994). About 2.5×10^5 ha of sorghum and millet are cultivated in central Tanzania producing about 2.28×10^5 tons of grain (Smith, 1990). In Tanzania the semi-arid zones occupy about one third (295,000 km^2) of the total land area and extend NE to SW across the central part of Tanzania (Hatibu *et al.* 1995). According to FAO, (1986), approximately 500 million people in semi-arid zones depend on agriculture for their livelihood where bulrush (pearl) millet (*Pennisetum americum*) is the most important food crop followed by sorghum (*Sorghum vulgare* L) and maize (*Zea mays* L.). Sorghum and millet contribute 24% of the total cereal production in Tanzania's semi-arid areas, especially Dodoma. Sorghum and millets are of vital importance in low rainfall areas or semi-arid zones.

One of the limiting factors in cereal production is the invasion and increasing density of noxious plants and associated reduction in yield. In Sub-Saharan Africa (SSA), *Striga spp.* is probably the single most important biotic constraint to crop production affecting an estimated 44 million hectares of crop land and causing yield loses worth up to US \$ 7 billion a year (ICRISAT, 1998). In drier parts of Tanzania vast expanses of otherwise good arable land are covered by *Striga spp.* a noxious parasitic weed belonging to the family *Scrophulariaceae.*

Plants, which belong to genus, *Striga* are commonly referred to as "witchweeds" and the highest number of species recorded is 60 all of which are parasitic to other plants (Ayensu *et al*; 1984, Tarr, 1962). *Striga spp* as described by Ivens, (1975) is a herbaceous annual that propagates by seeds. As with any other weed, *Striga spp.* poses serious competition for moisture and nutrients with cereal crops such as sorghum, millet and maize, through parasitism.

Cereal production in Tanzania has been adversely affected by the spread of common parasitic weeds (*Striga hermonthica, Striga asiatica*, and *Striga forbesii*) making the already existing problem of food scarcity in semi-arid areas more serious. Tanzania lies in a unique belt of the tropics where the most significant *Striga* spp. in Africa i.e. *Striga hermonthica* and *Striga asiatica,* are observed to coexist especially in western Tanzania (Mbwaga, 1988/89). These weeds together with other problems are known to constitute a major constraint in cereal production.

The strategies for controlling *Striga* infection in Tanzania have focused mainly on planting of resistant varieties of sorghum such as SPN 39, SAR 29, P 9405, P 9406 and Serena (Mbwaga *et al.* 2000). Whereas *Striga* is still a major constraint in cereal production other methods to control *Striga* such as the use of catch and trap crops in cropping systems (intercropping) has received very little attention despite the fact that people intercrop cereals with traditional legumes such as cowpeas and pigeon peas. Catch and trap crops induce the germination of *Striga* seeds but whereas trap crops are not parasitized, catch crops are and therefore have to be destroyed as soon as they are infested. In Dodoma farmers intercrop cereals with traditional crops like groundnuts, bambara groundnuts, watermelon, calabash and vegetables (Hotland, 1994). The main objective of the study was to investigate the effectiveness of traditional legumes (groundnuts and bambara groundnuts) for *Striga* control or suppression in sorghum (*Sorghum bicolor*). This practice can easily be adopted by farmers as they are already mix-cropping cereals with legumes.

Specific objectives were

1. To study the emergence pattern of *Striga* spp (withweeds) in sorghum under intercrop and monoculture cropping systems.
2. To compare the effect of groundnuts and bambara groundnuts intercrops on *Striga* control and yield of sorghum.
3. To determine suitable intercropping pattern for *Striga* control in sorghum.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Parasitic Weeds

Parasitic weeds such as mistletoes (*Viscum album* L.), orobanche (*Orobanche* spp.) dodder (*Cascuta chinensis* Lam.) and witchweeds (*Striga* spp.) attack other plants by making an organic connection with the tissues of the host, depriving part or all of their food from the host. The two largest families of parasitic weeds are *Loranthaceae* and *Scrophulariaceae.* The genus *Striga* belongs to the family *Scrophulariaceae*. Plants belonging to this genus are commonly referred to as "witchweeds" and 41species are known to be parasitic on wild host of which 11 can attack cultivated crops. Only three species are known to cause serious damage to food crops, these include *Striga hermonthica*, *Striga asiatica* and *Striga gesnerioides* (Roynal- Roques 1991; 1996).

2.2 Geographical distribution of witchweeds

Witchweeds occur in Africa, Asia, Australia and America. In North and West Africa they occur in Mali, Upper Volta, Niger, Nigeria, Cameroon, Chad, Togo, Gambia, Mauritania and Ghana, while in East and Central Africa they occur in Kenya, Uganda, Sudan, Zaire, Congo, Ethiopia and Tanzania. In Southern Africa they occur in Botswana, Swaziland, South Africa and Mozambique (Lagoke *et al*; 1994) Appendix 2. The most important *Striga* species are those, which affect cereals and these, include *Striga hermonthica* in Africa, *Striga asiatica* both in Africa and Asia, and *Striga densiflora* in Asia. Sorghum, maize, sugarcane, and upland rice are all subjected to *Striga* attack. *Striga gesnerioides*, which affects cowpeas, occurs in both Africa and Asia. Other species of economic importance *are Striga euphrasioides, Striga aspera, Striga forbesii, Striga parviflora* and *Striga elegans* (Ayensu *et al.*, 1984; Dutta, 1991).

Striga asiatica, is second in importance to *Striga hemonthica* in Tanzania and is widely spread from Lake Victoria in the north down to Ruvuma in the south including the coastal regions of Tanga and Mtwara (Mumera, 1984). *Striga* causes extensive damage to cereal and legume crops in Africa. According to M'Boob (1991), Pieterse and Pesch (1983), Ogborn (1987), Anon, (1989) and Lagoke *et al.*, (1991) the most economically important *Striga* spp. in Africa are *Striga hemonthica, Striga asiatica, Striga aspera, Striga forbesii* and *Striga gesnerioides*. Dogget (1965), Aggarwal and Ouedraogo (1989), Anon (1989) and Carson (1989) reported that a diverse number of parasitic weed plants in Africa pose serious threat to both cereal and legume production.

The discovery of witchweed (*Striga asiatica* (L) in North and South Carolina in 1956 was the first known report of the genus *Striga* in the Western Hemisphere while it was long known to occur in the old world tropics in the Western Hemisphere in Africa, Australia, India, Indonesia, Arabia and China (Shaw *et al. 1962*., Tarr 1962). *Striga hemonthica* was reported from the continent of Africa, in Madagascar and in Aden between latitudes 20° N and 20° S (Rao and House, 1972). *Striga hemonthica* is said to be a native in Africa and that it spread with the sorghum spread from Eastern Africa to Arabia (Husle *et al.*, 1991); Tarr, 1962). *Striga hermonthica* also referred to as purple witchweed is widely found parasitizing grains such as sorghum, pearl millet and rice.

2.3 Ecology

Striga spp. are tropical plants which rarely occur at altitudes greater than 1000m above sea level and are well adapted to condition of the semi-arid tropics (Rao and House (1972). Germination, establishment and growth of *Striga* occur in all types of soils including sand, sandy loam, sandy clay loam, clay loam, and light clay to heavy clay. Well-drained soils and temperature range of 22-35^{0}C in the presence of *Strigol acetate* and nitrogen deficiency are more favourable to *Striga* germination and growth (Ayensu *et al* 1984; Mumera 1984; Shaw *et al.* 1962). Soil temperature and soil types are major factors influencing the geographical distribution of *Striga.* Heaviest infestation occurs in areas with light soils and rainfall ranging from 453-633 mm.

2.4 Botanical description

2.4.1 Physiology and morphology

Striga hermonthica is an erect green C_3 annual herb which grows to a height of 0.5-0.8 meters. Its principal pigments are chlorophyll a and b in stems and leaves and can fix CO_2. *Striga hermonthica* is classified as a facultative autophyte or a hemiparasite since it passes part of its life through a totally parasitic phase although it contains chlorophyl and can fix CO_2 (Dogget 1970; Ismail and Abeid 1976; Rogers and Nelson, 1962; and Young, 1927).

2.4.2 Aerial parts

The vegetative parts of *Striga hermonthica* consist of a main axis, which is circular at the base, but four sided at abascet 2-3 cm above the ground. The main axis consists of a long terminal inflorescence which exerts apical dominance over the axially buds. The leaves are linear 2.5 to 10cm long, sometimes longer and 15-20 mm wide and have serrated margins. The size of leaves varies with environmental conditions. The stem and leaves are covered with short stiff hairs (Ayensu *el al.*, 1984).

2.4.3 Underground parts

The radicle usually produces primary haustorium as it emerges at germination and also produces fibrous roots. Numerous secondary haustoria are produced later and are nearly of the same size of 1-2mm. Up to 80 or more haustoria have been observed on one *Striga* shoot. The roots are functional and can absorb nutrients and water. They also save as sites for synthesis of organic compounds necessary for whole growth of the shoot.

2.5 Water relations

Striga is usually regarded as a xylem parasite as it establishes a xylem to xylem contact with the host roots. Its water requirement from the soil passes through the host root to the *Striga* xylem, to its leaves and to the atmosphere. This connection implies competition for water between the host and the parasite shoot. Striga is more competitive because of its higher osmotic and lower stomatal resistance, which result into higher transpiration rates. Water moves from high to low water potential and measurements of *Striga* water potential have shown that watered plants and leaf of *Striga* have 0.1 – 0.37 mega Pascal lower than that of the host as a result more water will be supplied to *Striga*. Under water stress, *Striga* loses more water because it cannot balance its water relations. *Striga hermonthica* thrives well under conditions of limited moisture availability and water logging is undesirable. Its growth and development in most hosts is enhanced by modest drought stress (Ayensu *et al.*, 1984).

2.6 Growth and development

2.6.1 Seed viability and germination

Striga hermonthica seeds have a remarkable capacity to remain viable in dry soil for 15 – 20 years in the absence of a germination stimulant. According to Bebawi *et al.* (1984) seeds *of Striga asiatica* collected annually for 23 years in North Carolina remained viable for six years under laboratory conditions with 2, 94-94, 83 and 70% viability, as shown by tetrazolium test, after storage for 1, 1-3, 4, 5-6 years respectively. However, the newly harvested seeds did not germinate implying that *Striga* seeds undergo a dormancy period before germination can take place. Singh (1971) evaluated the viability of the seeds of *Striga euphrasioides, Striga lutea*, *Striga densiflora* and *Centhrathica nepalensis* stored either indoors or outdoors. Results from field experiments indicated that all species remained viable for 4-11 years, while in petri dishes experiment only *Striga enphrasioides* and *Centathica nepalensis* germinated without the presence of host and remained viable for 1-2 years.

Striga seeds are usually dormant for few months after harvest of the crop before they acquire the capacity to germinate. Maximum germination occurs when *Striga* seeds are 9 months or older (Kust, 1963) but Ayensu *et al.,* (1984) reported of *Striga hermonthica* germination of 80% within three months from collection. It is evident that *Striga* germination is very variable and hence cannot be generalized. Prior to germination the seeds require a period of conditioning and this may last for 10-15 days under optimum moisture and temperature conditions before the seeds can respond to a germination stimulant such as *Strigol acetate*, ethylene or thiolurea. A temperature range of 22-35°C is favourable for *Striga hermonthica* germination, which would normally occur within 24 hours (Ayensu *et al.*, 1984; Dogget 1970; Mumera 1984). The young host root produces the natural stimulant strigol. Seeds must be within 10mm from the host to be stimulated but a distance of 3-4mm is preferable.

On germination the radicle tip is transformed into a haustorium. The radicle secretes enzymes that assist it in penetrating the host root and the xylem of *Striga* establishes the connections with the xylem of the host to complete the host parasite relationship. After establishment, the parasite becomes a metabolic sink for the carbohydrates produced in the host thus rob the host of its photosynthates.

Striga seedlings grow parasitically underground for about 4-6 weeks after germination and during this time depend upon the host for food and water causing extensive injury to the host plant. Once *Striga* appears above the ground, it produces chlorophyll and becomes a semi-parasite manufacturing part of the food but continuing to depend on the host for water and minerals. Flowering occurs about 2 weeks later and it takes another 2 weeks for the seed to mature. Flowering and fruiting continues until death of the host (Ayensu *et al 1984;* Dogget 1970; Mumera 1984; Ramaiah *et al.,* 1983).

2.7 Reproduction

2.7.1 Seed production

Being annuals, *Striga* spp. reproduce by seed. Seeds are produced in very large numbers and each capsule produces 400-900 seeds. A single *Striga hermonthica* can produce as many as 50,000 seeds on average but records of up to 84,392 seeds per plant have been reported. Other *Striga* spp. can produce as much as 500,000 seeds per plant. Seeds are very minute and measure 0.2-0.3 mm and have prominent ridges on the seed coat surface. The seeds are very light and are generally dispersed by wind, water, cattle and man through contamination of crop seed and by agricultural machinery. The seeds move down through the soil pores and through the pathways caused by decay and decomposition of plant roots. *Striga* is strictly an annual plant; Jones 1953; Lagoke *et al.*,1984; Ramaiah *et al.*, 1983; Russel and Mussil, 1961 and Robinson and Dowler, 1966).

The seeds are scattered by the rapture of pods, wind and dust storms. Seeds are known to be dispersed up to a distance of more than 4 km. Their small size enables them to be blown by wind over fairly long distances and also being dispersed by water flowing on the soil surface and as it seeps down the soil profile. *Striga* seeds have been observed at depths of up to 150cm down a profile of undisturbed soil, the seeds pass down with rain or irrigation water (Appendix 3).

2.8 Economic importance of *Striga* on host plants

2.8.1 Extent of *Striga* field infestation.

Striga have infested many fields in semi-arid and temperate areas in different parts of the world. Parkison, (1989) while surveying *Striga* spp. in Benin, Nigeria and Togo in West Africa revealed that 50-100% of the crop fields examined in all States/Provinces of these countries between latitudes 4 and 13; with the exception of the rain forest zone of Anambra and Oyo in Nigeria, were infested with *Striga* spp. (*Striga hermonthica, Striga aspera, Striga asiatica, Striga gesneroides, Striga parssargei, Striga granchcalyx* and *Striga forbesii.* Results of the survey indicated that between 66 – 100% of the maize crop was lost in Borno, Niger and plateau states in Nigeria, and Atakora and Borgou in Benin, due to infestation by *Striga hermonthica. Striga aspera* caused equivalent maize crop losses in Bauchi, Kwara and Niger states in Nigeria, whereas *Striga asiatica* was more prevalent in Nigeria and the Moretime Province of Togo.

Carson, (1988) surveyed the Gambia for *Striga* infestation and reported that *Striga hermonthica* was wide spread and infested sorghum, millet and maize. About 75% of 700 fields covered were infested at an average rate of 1 – 2 shoot/m^2 Maize was mostly attacked compared to other cereals. According to Musselman and Heppe (1986) *Striga asiatica* and *Striga hermonthica* are serious pests of sorghum, maize and millet in parts of Yemen and Saudi Arabia. Among the sorghums attacked by *Striga*are, *Sorghum vulgare, S. Sudanense, S. Purpureo-sericeum* and *S. arundinaceum.*

Preliminary survey by Mbwaga and Obilana (1990) in Tanzania indicated that *Striga asiatica, Striga hermonthica* and *Striga forbesii* were the major parasitic weeds in sorghum, maize and pearl millet fields. These crops are commonly grown in semi-arid areas of Tanzania. As such, *Striga* infestation is of particular importance to farmers in these areas. *Striga* spp. also occur in waste lands or grasslands where they parasitize grasses including *Sorghum* spp., *Pennisetum* spp., *Paspalum commersonii., Panicum miliaceum, oryza* spp., *Cynocon dactylon; Setaria italica; Euchlaeza mexicana; Dactyloctenium aegypticum; Eragrostis* spp; *Cenchrus biflorus; C.Ciliaris* and *Digitaria exilis.*

2.8.2 Effect of *Striga* on yield:

Witchweeds reduce yields in the crop plants they parasitize. The yield losses recorded vary with the density of parasites and up to total crop losses have been recorded in some areas. In the experiment conducted by Rao *et al.* (1989) on estimates of losses in sorghum (*Sorghum bicolor* L Moech) by *Striga asiatica*, it was indicated that in India 53,000 tons of sorghum grain worth $.4.5 million (approx.RS 67 million) are lost every year. Pieterse and Pesch (1983), Aggarwal and Oedraogo (1989) and Anon (1989) reported that *Striga spp.* in Nigeria attributed to yield losses of 50% or more on all host crops. In the absence of any control options, many farmers are forced to abandon their fields when infestation becomes so severe as to render any attempt to grow a crop impossible (Anon, 1989 and Lagoke *et al*, 1991). Carson (1989) in his two years study in Gambia found that crop loss due to *Striga* ranged from 20 – 35% resulting in an annual loss of about 10,000 tons of cereal grain valued over US $. 900,000. Parkinson (1985) reported losses attributed to *Striga* *hermonthica* of 10-91% in sorghum and maize in Nigeria and these losses were estimated to be worth US. $. 250 million annually. In East Africa, Dogget (1970) estimated a 20-95% total yield loss for sorghum and millet.

2.8.3 Effect of *Striga* on host plants

Musselman (1980) reported that parasitized host plants have 90-95% fewer cytokinins and 30-80% fewer gibberellins than in the uninfested plants while concentration of inhibitors such as abicissic acid and farnesol are increased. Other effects of *Striga* include differential absorption of minerals like P, K, S and Iron. *Striga* can absorb the minerals directly into non-haustorial portion of their roots. *Striga* has also been found to modify the host roots through increased lignification (Musselman, 1980). Direct effect of *Striga* infestation on the host plant includes stunted growth, scorching of leaves, wilting, yellowing and barreness (without setting cobs or heads). Under high infestation the host plant may die before flowering and symptoms may even be observed before the *Striga* emerges from the soil. (Mbwaga *et al.* 2000).

2.8.4 Effect of *Striga* on social economic factors

Striga spp. are important endermic pests of crops sown in semi arid and sub-tropical regions. *Striga* have been the direct cause of depopulation of useful agricultural land in Sukumaland, western Tanzania and the cause of food shortages in some years (Dogget, 1970; Mumera, 1984). Despite the serious disastrous effects of the witchweeds, *Striga* does have some beneficial uses. These include the use of *Striga* as livestock feed especially before seed setting. *Striga* is also alleged to have medicinal value and has been used in the treatment of diabetes. In some instances *Striga* is chewed to colour and strengthen teeth. It can also be used as green manure before seed setting (Kassasian 1971; Lagoke *et al* 1994; de Milliano *et al.* 1992). A direct social economic implication of crop yield losses due to *Striga* damage, which is estimated in Tanzania up to 90% depending on *Striga* infestation, is the migration of farmers to *Striga*-free areas, shifting cultivation, farm abandonment and change of cropping pattern (Mbwaga, 1991).

2.9 Strategies for *Striga* control

The strategies for *Striga* control should aim at attaining one or more of the following objectives (Ayensu *et al.* 1984):-

i). Reduction of seed number (weed seed bank)

ii). Prevention of new seed production

iii). Prevention of movement of seed from infested areas.

Striga control is made difficult by the ability of the plants to produce very large number of seeds. The high longevity of the seeds makes the complete elimination of *Striga* impossible. Various methods have been tested for the control of *Striga*, that is from the use of tolerant/resistant varieties, use of herbicides, use of catch and trap crops, pulling by hand, use of crop rotations, nitrogen fertilizers, germination stimulant and biocontrol. (Kim 1991; Kassasian 1971; Lagoke *et al.,* 1991; Ramaiah *et al.*, 1983; Rao 1987).

2.9.1 Use of resistant or tolerant varieties

Use of resistant or tolerant varieties is considered a practical and reliable approach to solving the *Striga* problem. This is the cheapest and most effective method of *Striga* control. Resistant is defined as the ability of the same variety to produce satisfactory grain yield when grown in *Striga* infested fields, supporting at the same time markedly fewer flowering *Striga* than susceptible variety under similar condition. Resistant sorghum varieties identified are SRN 39, SAR 29, P9405, P9406 and Serena. A tolerant sorghum variety "Wayjita" – a local sorghum variety from Mara region (Mbwaga *et al.*, 2000) has also been identified. In East Africa good, resistance has been found in varieties Framida and N 13, from India and South Africa, respectively, as well as two Eastern Africa varieties Dobbs and Serena (Ayensu *et al.*, 1984; Mumera 1983; Ramaiah *et al.*, 1983). According to Kim, (1991) the development of resistant varieties is often accompanied by reductions in yield and quality.

2.9.2 Use of trap and catch crops

Both trap and catch crops induce germination of *Striga* seeds. Crops like cotton, cassava, sunflower, groundnuts, bambara groundnuts and other plants such as sudan grass and cotton induce germination but are not parasitized by *Striga*. These plants are referred to as trap crops. Other trap crops include cowpea and pear, pigeon pea are also potential trap crops. The Stylosanthes used in fodder bank may be able to act as a trap crop but research is needed to confirm its suitability. (Mumera, 1984; Ramaiah *et al* 1983; Tarr 1962). Catch crops are the true hosts of the weed, and therefore have to be destroyed once the weed germinates These include susceptible cultivars of sorghum such as Tegemeo or maize variety Staha. Limited availability of resources to small-scale farmers makes this approach unacceptable to most of them. Some trap crops e.g. cowpea encourage development of another problem weed *Alectra* spp. Also most of the *Striga* weeds have a large number of alternate hosts and therefore they cannot be easily eliminated. It has been suggested that trap and catch crops should be alternated because catch crops cause a higher percentage of weed germination (Kassasian 1971; Kim 1991; Lagoke *et al.*, 1994; Tarr 1962).

2.9.3 Use of fertilizers and animal manure

In both on station and on farm trials, the use of urea has been observed to suppress *Striga* and also increase crop yield compared to non-use of fertilizer. According to Mbwaga *et al.*, 2000, the use of nitrogen urea of 50 to 75 kg/ha was effective and also suppressed *Striga* germination, but CAN (Calcium Ammonia Nitrate) was not effective. Animal manure has also been observed to be effective but the rate is still to be established (Kim 1991; Mumera 1984; Ramaiah *et al.*, 1983).

2.9.4 Chemical germination stimulants

The natural stimulant strigol and strigol analogues such as GR 7 and GR 24 have been used to control *Striga*. This compound is extracted from the roots of maize (*Zea mays*) and cotton (*Gossypium hirsutum* L.) and is capable of inducing *Striga* seeds to germinate but such germination is suicidal in the absence of host plants. The most limiting factor against the use of natural germination stimulant is the low yield of strigol and the expense, which has to be incurred in extracting the stimulants. For instance, 2mg of pure strigol requires up to 20,000 maize seedlings. Ethylene gas also acts as a germination stimulant and has been used with success in North America but it is very expensive and requires special skills in application. (Eplee *et al.*1991; Kim 1991; Mumera 1983; Shaw *et al*, 1962).

2.9.5 Fallowing

Leaving land on fallow for some years is not very practical because of the presence of other alternative hosts of *Striga.* Most of the grass species in savannah are alternative hosts to *Striga hermonthica* while some leguminous plants, especially *Tephrosia spp.*, *Indigofera spp.* and *Desmodium spp.* serve as hosts to *Striga gesnerioides* (Eplee and Langston, 1991).

2.9.6 Seed treatment

Treatment of crop seed with brine solution has been found to be effective in reducing the *Striga* problem (Kim 1991). Konate (1986) reported that farmers in Sokoto state in Nigeria claimed that soaking the crop seed in brine or an extract of *Parkia filicoides* reduced *Striga* infestation. In Mali however, the use of nere (*Parkia biglobosa*) powder was shown to be ineffective.

2.9.7 Herbicides

Herbicide have been reported to be effective in controlling *Striga* including 2,4-D amine, ticolor, dicamba (3,6-dichloro-2-mthoxy-benzoic), glyphosate and a mixture of dimethametryn. and diflufenican. (Ayensu *et al.*1984; Ivens 1975). Timing of the herbicide application is also very essential e.g. 2,4-D can kill emerged *Striga* but if applied later than 3 weeks after planting or when crop is under moisture stress, it will induce more *Striga* to germinate (Edgeton 1955; Setty and Hosmani 1987 and Singh *et al.*1991). TBA is effective when mixed with other herbicides. Most of the herbicides do not destroy *Striga* seeds (Ramaiah *et al* 1983; Tarr 1962).

2.9.8 Biological control of Striga

The use of biological control techniques for *Striga* are still being developed and the potential organisms being identified. These organisms include the gall forming weevil (*Smicromyx spp.*) which lays eggs in the flower buds; thus grabs feed on the ovules and effectively reduces seed production. The larvae of butterfly Precis (*Jononia orithya*) have also been observed to feed on leaf buds, leaves and capsules of *Striga* species. Fungi such as *Fusarium nyganai* and *Fusarium oxysporum* have been observed to cause wilting of *Striga* plant, girdling of stem and also cause other damage to *Striga* plants. The effect of soil borne parthogen on *Striga* control is under investigation (Mbwaga *et al.* 2000).

2.9.9 Integrated control

Williams (1984) defined integrated weed control as a management system that, on the basis of knowledge of ecology and population dynamics of a particular organism, uses all appropriate techniques including cultural, chemical and biological in as compatible a manner as possible and with due consideration to the environmental quality to maintain populations of these organisms at levels below those causing economic damage in current and future years.

None of the above mentioned methods alone can be effective in managing *Striga*. A combination of two or more control methods into one strategy with some background knowledge of the expected contribution of each component to the control strategy gives a significant impact on *Striga* control. The methods selected should be as compatible as possible, should be economically feasible, acceptable and environmentally friendly (Ayensu *et al.*, 1984; Ramaiah *et al.*, 1983).

2.9.10 Intercropping

Intercropping has been defined in many different ways. Grimes (1963) defined intercropping or mixed cropping as the practice whereby crops are grown randomly as a mixture, which involves two or more crops. These crops may be grown simultaneously and intermingled within an area without following any proper arrangement. Ruthernburg, (1971) defined the system as a practice where two or more crops are grown simultaneously in alternate rows in the same ground. According to (Krantze *et al.* 1976) intercropping or mixed cropping is a system where two or more crops are grown simultaneously on the same area of land with no row arrangement.

Intercropping is a widely used system practiced by subsistance farmers in Tanzanian and other tropical and subtropical countries where the hoe is the most important agricultural implement. Intercropping has long been recognized as a very common practice throughout the developing tropics (Willey, 1979). In India for example, its importance was highlighted almost 30 years ago in a very comprehensive review by Aiyer, (1949). Historically, however, it has been regarded as a primitive practice which would give way to sole cropping as a natural and inevitable consequence of agriculture development (Willey, 1979) Hence, monocropping is a relatively recent innovation in agriculture.

Narang *et al.,* (1969) pointed out that intercropping aims at producing better quality and quantity of grain, better utilization of land, maintenance of soil fertility, supply of supplimentary requirements of farmers, economic distribution of labour, safety against weather conditions and conservation of soil moisture. To some extent the incidence of some diseases and insect pests are checked and also weed growth is suppressed. There is also efficient use of fertilizer and irrigation water by plants.

Intercropping is a Tanzanian traditional cropping practice characterized by minimal utilization of inputs such as fertilizers and insecticides (Nyambo *et al.*, 1982). It is a major cropping system practiced by an estimated 90% of the small holder farmers in Tanzania (Evans, 1960; Finlay *et al.*, 1974). The types and choice of crops grown in this system depend on biological, social, physical and economic factors, such as soil characteristics, temperature and rainfall regimes, tastes and traditions, risks, market prices and general infrastructure (Mwambene, 1977). However, the commonest system involves cereal legume intercropping, the cereal as the major and the legume as the minor crop.

Nevertheless, there are limitations usually attributed to the intercropping system. These include inability to use farm machinery for fertilization, insect pests and disease control, harvesting and crop competition for light, moisture and nutrients (Temu *et al.*, 1989).

Intercropping studies however, revealed that the advantages far outweigh the disadvantages often proclaimed. Moreover a large number of smallholder farmers still perform field operations manually and thus mechanization cannot be considered as a serious limitation in smallholder agriculture.

2.10.1 Influence of intercrops on Striga population dynamics

Ngomou nga *et al.* (1991) experimenting with maize and sorghum intercropped with cowpeas in Nigeria showed that *Striga* counts were higher in pure stand than mixtures and that highest grain yields were obtained from mixtures. Trap crops can be intercropped with or rotated with a susceptible host. In the Gambia, alternating sorghum or millet with groundnuts resulted into a low *Striga* infestation, while growing three successive crops of groundnuts as a trap crop further reduced *Striga* population. From his trial Parkinson *et al.* (1987) reported that soya bean, cotton and bambara groundnuts when grown in rotation with susceptible host or as intercrop induced abortive germination of *Striga* seeds and consequently reduced infestation. A similar observation was made with soya bean in Northern Nigeria but its effectiveness was reduced by the presence of alternate hosts such as *Digitaria ciliaris*.

In trials of sorghum intercropped with cowpea in the same row in northern Tanzania, Mbwaga, (1996) reported that this mixture reduced *Striga* infestation significantly.

The reduction in *Striga* infestation was attributed to the soil cover of cowpea creating unfavourable conditions for *Striga* germination. Similar results were reported by Singh *et al.* (1991) in Cameroon and by Reda (1996) in Ethiopia. Ndikawa and Kenga, 1993 conducted an experiment to ascertain the effect of associating cereals with legume species such as cowpea of a spreading growth habit, senna (*Cassia obstusifolia* (Lamb) and *Cassia accidentalis* (L) sun hemp and showed that the adverse effects of *Striga* effect were alleviated.

Trials on mixtures of sorghum with mungbean (*Vigna radiata* (L) by Reda, (1993) indicated that *Striga* population was low in mixture compared to sole crop. Kidane *et al.*, (1989) observed similar results when sorghum was grown alone compared to sorghum/ mungbean intercropped. Results of the experiment conducted by Mbwaga *et al.*, (1993) on intercropping sorghum/ cowpea intercrop especially in the in-row intercropping pattern in Tanzania showed that *Striga hermonthica* infestation was low in the mixture as compared to the sole crop.

2.10.2 Influence of different intercropping patterns on growth and yield attributes of components of crops

Intercropping patterns have a definite effect on sorghum yield and yield components. This has been indicated in different trials and thus experience has shown that high yields can be obtained or realized in pure stand. Moreover, a reasonable yield may be recorded in the intercrops. Moreover, intercropping was effective in increasing the overall productivity under *Striga* infestation (Singh *et al.*, 1991). The results of experiment carried out by Ngoumou nga *et al.* (1991) on intercropped maize with cowpeas and sorghum with cowpeas showed that sorghum and maize in intercrops was higher than in mono-crop.

Trials on intercropping of sorghum with cowpeas, by Carson (1985) indicated that sorghum and maize yield from the mixtures was 60% higher than in monocrop. This was due to the effectiveness of cowpea in controlling *Striga* damage on host plants. Odhiambo and Ramsom, (1996) while working on the effect of continuous cropping with trap crops and maize under varying management systems on the restoration indicated that maize yield had increased considerably.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Location of the experimental sites

Field experiments were conducted during the 1998/99-rain season at Bihawana Farmers Training Centre (latitude 7° 24' SE, longitudes 36°40'NS, altitude 1372m above sea level) and Hombolo Research Institute (latitude 5°45'SE, longitudes 35°57'NS, altitude 1100m above sea level) both located near Dodoma, in central Tanzania. Bihawana is about 19km South West while Hombolo is 55km north East of Dodoma municipality (Figure 3.1).

At Bihawana location, the experiment was laid out on land previously under cowpeas and bambara groundnuts. At Hombolo location, the experiment was laid on land previously under sorghum. Soils at the experimental site at Hombolo Research Station are fairly uniform based on colour and texture (Hatibu *et al.* 1995). A description of a representative soil profile is given in Appendix 4. It has been classified as Typic Ustorthent in US Soil Taxonomy as or Dystric Regosol in FAO – UNESCO system (Mahoo and Kaaya, 1995).

The soils at Bihawana Farmers Training are gritty in which colloidal substances become loose when wet and hard when dry. The soils are poor with low fertility, which results into low crop low productivity. The soil has a pH of 6.5- 6.9, active phosphorus 30.9 ppm, active potassium 224.4 ppm, total nitrogen 0.45%, total

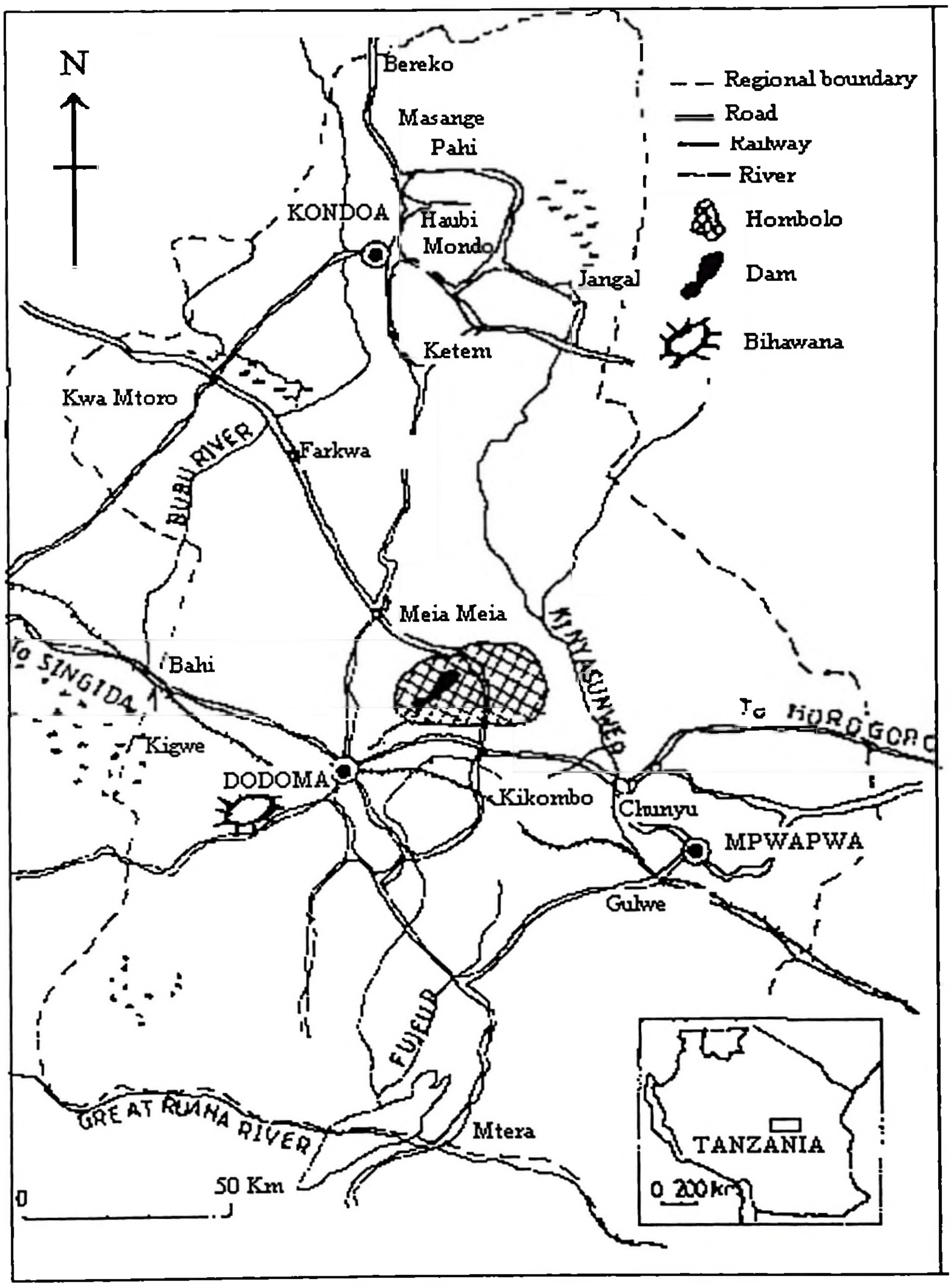


Figure 3.1 Location of Hombolo and Bihawana

phosphorus 0.04%. The soil is generally described as having low fertility (Bihawana Climate Handbook, 1973).

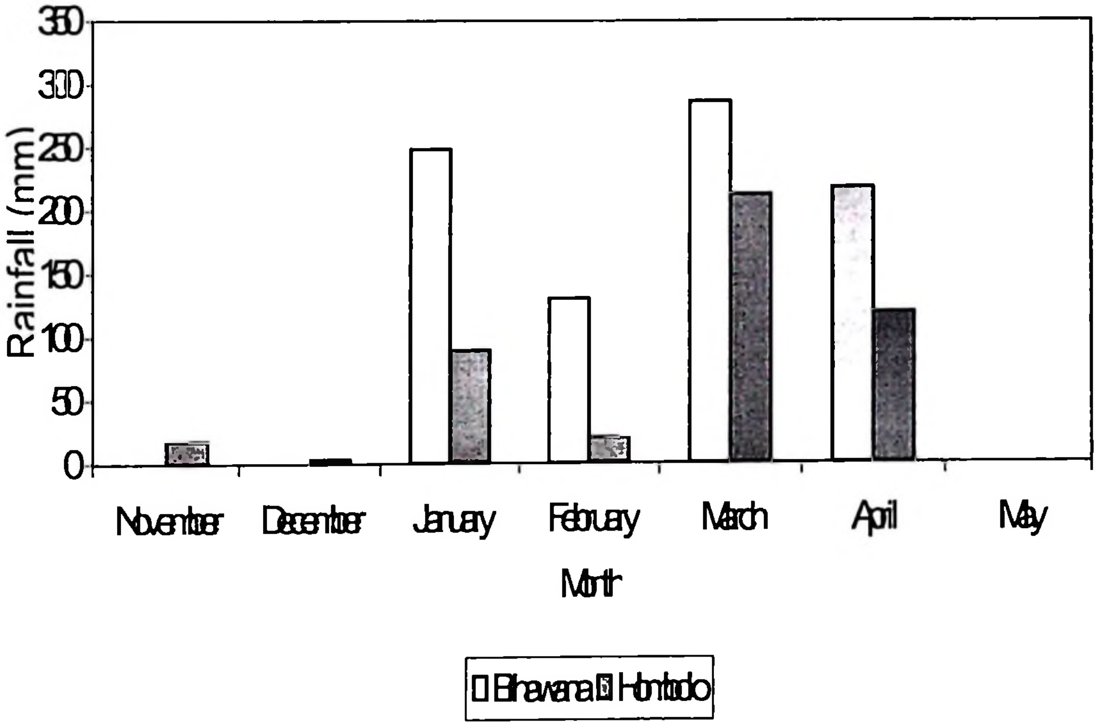
Both Bihawana and Hombolo receive a mean annual rainfall of between 500 and 800 mm per year. In a normal year, Dodoma region experiences a unimodal type of rainfall with rains falling between November and May. In 1998/99 seasons, however, rainfall was irregularly distributed. Both experiments were conducted during the rain season. Due to irregular nature of rainfall, crop and *Striga* growth and development for the experiment was very much affected. Monthly rainfall received at Bihawana and Hombolo are presented on Figure 3.2.

3.2. Experimental layout

At both sites the experimental design was a Randomised Complete Block with three replications. Sorghum variety Tegemeo, groundnuts landrace Mamboleo and bambara groundnuts landrace Nzugu bought from the town market was used.

The treatment consisted of eight cropping patterns which were : ABR = Alternative between rows, DR = Double rows, AWR = Alternative within rows, AWRABR = Alternate between rows and alternate within rows, RP = Random planting, SH = Same hill, S = Monocrop sorghum, G = Monocrop groundnuts, BG = Monocrop bambara groundnuts (Table 3.1). For sorghum sowing was in row arrangement (75 x 30 cm) and random planting, whereas for groundnuts and bambara groundnuts sowing was also in row arrangement (50x10cm) and random planting (Figure 3.3). Individual plots were 5x3m in size.

Figure 3.2 Bihawana and Hombolo monthly rainfall distribution for 1998/99 Cropping season.



Source: Bihawana Hombolo Meteorological Station, 1998/99 Season.

Table 3.1 The treatment combinations during the cropping season 1998/99

Cropping pattern	Plant ratio	Estimated plant population/ ha		
		Sorghum	Groundnuts or Bambara groundnuts	Total
ABR	1:2 ratio alternate row	85333	99999	185332
DR	1:2 ratio alternate row	85333	199999	285332
AWR	1:1 ratio within row	85333	79999	165332
RP	1:1random planting	85333	99999	185332
AWRABR	1:2. Ratio alternate and within row	85333	179999	265332
S	2 plants per hill	85333	-	85333
G	1 plant per hill	-	199999	199999
BG	1 plant per hill	-	199999	199999

ABR = Alternate between rows, DR = Double rows, AWR = Alternate within rows, RP = Random planting, AWRABR = Alternate between rows and alternate within rows, S = Monocrop sorghum, G=Monocrop groundnuts, BG= Monocrop bambara groundnuts

Figure 3.3 Crop arrangement

S G S G S G S

S G S G S G S

S G S G S G S

S G S G S G S

ABR= Alternate between rows

S G G S S G S S G S G G

G S G S G G G S S G S

G S S G S G G S S G G S S G

S G S S G S G S G S S G G S S

RP = Random planting

S GG S GG S GG S

S GG S GG S GG S

S GG S GG S GG S

S GG S GG S GG S

DR= Double rows

S G S G S G S

G G G G G G G

S G S G S G S

G G G G G G G

Alt. within rows and alt. between rows

S S S S

G G G G

S S S S

G G G G

AWR= Alternate within rows

S S S S

S S S S

S S S S

S S S S

S= Monocrop sorghum

SG SG SG SG

SG SG SG SG

SG SG SG SG

SG SG SG SG

SH= Same hill

GB GB GB GB GB GB

GB GB GB GB GB GB

GB GB GB GB GB GB

GB GB GB GB GB GB

G or B= Monocrop groundnuts or B/nuts

At both sites land was ox-ploughed just before the first rains. At both sites phosphorus at the rate of 50 kg P_2O_5/ha in the form of TSP, and nitrogen at the rate of 40 kg N/ha in the form of urea were mixed and broadcasted after land preparation. Seeds were sown on 15th January and 22nd January at Hombolo and Bihawana locations, respectively. After three weeks of growth, nitrogen in the form of Urea was applied at the rate of 25 kg N/ha at both locations as top dressing.

Insect pest control was carried out using Diazinon 50% at the rate of one litre per hectare in 500 liters of water two weeks after planting for control of *Otheca beningseni* and *Calidea dregae* in groundnuts, bambara groundnuts and sorghum. Malathion 5% at the rate of 2.5 kg/ha for control of stalk borers in sorghum was applied three weeks after planting. All plants were maintained weed-free by using hand hoe; and weeds close to the crop were removed by hand weeding. Weeding had to commence ten days after planting to allow the young crop roots to hold firmly in the soil, lest they get damaged and cause the young plants failure to absorb moisture from the soil and hence led to wilting.

3.3 Data Recorded

3.3.1. Striga incidence (count/m^2)

Striga incidence was assessed on the basis of *Striga* counts (number of plants/ m^2) at different intervals. Counting was done from plots earmarked for final harvest at 8, 10, 12 and 14 weeks after planting.

3.3.2 Dry matter of *Striga* plants (gm)

The dry matter yield of *Striga* plants was determined by oven drying ten *Striga* plants randomly sampled from two inner guard rows on both sides of the plot to avoid lowering the *Striga* population in the unit area. The *Striga* plants were cut just above the root crown, and were oven dried at 60°C for 24 hours so as to get constant dry weight. The weight obtained was computed and recorded as gm/ plant.

3.4 Growth, yield and yield attributes for sorghum

During the course of crop growth and development, growth and yield attributes were measured from plants sampled from the central harvest area of 5x1.5m (7.5m^2.) The data collected was as outlined below.

3.4.1 Growth attributes for sorghum

3.4.1.1 Seedling emergence percentage

The seedlings that emerged 14 days after planting were counted and later seedling emergence percentage recorded as number of plants per plot. This was done by counting the seedlings emerged from all rows in the plot.

3.4.1.2 Plant height at booting stage

Plant height at booting stage was measured first by sampling 10 plants in each plot when sorghum plants had attained 50% flowering (booting stage). The sampled plants were taken from the harvest area and the height was measured from the ground level (soil surface) to the low end of the sorghum head (panicle or head). Data was recorded in cm.

3.4.1.3 Plant height at harvest

Plant height at harvest was measured first by sampling 10 plants in each plot when sorghum plants had attained maturity stage. The sampled plants were taken from the harvest area and the height was measured from the ground level (soil surface) to the top of sorghum head (panicle). The data were recorded in cm.

3.4.1.4 Dry matter yield of sorghum

The dry matter yield of sorghum was taken by oven drying 10 plants randomly sampled from two inner guard rows on both sides of the plot. The plants were cut just above the root crown, and were oven dried at 80^0C for 48 hours so as to get constant dry weight. The weight obtained was recorded as gm/plant.

3.4.2 Yield attributes of sorghum

3.4.2.1 Head size (cm)

This was carried out by measuring head (panicle) length from 10 sampled plants from plots earmarked for final harvest in each plot. Then a mean head length (cm) was calculated.

3.4.2.2. Thousand seed weight (gm)

A sample of 1000 sorghum seed were counted from the plot seed lot and then weighed. The seeds were first obtained from sun dried and threshed sorghum head. Seed weighing was done when the moisture content was 13%.

3.4.2.3 Number of plants at harvest

This was carried out by counting the number of harvested plants in the plot.

3.4.2.4. Grain yield per head (panicle) (gm)

This was established by taking ten sorghum heads from the area earmarked for harvesting in each treatment (plot), threshed separately and weighed.

3.4.2.5 Sorghum grain yield per hectare (kg/ha)

This was done by first taking all sorghum grain (seed) from the harvest area in each plot (treatment) and weighed separately (gm) and computed into kg/ha basis i.e. (kg/ha = (g/plot)/ 1000g x 10,000/plot size (7.5m^2).

3.5 Growth, yield attributes for groundnuts and bambara groundnuts:

3.5.1 Growth attributes:

3.5.1.1 Seedling emergence percentage

Seedlings emergence counts and plant establishment data was obtained by taking the plant population of each plot (treatment) 14 days after planting.

3.5.1.2 Days to 50% flowering

Number of days to 50% flowering was established by taking ten plants from each treatment (plot) and recording the days taken from planting to the time when 50% of plants had flowered.

3.5.1.3 Dry matter yield per plant at 50% flowering

Oven drying 10 plants randomly sampled from inner guard rows on both sides of the plot when they had attained 50% flowering obtained the dry matter yield for groundnuts and bambara groundnuts. The plants were cut just above the root crown and were dried in the oven at 60°C for 24 hours as to get a fairly constant dry weight. The weight obtained was then computed per plant basis and recorded for analysis.

3.5 Yield attributes

3.5.2.1 Number of plants at harvest

This was carried out by counting the number of harvested plants per plot.

3.5.2.2 Number of pods per plant

This was established by counting the total number of pods from 10 sampled plants from the harvest area. This was done at harvest and then the average number of pods per plant was computed and recorded.

3.5.2.3 Number of seeds per pod

At harvest 10 pods from 10 randomly sampled plants from plots earmarked for harvesting were threshed and then the number of seeds determined. The average number of seed per pod was computed and recorded

3.5.2.4 Number of filled pods per plant

At harvest, filled pods were counted from 10 pods of randomly sampled plants form plots earmarked for harvesting and then the average number of filled pods per plant was computed to obtain number of filled pods per plant.

3.5.2.5 Hundred seed weight (gm)

This was obtained by weighing 100 seeds harvested from plots earmarked for harvesting from each plot. This was done when the seeds were sun dried and had attained moisture content of approximately 10%.

3.5.2.6 Grain (seed) yield per plant (gm)

The seed weight per plant was established by first determining the seed yield per plot earmarked for harvesting and then the yield was divided by the number of plants at harvest so as to get seed yield per plant.

3.5.2.7 Pod yield per hectare (kg/ha)

This was done first by weighing groundnuts and bambara groundnuts pod in the harvest area in each treatment (plot) in grams and then computed per hectare basis kg/ha = (g/treatment)/1000gx 10000/plot size (7.5m^2)

3.5.2.8 Grain yield per hectare (kg/ha)

This was done by first weighing all grain (seed) from $7.5m^2$ harvest area in each treatment (plot) in grams and then computed to kg/ha = (g/treatment)/ 1000gx10000/plot size ($7.5m^2$)

3.5.2.9 Shelling percentage

This was established by taking the weight difference between pod yield and grain yield per hectare and divided by the total of pod yield and seed (grain) yield per hectare and computed to percentage.

3.5.2.10 Land Equivalent (LER)

This is the relative land required as a sole crop to produce the yield achieved in intercropping (Gomez, 1983; Willey, 1985). The LER concept was initially proposed by Willey and Osiru (1972) as an index to Asses the yield advantage in intercropping. In a binary intercrop, LER may be represented as:

$$LER = \frac{(Yij)}{(Yii)} + \frac{(Yji)}{(Yjj)}$$ (Willey and Osiru, 1972)

Where Y is the yield per unit area, Yii and Yjj are sole crop yields of the component crops i and j, Yij and Yji are intercrop yields (Mead and Willey, 1980). If LER = 1, the various yields harvested from the intercrop could have been obtained from the unit area planted to sole crops each occupying an appropriate fraction of the total area. An LER of 1 + X implies that the intercrop outyields the sole crops by X%.

Thus an extra X units of area of sole cropping would be necessary to produce the yields obtained from the unit area of intercropping (Mkandawire *et al*, 1989). The LER concept has been extended to standardization of sole crop yields (Oyejola and Mead, 1982) and comparison of intercrops having different yield proportions (Riley, 1984). In fact the LER is the most frequently used index of combined yield from intercropping data (Willey and Osiru, 1972; Willey 1979).

3.6 Statistical analysis

Analysis of variance was run using MSTAT version 3.00/EM for the observed parameters. Statistical model used was as described by Montgomery, (1983) and is shown below:

$Yij = \mu + \delta i + \beta j + \Sigma ij$

Yij = response

μ = Overall mean

δi = the effect of ith treatment

βJ = the effect of the jth block

Σij = NID (O, r^2) random error.

CHAPTER FOUR

4.0 RESULTS

4.1. General observations

During the entire period of the experiment the rainfall pattern was quite erratic. The rainfall and temperature data for 1998/99 for Bihawana and Hombolo are shown on Appendix 1. Generally, these areas receive a mean annual rainfall of between 500 - 800 mm per year (RIDEP, 1978). At Bihawana, rainfall started in January and ended in April. The total rainfall received at Bihawana in January, February, March and April was high in this cropping season (884 mm) as compared to the mean annual rainfall (550 mm). In November and December no rain was received at all, which is not common for Bihawana. The mean maximum and minimum temperatures were as follows: - mean temperatures were 27.2^{0}C (max) and 15.3^{0}C (Min.). In case of Hombolo the data generally showed that the total rainfall received in November, December, January and February was low in this cropping season (463.8) as compared to normal annual rainfall for Dodoma region (500 mm). At this location, rainfall distribution was also poor although it started in November as is normally expected. At Hombolo, the mean maximum and minimum temperatures were 33.2^{0}C (max.) and 17.3^{0}C (min).

As regards to insect pest and disease, at both sites sorghum as infested by stalkborers. Symptoms were seen three weeks after planting expressed by characteristic small holes in plant leaves and stalks. Tegemeo, the variety of sorghum used in the experiment, seemed to be highly susceptible to *Calidea dregae and* Quelea Quelea birds attack especially at the milking stage.

4.2. Physico-chemical properties of surface soil

Dodoma soils are sandy or sandy clay loam with low soil fertility due to low levels of organic matter as a result of reduced decomposition (RIDEP, 1978). The physio – chemical properties of the surface soil (25 cm) for Hombolo as summarised on Table 4.1. The soils of both sites Bihawana and Hombolo indicated that there deficiencies in nitrogen thus are more favourable to Striga germination.

Table: 4.1. Physio-chemical properties of the surface soil (0.2m) at Hombolo during 1997/98 cropping season

	Unit	Mean
Texture Clay	%	21 ± 4.5
Silt	%	3.3 ± 1.5
Sand	%	75.8 ± 4.6
Textural		SCL
Bulk density	gm^{-3}	27
PH		1.49 ± 0.4
In 2.5 H_2O		5.9 ± 0.5
In 1:2.5 KC		14.4 ± 0.01
Organic carbon	%	0.53 ± 0.2
Total nitrogen	%	0.05 ± 0.2
Available phosphorus	$Mgkg^{-1}$	5.7 ± 0.2
Exchangeable bases	Mol (+) kg	
Calcium		5.4 ± 3.5
Magnesium		0.9 ± 0.9
Potassium		0.7 ± 0.8
Sodium		1.1 ± 0.1
C.E.C.		14.2 ± 2.2
Base saturation	%	57.7 ± 25

Mean average of four samples.

Source: Swai E.Y. (1998)

4.3. *Striga* population dynamics for Bihawana

4.3.1. *Striga* counts in sorghum/ groundnut intercrop

At Bihawana in all cropping patterns there were no *Striga* observed at all counting dates (8, 10, 12 and 14 weeks after planting).

4.3.2. *Striga* counts in sorghum/ bambara groundnut intercrop

Not a single *Striga* was observed in all cropping patterns at all counting date (8, 10, 12 and 14 WAP).

4.4. *Striga* population dynamics for Hombolo

4.4.1. *Striga* counts in sorghum/ groundnut intercrops

A steady increase in number of *Striga* was observed as the cropping season advanced (Table 4.2). *Striga* counts in sorghum/ groundnut intercrops differed significantly ($P \leq 0.05$) among cropping patterns at different counting dates recorded between 8 and 14 WAP (Table 4.2). At 8 weeks after planting a significantly higher *Striga* count was observed in monocrop sorghum as compared to all other intercrops. Similar results was observed at 10 WAP. Twelve weeks after planting a significantly higher *Striga* population was observed in monocrop sorghum as compared to DR, SH, RP and ABRAWR intercrops. Similar results were also observed at 14 weeks after planting.

Table 4.2. ***Striga*** **population dynamics (number of plants/m²) in sorghum/ groundnuts intercrop at Hombolo**

Cropping pattern	Counting dates				
	8 WAP	10 WAP	12 WAP	14 WAP	Mean
ABR	0.7b	2.7b	9.0ab	8.3ab	5.2
DR	0.7b	3.0b	2.7b	5.0b	2.9
AWR	0.0b	2.3b	5.3ab	7.0ab	3.7
SH	0.7b	2.7b	4.0b	6.7b	3.5
RP	0.3b	1.3b	2.7b	2.7b	2.3
AWRABR	0.0b	0.7b	1.0b	1.7b	0.9
S	2.7a	9.0a	14.0a	1.6b	6.8
G	-	-	-	-	-
Mean	0.6	1.2	4.8	4.1	
SE±	0.5	5.2	2.9	3.1	

Means within the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate between rows, DR=Double rows, AWR=Alternate within rows, AWRABR=Alternate within rows and alternate between rows, SH=Same hill, RP=Random planting, S=Monocrop sorghum, G=Monocrop groundnuts.

4.4.1.1 Dry matter of *Striga*

There was a significant difference ($P \leq 0.05$) in dry matter yield of *Striga* plants at flowering stage in sorghum/ groundnut intercrop among cropping patterns at Hombolo. Higher dry matter yield per *Striga* plant was observed in AWRABR and RP intercrop (3.8gm and 3.8gm) and monocrop sorghum (3.7gm) and the lowest in SH intercrop (2.1gm) which differed significantly (Table 4.3).

Table 4.3. Dry matter yield of *Striga* in sorghum/ groundnuts intercrop at Hombolo

Cropping patterns	*Striga* dry matter (gm/pant)
ABR	2.6c
DR	2.7c
AWR	3.2b
SH	2.1d
RP	3.8a
AWRABR	3.8a
S	3.7a
G	-
Mean	2.7
SE±	0.08

Means within the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate between rows, DR=Double rows, AWR=Alternate within rows, AWRABR=Alternate within rows and alternate between rows, SH=Same hill, RP=Random planting, S=Monocrop sorghum, G=Monocrop groundnuts.

4.4.2 *Striga* counts in sorghum/ bambara groundnut intercrops

The *Striga* population was significantly ($P \leq 0.05$) different between treatments at 8 weeks after planting. The *Striga* population (plants/ m^2) was significantly ($P \leq 0.05$) higher in ABR intercrop (3.0) and monocrop sorghum (2.7) as compared to SH intercrop (0.3). There were no significant differences ($P \geq 0.05$) at all in other counting dates (10, 12 and 14 weeks after planting) during which *Striga* counts were similar in all cropping patterns. As in sorghum / groundnuts intercrops there was a steady increase in *Striga* counts as the season advanced (Table 4.4).

Table 4.4. *Striga* population dynamics (number of plants/m^2) in sorghum/ bambara groundnuts intercrop at Hombolo

Cropping pattern	Counting dates				
	8 WAP	10 WAP	12 WAP	14 WAP	Mean
ABR	3.0a	11.3a	12.6a	13.0a	10.0
DR	1.0abc	5.0a	8.6a	12.0a	6.7
AWR	0.7abc	6.3a	8.3a	9.6a	6.2
SH	0.3bc	2.3a	4.3a	6.3a	3.3
RP	1.0abc	2.3a	4.6a	5.0a	3.2
AWRABR	0.7abc	5.3a	5.6a	9.6a	5.3
S	2.7a	9.3a	17.0a	18.0a	11.8
G	-	-	-	-	-
Mean	1.2	5.2	7.6	9.2	
SE±	0.51	1.66	1.35	1.34	

Means within the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate between rows, DR=Double rows, AWR=Alternate within rows, AWRABR=Alternate within rows and alternate between rows, SH=Same hill, RP=Random planting, S=Monocrop sorghum, G=Monocrop groundnuts.

4.4.2.1 *Striga* dry matter yield

Significant difference ($P \leq 0.05$) in dry matter per Striga plant was observed among cropping patterns in sorghum / bambara groundnuts intercrop at

Hombolo. The dry matter yields for monocrop sorghum (3.7 gm/ Striga plant) and SH intercrop (3.8gm/ Striga plant) was significantly ($P \leq 0.05$) higher as compared to other cropping patterns (Table 4.5).

Table 4.5 Dry matter yield for *Striga* (gm/plant) in sorghum/ bambara groundnuts intercrop at Hombolo

Cropping patterns	*Striga* dry matter (gm/plant)
ABR	2.9cd
DR	3.3b
AWR	2.7d
SH	3.8a
RP	2.9cd
AWRBAR	3.2b
S	3.7a
BG	-
Mean	2.8
SE±	0.1

Means within the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate between rows, DR=Double rows, AWR=Alternate within rows, AWRABR= Alternate within rows and alternate between rows, SH=Same hill, RP=Random planting, S=Monocrop sorghum, G=Monocrop groundnuts.

4.5 Growth and yield attributes for sorghum at Bihawana and Hombolo

4.5.1 Growth attributes for sorghum

4.5.1.1 Seedling emergence percentage

At Bihawana, seedling emergence percentage differed significantly (P≤0.05) among cropping patterns in sorghum/ groundnut intercrop. Higher seedling emergence percentage was observed in AWRABR, DR, SH, ABR intercrop and monocrop sorghum (84.05, 83.00, 81.92, 76.67 and 77.52%) and the lowest in AWR and RP intercrop (61.01 and 64.71%) which differed significantly between them (Table 4.6).

At Hombolo, seedling emergence percentage was significantly different (P≤0.05) between treatments in sorghum/ groundnut intercrop. ABR, AWR and RP intercrop (73.0, 73.3 and 75.7%) had significantly higher seedling emergence percentage as compared to AWRABR intercrop (56.7%) (Table 4.6).

4.5.1.2 Plant height at booting stage

The effect of cropping patterns on plant height at booting stage in sorghum/ groundnut intercrop at Bihawana was significantly differenct (P≤0.05) between cropping patterns (Table 4.6) and plants in SH and DR intercrop were significantly taller (128.0 and 127.3 cm) than plants in monocrop sorghum and AWRABR intercrop (112.4 and 115.5 cm).

At Hombolo, a significant difference ($P \leq 0.05$) in plant height at booting stage was observed in sorghum/ groundnut intercrop. Significantly taller plants were observed on RR and AWRABR intercrops (121.6 and 121.6 cm) as compared to monocrop sorghum (102.5 cm) (Table 4.6).

4.5.1.3 Plant height at harvest

Significant difference ($P \leq 0.05$) in plant height was observed among cropping patterns in sorghum/ groundnut intercrop at Bihawana. RP intercrop had taller plants (167.7 cm) than on AWRABR intercrop (149.0 cm) (Table 4.6).

The plant height for sorghum in sorghum/ groundnut intercrop at Hombolo is presented in Table 4.6. The mean plant heights at harvest were significantly ($P \leq 0.05$) different between treatments. The DR intercrop and monocrop sorghum (119.3 and 121.0 cm) had shorter plants, which differed significantly as compared to RP intercrop (136.7 cm).

4.5.1.4 Dry matter yield

Significant differences ($P \leq 0.05$) in dry matter yield per plant were observed among cropping patterns in sorghum/ groundnut intercrop at Bihawana (Table 4.6). ABR intercrop (59.76 gm) had higher dry matter yield per plant as compared to other cropping patterns. Higher dry matter per plant was observed in ABR intercrop and the lowest in ABRAWR intercrop (46.16 gm) and they significantly differed.

At Hombolo, dry matter per plant was significantly different ($P \leq 0.05$) among cropping patterns in sorghum/ groundnuts intercrop (Table 4.6). ABR intercrop (58.5 gm) gave a significantly higher dry matter yield per plant as compared to other treatments. The lowest dry matter yield per plant was obtained in AWRABR intercrop (43.5 gm).

Table 4.6. Growth attributes of sorghum in sorghum/ groundnut intercrop As affected by cropping patterns

Cropping Patterns	Seedling emergence %		Plant height at Booting stage (cm)		Plant height at harvest (cm)		Dry matter yield (g/plant)	
	Bih.	Homb.	Bih.	Homb.	Bih.	Homb.	Bih.	Homb.
ABR	76.67a	73.0a	120.0abc	119.8ab	153.0ab	126.7ab	59.76a	58.5a
DR	83.00a	62.3ab	127.3a	108.3ab	153.3ab	119.3b	47.73cde	46.2cd
AWR	61.01b	73.3a	118.0abc	118.3ab	159.7ab	127.3ab	48.54c	48.3bc
SH	81.92a	68.3ab	128.0a	119.2ab	164.ab	126.0ab	50.38b	47.0bc
RP	64.71b	75.7a	124.8ab	121.6a	167.7a	136.7a	47.86ce	46.4cd
AWRABR	84.05a	56.7b	115.5bc	120.6a	149.0bc	127.3ab	46.16e	43.5b
S	77.52a	61.3ab	112.4c	102.5b	159.3ab	121.0b	46.36ce	44.8de
G	-	-	-	-	-	-	-	-
Mean	65.86	58.83	105.76	101.3	158.0	126.3	42.97	41.84
SE±	0.5	4.78	3.2	5.34	5.2	4.5	0.5	0.54

Bih. = Bihawana; Homb. = Hombolo

Means within the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate between rows, DR=Double rows, AWR=Alternate within rows, AWRABR=Alternate between rows and alternate within rows, SH= Same hill, RP=Random planting, S=Monocarp sorg hum, G=Monocrop groundnuts.4.5.2 Growth attributes for sorghum.

4.5.2.1 Seedling emergence

In sorghum/ bambara groundnuts intercrop no significant difference ($P \geq 0.05$) was observed between treatments at Bihawana. Similar results were observed in seedling emergence in all cropping patterns (Table 4.7).

Similarly, in sorghum/ bambara groundnuts intercrop at Hombolo no significant difference ($P \geq 0.05$) in seedling emergence percentage was observed among cropping patterns as all treatments had similar results (Table 4.7).

4.5.2.2 Plant height at booting stage

In sorghum/ bambara groundnuts intercrop at Bihawana, no significant differences ($P \geq 0.05$) in plant height at booting stage were observed. All treatments had similar results (Table 4.7).

In case of plant height at booting stage in sorghum/ bambara groundnuts intercrop at Hombolo, the crop under all treatments did not differ significantly ($P \geq 0.05$) (Table 4.7).

4.5.2.3 Plant height at harvest

At Bihawana, location, plant height at harvest in sorghum/ bambara groundnuts intercrop significantly differed ($P \leq 0.05$) among cropping patterns (Table 4.7). The plants on AWRABR intercrop and monocrop sorghum (152.7 and 146.3 cm) were significantly taller than sorghum plants in AWR intercrop (125.3 cm).

Table 4.7 shows the mean plant height for sorghum in sorghum/ bambara groundnuts intercrop at harvest at Hombolo. The mean plant height at harvest was significantly ($P \leq 0.05$) different among treatments. Sorghum plants in monocrop sorghum and RP intercrop (130.0 and 130 cm) had significantly taller plants as compared to other cropping patterns.

4.5.2.4 Dry matter

In sorghum/ bambara groundnuts intercrop at Bihawana, a significant difference ($P \leq 0.05$) in dry matter yield per sorghum plant was observed among cropping patterns (Table 4.7). The highest dry matter yield per plant was observed in ABR intercrop (59.37 gm), while the lowest in SH intercrop (34.5 gm) and they differed significantly.

There was a significant difference ($P \leq 0.05$) in dry matter yield per sorghum plant in sorghum/ bambara groundnuts intercrop between treatments (Table 4.7). ABR intercrop (58.8gm) had significantly higher dry matter yield per sorghum plant as compared to monocrop sorghum (34.6 gm).

Table 4.7. Growth attributes of sorghum in sorghum/ bambara groundnuts intercrop as affected by cropping patterns

Cropping Patterns	Seedling emergence %		Plant height at Booting stage (cm)		Plant height at harvest (cm)		Dry matter yield (g/plant)	
	Bih.	Homb.	Bih.	Homb.	Bih.	Homb.	Bih.	Homb.
ABR	67.27a	82.7a	124.2a	121.9a	136.7ab	117.0bc	59.37a	58.8a
DR	65.28a	74.7a	113.6a	112.6a	136.7ab	119.0bc	46.95ab	46.9ab
AWR	63.21a	76.3a	105.3a	122.2a	125.3b	123.0b	49.16ab	47.7ab
SH	53.61a	80.7a	114.3a	120.5a	136.7ab	115.0c	34.50b	47.5ab
RP	72.96a	74.3a	114.4a	123.5a	134.7ab	130.0a	46.87ab	45.6ab
AWRABR	66.99a	78.3a	120.0a	124.9a	152.7a	115.0c	44.55ab	43.1ab
S	58.88a	69.0a	110.9a	120.7a	146.3a	130.0a	50.54ab	34.6b
BG	-	-	-	-	-	-	-	-
Mean	56.03	67.0	100.34	105.8	138.4	121.3	41.49	40.5
SE±	8.0	5.3	8.1	3.8	6.1	2.1	6.0	4.7

Bih. = Bihawana; Homb. =Hombolo

Means within the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate between rows, DR=Double rows, AWR=Alternate within rows, AWRABR=Alternate between rows and alternate within rows, SH=Same hill, RP=Random planting, S=Monocrop sorghum, G=Monocrop groundnuts.

4.6.1 Yield attributes

4.6.1.1 Number of plants at harvest

Number of plants at harvest in sorghum/ groundnut intercrop at Bihawana was significantly different ($P \leq 0.05$) among cropping patterns (Table 4.8). AWRABR intercrop had significantly higher number of plant (65.7) at harvest as compared to AWR, RP, and ABR intercrops (47.7, 51.3 and 58.3).

No significant difference ($P \geq 0.05$) was observed in number of plants at harvest in sorghum/ groundnut intercrop at Hombolo. Similar results were observed in all treatments (Table 4.8).

4.6.1.2 Head size (panicle length)

Significant difference ($P \geq 0.05$) in head size was observed in sorghum/ groundnut intercrop among treatments at Bihawana. DR, AWR intercrop and monocrop sorghum had significantly longer heads (18.7, 18.7 and 19.0 cm) as compared to ABR intercrop (16.7 cm) (Table 4.8).

The heads size for sorghum in sorghum/ groundnuts intercrops at Hombolo during harvest was not significantly ($P \geq 0.05$) different among treatments (Table 4.8). Similar results were observed in all cropping patterns.

4.6.1.3 Grain yield per head (panicle)

Grain yield per head did not differ significantly ($P \geq 0.05$) among cropping patterns in sorghum/ groundnut intercrop at Bihawana. Similar results were observed between treatments (Table 4.8).

At Hombolo, a significant difference ($P \leq 0.05$) in grain yield per (head) panicle was observed in sorghum/ groundnut intercrop. Monocrop sorghum had significantly greater grain yield (22.3gm) per panicle as compared to DR, AWR and AWRABR intercrop (19.7, 19.7 and 19.7 gm) (Table 4.8)

4.6.1.4 One thousand seed weight

Significant difference ($P \leq 0.05$) in 1000 seed weight was observed among cropping patterns in sorghum/ groundnuts intercrop at Bihawana (Table 4.8). Among treatments, AWR gave significantly higher 1000 seed weight (28.3 gm) than other cropping patterns.

Similarly, 1000 seed weight was significantly ($P \leq 0.05$) different between cropping patterns in sorghum/ groundnuts intercrops at Hombolo (Table 4.8). However, 1000 seed weight from ABR and DR intercrop (12.4 and 12.0 gm) had significantly higher 1000 seed weight as compared to AWR and SH intercrop (6.5 and 7.2 gm).

4.6.1.5 Sorghum grain yield per hectare

Sorghum grain yield did not differ significantly ($P \geq 0.05$) among cropping patterns in sorghum/groundnuts intercrops at Bihawana. Similar results were observed between cropping patterns (Table 4.8).

The yield data for sorghum at Hombolo in sorghum/ groundnut intercrops is presented in Table 4.8. Significantly ($P \leq 0.05$) higher grain yield for sorghum was realised in RP intercrop (1500 kg/ha) as compared to monocrop sorghum (500 kg/ha (Table 4.8)

Table 4.8. Yield attributes for sorghum as affected by different cropping patterns in sorghum/groundnuts intercrop

Cropping patterns	Number of plants at harvest		Head size (cm)		Grain yield per head (g		1000 seed weight (g)		Sorghum grain yield (kg/ha)	
	Bih.	Homb	Bih.	Homb	Bih.	Homb.	Bih.	Homb	Bih.	Homb.
ABR	58.33ab	47.0a	18.3ab	19.3a	59.2a	20.0ab	25.7bc	12.4a	1770a	1200ab
DR	64.3a	69.3a	18.7ab	19.7a	59.2a	19.7b	24.3c	12.0a	1540a	1100ab
AWR	47.7c	47.7a	18.7ab	18.3a	66.7a	19.7b	28.3a	6.5b	1340a	1200ab
SH	64.0ab	44.3a	18.3ab	18.7a	59.2a	20.3ab	26.3b	7.2b	1710a	1200ab
RP	51.3c	41.0a	18.0ab	19.7a	60.0a	20.3ab	26.3b	8.6ab	1860a	1500a
AWRABR	65.7a	46.7a	16.7b	18.3a	47.5a	19.7b	24.7bc	8.6ab	1070a	800ab
S	60.7a	52.7a	19.0a	17.3a	50.7a	22.3a	25.7bc	9.2ab	1900a	500bc
G	-	-	-	-	-	-	-	-	-	-
Mean	51.5	43.6	18.2	18.8	50.3	20.3	25.9	8.1	1600	1070
SE±	2.2	11.1	0.5	0.8	6.3	0.8	0.6	1.2	284.0	220.9

Bih. = Bihawana; Homb. = Hombolo

Means within the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate between rows, DR=Double rows, AWR=Alternate within rows, AWRABR=Alternate between rows and alternate within rows, SH=Same hill, RP=Random planting, S=Monocrop sorghum, G=Monocrop groundnuts.

4.6.2 Yield attributes

4. 6. 2. 1 Number of plants at harvest

At Bihawana, in sorghum/ bambara groundnuts intercrop there was no significant difference ($P \geq 0.05$) in number of plants at harvest among cropping patterns. Similar results were observed in all treatments (Table 4.9).

Similarly, no significant differences ($P \geq 0.05$) in number of plants at harvest were recorded among cropping patterns at Hombolo, in sorghum /bambara groundnuts intercrop. All treatments gave similar results in number of plants at harvest (Table 4.9).

4.6.2. 2 Head size (panicle length)

Sorghum heads from different cropping patterns were significantly ($P \leq 0.05$) difference among treatments in sorghum/ bambara groundnut intercrops at Bihawana (Table 4.9). ABR intercrop gave significantly longer heads (19.7 cm) as compared to AWR intercrop (17.3 cm).

Table 4.9 showed a significant difference ($P \leq 0.05$) in heads size among treatments in sorghum/ bambara groundnuts intercrop at Hombolo. Among the cropping patterns, RP intercrop gave significantly greater head length (19.0 cm) than in all other cropping patterns.

4.6.2. 3 Grain yield per head (panicle)

In sorghum/ bambara groundnut intercrop, a significant difference (P≤0.05) was observed in grain yield per plant among cropping patterns (Table 4.9). ABR intercrop gave a significantly higher grain yield per head (81.67 gm) as compared to AWR intercrop (53.33 gm)

No significant difference (P≥0.05) in grain yield per panicle was observed in sorghum / bambara groundnuts was observed between treatments at Hombolo. All treatments gave similar results in all cropping patterns (Table 4.9).

4.6.2.4 1000 seed weight

There were no significant difference (P≥0.05) among cropping patterns in 1000 seed weight in sorghum/ bambara groundnuts intercrop at Bihawana. All cropping patterns gave similar results in 1000 seed weight (Table 4.9).

At Hombolo, 1000 seed weight of sorghum in sorghum/ bambara groundnuts intercrop differed significantly (P≤0.05) among cropping patterns (Table 4.9). Monocrop sorghum had significantly greater 1000 seeds weight (22.0 gm) than in any other pattern except in DR intercrop (21.0 gm).

4.6.2.5 Sorghum grain yield per hectare

There were no significant differences ($P \geq 0.05$) in sorghum grain yield per hectare observed between treatments in sorghum/ bambara groundnuts at Bihawana. Similar results were realized in grain yield per hectare in all cropping patterns (Table 4.9). There was a significant difference ($P \leq 0.05$) in sorghum grain yield per hectare in sorghum/ bambara groundnuts intercrop at Hombolo. Significantly higher sorghum grain yield was observed in RP intercrop (1180 kg/ha) as compared to all other cropping patterns (Table 4.9).

Table 4.9 Yield attributes for sorghum as affected by different cropping patterns in sorghum/ bambara groundnuts intercrops at Bihawana and Hombolo

Cropping patterns	Number of plants at harvest		Head size (cm		Grain yield per head (g)		1000 seed weight (g)		Sorghum grain yield kg/ha	
	Biha.	Homb.	Biha.	Homb.	Biha.	Homb.	Biha.	Homb.	Biha.	Homb.
ABR	51.3a	53.3a	19.7a	17.0bc	81.67a	133.3a	25.0a	19.0c	1820a	800bc
DR	51.0a	48.0a	18.0ab	20.0bc	60.83ab	121.3a	24.3a	21.0ab	1790a	980bc
AWR	46.3a	49.0a	17.3b	18.0b	53.33b	148.7a	24.0a	20.0bc	1760a	800bc
SH	42.7a	52.0a	18.7ab	18.0c	68.33ab	154.7a	25.3a	19.0c	2180a	600c
RP	57.0a	48.0a	19.3ab	19.0a	79.17ab	176.7a	25.0a	19.0c	2240a	1180a
AWRABR	52.0a	50.3a	17.7ab	18.0c	62.50ab	108.3a	24.3a	19.0c	1690a	500c
S	46.0a	53.3a	18.0ab	19.0c	59.90ab	121.0a	25.0a	22.0a	1800a	620bc
BG	-	-	-	-	-	-	-	-	-	-
Mean	43.3	44.4	18.4	18.4	48.0	120.5	24.7	20.1	1890	1710
SE±	5.3	3.4	0.67	0.4	7.8	19.0	0.91	0.4	252.8	112.6

Bih. = Bihawana; Homb. = Hombolo

Means within the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate between rows, DR=Double rows, AWR=Alternate within rows, AWRABR=Alternate within rows and alternate between rows, SH=Same hill, RP=Random planting, S=Monocrop sorghum, G=Monocrop groundnuts.

4.7 Growth and yield attributes for groundnuts at Bihawana and Hombolo:

4.7.1 Growth attributes

4.7.1.1 Seedling emergence

Significant difference ($P \leq 0.05$) in seedling emergence percentage among cropping patterns was observed in sorghum/ groundnut intercrop at Bihawana. A significantly higher seedling emergence percentage was realised in ABR intercrop (76.27%) compared to all other treatments (Table 4.10).

No significant difference ($P \leq 0.05$) in seedling emergence percentage was observed among cropping patterns in sorghum/ groundnut intercrop at Hombolo. All cropping patterns had similar results in seedling emergence percentage (Table 4.10).

4.7.1.2 Days to 50% flowering

There was a significant ($P \leq 0.05$) difference in number of days to 50% flowering among cropping patterns in sorghum/ groundnut intercrop at Bihawana (Table 4.10). AWRABR and RP intercrop gave significantly higher number of days to 50% flowering (30.65 and 30.57 days) than in AWR intercrop (28.38 days)

There was no significant difference ($P \leq 0.05$) in number of days to 50% flowering was observed in sorghum/ groundnuts intercrop among cropping patterns at Hombolo. Similar results in number of days to 50% flowering were observed in all treatments (4.10).

4.7.1.3 Dry matter yield

There was significant difference (P≤0.05) in dry matter yield per plant between treatments at Bihawana in sorghum/ groundnut intercrop. Dry matter yield per plant in ABR intercrop gave significantly higher dry matter yield per plant (7.83 gm) than in any other cropping patterns except in RP intercrop (7.62 gm) (Table 4.10).

At Hombolo, dry matter yield per plant differed significantly (P≤0.05) among cropping patterns in sorghum/ groundnut intercrop. The crop on ABR intercrop gave significantly higher dry matter yield per plant (7.6 gm) than in all other treatments. (Table 4.10).

4.7.2 Yield attributes

4.7.2.1 Number of plants at harvest

Number of plants harvested was significantly different (P≤0.05) among cropping patterns in sorghum/ groundnut intercrop at Bihawana. AWR intercrop had significantly higher number of plants at harvest as compared to all other cropping patterns (Table 4.11a).

At Hombolo, no significant difference (P≤0.05) was observed in number of plants at Harvest in sorghum/ bambara among cropping patterns. All treatments had similar results in number of plants at harvest (Table 4.11a).

Table 4.10 Growth attributes for groundnuts as affected by sorghum/ groundnuts intercrop at Bihawana

Cropping patterns	Seedling emergence%		Days to 50% Flowering		Dry matter per Plant (g)	
	Bih.	Homb.	Bih.	Homb.	Bih.	Homb.
ABR	76.27a	53.4a	29.28ab	30.1a	7.83a	7.6a
DR	71.73c	52.3a	29.89ab	30.7a	6.94bc	6.8bc
AWR	70.28d	65.5a	28.38b	29.6a	5.75d	6.5bc
SH	67.60e	69.9a	29.37ab	30.5a	6.55bc	7.0b
RP	59.87f	57.2a	30.57a	30.7a	7.62ab	6.8bc
AWRABR	69.03d	72.6a	30.65a	30.4a	6.66c	6.5bc
S	-	-	-	-	-	-
G	74.12b	69.1a	29.25ab	29.5a	6.60c	6.6bc
Mean	61.11	55.0	25.92	26.4	5.99	47.8
SE±	0.47	8.4	0.47	0.8	0.24	0.2

Bih. =Bihawana; Homb. =Hombolo

Means within the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate within rows, DR=Double rows, AWR=Alternate within rows, SH=Same hill, RP=Random planting, AWRABR=Alternate within rows and Alternate between rows, S=Monocrop sorghum, BG= bambara groundnuts.

4.7.2.2 Number of pods per plant

There were no significant difference (P≤0.05) in number of pods per plant in sorghum /groundnuts intercrop among treatments at Bihawana. Similar results in number of pods per plant were observed in all treatments (Table 4.11a).

A significant difference (P≤0.05) in the number of pods per plant was observed between treatments at Hombolo in sorghum/ groundnut intercrops (Table 4.11a). ABR and AWR intercrop gave the higher number of pods per plant (21.3 and 19.7) as compared to other treatments except in RP and AWRABR and monocrop groundnuts (18.0, 14.7 and 17.7)

4.7.2.3 Number of filled pods per plant

There was a significant difference (P≤0.05) in mean number of filled pods per plant among cropping patterns in sorghum/ groundnut intercrop at Bihawana (Table 4.11a). Higher number of filled pods was observed on DR intercrop (25.0) as compared to all other cropping patterns.

At Hombolo, the number of filled pods per plant was significantly different (P≤ 0.05) among cropping patterns in sorghum/ groundnuts intercrop. In AWR intercrop the number of filled pods per plant was significantly higher (17.0) as compared to all other treatments (Table 4.11a).

4.7.2.4 Pod yield per hectare

The pod yield per hectare was significantly difference ($P \leq 0.05$) among cropping patterns in sorghum/ groundnut intercrop at Bihawana. Higher mean seed yield was realised in monocrop groundnuts (890.3 kg/ha) as compared to all other cropping patterns (Table 4.11a).

There was a significant difference ($P \leq 0.05$) in pod yield per hectare among cropping patterns in sorghum/groundnuts intercrop at Hombolo. AWR intercrop had higher pod yield per hectare (931.0 kg/ha) as compared to other cropping patterns (Table 4.11a).

4.7.2.5 Groundnut yield per plant

There was a significant difference ($P \leq 0.05$) in grain yield per plant in sorghum/ groundnut intercrop at Bihawana. Monocrop groundnuts gave significantly higher grain yield per plant (30.0 gm) than any other cropping patterns except DR and AWR intercrop (23.3 and 25.8 gm) (4.11b).

Groundnuts grain yield per plant was significantly different ($P \geq 0.05$) among cropping patterns in sorghum/ groundnuts intercrop at Hombolo. The grain yield per plant in ABR and DR treatments was significantly greater 12.4 and 12.0 gm) as compared to grain yield per AWR and SH intercrop (6.5 and 7.2 gm) (Table 4.11b).

4.7.2.6 Number of seeds per pod

Number of seeds per pod was significantly different ($P \leq 0.05$) among cropping patterns in sorghum/ groundnut intercrop at Bihawana. Higher number of seeds per pod was observed in AWR intercrop and monocrop groundnuts (2.0 and 2.0) which differed significantly with AWRABR intercrop which had the lowest number of seeds per pod (1.0) (Table 4.11b).

At Hombolo, there was no significant difference ($P \leq 0.05$) in number of seeds per pod observed in sorghum/ groundnuts intercrop. All treatments had similar number of pods per plant (Table 4.11b).

4.7.2.7 100 seed weight

100 seed weight did not differ significantly ($P \geq 0.05$) among treatments in sorghum/ groundnut intercrop at Bihawana. Similar results in 100 seed weight were observed in all cropping patterns (Table 4.11b).

Similarly at Hombolo, 100 seed weight was not significantly difference ($P \geq 0.05$) among treatments. In all treatments the 100 seed weight gave similar results among cropping patterns (Table 4.11b).

4.7.2.8 Groundnuts yield per hectare

There was significant difference ($P \leq 0.05$) in grain yield among cropping patterns in sorghum/ groundnut intercrop at Bihawana (Table 4.11b). The groundnuts on DR intercrop and monocrop groundnuts had significantly higher yield (580 and 600 kg/ha) as compared to AWR and SH intercrop (350 and 160 kg/ha).

At Hombolo, groundnuts yield per hectare was significantly difference ($P \leq 0.05$) among cropping patterns in sorghum/ groundnut intercrop. Groundnuts grain yield per hectare was significantly higher in AWR intercrop (931.0 kg/ha) as compared to groundnuts yield per hectare in all other treatments (Table 4.11b)

4.7.2.9 Shelling percentage

The shelling percentage was significantly different ($P \leq 0.05$) among treatments in sorghum/ groundnut intercrop at Bihawana (Table 4.11). Monocrop groundnuts had significantly higher shelling percentage (32.6%) as compared to other cropping patterns except RP, AWRABR and DR intercrop (31.8, 32.1 and 30.9%)

At Hombolo, shelling percentage was significantly different ($P \leq 0.05$) in sorghum/ groundnut intercrop at Hombolo (Table 4.11b). Higher shelling percentage was observed in AWR and RP intercrop (35.5 and 34.2 %) as compared to AWRABR and DR intercrop (31.6 and 31.9 %).

Table 4.11a. Yield attributes for groundnuts as affected by different cropping patterns in sorghum/ groundnuts intercrop at Bihawana and Hombolo

Cropping Patterns	Number of plants at harvest		Number of pods per plant		Number of filled pods per plant		Pod yield (kg/ha)	
	Bih.	Homb.	Bih.	Homb.	Bih.	Homb.	Bih.	Homb.
ABR	50.8b	47.0a	23.7ab	11.3a	20.0c	8.7b	339.3f	452.3c
DR	24.0d	69.3a	28.0ab	10.3c	25.0a	9.3b	829.3b	444.0d
AWR	58.0a	47.7a	28.0ab	19.7a	23.0b	17.0a	489.0e	931.0a
SH	52.2b	44.3a	18.3ab	13.7bc	15.3d	10.0b	229.0g	453.0c
RP	37.7c	41.0a	18.3ab	18.0ab	16.3d	9.7b	701.0d	152.0e
AWRABR	24.0d	46.7a	26.7ab	14.7abc	22.3e	10.0b	721.0c	585.0b
S	-	-	-	-	-	-	-	-
G	24.0d	52.7a	23.0ab	17.7ab	22.0b	6.3b	890.3a	453.0c
Mean	33.8	43.5	31.9	15.1	18.0	9.3	524.9	254.9
SE±	1.0	11.1	18.4	1.7	0.4	1.1	4.2	3.4

Bih. =Bihawana; Homb. =Hombolo

Means within the same column followed by the same letter(s) within rows are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate within rows, DR=Double rows, AWR=Alternate within rows, SH=Same hill, RP=Random planting, AWRABR=Alternate within rows and Alternate between rows, S=Monocrop sorghum, BG= groundnuts.

Table 4.11b. Yield attributes for groundnuts as affected by different cropping patterns in sorghum/ groundnuts intercrop at Bihawana and Hombolo

Cropping patterns	Number of at harvest		Seed yield per plant (g)		100 seed weight (g)		Groundnuts yield (kg/ha)		Shelling percentage	
	Bih.	Homb	Bih.	Homb	Bih.	Homb.	Bih.	Bih.	Bih.	Homb.
ABR	1.3ab	1.7a	21.7b	12.4a	125.0a	141.7a	240abc	300b	29.3cd	33.8ab
DR	1.7ab	1.0a	23.3ab	12.0a	133.3a	116.7a	580a	300b	30.9abc	31.9bc
AWR	2.0a	1.3a	25.8ab	6.5b	141.7a	141.7a	350bc	600a	28.4d	35.5a
SH	1.7ab	1.3a	22.5b	7.2b	133.3a	125.0a	160bc	300ab	30.1bcd	33.8ab
RP	1.7ab	1.7a	22.5b	8.6ab	133.3a	125.0a	480ab	100bc	31.8ab	34.2a
AWRABR	1.0b	1.7a	21.5b	8.6ab	116.7a	125.5a	490ab	400ab	32.1ab	31.6c
S	-	-	-	-	-	-	-	-	-	-
G	2.0a	1.7a	30.0a	9.2ab	113.3a	108.3a	600a	300ab	32.6a	33.8ab
Mean	1.4	1.3	29.0	8.1	130.9	126.2	410	300	61.9	33.0
SE±	0.2	0.3	2.1	1.3	9.4	10.6	120.8	75.4	0.6	0.6

Bih. =Bihawana,; Homb.= Hombolo

Means within the same column followed by the same letter(s) within rows are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate within rows, DR=Double rows, AWR=Alternate within rows, SH=Same hill, RP=Random planting, AWRABR=Alternate within rows and Alternate between rows, S=Monocrop sorghum, BG= groundnuts.

4.8 Growth and yield attributes for bambara groundnuts at Bihawana and Hombolo

4.8.1 Growth attributes

4.8.1.1 Seedling emergence percentage

Significant ($P \leq 0.05$) differences in seedling emergence percentage were observed among cropping patterns in sorghum/ bambara groundnuts at Bihawana (Table 4.12). bambara groundnut under ABR intercrop had significantly higher seedling emergence percentage (70.71 %) as compared to AWR, SH; AWRABR and RP intercrop (60.28, 64.77, 64.72 and 54.68%)

At Hombolo, there was a significant difference ($P \leq 0.05$) in seedling emergence percentage among treatments in sorghum/ bambara groundnut intercrop. However, bambara groundnuts in ABR and AWR, SH intercrop and monocrop bambara groundnuts had significantly higher seedling emergence percentage (78.1, 78.3, 77.9 77.9%) as compared to seedling emergence percentage in RP intercrop (64.5%) (Table 4.12).

4.8.1.2 Days to 50% flowering

At Bihawana, in sorghum/ bambara groundnut intercrop there was a significant difference ($P \leq 0.05$) in number of days to 50% flowering among cropping patterns. However, ABR and AWRABR intercrops had higher number of days to 50% flowering (30.32 and 30.45 days) than in any other treatments (Table 4.12).

No significant difference ($P \geq 0.05$) in number of days to 50%flowering was observed among cropping patterns at Hombolo in sorghum/ bambara groundnuts intercrop (Table 4.12). All treatments had similar results in duration to 50% flowering.

4.8.1.3 Dry matter per plant

There was a significant difference ($P \leq 0.05$) in dry matter yield per plant among cropping patterns in sorghum/ bambara groundnuts intercrop at Bihawana. Overall, dry matter of bambara groundnut yield per plant was significantly higher in RP, AWRABR, SH, ABR intercrop and monocrop bambara groundnuts (6.90, 6.38, 6.74, 6.54 and 6.64 gm) as compared to dry matter yield per plant in AWR intercrop at Bihawana (5.25 gm) (Table 4.12).

There were no significant differences ($P \geq 0.05$) in dry matter yield per plant among cropping patterns at Hombolo in sorghum/ bambara groundnuts. All cropping patterns had similar results in dry matter weight per plant (Table 4.12).

Table 4.12. Growth attributes for bambara groundnuts as affected by sorghum/ bambara groundnuts intercrop

Cropping patterns	Seedling emergence %		Days to 50% flowering		Dry matter per Plant (g)	
	Bih.	Homb.	Bih.	Homb.	Bih.	Homb.
ABR	70.71a	78.1a	30.32a	30.4a	6.54a	6.8a
DR	68.83ab	75.5ab	29.24b	31.1a	6.12ab	6.9a
AWR	60.28c	78.3a	29.12b	29.7a	5.25b	6.7a
SH	64.77bc	77.9a	28.96b	29.7a	6.74a	6.3a
RP	54.68c	64.5b	28.57b	30.2a	6.90a	6.7a
AWRABR	64.72bc	75.9ab	30.45a	31.2a	6.38a	6.4a
S	-	-	-	-	-	-
BG	68.65ab	77.9a	29.47b	29.3a	6.64a	6.2
Mean	56.6	56.3	22.10	26.5	5.6	5.8
SE±	1.67	3.8	0.00c	0.6	0.31	0.3

Bih. = Bihawana; Homb. = Hombolo

Means within the same column followed by the same letter(s) within rows are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate within rows, DR=Double rows, AWR= Alternate within rows, SH=Same hill, RP=Random planting, AWRABR = Alternate within rows and Alternate between rows, S=Monocrop sorghum, BG = Monocrop bambara groundnuts.

4.8.2 Yield attributes

4.8.2.1 Number of plants at harvest

No significant difference (P≥0.05) in number of plants at harvest was realised in sorghum/ bambara groundnuts at Bihawana. However, higher number of plants at harvest were observed in monocrop bambara groundnuts as compared to AWRABR intercrop did not significantly differ with other treatments Table 4.13a).

In case of Hombolo, a significant difference (P≤0.05) in number of plants at harvest among cropping patterns was observed in sorghum/ bambara groundnuts intercrop (Table 4.13a). A significantly higher number of plants at harvest were observed in DR intercrop (12.2) as compared to AWRABR intercrop (6.1).

4.8.2.2 Number of pods per plant

No significant differences (P≥0.05) in the number of pods per plant were observed among cropping patterns in sorghum/ bambara groundnuts intercrop at Bihawana (Table 4.13a). All treatments had similar results in number of pods per plant.

Significant difference (P≤0.05) in number of pods per plant was observed in sorghum/ bambara groundnuts intercrop at Hombolo (Table 4.13a). Among different cropping patterns, AWRABR intercrop gave higher number of pods per plant (21.0) as compared to ABR and DR intercrop (14.0 and 11.0)

4.8.2.3 Number of filled pods per plant

The number of filled pods per plant was significantly difference (P≤0.05) among treatments in sorghum/ bambara groundnuts intercrop at Bihawana (Table 4.13a). RP intercrop had higher number of filled pods per plant (26.0) than other cropping patterns except SH, ABR intercrop (24.0 and 24.3).

At Hombolo, a significance difference (P≤0.05) in number of filled pods per plant was observed among cropping patterns in sorghum/ bambara groundnuts intercrop (Table 4.13a). SH intercrop had higher number of filled pods per plant (12.3) as compared to RP intercrop (3.0).

4.8.2.4 Pod yield per hectare (kg/ha)

There was a significant difference (P≤0.05) in pod yield per plant among cropping patterns in sorghum/ bambara groundnuts intercrop at Bihawana (Table 4.13a). Monocrop bambara groundnuts out yielded all other cropping patterns in pod yield per hectare (1031.7 kg/ha).

The mean value for pod yield per hectare was significantly difference (P≤0.05) among cropping patterns in sorghum/ bambara groundnuts at Hombolo. Higher pod yield per hectare was observed in SH intercrop (1149.3 kg/ha) as compared to that of other cropping patterns (Table 4.13a).

Table 4.13.a Yield attributes for bambara groundnuts as affected by different sorghum/bambara groundnuts intercrop

Cropping Patterns	Number of plants at harvest		Number of pods per plant		Number of filled pods per plant		Pod yield (kg/ha)	
	Bih.	Homb.	Bih.	Homb.	Bih.	Homb.	Bih.	Homb.
ABR	25.8a	10.9ab	27.0a	14.0bc	24.3ab	10.3ab	544.0d	544.0d
DR	24.2a	12.2a	28.0a	11.0c	23.7bc	6.3ab	386.3e	588.0e
AWR	29.2a	9.1ab	29.0a	19.0ab	21.0d	10.0ab	615.0b	956.0c
SH	22.5a	9.0ab	24.7a	19.0ab	24.0abc	12.3a	536.7d	1149.3a
RP	30.8a	11.4ab	33.0a	19.0ab	26.0a	3.0b	583.0c	168.3f
AWRABR	12.7a	6.1b	19.7a	21.0a	16.7e	9.7ab	365.7f	1027.3ab
S	-	-	-	-	-	-	-	
BG	35.8a	6.6ab	23.7a	19.0ab	22.0cd	7.6ab	1031.7a	791.3d
Mean	23.8	8.2	26.3	17.5	19.7	7.4	507.8	703.8
SE±	4.4	1.7	4.9	1.9	0.7	2.8	3.7	5.7

Bih. =Bihawana; Homb. =Hombolo

Means within the same column followed by the same letter(s) within rows are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate within rows, DR=Double rows, AWR=Alternate within rows, SH=Same hill, RP=Random planting, AWRABR=Alternate within rows and Alternate between rows, S=Monocrop sorghum, BG= groundnuts.

4.8.2.5 Number of seeds per pod

No significant difference (P≥0.05) in number of seeds per pod was observed in sorghum/ bambara groundnuts intercrop at Bihawana. All treatments had similar results in number of seeds per pod (Table 4.13b).

At Hombolo, a significant difference (P≤0.05) in number of seeds per pod was observed in sorghum/ bambara groundnut intercrop. A significantly higher number of seeds per pod were observed in AWR intercrop (2.0) as compared to RP intercrop (1.0) (Table 4.13b).

4.8.2.6 Grain yield per plant

Grain yield per plant in sorghum/ bambara groundnut intercrop differed significantly (P≤0.05) among cropping patterns at Bihawana (Table 4.13b). Higher bambara groundnuts grain yield was observed in AWR intercrop (49.7 gm) as compared to DR, RP, AWRABR intercrop and monocrop bambara groundnuts 22.3, 35.3, 32.0 and 22.3 gm).

At Hombolo, no significant difference (P≥0.05) in grain yield per plant was observed among cropping patterns in sorghum/ bambara groundnuts intercrop. The crop on ABR gave higher weight in grain yield per plant as compared other treatments but did not differ significantly (4.13b).

4.8.2.7 Hundred seed weight

At Bihawana, 100 seed weights were not significantly different (P≥0.05) among cropping patterns in sorghum/ bambara groundnut intercrop. All treatments had similar results in 100 seed weight (Table 4.13b).

There were significant difference (P≤0.05) in 100 seeds weight among cropping patterns in sorghum/ bambara groundnuts intercrop at Hombolo. Higher 100 seed weights were recorded for ABR and AWR intercrop which had similar in 100 seed weights (150 gm) as compared to other treatments (Table 4.13b).

4.8.2.8 Bambara groundnut yield

There was significant difference (P≤0.05) in bambara groundnut yield per hectare among treatments in sorghum/ bambara groundnuts at Bihawana (Table 4.13b). Monocrop bambara groundnuts gave significantly higher yield per hectare (510 kg/ha) as compared to DR and AWRABR intercrops (200 and 190 kg/ha) respectively.

Table 4.13b shows a record of bambara groundnuts grain yield as affected by sorghum/ bambara groundnuts, which was realised at harvest. A significant difference (P≤0.05) was observed in bambara groundnuts grain yield realised among cropping patterns at Hombolo. Higher bambara groundnuts grain yield was realised in SH, AWR and AWRABR intercrop (560, 480 and 510 kg/ha) as compared to other treatments (Table 4.13b).

4.8.2.9. Shelling percentage

There were a no significant differences (P0.05) in shelling percentage among treatments in sorghum/ bamabara groundnuts at Bihawana. All cropping patterns had similar results in shelling percentage (Table 4.13b).

At Hombolo, there were significant differences ($P \leq 0.05$) in shelling percentage among cropping patterns in sorghum/ bambara groundnut intercrop. There was lower shelling percentage on RP intercrop (40.4 %), which significantly differed with all other cropping patterns (Table 4.13b).

Table 4.13.a Yield attributes for bambara groundnuts as affected by different sorghum/bambara groundnuts intercrop

Cropping Patterns	Number of plants at harvest		Number of pods per plant		Number of filled pods per plant		Pod yield (kg/ha)	
	Bih.	Homb.	Bih.	Homb.	Bih.	Homb.	Bih.	Homb.
ABR	25.8a	10.9ab	27.0a	14.0bc	24.3ab	10.3ab	544.0d	544.0d
DR	24.2a	12.2a	28.0a	11.0c	23.7bc	6.3ab	386.3e	588.0e
AWR	29.2a	9.1ab	29.0a	19.0ab	21.0d	10.0ab	615.0b	956.0c
SH	22.5a	9.0ab	24.7a	19.0ab	24.0abc	12.3a	536.7d	1149.3a
RP	30.8a	11.4ab	33.0a	19.0ab	26.0a	3.0b	583.0c	168.3f
AWRABR	12.7a	6.1b	19.7a	21.0a	16.7e	9.7ab	365.7f	1027.3ab
S	-	-	-	-	-	-	-	
BG	35.8a	6.6ab	23.7a	19.0ab	22.0cd	7.6ab	1031.7a	791.3d
Mean	23.8	8.2	26.3	17.5	19.7	7.4	507.8	703.8
SE±	4.4	1.7	4.9	1.9	0.7	2.8	3.7	5.7

Bih. =Bihawana; Homb. =Hombolo

Means within the same column followed by the same letter(s) within rows are not significantly different at 5% level of significance according to Duncans Multiple Range Test. ABR=Alternate within rows, DR=Double rows, AWR=Alternate within rows, SH=Same hill, RP=Random planting, AWRABR=Alternate within rows and Alternate between rows, S=Monocrop sorghum, BG= groundnuts.

4.8.2.10. Land Equivalent Ratio (LER)

In general within cropping pattern in sorghum groundnut intercrop at Bihawana, SH intercrop was superior to other patterns because it gave a mean Land Equivalent Ratio of 12.197, thus exhibiting 25.9% (Appendix 6). In sorghum/bambara groundnuts intercrop, DR intercrop was superior to other treatments as the mean Land Equivalent Ration was10.20, thus showing an intercropping advantage of 11.9% (Appendix 7). For cropping pattern at Hombolo SH intercrop was superior to other pattern because it gave the mean Land Equivalent Ratio of 17.07, thus exhibiting an intercropping advantage of 30.2% (Appendix 8). In sorghum/bambara groundnuts at Hombolo, AWRABR intercrop was superior to other cropping patterns because it gave a mean of 13.89 Land Equivalent Ratio, thus exhibiting an intercropping advantage of 28.2% (Appendix 9).

CHAPTER FIVE

5.0. DISCUSSION:

5.1 Effect of intercropping patterns on Striga population dynamics and dry matter production:

These experiments were carried out to study the effect of intercropping patterns on *Striga* population dynamics and yield of sorghum, in sorghum/ groundnuts and sorghum/ bambara groundnuts intercrop at Bihawana and Hombolo under Dodoma soil and weather conditions (Table 4.1 and Appendix 1).

At Bihawana, no *Striga* was observed in all cropping patterns in both sorghum/ groundnuts and sorghum/ bambara groundnut intercrop. This could be attributed to the environmental influence especially the continuous wet soil condition observed during the growing period. The water logging condition affected *Striga* germination due to the phenomenon known as wet dormancy. The high rainfall in this growing season at Bihawana also probably lead to leaching of soil nutrients; lowering of soil temperatures; dilution and / or leaching of root exudates which are regarded as favourable conditions for *Striga* growth and establisment. Ogborn, (1972) reported that under continuous wet soil condition, as occurs during the peak rainy season in Northern Nigeria, *Striga* emergence was suppressed. Similarly Steeramula (1959) observed that *Striga* did not attack sorghum or rice if kept under high soil moisture or irrigation.

At Hombolo, a significantly higher *Striga* population was observed in monocrop sorghum as compared to intercropping with groundnuts or bambara groundnuts

(Table 4.2 and Table 4.4). This could be attributed to a number of climatic and agronomic factors notably soil moisture, soil fertility and monocropping. The low and erratic rainfall distribution caused intermittent dry spells, at this location while the low organic matter contents in the soil, implied low soil fertility. These factors favour *Striga* growth and establishment. Ogborn, (1972) reported that *Striga* appears to thrive well on intermittent dry conditions, low soil fertility and particularly low nitrogen status. The continuous monocropping normally practiced at Hombolo apparently also favours the distribution and severity of *Striga* infestation. These results are comparable with that observed by Babewi (1987) in maize/ cowpea intercrops where higher *Striga* population was observed in monocrop maize. Similarly, Aflakpui *et al.* (1990) recorded severe infestation of *Striga* in sole crop maize as compared to mixtures of maize with groundnuts. On the other hand, Parkinson *et al.* (1986) reported that soya bean, cotton and bambara groundnut, when grown in rotation with susceptible host or as intercrop, can induce arbortive germination of *Striga* seeds with a consequent reduction in infestation. The relatively lower *Striga* emergence in mixtures indicated the reduced potential of *Striga* for flower and capsule production consequently reducing *Striga* seed return to the soil seed.

Striga control methods are generally based on the fundamental understanding of the germination, growth and the host-parasite relationships. An important feature in any *Striga* control strategy is prevention of seed formation, dispersal and to encouragement of abortive germination (Mbwaga *et al.* 2000).

5.2 Effect of intercropping patterns on growth attributes of sorghum.

The seedling emergence percentage in sorghum/ groundnuts intercrop varied significantly among cropping patterns at Bihawana despite moisture supply being adequate during and after planting. The plants on ABR, DR, SH, AWRABR intercrop and monocrop sorghum had significantly higher seedling emergence percentage than for AWR and RP intercrop (Table 4.6). Similarly, seedling emergence percentage in sorghum/ groundnut intercrop differed significantly between treatments at Hombolo. The seedling emergence percentage was higher for ABR, AWR and RP intercrop than for AWRABR intercrop (Table 4.6). A possible explanation for the significant differences among treatments at both locations could be due to water logging condition which occurred in some plots which was not properly levelled just after sowing thus affecting seed germination. The reason for lower seedling emergence in some plots has not been identified, as detailed soil analysis was not done before the commencement of the trial.

The lack of significant difference in seedling emergence percentage in sorghum/ bambara groundnuts intercrop at Bihawana (Table 4.7) is probably due to reduced ability of the crop seeds to germinate timely from under the soil due to water logged condition throughout the growing period. This partially affected sorghum seed germination. In case of *Striga* seeds the wet dormancy phenomenon also came into operation. Furthermore, excess moisture in the soil affected seed germination due to low air circulation (O_2) needed for respiration. This result into lower stands density due to poor germination. Similarly at Hombolo, all cropping patterns gave similar seedling emergency percentage (Table 4.7). At this site, the reduced ability of seedling to emerge was ascribed to the hard crust, which had formed on the soil surface as a result of low and erratic rainfall, which was received in February (20.8 mm), just after planting. Hence germination was affected in all treatments.

The effect of intercropping patterns in plant height at booting stage varied significantly ($P \leq 0.05$) in sorghum / groundnuts intercrop at Bihawana (Table 4.6). The plants on DR and SH intercrop were significantly taller at booting stage as compared to AWRABR and monocrop sorghum, while at Hombolo (Table 4.6) in sorghum/ groundnuts intercrop, the plants on RP and AWRABR intercrop were significantly taller at booting stage compared to monocrop sorghum (Table 4.6). This could be attributed to beneficial effect obtained from Nitrogen – fixation by leguminous crops especially groundnuts. Groundnuts like many other legumes are known to fix nitrogen thus improve soil fertility (Carsky and Berner 1995) some of which eventually benefits an associated crop grown with the legume.

In sorghum / bamabara groundnuts intercrop, plant heights at booting stage were similar in all cropping patterns at Bihawana (Table 4.7). Similarly, all treatments gave similar plant height at booting stage in sorghum/ bambara groundnuts at Hombolo (Table 4.7).

The lack of significant differences in plant height at booting stage in all cropping patterns at Hombolo, despite the competition in intercropping, is probably due to low *Striga* population which appeared later in the season due to irregular rainfall distribution which affected both crops and *Striga* growth and development.

The plant height at harvest varied significantly among cropping patterns in sorghum/ groundnut intercrop at Bihawana (Table 4.6). The plants on RP intercrop were significantly taller at harvest than for AWRABR intercrop. Similarly, plant height at harvest in sorghum/ groundnut intercrop differed significantly among cropping patterns at Hombolo (Table 4.6). Taller plants were observed on RP intercrop than on DR and monocrop sorghum. This could be due to crop arrangement used and total plant population densities, which created competition for light between plants. Differences in plant height at harvest at Hombolo could be also attributed to reduce *Striga* infestation and hence reduced competition. At this site the soil cover of groundnuts created unfavourable conditions for *Striga* germination.

The plant height at harvest differed significantly among cropping patterns in sorghum/ bambara groundnuts at Hombolo (Table 4.7). The plants on RP and monocrop sorghum were significantly taller than in other cropping patterns except ABR and DR intercrop. Differences in plant height at harvest were also attributed to low *Striga* population in intercrop as compared to pure stand sorghum. *Striga* plants had harmful effect on its host as they deprive the host of water and nutrients, which results into reduced crop vigour and stunted growth. Similar results have been reported by Parker, (1984); Sharif and Parker, (1986) and Dogget, (1984); Solomon, (1952).

The effect of intercropping patterns on dry matter yield per plant in sorghum/ bambara groundnuts was significantly different among cropping patterns at Bihawana (Table 4.7). ABR intercrop had significantly higher dry matter yield per plant than for SH intercrop at Bihawana. Dry matter yield per plant in sorghum/ bambara groundnuts intercrop at Hombolo also differed significantly among treatments (Table 4.7). Generally dry matter production was higher in intercropped compared to monocrop sorghum. This suggests that there was less competition between host plants and *Striga* plants for carbon, which is required for effective photosynthesis. Stewart *et al. (1988)* reported that *Striga* reduces host growth via two processes the competition for carbon and impairment of photosynthesis. The higher value in dry matter yield per plant, also suggests that there was better utilisation of the environmental resources by sorghum, especially light, when sorghum was grown under intercropping (Willey and Osiru 1972; Baker and Yusuf 1976, Willey 1979).

5.3 Effect of intercropping patterns on yields and yields attributes for sorghum.

Differences in grain yield in crop plants could be attributed to the effects of weather, soil fertility status, cropping patterns and *Striga* population dynamics. Grain yield per plant at Bihawana depended on weather and cropping pattern. Although there was a lack of significant difference in grain yield per plant on all cropping patterns at Bihawana (Table 4.8), the monocrop sorghum had high grain yield per plant. Finlay, (1982) observed that ABR intercrop is superior to SH intercrop or AWR intecrop. However May and Misangu (1982) observed that although the AWR intercrop produced more uniform plant spacing, the grain yield per plot and the Relative Yield Totals were not superior in the alternate hole intercropping arrangement.

The treatment effect in sorghum/ bambara groundnuts intercrop at Bihawana, was expressed significantly in some variables including the head size per plant and grain yield per plant. Head sizes were significantly longer and grain yield per head higher in ABR intercrop than on AWR intercrop and greater grain yield per head on ABR intercrop than on AWR intercrop (Table 4.9).

There was a significant effect in sorghum grain yield per head (panicle) in sorghum/ groundnut intercrop at Hombolo (Table 4.8). Monocrop sorghum had higher grain yield per head than on DR, AWR and AWRABR intercrop, while in 1000 seed weight there was a significantly greater weight on ABR and DR intercrop than AWR and SH intercrop.

The RP intercrop had significantly larger in head size than on other cropping patterns. The sorghum grain yield per hectare was significantly higher on RP intercrop (1180kg/ha) than all other cropping patterns except DR intercrop where 1000 seed weight was significantly greater on RP intercrop than all other treatments in sorghum/ bambara groundnuts intercrop at Hombolo (Table 4.9). The higher sorghum grain yield per plant on ABRAWR intercrop could also be attributed to reduced *Striga* infestation in this area. This is thought to be due to soil cover of groundnuts creating unfavourable conditions for *Striga* germination. Singh et al. (1991) and Reda (1996) observed that intercropping cereal with cowpea in the same row gave the highest yield. Similar findings were reported by Ngoumou nga *et al.*, (1991) who attributed higher yield under different sorghum/ cowpeas and maize/ cowpea intercrops primarily to decreased *Striga* incidence and consequently decreased *Striga* damage under semi–arid conditions. This also suggests that sorghum suffer less competition for nutrients, moisture and damage in the mixtures than if grown in pure stand indicating that *Striga* deleterious effect of *Striga* on host plants can be reduced by intercropping.

5.4 Effect of intercropping patterns on growth attributes for groundnuts.

The seedling emergence percentage varied significantly among cropping patterns at Bihawana. The seedling emergence percentage was higher on ABR intercrop than on other cropping patterns at Bihawana (Table 4.10). This could be attributed to environmental influence particularly continuous moisture, which enhanced growth and establishment. At Hombolo, seedling emergence percentage was similar in all cropping patterns (Table 4.10). This could possibly be due to reduced ability of crop seedlings to exert a force in emerging from under the soil, which at time hardened at the surface due to intermittent high temperatures, low and erratic rains. Days to 50% flowering differed significantly among cropping patterns. The plants on SH and AWRABR intercrop took much longer time to attain 50% flowering at Bihawana (Table 4.10). This could be due to the intercropping pattern used and higher plant population where sorghum created a shading effect to groundnuts. The continuous wet moisture condition, which was observed at the time the groundnuts were approaching flowering stage could also delayed groundnuts to attain to 50% flowering. The continuous rainfall, which caused continuous wet soil condition, induced groundnuts to extend vegetative growth and consequently flowered late. This suggests that in pulses continuous moisture condition could lengthen the crop life cycle especially vegetative growth at the expense of reproductive growth.

Dry matter per plant at harvest varied significantly among cropping patterns at Hombolo. The crop on ABR intercrop gave higher dry matter yield per plant than on other treatments (Table 4.10). During early growth, DM partitioning among morphological components is aimed at increasing morphological components is aimed at increasing vegetative growth to maximize radiation interception. With the development of reproductive structures (anthesis), DM partitioning is directed towards initiation and growth of those structures (flowers, pods, and seeds) while the vegetative growth is curtailed. These results agree well with the findings of Mahatanya (1972) in soya bean in which greater proportion of DM was diverted into pods towards maturity because DM demand was higher in pods.

5.5 Effects of intercropping patterns on yield attributes for groundnuts.

The number of pods per plant was similar in all treatmets in sorghum/ groundnuts intercrop at Bihawana. This is possibly because of uniformity on plant growth due to soil and weather condition during the growing period. At Hombolo, the number of pods per plant was significantly higher in ABR and AWR intercrop as compared to DR and SH intercrops.

Grain yield per hectare was significantly higher in monocrop groundnuts (600kg/ha) and DR intercrop (580kg/ha) than on AWR (240kg/ha) and SH (160kg/ha) intercrop, at Bihawana, where the number of seeds per pod, seed yield per plant and shelling percentage was also higher. Groundnuts yield in mixture (580kg) was 77% of that realised in sole cropping (600kg/ha). Similarly grain yield per hectare was significantly higher on AWR intercrop (600kg/ha) as compared to ABR and DR and

RP intercrop where shelling percentage was also higher (35.5%) at Hombolo. Groundnuts yield in intercropping (300kg/ha) 50% of that observed in monocropping (600kg/ha).

Shelling percentage varied significantly among treatments (Table 4.11). The crop on monocrop groundnuts had higher shelling percentage than on SH and ABR intercrop at Bihawana. At Hombolo, the crop on AWR and RP intercrop had higher shelling percentage than on DR and AWRABR intercrop.

The greater performance in ABR intercrop and monocrop groundnuts is possibly attributed to less shading effect occurring in other cropping patterns in which sorghum shoots reduce light penetration to groundnut leaves for photosynthesis. Therefore in AWR intercrop and monocrop groundnuts there are more light penetration enhancing podding and seed filling than in other cropping patterns. Baker and Yusuf, (1976); Marshal and Willey (1983); Zafaroni and Scheiter (1989) who stipulated that intercropping favors the yield of tall varieties against the short varieties due to their differential interception of light by their photosynthetic sites.

The lack of significant difference in number of plants at harvest, number of seeds per pod, 100 seed weigh, in all cropping patterns in sorghum/ groundnuts intercrop at Hombolo could be attributed to poor pod filling as a result of competition for assimilates and moisture between crop plant and *Striga* infestation during vegetative and reproductive growth. The low and erratic rainfall experienced at Hombolo during crop growth and establishment period also affected yield components.

5.6 Effect of intercropping patterns on growth and yield attributes for bambara groundnuts.

The 100 seed weight was similar in all treatments at Bihawana (Table 4.13). This was attributed to a reasonable wet soil condition experienced in the area during this growing season. At Hombolo, the crop on ABR and AWR intercrop (150g and 150g)) had higher weight on 100 seed weight than on other treatments. This could be attributed to poor pod filling between treatments as result of competition for assimilates between vegetative and reproductive growth, particularly from 49 DAS to maturity, the period of maximum pod filling (Tarimo and Blamey 1997)

Bambara groundnut yield per hectare was significantly higher on monocrop bambara groundnuts (510kg/ha) than on AWRABR and DR intercrop (190kg/ha and 200kg/ha) at Bihawana. Bambara groundnut yield in intercropping was (330 kg/ha) which was 59% of that observed in monocropping (510kg/ha). This could be attributed to reduce competition for the resources between monocrop bambara groundnuts and bambara groundnuts intercropped with sorghum during vegetative and reproductive growth under low and erratic rainfall throughout the growing period. The reduction in bambara groundnut yield could also be due the intercropping pattern used and higher plant population where sorghum created shading effect created to bambara groundnuts plants. Higher infestation of *Otheca beningseni* in some extent also lowered yield of bambara groundnuts. At Hombolo, the crop on AWR, SH and AWRABR intercrop (480, 560 and 510kg/ha) had higher bambara groundnut yield than on RP intercrop100kg/ha). This might have been partly due to a greater insect pressure in this location.

Shelling percentage was similar in all cropping patterns at Bihawana (Table 4.13b). As regards to cropping patterns, in sorghum/ bambara groundnuts at Bihawana, the non significant effect and exhibited on number of plants at harvest, number of pods per plant, number of filled pods per plant, number of seeds per pod, 100 seed weight and shelling percentage. The greater seed yield per plant in AWR intercrop (Table 4.13a) compared to other treatment could be attributed to higher radiation interception rate at the start of flowering or at pod development stage which maximise assimilate production. The rate at which a crop attains maximum canopy development is influenced by the degree of branching and the rate of leaf production (Squire, 1993). Both these factors influence the amount of radiation intercepted during a given growth duration and subsequent productivity.

At Hombolo, AWRAWR gave higher shelling percentage (Table 4.13a) in sorghum/ bambara groundnuts. The treatment also had higher grain yield per hectare and seed yield per plant. Higher shelling percentage was also associated with higher number of pods per plant despite rainfall being low and erratic during growing period. This could be due to reduced competition between crops and also attributed to reduced *Striga* population.

5.7 Effect of cropping patterns on yield and intercropping advantage.

There was an intercropping advantage in sorghum/ groundnut intercrop and sorghum/ bambara groundnuts intercrop at different levels in yield of both crops respectively as indicated by the Land Equivalent Ratio (Tables 4.6, 4.7, 4.8 and 4.9) values. As regards to cropping patterns in sorghum/ groundnuts intercrop at

Bihawana, ABR and RP intercrop exhibited a greater intercropping advantage, while in sorghum/ bambara groundnuts at Hombolo RP intercrop exhibited greater intercropping advantage, which was associated with good sorghum performance in the same pattern with fairly less competition among the intercrop for sustainable resources.

Osiru (1975) who reported that there can be situations when a given crop will actually grow better in the presence of another crop than as a sole crop, for example when there is a beneficial effect of due to shade. This was more or less the case during the dry spell in which perhaps the sorghum shoots had a beneficial shade effect on groundnuts bambara groundnuts against excessive evapotranspiration. Also the yield of both crops in the intercrop was lower than their respective pure stands (Table 4.9). This is essentially due to the decrease in plant population in case of intercropping as well as competitive relationship between crops such as light, water and nutrient factors. However, the combined yield of both crops in sorghum groundnuts and sorghum / bambara groundnuts intercrop was advantageous.

In sorghum/ groundnuts intercrop at Hombolo in AWRABR intercrop had a decreasing *Striga* population of 40% and in ABR intercrops a decrease in of 10%. In sorghum/ bambara groundnuts at Hombolo, ABR intercrop had a decrease in *Striga* population by 21% whereas in RP intercrop decrease of 27% was recorded. Such reduction in *Striga* population is probably due to the less competitive ability of *Striga* plants to environmental factors when sorghum intercropped with groundnuts or bambara groundnuts.

In sorghum/ groundnuts and sorghum bambara groundnuts intercrop at Bihawana, the overall intercropping advantage, the groundnuts showed more decrease in yield in SH intercrop than when in monoculture. Groundnuts in ABR intercrop had an increase in yield per hectare by 59% whereas, groundnuts in SH intercrop At Hombolo, had an increase in groundnuts yield by 45%.

In sorghum/ bambara groundnuts intercrop at Bihawana, bamabara groundnuts in AWR intercrop had a yield increase of 55% whereas in AWR intercrop had an increase of 66% at Hombolo. The bambara groundnuts yield had an increase of 62% in ABRAWR intercrop and 35% in ABR intercrop. Similar results have been reported for maize and cowpea and sorghum and cowpea in which the cowpea grain yield decreased due to intercropping was greater than that of maize and sorghum. Such reduction in yield is probably due to less competitive ability of groundnuts and bambara groundnuts to environmental factors when intercropped with sorghum. Considering the plant height and root system, sorghum will be more advantageous in acquisition of below and above ground growth resources than groundnuts and bambara groundnuts.

The results are supported by findings by Agboola and Fayemi (1971) and May and Misangu (1982) who observed that although intercropping increases total yield of the combined crops, it often results in the depression of the yield of one or both of the component crops relative to the yield in pure stand. Nyambo *et al.* (1982) observed that where the intercropping involves legume and cereal, the legume yield tends to decrease to a greater extent than cereal yield, but this also depends on the planting patterns (May and Misangu, 1982)

The yield reduction is believed to be a result of various forms of competition for below- ground and aboveground factors. The root system of a cereal like sorghum is structured such that roots are more efficient in nutrient and water absorption. Sorghum for examlpe has profusely branched adventitious roots, which develop quickly and tap a large amount of water and nutrients from the soil. Therefore this root quality allows for more drought resistance and securing distant nutrients in soil. Legumes on the other hand have taproots, which absorb deeper water yet they have less branched roots for nutrient absorption in the topsoil thus making them less competitive.

The results of this experiment, in which generally there was a yield reduction in bambara groundnuts intercropped with sorghum in the same whole pattern, differ with the findings by May and Misangu (1982). The authors reported that the yield was less severe or non-existent when cereal and legumes were planted in the same hole than in other planting patterns. In fact they observed advantageous intimate association. These results also do not agree with postulates put forward by Wiley (1979), Bandyopadhya and De R, (1986), Elmore and Jackobs, (1986) and Ahuja and Singh (1987) that the intimate association between cereal and legumes enhanced nitrogen fixation by the legume. This is due to continuos removal of N fixed by the legume in the pool by the cereal which ultimately increases both legume and sorghum yield.

Nevertheless, the low yield observed in sorghum in mixtures at Hombolo could necessarily be due to the failure of the cereal to benefit from the legumes N fixation. This could probably have been due to the adverse environmental factors e.g. weather, weed and insects pest, which affected the crops in their young stage of growth.

CHAPTER SIX

6.0. CONCLUSION AND RECOMMENDATIONS.

6.1. Conclusions

The study has revealed that *Striga* can be suppressed/ controlled by different sorghum/ groundnuts and sorghum/ bambara groundnuts intercropping patterns under semi – arid tropics. On the basis of these results, the following conclusions were drawn:

i) Soil moisture, soil fertility and cropping patterns as it has been experienced at both locations can influence *Striga* distribution and severity of infestation. At Bihawana a continuous wet soil conditions between January and April due to high rainfall resulted into reduced *Striga* germination (wet dormancy). Incorcomitent dry condition accelerated *Striga* germination as observed at Hombolo where a steady increase in *Striga* population was realized throughout the crop growth and development period.

ii) At Hombolo location, the crop on mixtures had lower *Striga* population compared to monocrop sorghum indicating that intercropping was very effective in *Striga* control which is a traditional practice in the semi – arid tropics. The low and erratic rainfall at Hombolo influenced *Striga* germination which compete for moisture and nutrients with the host plants

iii) The crop in both mixtures and monocrop at Bihawana where *Striga* not observed were highly productive compared to crops from Hombolo indicating that *Striga* reduced yield in cereals creating a chronic food deficit in semi – arid tropics.

iv) *Striga* population was higher in sorghum/ bambara groundnuts as compared to sorghum/ groundnuts intercrop indicating that bambara groundnuts was more effective in *Striga* control by creating abortive germination as compared to groundnuts

v) Growth and yield attributes for all crops were also affected, as they are the important indicators in yield assessment process. Little difference under any circumstances will lead to low yield.

6.2 Recommendations:

In view of the above conclusions it is recommended that in sorghum/ groundnuts intercrop AWRABR intercrop was more superior in controlling *Striga* than other intercropping patterns. In case of sorghum/ bambara groundnuts intercrop, RP intercrop was superior in *Striga* control as compared to other intercropping patterns. These findings indicated that more studies which focus on the use of different intercropping patterns with inclusion of legumes (trap or catch crops) in the cropping system should be done. Since the present work was confounded by continuous rainfall, which started in January up to April at Bihawana and abnormal rainfall distribution with continuous dry condition at the start of the season at Hombolo, respectively, further studies are needed in order to enrich the knowledge on the use of intercropping by smallholder farmers in controlling *Striga*. Special emphasis should be aimed at: -

(i) Long-term effect intercropping on *Striga* infestation.

(ii) Long-term effects of traditional legumes on controlling *Striga* infestation.

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8.0. APPENDICES:

Appendix 1. Summary of rainfall and temperature data for Bihawana and Hombolo during 1998/99 cropping season.

Month	Bihawana			Hombolo		
	Rainfall (mm)	Temperature oC		Rainfall (mm)	Temperature oC	
		Max.	Min.		Max.	Min.
November	0	29	14.5	18.3	34.4	16.0
December	0	27	17.5	3.5	36.4	19.0
January	249	26	15.5	89.7	34.6	18.5
February	130.4	29	16.0	20.8	34.5	18.0
March	286.6	27	11.5	212.4	34.5	18.4
April	218	26.5	11.5	119.1	28.6	16.0
May	0	25.6	10.7	0	29.2	15.4

Source: Bihawana and Hombolo Meteorological Stations, Dodoma 1998/99.

Appendix 2. Distribution and host crop of *Striga* species in some African countries. Crop hosts some countries of occurrence.

Striga hermonthica

Millet	Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Egypt, Ethiopia, The Gambia, Ghana, Kenya, Guinea, Mali, Niger, Nigeria, Sudan, Tanzania, Togo.
Maize	Benin, Burkina Faso, Cameroon, Cote d'Ivoire, Egypt, Ethiopia, The Gambia, Ghana, Kenya, Mali, Niger, Nigeria, Senegal, Tanzania, Togo.
Upland Rice	Benin, Burkina Faso, Cameroon, Cote d'Ivoire, The Gambia, Kenya, Mali, Nigeria.
Fonio (hungry rice)	Guinea, Mali, Togo.
Sugar Cane	Burkina Faso, Kenya, Mali, Nigeria.
Tef	Ethiopia

Striga asiatica

Maize	Benin, Burkina Faso, Botswana, Cote d'Ivoire, Egypt, Ghana, Ethiopia, Senegal, Sudan, Tanzania, Togo, Zimbabwe.
Upland rice's	Cote d'Ivoire, Kenya, Senegal, and Nigeria.
Tef	Ethiopia.

Striga gesnerioides

Cowpeas	Burkina Faso, Cameroon, Chad, Cote d'Ivoire, The Gambia, Ghana, Mali, Niger, Nigeria, Senegal, Togo.

Tobacco	Zimbabwe
Striga aspera	
Maize	Burkina Faso, The Gambia, Mali, Nigeria
Millet	Burkina Faso, Cameroon, Mali, Niger, Nigeria
Sorghum	Burkina Faso, Cameroon, Mali, Nigeria
Upland rice	Mali, Togo
Lowland rice	Togo
Fonio	The Gambia, Mali
Sugarcane	Burkina Faso, Mali, Nigeria
Striga forbesii	
Maize	Ethiopia, Nigeria, Togo, Zimbabwe
Sorghum	Togo, Zimbabwe
Lowland rice	Togo
Sugarcane	Ethiopia
Striga passrgei	
Maize	Nigeria
Sorghum	Mali
Striga densiflora	
Sorghum	Sudan
Striga klingil	
Sorghum	Burkina Faso
Millet	Burkina Faso

Striga latericea	
Sugarcane	Ethiopia
Striga branchycalyx	
Sorghum	Mali
Millet	Mali

The overall effect of *Striga* damage on the crop is a reduction in crop yield, the extent of which is related to several factors, especially the incidence and severity of attack, the host susceptibility to *Striga*, environmental factors (edaphic and climatic) and the management level at which the crop is produced.

Source: Lagoke et al 1994.

Appendix 3: Number of witchweed (*Striga lutea* lour) seeds per 100 grams of air dry Soil, sampled in 6-inch increments to depth 5 feet.

	Number of seeds	
Depth (inches)	Total	Viable
0-6	284	60
6-12	84	45
12-18	15	8
18-24	8	5
24-30	9	7
30-36	8	9
36-42	9	6
42-48	20	17
48-54	13	12
54-60	8	7

Average of three replications. To convert to number of seed per 6-inch increment to the equivalent number per acre, multiply the respective number by 8 million.

Source: Robinson, E. L. Kust. 1962. Weeds 10:335

Appendix 4: Soil characterization and classification of Hombolo Research Station.

Profile No: Hombolo Agricultural Station.

Location: Hombolo Agricultural Research Station Farm, about 400m East of the Agriculture Station Offices.

Elevation: 1037m above mean sea level.

Land form: On middle of a long uniform slop of about 2%.

The area has been under fallow for the past five years. However, the native vegetation in the surrounding areas consisted of scattered *Adansonia digitate* (baobab) and *Hyperhenia acacia* bush with grassland. The Agriculture Institute Hombolo has also introduced exotic species. These include *Leucaena spp*. Parent materials: Silicon rich gneiss with granite.

Profile description:

AP 0-12cm Brown (7.5YR 5/4) moist and light brown (7.5YR 6/4) dry sandy loam; moderately weak medium crumb; slightly sticky, slightly plastic (wet), very friable (moist) and slightly hard (dry); many very fine random pores; porosity 42.7%; common very fine roots; abrupt, smooth boundary.

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Profile description:

AP 0-12cm Brown (7.5YR 5/4) moist and light brown (7.5YR 6/4) dry sandy loam; moderately weak medium crumb; slightly sticky, slightly plastic (wet), very friable (moist) and slightly hard (dry); many very fine random pores; porosity 42.7%; common very fine roots; abrupt, smooth boundary.

AB 12-28 cm: Brown to brown (7.5YR 4/4) moist and brown (7.5YR 6/4) dry, sandy loam; strong coarse granular; slightly sticky, slightly plastic (wet), very friable (moist) and hard (dry); very few medium and common fine and very fine random pores; porosity 36.5%; few very fine roots; clear; smooth boundary.

Bu 28-46 cm: Strong brown (7.5YR 5/8) moist and reddish yellow (7.5YR 6/6) dry, sandy clay loam; moderately weak medium sub-angular blocky, non sticky, non plastic (wet), very friable (moist) and hard (dry); common fine and very random pores; porosity 38.55; gradual smooth boundary.

Bu 46-102 cm: Reddish yellow (5YR 6/8) moist reddish yellow (5YR 7/8) dry, sandy clay loam; moderately weak medium sub-angular blocky; non-stick non plastic (wet); very friable (moist) and hard (dry); common fine and very fine random pores; porosity 42.3%; gradual smooth boundary.

Bu 102-158 cm: Reddish yellow (5YR 6/8) moist and reddish yellow (5YR 7/8) dry, sandy clay loam; moderately weak fine and medium sub-angular blocky; slightly sticky, slightly plastic (wet), very friable (moist) and hard (dry) common fine and very fine random pores; porosity 40.4%; clear smooth boundary.

Bgcs 158-178 cm: light brown (7.5YR 6/8) moist and pink (7.5YR 7/4) dry, common fine faint clear strong brown (7.5YR 5/6 and 7.5YR 5/8) mottles; slightly gravelly sandy clay loam; moderate course sub-angular blocky sticky and plastic (wet), firm (moist) and very hard (dry); few fine to medium pores; porosity 35% very few angular quartz gravel (2-4mm) very few large (1.0-1.5cm) slightly soft irregular dark red ironstone nodules; abrupt boundary.

Ccs 178-184 cm: Pinkish gray (7.5YR 6/2) moist and pinkish gray (7.5yr 7/2) &7.5YR 7/2) dry; common medium distinct clear strong brown mottles, slightly gravelly sandy clay loam; massive; sticky and plastic (wet), firm (moist) and extremely hard (dry); few fine pores; porosity 30.7%; very few large (1.0-1.5cm) slightly soft irregular darkled ironstone nodules.

Appendix 5. Analytical data of the profile:

Horizon	Depth (cm)	Clay	Silt	Sandy	Textural Class	H_2O (1:2.5)	KCI (1:2.5)	Organic carbon %	Total Nitrogen %
Ap	0-12	16.0	5.0	79.0	SL	5.4	4.2	1.03	0.05
AB	12-28	17.0	5.0	78.0	SLSL	5.1	4.0	0.62	0.03
BU1	28-46	22.0	4.0	74.0	SCL	5.2	3.8	0.57	0.04
BU2	46-102	23.0	5.0	72.0	SCL	6.0	3.8	0.28	0.02
BU3	102-158	32.0	2.0	66.0	SCL	5.5	3.8	0.28	0.03
Bgcs	158-178	27.0	4.0	69.0	SCL	5.4	3.7	0.34	0.03
Ccs	178-184	24.0	2.0	74.0	SCL	5.3	5.8	0.19	0.19

Nd = not determined

Source: Swai, 1998.

Appendix 6 Land Equivalent Ratio in sorghum/groundnut intercrop at Bihawana

Cropping Pattern	Sorghum Yield kg/ha	Groundnuts Yields Kg/ha	Total yields	LER
ABR	1770	240	2010	8.375
DR	1540	580	2120	5.032
AWR	1340	350	1690	6.090
SH	1710	160	1870	12.197
RP	1860	480	2340	6.197
ABRAWR	1070	490	1560	5.642
S	1900	-	1900	-
G	-	600	600	-

$$LER = \frac{(Yij)}{(Yii)} + \frac{(Yji)}{(Yjj)}$$ (Willey and Osiru, 1972)

Where Y is the yield per unit area, Yii and Yjj are sole crop yields of the component crops i and j, Yij and Yji are intercrop yields (Mead and Willey, 1980).

Appendix 7 Land Equivalent Ratio in sorghum/bambara groundnut intercrop at Bihawana

Cropping Pattern	Sorghum Yield kg/ha	Groundnuts Yields Kg/ha	Total yields	LER
ABR	1820	270	2090	8.71
DR	1790	200	1990	11.08
AWR	1760	330	2090	7.52
SH	2180	270	2450	10.20
RP	2240	290	2530	9.90
ABRAWR	1690	190	1880	11.01
S	1800	-	1800	-
BG	-	510	510	-

Appendix 8. Land Equivalent Ratio in sorghum/groundnut intercrop at Hombolo

Cropping Pattern	Sorghum Yield kg/ha	Groundnuts Yields Kg/ha	Total yields	LER
ABR	1200	300	1500	6.25
DR	1100	300	1400	5.94
AWR	1200	600	1800	4.50
SH	1200	300	1500	6.25
ABRAWR	1500	100	1600	17.07
RP	800	400	1100	4.13
S	500	-	500	-
G	-	300	300	-

Appendix 9 Land Equivalent Ratio in sorghum/bambara groundnut intercrop at Hombolo.

Cropping Pattern	Sorghum Yield kg/ha	Groundnuts Yields Kg/ha	Total yields	LER
ABR	800	470	1170	3.95
DR	980	300	1280	5.67
AWR	800	480	1280	4.27
SH	600	560	1160	4.00
ABRAWR	1180	100	1280	13.89
RP	500	510	1010	2.00
S	620	-	620	-
BG	-	390	390	-