USE OF COVER CROPS AND PRE-EMERGENCE HERBICIDES AS WEED MANAGEMENT OPTION IN CONTINUOUS MAIZE (*Zea mays* L.) PRODUCTION IN IBADAN, NIGERIA

By

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ABSTRACT

Crop Rotation (CR) and planting of Cover Crops (CC) are important methods of weed management for sustainable crop production. These and various other methods are usually integrated to enhance weed management in crop production. While reports abound on integrated weed management involving these and other practices, there is inadequate information on integrated use of Pre-emergence Herbicides (PH), CC, and CR in maize production. Therefore, effects of continuous use of CC with PH were evaluated in Ibadan for maize production.

Hundred, 75, 50 and 25% of the recommended rates of maize-based PH (atrazine, atrazine + metolaclor® and metolaclor®) were evaluated on the performance of Cowpea (α), Melon (β), Pumpkin (γ) and "Akidi" (*Vigna unguiculata* sub-sp *sesquipedalis*) (θ). The densities of 10,000 and 20,000 plants/ha for γ and α/β/θ respectively were integrated with the effective minimum dose of the PH and evaluated on weed control and maize performance. The appropriate sequence of the CC complemented with hoe-weeding at four Weeks After Sowing (WAS) for weed suppression in intensive maize cropping over four cropping cycles in two years was also evaluated in randomized complete block design. The CC sequences were combinations of any of γ/β and θ/α in early and late seasons (βθγα/βαγθ/γθβα/γαβθ) and continuous sole CC (ββββ/θθθθ/γγγγ/αααα) over four cropping cycles. The controls in each case were three hoe-weedings and unweeded maize plots. Data collected on emergence and Dry Matter Yields (DMY) of the CC, Ground Coverage (GC) of CC, Weed Density (WD), weed biomass at 8 WAS and Maize Grain Yield (MGY) were analysed using descriptive statistics and ANOVA at p=0.05.

Atrazine and atrazine + metolaclor at rates higher than 50% significantly reduced the emergence of β (17.9 and 18.2%); γ (33.1 and 33.2%); α (17.5 and 16.7%) and θ (20.8 and 19.0%) respectively while 100% of metolaclor reduced emergence of γ (7.3%) and β (11.0%) with no significant effect on emergence of α and θ. Similar reduction was observed on the DMY of the CC. The WD reduction due to 20,000 plants/ha of α, β and θ, and 10,000 plants/ha of γ were 88.1, 81.7 and 80.0, and 87.4% respectively. The order of GC was γ (78.4%) > θ (70.2%) > β (69.7%) > α (68.9%). The MGY of 2.18, 2.16, 2.21 and 2.17 t/ha from θ, γ, α and β respectively were comparable to 2.29 t/ha obtained from hoe-weeded but significantly higher than 1.63 t/ha from unweeded controls. The 62.4% weed biomass reduction from ββββ was significantly lower than values that ranged between 65.6 and 68.1% from CC sequence βθγα/βαγθ/γθβα/γαβθ, while the 73.2% reduction from θθθθ was significantly higher than reduction from other CC and comparable to hand-weeded control. The order of MGY was θθθθ (95.7%) > γθγα/βαγθ/γθβα/γαβθ (94.0 - 95.3%) > ββββ (90.6%) of hoe-weeded control.

All the cover crops tolerated up to 50 and 75% recommended rates of atrazine and atrazine + metolaclor respectively, while cowpea/akidi tolerated 100% rate of metolaclor. Thus these could be used in integrated weed management in maize production with early and late season planting of pumpkin/melon and cowpea/akidi in Ibadan.

Keywords: Integrated weed management, Pre-emergence herbicides, Cover crop density, Continuous maize production, Crop sequence.

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CERTIFICATION

I certify that this work was carried out by Mr. Olalekan Wasiu OLANIYI of the Department of Agronomy, University of Ibadan, under my supervision.

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DEDICATION

This thesis is dedicated to God Almighty,

The Awesome One who is unquestionable,

The One who sets the poor among the princes.

The Hope of the hopeless.

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CHAPTER ONE

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in Nigeria. Its diverse uses as human food, livestock feed as well as industrial raw materials give it a relative advantage over many of other food crops (FMAWRRD, 1988; Aderibigbe *et al*., 2011). It is an important food in Asia, Africa, Latin America and parts of the former Soviet Union. It is grown in more than 16 million ha in the Midwestern U.S. (NACWC, 1994). After wheat and rice, it is the most important cereal grain in the world providing nutrients for human and animals.

According to the Federal Ministry of Agriculture, Water Resources and Rural Development (1988), the estimated total grain production of maize amounted to 1.37 million tonnes in 1987 with an annual increase rate of 10.2%. The Central Bank of Nigeria (2003) reported that the output of maize has continued to increase in Nigeria (1.34 million tonnes in 1986 to 7.02 million tonnes in 2003). Shaib *et al*. (1997) projected 13.39 million tonnes for the year 2010. Despite the increase in annual maize production in Nigeria, the production per unit area is very low compared to the yield obtained in the U.S. (Onwueme and Sinha, 1997). This low production is often attributed to the problems of soil fertility and pest infestation among which weeds are the most important. Parker and Fryer (1975) estimated that weed competition in developing countries results in 125 million tonnes of loss in food production annually. In addition, over 40% of the farm labour in smallholder agriculture in developing countries is expended in removing weeds (Labrada and Parker, 1994). In south-western Nigeria, smallholder farmers are faced with increasingly high weed densities as a result of continuous cultivation of limited available arable land. Crops are produced on land that is highly fragmented (average farm size of 1.5 ha), marginally fertile, and frequently cultivated without receiving any agrochemical input (Akobundu, 1991; Raji *et al*., 1995). These conditions favour the proliferation of weeds.

Maize is extremely sensitive to competition from weeds because it emerges more slowly than weeds and does not completely cover the soil in the early growth stage. Weed interference causes severe yield reduction in field crops. Akobundu (1987) observed that uncontrolled weed infestation may cause yield loss of 40-60% in maize, and that maize is susceptible to weed interference during the first 6-8 weeks after sowing (WAS). Maize crop growth and grain yield are also influenced by duration of weed interference, weed species, density and the environment in which maize grows (Hall *et al*., 1992).

Hand weeding is the most widely used traditional method of weed control in maize among small-scale peasant farmers. Akobundu (1987) observes that maize yield among this group of farmers is generally low and one of the causes of this low yield is delay in the time of first weeding. Weeding is usually carried out about two to three times depending on the degree of weed infestation. Other means of weed control include tillage, use of herbicides, use of cover crops, mulching and crop rotation. Although intercropping has been found to reduce weed growth (Moody, 1978) yield reduction of up to 40-53% due to weed interference has been reported for mixed cropping system (Parker and Fryer, 1975; Akobundu, 1979). Eneji *et al*. (1995) observes that weed suppression in small holder farming system is not apparent because crops are grown at such wide spacing that weed suppression is nearly always ruled out.

Intercropping easily fits into the traditional farming methods, which relies heavily on household labour since hiring of labour is expensive. Widespread adoption of chemical herbicides which are often preferred (George, 1982) among farmers is hampered by high cost, non availability of chemicals and certain other constraints such as technical requirement and weather condition. Cover crops have growth characteristics that enable them to compete with weeds. Some of these include light interception by canopy, which generally increases their competitiveness with weeds, and smothering growth habit, which enables them to prevent the development, growth and continued existence of weeds. Smother crops like cowpea, groundnut, sweet potato and melon have been successfully used in maize, cassava, yam and plantain (Ayeni *et al*., 1984; Zuofa *et al*., 1992; Eneji *et al*., 1995; Akinyemi and Tijani-Eniola, 1997). Crop combinations with cover crops may however require initial weeding before the cover crop spreads over the soil to prevent the growth and development of late emerging weeds.

This cropping system may also be enhanced by rotation of cover crops with high competitive ability with weeds. When highly competitive crop varieties are employed, they may help to control weeds in crop rotation (Wicks *et al*., 1994, Creamer and Baldwin 2000), reduce herbicide use (Christensen, 1994; Lermerle *et al*., 1996; Hutchinson and McGiffen, 2000); reduce the number of cultivation needed

(Garrity *et al*., 1992) and improve yield stability in weedy fields (Lindguist and Mortensen, 1998).

Recent research efforts indicate that certain indigenous or local varieties of cowpea show higher ability to compete with weeds than some improved cultivars. Such varieties include “iron clay”, a traditional cowpea variety in south-eastern U.S. (Wang *et al*., 2004) and “akidi” a black seeded, wild and local variety of cowpea endemic in tropical rainforest of south-east Nigeria (Eke-Okoro *et al*., 1999). Exploring the potentials of such competitive crops in an integrated approach with chemical herbicides with cover crops rotation may hold the key to sustainability in continuous maize production. The dearth of information in this research area calls for consideration. This research effort is thus set to explore the potentials of some of the competitive cover crop varieties, alongside other established cover crops individually and in rotation with or without herbicides for weed control in maize production. The objectives of this study were therefore to:

1. explore the potentials of complementary use of herbicides at reduced rates with cover crops for weed control in maize production.
2. evaluate the comparative effects of akidi (*Vigna unguiculata*), pumpkin (*Cucurbita pepo* L.), cowpea (*Vigna unguiculata* (L). Walp.) and melon (*Citrulus collocythis* (L.) Schrad.) in weed control in maize production.
3. determine the effects of continuous use of cover crops on weed control and yield sustainability in maize production
4. determine the influence of cover crop rotation and its appropriate sequence on weed control in a continuous maize production system.

CHAPTER TWO

LITERATURE REVIEW

2.1 Cover crops and their functions

Cover crops are crops grown to provide soil cover; regardless of whether it is later incorporated (Sullivan, 2003). They can be annual, biennial or perennial herbaceous plants grown in pure or mixed stand during all or part of the growing season. According to Asadu *et al.* (2004) crops that cover the soil are integrated in different cropping system; crop rotation, mixed cropping and relay cropping. It has been well reported that soils covered with cover crops offer better resistance to invasive weed species, whose competition with crops leads to a reduction in crop yield; such soils are less susceptible to run off and are better protected against wind erosion. It also cushions the effects of temperature changes and keeps the base of the plants cool and helps in controlling weeds which find it hard to compete with cover crops (Ngouaiji *et al*., 2003; Anon., 2004). At the same time the soils are not compacted thereby allowing roots to penetrate more easily and improve water infiltration. The dropping leaves slowly enrich the soil and foster the activities of soil fauna like earthworms which play a prominent role in soil fertility (Anon, 2004). In addition to their role in covering the soil, cover crops perform other functions, the sum total of which results in improved soil productivity.

Cover crops are incredible tool to harvest multi-benefits among which are: reduction in soil-erosion, conservation of moisture, protection of beneficial organisms, and provision of soil amendment (Blevins *et al*., 1971; Kaspar *et al*., 2001). The shoots cover the soil while the roots bind and stabilize the soil particles (Varhallen *et al*., 2003). Cover crops thus reduce soil erosion, increase water infiltration, help to retain soil water, improve soil tilth, and suppress weeds (Teasdale, 1996; Sarrantonio and Gallandt, 2003). Edwards and Burney (1991) found that cover crop residue remaining on the soil surface intercepted rain drops and decreased the disruption and erosion of soil particles. Singer *et al.* (1981) concluded that the transport of soil particles by surface flow decreased as the amount of surface residue increases from 0 to 96%.

Cover crops are found suitable for use as live mulches to suppress weed in crop production because they reduce weed seed population in the soil, increase soil organic matter content and provide favourable conditions for earthworm and microbial activities; they also reduce soil erosion and compaction and increase water infiltration, and may provide additional fodder for livestock after harvest (Aderibigbe *et al*., 2011).

Cover crop residue provides soil with a cover which plays a vital role in increasing soil organic matter and nutrient recycling (Bradley, 1995; Kaspar *et al*., 2001). Organic matter is important both in improving soil fertility and the physical condition. It acts as a store house of nitrogen and other nutrients such as phosphorous and sulphur and it influences soil exchange capacity, improves water holding capacity and increases aeration, especially in clay soils (Janick, 1982; Sullivan, 2003). Beneficial effects of cover crops on soil and water in an agricultural system depends on the amount of biomass produced by the cover crop and the management of this residue on the soil surface (Munawar *et al*., 1990). Using cover crops in a no-till system leaves the soil surface relatively undisturbed allowing for slow residue decomposition which adds organic matter to the soil (Boquet *et al*., 1994). Utomo *et al*. (1987) reported a significant increase of total organic matter in the top three inches (8 cm) of soil in a no-till system compared to a conventional tillage system. After many years of conservation tillage research in Tennessee, Bradley (1995) reported that additions of organic matter improve soil tilth, moisture holding capacity, and cation exchange capacity.

Cover crops help in reducing the loss of nutrients from the soil. Nutrients held in the plant tissues are returned to the soil when the plants are dead, allowed to decay on the soil or incorporated into the soil and subsequent plants make use of the nutrients. Cover crops take in nitrogen from the soil thereby reducing nitrogen loss through leaching which may contaminate the ground water table (Varhallen *et al*., 2003). Some cover crops help in making phosphorous available to crops that need it by the action of their roots (Varhallen *et al*., 2003). They generally improve soil quality (Reeves, 1997). Deep rooted cover crops such as alfalfa (*Medicago sativa*) can draw up nutrients from lower depth in the soil profile and make them available to other plants. Cover crops are sometimes used for soil conservation and nutrient recycling. For this purpose, grass species may be best (Shipley *et al*., 1992). To reduce the cost of inorganic fertilizer-N, a legume cover crop can be planted to provide N for the following annual crop through the process of nitrogen fixation (Thompson and Varco, 1996). In addition to nitrogen from legumes, cover crops help recycle other nutrients on the farm. Nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), and other nutrients are accumulated by cover crops during a growing season. When the green manure is incorporated, or laid down as no-till mulch, these plant-essential nutrients become slowly available during decomposition (Hoyt, 1987). The use of cover crops for weed control is gaining more importance in today's conservation tillage systems when increasing number of weed species are becoming resistance to herbicides. Previous research has shown that early season weed control by using cover crops with conservation tillage systems is comparable to chemical control in many situations (Teasdale and Mohler, 1992; Johnson *et al*., 1993; Reeves *et al*., 2005).

The degree of weed control provided by a cover crop depends on the management strategies. Light and space will be taken up by cover crops which help in covering the soil and reducing the opportunity of weeds to be established (Sullivan, 2003). In a cropping system where labour is scarce and productivity is declining due to weeds invasion, cover crops can provide an effective alternative to chemical weed control with a reduction in labour input (Stockwell and Fisher, 1996). Teasdale and Mohler (1993) observed that live cover crops reduce the amount of moisture available to and the quantity of light that falls on germinating seeds. Weeds attempting to establish along with a cover crop would be in competition for resources and may not develop sufficiently to survive the inclement weather conditions. This implies that the weed would not be able to pose any threat to the crop's performance. Cover crop residue can modify the conditions under which weeds germinate. Such effects could be due to changes in soil temperature, increase in soil moisture, release of allelopathic chemicals and physical impediments to the development of weed seedlings (Facelli and Pickett, 1991; Teasdale and Mohler, 1993; Teasdale, 1996). Melon interplant with maize was found to suppress weeds when the two crops were sown simultaneously (Okoh *et al*., 2001). In a similar study, Kolo and Abdullahi (1994) reported that both melon and cowpea interplant with maize suppressed weed growth when compared with maize grown as a sole crop. Allelopathic effects of cover crops on weeds have been reported in maize and cotton (Vasilakoglou *et al*., 2005; Dhima *et al*., 2006) and in other cropping systems (Caamal-Maldonaldo *et al*., 2001). Caamal-Maldonaldo *et al*. (2001) and Dhima *et al*. (2006) noted that the most practical and immediate way to use allelopathy in weed control is to use allelopathic cover crops in rotations, or apply residues of allelopathic weeds or crops as mulches.

Intercropping involving cover species has been practiced because of the additional benefits of pest problem reduction among farmers. Farmers have for decades intercropped in the tropics for a variety of reasons including insurance against crop failure, better and more efficient use of labour and reduction of pest problems among others (Okigbo, 1978; Francis *et al*., 1986). Some species of cover crops may be a non host for pest or may release toxic materials (allelopathic chemicals) that are harmful to the pest or other plants. On the other hand, some crops attract beneficial insects which are detrimental to other pest as a result forcing them to leave (Sullivan, 2003).

Cover crops improve soil structure and reduce soil compaction. Plant residues help in improvement of water holding capacity and infiltration, reduction of soil compaction, consequently improving soil structure. According to Sullivan (2003) some cover crops with extensive root system are highly effective in loosening and aerating the soil. Erosion increases where there is no plant cover, but where permanent and undisturbed plant cover exist, erosion is more or less gradual (Janick, 1982). It is generally agreed that the additions of organic matter to the soil system improves the soil physical properties such as aeration and drainage, water infiltration and retention, and the ability of the soil to retain and supply nutrients to crops (Hargrove and Frye, 1987; Breitenbeck and Hutchinson, 1994). Cover crops were found to improve soil organic matter, total nitrogen, cation exchange capacity (CEC), infiltration rate, water retention capacity as well as lowering soil bulk density (Lal and Couper, 1990).

When cover crops in form of green manure are incorporated into the soil, soil microbial activities are promoted. Soil microbes multiply to attack the freshly incorporated plant materials. Therefore, nutrients held in the plant tissues are released due to the microbial breakdowns which are then made available to the crops (Sulivan, 2003). Cover crops provide forages to animals (Crawford *et al*., 1989; Varhallen *et al*., 2003). Under adverse conditions and/or dry season in northern Nigeria, there is a shortage of pasture; cover crops can make available the much needed pasture for animals and help in settling the nomads who move from the North to the South in search of pasture in the dry season.

Cover crop in a mixed cropping increases farmer's income and insurance against any crop failure. Cover crops such as cowpea, groundnut and cowpea when integrated in a cropping system help in increasing farmer's income per unit area.

Similarly in case of the failure of one crop, the other will protect the farmer from complete crop failure (Sulivan, 2003). Cover crops and tillage systems can be managed to conserve soil moisture for crop use throughout the growing season (Bordovsky *et al*., 1994). Organic matter inputs to the soil influence soil aggregate properties increasing the ability of the soil to store moisture for crop extraction (Bordovsky *et al*., 1994). Jones *et al*. (1969) reported that ground cover residue provides soil water conservation. Surface residue slows the velocity of runoff and allows for greater infiltration of water into the soil surface by 25 to 50% compared to a conventional tillage system (Naderman, 1991). These benefits of cover crops and no-till can protect the soil against erosion and allow row crop production on sloping upland soils (McGregor *et al*., 1975). Sullivan *et al*. (1991) found that no-till resulted in higher levels of soil moisture when compared to conventional tillage, and the more biomass produced by the cover crops the greater the soil moisture retention throughout the soil profile. The increased organic matter at the soil surface reduces crusting which aids water infiltration, enabling the soil profile to be more effectively used for water storage (Baumhardt *et al*., 1993; Busscher and Bauer, 1993; Moseley *et al*., 1996; Reeves *et al*., 1996).

Selecting the best crop species for use as a cover crop depends on the needs of the agricultural system. A cover crop must be adaptable to location, soil type, and climate for optimum growth and production of biomass. According to Power and Koerner (1994), three factors affecting residue management are cover crop growth rate, stage of growth, and the length of the growing season. However, the growth habit of cover crops as well as their competitiveness with weeds and the main crops also remain important factors to be considered in a production system. It is very important to seed the cover crop during the recommended planting period to help insure good stand establishment and growth. In terms of costs for establishment and management, legumes are much more expensive to establish and sometimes more difficult to be chemically controlled compared to small grains like wheat (Stevens *et al*., 1992; O'Brien-Wray, 1995). Regardless of the cover crop used, careful planning is needed in selecting and managing a cover crop for maximum beneficial effects.

According to Versteeg and Koudokpon (1990), the recommendation for the integration of cover crops in agro-ecological zones with bimodal rainfall distribution is relay cropping of the cover crops into the primary crop. For example, in maize, it is recommended to sow cover crops six weeks after the maize to avoid severe competition between the cover crop and the primary crop. The cover crop germinates and establishes at the end of the first rainy season and utilizes the second growing season, after the primary crop has been harvested, to develop a leaf canopy that can suppress weeds. Alternatively, cover crops may be sown, as fallow, with the first rains and allowed to grow for the entire rainy season prior to sowing food crops the following year (Versteeg and Koudokpon, 1990). Some of the major problems arising from the use of cover crops are that they occupy land that would be otherwise used for food production. The investment made to establish and manage cover crops may be more than the benefit (reduced weed pressure and increased soil nitrogen) (Manyong *et al*., 1999). It is unlikely that the use of cover crops will be widely adopted in areas with severe land shortage.

2.2 Crop rotation and weed control

Crop rotation can be an effective tool in reducing the build-up of problematic weeds and other pests and to keep their populations under control. Researches on the influence of crop rotation on weed control have been reported with varying results. Mulugeeta and Stolberg (1977) reported that crop rotation was not a major factor influencing weed population and seed-bank dynamics. In a field study conducted over seven years in south-western Slovakia to investigate the effects of different soil tillage intensities and crop rotation on weed density, weed diversity and weed dry biomass in maize, Demjanová *et al*. (2009) reported that crop rotation did not have a significant influence on variability of species richness expressed according to Margalef's index in maize and that tillage system was more influential than crop rotations on the weed density and diversity and weed biomass. Akobundu (1987), however, observes that rotation plays a long term role in weed control by preventing particular weed species from adapting to the growth cycle of specific crops. Crop rotation also helps farmers to rotate herbicides, thus ensuring that weed resistance to a given herbicide does not take place in a field (Akobundu, 1987). Crop rotation can disrupt the continuous dominance of specific weed in a field and decrease the building of weed species composition (Schweizer and Zimdahl, 1984; Hall, 1992). Benoit *et al*. (2003) reported that weed seed bank was higher after 3-year carrot (*Daucus carota* L.) monoculture than when barley (*Hordeum vulgare* L.) was rotated. Porter *et al*. (2003) also reported that weed control and crop yield were better in organic maize and soybean when they were parts of a 4-year maize-soybean- oat (*Avena sativa*)-alfafa rotation than a 2-year maize-soybean rotation. Teasdale *et al*. (2004) reported that long rotations with more phenologically diverse crops can reduce weed seed bank population and abundance of important annual broadleaf weed species in organic production system. The report also emphasized the importance of cropping sequence in weed control. Improvement of weed management in crop rotation by combination of agronomic practices and herbicides has also been reported (Blackshaw *et al*., 2005). Also, Macák *et al*. (2005), noted that greater diversity prevents the domination of a few problematic weeds. Crop rotation is thus considered an essential component of integrated weed management systems (Clements *et al*., 1994). Weed diversity has been shown to increase under crop rotation compared to monoculture (Stevenson *et al*., 1997). It has also been suggested that weed densities are lower in crop rotational systems than in monocultures (Doucet *et al*., 1999). For these reasons, crop rotation is an important weed management tool in low input and organic systems.

Légère and Samson (1999) attempted to evaluate the relative importance of crop rotation, tillage, and weed management as factors affecting weed communities and tested the hypothesis of an association between management practices and weeds from certain life cycle groups. They observed that the weed species segregated roughly according to life cycles and that, interactions among weed management intensity, tillage, and crop rotation mostly explained species dominance in the various cropping systems.

2.3 Cover crops, crop sowing densities and weed suppression

The ability of cover crops to compete with weeds is determined by a number of factors. These include light interception (Challiar *et al*., 1983) by the cover crops, smothering growth habit and large biomass production. Potato is able to suppress weed growth by light interception and its smothering growth habit (Sweet *et al*., 1974). The smothering growth habits of cowpea, groundnut, sweet potato and melon have been explored for weed suppression in maize, cassava, yam and plantain (Ayeni *et al*., 1984; Zuofa *et al*., 1992; Eneji *et al*., 1995; Akinyemi and Tijani-Eniola, 1997). The ability to suppress weeds also depends on cultivars, plant densities, rate of growth and establishment of canopy cover, competitive ability and moisture status of the soil (Bantilan *et al*., 1974; Moody and Shetty, 1981).

The growth habit of crops and competing weed species are important determinants of crop-weed competition (Wang *et al*., 2004). Even within a particular crop species, the competitive ability may be determined by genotypes or varieties of the species. Bussan *et al*. (1997) evaluated sixteen soybean genotypes for weed competitiveness and reported that the yield and ranking of soybean genotypes often varied with weed species. The report further indicated that the grass weed species reduced the yield the most and small seeded broadleaf weeds reduced yield the least across two years of cropping. In an assessment of three cowpea genotypes with similar vegetative vigour but different growth habit for their relative competitiveness with two weed species, Wang *et al*. (2004) reported that "iron clay" with an erect growth habit may be more effective in suppressing weeds than semi-erect or prostrate growth habit. It is however important to note that the effectiveness of crop genotype with erect growth habit in weed suppression may be determined by the crop biomass, crop density and spatial arrangement (Mohler, 2001; Olsen *et al*., 2005). Weed biomass was lower and crop biomass higher in wheat sown in random and uniform patterns than in normal rows in a 2-year field experiment to determine the spatial arrangement on weed suppression by spring wheat (Olsen *et al*., 2005). According to the report, increased density and spatial uniformity increased weed suppression by the wheat crop. Saini *et al*. (2007), in a field experiment to evaluate weed suppression provided by winter cover crops in a conservation tillage maize and cotton rotation noted a dramatic impact of planting date and the termination date of the cover crops of clover (*Trifolium incarnatum* L.) and rye (*Secale cereale* L.) on their biomass production even with a week's delay in winter cover crops planting, and corresponding reduction in summer annual weed suppression. The report further stated that more than ten times difference in biomass produced by clover was observed when clover was planted on the earliest and terminated on last date compared to late planting and early termination. Rye produced almost eight times more biomass in the same comparison. Correspondingly, weed biomass was 556 kg/ha in the treatment with least rye biomass, 8 times higher compared to the treatment with greatest rye biomass. Weed populations observed in clover were less than in rye even though the difference was only 34 kg/ha in case of clover. The data for the first two years show no significant relationship between cover crop biomass and the cash crop yield (Saini *et al*., 2007).

The effects of increased plant population on weed control in maize, cowpea, wheat and many other crops have also been reported. Norsworthy and Frederick (2005) reported that reducing the row width of *Zea mays* improved *Sida obtusifolia* and *S. rhombifolia* control while increasing grain yield by 10-15%. Other reports however indicated that climate, management and/or soil factors may affect crop responses to narrow row width (Jones *et al*., 2001; Norsworthy and Oliveira, 2004). Sowing the smother crops at optimum density is required to minimize inter- and intra-specific competitions among crops. At a higher smother crop population, the magnitude of competition may reduce the effectiveness of the smother crop and the main crop in controlling weeds (Zimdahl, 1980; Ayeni *et al*., 1984; Zuofa *et al*., 1992; Olsen *et al*., 2005).

Olasantan (2007), in his experiment to evaluate the effects of population density and sowing date of pumpkin on soil hydrothermal regime, weed control and crop growth in a yam–pumpkin intercrop reported that growing pumpkin between yam mounds reduced maximum diurnal soil temperature by 4.3–8.1 °C, weeding frequency by 52% and weed dry biomass by 50–67%, while soil moisture was conserved by 48–62 g kg^{-1}, earthworm casts were increased by 58–68% and yam tuber yield by 30–52%, irrespective of population density or sowing date, compared with yam monoculture. Intercropping had no effect on the growth and fruit yields of pumpkin, but leaf area index and apical shoot and fruit yields increased by 30–49% as the plant population increased to 10,000 plants ha^{-1}, beyond which there was no further significant increase. He further observed that increasing pumpkin population up to 10,000–15,000 plants ha^{-1} reduced soil temperatures by 0.7–1.2 °C, weeding frequency by 15–35% and weed dry biomass by 36–57%, conserved soil moisture by 46–63 g kg^{-1}, and increased earthworm casts by 20% compared to 5000 plants ha^{-1} in both cropping systems. The report further hinted that the sowing date did not affect earthworm casts and weeding frequency, but that pumpkin sown in March or April reduced soil temperatures by 2.6–4.0 °C and weeds by 27%, and conserved soil moisture by 15–37 g kg^{-1}, compared with May-sown plants. The report concluded that intercropping pumpkin up to 10,000 plants ha^{-1} with yam at an optimal sowing date target in March-April is recommended for maximum development and productivity, and when pumpkin is used for live mulch in yam plots to reduce supra-optimal soil temperature, excessive evaporation and weed growth.

2.4 Cover crops and herbicides

Using crop rotations with an effective herbicide programme can help alleviate some of the problems associated with some problematic weeds (Saini *et al*., 2007).

There are however, mixed results on the complementary use of cover cropping and herbicides on weed control in crop production. Ngouajio *et al*. (2003) reported no interaction of cover crops and herbicides on weed population in lettuce. Similar report was made on integration of cover crops with post emergence herbicides in no-till maize and soybean (Gallagher *et al*., 2003). Antagonistic effects were reported with herbicides and hairy vetch (*Vicia villosa* Roth.) cover crop for no-tillage maize (Teasdale, 1993). In a green house experiment, Teasdale *et al*. (2005) reported synergistic effects of cover crops residues and herbicide activity. There is dearth of published reports on the activity of pre-emergence herbicides and live cover crops. Most of the works reported here explored cover crop residues and herbicides. There are also mixed results on the post-emergence activities of some herbicides on legumes. While the National Advisory Committee on Weed Control (NACWC, 1994) observed that imazaquin could be used post-emergence within fourteen days after sowing of cowpea seeds, Ayeni *et al*. (1996) reported that imazaquin at 0.15 and 0.30 kg ai/ha killed cowpea while its mixture with acifluorfen, oxyfluorfen and pendimetalin severely reduced the crop growth.

2.5 Importance of Maize

Maize is a cereal crop that is grown widely throughout the world in a range of agro-ecological environments. More maize is produced annually than any other grain (IITA, 2007). Maize is an important source of food for man, component of livestock feeds and raw material for agro-allied industries. It is an important food security crop (Babatunde *et al*., 2008) as it provides for the consumption and income needs of the households and as an important component of livestock feeds. It is the most important cereal crop in Sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America. All parts of the crop can be used for food and non-food products. In industrialized countries, maize is largely used as livestock feed and as a raw material for industrial products. Maize accounts for 30−50% of low-income household expenditures in Eastern and Southern Africa (IITA, 2007). A heavy reliance on maize in the diet, however, can lead to malnutrition and vitamin deficiency diseases such as night blindness and kwashiorkor. According to some estimates of the Food and Agricultural Organization (2007), 158 million hectares of maize are harvested worldwide. Africa harvests 29 million hectares, with Nigeria, the largest producer in SSA, harvesting 3%, followed by Tanzania.

Federal Department of Agriculture (FDA) (1980) reported that maize was cultivated on about 1.5 million hectares of land (CIMMYT, 1994) with yield ranging between 0.2 and 2 tonnes per hectare. The total land area planted to maize in 2003 in Nigeria was about 4.7 million hectares with an estimated output of about 5.2 million metric tonnes (FAO, 2006). The output increased by 14.2% to 5.9 million metric tonnes in 2005. The world's production forecast for 2008 – 2009 seasons is 774 million metric tonnes for a consumption value of 789 million metric tonnes (IGC, 2008). This clearly demonstrates the important status maize has attained as source of food, feed and raw material as stated earlier on. The figures clearly indicated the inability of the present production systems to meet the current demand in the world which is much the same in Nigeria. Other reports put world-wide production of maize at 785 million tonnes, with the largest producer, the United States, producing 42%. Africa produces 6.5% and the largest African producer is Nigeria with nearly 8 million tonnes, followed by South Africa. Africa imports 28% of the required maize from countries outside the continent (IITA, 2007).

Maize is processed and prepared in various forms depending on the country. Ground maize is prepared into porridge in Eastern and Southern Africa, while maize flour is prepared into porridge in West Africa. Ground maize is also fried or baked in many countries. In all parts of Africa, green (fresh) maize is boiled or roasted on its cob and served as a snack. Popcorn is also a popular snack.

2.5.1 Production Constraints

The production of maize is still largely in the hands of peasant farmers who operate on areas of land that is less than 2 ha (Chikoye, 2000). Besides land consideration, other problems exist, which include: drought, insect pests and diseases and weeds. Drought could seriously reduce the yield of maize particularly when it occurs at the critical stages of its growth. These critical stages are the 3-leaf and 14-leaf stages of crop plant development (Hall *et al*., 1992). Maize does not tolerate drought well and the grain can rot during storage in tropical climates. A lack of sunshine and nitrogen can reduce the production potential of the crop. Insect pests and diseases constitute major constraints to the production of maize. Grasshopper, stem borer and others are examples of insects whose activities retard the growth and reduce the yield or performance of maize crop. Various species of stem borers rank as the most devastating maize pests in SSA. They can cause 20-40% losses during cultivation and 30-90% losses postharvest and during storage. Other pests in SSA include ear borers, armyworms, cutworms, grain moths, beetles, weevils, grain borers, rootworms, and white grubs (IITA, 2007). Diseases caused by *Puccinia polysora*, *Helminthosporium maydis* (leaf blight) equally adversely affect the performance of maize (Ogunbodede, 2000). Other maize diseases in SSA include downy mildew, rust, leaf blight, stalk and ear rots, leaf spot, and maize streak virus (MSV).

2.6 Weeds in crop production

Weed is one of the most important problems or pests that consistently make the dream of producing enough maize for the people unrealizable. It is a concept that means different things to different people resulting in the different ways it is defined. The Weed Science Society of America (Anon, 1983) defines a weed as "any plant that is objectionable or interferes with the activities or welfare of man." The emergence and development of any plant that is not deliberately raised by man constitute weed. Weeds represent an important variable in maize production, both economically and ecologically. For instance, smallholder farmers spend 50–70% of their total available farm labour on weed control and this control is usually carried out by hoe-weeding (Chikoye *et al*., 2002). Weeds bring about negative impacts on the crops growing around it. It also adversely affects the environment in diverse ways. Weed-related yield losses in maize ranging from 65 to 92% have been recorded in the Nigerian savanna (IITA, 2007). While Usman *et al*. (2001) observed that weeding maize after the critical period of weed removal can result in up to 83% losses in grain yield. Teasdale (1995) noted that weed competition can cause yield reductions of up to 70% in maize grain yields.

2.6.1 Weed-Crop Interaction

Weeds, like crops survive on the availability in quantity and quality of certain chemical substances and physical conditions of the soil. The chemical substances refer to plant nutrients, while physical conditions of the soil imply the structure, texture, porosity, consistency and bulk density that influence crops' performance.

Competition is a process driven by limiting resources such as nutrients, light, water etc (Silva *et al*., 2004). Rajcan and Swanton (2001) postulated that early season weed interference alters light quality (infra red ray) and triggers shade avoidance characteristics in maize resulting in reduced photosynthetic rate and reduced water and nutrient absorption. Akobundu, (1997) observed that in spite of the increase in improved cultivars, there is lower yield from the cultivars brought about by the degraded production environment compared to the 1980s. This is attributable to the influence of weeds.

The reduction in maize yield due to the presence of weeds is attributed to the crop-weed competition for water, light and nutrients (Silva *et al*., 2004). When infested by weeds, maize develops stress symptoms earlier due to the lack of water than when it is weed free (Tollenaar *et al*., 1997). However, Thomas and Allison (1975) observed that the water content in maize plots infested with weeds was greater than in maize plots without weed. Since infestation of weeds brought about stress symptoms in maize and weed infested plot contain more water than plots without weeds, it then follows that availability of water may not be responsible for the stress observed; poor root development due to physical impediment created by weeds may be responsible. Silva *et al*. (2004) observed that maize grown in the presence of weeds would have a less developed root system than when grown without weeds. Since there is poor root development, little quantity of roots will be formed and consequently, only small quantity of water will be absorbed leading to the observed stress condition in maize growing in weed infested plots. Yield loss due to maize-weed competition can be explained using Leaf Area Index (LAI) rather than reduced photosynthetic rates. The term "LAI" defines a plant's ability to intercept the incident photo flux. It is an important factor in determining dry matter accumulation (Rajcan and Swanton, 2001). High competition by weeds reduces LAI in maize at blooming by 15% (Tollenaar *et al*., 1994).

Weed problems in the Semi-Arid Tropics (SAT) are more complex than in temperate regions because of heterogeneous soil conditions, erratic rainfall, small holdings, and limited resources (Ramakrishna, 2003). Losses due to weeds are greater in raining season crops than in post raining-season crops because of labour shortages as heavy labour is required for rain-fed crops (Ramakrishna, 2003). The fertility of the soil plays a major role in the influence weeds bring to bear on companion crops. Ramakrishna (2003) observed that weed competition usually increases with increase in soil fertility. He observed further that in a naturally fertile vertisol, weed growth could be 2 to 3 times greater than a comparatively low fertile alfisol.

2.6.2 Weed Management

Weed management in crop production describes all the production efforts which directly or indirectly reduce the effects of weed-crop interference to an economically acceptable level. If weeds are not controlled in maize before it reaches critical period of weed competition, grain losses could be between 35 and 70% (Ford and Pleasant, 1994; Teasdale, 1995). Hall *et al*. (1992) defined the 3 – leaf and 14 – leaf stages of maize plant development as the critical period before which weed must be controlled. Several factors influence the response of maize to weed control. These include cultivars (Begna *et al*., 2001; Oswald and Ransom, 2002), weeds (species and densities) (Bendix, 1986), type of control (Saikia and Pandey, 1999) and other cultural practices (Begna *et al*., 2001).

Management methods being adopted to reduce weed incidence and interference with crop performance include burning, mechanical/physical, chemical and biological methods. Burning describes the use of heat (fire) to manage weeds such that they do not constitute any harm to the growth and development of crops. Disadvantages however accompany this method. These include destruction of microbes, loss of nutrients through volatilization as in the loss of S, C and N as SO_2, H_2S, NH_4^+ and CO_2 into the atmosphere. Organic matter and structure of the soil are also adversely affected (Ampong-Nyarko and Surajit, 1991).

Mechanical/Physical method describes any physical measure taken to remove weeds from the farm. It could be in the form of hand pulling, slashing with cutlass or hoe weeding, the use of motorised slashers and so on. Mechanical weeding and tillage are only common in large-scale production. The use of machine for weeding might be encouraged where large acreage of land is put under cultivation. The trend in many countries is to use mechanical weed control methods in order to reduce the use of herbicides (Liebman and Dick, 1993; Carruthers *et al*., 1998). The use of mechanical tillage for weed control could lead to depletion of soil organic matter and exposure to wind and water erosion (Rasmussen and Porton, 1994). The use of hoes or weeding generally by inexperienced or lazy workers may not be efficient resulting in higher or increased weeding frequency which invariably raises the cost of production (Akobundu, 1987).

Hand weeding is the most widely used method of weed control in maize used among small scale/peasant farmers. Generally, the first hand weeding in the humid tropics requires 25-30 man-days/ha (based on an 8 hour day). The second weeding takes 15-20 man-days/ha (Akobundu, 1987). Two or three hoe weedings 2-3, 5-6 and 8-9 WAS are considered satisfactory for most crops (Kumar, 1993). Two timely weeding within the first eight weeks of planting are recommended for maize to minimize yield reduction caused by weeds (Akobundu, 1987).

In organic farming systems, mechanical weed control is the most important measure for suppressing weeds. However, the repeated disturbance of the soil prevents the build-up and/or the maintenance of a stable soil structure (Moseley *et al*., 1996; Reeves *et al*., 1996). Furthermore, soil left bare after tillage operations is prone to erosion, and the run-off and leaching of pesticides into surface and ground water is a major concern in today's agriculture. Hence, there is a dilemma as to whether mechanical operations should be reduced or herbicides should be used to control weeds. The change from conventional to organic farming, as well as the adoption of conservation tillage, of which no-tillage is the most extreme form, leads to changes in weed populations. Perennials may be a problem in both organic farming and conservation tillage: in the former system when ploughing is shallow and in the latter because it favours anemochore (wind-borne weed seeds) and monocotyledonous species (Buhler, 1995). As organic farming systems rely on a limited spectrum of means for controlling an established weed community, prevention of seed production is especially important in contributing to the long-term productivity of the targeted areas. Adequate weed control is necessary for achieving the benefits of both no-tillage and organic farming practices. Living soil cover between crop plants (living mulches) has been proposed as an environmentally sound option for suppressing weeds (Liebman and Dyck, 1993; Teasdale, 1996).

The use of herbicides which may be in form of liquid, powder or solid which may be applied as pre or post weed emergence treatment to manage weeds incidence such that their effect is reduced to harmless levels is referred to as chemical weed management. Chemical weed control is usually preferred (Geoge, 1982) because it has several advantages which include precision, it is relatively cheaper and more effective than manual hoe-weeding. However, continuous use of herbicides may induce the development of resistance in the weeds. De Prado and Franco (2004) observed a development of resistance by weeds in conventional agriculture to pesticides being used to control them, making them less and less effective. Resistance to herbicide is increasing aside being expensive and causing environmental pollution (Carrathers *et al*., 1998). Pollution of land and water resources makes the search for a more cost effective and environmentally friendly alternative imperative. Field and weather conditions can delay application as well as reduce uptake of herbicide into plant tissue (Fisk *et al*., 2001). Akobundu (1987) opined that the effectiveness of applied herbicides depend on environmental factors such as weather (rainfall, humidity, temperature, etc), leaching, adsorption to soil colloids and volatilization, etc. He further observed that too dry soil during application renders it ineffective or if dry spell follows application made on moist soil.

Biological Weed Management describes the processes whereby living organisms such as insect predators, pathogens, growing plants, etc are used to manage weeds such that crops grow and develop optimally. Some insects e.g. beetles are used to manage some weed incidence as found in the use of some moths which feed on water hyacinth thereby reducing their growth and development. Low growing or creeping crops can be planted in between established crops such that when they grow, the ground surface is covered including weeds. They are then deprived of light and other resources. The use of these methods (cover cropping or mulch inter-planting) brings about considerable benefits to the farmer, his crops and the soil.

2.6.3 Weed Suppression with cover crops

Cover crops produce biomass, mass of leaves and branches which cover the surface of the soil and weeds together. In so doing, weeds are deprived of essential requirements for their growth and development. Their performance in terms of vegetative growth and yield are retarded. Through this, competition between weeds and crops will not reach a level that will be harmful to the crops. Akobundu (1980; 1982) stated that leguminous cover crops have the ability to suppress weeds. Various forms of cover cropping exist which can be utilized for weed suppression roles. They are sources of food for man e.g. cowpea, groundnut, sweet potato and soybean. Akobundu (1980) and Wahua (1985) observed that as *in-situ* mulch, low growing crops or creepers are beneficial to the farmer. He gets additional income in the form of little harvest, which can be consumed before the main crop is ready or make some money from their sale. They further observed that sweet potato and 'Egusi' melon are very effective in suppressing weeds in maize cassava intercropping system as they provide a good substitute for repeated hand weeding. Other forms of cover crops provide ready feed source for livestock. Examples include *Centrosema pubescens*, *Pueraria phaseloides, Calopogonium mucunoides, Stylosanthes gracilis* and *Mucuna pruriens* var *utilis.*

Selection of a particular species for weed suppression role would be based on a number of characteristics among which are growth habit, whether it is a creeper or it is one that grows erect on the field, length of time taken to fully establish and cover the ground and quantity of biomass produced. A creeper performs a better weed suppression job than an erect one. 'Egusi' melon matures in less than 3 months and being a fast spreading creeper, it usually provides effective weed suppression in traditional mixed cropping with other crops such as yam, maize or cassava (Aseogwu, 1987, Obiefuna, 1989). Melon could produce a few centimetres (3 - 5 cm) of its vine in a day. Quantity of biomass produced is directly related with the area of land it can cover. When biomass is high, area of ground covered is equally high and weed suppression is more effective. Reduction in weed biomass or its suppression as observed by Akinyemi and Tijani-Eniola (1997) is achieved through reduction in weed seed germination or smothering of germinated seedlings and established weed.

Percentage of the ground covered and duration of the biomass production are among other important characteristics, which enhance weed suppression ability of cover crops. This is the area of the ground effectively covered by the cover crop biomass such that weeds growing in such areas are rendered harmless. The duration of the biomass production is, the length of time the effective cover provided by the cover crop biomass is maintained. This is important to keep weeds at harmless level or below threshold point thus encouraging the crops to perform optimally.

Intercropping melon at 20,000 plants per hectare in cassava/maize mixture has been found to reduce weeding frequency from 2 or 3 times to just once at 2-3 weeks after planting (IITA, 1984). Akinyemi and Tijani-Eniola (1997) stated that over the years, intercropping of plantain with low growing crops such as 'egusi' melon (*Colocynthis citrullus*) has been common practices by local farmers to reduce weed growth at critical stages. Cover crops often reduce density and biomass of annual weeds in no-till cropping systems (John, 2001). Density of winter annual weeds were observed to be between 41 and 78% lower following most cover crops when compared with no cover control in 2 out of 4-sites-year. While dry weight was between 26 and 80% lower in all 4-site-year (Teasdale *et al*., 1991; John, 2001). Bilalis *et al*. (2010) recorded a statistically significant negative correlation between the fraction of photosynthetically active radiation (Fint PAR) intercepted by the canopy, and both weed density and weed dry matter. Maize–legume intercropping led to a higher soil canopy cover (leaf area index) than sole crops. The lowest values for Fint PAR were received in sole crops. Thus, in maize–legume intercrops the decrease in available light for weeds led to a reduction of weed density and dry matter, compared to sole crops.

Cover crops like velvetbean (*Mucuna cochinchinensis*), hairy vetch (*Vicia villosa* Roth), crimson clover (*Trifolium incarnatum*) and subterranean clover (*T. subterraneum* L.) have been shown to reduce weed density and dry weight of early season weeds (Teasdale *et al*., 1991; Johnson *et al*., 1993; Yenish *et al*., 1996; Chikoye *et al*., 2004). In a trial where weed suppression by annual leguminous cover crop in no-tillage maize was investigated, John *et al*. (2001) found out that legumes have the potential to reduce weed populations. In the same vein, De Haan *et al*. (1997), discovered that weed populations were reduced when annual medics were inter-seeded with maize. Intercropping and cover crops can significantly reduce weed infestations (Liebman and Dyck, 1993).

Weed establishment and growth is reduced by competing with the cover crop for growth resources, changing environmental factors and possibly phytotoxins released from the cover crops. Yenish *et al*. (1996), in their work that evaluated forage yield and quality of six annual Medicago species in the north central USA, reported a reduction in the biomass of weeds sampled 45 days after crop planting, by winter annual legume cover crops.

It has been suggested that weed biomass may be less influenced than weed density by the residual of over-wintering cover crops (Teasdale, 1996), because weeds will compensate for lower density by increasing biomass. Reduction in weed growth could result from allelopathic chemicals released by the legumes from microbial metabolic activity on the residue (Worsham, 1991).

2.6.4 Effects of Cover Crops on the Soil

It is observed that leguminous cover crops can replace fertilizer nitrogen (Blevin *et al*., 1990; Hesterman *et al*., 1992), maintain and improve soil organic matter and structure (Frye *et al*., 1988; Smith *et al*., 1987). When leguminous cover crops are integrated into cropping systems as observed by Carsky *et al*. (1999), they are usually expected to enhance nutrient availability for companion crops. They are known to promote efficient utilization of soil and fertilizer nutrients and make direct contributions to improve soil nutrient content. Hauggaard-Nielsen *et al*. (2001) observed that legume–cereal intercropping offers a potential method of reducing inputs such as fertilizers.

Incorporation of grain legumes such as cowpea, pigeon pea, soybean and groundnut into rotation in cropping systems improves soil fertility (Hulugalle and Lal 1986; IFDC, 1993). The use of legume is recommended (Oliveira and Carvallo, 1988) for the recovery of soils with poor natural fertility in Brazil or that have been depleted by intensive use, a common occurrence in the region. Crawford *et al*. (1989) observed that annual medics (*Medicago* spp), a leguminous cover crop provide high quality forage, contribute N to the soil and non-leguminous species of crops and improved physical structure of the soil. The importance of melon in conserving soil moisture and reducing supra-optimal soil temperature early in the growing season reported by Ikeorgu and Ezumah (1991) suggest the crop's suitability for inter cropping with yam minisetts. Miracle (1967) intercropped *Cucurbits* spp (Pumpkin) with maize in Congo basin mainly for weed control and to conserve moisture. Ikeorgu *et al*. (1988) working on cassava/maize/melon intercrop showed that melon (*Citrullus lanatus*) cucurbitaceae was effective in conserving soil moisture increasing leaf water status and yield.

2.6.5 Effects of cover crops on Crop Yield

Cover crops' effect on the soil's physical, biological and chemical characteristics could bring about positive effects on the yield of companion crops. A group of investigators observed that despite the positive effects often produced by winter annual cover crops in maize production, there is also a potential for reduction in maize yield (Badaruddin and Meyer, 1989; Hesterman *et al*., 1992; Tiffin and Hesterman, 1998). They further observed that spring re-growth of legumes can lower available water in the subsoil creating conditions of moisture stress for maize in years of low precipitation. De Haan *et al*. (1997) observed that annual medics inter-seeded several weeks after maize planting did not affect maize yield. However, in IITA (2004) annual report, it was noted that intercropping maize with legumes or cassava reduces stem borer infestations and increased maize yield in Southern Cameroon. The inclusion of grain legumes like groundnut, cowpea, pigeon pea, soybean, etc into the cropping systems, increases maize yield by about 50% (Hulugalle and Lal, 1986;

IFDC, 1990; 1992; 1993). Grain yield of maize in maize/melon mixture was found to be slightly higher than sole crop (IITA, 1974).

The inclusion of vegetable such as melon and okra as observed by Ikeorgu *et al*. (1989) did not depress maize or cassava yields but rather helped to improve total productivity of the inter-crop system. In his work on the effect of soil management on maize yield and soil nutrient in rain forest zone of West Africa, Agboola, (1972) found out that when maize is intercropped with cowpea, the yield of the former was significantly increased. Also, Aladesanwa and Adigun (2008), in a trial that investigated the influence of sweet potato live mulch at three intra-row spacings (60 x 25 cm, 60 x 50 cm and 60 x 75 cm) on weed suppression and yield response of maize in South-western Nigeria, reported that all the spacings tested significantly ($P < 0.05$) suppressed weed growth and increased grain yield over the unweeded sole maize.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of Experimental Sites

3.1.1 Location

The trials were conducted at Lanlate (7^{o} 33^{1} N and 3^{o} 27^{1} E) in 2007 cropping seasons and Ido (7^{o} 28^{1} N and 3^{o} 45^{1} E) in 2008 to 2009 cropping seasons. Both sites are on 192 m above sea level in Oyo State of south-western Nigeria. Ido is located in the forest-savanna transition zone of the country. Lanlate, which is also in the forest-savanna transition zone of the country, shares boundary with Eruwa, the capital of Ibarapa East local government Area of Oyo State. The meteorological data (rainfall and temperature) for the sites during the experimental period are presented in Table 3.1.

3.1.2 Cropping History of the Sites

The site used for the trials at Lanlate was a field cropped with maize, okra, melon and pepper intensively in the previous years put under fallow in the last seven year before the trial. The dominant weed types were grasses with *Panicum laxum* Sw., *P. ripens* Linn., *P. maximum* Jacq., *Brachiaria lata* Schumach. and some stands of *Imperata cylindrica* Linn.. The broad-leaved weeds encountered included *Vernonia cinerea* Linn., *Cleome viscosa* Linn., *Gomphrena celosioides* Mart., *Mitracarpus villosus* (Sw.) DC. The site at Ido was cropped with yam, cassava, cocoyam and pepper and left under fallow for a period of over 8 years before the commencement of the trials. Predominant weed encountered at the site before the experiment began was siam weed (*Chromolaena odorata* (L.) R.M. King & Robinson). Other weeds found on the site included *Aspilia africana* (Pers.) C.D. Adams, *Sclerocarpus africanus* Jacq. ex Murr., *Synedrella nodiflora* Gaertn., *Combretum hispidum* Laws., *Momordica charantia* Linn., *Alchornea cordifolia* (Schum & Thonn.) Mull. Arg., *Senna hirsuta* (Linn.) Irwin & Barneby.

3.2 Cultural practices

3.2.1 Land preparation

Vegetation on the sites was slashed using cutlass. Dried residues were burnt before stumping was carried out. The land was then ploughed and harrowed.

3.3 Soil sampling and Analysis

After land preparation but prior to planting, 15 core soil samples were collected from the experimental sites with soil auger at 0-15 cm depth. These were bulked together, air dried and later ground in a mortar to break the soil aggregates. The bulked sample was passed through a 2 mm sieve to remove large particles, debris and pebbles. Routine soil analyses were carried out to determine the physical and chemical properties of the soil. The sieved sample was analysed for pH in 1:1 soil to water ratio using the Coleman's pH meter. Organic carbon was determined by Walkley and Black procedure (Nelson and Somers, 1982). Organic matter was estimated as organic carbon multiplied by 1.724 (Odu *et al*., 1986).

Total N was determined by Micro Kjedhal Method (Bremner, 1960) while available P was extracted by Bray's P1 Method (Bray and Kurtz, 1945) and read from a spectrophotometer. Potassium, calcium, sodium and magnesium were first extracted using NH_4OAC. Thereafter, K, Na and Ca were determined using flame photometer while Mg was read from atomic absorption spectrophotometer (AAS). Textural analysis was done by hydrometer method as described by Odu *et al*. (1986). Exchangeable acidity (H^+) was determined by titration method. Particle size distribution was done by hydrometer method of soil mechanical analysis, as outlined by Bouyoucos (1951).

3.4 Experiment 1: Comparative effects of some pre-emergence herbicides on emergence and growth of cowpea, melon, "akidi" and pumpkin

3.4.1 Experimental design, treatments, procedure and layout

The experiment was conducted to evaluate the effects of pre-emergence herbicides recommended for maize on the performance of cowpea, melon, akidi and pumpkin. The herbicides included atrazine (Atraforce® 50% SC), a formulated mixture of atrazine and metolachlor (Xtravest®), S-metolachlor (Dual® gold 950 g/l EC), a mixture of promectryne + metolachlor (Codal® gold 250 g + 162.5 g) and a mixture of S-metolachlor + terbutryn (Igran Combi® Gold 250 g + 200 g). The experiment was carried out in the 2007 and 2008 cropping seasons at Lanlate, Ibarapa area of Oyo state, Nigeria. In 2008 cropping seasons, Metaforce (960 g/l EC S-metolachlor), Atraforce and Xtravest were evaluated in Ido site.

Table 3.1: Rainfall and temperature data for Ido during the experimental period (2007, 2008 and 2009)

	2007				2008				2009			
	Rainfall		Temperature (^0C)		Rainfall		Temperature (^0C)		Rainfall		Temperature (^0C)	
	No of wet days	Month total (mm)	Min. Temp.	Max. Temp.	No of wet days	Month total (mm)	Min. Temp.	Max. Temp.	No of wet days	Month total (mm)	Min. Temp.	Max. Temp.
Jan	0	0	16.2	33.5	0	0	16.6	33.2	1	16.6	20.38	34.58
Feb	0	0	22.5	35.8	1	3	19.3	36.2	6	73.0	22.36	35.11
Mar	4	12.2	22.8	36.9	10	43.2	21.9	36.2	7	90.5	22.32	35.13
Apr	6	36.4	20.7	35.3	6	126.6	21.6	34.2	10	200.8	21.50	33.67
May	9	143.8	21.9	33.3	11	188.9	21.0	33.5	9	203.5	21.34	33.35
Jun	13	182.2	20.8	31.2	15	235.8	20.9	31.5	12	226.9	21.10	31.77
Jul	16	184.7	20.7	29.3	16	142.3	21.1	30.8	16	155.7	20.81	30.39
Aug	11	111.4	19.4	28.6	11	179.8	20.7	30.1	11	38.0	20.90	29.06
Sep	17	245.8	20.6	30.0	17	197.2	21.3	31.2	11	136.1	20.97	31.00
Oct	16	256.6	20.6	30.7	9	167.9	20.8	32.8	12	213.3	21.32	31.19
Nov	3	39.5	21.5	32.6	2	12.4	22.0	34	6	57.8	18.63	33.77
Dec	1	11.5	19.1	33.0	2	22.2	20.5	34.9	1	12.5	21.32	35.71
Total		1224.1			100	1319.3	-	-	102	1424.7	-	-

Source: Institute of Agriculture Research and Training, Ibadan

The experimental design was a split-split plot with four replications. The four cover crops were the main plot factor with the five herbicide types as the sub-plot factor while the five rates for each of the herbicides were the sub-sub-plot factor. The herbicides were applied at 0, 25, 50, 75 and 100% recommended rates of the active ingredients as shown in Table 3.2. The herbicides were applied with knapsack sprayers with flood nozzle tips which were calibrated to discharge spray liquid at known rates. One of the sprayers for instance discharged spray liquid at the rate of 25 ml/s and had a spray swath of 0.8 m at nozzle kneel level. This translated to a spray volume of about 313 l/ha. Equivalent amounts of each herbicide were calculated and applied to each of the plots.

3.4.2 Cultural practices

Three seeds per stand of each of the four cover crops were sown 25 cm within row and 50 cm between rows. The seeds used had previously been tested for viability and were found to have viability which ranged between 95 to 100% for all the cover crops. There were two rows for each of the crops in plot that measured 3.5 x 2.75 m. There were thus 60 seeds sown for each of the crops upon which observations were made for seedling establishment. The seedlings were thinned to one per stand at 14 days after sowing and samples were harvested from an area of 1 m^2 using a quadrat for dry matter yield at 4 WAS.

3.4.3 Data collection and analysis

Data were collected on emergence count of cowpea, akidi, melon and pumpkin at 2 weeks after sowing and on the dry mater production at 4 WAS. The drying was done using an oven at temperature of 100^0C until constant weights were obtained. The data collected were subjected to Analysis of Variance (ANOVA) and means were separated using Least Significant Difference (LSD) test.

Table 3.2: The formulations, recommended rates and the amount of the herbicides used for the trial

Herbicides	Formulation	Recommended rate (Kg a.i/ha)	Amount used (Kg a.i/ha) for the employed percentages (0 – 100%)				
			100	75	50	25	0
AtraForce®)	Atrazine 50% SC	1.2 – 2	1.20	0.9	0.6	0.3	0
MetaForce®)	S-metolachlor 960 g/l EC	0.58 – 1.92	0.58	0.44	0.29	0.15	0
Xtravest®)	Atrazine + S-metolachlor (270 + 150 g/l SE)	1.68 – 2.1	1.68	1.26	0.84	0.42	0
Dual®	S-metolachlor 950 g/l EC	0.57 – 1.43	0.57	0.43	0.29	0.15	0
Codal®	Promectryne + S-metolachlor (250 +162.5 g/l EC)	1.65 – 2.06	1.65	1.24	0.83	0.41	0
Igran Combi®	S-metolachlor + terbutryn (250 + 200 g/l EC)	1.8 – 2.25	1.80	1.35	0.90	0.45	0

3.5 Experiment 2: Comparative effects of various densities of cowpea, melon, "akidi" and pumpkin on weed suppression, growth and yield in maize production

3.5.1 Experimental design, treatments, procedure and layout

The experiment was conducted at Lanlate between July and November 2007 and at Ido in the early and late cropping seasons (May to August) and (August to November) in 2008. The experiment was conducted to evaluate the cover crops at various populations and determine the appropriate population density that would enhance weed suppression and good maize crop performance.

Three seeds of maize (variety ACR 9931 DMR SR Y), the main crop, was sown on the flat on 80 cm wide rows and intra-row spacing of 50 cm. Maize was thinned to 2 plants per stand two weeks later, thus having a population of 50,000 plants per hectare. The cover crops were sown in rows 40 cm from each maize row. The intra-row spacing for the cover crops are indicated in Table 3.3. Melon and pumpkin were sourced from local markets in Lanlate while akidi was obtained from markets in Jalingo in Taraba State. Cowpea (ITK97K-1069-6) was obtained from IITA, Ibadan. The experiment was laid out in Randomized Complete Block Design (RCBD) with four replicates. The plot size measured 5 m x 5 m and was separated by 1 m borders from the next. The blocks were partitioned by 2 m pathways. All the plots, except those of the weedy check had one hoe weeding which was done at 4 weeks after sowing (WAS) of the maize and the cover crops seeds.

3.5.2 Data collection and analysis

Data were collected on weed floral composition, density and biomass either at harvest or at physiological maturity of maize. The weed densities were measured by counting the number of weeds found within a 0.25 m^2 quadrat randomly placed on each of the plots. The weed floral composition was assessed by sorting the weeds that were counted for weed density into their respective species and identification made using standard reference (Akobundu and Agyakwa, 1987). The weed samples were then oven-dried to constant weight and weighed for weed dry matter assessment. The growth parameters of the cover crops (the growth of the cover crops were measured in terms of their vine spread on the soil surface, thus a measure of their percentage soil coverage was used).

Table 3.3: Treatment combinations for Experiment 2

S/N	Crops combinations	Cover crop density (Number of plants/ha)	Planting Spacing	
			Maize	Cover crops
1	Maize + akidi	20,000	0.5 m x 0.8 m	0.63 m x 0.8 m
2	Maize + akidi	26,666	0.5 m x 0.8 m	0.47 m x 0.8 m
3	Maize + akidi	40,000	0.5 m x 0.8 m	0.31 m x 0.8 m
4	Maize + cowpea	20,000	0.5 m x 0.8 m	0.63 m x 0.8 m
5	Maize + cowpea	26,666	0.5 m x 0.8 m	0.47 m x 0.8 m
6	Maize + cowpea	40,000	0.5 m x 0.8 m	0.31 m x 0.8 m
7	Maize + melon	20,000	0.5 m x 0.8 m	0.63 m x 0.8 m
8	Maize + pumpkin	10,000	0.5 m x 0.8 m	0.8 m x 1.25 m
9	Maize + pumpkin	12,500	0.5 m x 0.8 m	0.8 m x 1 m
10	Maize + pumpkin	15,000	0.5 m x 0.8 m	0.8 m x 0.83 m
11	Sole maize HW control	-	0.5 m x 0.8 m	--
12	Sole maize weedy check	-	0.5 m x 0.8 m	--

Note: HW = Hoe-weeded

The yields of maize and the cover crops as well as their total biomass after harvest were also measured. Soil coverage percentages were obtained by visual estimation of soil covered by the cover crops within a 1 m quadrat. The data collected were subjected to ANOVA and the means, where significant differences existed, were separated using either Duncan's Multiple Range Test (DMRT). Correlation analyses were also carried out.

3.6 Experiment 3: Weed management with complementary use of pre-emergence herbicides and cover crops in maize production

3.6.1 Experimental design, treatments, procedure and layout

The experiment was conducted in Ido in the early and late cropping seasons of 2008 and 2009 to determine the effects of complementary use of cover crops on the efficacy of pre-emergence herbicides for weed control in maize production. The effective rates of the selected herbicides that were found compatible with the cover crops and the optimum densities of each of the cover crops determined in experiments 1 and 2 respectively were used for this experiment. The treatments thus consisted of three herbicides - Metaforce, Xtravest and Atraforce at 50 and 75% recommended rates in combinations with the cover crops of cowpea, akidi and melon each at population density of 20,000 plants/ha, and pumpkin at population density of 10,000 plants/ha. The treatments were laid out in RCBD, with four replicates. The treatments combinations are shown in Table 3.4. Maize was maintained at population density of 50,000 plants per ha. The treatments were randomly allocated to the plots at the start of each trial. No weeding was done and no fertilizer application was made.

3.6.2 Data collection and analysis

Data collection and analysis were as in experiment 2.

3.6.3 Economic analyses

Economic analysis was carried out using Partial Budget Technique (PBT) after Alimi and Manyong (2000). Partial budgets were developed for each treatment in Experiments 2 and 3. The application rates of all the variable inputs including the operational costs were those prevalent in the study area during the period of investigation. Gross returns per hectare were calculated as the product of the adjusted

Table 3.4: Treatment combinations for Experiment 3

S/N	Cover crop	Herbicides	Herbicide rate	Kg ai/ha
1	Akidi	Metolachlor	75%	0.44
2	Akidi	Metolachlor	50%	0.29
3	Akidi	Atrazine	50%	0.60
4	Akidi	Xtravest	50%	0.84
5	Melon	Metolachlor	75%	0.44
6	Melon	Metolachlor	50%	0.29
7	Melon	Atrazine	50%	0.60
8	Melon	Xtravest	50%	0.84
9	Pumpkin	Metolachlor	75%	0.44
10	Pumpkin	Metolachlor	50%	0.29
11	Pumpkin	Atrazine	50%	0.60
12	Pumpkin	Xtravest	50%	0.84
13	Sole maize HW control	-	-	-
14	Sole maize weedy check	-	-	-

Note: HW = Hoe-weeded

treatment yields and the farm gate prices. The treatment yields were scaled down by 10% (Alimi and Manyong, 2000) to obtain the approximate yields that the farmers can achieve on his farm as provided in the PBT. Net returns were calculated as the differences between the gross incomes and the total costs. The Marginal Rate of Return (MRR) for each treatment was calculated as the ratio of the change in the net benefit to change in total variable input cost. The MRR compares the extra (marginal) cost of production with the extra benefit resulting there from. This was computed as the percentage of the ratio of the extra benefit from investment on a weed management practice to the extra investment on the practice (Alimi and Manyong, 2000).

3.7 Experiment 4: Effects of cover crop rotation on weed infestation and maize growth and productivity

3.7.1 Experimental design, treatments, procedure and layout

The experiment was conducted at Ido in the early and late cropping seasons in year 2008 and 2009. There was alternation or rotation of the four cover crops, two of which were of Fabaceae (legumes: cowpea and akidi) and the other two Cucurbitaceae (non-legumes: melon and pumpkin) families, on the plots that were planted to maize. There were 13 treatment combinations made up of the various cover crops combinations and controls of hoe-weeded, no weeding and herbicide managed plots (Table 3.5). The cover crops were planted at the densities that were found optimum for use for weed control in maize plots from experiment 2. Thus a density of 20,000 plants/ha was used for akidi or cowpea and a density of 10,000 plants/ha was used for pumpkin and a standard 20,000 plants/ha was used for melon. The weed control in the hoe-weeded plot was done three times, while for the herbicide control plot, Xtravest® was employed at the rate of 1.26 kg a.i/ha and applied pre-emergence at 2 days after sowing. All the plots except the sole maize weedy checks were hoe-weeded once at 4 WAS. The treatments were replicated four times in RCBD. The plot sizes were 4 m x 5 m with 1 m boarders separating two plots and a 2 m path separated two blocks. The experimental field measured about 1,365 m^2.

3.7.2 Data collection and analysis

Data collection and analysis were as in experiment 2.

Table 3.5: Treatment combinations for Experiment 4

S/N	Early 2008	Late 2008	Early 2008	Late 2008
1	Maize + Melon	Maize + Akidi	Maize + Pumpkin	Maize + Cowpea
2	Maize + Melon	Maize + Cowpea	Maize + Pumpkin	Maize + Akidi
3	Maize + Pumpkin	Maize + Akidi	Maize + Melon	Maize + Cowpea
4	Maize + Pumpkin	Maize + Cowpea	Maize + Melon	Maize + Akidi
5	Maize + Melon	Maize + Akidi	Maize + Melon	Maize + Akidi
6	Maize + Melon	Maize + Cowpea	Maize + Melon	Maize + Cowpea
7	Maize + Melon	Maize + Melon	Maize + Melon	Maize + Melon
8	Maize + Akidi	Maize + Akidi	Maize + Akidi	Maize + Akidi
9	Maize + Cowpea	Maize + Cowpea	Maize + Cowpea	Maize + Cowpea
10	Maize + Pumpkin	Maize + Pumpkin	Maize + Pumpkin	Maize + Pumpkin
11	Maize + Herbicide	Maize + Herbicide	Maize + Herbicide	Maize + Herbicide
12	Hoe-weeded	Hoe-weeded	Hoe-weeded	Hoe-weeded
13	No weeding	No weeding	No weeding	No weeding

Note: S/N 1 = Melon, akidi, pumpkin and cowpea were used as cover crops in maize plots in sequence in early, late 2008, early and late 2009 seasons respectively.

CHAPTER FOUR

RESULTS

4.0 General properties of the soil of the experimental site

The pre-cropping physical and chemical properties of the soil at the experimental sites are presented in Table 4.0. The soil at Ido was fairly high in organic matter content (31.65 g kg^{-1}). It was also moderately high in organic nitrogen, available P and exchangeable bases. The textural class was sandy loam. The soil at Lanlate site had lower amount of organic matter (24.17 g Kg^{-1}) and other soil nutrients. The textural class was also sandy loam.

4.1 Experiment 1: Effects of some pre-emergence herbicides on emergence and growth of cowpea, melon, "akidi" and pumpkin

Results on the effects of the pre-emergence herbicides on cover crops seedling emergence and dry matter production of cowpea, melon, akidi and pumpkin are contained in Tables 4.1 to 4.9.

4.1.1 Seedling emergence

The emergence of seedlings of cover crops at 2 WAS was significantly affected by the type of cover crops as well as types and rate of the herbicides at Lanlate in 2007 and Ido in 2008 (Table 4.1). The emergence of pumpkin seedlings was significantly lowered by 10 and 12% at Lanlate and Ido respectively compared to other cover crops. Pre-emergence application of Atraforce and Xtravest similarly reduced seedling emergence of the cover crops by 12 and 10% respectively at Lanlate and Ido. Across the different types of the pre-emergence herbicides and the cover crops, herbicide application at 100 and 75% of recommended rate respectively reduced cover crop seedling emergence by 15 and 10% at Lanlate and correspondingly by 19 and 12% at Ido.

The interaction between herbicide types and cover crops was significant on cover crops seedling emergence at Lanlate (Table 4.2). Among the treatment combinations, akidi and melon treated with Codal, Dual and Igran combi had significantly higher seedling emergence than the minimum with pumpkin treated with Atraforce and Xtravest. Pumpkin seedling emergence on the plots treated with atraforce and Xtravest at Lanlate was 16% lower compared with the

Table 4.0: Physical and Chemical properties of the soil before planting

Soil properties and units	Values	
	Ido	**Lanlate**
pH (KCl)	5.4	5.6
pH (H_2O)	6.3	6.4
Organic C (g Kg^{-1})	18.4	14.2
Total N (g Kg^{-1})	4.5	2.7
Available P (g Kg^{-1})	14.9	12
Exchangeable bases (cmol Kg^{-1})		
Ca	12.7	10.3
Mg	1.74	1.53
Na	0.9	1.0
K	1.5	1.1
Exchangeable Acidity (cmol Kg^{-1})	0.4	0.5
CEC (cmol Kg^{-1})	17.24	14.43
Base saturation (cmol Kg^{-1})	84.91	96.54
Particle size (g Kg^{-1})		
Sand	806	831
Silt	114	98
Clay	80	71
Textural class	Sandy loam	Sandy loam

Table 4.1: Cover crops seedling emergence and dry matter production as influenced by types of the cover crops and types and rate of pre-emergence herbicides at Lanlate in 2007 and Ido in 2008

Treatments	Emergence		Dry matter	
	Lanlate	Ido	Lanlate	Ido
Cover crops				
Akidi	56.5a	55.9a	8.04a	8.3a
Cowpea	56.8a	56.5a	9.3a	9.0a
Melon	56.9a	56.1a	6.2b	6.0b
Pumpkin	54.1b	52.8b	6.5b	6.6b
Herbicides				
Atraforce	53.0b	54.1b	7.0b	7.4a
Codal	58.2a	-	7.9a	-
Dual	57.5a	57.8a	7.7ab	7.6a
Igran-combi	58.4a	-	7.9a	-
Xtravest	53.3b	54.1b	7.1b	7.4a
Herbicide rates				
100%	51.1d	48.5d	6.9b	6.4b
75%	54.1c	52.9c	7.6a	7.6a
50%	57.7b	57.8b	7.8a	7.7a
25%	58.6a	58.6ab	7.5a	7.7a
Control	58.9a	58.9a	7.8a	8.0a
Interactions*	LSD			
C x H	1.13	1.55	1.08	1.11
C x R	1.21	1.99	1.09	1.17
H x R	1.32	1.68	1.07	0.95
C x H x R	2.57	3.27	0.71	1.50

Means in a column with the same letters for treatments within each factor are not significantly different using LSD ($P \leq 0.05\%$)

* all interactions were significant ($P \leq 0.05\%$)

- Codal and Igran-combi were not used at Ido

Table 4.2: Interaction of types of herbicide and cover crops on seedling emergence at Lanlate in 2007 and Ido in 2008

	Atraforce	Codal	Dual gold	Igran-combi gold	Xtravest
			Lanlate		
Akidi	52.9ab	58.6a	58.1a	58.8a	54.2ab
Cowpea	54.6ab	58.9a	57.4ab	59a	54.3ab
Melon	54.8ab	58.2a	57.8a	58.7a	54.9ab
Pumpkin	49.7b	57.3ab	56.8ab	57.1ab	49.8b
			Ido		
Akidi	54.4a	-	58.4a	-	54.9a
Cowpea	56.1a	-	58.2a	-	55.3a
Melon	55.4a	-	57.7a	-	55.1a
Pumpkin	50.4a	-	57.0a	-	51.0a

Means with the same letters for interaction in each location are not significantly different using DMRT ($P \leq 0.05\%$)

- Codal and Igran-combi were not used at Ido maximum obtained for cowpea on plots sprayed with Igran combi. The interaction of herbicide types and rates was significant on cover crops seedling emergence at Lanlate and Ido (Table 4.3). Application of Xtravest at 75 and 100% and Atraforce at 100% of recommended rates caused significant reduction in cover crops seedling emergence by 27, 30 and 19% respectively compared with control at Lanlate. Similarly at Ido, application of atraforce and Xtravest each at 100% of recommended rate resulted in significant reduction of cover crops seedling emergence by 24%.

The interaction of rates of herbicides and cover crop types was significant on seedling emergence of the cover crops (Table 4.4). Application of the herbicides at 100% of recommended rates reduced the emergence of pumpkin by 23 and 29% at Lanlate and Ido respectively compared to the controls while 75% herbicide rate caused 16% reduction at Ido. Furthermore, application of the herbicides at 100% of recommended rates reduced the seedling emergence of melon by 15% relative to control at Ido.

The results of interaction of rates and types of herbicides and cover crops on seedling emergence of the crops are presented in Table 4.5. All the herbicides at 100% of recommended rates significantly reduced the seedling emergence of pumpkin, while Atraforce and Xtravest each at 100% of recommended rates also reduced seedling emergence of the other three cover crops, akidi, cowpea and melon at both locations. With the exception of cowpea at Ido, Atraforce and Xtravest each at 75% of recommended rates significantly reduced seedling emergence of the four cover crops compared with controls of no herbicides in both locations. Atraforce and Dual at 75% of recommended rates did not cause significant reduction in seedling emergence of cowpea compared with the control at Ido while Dual at 75% of recommended rate reduced pumpkin seedling emergence at Lanlate. The highest seedling emergence reductions of 34.5 and 33.0% were obtained with pumpkin treated with Atraforce and Xtravest respectively at Lanlate while the corresponding values were 38.8 and 34.3% at Ido. Among the combinations of herbicide rates and types, application of Codal at 75% of recommended rate resulted in maximum seedling emergence of cowpea at Lanlate.

Table 4.3: Interaction of rates and types of herbicides on cover crop seedling emergence at 2 WAS at Lanlate in 2007 and Ido in 2008

	Control	25%	50%	75%	100%
			Lanlate		
Atraforce	58.4a	58.2a	56.9ab	49.6abc	41.8d
Codal	59.4a	58.9a	58.4a	57.6a	56.9ab
Dual	58.9a	58.5a	58.1a	56.4ab	55.5abc
Igran-combi	59.1a	58.8a	58.5a	58.1a	57.3ab
Xtravest	58.6a	58.9a	56.5ab	48.6bcd	43.8d
			Ido		
Atraforce	58.5a	58.5a	57.1a	51.3ab	44.9b
Dual	59.3a	58.8a	58.3a	57.1a	55.6a
Xtravest	58.8a	58.4a	57.9a	50.3ab	44.9b

Means with the same letters for interaction in each location are not significantly different using DMRT ($P \leq 0.05\%$)

Table 4.4: Interaction of rates and cover crop on seedling emergence of cover crops at 2 WAS at Lanlate in 2007 and Ido in 2008

	Control	25%	50%	75%	100%
			Lanlate		
Akidi	58.9a	58.5a	57.6a	54.3ab	53.1ab
Cowpea	59.0a	58.7a	58.0a	55.9a	52.6ab
Melon	59.0a	59.0a	58.4a	55.0a	53.0ab
Pumpkin	58.6a	58.4a	56.8a	51.1ab	45.7b
			Ido		
Akidi	59.0a	58.7a	58.1a	53.0abc	50.7abc
Cowpea	59.0a	58.9a	58.1a	55.7abc	50.9abc
Melon	59.0a	59.1a	58.4a	53.5abc	50.3bcd
Pumpkin	58.8a	57.7a	56.4abc	49.3cd	42.1d

Means with the same letters for interaction in each location are not significantly different using DMRT ($P \leq 0.05\%$)

Table 4.5: Interaction of herbicide rates and types and cover crop on seedling emergence at 2 WAS at Lanlate in 2007 and Ido in 2008

Crop (C)	Herbicide (H)	100%	25%	50%	75%	Control	100%	25%	50%	75%	Control
				Lanlate					**Ido**		
Akidi	Atraforce	44.8nop	57.8abc	55.8a-f	47.5k-n	58.8ab	48.0f-i	58.8a	56.8abc	50.0e-h	58.5a
	Codal	58.8ab	58.5ab	58.3ab	58.0ab	59.3a	-	-	-	-	-
	Dual	56.5a-f	58.8ab	58.3ab	58.0ab	58.8ab	56.5abc	59.0a	59.0a	58.0ab	59.3a
	Igran-combi	59.0ab	58.5ab	58.3ab	58.8ab	59.3a	-	-	-	-	-
	Xtravest	46.3lmn	59.0ab	57.5a-d	49.3i-m	58.8ab	47.5ghi	58.3ab	58.5a	51.0d-g	59.3a
							-	-	-	-	-
Cowpea	Atraforce	42.0p	58.8ab	57.8abc	55.3b-f	59.0ab	45.5hi	59.5a	58.8a	57.3ab	59.3a
	Codal	58.0ab	59.0ab	58.8ab	59.3a	59.5a	-	-	-	-	-
	Dual	56.0a-f	57.8abc	58.3ab	56.3a-f	58.8ab	57.5ab	58.5a	58.3ab	57.5ab	59.3a
	Igran-combi	58.5ab	59.0ab	59.0ab	59.0ab	59.3a	-	-	-	-	-
	Xtravest	48.3j-n	58.8ab	56.0a-f	49.8h-m	58.5ab	49.8e-h	58.8a	57.3ab	52.3c-f	58.5a
							-	-	-	-	-
Melon	Atraforce	46.0mno	59.0ab	57.5a-d	53fgh	58.5ab	47.5ghi	59.0a	58.0ab	53.5b-e	58.8a
	Codal	57.3a-e	59.0ab	58.8ab	56.8a-e	59.3a	-	-	-	-	-
	Dual	56.0a-f	58.8ab	58.3ab	56.8a-e	59.3a	55.3a-d	59.0a	58.3ab	56.8abc	59.3a
	Igran-combi	58.0ab	59.0ab	58.8ab	58.3ab	59.3a	-	-	-	-	-
	Xtravest	47.5k-n	59.3a	58.8ab	50.0g-k	58.8ab	48.0f-i	59.3a	59.0a	50.3efg	59.0a
							-	-	-	-	-
Pumpkin	Atraforce	34.5q	57.3a-e	56.5a-f	42.5op	57.5a-d	38.8j	56.8abc	54.8a-e	44.3i	57.5ab
	Codal	53.8d-g	59.0ab	58.0ab	56.3a-f	59.5a	-	-	-	-	-
	Dual	53.5e-h	58.8ab	57.8abc	54.8c-f	59.0ab	53.3b-e	58.8a	57.8ab	56.0abc	59.3a
	Igran-combi	53.8d-g	58.5ab	58.0ab	56.3a-f	58.8ab	-	-	-	-	-
	Xtravest	33.0q	58.5ab	53.8defg	45.5nop	58.3ab	34.3j	57.5ab	56.8abc	47.8ghi	58.5a

Means with the same letters for interactions in each location are not significantly different using DMRT ($P \leq 0.05\%$)
- Codal and Igran-combi were not used at Ido; a-f = abcdef, j-n = jklmn, etc.

4.1.2 Dry matter production

The dry matter production of cover crops at 4 WAS was significantly affected by the type of cover crops as well as types and rate of the herbicides at Lanlate in 2007 and Ido in 2008 (Table 4.1). The dry matter productions of melon and pumpkin seedlings were significantly lowered by 33 and 30% at Lanlate and 33 and 27% at Ido respectively compared to cowpea. Pre-emergence application of Atraforce and Xtravest similarly reduced dry matter production of the cover crops by 11% compared to the maximum dry matter production obtained from the application of Igran combi at Lanlate while the lower dry matter production caused by the application of the same herbicides were not significant at Ido. Across the different types of the pre-emergence herbicides and the cover crops, Herbicide application at 100% of recommended rate reduced the dry matter production of the cover crops seedlings by 10 and 19% at Lanlate and Ido respectively.

The interaction of rates and types of herbicide was significant on dry matter production of cover crops at Lanlate (Table 4.6). Among the combinations of herbicide types and rates, Atraforce and Xtravest at 100% of recommended rate resulted in maximum reduction of dry mater of the cover crops by about 24%. Similarly, the interaction of herbicide types and cover crops was significant on cover crops dry matter production at Lanlate (Table 4.7). The dry matter production of melon and pumpkin was significantly lowered by about 35 and 32% respectively by application of all the herbicides at the location. The dry matter production of the other two cover crops, akidi and cowpea was not significantly lowered by application of the herbicides except that of akidi which was lowered by 23% by Xtravest. The difference in dry matter production obtained from melon and pumpkin compared to cowpea and akidi when the three herbicides were used at Ido was not significant.

The interaction of cover crops and herbicide rates was significant on dry matter production at both locations (Table 4.8). Dry matter production of melon and pumpkin were significantly lower than that of cowpea. Among herbicide rates and cover crops combinations, melon and pumpkin treated with 100% of recommended rates of the herbicide produced significantly lower dry matter compared to the controls. Similarly, melon and pumpkin produced significantly lower dry matter than akidi and cowpea when herbicides were applied at 100% of recommended rates at Lanlate. At Ido, compared with the control, application of herbicide at 100% of recommended rates reduced dry matter significantly by 33.8%.

Table 4.6: Interaction of rates and types of herbicides on cover crop dry matter production at 4 WAS at Lanlate in 2007 and Ido in 2008

	Control	25%	50%	75%	100%
			Lanlate		
Atraforce	7.5ab	7.4ab	7.5ab	7.0abc	5.7c
Codal	7.8ab	8.1a	8.3a	7.6ab	7.6ab
Dual	7.8ab	7.3abc	7.7ab	7.8ab	7.7ab
Igran-combi	8a	7.9ab	7.8ab	7.9ab	7.9ab
Xtravest	7.7ab	7.0abc	7.4ab	7.6ab	5.8bc
			Ido		
Atraforce	8.1a	7.6a	7.3a	7.9a	6.0a
Dual	8.0a	7.5a	7.6a	7.5a	7.5a
Xtravest	7.7a	7.7a	8.3a	7.8a	5.6a

Means with the same letters for interactions in each location are not significantly different using DMRT ($P \leq 0.05\%$)

Table 4.7: Interaction of types of herbicide and cover crops on dry matter production at 4 WAS at Lanlate in 2007 and Ido in 2008

	Atraforce	Codal	Dual gold	Igran-combi gold	Xtravest
			Lanlate		
Akidi	7.3bcd	8.7abc	7.9abcd	8.9ab	7.4bcd
Cowpea	8.6abc	9.6a	9.6a	9.6a	8.9ab
Melon	6.0d	6.4d	6.0 d	6.5d	6.1d
Pumpkin	6.3d	6.7cd	7.0bcd	6.6d	6.0d
			Ido		
Akidi	7.7a	-	8.6a	-	8.5a
Cowpea	9.2a	-	9.0a	-	8.7a
Melon	5.9a	-	6.2a	-	6.1a
Pumpkin	6.7a	-	6.7a	-	6.4a

Means with the same letters for interactions in each location are not significantly different using DMRT ($P \leq 0.05\%$); - Codal and Igran-combi were not used at Ido

Table 4.8: Interaction of rates and cover crop on dry matter production of cover crops at 4 WAS at Lanlate in 2007 and Ido in 2008

	100%	25%	50%	75%	Control
			Lanlate		
Akidi	7.5abc	7.8abc	8.5abc	8.0abc	8.5abc
Cowpea	8.5abc	9.4a	9.7a	9.3a	9.5a
Melon	6.0d	7.2.c	7.3c	6.4cd	7.6bc
Pumpkin	5.8d	6.8bc	7.6c	6.6cd	7.8bc
			Ido		
Akidi	7.7abc	8.5ab	8.3ab	8.6ab	8.4ab
Cowpea	7.0abc	9.1ab	9.4ab	9.1ab	10.4a
Melon	5.3c	6.1bc	6.4bc	6.4bc	8.0ab
Pumpkin	5.6bc	6.8abc	6.8abc	6.9abc	8.0ab

Means with the same letters for interactions in each location are not significantly different using DMRT ($P \leq 0.05\%$)

The interaction among rates and types of herbicides and cover crops was significant at the two locations (Table 4.9). Application of Atraforce and Xtravest each at 100% of recommended rates resulted in significantly lower dry matter production compared with controls of no herbicides in both locations. Furthermore, the dry matter productions of akidi, melon and pumpkin was significantly reduced by the two herbicides applied at 75% of recommended rates at Ido while that of cowpea was also reduced by Xtravest at the same rate in Lanlate. At Ido, significant reductions in dry matter production of akidi were caused by Atraforce and Xtravest as well as melon by Codal all applied at 75% of recommended rate compared with controls of no herbicide. At 100% of recommended rate, Codal also reduced dry matter production of Akidi and pumpkin while Dual reduced that of melon at Lanlate. At the location, Xtravest and Dual at 50% of recommended rate reduced melon dry matter production while at 75% of recommended rates, dry matter production of akidi was reduced by Atraforce and Dual and that of melon by Codal.

4.2 Experiment 2: Comparative effects of various densities of cowpea, akidi, pumpkin and melon on weed suppression in maize production

The effects of various densities of cowpea, akidi, pumpkin and melon, on growth and yield parameters of maize in the late cropping season of 2007 at Lanlate and in the early and late cropping seasons of 2008 at Ido are presented in Tables 4.10 and 4.11.

4.2.1 Maize plant height

Plant height of maize was significantly affected by the cover crops densities at both locations (Table 4.10). Maize plants of the plots kept weedy throughout were significantly shorter than those of the other treatments and hoe-weeded control during the late season of 2007 at Lanlate. At Ido, maize plants intercropped with akidi at 26,666, cowpea at 20,000, melon at 20,000 and pumpkin at 12,500 plants/ha in the early season of 2008 and maize intercropped with akidi at 20,000 and 40,000 plants/ha and pumpkin at 15,000 plants/ha in the late season had significantly taller plants compared to those of the weedy check. The maize plants intercropped with akidi at 20,000 plants/ha were significantly taller than those intercropped with akidi of highest density of 40,000 plants/ha and pumpkin at 15,000 plants /ha.

Table 4.9: Interaction of herbicide rates and types and cover crop on the crops dry matter production at 4 WAS at Lanlate in 2007 and Ido in 2008

		100%	25%	50%	75%	Control	100%	25%	50%	75%	Control
		Lanlate					Ido				
Akidi	Atraforce	5.8s-w	8.0g-l	7.7h-n	6.9m-s	8.2e-k	48.0f-i	58.8a	56.8abc	50.0e-h	58.5a
	Codal	8.0g-l	8.6b-h	9.9a	8.5c-h	8.7b-h	--	--	--	--	--
	Dual	8.1f-l	7.2k-p	8.6b-h	7.3i-o	8.5c-h	56.5abc	59.0a	59.0a	58.0ab	59.3a
	Igran-combi	9.2a-f	8.8a-g	8.6b-h	9.2a-f	8.6b-h	--	--	--	--	--
	Xtravest	6.3o-t	6.4o-t	7.7h-n	8.0g-l	8.4c-i	47.5ghi	58.3ab	58.5a	51.0d-g	59.3a
Cowpea	Atraforce	6.4o-t	9.4a-d	9.7ab	8.3d-j	9.1a-f	45.5hi	59.5a	58.8a	57.3ab	59.3a
	Codal	9.7ab	9.7ab	9.8a	9.3a-e	9.7ab	--	--	--	--	--
	Dual	9.5abc	9.3a-e	9.8a	9.9a	9.7ab	57.5ab	58.5a	58.3ab	57.5ab	59.3a
	Igran-combi	9.7ab	9.5abc	9.7ab	9.7ab	9.2a-f	--	--	--	--	--
	Xtravest	7.2k-p	9.2a-f	9.3a-e	9.3a-e	9.7ab	49.8e-h	58.8a	57.3ab	52.3c-f	58.5a
Melon	Atraforce	5.5t-w	5.9s-v	6.9m-s	6.3o-t	7.3 k-o	47.5ghi	59.0a	58.0ab	53.5b-e	58.8a
	Codal	6.6n-s	6.9m-s	6.9m-s	6.1q-u	7.6 h-n	--	--	--	--	--
	Dual	6.1q-u	5.8st-w	5.8st-w	6.7n-s	7.8 h-n	55.3a-d	59.0a	58.3ab	56.8abc	59.3a
	Igran-combi	6.7n-s	6.2p-t	6.4o-t	6.5o-t	6.9m-s	--	--	--	--	--
	Xtravest	4.9vw	6.0r-u	6.1q-u	6.6n-s	7.7 h-n	48.0f-i	59.3a	59.0a	50.3efg	59.0a
Pumpkin	Atraforce	5.1uvw	6.4o-t	6.6n-s	6.7n-s	7.5 h-n	38.8j	56.8abc	54.8a-e	44.3i	57.5ab
	Codal	6.0r-u	7.2k-p	6.7n-s	6.4o-t	7.1l-p	--	--	--	--	--
	Dual	6.9m-s	6.9m-s	6.7n-s	7.4i-o	7.1l-q	53.3b-e	58.8a	57.8ab	56.0abc	59.3a
	Igran-combi	6.2p-t	6.9m-s	6.5o-t	6.3o-t	7.2k-p	--	--	--	--	--
	Xtravest	4.8w	6.6n-s	6.3o-t	6.3o-t	7.1 k-p	34.3j	57.5ab	56.8abc	47.8ghi	58.5a

Means with the same letters for interactions in each location are not significantly different using DMRT ($P \leq 0.05\%$)
-- Codal and Igran-combi were not used at Ido; s-w = stuvw, g-l = ghijkl, etc.

4.2.2 Maize stem diameter

At Lanlate in 2007, maximum stem diameter (2.45 cm) was obtained with plants of sole maize plants hoe-weeded while that of plot kept weedy throughout (2.17 cm) was significantly thinner than those of all the other treatments (Table 4.10). Furthermore, maize plants intercropped with pumpkin at 15,000 plants/ha had the least stem diameter (2.31 cm) among the plots that were planted to the different cover crops at the various densities. The plots with intercrop of akidi at 20,000 and 26,000 plants/ha and cowpea at the three densities also had maize plants with significantly thicker stem (2.37 to 2.39 cm) than those with pumpkin at 15,000 plants/ha. Among the treatments, maize intercropped with cowpea at 20,000 and 26,000 and pumpkin at 15,000 plants/ha were comparable to the maximum in stem diameter. At Ido maximum stem diameter (2.48 cm) was obtained with maize intercropped with cowpea at 40,000 plants/ha and the hoe-weeded plots (2.49 cm) in the early and late seasons of 2008 respectively. Among the treatments maize intercropped with akidi at 26,666 plants/ha and those hoe-weeded had stem diameter (2.44 and 2.42 cm) that were comparable to the maximum (2.49 cm) in the early season. Although, not comparable to the maximum, stem diameter of the maize plants intercropped with akidi at 20,000 (2.37 cm) and 40,000 plants/ha (2.35 cm), cowpea at 26,666 plants/ha, melon at 20,000 plants/ha and pumpkin at 15,000 plants/ha (2.33 to 2.36 cm) were also significantly higher than the least obtained from the weedy checks (2.23 cm) in the early season. In the late season, while maize plants of all the other treatments had bigger stem diameter than that of the weedy check, only those of the plants intercropped with akidi at 20,000 plants/ha, cowpea at 40,000 plants/ha, and melon and pumpkin at the three densities each were comparable to the maximum.

4.2.3 Maize shoot dry matter production

The cover crop densities had significant effects on maize shoot dry matter production in all the experiments at both locations where the plots kept weedy throughout produced lower maize shoot biomass compared to all the other treatments (Table 4.11). The highest densities of intercropped of akidi and cowpea (40,000 plants/ha) and pumpkin (15,000 plants/ha) significantly ($P \leq 0.05$) reduced maize shoot dry matter production by 10, 11 and 16% respectively, compared to the hoe-weeded control in the early season of 2008 at Ido. While the various cover crop and

Table 4.10: Maize plant height and stem diameter (cm) as influenced by various densities of cowpea, akidi, pumpkin and melon in Lanlate in 2007 and Ido in 2008

	Late season in 2007 at Lanlate		Early season in 2008 at Ido		Late season in 2008 at Ido	
	Plant height	Stem diameter	Plant height	Stem diameter	Plant height	Stem diameter
Maize + $Akidi_1$	242a	2.37b	246ab	2.37bcd	251a	2.39abc
Maize + $Akidi_2$	239a	2.37b	249a	2.44ab	247ab	2.33c
Maize + $Akidi_3$	242a	2.35bc	238b	2.35cd	242b	2.34bc
Maize + $Cowpea_1$	243a	2.39ab	249a	2.31de	245ab	2.33c
Maize + $Cowpea_2$	241a	2.39ab	241ab	2.36bcd	244ab	2.31c
Maize + $Cowpea_3$	242a	2.37b	245ab	2.48a	244ab	2.36abc
Maize + $Melon_1$	242a	2.36bc	248a	2.36bcd	250ab	2.41ab
Maize + $Pumpkin_4$	242a	2.39ab	243ab	2.31de	246ab	2.36abc
Maize + $Pumpkin_5$	239a	2.33bc	248a	2.30de	247ab	2.37abc
Maize + $Pumpkin_6$	241a	2.31c	243ab	2.34cd	242b	2.35abc
Sole maize HW	242a	2.45a	241ab	2.42abc	248ab	2.43a
Sole maize WC	217b	2.17d	238b	2.23e	227c	2.19d

$_1$, $_2$ and $_3$ = 20,000, 26,666 and 40,000 plants/ha; $_4$, $_5$ and $_6$ = 10,000, 12,500 and 15,000 plants/ha; HW = Hoe-weeded; WC = Weedy check.
Means with the same letter(s) along the same column are not significantly different using DMRT at $P \leq 0.05$

hoe-weeded treatments had similar maize shoot dry matter production at Lanlate in 2007 (6.92 to 7.53 t/ha) and late season in 2008 (6.93 to 7.48 t/ha) at Ido, the weedy check plot produced maize dry matter (5.92 and 6.14 t/ha respectively) that was significantly lower than those obtained from all the other plots. In the early season at Ido, maize shoot dry matter production obtained from plots that had akidi and cowpea at 40,000 plants/ha (7.20 and 7.17 t/ha respectively) were similar to that obtained from the plots that had pumpkin at the density of 15,000 (6.73 t/ha) plants/ha but significantly lower than that of the hoe-weeded control (8.04 t/ha). Crop dry matter productions from all other plots were not significantly different from that of the hoe-weeded plots which had the highest crop dry matter production.

4.2.4 Maize grain yield

Maize grain yield was significantly affected by the intercropped cover crops in the three experiments (Table 4.11). In the three experiments, the plots with sole maize hoe-weeded had the maximum maize grain yields which were significantly higher than those of the weedy check. At Lanlate in the late season of 2007, among the cover crop treatments, cowpea and pumpkin at 40,000 and 15,000 plants/ha respectively caused the highest reduction of maize grain yield by 11% compared to the maximum of hoe-weeded control, while all the other cover crops had comparable effects. At Ido in the early and late seasons of 2008, intercropped pumpkin at population density of 15,000 plants/ha, significantly reduced maize grain yield by about 14% relative to the hoe-weeded controls. While all the other cover crops treatments had maize grain yields that were similar to the hoe-weeded control in the late cropping season at Ido, akidi at 20,000 and 26,666 plants/ha and cowpea at 20,000 plants/ha produced yields that were comparable but higher than that of pumpkin at 15,000 plants/ha.

4.2.5 Performance of cowpea, melon, "akidi" and pumpkin used for weed suppression in maize production

The vine spread (scored as percentage soil coverage), as a measure of growth performance, shoot dry matter production and seed yields of the cover crops intercropped with maize for weed suppression in the late season of 2007 at Lanlate and the early and late seasons of 2008 at Ido are presented in Table 4.12.

Table 4.11: Maize shoot dry matter production and grain yield (t/ha) as influenced by various densities of cowpea, akidi, pumpkin and melon at Lanlate in 2007 and Ido in 2008

	Late season in 2007 at Lanlate		Early season in 2008 at Ido		Late season in 2008 at Ido	
	Dry matter production	Grain yield	Dry matter production	Grain yield	Dry matter production	Grain yield
Maize + $Akidi_1$	7.28a	2.08abc	7.90ab	2.30ab	7.25a	2.15ab
Maize + $Akidi_2$	7.28a	2.15abc	7.70ab	2.21abc	7.27a	2.16ab
Maize + $Akidi_3$	7.33a	2.12abc	7.20bc	2.10cde	7.18ab	2.11ab
Maize + $Cowpea_1$	7.22a	2.18ab	7.67ab	2.32a	7.48a	2.12ab
Maize + $Cowpea_2$	7.13a	2.19ab	7.68ab	2.13bcde	7.28a	2.06ab
Maize + $Cowpea_3$	6.92a	1.99c	7.17bc	2.14bcde	6.93a	2.11ab
Maize + $Melon_1$	7.53a	2.17ab	7.70ab	2.19abcd	7.47a	2.16ab
Maize + $Pumpkin_4$	7.31a	2.12abc	7.82ab	2.20abcd	7.31a	2.17ab
Maize + $Pumpkin_5$	7.22a	2.08abc	7.95ab	2.14bcde	7.39a	2.07ab
Maize + $Pumpkin_6$	6.94a	2.00bc	6.73cd	2.02de	6.98a	1.97b
Sole maize 3HW	7.33a	2.24a	8.04a	2.36a	7.22a	2.26a
Sole maize WC	5.92b	1.22d	6.35d	1.98e	6.14b	1.70c

$_{1,2}$ and $_3$ = 20,000, 26,666 and 40,000 plants/ha; $_4$, $_5$ and $_6$ = 10,000, 12,500 and 15,000 plants/ha;
HW = 3 times Hoe-weeded; WC = Weedy check.
Means with the same letter(s) along the same column are not significantly different using DMRT at $P \leq 0.05$

4.2.5.1 Percentage soil cover scores of cover crops

The percentage soil cover score differed significantly among the cover crops in the three trials at both locations (Table 4.12). In the three trials, maximum percentage soil coverage was obtained with maize intercropped with akidi at density of 40,000 plants/ha in the late seasons at both locations (90 and 95%). In the early season at Ido, soil coverage obtained from akidi at 40,000 plants/ha (87%) was comparable to that obtained from pumpkin (80%) at 15,000 plants/ha in the early season at Ido. The maximum value maximum recorded at Lanlate was significantly higher than those recorded for all the other cover crops treatments while intercropped akidi and cowpea both at the highest population density of 40,000 plants/ha were comparable at early and late seasons respectively at Ido. At Lanlate, soil coverage percentages of between 73 to 86% on plots of akidi and cowpea both at densities of 20,000 and 26,000 plants/ha and that of pumpkin at 15,000 plants/ha were similar and significantly higher than those of melon at density of 20,000 plants/ha. Furthermore, the highest population densities of akidi and cowpea resulted in higher cover scores than all the pumpkin densities and melon at 20,000 plants/ha.

At Ido in the late season of 2008, the percentage soil coverage scores for plots with highest population densities of akidi, cowpea and pumpkin (90, 88 and 83%) were significantly higher than those of the corresponding lower densities that were also similar. While the highest population of akidi had higher cover score than the low densities of 20,000 and 26,666 plants/ha, lowest densities of cowpea had less cover than the higher densities. Also soil cover score of akidi at 26,000 plants/ha and cowpea at density of 40,000 plants/ha and pumpkin at 10,000 and 12,500 were similar and comparable to melon at 20,000 plants/ha.

In the early season of 2008 at Ido, vine cover score increased significantly with population densities of akidi, cowpea and pumpkin. Although, akidi and cowpea both at 26,666 plants/ha had similar score compared to pumpkin at 15,000 plants/ha, only the cover score of cowpea and akidi were comparable to that of cowpea at 40,000 plants/ha. In this trial, all the cover crops had higher soil coverage than melon at 20,000 plants/ha.

4.2.5.2 Shoot dry matter production of the cover crops

Shoot dry matter production was significantly different among cover crops with pumpkin at 15,000 plants/ha having the highest (350, 405 and 291S kg/ha) values in the three trials (Table 4.12). At Ido, pumpkin at 12,500 and 15,000 plants/ha produced similar dry matter that were significantly higher than those of the corresponding low density of 10,000 plants/ha by 9 and 19% in the two cropping seasons. However, at Lanlate, shoot dry matter production increased significantly with population density of pumpkin. In Lanlate in 2007, and in the late season at Ido in 2008, cowpea at densities of 26,666 and 40,000 plants/ha respectively produced similar dry biomass that were significantly higher than those of respective lower population density of 20,000 plants/ha. However in the late season at Ido, shoot biomass production was higher at 40,000 plants/ha compared with lower densities that were similar. Melon produced the least shoot dry matter production in the two late seasons but higher than akidi and cowpea in the early season in 2008. In the two late season croppings, akidi at the lowest density produced significantly lower shoot biomass than the highest population which also produced higher value than the two lower densities in the early season.

4.2.5.3 Seed yields of the cover crops

Seed yields differ significantly among cover crops in the three croppings seasons (Table 4.12). In the late cropping seasons at both locations, akidi produced highest seed yields at all population densities (49 to 57 kg/ha at Lanlate and 55 to 66 kg/ha at Ido) while those of the other two populations were comparable. Only pumpkin at the two high densities at Lanlate produced yields (40 and 42 kg/ha) that were comparable to that produced by the least population density of akidi while cowpea at population density of 20,000 plants/ha (43 kg/ha) produced seed yield that was comparable to those of the two lower densities of akidi at Ido. Also, seed yields of cowpea at all densities in the three trials and pumpkin at the three densities in the late seasons were similar while that of pumpkin at 10,000 plants/ha was lower than that of 15,000 plants/ha in the early season at Ido in 2008. In the late season, cowpea also produced higher yields than melon except at similar population density of 20,000 plants/ha while melon yield was higher in the early wet season.

Table 4.12: Growth and dry mater yields of cowpea, melon, "akidi" and pumpkin used for weed suppression in maize production in Lanlate in 2007 and Ido in 2008

	Late season in 2007 in Lanlate			Early season in 2008 in Ido			Late season in 2008 in Ido		
	VS (% SC at 8 WAS)	Shoot biomass (kg/ha)	Seed yield (kg/ha)	VS (% SC at 8 WAS)	Shoot biomass (kg/ha)	Seed yield (kg/ha)	VS (% SC at 8 WAS)	Shoot biomass (kg/ha)	Seed yield (kg/ha)
Maize + $Akidi_1$	73bcd	128f	48.6abc	69de	117f	15.7def	77ef	119g	56.3ab
Maize + $Akidi_2$	86b	143ef	51.2a	73cd	138ef	18.2de	85bc	132fg	54.6ab
Maize + $Akidi_3$	95a	174de	56.6a	87ab	147de	22.7d	90a	161e	66.5a
Maize + $Cowpea_1$	70d	181d	21.8ef	64e	112f	5.6f	74fg	189d	42.7bc
Maize + $Cowpea_2$	79bc	251c	23.1e	69de	171d	7.4ef	85bc	206cd	39.5c
Maize + $Cowpea_3$	86b	280bc	25.4e	76c	154de	12.3def	88ab	262b	35.7c
Maize + $Melon_1$	58e	132f	12.8f	79c	222c	43c	53i	78h	5.6d
Maize + $Pumpkin_4$	63de	252c	39.5cd	73cd	354b	66.9b	66h	221c	29.7c
Maize + $Pumpkin_5$	69d	300b	41.6bcd	80bc	388a	74.3ab	72g	272ab	36c
Maize + $Pumpkin_6$	77bcd	350a	36.8d	92a	405a	77.8a	83cd	291a	39.8c

VS = Vine spread, SC = Soil coverage, $_1$, $_2$ and $_3$ = 20,000, 26,666 and 40,000 plants/ha; $_4$, $_5$ and $_6$ = 10,000, 12,500 and 15,000 plants/ha;
HW = Hoe-weeded; WC = Weedy check.
Means with the same letter(s) along the same column are not significantly different using DMRT at $P \leq 0.05$

4.2.6 Effects of densities of cowpea, akidi, pumpkin and melon on weed densities, floral composition and dry weed biomass

Weed density and floral composition and dry weed biomass as influenced by the cover crops treatments at Lanlate in the late cropping season of 2007 and at Ido in the early and late cropping seasons of 2008 are presented in Tables 4.13 to 4.16.

4.2.6.1 Weed density

At Lanlate, the dominant weed species in terms of abundance was *Mitrocarpus villosus* (Sw.) DC. which had a density of 236/m^2 and relative density (r.d.) of 44.5% (Table 4.13). Others included *Cleome viscosa* (r.d. 7.1%), *Brachiaria deflexa* (Schumach.) C.E. (r.d. 5.2%), *Panicum laxum* Sw. (r.d. 6.4%). Other weeds that were present in variable amounts included *Commelina benghalensis* L., *Pouzolzia guineensis* Benth. and *Tephrosia bracteolata* Guill.& Perr.

The total number of weeds per unit area generally decreased as the plant population of the cover crops increased. The weed density was higher on the plots that had melon compared to other cover crops. Weed density under the cover crops followed the order: melon > cowpea > akidi > pumpkin. The weed density within the same cover crop species was proportional to the density of the crop except in the cowpea where there were more weeds per unit area in 26,000 crop density than in the 20,000 density. The weed species that dominated the plots in the early cropping seasons at Ido in 2008 included *Spigelia anthelmia* (r.d. 17.7%), *Phyllanthus amarus* (r.d. 18.8%), *Chromolaena odorata* (r.d. 12.5%), *Peperomia pellucidia* (r.d. 9.0%), *Senna hirsuta* (r.d. 7.9%), *Acalypha ciliata* (r.d. 6.3%), *Ipomoea triloba* (r.d. 6.7%) and *Ageratum conyzoides* (r.d. 6.9%) (Table 4.14). The weed density distribution seemed not to follow any observable trend but, generally, more number of weeds per unit area was encountered as the population of cover crops decreased. Weed density under the cover crops in the early planting season in Ido in 2009 followed the order: number of weeds per squared meter from the plots planted to cowpea > melon > akidi > pumpkin.

In the late cropping season at Ido in 2008, the pattern of weed density encountered followed a trend similar to that obtained in the previous seasons at the location with the plots planted to melon having the highest number of weeds per unit area (Table 4.15). In this trial, weed density under the cover crops followed the order: melon > akidi > cowpea > pumpkin

The weed floral composition was similar to that observed at the location in the early wet season. The dominant weed species observed in terms of abundance were *Ageratum conyzoides* Linn. (r.d. 16.2%), *Phyllanthus amarus* Schum. &Thonn. (r.d. 15.8%), *Peperomia pellucidia* (L.) H.B. & K. (r.d. 8.5%), *Senna hirsuta* (L.) Irwin & Barneby (r.d. 9.7%), *Spigelia anthelmia* Linn. (r.d. 8.6%), *Chromolaena odorata* (L.) R.M King & Robinson (r.d. 7.2%), *Acalypha ciliata* Forsk. (r.d. 7.0%), and *Ipomoea triloba* Linn. (r.d. 5.8%).

4.2.6.2 Weed dry matter production

The weed dry matter production was significantly affected in the three experiments (Table 4.16). In all cases, the highest dry matter production occurred on the plots of sole maize kept weedy throughout. Conversely, plots of maize intercropped with akidi at 40,000 plants/ha consistently produced weed dry matter comparable to the lowest of sole maize that was hoe-weeded three times in the three trials. Weed dry matter productions due to the use of 40,000 plants/ha of akidi and to three times hoe-weeded controls for late season trial at Lanlate, and early and late seasons trials at Ido were 15.8, 32.3 and 32.8 kg/ha, and 18.8, 23.5 and 15.3 kg/ha respectively. Highest weed dry matter productions of 132.5, 127.8 and 131.8 kg/ha were recorded at the three respective trials. Weed control efficiencies due to three times hoe weeding control and 40,000 plants/ha of akidi intercropped with maize were 86 and 88% and 88 and 75% respectively for the late season trials at Lanlate and Ido.

Furthermore, plots with maize intercropped with akidi at 26,666 plants/ha in the late season of 2007 at Lanlate and early season at Ido in 2008 as well as pumpkin at 12,500 and 15,000 plants/ha in the early wet season at Ido produced weed dry matter comparable to those of their respective hoe-weeded controls. At Lanlate, maize intercropped with akidi and cowpea each at 20,000 and 40,000 plants/ha, pumpkin at densities of 12,500 and 15,000 plants/ha and akidi at 26,666 plants/ha resulted in weed dry matter production that were comparable. Intercropping of the highest population of akidi and cowpea (40,000 plants/ha) each resulted in significantly lower weed dry matter production than corresponding low population of 20,000 plants/ha while no difference was observed among the densities of pumpkin. Among the cover crops, only cowpea at 20,000 and 26,666 plants/ha, pumpkin at 10,000 plants/ha and

Table 4.13: Weed densities (number/0.25^2) and floral composition as influenced by different densities of cowpea, akidi, pumpkin and melon 8 WAS at Lanlate in the late season of 2007

	A1	A2	A3	C1	C2	C3	Me	P1	P2	P3	HW	WC	Total
Acanthospermum hispidum DC.	0.33	0.83	0.3	0	0	0	0.3	0	0	0	0	0.6	2.36
Ageratum conyzoides Linn.	0	0.33	0.33	0.33	0.83	0	0	0	0.3	0.66	0	1	3.78
Brachiaria deflexa (Schumach.) C.E. Hubbard ex robins	0.3	0	0	0.3	0.3	0.3	0.6	1	0.3	0.33	2	0.6	6.03
Brachiaria lata (Schumach.) C.E. Hubbard ex Robins	0.36	0	0	0	0	0	0.3	0.3	0.66	0	1.67	1.2	4.49
Cleome viscosa L.	0.33	0	0	0.3	0.3	0	0.3	0.3	0.3	0.3	0.33	6	8.13
Commelina benghalensis L.	0	0	0.67	0.3	0	0	0	0.6	0	0	0	0.3	1.87
Euphorbia heterophylla Linn.	0.3	0.3	0.3	0.6	0.6	0.3	0.3	0.3	0	0.3	0.67	1.2	5.17
Euphorbia hirta Linn.	0.33	0.3	0	0.3	0.3	0	0.3	0	0.3	0	1.67	0.7	4.2
Gomphrena celosioides Mart.	0.33	0.33	0	0.33	0.33	0.33	0.33	0.3	0.3	0	0.33	1.5	4.41
Mitracarpus villosus (Sw.) DC.	4.33	1.33	1.67	2.33	2	2	6	3	2.33	1.83	3	21	50.82
Panicum laxum Sw.	0	0.3	0	0	3	0	0.3	0	0	0	0	3.67	7.27
Panicum repens Linn.	0.3	0	0	0.3	0.3	0	0.3	0.36	0	0	0	0.7	2.26
Rhynchelytrum repens (Willd.) C.E. Hubbard	0.37	0	0	0.3	0	1.3	0	0.3	0.33	0	0	3	5.6
Solanum nigrum L.	0.3	0.3	0	0.3	0	0	0.3	0.3	0	0	0	0.3	1.8
Spigelia anthelmia Linn.	0.3	0	0.3	0	0.3	0	0.67	0.3	0	0	0	0.67	2.54
Tridax procumbens Linn.	0.3	0.37	0	0.67	0	0	0.38	0.68	0	0	0.67	0.3	3.37
Total density	8.18	4.39	3.57	6.36	8.26	4.23	10.38	7.74	4.82	3.42	10.01	42.74	

A = Akidi, C = Cowpea, Me = Melon, P ≤ Pumpkin; $_1$, $_2$ and $_3$ = 20,000, 26,666 and 40,000 plants/ha; $_4$, $_5$ and $_6$ = 10,000, 12,500 and 15,000 plants/ha; HW and WC = Hoe-weeded and Weedy check controls.

Table 4.14: Weed densities (number/0.25^2) and floral composition as influenced by different densities of cowpea, akidi, pumpkin and melon at 8 WAS at Ido in early season of 2008

	A1	A2	A3	C1	C2	C3	Me	P1	P2	P3	HW	WC	Total
Acalypha ciliata Forsk.	0.25	0	0	0.5	0.25	0.25	1.25	0.25	3.25	0.75	0.75	2.25	9.75
Acanthospermum hispidum DC.	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5
Ageratum conyzoides L.	0	0.25	0	1.75	0	0.25	0.25	1.5	1.25	1	1	3.5	10.75
Senna hirsuta (L.) Irwin & Barneby	2.5	0.25	0.25	0.25	0.25	0	0.25	0.25	0	0	0.25	8	12.25
Chromolaena odorata (L.) R.M King & Robinson	3.25	1.25	1.25	1.25	0.75	0.5	0.75	0.25	0.25	0.25	0.25	9.5	19.5
Euphorbia hirta Linn.	0	0	0	0.25	0.25	0	0	0	0	0	0	1.25	1.75
Laportea aestuans (Linn.) Chew.	0	0.25	0	0.25	0	0.25	0.25	0.25	0	0	0	1.75	3
Ipomoea triloba Linn.	0.25	0.5	0.25	0.75	0.5	0.5	0.25	0.25	0.25	0.25	0.25	6.5	10.5
Momordica charantia Linn.	0	0	0.5	0	0	0.25	0.25	0.25	0	0	0	0.25	1.5
Panicum laxum Sw.	0	0	0	0	0	0	0	0	0	0	0	0.75	0.75
Panicum maximum Jacq.	0	0	0	0	0	0.25	0	0	0	0	0	2	2.25
Panicum repens Linn.	0	0	0	0	0	0	0	0	0	0	0	1	1
Peperomia pellucida (L.) H.B. & K.	1.5	0.25	0.25	0.25	0.25	0	1.25	0.25	0	0	0.25	9.75	14
Phyllanthus amarus Schum. &Thonn.	7	2.25	1	0.5	2.75	1.25	0.25	0.5	0.25	0	0.25	13.25	29.25
Physalis angulata Linn.	0.25	0	0	1.5	0	0	2	0	0	0	1.25	1.75	6.75
Solanum nigrum L.	0.25	0	0	0	0.25	0.25	0	0	0	0	0	1	1.75
Solanum torvum Swartz.	0	0.25	0	0	0	0.5	0	0	0	0	0.5	1.75	3
Spigelia anthelmia Linn.	1.52	2.5	0.5	2.25	7.5	1.25	1.75	1.25	0	1	1	7	27.52
Total density	16.77	7.75	4	9.5	12.75	5.5	8.5	5	5.25	3.25	5.75	71.75	

A = Akidi, C = Cowpea, Me = Melon, P ≤ Pumpkin; $_1$, $_2$ and $_3$ = 20,000, 26,666 and 40,000 plants/ha; $_4$, $_5$ and $_6$ = 10,000, 12,500 and 15,000 plants/ha; HW and WC = Hoe-weeded and Weedy check controls

Table 4.15: Weed densities (number/0.25^2) and floral composition as influenced by different densities of cowpea, akidi, pumpkin and melon at 8 WAS at Ido in late season of 2008

	A1	A2	A3	C1	C2	C3	Me	P1	P2	P3	HW	WC	Total
Acalypha ciliata Forsk.	0.75	1.25	0.75	0.5	0.25	0.25	1.25	1.25	1.75	2.5	0	2.25	12.75
Acanthospermum hispidum DC.	0	0	0	0	0	0	0	0.25	0	0	0	0.5	0.75
Ageratum conizoides L.	1	0.25	0.25	0.5	0.25	1.5	3.75	2.5	1.75	1.75	2.25	13.75	29.5
Brachiaria deflexa (Schumach.) C.E. Hubbard ex Robins	0	0	0	0	0.25	0	0.25	0.25	0	0	0	1.75	2.5
Brachiaria lata (Schumach) C.E. Hubbard ex Robins	0.25	0	0	0	0.25	0	0.25	0	0.25	0	0	1	2
Senna hirsuta (L.) Irwin & Barneby	1.25	0.25	0.25	0.5	0.25	0	2.25	1.5	0.75	1	0.25	9.5	17.75
Chromolaena odorata (L.) R.M King & Robinson.).	1.5	0.25	1.25	1.25	0.75	0.2	1.25	0.25	0.25	0.25	0.25	5.75	13.2
Eragrotis tremula Hochst & Steud	0.25	0	0	0	0	0	0.25	1.75	0	0	0	1	3.25
Euphorbia hirta Linn.	0.25	0	0	0.25	0.25	0	1	0.5	0	0	0.25	3.25	5.75
Laportea aestuans (Linn.) Chew.	0	0.25	0	0.25	0	0.25	0.25	0.25	0	0	0	1.75	3
Gomphrena celosioides Mart.	0.25	0.25	0	0.5	0.25	0	1.25	0	0	0	0	0.75	3.25
Ipomoea turiboba Linn.	0.25	0.5	0.25	0.75	0.5	0.5	0.25	0.25	0.25	0.25	0.25	6.5	10.5
Momordica charantia Linn.	0	0	0	0	0	0.25	0.25	0.25	0	0	0	0.25	1
Panicum laxum Sw.	0	0	0	0	0	0	0	0	0	0	0	0.75	0.75
Panicum maximum Jacq.	0	0	0	0	0	0	0	0	0	0	0	2	2
Panicum repens Linn.	0	0	0	0	0	0	0	0	0	0	0	1	1
Peperomia pellucida (L.) H.B. &K.	1.5	0.25	0.25	0.25	0.25	0	1.25	1.75	0	0	0.25	9.75	15.5
Phyllanthus amarus Schum. & Thonn.	7	3.25	1.5	0.5	0	0	1.5	0.5	0.25	0.75	0.25	13.25	28.75
Physalis angulata Linn.	0.25	0	0	1.5	1.25	0.75	2	0	1	0	0	1.75	8.5
Solanum nigrum L.	0.25	0	0	0	0	0.25	0	0	0.25	0	0	1	1.75
Solanum torvum Swartz.	0	0.25	0	0	0	0.5	0	0	0	0	0.5	1.75	3
Spigelia anthelmia Linn.	0.52	0.5	0.15	1.25	0.75	0.5	0.75	1.25	1.25	0.75	1	7	15.67
Total density	15.27	7.25	4.65	8	5.25	4.95	17.75	12.5	7.75	7.25	5.25	86.25	

A = Akidi, C = Cowpea, Me = Melon, P ≤ Pumpkin; $_{1}$, $_{2}$ and $_{3}$ = 20,000, 26,666 and 40,000 plants/ha; $_{4}$, $_{5}$ and $_{6}$ = 10,000, 12,500 and 15,000 plants/ha; HW and WC = Hoe-weeded and Weedy check control

Table 4.16: Effects of various densities of cowpea, akidi, pumpkin and melon on weed dry matter (kg/ha) in maize production at Lanlate in 2007 and Ido in 2008

	Late season in 2007 at Lanlate	Early season in 2008 at Ido	Late season in 2008 at Ido
Maize + $Akidi_1$	44.5de	48.25bc	43bc
Maize + $Akidi_2$	33.25ef	40.5bcd	38.75c
Maize + $Akidi_3$	15.75f	32.25cd	32.75cd
Maize + $Cowpea_1$	65.75bc	57.25b	55bc
Maize + $Cowpea_2$	57.5bcd	56.5b	49.75bc
Maize + $Cowpea_3$	43de	49.5bc	39c
Maize + $Melon_1$	73.25b	48.5bc	64.75b
Maize + $Pumpkin_4$	55.5bcd	45.75bc	50.25bc
Maize + $Pumpkin_5$	51.5cde	38bcd	48.25bc
Maize + $Pumpkin_6$	40.5de	31.25cd	41.5bc
Sole maize 3HW	18.75f	23.5d	15.25d
Sole maize WC	132.5a	127.75a	131.75a

$_1$, $_2$ and $_3$ = 20,000, 26,666 and 40,000 plants/ha; $_4$, $_5$ and $_6$ = 10,000, 12,500 and 15,000 plants/ha; HW = Hoe-weeded three times; WC = Weedy check.
Means with the same letter(s) along the same column are not significantly different using DMRT at $P \leq 0.05$

melon at 20,000 plants/ha caused dry matter production that were comparable, while all other treatments resulted in lower values.

At Ido, all other cover crops at the various densities produced weed dry matter that were comparable to that of melon in the early cropping season. In the late cropping season, plots of maize intercropped with akidi at 26,666 and 40,000 plants/ha and cowpea at 40,000 plants/ha as well as hoe-weeded three times produced significantly lower dry matter than those with melon intercrop. Among the cover crops, akidi generally resulted in lower weed dry matter production.

4.2.7 Relationships among cover crops growth and yield parameters, weed density and dry matter production and maize grain and dry matter production

The result of correlation coefficient analyses which depict the relationship among maize yield parameters, ground cover, and dry matter production of cover crops as well as weed dry mater production are contained in Table 4.17. At Lanlate in the late season, weed dry matter production had negative correlation with ground coverage and dry matter production of all the cover crops except akidi with maize grain and dry matter production. The correlation coefficients of ground coverage and dry matter production of pumpkin with maize and weed parameters were significant in all the case at Ido except with weed dry matter production in the late season. Cowpea ground coverage significantly correlated with maize grain yield and weed and maize dry matter production in the late season trials at both locations. Cowpea dry matter production also had negative correlations with maize grain and dry matter production and with weed dry matter production in the late season at Lanlate. Furthermore, the cover crops dry matter production also had negative correlations with maize grain yield and weed dry matter production in the early season at Ido as well as maize and weed dry matter production in the late season at Ido.

4.2.8 Economic analysis

The partial budget analysis for maize production with the use of cover crops of akidi, cowpea, melon and pumpkin is presented in Table 4.18. The weedy check had the least net benefit of ₦18,180/ha for capital investment and entrepreneurship. Although the hoe-weeded control (M + HW) had significantly higher grain yield than the plots that had 15,000 plants/ha of pumpkin (M + P3), the Marginal Rate of Return

(MRR), the extra benefit relative to the extra capital investment from M + P3 was higher (169%) than that obtained from M + HW (100%). Higher MRR which ranged from 174 to 235% was realized from plots that were cover-cropped with akidi, cowpea and melon at densities that ranged from 20,000 to 40,000 plants/ha and pumpkin at densities of 10,000 and 12,500 plants/ha. Averaged across the three densities of each of the cover crops, maize cover cropped with akidi had the highest MRR of 211% followed by the maize cover-cropped with pumpkin MRR of 205% and cowpea with 196%.

4.3 Experiment 3: Weed management with complementary use of pre-emergence herbicides and cover crops in maize production

The effects of complimentary use of pre-emergence application of metolachlor, atrazine and Xtravest and cover crops of akidi, pumpkin, cowpea and melon on growth and yield parameters of maize in the early and late cropping seasons of 2008 and 2009 at Ido are presented in Tables 4.19 to 4.21.

4.3.1 Maize plant height

The weed control treatments significantly influenced plant height of maize in all the trials (Table 4.19). All the treatment combinations and hoe-weeded control resulted in significantly taller maize plants than the weedy check in the late seasons of 2008 and 2009. In early season 2008, combinations of akidi with metolachlor at 75% and 50% each of atrazine and Xtravest as well as pumpkin with 75% metolachlor resulted in plant heights (183, 190 and 190 cm respectively) that were comparable to the hoe-weeded control (192 cm) and significantly higher than that of the weedy check (176 cm). Furthermore in the late season of 2008, combination of akidi plus 50% atrazine, pumpkin plus both rates of metolachlor and melon plus Xtravest at 75% had plants with height (187, 186, 184 and 184 cm) that were comparable to that of pumpkin with 50% atrazine (186 cm), while all the other treatment combinations resulted in maize plants of similar heights. In the late season of 2009, the plots that had melon plus 75% Xtravest and pumpkin + 75% Metolachlor had maize plant heights (179 and 173 cm) that were comparable to the akidi plus 50% Xtravest (176 cm) and taller than those of the weedy check (167).

Table 4.17: Correlation coefficients values among grain and biomass yields of maize, weed dry matter production and growth and yield parameters of the cover crops

Parameters and Location	Ground coverage			Cover crop dry matter production		
	Akidi	Cowpea	Pumpkin	Akidi	Cowpea	Pumpkin
Maize grain yield						
Late season at Lanlate	-0.11	-0.69*	-0.53*	-0.23	-0.41*	-0.68*
Early season at Ido	-0.63*	-0.12	-0.81*	-0.61*	-0.64*	-0.33*
Late season at Ido	-0.24	-0.28	-0.74*	-0.28*	0.18	-0.74*
Maize dry matter production						
Late season at Lanlate	0.11	-0.33*	-0.50*	0.10	-0.35*	-0.53*
Early season at Ido	-0.67*	-0.10	-0.68*	-0.66*	-0.03	-0.36*
Late season at Ido	-0.05	-0.27	-0.56*	-0.07	-0.37*	-0.50*
Weed Dry matter						
Late season at Lanlate	-0.54*	-0.28*	-0.46*	-0.53*	-0.75*	-0.33*
Early season at Ido	-0.44*	-0.12	-0.80*	-0.53*	-0.31*	-0.35*
Late season at Ido	-0.36*	-0.70*	-0.20	-0.54*	-0.61*	-0.26

* Significant ($P \leq 0.05$); n = 56

Table 4.18: Partial budget analysis for maize production with the use of cover crops for weed control

Treatments	Maize grain yield (t/ha)		Cover crops seed yield (kg/ha)		Gross farm gate price (₦'000)		Total variable cost	Net benefit	Marginal rate of return
	Experimental yield	Adjusted yield	Experimental yield	Adjusted yield	Maize	Cover crops	(₦'000)		
Maize + Akidi$_1$	2.18	1.96	40.20	36.2	90.08	4.34	52.75	41.67	194
Maize + Akidi$_2$	2.17	1.96	41.33	37.2	89.98	4.46	51.50	42.94	228
Maize + Akidi$_3$	2.11	1.90	48.60	43.7	87.22	5.25	51.50	40.97	210
Maize + Cowpea$_1$	2.20	1.98	23.37	21.0	91.25	2.52	51.50	42.27	222
Maize + Cowpea$_2$	2.13	1.91	23.33	21.0	88.04	2.52	51.50	39.06	192
Maize + Cowpea$_3$	2.08	1.87	24.47	22.0	85.94	2.64	51.50	37.08	174
Maize + Melon$_1$	2.17	1.96	20.47	18.4	90.01	2.21	51.50	40.72	207
Maize + Pumpkin$_4$	2.16	1.94	45.37	40.8	89.42	2.45	50.50	41.37	235
Maize + Pumpkin$_5$	2.10	1.89	50.63	45.6	86.80	2.74	50.50	39.04	211
Maize + Pumpkin$_6$	2.00	1.80	51.47	46.3	82.63	2.78	50.50	34.91	169
Sole maize HW	2.29	2.06	-	-	94.60	-	58.50	36.10	100
Sole maize WC	1.64	1.47	-	-	58.80	-	40.63	18.18	-

4.3.2 Maize stem diameter

The weed control treatments had significant effect on the stem diameter of maize plants in the four cropping cycles (Table 4.19). In the two croppings of 2008 and the late one of 2009, the plants of plots with all treatment combinations and the sole hoe-weeded (three times) maize produced crops with stem diameters (2.42 to 2.55, 2.39 to 2.51 and 2.28 to 2.86 cm respectively) that were significantly bigger than those of the weedy checks (2.34, 2.14 and 1.81 respectively. In the early season of 2008, only the treatment combinations involving akidi + 50% Metolachlor and 50% atrazine resulted in maize plants that had significantly thinner stem (2.42 cm) than the maximum (2.54 cm). All other treatments resulted in plants with similar maize stem to the maximum. In late 2008, melon + 50% atrazine and pumpkin + 50 or 75% Metolachlor produced maize plants with stem diameter that were comparable to the maximum obtained from pumpkin + 50% Xtravest.

In early 2009, there was no significant difference in stem diameter of maize plants produced by the various cover crop and herbicide treatment combinations. Furthermore, the weedy check produced significantly thinner plants than the sole maize hoe-weeded control and all the cover crops and herbicides treatment combinations except those of akidi or melon each +50% atrazine and pumpkin + 50% Xtravest.

4.3.3 Maize shoot dry matter production

The weed control treatments had significant effect on maize dry matter production in all the trials (Table 4.20). In the early season of 2008, all treatment combinations and sole maize hoe-weeded control resulted in maize shoot biomass (7.3 to 8.3 t/ha) that were significantly higher than that of the weedy check (6.6 t/ha). Among the treatments of cover crop-herbicide treatment combinations, only akidi + 75% Metolachlor produced significantly lower shoot biomass (7.3 t/ha) than the others 7.9 to 8.3 t/ha). In the late cropping of the same year, among the weed control treatments, akidi + 50% atrazine or 75% metolachlor, pumpkin + 50% Xtravest and akidi + 50% metolachlor produced shoot biomass (6.8, 6.5, 6.5 and 6.9 t/ha respectively) that were comparable and significantly higher than that of weedy check (5.93 t/ha).

Table 4.19: Maize plant height and stem diameter (cm) as influenced by cover crops and herbicides in Ido in 2008 and 2009

Cover crop + Herbicide Treatments	Early 2008		Late 2008		Early 2009		Late 2009	
	Plant height	Stem diameter	Plant height	Stem diameter	Plant height	Stem diameter	Plant height	Stem diameter
Akidi + 75% Metolachlor	190ab	2.49ab	171e	2.41ef	196a	2.42a	182ab	2.33b
Akidi + 50% Metolachlor	183abc	2.42b	173de	2.43ef	196a	2.52a	172de	2.31b
Akidi + 50% Atrazine	190ab	2.42b	187a	2.46bcde	184a	2.35ab	185a	2.42b
Akidi + 50% Xtravest	190ab	2.49ab	180bc	2.39f	190a	2.38a	176bcd	2.86a
Me + 75% Metolachlor	189abc	2.47ab	178cd	2.41ef	187a	2.38a	173cde	2.41b
Me + 50% Metolachlor	182abc	2.55a	178cd	2.46bcde	185a	2.39a	171de	2.40b
Me + 50% Atrazine	178bc	2.55a	169e	2.51ab	186a	2.35ab	172de	2.34b
Me + 75% Xtravest	188abc	2.49ab	184ab	2.45def	193a	2.43a	179bc	2.48ab
Pm + 75% Metolachlor	189ab	2.51a	186a	2.51abc	187a	2.42a	173cde	2.47ab
Pm + 50% Metolachlor	181abc	2.49ab	184ab	2.50abcd	196a	2.42a	182ab	2.28b
Pm + 50% Atrazine	186abc	2.52a	186a	2.52a	194a	2.37a	180ab	2.31b
Pm + 50% Xtravest	185abc	2.54a	173de	2.46bcde	190a	2.35ab	176bcd	2.24b
Sole maize Hoe-weeded	192a	2.53a	189a	2.45cde	190a	2.41a	176bcd	2.40b
Sole maize Weedy check	176c	2.34c	162f	2.14g	161b	2.2b	167e	1.81c

Means with the same letter(s) along the same column are not significantly different using DMRT at $P \leq 0.05$

In the early season of 2009, the shoot biomass produced by the plots kept weedy throughout (1.97 t/ha) was significantly lower than those produced by all the cover crop-herbicide treatment combinations and the hoe-weeded control (6.21 to 6.81 t/ha). In the trial, melon + 75% Metolachlor caused the maximum maize dry matter production (6.81 t/ha) which was significantly higher than those produced with melon + 75% Xtravest and pumpkin plus Metolachlor at 75% or 50% recommended herbicide rate (6.2 to 6.3 t/ha). In the late season of 2009, akidi + 50% Metolachlor, pumpkin + 50% atrazine and melon + 75% Xtravest resulted in maize shoot dry matter production (7.1, 6.8, and 6.8 t/ha) comparable to the maximum of akidi + 50% atrazine (7.2 t/ha) and significantly higher than the lowest (5.9 t/ha) in the trial. All the other treatments resulted in significantly lower shoot biomass than the maximum.

The mean maize shoot dry matter production in the four cropping cycles is presented in Figure 4.1. The mean dry shoot weight from the plots kept weedy throughout (6.0 t/ha) was significantly lower than those of all the cover crops/herbicides treatment combinations (6.5 to 7.1 t/ha). Akidi + atrazine at 50% and melon + metolachlor at 75% resulted in maize shoot dry matter production (7.08 and 6.99 t/ha respectively) comparable to the maximum of akidi + metolachlor at 50% (7.14 t/ha) but significantly higher than that of akidi + 75% metolachlor (6.53 t/ha). Furthermore, melon and pumpkin each plus 50% metolachlor resulted in significantly lower maize shoot dry matter production (6.70 and 6.69 t/ha respectively) compared with the maximum dry matter (7.14 t/ha) of akidi plus the same herbicide application.

4.3.4 Maize grain yield

In the early cropping of both years and late cropping of 2009, maize grain yields of all the plots with all the treatment combinations and the hoe-weeded control were significantly higher than those of the weedy check (Table 4.20). Also in early season of both years, all the treatment combinations resulted in similar maize grain yield to the hoe-weeded sole maize (2.26 t/ha in early 2008 and 2.38 t/ha in early 2009). In the late season cropping of 2009, among all the treatment combinations, akidi and pumpkin + each of 50% metolachlor and 75% metolachlor, pumpkin + 50% atrazine and melon + 75% metolachlor as well as sole maize hoe-weeded three times resulted in maize grain yields (2.11 to 2.19 t/ha) comparable to the maximum (2.26 t/ha) obtained from combination of pumpkin with 50% Xtravest.

Table 4.20: Maize grain yield and shoot biomass as influenced by cover crops and herbicides at Ido in 2008 and 2009

Cover crop + Herbicide Treatments	Early 2008		Late 2008		Early 2009		Late 2009	
	Grain yield (t/ha)	Shoot biomass (t/ha)	Grain yield (t/ha)	Shoot biomass (t/ha)	Grain yield (t/ha)	Shoot biomass (t/ha)	Grain yield (t/ha)	Shoot biomass (t/ha)
Akidi + 75% Metolachlor	2.35a	7.25b	2.16bcd	6.47ab	2.43a	6.34ab	2.16abc	6.06ef
Akidi + 50% Metolachlor	2.39a	8.02a	2.33abc	6.90a	2.36a	6.52ab	2.13abc	7.13ab
Akidi + 50% Atrazine	2.30a	7.95a	2.28abc	6.72ab	2.34a	6.41ab	2.02c	7.24a
Akidi + 50% Xtravest	2.28a	8.18a	2.41a	6.32bc	2.40a	6.33ab	2.03c	6.36cdef
Me + 75% Metolachlor	2.23a	8.21a	2.23abcd	6.33bc	2.37a	6.81a	2.11abc	6.59bcde
Me + 50% Metolachlor	2.24a	8.03a	2.11cd	6.19bc	2.35a	6.51ab	2.07bc	6.06ef
Me + 50% Atrazine	2.21a	8.27a	2.35ab	6.17bc	2.38a	6.40ab	2.08bc	6.33cdef
Me + 75% Xtravest	2.23a	8.12a	2.04c	6.23bc	2.32a	6.30b	2.05bc	6.79abcd
Pm + 75% Metolachlor	2.30a	8.07a	2.14bcd	6.31bc	2.23a	6.21b	2.25a	6.54cde
Pm + 50% Metolachlor	2.29a	8.00a	2.28abc	6.27bc	2.35a	6.23b	2.19ab	6.26cdef
Pm + 50% Atrazine	2.27a	8.01a	2.05c	6.31bc	2.22a	6.39ab	2.17abc	6.83abc
Pm + 50% Xtravest	2.33a	7.91a	2.42a	6.39ab	2.43a	6.63ab	2.26a	6.22def
Sole maize Hoe-weeded	2.26a	8.04a	2.29abc	6.30bc	2.38a	6.37ab	2.17abc	6.12ef
Sole maize Weedy check	1.93b	6.57c	1.74d	5.93c	1.97b	5.77c	1.69d	5.85e

Means with the same letter(s) along the same column are not significantly different using DMRT at $P \leq 0.05$

All other treatment combinations resulted in significantly lower yields (2.02 to 2.08 t/ha) than the maximum but significantly higher than the minimum yield obtained from the plots kept weedy throughout (1.69 t/ha). Also in the late season of 2008, akidi and melon + 75 and 50% Metolachlor respectively, melon + 75% Xtravest and pumpkin + 50% atrazine and 75% Metolachlor resulted in significantly lower maize grain yield (2.16, 2.11, 2.05 and 2.18 t/ha respectively) than the maximum obtained from akidi or pumpkin each + 50% Xtravest (2.42 t/ha).

Averaged over four cropping cycles, maize grain yield was significantly influenced by the weed control treatments (Figure 4.2). The mean maize grain yield (1.83 t/ha) obtained from the plots kept weedy throughout was significantly lower than those of all the cover crops/herbicide combinations treatments and the maximum of sole maize hoe-weeded three times (2.16 to 2.36 t/ha). Among the treatment combinations, akidi + 50% metolachlor resulted in maize grain yield (2.30 t/ha) comparable to the maximum (2.36 t/ha) and significantly higher than that of melon + 75% Xtravest (2.16 t/ha). Furthermore, the maximum grain yield was significantly higher than those of treatment combinations of melon + 50% metolachlor or 75% Xtravest and pumpkin + 50% atrazine or 75% metolachlor (2.16 to 2.19 t/ha). The yield increase due to weed control with complementary use of cover crops and pre-emergence herbicides ranged from 18.0 to 25.7%.

4.3.5 Cover crops shoot dry matter

In the early season of both years, irrespective of the type of herbicide applied, pumpkin produced significantly higher shoot biomass than all the other cover crops (Table 4.21). In the early season of 2008, among the treatment combinations, pumpkin + 50% atrazine resulted in cover crops dry matter production (302 kg/ha) comparable to that of the maximum of the same crop with 75% metolachlor (321 kg/ha). The akidi treatment combinations generally had the least dry matter yields (129 to 140 kg/ha) while melon + 75% metolachlor and 50% atrazine as well as all pumpkin treatments had higher dry matter production (176 to 321 kg/ha). In early 2009, pumpkin + 75% metolachlor produced dry matter (348 kg/ha) comparable to the maximum of the same crop with 50% Xtravest (381 kg/ha) while the other akidi treatments also produced higher dry matter than treatment combinations involving melon but comparable to those of pumpkin.

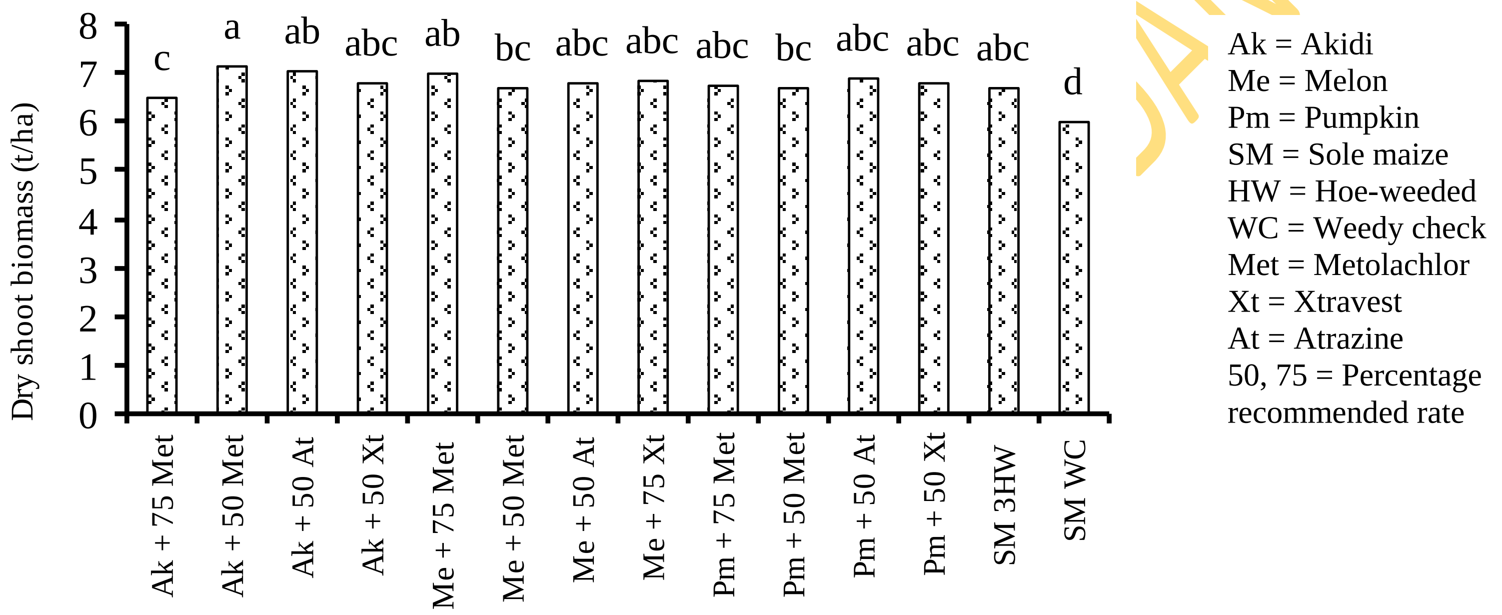

Figure 4.1: Mean maize shoot dry matter of the combined analyses of the four cropping cycles as affected by cover crop and pre-emergence herbicide treatment combinations

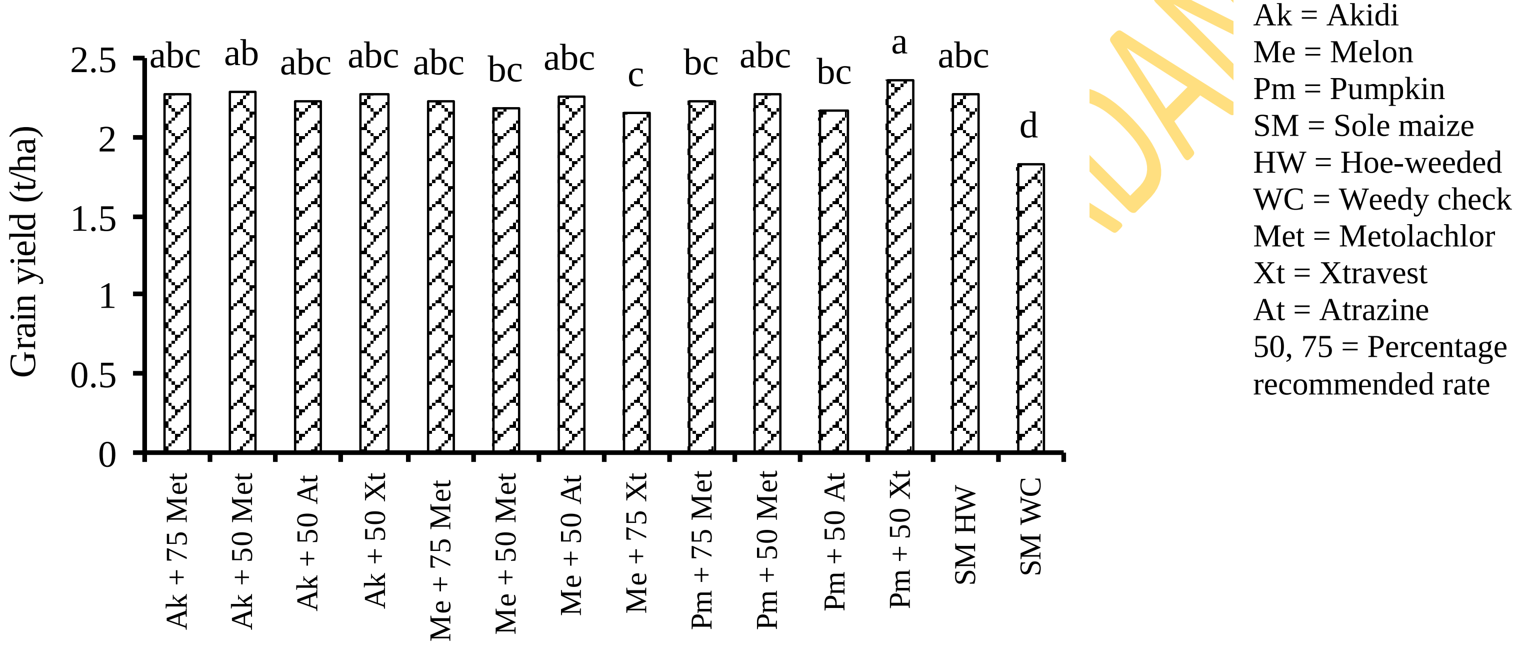

Figure 4.2: Mean maize grain yields of the combined analyses of the four cropping cycles as affected by cover crop and pre-emergence herbicide treatment combinations

Conversely, in the late seasons of 2008 and 2009, akidi plus 50% atrazine and 50% metolachlor produced shoot dry matter yields that were comparable to the maximum of the same crop plus 75% metolachlor. Akidi generally produced the highest shoot dry matter while melon produced the least dry matter compared to the other crops.

4.3.6 Dry seed yield

As observed with the dry matter production (Table 4.21), seed yield followed a trend whereby pumpkin generally produced maximum seed yields while akidi produced the lowest in the early seasons. Conversely, akidi produced maximum seed yields while melon produced the lowest in the late seasons. Melon of plots which had application of 75% Xtravest also produced yields comparable to the appropriate maximum in the early season trials.

In the early season of 2008, melon + 75% Xtravest resulted in similar seed yield (58.1 kg/ha) to the maximum of pumpkin + 75% metolachlor (59.8 kg/ha) that was significantly higher than those of the other treatments (36 to 49 kg/ha) except that of pumpkin plus 50% metolachlor (51.1 kg/ha). All other treatment combinations produced seed yields which was comparable to pumpkin + 50% Metolachlor except melon + 50% atrazine (36 kg/ha). Melon + 50% atrazine also produced significantly lower seed yield than those obtained of akidi + 50, 75% metolachlor and 50% atrazine and those of pumpkin and melon each + 50% Xtravest and metolachlor respectively (41.2 to 49.0 kg/ha. In early season cropping of 2009, pumpkin + 50% metolachlor produced maximum seed yield (58.2 kg/ha) which was significantly higher than those of the other treatment combinations (36.5 to 45.6 kg/ha) except those produced by the same crop combined with 50% atrazine and Xtravest as well as melon + 75% Xtravest 49.9 to 51.3 kg/ha). In the trial, in addition to the aforementioned melon + 75% Xtravest produced seed yield comparable to those pumpkin and melon each with 75% metolachlor while pumpkin plus 50% atrazine and Xtravest produced higher seed yields than akidi treatments except with Xtravest and melon plus atrazine.

In the late season of 2008, akidi plus metolachlor and atrazine each at 50% of the recommended rate produced significantly higher seed yield (57.3 and 60.1 kg/ha) comparable to the maximum of akidi plus 75% metolachlor (63.8 kg/ha) and significantly higher than those of the other cover crops combinations with herbicide (2.6 to 49.4 kg/ha). Yields of melon (2.6 to 5.8 kg/ha) produced on herbicide plots were significantly lower than those of other crop-herbicide combinations in the trial

(21.2 to 63.8 kg/ha). In the late season of 2009, akidi plus 50% atrazine produced seed yield (81.0 kg/ha) comparable to maximum (89.0 kg/ha) and those of the same crop (69 to 72 kg/ha) with other herbicides, but pumpkin with herbicides also produced higher seed yields than melon in this trial.

4.3.7 Weed density and weed dry matter production as influenced by complementary use of pre-emergence herbicides and cover crops

The results of weed density and weed dry matter production as influenced by the cover crops and herbicides treatment combinations are presented in Table 4.22 and Figures 4.3 and 4.4. In all the cropping seasons, the plots that had cover crops and herbicide treatment combinations and the sole maize had significantly lower weed density (26.7 to 89.6 /m^2 across seasons) than those kept weed free throughout lifecycle (100 to 153 /m^2 across seasons) (Table 4.22). Furthermore, the treatment combination of akidi + 75% Metolachlor resulted in weed densities (46.0 to 56.0 /m^2) that were comparable to the hoe-weeded control in the four maize cropping cycles of the two years (30 to 60.4 /m^2). Plots with akidi plus 50% metolachlor or Xtravest each at 50% recommended rate also had weed density () comparable to those of the respective hoe-weeded controls. Weed density of the plots with melon plus 50% metolachlor was however only comparable to that of the control in early season of 2008. Other treatment combinations that resulted in weed density comparable to that of the hoe-weeded control in the early season of 2009 were akidi plus 50% atrazine, melon plus 75% each of metolachlor or Xtravest and 50% atrazine as well as pumpkin plus 50% atrazine.

However, in the late cropping of both years, all cover crops and herbicide treatment combinations had weed densities (27 to 90 and 40 to 80 /m^2 in late 2008 and 2009 respectively) comparable to that of their respective hoe-weeded sole maize (52 and 60 /m^2) although lower values were observed with pumpkin plus 75% metolachlor in 2008 and 50% Xtravest in 2009. Among the treatments, melon plus 75% metolachlor or Xtravest, 50% atrazine and pumpkin plus 50% each of metolachlor, atrazine and Xtravest had densities comparable to the appropriate lowest in the late season of 2008.

Table 4.21: Dry matter production (kg/ha) of akidi, melon and pumpkin used as cover crops

Cover crop + Herbicide Treatments	Early 2008		Late 2008		Early 2009		Late 2009	
	Shoot biomass	Seed yield	Shoot biomass	Seed yield	Shoot biomass	Seed yield	Shoot biomass	Seed yield
Akidi + 75% Metolachlor	132e	46.5b	148bc	63.8a	117f	37.0e	191a	69b
Akidi + 50% Metolachlor	140de	48.0b	136bcd	57.3ab	126ef	36.5e	172abc	72b
Akidi + 50% Atrazine	129e	45.2b	159ab	60.1ab	137def	37.5e	183ab	81ab
Akidi + 50% Xtravest	135e	44.3bc	168a	49.4b	124ef	42.5cde	169abc	89a
Me + 75% Metolachlor	165cd	43.2bc	38.5e	3.1e	171d	47.5bcd	26d	1.9e
Me + 50% Metolachlor	148cde	48.7b	41e	7.3e	154def	38.9de	36d	2.2e
Me + 50% Atrazine	171c	36.0c	33e	2.6e	162de	42.1cde	32d	4.2e
Me + 75% Xtravest	128e	58.1a	36e	5.8e	154def	56.0ab	43d	1.2e
Pm + 75% Metolachlor	321a	59.8a	121d	34.2c	348ab	45.6bcde	153bc	25.4d
Pm + 50% Metolachlor	289b	51.1ab	134bcd	28.5cd	305c	58.2a	14d	28.5d
Pm + 50% Atrazine	302ab	43.8bc	149bc	21.2d	332bc	49.9abc	174ab	47.2c
Pm + 50% Xtravest	291b	49.0b	128cd	33.9c	381a	51.3abc	140c	30d

Means with the same letter in the same column are not significantly different using DMRT ($P \leq 0.05$).

Similarly in 2009 late season, all the plots with akidi, melon plus 75% metolachlor and atrazine as well as pumpkin plus 75% metolachlor and 50% Xtravest had weed densities comparable to the appropriate lowest.

As observed with density, all the plots with cover crop-herbicide treatment combinations and hoe-weeded plots had significantly lower weed dry matter (81 to 268 g/m^2) than those kept weedy throughout (508 to 608 g/m^2) (Table 4.22). In 2008, among treatment combinations, melon + 50% metolachlor in both seasons as well as akidi plus 50% each of metolachlor and Xtravest and melon plus 75% each of metolachlor and Xtravest in the late season had weed dry matter (109 to 140 g/m^2) comparable to the lowest of the hoe-weeded sole maize treatment (80 to 100 g/m^2). In the two seasons, melon + 50% atrazine consistently resulted in high weed dry matter production. In 2009, none of the treatment combinations caused weed dry matter production comparable to the lowest with hoe-weeded control. However, akidi plus 75% metolachlor, melon + 75% Xtravest in the early season as well as pumpkin + 75% metolachlor in the early and late season respectively caused low weed dry matter production in the year. Weed dry matter production (averaged over four cropping cycles) as affected by cover crop and pre-emergence herbicide treatments is presented in Figure 4.4.

4.3.8 Relationship of maize grain yield with maize shoot biomass, weed density and dry weed biomass in Ido in four cropping cycles

The relationship between maize grain yields and each of maize shoot biomass, weed density and weed dry matter as influenced by the complementary use of pre-emergence herbicides and the cover crops is presented in Table 4.23. Maize shoot biomass and the weed parameters had significant correlations with maize grain yield in all the trials. While the correlation coefficients were positive with maize shoot biomass, those of the weed parameters were negative in all cases.

Table 4.22: Weed density (number/m^2) and dry biomass (g/m^2) as influenced by cover crops and herbicides in Ido in 2008 and 2009

Cover crop + Herbicide	Early 2008		Late 2008		Early 2009		Late 2009	
Treatments	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
Akidi + 75% Metolachlor	46cd	193.0b	56.0cd	124def	54bc	116g	46.4cd	172bc
Akidi + 50% Metolachlor	42cd	125.2cd	89.6b	140cdef	45.6bc	224c	58.8bcd	180b
Akidi + 50% Atrazine	47.2c	148.6cd	66.0bcd	148cde	55.2bc	140efg	47.6cd	138bcd
Akidi + 50% Xtravest	38.8d	164.5bc	72.8bc	112ef	46.4bc	268b	54.8cd	175bc
Me + 75% Metolachlor	57.2bc	130.0cd	54.4cd	128def	43.2bc	200cd	56bcd	152bcd
Me + 50% Metolachlor	39.2cd	109.4de	74.8bc	120def	56.8b	140efg	80b	160bcd
Me + 50% Atrazine	61.2b	154.6bc	46.8de	192b	39.6c	132fg	66bcd	156bcd
Me + 75% Xtravest	56.8bc	135.9cd	54.8cd	112ef	47.6bc	116g	72.8bc	168bc
Pm + 75% Metolachlor	54bc	129.9cd	27.6e	160bcd	56.4b	172de	67.6bcd	124d
Pm + 50% Metolachlor	34.8d	136.0cd	49.2cde	176bc	39.2c	196cd	73.2bc	132cd
Pm + 50% Atrazine	49.6bc	130.1cd	50.4cde	152cde	49.6bc	152ef	70.4bc	136bcd
Pm + 50% Xtravest	46.4c	121.2cd	40.8de	176bc	43.2b	224c	40.8d	180b
Sole maize Hoe-weeded	30d	80.7e	52.4cde	100f	40c	80h	60.4bcd	56e
Sole maize Weedy check	111.6a	535.a	134.0a	408a	100.4a	608a	153.2a	508a

Means with the same letter in the same column are not significantly different using DMRT ($P \leq 0.05$)

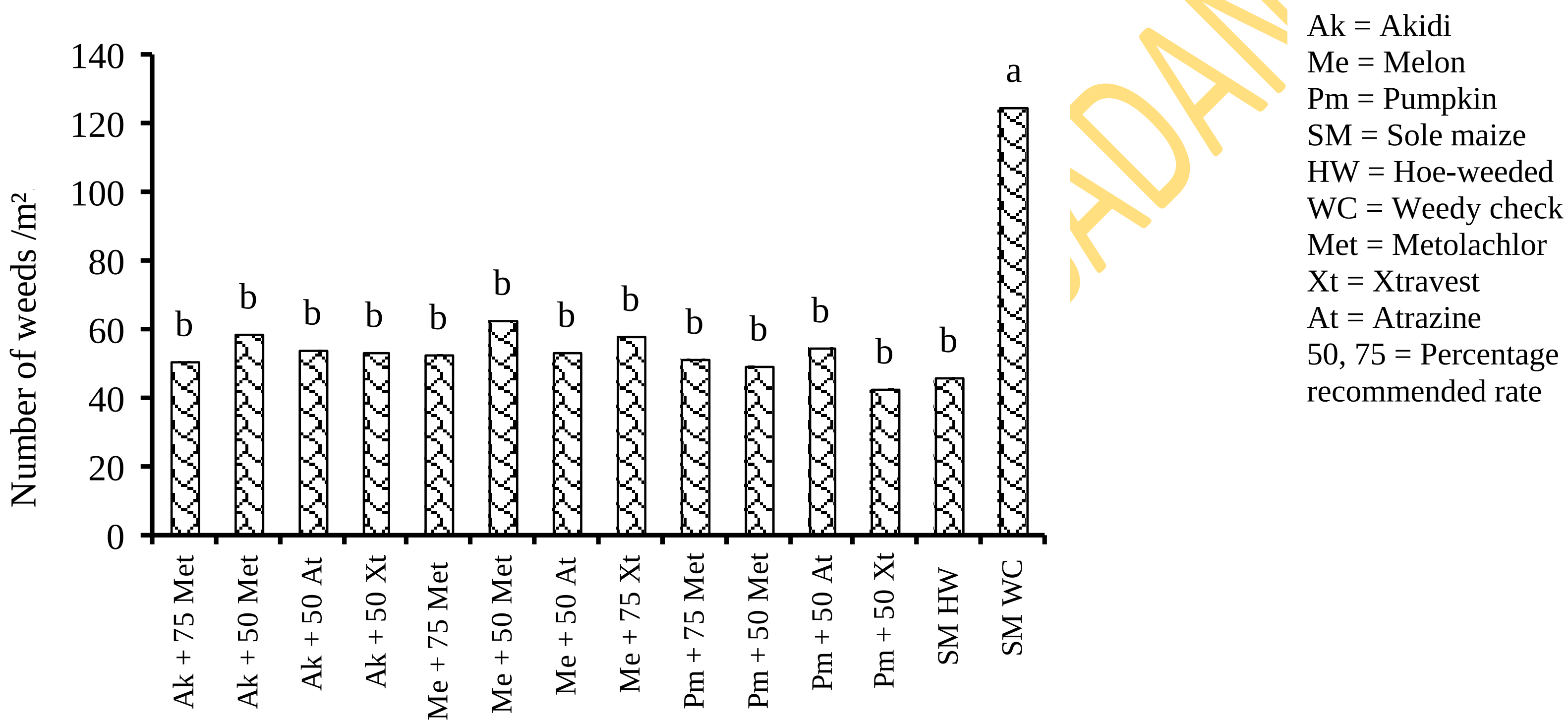

Figure 4.3: Weed densities (averaged over four cropping cycles) as affected by cover crop and pre-emergence herbicide treatments

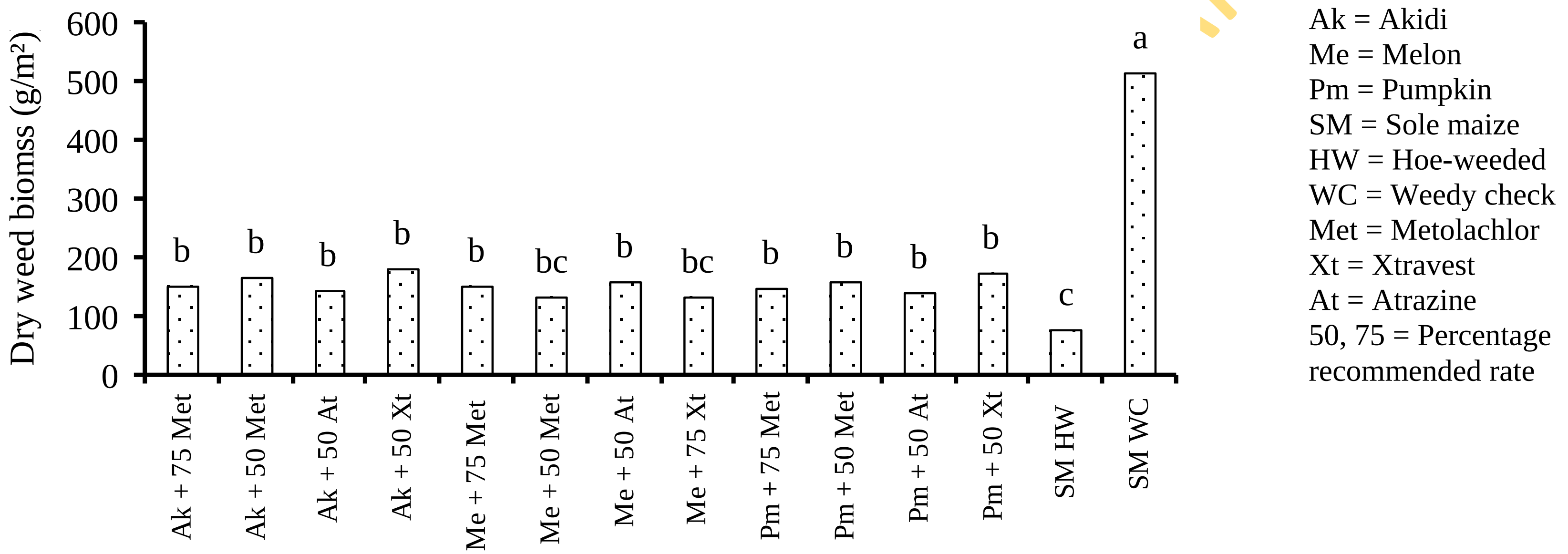

Figure 4.4: Weed dry matter production (averaged over four cropping cycles) as affected by cover crop and pre-emergence herbicide treatments

4.3.9 Economic analysis of maize production with complementary use of cover crops and pre-emergence herbicides for weed control

The partial budget analysis of maize production with the complementary use of pre-emergence herbicides and cover crops is presented in Table 4.24. The no-weeding plots had the least maize grain yield which resulted in a net benefit of N25,260 as return on investment and management. The Marginal Rate of Return (MRR) for extra investment on weed control with hoe weeding was 59%. Higher MRRs were obtained for investing on weed management with complementary use of cover crops and pre-emergence herbicides. The MRRs of 169 to 190% were obtained when extra investments were made on weed management with akidi with pre-emergence herbicides of atrazine or Xtravest at 50% recommended rate or metolachlor at 50 or 75% recommended rate. The MRR for melon plus the same herbicides treatments ranged from 98 to 130% while that of pumpkin was 120 to 170%.

4.4 Experiment 4: Effects of cover crop rotation on weed infestation and `maize growth and productivity

The results on growth and yield parameters of the cover crops, viz: melon, cowpea, akidi and pumpkin as well as the weed parameters in the early and late cropping seasons of 2008 and 2009 are presented in Tables 4.25 to 4.26.

4.4.1: Percentage soil coverage

Percentage soil coverage at 4 WAS differed significantly among cover crops in late seasons of both years and in early 2009 (Table 4.25). In the late seasons of both years, cowpea had percentage soil coverage comparable to the maximum of akidi intercropped with maize and higher than the lowest with melon. Furthermore, pumpkin had percentage soil coverage comparable to that of cowpea in both years. In early 2009, pumpkin had the maximum percentage soil coverage (47.0%) which was significantly higher than 33.8 and 36.0 of akidi and cowpea respectively. The 43.8% of melon was also significantly higher than the soil coverage obtained of cowpea in the season. Akidi produced the maximum ground coverage of 51% which was significantly higher than 37.75 and 39.75% obtained for melon and pumpkin respectively.

Table 4.23: Correlation coefficient values of maize grain yield with maize shoot dry matter, weed density and weed dry matter in Ido in four cropping cycles

Parameters and seasons	Maize shoot dry matter	Weed dry matter	Weed density
Maize grain yield			
Early 2008	0.17*	-0.49*	-0.41*
Late 2008	0.35*	-0.64*	-0.40*
Early 2009	0.17*	-0.52*	-0.36*
Late 2009	0.15*	-0.70*	-0.63*

* Significant ($P \leq 0.05$); n = 56

Table 4.24: Partial budget analysis for maize production with complementary use of cover crops and pre-emergence herbicides for weed control

Treatments	Maize grain yield (t/ha)		Cover crops seed yield (kg/ha)		Gross farm gate price (₦'000)		Total variable cost	Net benefit	Marginal rate of return
	Experimental yield	Adjusted yield	Experimental yield	Adjusted yield	Maize	Cover crops	(₦'000)		
Akidi + 75% Metolachlor	2.28	2.05	54.08	48.67	94.39	9.73	54.43	49.70	177
Akidi + 50% Metolachlor	2.3	2.07	55.95	50.36	95.22	10.07	54.20	51.09	190
Akidi + 50% Atrazine	2.24	2.02	55.95	50.36	92.74	10.07	54.35	48.46	169
Akidi + 50% Xtravest	2.28	2.05	56.30	50.67	94.39	10.13	54.76	49.76	173
Me + 75% Metolachlor	2.24	2.02	23.15	20.84	92.74	4.17	54.43	42.49	125
Me + 50% Metolachlor	2.19	1.97	23.73	21.35	90.67	4.27	54.20	40.74	114
Me + 50% Atrazine	2.26	2.03	21.23	19.10	93.56	3.82	54.35	43.03	130
Me + 75% Xtravest	2.16	1.94	29.98	26.98	89.42	5.40	55.26	39.56	98
Pm + 75% Metolachlor	2.23	2.01	41.25	37.13	92.32	3.71	53.43	42.61	136
Pm + 50% Metolachlor	2.28	2.05	41.58	37.42	94.39	3.74	53.20	44.93	156
Pm + 50% Atrazine	2.18	1.96	40.53	36.47	90.25	3.65	53.35	40.55	120
Pm + 50% Xtravest	2.36	2.12	41.05	36.95	97.70	3.69	53.76	47.63	170
Sole maize Hoe-weeded	2.28	2.05	-	-	94.39		58.50	35.89	59
Sole maize Weedy check	1.83	1.65	-	-	65.88		40.63	25.26	0

Table 4.25: Percentage soil coverage as influenced by cover crops of pumpkin, melon, akidi and cowpea at 4, 6 and 8 WAS in four seasons

	Maize + Pumpkin	Maize + Melon	Maize + Akidi	Maize + Cowpea	LSD
	% soil coverage 4 WAS				
Early 2008	44.00	42.75	43.50	37.25	ns
Late 2008	43.00	35.25	49.25	47.25	6.05
Early 2009	47.25	43.75	36.00	33.75	9.44
Late 2009	39.75	37.75	51.00	45.25	8.32
	% soil coverage 6 WAS				
Early 2008	59.06	60.13	58.13	50.38	6.80
Late 2008	58.63	49.00	63.75	56.94	6.40
Early 2009	59.06	51.50	58.88	54.06	ns
Late 2009	56.56	49.31	64.19	61.63	ns
	% soil coverage 8 WAS				
Early 2008	74.00	69.20	73.60	56.40	ns
Late 2008	80.55	78.00	85.65	76.90	ns
Early 2009	77.20	72.40	63.60	64.95	ns
Late 2009	80.40	59.00	81.70	77.45	13.43

The LSD compares the means along the same row.

Percentage ground coverage was only significantly different among the cover crops at 6 weeks after sowing in the early and late season of 2008. In the early season of the year, the plots that were cover-cropped with melon produced significantly lower percentage soil coverage (49%) than other cover crops. In contrast, melon produced higher percentage soil coverage at 6 WAS than cowpea in early 2008. The percentages ground coverage at 8 WAS in maize only differed significantly among cover crops in the late season of 2009 when pumpkin, akidi and cowpea had similar values that were higher than 59% of melon. Furthermore, akidi had higher ground coverage than cowpea.

4.4.2: Weed density and dry weed dry matter production

The result of weed density and dry weed dry matter production as influenced by various management practices in maize are presented in Table 4.26.

4.4.2.1 Weed density

In all the cropping seasons, the respective weedy checks had the highest weed densities. In the early season of year 2008, the plots with pumpkin and akidi as well as the hoe-weeded control had significantly lower weed density (32 to 44 /m^2) than those that had melon and cowpea cover crops weed control treatments (56 /m^2). All the plots with cover crops and those hoe-weeded once at 4WAS had similar weed densities while those with melon and cowpea had higher values than those hoe-weeded twice. In early 2009, the plots hoe-weeded three times, and those with akidi treatments (40 to 48 /m^2) had significantly lower weed densities than those of cowpea (52 /m^2).

In the late season of 2008, all the weed control treatments resulted in similar weed densities in all the maize plots. However, in the late season of 2009, the plots hoe-weeded three times (128 /m^2) and those treated with herbicide (56 /m^2) had significantly lower weed densities than those with melon (76 /m^2) and those hoe-weeded once at 4 WAS (68 /m^2).

4.4.2.2 Weed dry matter production

The plots kept weedy throughout crop lifecycle had significantly higher weed dry matter production than all other weed control treatments in all the trials (92 to 412 g/m^2) (Table 4.26). Similarly the plots hoe-weeded three times had significantly lower weed dry matter production (49 to 58 g/m^2) than all the other treatments (91 to 166 g/m^2) in the two seasons of 2008 and early season of 2009. In the late season of 2009, the plot that had akidi produced weed dry matter (93 g/m^2) comparable to those of the hoe-weeded control (61 g/m^2). Also, in the trials in 2008, among the four cover crops, akidi resulted in significantly lower weed dry matter (106 g/m^2) than those caused by the other cover crops (142 to 152 g/m^2) except that of cowpea with similar dry matter production values (120 g/m^2) in the late season of the year. Furthermore, the weed dry matter production of cowpea plots were comparable to that treated with herbicides (117 g/m^2) but lower than those of plots with melon and pumpkin or the plots hoe-weeded once at 4 WAS which were also similar (152, 142 and 166 g/m^2 respectively).

In both seasons of 2009, among the four cover crops which caused similar weed dry matter production, akidi caused significantly lower production (110 and 93 g/m^2 respectively in early and late season) than one hoe-weeding at 4 WAS (164 and 167 g/m^2 respectively). In the late season of 2009, pumpkin and cowpea in addition caused lower weed dry matter production (122 and 117 g/m^2 respectively) than one hoe-weeding at 4 WAS (167 g/m^2).

4.4.3 Maize growth and yield parameters as influenced by different cover crops in maize in four cropping cycles

The results of maize plant height, stem diameter at 8 WAS as well as the shoot dry matter production and grain yield are presented in Tables 4.27 and 4.28.

4.4.3.1 Maize plant height

Maize plant height was not significantly influenced by the weed management practices in each of the four cropping cycles of maize in 2008 and 2009. The trend however shows that plots kept weedy throughout the growing season had shorter plants in the late seasons of 2008 and 2009 (Table 4.27).

4.4.3.2 Maize stem diameter

The weed control treatments had significant effects on maize stem diameter in the late season of 2008 and the two seasons of 2009. In these three trials, all the treatments, except the one that received a single weeding at 4 WAS in late 2008 (2.12 cm) and early season of 2009 (2.13 cm), had similar maize plant stem diameters which were comparable to those of the weedy checks (1.99 and 2.03 cm respectively).

Table 4.26: Weed density (number/m^2) and dry weed biomass (g/m^2) at 8 WAS as influenced by cover crops and other management weed practices in maize in four cropping seasons

	Early 2008		Late 2008		Early 2009		Late 2009	
	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
Maize + Pumpkin	43bcd	136c	34b	142c	73bc	136bc	49bc	122cd
Maize + Melon	56b	163b	41b	152b	63bc	143bc	74b	146bc
Maize + Akidi	41bcd	99d	40b	106d	49c	110c	45bc	93de
Maize + Cowpea	55b	144bc	51b	120cd	95b	135bc	55bc	117cd
Maize + Herbicide	25d	91d	37b	117cd	42c	123bc	37c	113cd
Maize + HW 4WAS	46bc	182b	57b	166b	76bc	164b	66b	167b
3 Hoe-Weeded control	33cd	49e	31b	58e	41c	56d	33c	61e
Weedy check	92a	397a	117a	366a	138a	411a	131a	407a

HW 4WAS = Hoe-weeding at 4 weeks after sowing
Means with the same letter along the same column are not significantly different using DMRT ($P \leq 0.05$).

Table 4.27: Maize plant height and stem diameter at 8WAS as influenced by different weed management practices in four cropping seasons

	Plant height				Stem diameter			
	Early 2008	Late 2008	Early 2009	Late 2009	Early 2008	Late 2008	Early 2009	Late 2009
Maize + Pumpkin	188.0	190.5	191.3	183.8	2.39	2.20ab	2.18abc	2.15a
Maize + Melon	190.5	192.0	189.3	182.5	2.58	2.18ab	2.24ab	2.19a
Maize + Akidi	189.3	188.8	192.0	183.0	2.31	2.24ab	2.26ab	2.13a
Maize + Cowpea	186.3	190.5	187.0	182.0	2.36	2.16ab	2.20abc	2.12ab
Maize + Herbicide	186.3	191.8	187.5	187.8	2.53	2.28ab	2.33a	2.23a
Maize + HW 4WAS	183.5	192.8	185.8	177.8	2.31	2.12bc	2.13bc	2.07ab
Maize + 3HW	190.3	188.8	190.3	187.5	2.54	2.30a	2.36a	2.28a
Maize + Weedy check	192.3	185.8	192.3	173.8	2.33	1.99c	2.03c	1.83b
	ns	ns	ns	ns	ns			

HW 4WAS = Hoe-weeding at 4 weeks after sowing; 3HW = 3 times hoe weeded

Means with the same letter along the same column are not significantly different using DMRT ($P \leq 0.05$). ns = not significant.

4.4.3.3 Maize shoot dry matter production

Maize shoot biomass was significantly affected by the weed control treatments in the late season of 2008 and both seasons of 2009 (Table 4.28). In all cases, maize plants hoe-weeded three times produced higher crop biomass than those kept weedy throughout crop's lifecycle. Furthermore, all the weed control treatments resulted in higher maize biomass (6.35 to 7.06 t/ha) than the weedy check (5.22 t/ha) in the late season of 2009. In late 2008, among other weed control treatments, maize hoe-weeded once produced lower biomass (6.56 t/ha) than those hoe-weeded three times (7.25 t/ha) and those treated with herbicides (7.24 t/ha). The maize intercropped with each of the four cover crops also produced significantly higher biomass (6.79 to 6.97 t/ha) than those of the weedy check (6.18 t/ha). In 2009, maize intercropped with pumpkin in the early season as well as akidi and cowpea in the late season produced biomass (6.91, 6.76 and 6.63 t/ha respectively) comparable to the maximum with herbicide application (6.91 to 7.24 t/ha) and three hoe-weeding (7.06 to 2.25 t/ha) and significantly higher than the lowest with the weedy check (5.222 to 6.29 t/ha).

4.4.3.4 Maize grain yield

The weed control treatments had significant effects on maize grain yields in the four trials. Maize grain yields produced on the plots that received three hoe-weeding and those treated with herbicide were consistently higher (2.23 to 2.43 t/ha) than those produced on weedy checks (1.62 to 2.03 t/ha) and those that were weeded once at 4 WAS (2.00 to 2.18 t/ha). Among the cover crop treatments, the plots that had akidi consistently produced maize grain yields (2.16 to 2.29 t/ha) that were comparable to those produced by three hoe-weeding controls (2.28 to 2.42 t/ha). The plots that had pumpkin also produced comparable maize grain yields to the hoe-weeded control in early 2008 and in both trials in 2009. Maize grain production (2.22 t/ha) on plots that had melon was comparable to the hoe weeded control only in the early season of 2009 while cowpea plots produced comparable maize grain yields (2.18) t/ha to the control only in the late seasons of 2009.

Furthermore, maize grain yields from plots that had melon as weed control treatment was consistently comparable to those obtained from the plots that were weeded only once at 4 WAS; while pumpkin and cowpea treatments also produced comparable yields in the first three trials with the late cropping of 2009 producing

Table 4.28: Maize shoot biomass and grain yields as influenced by cover crops and other weed management practices in maize in four cropping seasons

	Early 2008		Late 2008		Early 2009		Late 2009	
	Biomass	Grain yield	Biomass	Grain yield	Biomass	Grain yield	Biomass	Grain yield
Maize + Pumpkin	7.08	2.26ab	6.79ab	2.19bc	6.91ab	2.23abc	6.73ab	2.17ab
Maize + Melon	7.07	2.22b	6.82ab	2.12bc	6.95ab	2.22abc	6.35b	2.02bc
Maize + Akidi	7.08	2.29ab	6.97ab	2.25ab	6.76abc	2.25abc	6.76ab	2.16ab
Maize + Cowpea	7.02	2.27ab	6.88ab	2.22bc	6.67bc	2.15bcd	6.63ab	2.18ab
Maize + Herbicide	7.36	2.43a	7.24a	2.34ab	7.22a	2.33ab	6.91a	2.23a
Maize + HW 4 WAS	6.82	2.18bc	6.56bc	2.10c	6.6bc	2.13cd	6.26b	2.00c
Sole maize + 3HW	7.47	2.42a	7.25a	2.36a	7.24a	2.36a	7.06a	2.28a
Sole maize + Weedy check	6.7	2.03c	6.18c	1.87d	6.29c	2.03d	5.22c	1.62d

HW 4WAS = Hoe-weeding at 4 weeks after sowing; 3HW = 2 times hoe weeded
Means with the same letter along the same column are not significantly different using DMRT ($P \leq 0.05$).

significantly higher grain yields with these treatments, maize grain yields from the plots that had akidi were significantly higher in the tow late seasons production.

4.4.4 Weed floral composition, density and dry biomass as influenced by different cover crops sequence in maize in four cropping cycles

The weed floral composition, weed density and dry weed biomass as influenced by the rotation or continuous use of a cover crop and other weed management practices at the end of four seasons of maize cropping in 2008 and 2009 cropping seasons are presented in Table 4.29 and in Figures 4.5 and 4.6.

4.4.4.1 Weed floral composition

Although present on all the other plots at the end of the four cropping cycles, *Cyperus rotundus* Linn., *Mariscuss alternifolius* Linn. and *Momordica charantia* Linn. were not found on those left weed invested throughout in each season. The dominant weed species in terms of abundance on the plots weed-infested throughout maize lifecycles included *Chromolaena odorata* with relative density (r.d) of 22.3%, *Senna hirsuta* (1.72%), *Laportea aestuans* (10.7%), *Spigelia anthelmia* (9.7%), *Talinum fruticoum* (8%) and *Solanum torvum* (6.8%) (Table 4.29). Other species that had lower relative density of about 5% included *Acalypha ciliata*, *Ageratum conyzoides*, *Euphorbia hirta, Panicum laxum*, and *Phyllanthus amarus*. Compared with the weedy check, the number of weed species encountered on the plots with cover crops and those hoe-weeded reduced at the end of the cropping cycles. While such species as *Acalypha ciliata*, *Ageratum conyzoides*, *Senna hirsuta* and *Chromolaena odorata* were generally present on all the plots; others like *Panicum laxum*, *Cyperus rotundus* and *Mariscus alternifolius* were present on plots where the same cover crops was continuously used except on akidi plots.

4.4.4.2 Weed dry matter production as influenced by different cover crops sequence in maize over four cropping cycles

The weed dry matter production at the end of the four cropping cycles of maize was significantly affected by the different cover crop sequences (Figure 4.5). The highest weed dry matter production (99 g/m^2) occurred on the plots of weedy check while the hoe-weeded plots produced the least (14 g/m^2). Rotation of pumpkin,

Table 4.29: Weed floral composition and density as influenced by different weed management practices over four Seasons at Ido

	MAPC	MCPA	PAMC	PCMA	MAMA	MCMC	MMMM	AAAA	CCCC	PPPP	Xtravest	HW 4WAS	3HW	Weedy check
Acalypha ciliata Forsk.	1.25	0.75	1.5	0.5	1.25	2.25	1.25	1	3.25	0.75	-	2.75	1	1.25
Ageratum conizoides L.	3.75	1.5	1.75	1.5	2.5	1.75	1.75	4.25	2.25	5.25	2.75	1.75	1.5	1.25
Cassia hirsuta L.	-	1.25	0.75	1.75	-	0.25	2.25	2.5	1.75	0.25	-	1.5	0.5	3
Chromolaena odorata (R.M King & Robinson.).	3.25	3	3.75	2.75	2.5	2.75	2.25	2.25	2.5	2.25	1.75	1.75	1.5	5.75
Cyperus rotundus L.	-	-	-	-	-	-	0.75	-	-	-	0.75	0.5	-	
Euphorbia hirta L.	-	-	0.25	0.5	0.25	0.5	1.25	1.25	0.75	-		1.25	-	1.25
Fluerya aestuans L.	-	-	-	-	0.25	-	-	-	0.5	-		-	-	2.75
Mariscuss alternifolius L.	-	-	-	-	-	-	0.75	-	0.5	0.25	0.75	2	-	
Momordica charantia L.	-	0.5	0.25	0.5	-	0.75	-	0.5	0.75	-	-	-	-	
Panicum laxum Sw	-	-	-	-	-	0.25	0.75	-	0.25	0.5	-	0.25	-	1.25
Panicum maximum Jacq	-	-	-	-	-	-	0.25	-	-	-	-	0.25	-	0.5
Panicum repens L.	-	-	-	0.25	-	-	1.25	-	-	-	0.25	0.75	-	0.25
Phyllanthus amarus Schum	1.25	0.75	1.75	0.75	1.25	1	1.25	0.25	0.75	-	-	1.5	1.25	1.25
Physalis angulata L.	1	0.5	0.50	0.5	1	0.25	-	-	0.25	0.75	-	0.5	0.25	0.75
Solanum nigrum L.	1	0.25	-	0.25	1	-	1.25	0.25	-	-	-			0.25
Solanum torvum Swartz	-	-	0.50	-	-	1.25	1.5	-	-	1.25	1.25	0.5	0.25	1.75
Spigelia anthelmia L.	3.75	2.25	1.75	2.5	2.25	1.75	0.75	0.75	-			1	1.75	2.5
Talinum triangulare L.	-		1	-	0.25	0.25	1.25	*0.5*	-	1	1.75	0.25	0.25	2
Total weed Density	15.25	10.75	13.75	11.75	12.5	13	18.5	13.5	13.5	12.25	9.25	16.5	8.25	25.75

M = melon, A = akidi, P = pumpkin C = cowpea; MAPC = sequence of use of the cover crops in early and late seasons of 2008 and 2009 in maize production; HW 4 WAS = Hoe weeding at 4 weeks after sowing; 3HW = 3 times hoe-weeded.

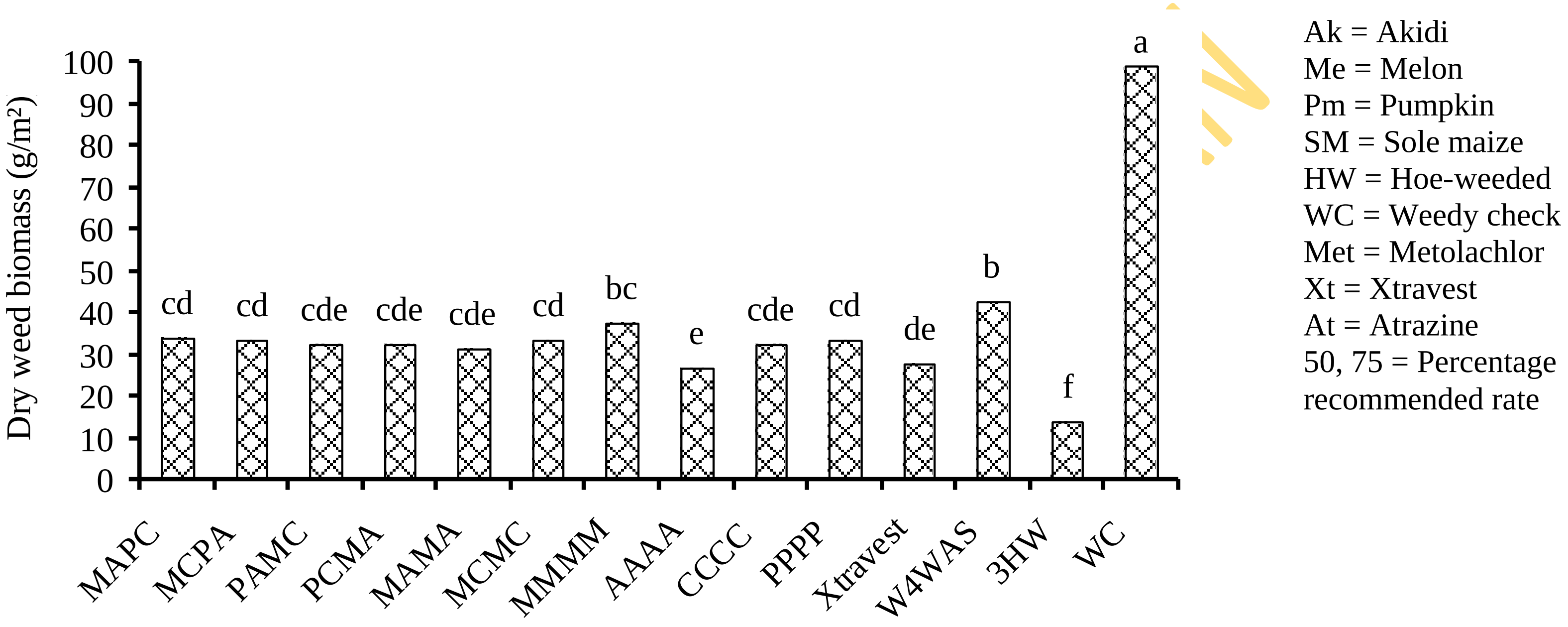

Figure 4.5: Dry weed biomass as influenced by different weed management practices over four cropping cycles

akidi, melon and cowpea (PAMC), MAMA, MCMC and CCCC resulted in weed dry matter production (32 g/m^2) comparable to the minimum (26 g/m^2) obtained with continuous use of akidi (AAAA) over the four seasons of maize production among the cover crop sequence treatments, All other cover crop sequences resulted in significantly higher weed dry matter production (33 to 47 g/m^2) than the minimum of akidi (26 g/m^2). The use of herbicides also resulted in weed dry mater production comparable to the minimum obtained with akidi. Single hoe-weeding at 4WAS resulted in significantly higher weed dry matter production (42 g/m^2) than all the cover crop treatments except the continuous use of melon (MMMM) to which it is comparable.

4.4.5 Maize shoot dry matter production as influenced by different cover crops sequence in maize over four cropping cycles

Sequence of intercropped cover crops had significant effect on maize shoot dry matter production (Figure 4.6). Plots of hoe-weeded sole maize and those treated with herbicides mixture continuously in four cropping cycles produced significantly higher maize dry matter (7.26 and 7.18 t/ha respectively) than all those with the various intercrops and the weedy check (6.09 to 6.93 t/ha). Conversely, the plots of sole maize kept weed infested throughout the cropping cycles produced the least maize dry matter (6.09 t/ha). Furthermore, single hoe-weeding at 4 WAS resulted in lower maize shoot dry matter (6.56 t/ha) than those obtained from the plots that had cover crops intercropped in various sequences (6.68 to 6.93 t/ha) and continuous use of akidi (6.94 t/ha) as cover crop but comparable to the continuous use of melon, pumpkin and cowpea (6.68 to 6.79 t/ha).

4.4.6 Maize grain yield as influenced by different cover crops sequence in maize over four cropping cycles

The final maize grain yield was significantly affected by the weed management practices consisting of combinations of cover crops and their sequences; herbicide and hoe-weeding in the four cropping cycles (Figure 4.7). As observed with maize shoot dry matter (Figure 4.6), sole maize treated with Xtravest and that hoe-weeded in the four cycles produced the highest maize grain yields (2.35 and 2.33 t/ha respectively) while that weed infested had the least grain yield (1.89 t/ha).

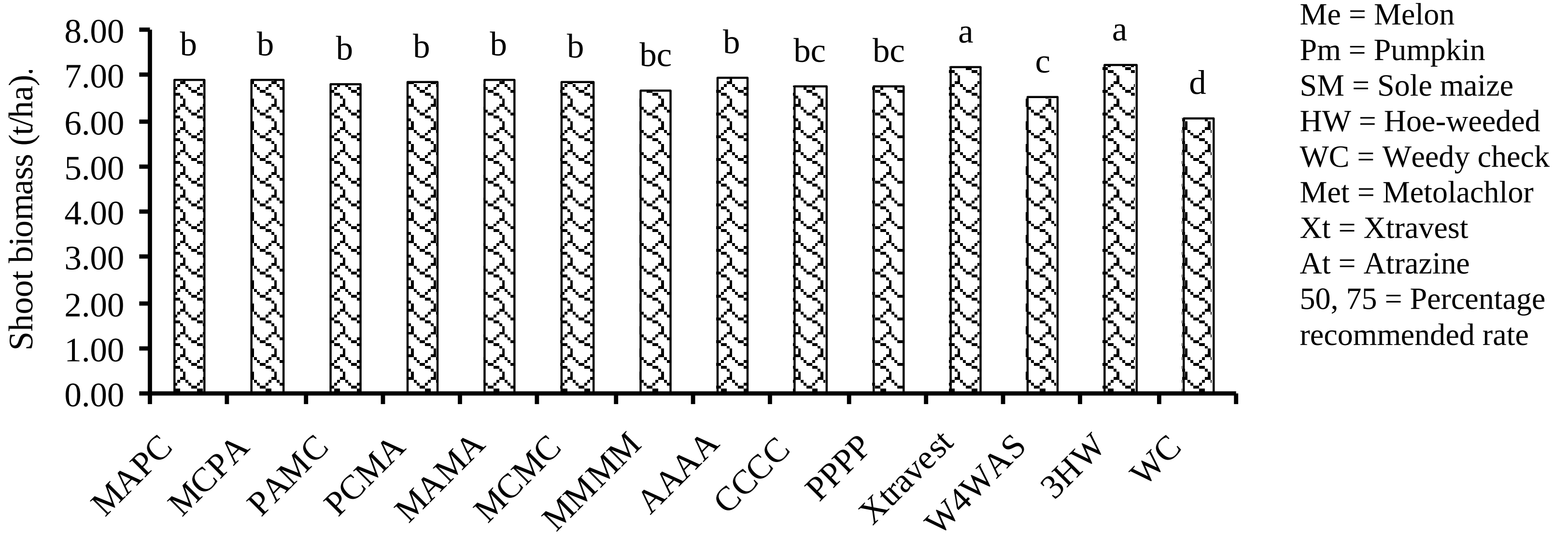

Figure 4.6: **Maize dry shoot biomass as influenced by different weed management practices over four cropping cycles**

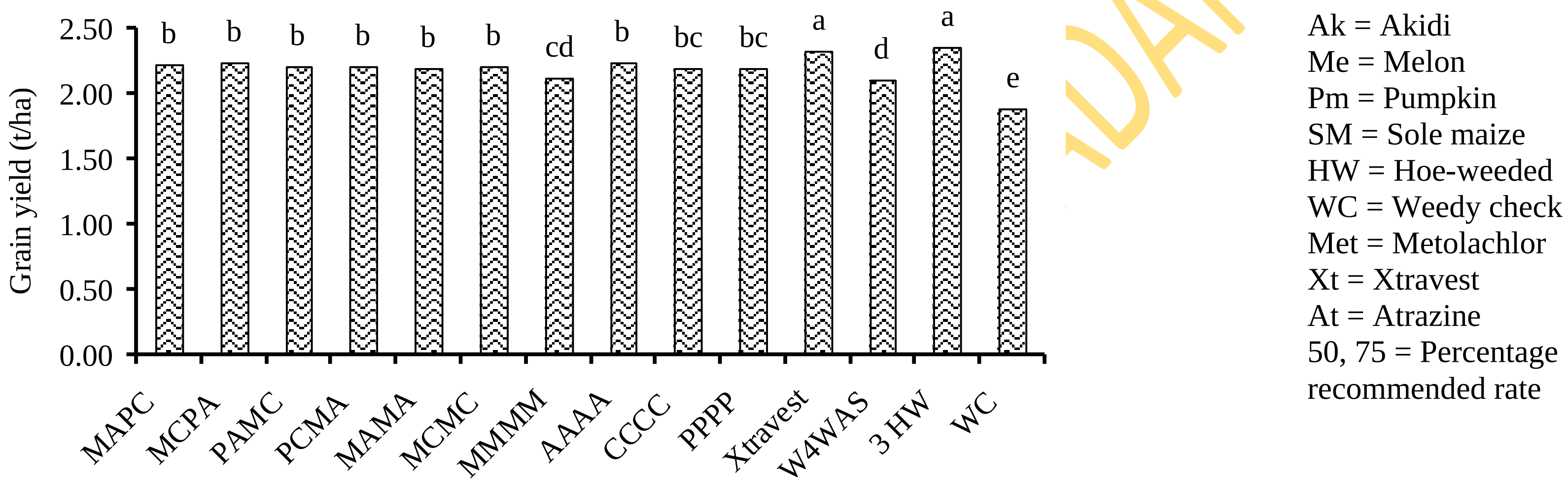

Figure 4.7: Maize grain yield influenced by different weed management practices over four cropping cycles

Furthermore, with the exception of continuous melon intercrop, maize hoe-weeded once at 4 WAS had significantly lower grain yield (2.11 t/ha) than the yields (2.20 to 2.24 t/ha) from all the other weed management treatments. The other cover crop treatments also produced significantly higher grain yield than one hoe-weeding at 4WAS except those of continuous use of cowpea and pumpkin.

4.4.7 Correlation coefficient of soil coverage by the cover crops, weed density and dry weed biomass and among grain yield and shoot biomass

Results of correlation analyses among maize grain yield and dry matter production and weed density and dry matter production as well as ground coverage by the cover crops over four cropping cycles are presented in Table 4.30. Maize grain yield and maize dry matter production had negative correlations with weed density and weed dry matter production and had positive relationship which were not significant with cover crop ground coverage. The correlation coefficients were significant in all the other cases except for maize dry matter production with weed dry matter production. Also, there existed negative significant interaction between cover crops ground coverage and weed density and dry matter production.

Table 4.30: Correlation coefficient values among soil coverage by the cover crops, weed density and dry weed biomass and among grain yield and shoot biomass

	Grain Yield	Maize dry matter	Weed dry matter	Weed density	Ground coverage
Grain yield					
Maize dry matter	0.30*				
Weed dry matter	-0.12	-0.01			
Weed density	-0.18*	-0.20*	0.15		
Ground coverage	0.11	0.09	-0.14	-0.39*	

* Significant ($P \leq 0.05$) ; n = 64

CHAPTER FIVE

DISCUSSION

The soil at Lanlate site was low in soil organic matter and other plant nutrients due to its continuous cultivation over a long period of time without adequate period of fallow for the soil to regain fertility. The major crops cultivated on the field were okra and pepper. The soil at Ido had been left to fallow for about eight years or more before the commencement of the trial. Both sites had sandy loam soils. In addition to low soil fertility at Lanlate site, the presence of high density of *Mitrocarpus villosus*, a species noted to reduce the yield of maize crops to zero on an abandoned adjacent field, could be responsible for low crop yield particularly on plots where weeds were not removed while the trial lasted in the late season of 2007. These might therefore be partly responsible for a significantly low maize grain yield of 1.22 t/ha which represent a 45.6% reduction in maize grain yield recorded on plots kept weedy throughout the period of growth compared with the hoe-weeded control at the site. The grain yield reduction due to maximum weed interference at Ido in the late season of 2008, where the amount and distribution of rainfall was similar to that of 2007, was 24.8% relative to hoe-weeded. The field at Ido was dominated by *Chromolaena odorata* due to the long period of fallow which also resulted in high amount of soil organic matter and higher nutrient status at the site. The maize grain yield was generally low at the two locations with an average of about 2.29 t/ha when the plots were hoe-weeded three times. IITA (2007) reported that maize grain yield is very low averaging 1.5 tonnes/ha in south-west Nigeria. Maize grain yield of 3 tonnes/ha and more have been recorded in Nigeria (Adeola and Akinwumi, 1993).

Pre-emergence application of atrazine at maximum rate of 1.2 kg a.i/ha alone and 0.6 kg a.i/ha in mixture with metolachlor at 1.08 kg a.i/ha, as well as metolachlor alone at 0.44 kg a.i/ha and its mixture at 0.75 kg a.i/ha with prometryne and terbutryne at 0.6 kg a.i/ha did not cause significant reduction in the emergence of all the cover crops. Among the herbicide treatments, atrazine alone and its mixture with metolachlor at the indicated rates significantly reduced the dry matter production of the crops. Khan *et al*. (2006) reported that pre-emergence application of atrazine, isoproturon, metribuzin and sulfosulfuron adversely affected plant vigour, nodulation, chlorophyll content, seed yield and protein content in seeds, in greengram inoculated with *Bradyrhizobium sp.* (*vigna*) at 400 μg kg^{-1} of soil. They further reported that atrazine at 200 and 400 μg kg^{-1} of soil inhibited its vegetative growth and decreased the seed yield by 25 % and 40%, respectively. However, dry matter production comparable to no herbicide control were obtained with the use of atrazine at 0.9 kg a.i/ha alone and 0.81 kg a.i./ha in mixture with metolachlor at 0.45 kg a.i/ha. The results therefore indicated that the herbicide treatments and their lower rates have potentials for use in integrated weed management involving the complementary use of the herbicides and the cover crops for season long weed control in maize production. Olabode and Ogunyemi (2002) and Olabode and Adesina (2010) also reported successes with the use of primextra at 1.5 kg a.i/ha for weed control in cowpea thereby suggesting a safe use of low rates of the herbicide mixture in cropping systems involving cowpea. Soltani *et al*. (2004) also reported that white beans are tolerant to pre-emergnce application of applications of S-metolachlor, clomazone, and clomazone + S-metolachlor as the herbicides had no negative effect on plant height, dry weight, maturity and yield of the crop.

Application of atrazine and its mixture with metolachlor at rates higher than 0.6 and 0.84 kg a.i/ha as well as metolachlor alone and its mixture with prometryne and terbutryne at higher rates than 0.43 and 1.24 kg a.i/ha had more adverse effects on dry matter production of pumpkin and melon. The dry matter production of cowpea and akidi were not adversely affected by these herbicides. At Samaru in the Norhern Guinea Savanna, Ishaya *et al*. (2008) reported that pre-emergence application of mixture of metolachlor and prometryne at 1.25 + 0.80 kg a.i./ha consistently resulted in good growth and seed yield of cowpea while mixtures containing terbutryne resulted in lower vigour score, higher phytotoxicity, smaller canopy spread and lower seed yield of the crop. They concluded that the mixture of metolachlor and prometryne gave good selective weed control and can be used instead of hand weeding in cowpea in northern Nigeria. It was possible that the effects of the herbicides on the dry matter production of melon was also confounded by the environmental conditions particularly diseases that affected its growth.

The results with the use of metolachlor on the crop establishment of the cover crops of cowpea, akidi, pumpkin and melon indicated that the herbicide can be used satisfactorily at dose rates lower than 0.43 kg a.i/ha for the cover crops without adversely affecting the cover crops vigour as measured by seedling emergence and the dry matter production at some growth stages of the crops. This may however be complemented with low doses of a triazine herbicide for broad spectrum activity. The choice of the dose to be used will then be dependent on other factors like the weed pressure, environmental condition, economic considerations etc. Melon tolerated the rates of the herbicides more than pumpkin in this study. This could be attributed to the fact that pumpkin had smaller seed sizes compared to melon and other cover crops. Sikkema *et al*. (2009) in an experiment to evaluate response of dry beans to pre-plant incorporated and pre-emergence application of S-metolachlor and fomesafen, observed that visible injury was generally greater in smaller seed market sizes compared to the larger seeded ones.

The problem of early weed interference while the cover crop get established may however be alleviated by complementing the cover crops with the appropriate types and rates of pre-emergence herbicides. The performances of the maize when herbicides were used to complement the cover crops were comparable to those obtained under the hoe-weeded control. In this study, the grain yields of the plots with different herbicides and cover crop combinations were either comparable or higher than those of the hoe-weeded control in spite of consistent higher weed density and biomass on plots with herbicide and cover crop combinations. It was however possible that early competition from the weeds was not high enough on the plots with herbicides-cover crop combinations as to affect the performance of the test crop. Earlier reports have emphasised that the weeds that emerged subsequently after the initial weed control did not have significant influence on the growth and yields of crops particularly when the crops has completed significant part of its reproductive stage (Havlin *et al*., 1990; Cambardella and Elliott, 1992; Zimdhal, 1993; Evans *et al*., 2003; Bukun, 2004; Al-Sheikh *et al*., 2005). Usman *et al*. (2001) observed that maize do not withstand weed infestation during the initial growth and the weeds that emerged at 6–9 weeks after sowing did not cause significant maize yield losses. Weeding maize after the critical period of weed interference resulted in up to 83% loss in grain yield (Usman *et al*., 2001). Mahmoodi and Rahimi (2009) observed that the critical period of weed interference of maize was between 19-55 days after emergence. In their experiment to evaluate cover crops and inter-row tillage for weed control in short season maize, Abdin *et al*. (2000) observed that although the cover crops provide additional weed control but the inter-row tillage or some herbicide application would still be necessary. The plots where no weeding was carried out throughout crop lifecycle produced lower cumulative yield over the four cropping cycles of maize compared with the herbicide-cover crop combinations and three hoe-weeding because of high weed competition and low fertility since no fertilizer was applied. Akobundu (1987) opined that pre-emergence or early post-emergence herbicides, e.g. metolachlor and atrazine, can control weeds for 6 weeks after application, depending on the dose, soil type, and environmental conditions, and thus can prevent early weed competition. The need to determine the doses that the cover crops could tolerate arose from the fact that most of the herbicides were those that were labelled for maize and in some cases cowpea. Melon and pumpkin are however the common cover crops that are found in association with maize and other arable crops cultivated particularly in the major cropping season in the south-western part of Nigeria.

Cowpea and pumpkin at their respective highest population density of 40,000 and 15,000 plants/ha caused significant reduction in maize grain yield due to high inter-specific competition between each of the cover crops and maize, in spite of obvious weed suppression. Intercropping the cover crops of akidi, cowpea and pumpkin at densities of 20,000 to 26,000 plants/ha, 20,000 and 10,000 plants/ha respectively resulted in maize grain yield that were comparable to hoe-weeded control. It also enhanced weed suppression as reflected in lower weed dry matter production recorded at these lower densities than at higher ones. The use of cowpea as cover crop gave relatively lower four season average maize yield than akidi cover crop and the rotation of melon, pumpkin with akidi and cowpea rotation systems. Although cowpea has been identified as an ideal cover crop for many areas (Wang *et al*., 2006), the cultivation of cowpea in the south western Nigeria is limited to the late season cropping partly because of high rainfall as well as pest and disease problems. The result from this work showed that yields of maize with cover crop of cowpea were low in the early season cropping. This might be due to competition from the cowpea as well as from the associated weeds as the cowpea planted in the early season did not produce enough ground coverage to exclude weed competition. The growth of cowpea was actually retarded in the early season trial by foliage pest infestation and diseases, which caused slow growth initially, hence poor ground cover, although the crop picked up as soon as insecticide was applied. In actual fact, the pod yields of the cowpea planted in the season were extremely low while those of the late season cropping were slightly higher. Silva *et al*. (2009) reported that although the cowpea cultivars had a certain control over weeds, they also competed with the maize plants, leading to maize grain yield reduction while the cowpea did not also produce grain, certainly due to the strong competition exerted by the maize and weeds on cowpea plants. The late season maize planted in plots that had cowpea as cover crop had yields that were relatively high when compared to what was obtained in the early seasons. These yields were also lower than those obtained from the hoe-weeded and herbicide-treated plots.

The non-significant influence of the various densities of the cover crops of melon, pumpkin, akidi and cowpea on the growth performance of maize as test crops in the trial in Lanlate might be due to the environmental conditions as influenced by the season of cropping. The season was one with low amount of rainfall. The location recorded low precipitation during the period. This influenced the performances of the cover crops. Pumpkin and melon for instance had slow growth rates during the period. This probably caused these cover crops to exert little influence in terms of competition with the main crop. It has been observed that reduced weed incidence in maize by intercropping depends on several factors, including planting season and intercropping species used (Skóra Neto, 1993), fertilizer doses (Olasantan *et al*., 1994), maize cultivar and year of evaluation (Kuchinda *et al*., 2003), among other factors. The crops might however be subjected to competition from weeds which the cover crops were not able to suppress. According to Hollander *et al*. (2007) cover crop efficiency is achieved by a rapid occupation of the open space between the main crop rows, consequently preventing weed seed germination and reducing weed seedling growth and development. Furthermore, the authors indicated that weed seeds germination may be inhibited by either complete light interception due to cover crop or allelochemical secretion. The influences of the various densities of the legume cover crops, (cowpea and akidi) on the performance of the test crop might be complicated by factors which included their wider spread to cover the soil surface as was the case with akidi and high biomass generation from cowpea which reduced the amount of weeds present on the field, their nitrogen fixing ability and soil water conservation due to high crop biomass that cover the soil surface. Hiltbrunner *et al*. (2007) suggested that with the inclusion of a legume in a cropping system, then reduced competition – at least for nitrogen – can be expected. The ability of some of these legumes to control weeds has been emphasised. Their efficiencies however depend on cultivars and a host of other factors as stated earlier. According to Silva *et al*. (2009) cowpea cultivars had a certain control over weeds. In the trial, significantly lower growth performance of maize was obtained only from the plots that were not weeded as control. The kind of weeds that were present in high abundance on the field might also have significant influence on the growth parameters of the test crop. The weeds included *Mitrocarpus villosus*, which dominated some of the no weed control plots in very high density. The maize crops on the plots where this weed species was present had stunted growth. This alone might be enough to cause the difference observed in the growth parameter of the test crop at Lanlate. The plots that had the cover crops were not significantly influenced by the noted troublesome weed. This further supported the proposition that living mulch between crop plants is an environmentally sound option for suppressing weeds (Liebman and Dyck, 1993; Teasdale, 1996). The trial with the densities of the cover crops of pumpkin, melon, cowpea and akidi at Ido had the maize significantly influenced by the different sowing densities of the cover crops. In general, there was an inverse relationship between the cover crop densities and the maize growth parameters. Maize plots that had the highest cover crop density consistently had the least growth parameter, while those kept weedy throughout had the shortest plants and smallest stem diameter. The total crop biomass of maize was also inversely related to the cover crop densities. In general high dry matter production was obtained from the plots hoe-weeded three times while those that had melon at 20,000 plants/ha produced crop biomass that was not significantly different from the hoe-weeded control. Cover cropping maize plots with higher planting density of cowpea than between 20,000 and 26,000 plants/ha and pumpkin at density greater than between 10,000 and 12,500 plants/ha resulted in significantly low dry matter yield of the test crop. The result is consistent with earlier observations made by some workers (Ayeni *et al*., 1984; Zuofa *et al*., 1992; Eneji *et al*., 1995; Akinyemi and Tijani-Eniola, 1997). The use of akidi up to 40,000 plants/ha in some instances however was found not to reduce the total dry matter of the test crop significantly. This might be partly explained by the fact that the akidi was able to out-compete weeds that might compete with the main crop. Uchino *et al*. (2009) observed that weed suppression was associated with the increase of vegetation cover ratio of main crops plus cover crops at the early growth stage of main crops. Akidi also had low crop biomass production, a quality that may make it a more suitable cover crop than those that accumulate high biomass with nutrient obtained from the same medium as the main crop during the growing season. It has been observed that the efficacy of cover crops depends most on soil coverage (> 50%), with light interception being the most important effect (Steinmaus *et al*., 2008). In this study, akidi had the widest spread and consequently high soil coverage at both locations and across the seasons. The planting of crops or the use of cover crops that develop canopy early enough in the season have been noted to be effective in weed management (Seavers and Wright, 1999; Chikoye *et al.*, 2001). According to Hollander *et al.* (2007), cover crop efficiency is achieved by a rapid occupation of the open space between the main crop rows, preventing weed seed germination and reducing weed seedling growth and development. The author further suggested that weed seed germination may be inhibited by either complete light interception due to cover crop or allelochemical secretion.

The results obtained from the grain followed the same trend as those of the total crop biomass. The plots kept weedy throughout had the least grain yields in all the seasons at both locations. This was expected as there were no conditions such as high soil nutrient level, fertilizer application and others that could favour better crop performance under the situation of unrestricted weed interference. The cover crops at the lower densities of 20,000 to 26,000 plants/ha for the legumes gave grain yields that were comparable to those of melon at population density of 20,000 plants/ha, especially in the early season cropping. The use of melon in the late season may however be considered with caution at both locations of the trial, since it did not provide enough soil coverage for adequate weed suppression in the season. Melon was also highly affected by disease during late season cultivation. In this study, the use of high densities of the cover crops effectively reduced weed infestation as reflected in the results. Earlier reports have also indicated a negative correlation between cover crops density or soil coverage and weed biomass (Akemo *et al.*, 2000; Ross *et al.*, 2001; Sheaffer *et al.*, 2002). The system however had negative effects on the performance of the main crop as the cover crops at such high density offered competition that resulted in reduced yield of the main crop. In spite of the observation, it is expedient to use cover crops at an optimum density as a component of integrated weed management without obvious adverse effects on the performance of the main crop. From the results of the study, the optimum density for the cover crops however varied with seasons, the prevailing environmental conditions and the weed pressure on the field. It is therefore obvious that a field that has potential high weed incidence would benefit from the use of cowpea and akidi at densities as high as 26,000 plants/ha or even akidi at density within 26,000 and 40,000 plants/ha as cover crops when there is optimum environmental condition. The practice would facilitate earlier soil coverage before the establishment of weed seedlings and thus reducing weed interference at the critical period of growth. The results obtained from the study also showed that pumpkin could be used successfully for weed suppression in maize field at a density of 10,000 plants/ha especially in the early season. The result further showed that it could also replace melon in the late season provided planting is done early. Olasatan (2007) had also recommended intercropping pumpkin up to 10 000 plants ha^{-1} with yam at an optimal sowing date target in March-April as live mulch in yam plots to reduce supra-optimal soil temperature, excessive evaporation and weed growth for maximum yam development and productivity. Care must however be taken in making the choice of the sowing density of the cover crops so that the competition likely to be offered by the cover crop will not have significant influence on the productivity of the main crops. Garibay *et al*. (1997) observed that there are limitations to using cover crops for weed control, due to the strong risk of a decrease in growth and yield of main crops. Other factors to be considered in the choice of the cover crops and the management practices to be employed include the biomass production of the cover crops as this is important in in-situ and post cropping soil properties maintenance. Crops that produce high biomass are of higher value in terms of addition of organic matter to the soil, soil erosion control, soil aggregate maintenance among other factors (Naderman, 1991; Baumhardt *et al*., 1993; Busscher and Bauer, 1993; Bradley 1995; Moseley *et al*., 1996; Reeves *et al*., 1996). Apart from these benefits from the biomass accumulation, legumes are known to additionally benefit the cropping system through nitrogen fixation (Holderbaum *et al*., 1990; Munawar *et al*., 1990; Boquet *et al*., 1994). Though this parameter was not examined in this study, the influence of the leguminous cover crops of cowpea and akidi used in the work cannot be under estimated. There are however contrasting opinion as to the way a legume that accompanies a cereal crop benefits the cereal. While research efforts pointed to the facts that the cereal benefits from the nitrogen fixed by the legumes intercropped with it (Donald *et al*., 1963; Weber, 1966; Fujita *et al*., 1992; Liebman and Dyck, 1993; Norman, 1996; Mohr *et al*., 1999; Akhtar *et al*., 2010), others reported that the legumes benefit the succeeding crops (Munawar *et al*., 1990; Thompson and Varco, 1996). The more obvious physical parameter that was measured and whose influence cannot be over emphasised is the total cover crop biomass. Apart from the benefits earlier highlighted, this parameter has significant influence on weed incidence as measured by weed density and weed biomass which in turn affect the main crop performance. Averaged over the cropping densities, pumpkin gave the highest crop biomass followed by cowpea, melon and akidi in that order. This had influence on respective weed density and biomass of the plots that had the various cover crops. The observation made on this total crop biomass relative to weed incidence supports earlier assertion on the relationship between cover crop density and weed biomass (Akemo *et al*., 2000; Ross *et al*., 2001; Sheaffer *et al*., 2002). The weed species that were found on the plots planted to various densities of cover crops did not differ significantly. At Lanlate, the density of the dominant weed species, *Mitrocarpus villosus*, differ among densities of the cover crops. Other species that were found in relatively high abundance at the location included *Brachiaria* spp, *Cleome viscosa*, *Rhynchelytrum repens*, which were also found not to be exclusively associated with any cover crop. Their abundance was related to the density of the cover crops. Although weeds have been variously associated with crop and cropping systems (Li and Kremer, 2000; Baumgartner, *et al*., 2008; Steenwerth *et al*., 2010), this usually takes some time to get expressed. In other study to evaluate the relative importance of crop rotation, tillage, and weed management as factors affecting weed communities and to test the hypothesis of an association between management practices and weeds from certain life cycle groups, Légère and Samson (1999) observed that the weed species segregated roughly according to life cycles and that the interactions among weed management intensity, tillage, and crop rotation mostly explained species dominance in the various cropping systems The weed species that were also found in the trial at Ido were also perceived not to be associated with the treatments. The plots were generally dominated by patches of seedlings and small stumps of *Chromolaena odorata* and *Senna hirsuta*, the predominant weeds prior to the commencement of the experiment. *Spigelia anthelmia* and *Phyllanthus amarus* were later observed on all the plots as soon as other weeds emerged.

Senna hirsuta was also one of the dominant weed species in the late season experiment at Ido as observed in the previous cases. The presence of the species with most other dominant ones on the plots indicated that there was no noticeable pattern of association of weeds and the treatments. The presence of the young seedlings of *S. hirsuta* and *C. odorata* was an indication that the soil seed bank of the field had a substantial amount of seeds of this species. Uchino *et al*. (2009), while evaluating yield losses of soybean and maize caused by competition with inter-seeded cover crops and weeds in organic-based cropping systems, observed that cover crops reduced the soil seed bank of dominant weeds thus highlighting the importance of proper weed management for suppressing weeds. Although, only present in high densities in adjacent fields, other weed species that included *Ageratum conizoides* and *Acalypha ciliata* might also have had large amount of seeds in the soil.

It is a common occurrence to have yields from the main crops reduced due to competition from the cover crops (Silva *et al*., 2009). Uchino *et al*. (2009) also observed that cover crops often suppress not only weeds, but also the main crops with which they are planted. A major reason for this could be optimum environmental conditions which facilitate the availability of adequate moisture and soil nutrient for both weeds and cover crops. This notion may further be supported by the fact that the yield from the no weeding control in the early cropping of year 2008 in this was not significantly different from the others though the yield so obtained was the least of the treatments. Though competition might be expected from the cover crops, the maize in the plots that had the cover crops however did not suffer from the early weed interference that usually accompanies manual weed removal which usually takes place around the fourth week after sowing (Hall *et al*., 1992). In the subsequent cropping, the yields from the no weeding control were always significantly lower than those from the plots that had the treatment combinations of the cover crops and the herbicides for weed control highlighting the efficacy of the system to alleviate the problems of weeds. The yield superiority of this system in the late seasons may also be explained in part by the facts that the cover crops are able to conserve soil moisture particularly at some period during the season when there were short dry spells (Sullivan *et al*., 1991; Reeves *et al*., 1996). The number of wet days for instance during the months of August through November in year 2008 and 2009 were lower than those obtained in the early seasons of the years.

Over four cropping season cycles, the use of melon as cover crop for weed suppression in maize gave the least average maize yields among various cover crops sequences. This could be attributed to a number of reasons which include the slower growth and rate of cover establishment of melon compared to poorer growth performances in the late cropping seasons and relatively shorter lifecycle compared to other cover crops evaluated. Melon usually has vigorous early growth when planted early enough in the season before the points when rainfall amount and intensity becomes much. That is why melon is considered an ideal cover crop for weed suppression in a number of annual crops. In the early season trial of this study, however, field crop establishment could not be achieved until early part of the month of May when high rainfall adversely affected the growth of melon partly due to serious disease infection. The implication of this was that the soil surface coverage obtained from melon was low and therefore, its weed smothering capacity was reduced. The maize that had melon as cover crop therefore suffered competitions, from weeds that grew before the weeding that preceded the cover crop establishment, with melon and the late weed competition which occurred due to failure of melon to effectively suppress the weeds. In their experiment to study the influence of melon (*Citrus lanatus* (thumb) MASF) in yam (*Dioscorea rotundata* Poir)/maize (*Zea mays* L.) melon intercrop on weed control and crop yield in Minna, northern Nigeria, Kolo *et al*. (2004) reported that, maize cobs in sole maize plots significantly out-weighed maize cobs in the intercrop in the two years of study. They however, observed that farm produce obtained from the plots of maize, yam and melon mixture gave more economic returns than that of sole maize. The ineffectiveness of this system is further accentuated by the fact that the cumulative yield obtained from the plots that received only one hand weeding each at the fourth week after planting was similar to that obtained from the continuously melon cover cropped plots.

Maize grain yield obtained with continuous use of pumpkin was similar to that of cowpea, although, weed control was better under pumpkin than that of cowpea over the seasons. This could be attributed to more serious inter-specific competition between maize and pumpkin. This was evidenced by the fact that the dry matter production of the cover crops as well as their percentages ground coverage correlated negatively with the maize grain and dry matter productions. The use of pumpkin as cover crop in maize production attract some consideration for a number of reasons which include wider crop spacing than other cover crops, reduced competition with the main crop, the extensive and aggressive growth to produce a lot of crop biomass for more effective weed suppression than other cover crops, moisture conservation due to adequate ground cover and high organic matter production and the ability of the crop to grow and produce substantial crop biomass with adequate moisture when planted in the early and late season. Olasantan (2007) reported that growing pumpkin between yam mounds reduced maximum diurnal soil temperature by 4.3–8.1 °C, weeding frequency by 52% and weed dry biomass by 50–67%, while soil moisture was conserved by 48–62 g kg^{-1}.

Akidi appeared to be less competitive than cowpea and pumpkin particularly in the late season productions as the correlation of these parameters were not significantly correlated. Continuous use of akidi therefore resulted in highest average maize grain yield among the cover crops. With or without herbicide complement, akidi as cover crop enhanced weed suppression and improved the performance of maize with which it was intercropped. Akidi might be able to sustain maize yield when used continuously as cover crop for a number of reasons. These include the fact that the biomass production of the crop (akidi) is very low implying low amount of nutrient mining (Rutunga *et al*., 1999); its ability to suppress weeds due to its growth habit, which include its extensive vines production which facilitates spread and rapid cover of the soil surface (Uchino *et al*., 2009). The grain yield obtained from the crop was however always low and highly variable particularly in the early seasons, and the fact that the weed density and dry biomass obtained from the plots that had this crop as cover crop was always low.

The continuous use of akidi, season after season with maize; and the rotation of cover crops of melon or pumpkin in the early seasons and that of cowpea and akidi in the late season sustained the yields of maize while the trial lasted. This system resulted in about 4.5% maize grain yield increase over the continuous use of melon and also in better weed control for about the same cost of production. The influence of crop rotation in improving the crop performance and yield sustenance is well documented (Mulugeeta and Stolberg, 1977; Akobundu, 1987; Légère and Samson, 1999; Smith *et al*., 2008). Rotation of leguminous crops with cereals has been particularly noted to be of high benefits in terms of soil and yield maintenance (Holderbaum *et al*., 1990; Munawar *et al*., 1990; Boquet *et al*., 1994; Thompson and Varco, 1996). This is always practicable under conditions of small holding for subsistent farming or in situations where the crops to be rotated are of high importance to the farmers. Cropping a whole season of the leguminous or other cover crops may not be too appealing to a farmer with a major crop-based cropping system.

CHAPTER SIX

SUMMARY AND CONCLUSION

Cover crops could be considered an important component of any annual cropping system that seeks to be sustainable while crop rotation, apart from being considered an important tool for reducing the incidence of pests, improving soil health and fertility, and increasing crop yields has also been traditionally viewed as one of the simplest and most effective methods of managing weeds. Cultivation of cover crops, which are not of major economic importance in monoculture, may not be an acceptable practice in any arable crop-based farming system. When cover crops are integrated in an arable crop production system, they often require manipulations that enable them to have an edge start over the weeds they are to suppress. This may be achieved either by initial manual hand weeding, which is known to be very tedious and labour intensive or the use of a pre-emergence herbicide, which also has its attendant problems of cost, environmental pollution among others. While most of the available pre-emergence herbicides have not been evaluated for their suitability with a number of these commonly used pre-emergence herbicides, many more cover crops are being considered for integration into the traditional arable crop production systems. The study was therefore conducted with the aim of evaluating some cover crops and pre-emergence herbicides in a continuous maize production system with the following specific objectives, to:

i. explore the potentials of complementary use of herbicides at reduced rates with cover crops for weed control in maize production.
ii. evaluate the comparative effects of akidi (*Vigna unguiculata* sub. spp. *sesquipedalis*, pumpkin (*Curcubita pepo*), cowpea (*Vigna unguiculata*) and melon (*Collocythis citrulus*) in weed control in maize production.
iii. determine the effects of continuous use of cover crops on weed control and yield sustainability in maize production
iv. determine the influence of cover crop rotation and its appropriate sequence on weed control in a continuous maize production system.

The findings revealed that:

1. Melon, pumpkin akidi and cowpea tolerated the pre-emergence application of atrazine (as Atraforce) and its mixture with metolachlor (as Xtravest) at low dose of up to 0.6 and 0.51 kg a.i./ha respectively which are equivalent to 50%

lower end recommended rate of the two herbicides while those of metolachlor (either as Dual or Metaforce) and prometryne + metolachlor (as Codal) are tolerated up to 0.44 and 1.24 kg a.i./ha (75% recommended rate) respectively by melon and pumpkin and up to 0.58 and 1.65 kg a.i./ha (100% recommended rate) by cowpea and akidi.

2. Akidi can be used at density of between 20, 000 and 40,000 plants/ha for weed control in maize. The chosen density will depend on the environmental conditions and the farmers objective; pumpkin controlled weeds effectively at density of 10,000 plants/ha without significantly affecting the performance of maize. The effectiveness of these densities of akidi and pumpkin was similar if not better than melon or cowpea at density of 20,000 plants/ha.
3. Akidi could be used as cover crop on continuous basis as maize yield was sustained with intensive maize cultivation over four consecutive seasons.
4. Melon was better used as cover crop in the early cropping season while cowpea did better as cover crop in the late cropping season. Melon planted in the late season had very slow growth rate, reached senescence earlier than any other cover crop used and had more insect pest attack in the late season than when cultivated in the early cropping season. Pumpkin and akidi could be used both at early and late cropping seasons if moisture is adequate throughout the year. Both of these crops had longer life span than melon and even the test crop with which they were planted.
5. Cover crops of melon, pumpkin, akidi or cowpea at density of 20,000, 10,000 and 20,000 plants/ha, complemented with low doses of pre-emergence herbicides of atrazine, mixture of atrazine and metolachlor, and metolachlor at 0.6, 0.84 and 0.89 a.i./ha respectively, which represent 50% recommended rates gave satisfactory weed control and reduced manual weed removal to roguing of the weeds that may be present in pocket of places in maize field so treated.
6. The ultimate maize yield was not significantly reduced when cover crops were used in continuous intensive cultivation in four seasons.
7. Rotation of cover crops with planting of melon or pumpkin in the early cropping season and cowpea or akidi in late cropping seasons sustained maize yield better than the continuous use of cowpea or melon or pumpkin in maize-based intensive cultivation system.

Effective weed control was achieved with continuous use of cover crops with pumpkin or melon in the early season and akidi or cowpea in the late season or with akidi in all seasons in maize cultivation. Cover crops when rotated over the seasons resulted in dominance of the field with annual broadleaf species compared to when weeds were suppressed with continuous use of a cover crop or continuous cultivation with manual weed removal which resulted in earlier emergence of grass weeds and sedges. This has implication for future weed management on the field.

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