INTEGRATING NITROGEN FERTILIZERAND ORGANIC MANURE ON SORGHUM (*Sorghum bicolor* (L.) Moench) VARIETIES GROWN ON STRIGA (*Striga hermonthica* (Del.) Benth) INFESTED FIELDS IN THE NIGERIAN SAVANNA

BY

Rabi'u ABDULLAHI

DEPARTMENT OF AGRONOMY,
FACULTY OF AGRICULTURE,
AHMADU BELLO UNIVERSITY,
ZARIA, NIGERIA

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BY

Rabi'u ABDULLAHI, B. Agric. (UDUS) 1998, M Sc Agronomy (ABU) 2011
(Ph.D. /AGRIC./46862/2012-2013)

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DEPARTMENT OF AGRONOMY
FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY,
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APRIL, 2018

DECLARATION

I here bydeclare that the work in this thesis entitled "**INTEGRATING NITROGEN FERTILIZER AND ORGANIC MANURE ON SORGHUM (*Sorghum bicolor* (L.) Moench) VARIETIES GROWN ON STRIGA (*Striga hermonthica* (Del.) Benth) INFESTED FIELDS IN NIGERIAN SAVANNA''** was by mein the Department of Agronomy under the supervision of ProfessorN. C. Kuchinda. The informationderived from the literature have been duly acknowledged in the text and list of references provided. No part of this thesis was previously presented for another degree or diploma at any Institution.

Rabi'u ABDULLAHI: …….. Date:……

CERTIFICATION

This thesis titled**"IntegratingNitrogen fertilizerand Organic manure on Sorghum (*Sorghum bicolor* (L.) Moench) Varieties Grown on *Striga* (*Striga hermonthica*(Del.) Benth.) Infested Fieldsin Nigerian Savanna"**by Rabi'u Abdullahi meets the regulations governing theaward of the degree of Doctor of Philosophyin Agronomy of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

Prof. N. C. Kuchinda . …….. Date:……
Chairman, Supervisory Committee

Prof. D. B. Ishaya …….. Date:……
Member, Supervisory Committee

Dr. M. A. Mahadi .. .……Date:……
Member, Supervisory Committee

Dr. M. A. Mahadi . …… Date: ……
Headof Department

Prof. S. Z. Abubakar. ……. Date:……
Dean,School of Postgraduate Studies

DEDICATION

This work is dedicated to the loving memory of my late father Malam Abdullahi Gambo Saulawa. May ALLAH grant him the eternal rest Ameen.

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ABSTRACT

A field experiment was conducted during the wet seasons of 2013 and 2014 at the research farm Institute for Agricultural research, Samaru (11 11N 7 38 E 686m above sea level) in the northern Guinea savanna and the Experimental farm of Hassan Usman Katsina Polytechnic, Katsina (12 56 N, 7 36 E 465m above sea level) in the Sudan savanna ecology of Nigeria to determine the effects of integrating nitrogen fertilizer and organic manures on sorghum varieties grown on *Striga*- infested field. The treatments consisted of two varieties of sorghum (SAMSORG-40 AND SAMSORG-41), three levels of nitrogen (0, 40 and 80kgNha^{-1}) and four levels of organic manure (*Cassia obtusifolia* green manure at 0, 7.5 and 15t ha^{-1} and cowdung at 10t ha^{-1}). The experiment was laid in a split-plot design and replicated three times; with nitrogen assigned to the main plot while factorial combinations of crop variety and organic manure were assigned to the sub-plots. The experimental sites were inoculated with *Striga* at the rate of 25 g seeds per Kg ha^{-1} of fine sand to boost*Striga* level. The experimental soil were*Striga* infested and low in organic matter, nitrogen and available phosphorus at Katsina (0.37 % N, 3.69 % P), (0.54 % N, 3.20 % P) at Samaru. Analysis of the soil after harvest showed that application of green manure at 15t ha^{-1}(46.0 % P, 0.59 %, N) with nitrogen at 80kg Nha^{-1}(0.46 % N, 14.2 % P) improved fertility status of the soil with respect to total N, available P and exchangeable K. SAMSORG-40 recorded more*Striga* shoot count, plant height, number of leaves, LAI, shoot dry weight and yield and yield attributes than SAMSORG-41 in both locations and seasons. Nitrogen application at 80kgN ha^{-1} reduced *Striga* count, number of infested plants with *Striga* and *Striga* crop reaction score compared to the untreated control. Nitrogen at 80kgN ha^{-1} improved plant height, number of leaves, LAI and shoot dry weight compared to zero and 40kgN ha^{-1},however, the use of 40kgN ha^{-1} increased grain yield over 80kgN ha^{-1} .*Striga*shoot count was found to be low to moderate with the use of green manure and cowdung when compared to the untreated control;however, application of cowdung at 10t ha^{-1} resulted in higher stand count, number of leaves, plant height and LAI when compared to treatment that receive of 0, 7.5 and 15t ha^{-1} of green manure for same parameters. Complementary application of 15tha^{-1} green manure with 80kgN ha^{-1} resulted in higher grain yield than cowdung at 10t ha^{-1} with 80kgN ha^{-1} at Katsina and Samaru respectively. Positive and significant relationship was recorded in Katsina between sorghum grain yield and stand count, number of leaves, LAI, shoot dry weight, panicle weight, 100- grain weight, grain weight, Stover yield, as the primary determinants for yield in combined years. In Samaru, grain yield was negative and not significantly correlated to LAI and *Striga* shoot count in combined years. Growth parameters, such as plant height, shoot dry weight and number of leaves showed significantdirect effectto yield. The highest individual percent contributions to yield wereby panicleweight and the highest combined contributions were by panicle weight via shoot dry weight. Sorghum grain yield showed linear response to the applied green manure from 0 – 15t ha^{-1} and N from 0 – 80kgha^{-1}, an indication that optimum levels were not attained. In both locations, highest gross margin was recorded by SAMSORG-40 under 10t ha^{-1} with 0kgN ha^{-1}, while the gross margin per naira invested was in SAMSORG-41 from untreated control in Katsina, and SAMSORG-40 with 0t ha^{-1} organic manure and 40kg Nha^{-1} in Samaru. The total variable cost (TVC) of sorghum production in Samaru (₦441, 669) was higher when compared to the TVC in Katsina site (₦ 422,219)in thetwo years of study. In conclusion, the study revealed that, the highest grain yield of sorghum was by the application of 15 t ha^{-1} green manureand 80 kg N ha^{-1} with SAMSORG-40 grown on *Striga*infested field,

irrespective of location. Improving soil fertility, especially N will reduce the effect of *Striga*on sorghum. Application of 15 t ha^{-1} green manure delayed *Striga* emergence at Samaru and reduced *Striga* shoot count and crop reaction score at Katsina. In contrast, grain yield was insignificantly and negatively correlated to *Striga* shoot count at Samaru. Panicle weight and panicle weight via shoot dry weight gave the highest percent contribution to sorghum grain yield. Grain yield showed linear response to the applied green manure from 0-15 t ha^{-1} and from 0- 80 kg N ha^{-1}, an indication that work still needs to be carried out in order to determine their optimum levels. The highest returns per Naira invested was obtained with SAMSORG-40 supplied with *Cassia* green manure at 15 t ha^{-1} and 80 kg N ha^{-1} at Katsina; and SAMSORG-40 supplied with 10 t ha^{-1} of cow dung, without any N input.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Importance andProduction ofSorghum

Sorghum (*Sorghum bicolor* (L.) Moench) is commonly referred to as guinea corn in West Africa, is the fifth most important cereal crop in the world being surpassed only by rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.)and maize (*Zea mays* L.) (Abunyewa, 2008). and the world production is between 55 and 70 million of grain per annum from between 40 and 45 million hectares. The world average yield is 1412 kg ha^{-1}(Samuel *et al.,* 2013).In 2010, the USA was the world largest producer of the crop (8.8) metric tones annually, followed by India (7.0), Mexico (6.9), Nigeria (4.8) and Argentina (3.6).It is unique to adapt to environmental extremes of abiotic and biotic stresses and essential crop to diets to poor people in the semi-arid tropics where drought causes frequent failure of other crops (Godbharle *et al*., 2010). Nigeria is the second largest producer of sorghum in the world, with an annual production in excess of 8 million metric tones. This energy crop is a basic food for mankind in regions of Africa, Asia and India. Sorghum is very hardy and grown in areas of the world that are either too hot or too dry for other crops to be grown successfully. Grain sorghum is a small round berry which vary in colour from red, yellow, cream to white.

In the semi-arid tropics sorghum is used in various ways. It is a principal source of nutrition for millions of people and provides a major source of energy to human diets in Africa and much of Asia. Sorghum is primarily used for human consumption and as a staple food in the diet of many people in countries of the world especially

sub – Saharan Africa. Sorghum grain is for human food such as porridge, or popped, infant food, syrup and local beveragesknown as “akamu” and “kunu” (semi-fluid like pap) and semi solid recipes like “tuwo”(Anon., 2015). The grain and vegetative parts of the crops are used as animal feed. Sorghum serves as a major raw material in the brewing industry. Some varieties of sorghum can be malted to produce nutritious food stuff for infants and use as bakery products. Malted sorghum can also be used in traditional beer production, an important income earning activity for village women in Nigeria. Besides providing food for human and feed for livestock, sorghum stem is used for a wide range of purposes, including the construction of wall fences and thatches roofs, and production of brooms, mats, baskets, fish-traps, sun shades, cooking fuel and additives to improve soil fertility (Murty *et al.*, 1994).

1.2 The Role of Mineral and Organic Fertilization in Sorghum

The use of mineral fertilizer has not been helpful under intensive agriculture because it is often associated with reduced crop yield due to soil acidity and nutrients imbalance (Ojeniyi, 2000 and Adeniyi*et al*., 2005). To enhance the quality, and hence the effectiveness of traditional soil fertility maintenance strategy such as manure application, a fertilizer augmented soil enhancement strategy (F A S E) that involves the addition of limited quantities of inorganic fertilizers has been suggested (McCown *et al.*, 1992;Probert *et al.*, 1992). Such combination has been found to be superior to the application of manure alone (Qureshi, 1991). Application of manure and nitrogenous fertilizers, provided that other major nutrients are not limiting, increases grain yield of the sorghum crop even under *Striga* pressure (Adeniyi *et al*., 2005). Esilaba *et al*. (2000)reported that application of farmyard manure at 10t ha^{-1} and

fertilizer at 40 and 80kg Nha^{-1} significantly increased sorghum grain yield, but the grain yield was severely depressed at 120kg Nha^{-1} due to poor germination. They further reported that application of 40kg Nha^{-1} with 20 and 30kg Nha^{-1} manure significantly improved sorghum grain yield. Sorghum Stover yields increased at all rates of manure application and the combined application of manure and fertilizer further increasedStover yields at 80 and 120kg N ha^{-1} rates. Esilaba *et al.*,(2000) further reported that combined application of manure and N enhanced soil fertility (that is, soil organic matter and total nitrogen) and increased crop yield at all rates of the fertilizer application. Nitrogen and manure did not affect Sorghum biomass and grain yield in the two seasons due to moisture stress and birds damage (Esilaba *et al.,* 2000).Sultani *et al.* (2007) reported that, combined application of manure and N enhanced soil fertility (that is, soil organic matter and total nitrogen) and increased crop yield at all rates of the fertilizer application.

1.3 Integrated Approaches to *Striga* Control in Sorghum

The problem of parasitism by *Striga* spp and other members of *Orobanchaeceae*is different from that caused by other parasitic plants because of the close biological association with a host plant. Three principles for *Striga* management are prevention of spread of *Striga* seeds to new areas, prevention of *Striga* plants from producing seeds and reduction of seed bank in the soil (Kureh *et al.,*1999) These can be achieved through the use of *Striga*-free planting material and equipment, host plant resistance, seed treatment, use of high rate of fertilizer, trap cropping & crop rotation.

1.4 Justification of the Study:

Despite the importance of sorghum as a food crop and industrial material the yields of the crop at farmers level remains low at 1.5 t ha^{-1}compared to yields from research fields of 4.6 t ha^{-1}.The production of sorghum varies from one place to another due to variation in climate, soil and agronomic practices. Differences in local cultivars compared to improved varieties have been reported by several authors (Mumera *et al.,* 1993; Myers, 1994). Elemo and Obilana (1985) reported yield of 4.6t ha^{-1} with local cultivars, whereas yield of up to 5.5t ha^{-1} had been reported with commercial hybrid. Generally, low yield of cereals, pulses and plantain crops are attributed to insufficient soil nutrients. According to Lombin (1987), the most limiting soil nutrients are identified as nitrogen and phosphorus. Fertilizer requirement of a crop changes with changes in crop varieties and production conditions (Lombin,1987). The use of high rate of nitrogen increased the performance of sorghum in *Striga* infested field. This is because nitrogen can reduce the severity of *Striga* attack and at the same time increase the performance of the host crop (Lagoke and Isah, 2010).

The use of mineral nitrogen and organic manure such as farm yard manure, green manure and compost has been reported to reduce *Striga* infestations (Piterse, 1996). Esilaba *et al.* (2000) reported that, the greatest decrease in mean *Striga* density across all treatments was obtained with 120 Kg N ha^{-1} and 20 t ha^{-1} manure for maize. Research has shown that when N fertilizer and organic matter were combined, *Striga* emergence declined over a three years period (Ransom and Odhiambo, 1994), compared to sorghum planted without manure and mineral fertilizer.

Application of 20 t ha^{-1} manure, 40 Kg N ha^{-1} with 30 t ha^{-1} manure, 80 Kg N ha^{-1} with 10 and 30 t ha^{-1} manure, and 120 Kg N ha^{-1} with 20 and 30 t ha^{-1} manure significantly reduced *Striga* infestation on sorghum

Application of 20 t ha^{-1} *Cassia obtusifolia* green manure with 50 Kg N ha^{-1} significantly inhibited *Striga* germination, infestation, and resulting in significant rice yield increased (Kayeke *et al.,* 2007). Suryawanshi *et al.*(2011) reported that *Cassia obtusifolia* green manure produced higher total dry matter (1,154kg ha^{-1}) than *Parthenium hytrophorus.* The phosphorus and potassium content was also higher in *Cassia obtusifolia.* Better results were observed from *Cassia obtusifolia* because it is a legume and contains more N, P and K as compared to other weeds. However, its assimilation rate was less compared to the other weeds. The need to use renewable forms of energy and reduce costs of fertilizing crops has revived the use of organic fertilizer worldwide.Some weed plants have the potential to provide nutrients. When we compare the available nutrients with the synthetic fertilizers and their market values, weeds reduce the input cost of crop production. Exploiting available natural resources is a better way of utilizing poor and marginal soils to get better yield.

The test crop varieties used in this research are SAMSORG -40 and SAMSORG -41. Although research has been conducted on different sorghum varieties, there is limited work on these two varieties in the areas of nutrients sourced from organic and inorganic fertilizers in the Northern Guinea Savanna of Nigeria.

With increase in the demand for sorghum and population of those that consume the crop, this study was necessitated with the following objectives:

1.5 Objectives of the study:

The study was under taken with the following objectives to :

a. Evaluate the effect of *Cassia obtusifolia*green manureand cow dung on *Striga*growth and yield performance of sorghum varieties.
b. Investigate the effect of N on *Striga*, growth and yield performance of sorghum varieties.
c. Determine the optimum combination of *Cassia* green manure and nitrogen rate for reducing the impact of *Striga* on sorghum growth and yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

Continuous cultivation of arable land without nutrients input results in degraded soils, accelerated soil erosion, depletion of soil nutrient reserves, reduced soil organic matter content, loss of soil physical structure and reduced crop productivity (Lee *et al.*,2007). Continuous removal of biomass from crop land without adequate nutrient replenishment can rapidly jeopardize the sustainability of agricultural production (Stoorvorgel and Smalling,1990). Parasitic weed species of the genus *Striga* establish preferentially on poor soils and fields which have been exhausted by continuous cropping (Vogt *et al.*,1991). Most *Striga* infested areas are characterized by agricultural production systems that witness low crop productivity. The use of inorganic nitrogen and organic fertilizer has been reported to reduce *Striga* infestation and are as effective as fallowing in maintaining soil productivity (Mumera and Bello, 1993; Pieterse, 1996) (Ogborn, 1984). This approach combines the short term benefits of inorganic fertilizer with the long term value of organic fertilizer (Mumera *et al.*,1993). Smalling *et al.*(1992) demonstrated the need for integrated nutrient management, especially in areas of low soil fertility where farmers cannot afford to rely on mineral fertilizer alone. Such integrated soil fertility management systems can reduce the inorganic fertilizer requirement, and at the same time increase the efficiency of the added input (Lee *et al.*, 2007).

Striga hermonthica reduces growth and markedly alters the architecture of sorghum plant, as result of its total reliance on the host for water, nutrient and some reducing sugars (Okonkwo, 1966). *Striga* parasitism caused stunting of the shoot, failure of panicle formation in extreme

cases and total collapse of theplant (Dogget, 1965) with yield reduction of 20% - 100% in sorghum depending on the level of attack and the variety (Kureh *et al.,* 1999).

Green manuring is the incorporation of, mostly fresh plants into the soil. The species most commonly used as green manure crops are members of the crop family leguminoseae. The legumes for green manure can be edible, herbaceous or forage legumes. Where the leguminous crops are planted in fallow and are properly managed and incorporated into the soil, substantial amounts of N and other nutrients and organic matter are added to the soil and this also improves soil physical condition (Francis *et al.,* 1986; Hullungale, 1988). If the crop is a legume, considerable N may be added to the soil as a result of its N-fixing ability (Leonard, 1986). Application of organic manure improves soil chemical, physical and biological properties in favour of crop plants. (Makinde*et al.,* 2001).

2.1 Response of Sorghum Varieties to *Striga* Infestation.

Striga hermonthica (Del.) Benth is a root and an obligate parasiticflowering plant of *Orobanchaeceae* family.It is commonly found in Sub Saharan Africa (SSA) causing severe constraints to crop production. It survives by diverting essential nutrients which are other wise taken up by Sorghum (*Sorghum bicolor* (L.) (Rodenburg *et al.,* 2006; Atera *et al.,* 2011). It parasitizes the host through haustorium connection to xylem of the host plant from which it draws nutrients and manufactured food like reducing sugars and amino acids, aspartic acid and asparagines (Dogget, 1984). The effect of *Striga* on sorghum crop has been reported by several authors (Anon., 2011; Esilaba, 2006; Kureh *et al.,* 1999). It is known to cause stunting of growth, reduction of vigor and failure of panicle formation of the infested plant. Chlorotic blotches and necrosis on the foliage also occur; and under severe attack, it

results in death of the plant. The adverse effects of *Striga*damage on sorghum have been attributed to many factors, reduction in yield. The extent of yield losses is related to the incidence and severity ofattack, the host's the susceptivility to *Striga,* environmental factors (edaphic & climatic) and the management level at which the crop is produced (Esilaba, 2006). Its effect on crop ranges from extraction of nutrients, moisture, diversion of host'sphotosynthates, mineral salts and water to the parasite, resulting in stunted growth, through wilting, yellowing and scorching of leaves to the lowered yields and death of many affected plants. It was reported that, annual sorghum losses attributed to *Striga*in SSA are estimated at 22-27 % but specifically 25% and 35 % in Ethiopia and Nigeria, respectively (Anon, 2011). In terms of monetary value, the annual cereal losses due to *Striga* are estimated at US$ 7 billion in SSA. In Ethiopia, Mali and Nigeria, the annual losses are estimated at US$ 75 million, US$ 87 million and US$ 12 billion, respectively (Anon., 2011). Altera and Itoh, (2011) reported that, approximately about 20-80% losses on sorghum are recorded on farmers field which forced him to abandoned his highly infested field. Abdullahi (2011) reported that, SAMSORG -40 which is a tolerant variety produced significantly higher yield and yield attributes when compared with SAMSORG-41 under severe attack of *Striga.* This was observed when SAMSORG-40 intercropped with cowpea produced significantly higher dry matter, longer panicle, higher 100-grain weight and grain than SAMSORG -41 under the same conditions.

2.3 Green Manure and Manuring

The green manure materials may either be obtained from quick growing green manure crops grown *in situ* or harvested from elsewhere. Any plant material incorporated into the soil while green or soon after maturing for the purpose of improving the soil organic matter is green manure (Azraful-Haq *et al*., 2001). Green manure is usually beneficial to soil that is well managed. Benefits attributed to green manuring include addition of nitrogen (when using legumes), addition of organic matter, increase in the conservation and availability of nutrients , improved physical condition of the soil , erosion control, weed and disease control (Azraful-Haq *et al*., 2001). The root systems of green manure crops also have a big effect in aggregation of the fine textured soils. Green manure crops also shade and cool the soil. By providing a dense vegetative cover, the damage to soil aggregation produced by rain drop splash is eliminated. The legumes for green manuring can be edible, herbaceous or forage legumes. Manure also improves the chemical, physical and biological characteristics of soils and increases the yield and quality of crops (Yolcu *et al.*,2010). Application of crushed cotton in the soil increased rice grain yield (5%) and other yield parameters such as grain protein concentrate (18%) and grain starch concentrate (7%) more than the application of crushed cotton with inorganic fertilizer (Makinde *et al.,* 2001).

In general, recovering of nitrogenfrom green manure gives N fertilizer equivalent (NFE) that ranges from 25-50%. A wide range of values were quoted up to 150kg N ha^{-1}, but it more typically lied between 50 and 100% N ha^{-1} (Meelu *et al.*, 1994). Green manure generally contains two fractions, the first fraction being 50-80% of the total

N in the green manure and decomposes during the first cropping and the second fraction was 40-60% available P decomposes over several years (Bouldin, 1988).

2.4 Soil Improvement with Organic Manures

2.4.1 Effect of cow dung manure on sorghum varieties

The practice of applying organic manure as farm yard manure (FYM) in crop production has been well recognized (Fillery, 2001). Besides supplying the major nutrients, organic manure also supplies the necessary minor nutrients that are usually lacking in inorganic fertilizers. The main nutrients supplied are nitrogen, phosphorus, potassium, calcium and magnesium. However, the response of crops to organic manure depends on several factors such as level of decomposition, soil characteristics, moisture regime, the crop species/growth and time of application. Sharifai *et al*. (2012) reported that optimum grain yield of extra early maize (2.26t ha^{-1}) under rain fed conditions was obtained with the combination of 25cm intra-row spacing, 82kgNha^{-1}as urea and 1.91t ha^{-1} poultry manure. Manure increases organic matter content, water holding capacity of soil and plant nutrients. It also increases the efficiency of mineral fertilizer by improving the physical properties of the soil and soil incorporated with cow dung contain enough suitable phosphoric acid, potash and lime (Lelei, *et al*., 2009).

According to Wild and Jones (1988), application of 75t ha^{-1} of fresh cattle dung returned about 160KgN, 22KgP and 110KgK to the soil and also supplied Ca, Mg, S and other micro-nutrients. Continuous use of cow dung maintains considerably high level of organic matter in soils with corresponding reduction in soil acidity and increased exchangeable cations (Singh and Balasubramanian, 1978). They further reported that 25t ha^{-1} of cow dung would supply 85.5 kg N, 23.0 kg P_2O_5 and 75 kg K_2O per hectare. Sorghum response to application of 25t ha^{-1} of cattle dung on phosphate deficient soils have been reported, and the response was

attributed to its phosphate content and probably, its contents of Ca, Mg, K and Na (Wild and Jones, 1988). Cow dung is therefore a source of plant nutrients, among the various animal droppings. Fillery *et al.* (2001), reported a significant increase in corn grain, and silage yields, plant N. P and K concentrations and uptake, as well as soil salinity by applicationof 80t ha^{-1}/year of liquid cattle dung. Patil *et al.* (2006) reported a significant increase in grain yield of 1,605kgh-^{1} winter sorghum that was treated with organic manure at 2.9kgha^{1} when compared with the yield of 1,595kgha^{1} by the application of 25kgN ha^{1}. Application of cow dung increased plant height of maize, and application of 8 and 12t ha^{-1} of cow dung produced taller plants than the N P K treatment while, the shortest plants were produced by the control, except at 3WAS; and application of cow dung at 12t ha^{-1} produced significantly higher leaf number than the N P K control at 3 and 9 WAS (Mahadi, 2011). Boateng *et al.* (2006) observed an increase in plant height, LAI and biomass when 4t ha^{-1} of poultry manure was applied on a maize crop.

2.4.2 Effectof green manure on soil

The potential benefits of green manures are many. Apart from increasing soil N (Islam*et al.*,2000), the soil organic matter is maintained and renewed, and the physical and chemical characteristics of soil are improved (Bouldin*et al.*, 1988). Mulangoy *et al.* (1993) observed that the level of organic matter in soil depends largely on the quality of plant material and water returned to soil. Incorporation of crop residues was beneficial to soil in terms of increased soil organic concentration (SOC) that was not only beneficial to soil in relation to agriculture, but also represents a sequestration of carbon from atmospheric carbon dioxide (Ogunwale *et al.*, 2010). Legumes incorporation is known to result in high soil organic carbon and exchangeable cations

and the impacts are mostly felt at the top soil of 0-15cm depth (Cassman*et al.*,2003). It was found that legume incorporation at Samaru did not affect soil pH, but observed difference in C : N ratios of the legume treatments.

When *Leucaena* as green manure at 2.5 t ha-^{1} was used, 1647 kg ha^{1} grain yield was at par with the application of 25 kg N ha^{-1} andstatistically similar to grain yield of 1657 kg ha^{-1} obtained by 50 kg N ha^{1} in sorghum. Similarly, the straw yield from the *leucaena* green manure of 1955 kg ha^{-1} significantly outweighed the yield of 1686 kg ha-^{1} obtained by 50 kg N ha^{1}.

Tanimu (1999) reported that, incorporation of legume after one or two years of growth improved soil pH, soil organic matter, exchangeable cations and cation exchange capacity. Legume straw incorporation has been discovered to increase water infiltration rate by 1.4 times and available water by 2cm in the 180cm depth of soil profile (Suryawanshi, 2011). Incorporation of*Crotalaria* sp. was reported by Azraf-ul-Haq *et al.* (2007) to sufficiently reduce soil bulk density up to 20cm depth. It was reported that bulk density of 0-10cm soil depth was less than that of 10 – 20cm depth. Lower bulk density implied greater pore spaces and improved aeration, developing a suitable environment for biological activity (Islam *et al.*, 2000; Min *et al*., 2003). In an experiment conducted in Pakistan to assess physical properties of soil as influenced by various green manure legumes, it was observed that leguminous green manure crops on the average reduced bulk density by 5%, enhanced total porosity by 8% and macrospores and large mesopores by 28% (Sultani *et al.*, 2007). This study further revealed a maximum reduction of 7% in the soil bulk density an increase of 11% in total soil porosity and 17% available water where *Sesbania* sp. was incorporated.

Incorporation of *Lablab, Crotalaria* sp and garden pea residues resulted in higher concentration of N and P in the soil through natural fallow control (Lelei *et al.,* 2009). Similarly, Ogunwale *et al.* (2010) reported that, incorporation of residues of *Centrosemapascuorum* and *Parkia biglobosa* into the soil increased total soil nitrogen, which they attributed to the quality (i.e. nutrient composition) of the incorporated residues. It was further asserted that higher total soil N in most cases means a small C:N ratio which is an indication of the rate of decomposition in the soil. N- studies have shown that a succeeding crop can recover 2-26% of the N-applied through grain legumes residues (Fillery, 2001). However, Rochester et *al.* (2001) reported that, when leguminous crops are grown and used for green manure they provide up to 40% of N available in soils by decomposition of nodules and other biomass of the leguminous green manure crops. Leguminous plants are superior to non-legume green manure because they have an exceptional ability to utilize inaccessible soil phosphorus and potassium thus improving availability of P and K to subsequent crops (Azraful-Haq, 2007).Makinde*et al.* (2001) indicated that, manure provides an excellent source of organic matter when added to the soil, and restore some of the depleted nutrients as well as increase in the soil pH, and soil macro and micro nutrients. Ayoola *et al.* (2006) reported that, when green manure crops are ploughed into the soil, their residue help to increase availability of phosphate and trace elements to the succeeding crops due to the lowering of the soil pH, brought about by the carbon dioxide produced during the process of decomposition.

2.4.3 Effect of *C.obtusifolia* green manure on sorghum

C. obtusifolia (L) is a legume belonging to the family *Caesalpiniaceae.* It grows wild mostly in the tropics and is considered a weed in many places. The boiled leaves of C. *obtusifolia* called "tafasa" in Hausa are used in soups and vegetable recipes in some parts of northern Nigeria. Until recently, little attention has been given to the role of the plant in Nigeria. Research on the utilization of weed for more remunerative purposes is in progress in many countries which may induce man to harvest weed extensively thus indirectly controlling them by utilization and as they are proposed for production of paper pulp (Nag,1973), extraction of leaf protein and green manure (Sanyasi,1992). Suryawansh (2011) reported that, when C. *obtusifolia* was used as green manure, a total of 30.7kg N ha^{-1}, 0.97kg Pha^{-1} and 32.8kg K ha^{-1} was supplied to the soil. The nitrogen supplied by C.*obtusifolia* was more than by *Parthenium hysterophorus* and *Achyranthus aspera* (Suryawansh, 2011), as in 427kg N ha^{-1} of C. *obtusifolia,* 352kg N ha^{-1} in *Parthenium* spand 53kg N ha^{-1}in*Achyranthusaspera*. When maize was cultivated with different weed green manure, it showed modification on growth, depending on the age (Suryawanshi, 2011). He further reported that, percentages of nitrogen, phosphorus and potassium were higher in *Cassia obtusifolia* than in the other weeds. Yield of fresh vegetable maize on weed green manure was highest 12702 kg ha^{-1}. by C. *obtusifolia.*

2.4.4 Effectof nitrogen on sorghum varieties

Sorghum requires relatively low soil nutrients as compared to maize, especially with respect to nitrogen. Nitrogen is generally the most limiting nutrient in sorghum production. Increasing N fertilizer rates generally results in improved grain yield (Lemond *et al.*, 1991). However, effective N-management may be equally important if the sorghum Stover is to beused as livestock feed. Ayoola*et al.* (2006) reported that application of N in split doses between planting and 8-leaf growth stage can improve grain yield. Application of 40 - 80 Kg

Nha^{-1} significantly increased sorghum grain yields, but grain yield was severely depressed at $120KgNha^{-1}$.

Germination count was found not significantly influenced in sorghum fertilized with N at the rate of $75Kgha^{-1}$ when compared with control treatment. Soleiman(2008) reported that, increasing nitrogen dose increased all sorghum growth attributes. Thus, the maximum plant height was obtained in with 100 Kg N ha^{-1} , having plant heights of 193.92 cm,195.24 cm and 192.8 cm (Fillery, 2001) at 100 Kg N ha^{-1}. Significantly, the maximum plant population of sorghum at harvest (72,000 plant ha^{-1}) was observed with the application of $75KgNha,^{-1}$ which was higher compared with 54,000 plant ha^{-1}obtained with the application of poultry manure. Patel *et al.* (1994) reported that dry matter yield increased with application of 40-160Kg Nha^{-1}.Grain and Stover yields increased significantly with N up to $25Kgha^{-1}$. Stover yield increased by 14-20 % with the application of 25- 50Kg N ha^{-1} over the untreated control. Stover yield was significantly affected by both organic and in organic fertilizer (Patil *et al.,* 2006). Patel *et al,* (1994) reported that grain yield of sorghum increased by 245 $Kgha^{-1}$ with the application of 25Kg Nha^{-1} and further increase in N to $50Kgha^{-1}$ increased grain yield by 349 $Kgha^{-1}$. Application of 25KgN ha^{-1} under deep and medium tillage increased significantly the grain yield of sorghum to 2,047 and 1,576 $Kgha^{-1}$ respectively, over the control, and further increased of 50Kg N ha^{-1} increased the grain yield marginally (Patil *et al*., 2006).

2.5 Control of *Striga hermonthica* by Crop Nutrition

It has been observed that continuous cropping and poor fertility statusof the soil tend to aggravate*Striga* infestation. Researchers have also indicated that the application of high rates

of nitrogen reduced the severity of *Striga* attack and increased the yield of the affected host plant (Lagoke *et al.*,1994; Carsky*et al.*, 1994). The use of high rate of nitrogen increased the performance of sorghum in *Striga* infested field. This is because nitrogen can reduce the severity of *Striga* attack and at the same time increase the performance of the host crop (Lagoke and Isah, 2010). To achieve sustainable food production in Nigeria there is need to control *Striga*. Application of nitrogen fertilizers is very essential as the most important component for solving *Striga* problems. Therefore, application of recommended nitrogen rate would help to increase plant vigor and dry matter accumulation per plant.Showemimo (2007) reported that, good plant vigor and with high dry matter weight are among the best criteria for selecting the sorghum as a test crop that are either resistant or tolerant *Striga* infestation. The effectiveness of nitrogen fertilizer in reducing *Striga* problem would depend on time of application, soil fertility status and crop variety. It thus appears that certain forms of nitrogen fertilizer which are beneficial to the host plant may be harmful to parasitic plant seedling. The use of mineral nitrogen and organic manure such as farm yard manure and compost have been reported to reduce *Striga* infestations (Piterse, 1996). Esilaba *et al.* (2000) reported that, the greatest decrease in mean *Striga*density across all treatments was obtained with 120Kg N ha^{-1} and 20t ha^{-1} manure for maize. Research has shown that when N fertilizer and organic matter were combined, *Striga* emergence declined over a three years period (Ransom and Odhiambo, 1994), compared to sorghum planted without manure and mineral fertilizer.Application of 20t ha^{-1} manure, 40Kg N ha^{-1} with 30t ha^{-1} manure, 80Kg N ha^{-1} with 10 and 30t ha^{-1} manure, and 120Kg N ha^{-1} with 20 and 30t ha^{-1} manure significantly reduced *Striga* infestation on sorghum at Makele in 1997, while application of 40kg N ha^{-1} in

combination with 10 and 20t ha^{-1} manure and 80kg N ha^{-1} with 20t ha^{-1} manure did not significantly reduce *Striga* infestation (Esilaba *et al.*,2000).

2.6 Integrated Approaches to *Striga* Controlin Sorghum

The problem of parasitism by *Striga* spp and other members of *Orobanchaeceae* is different from that caused by other parasitic species because of the close biological association with the host plant. Three principles for *Striga* management are prevention of spread of *Striga* to new areas, prevention of *Striga* plants from producing seeds and reduction of soil seed bank and this can be achieved through the use of *Striga*-free planting material and equipment, host plant resistance ortolerance, seed treatment, use of high rate of fertilizers, trap cropping and crop rotation (Kureh *et al.,* 1999), as follows

Trap cropping: Trap crops are non-hosts that stimulate the germination of parasite seeds in the soil but they are not suitable hosts, and this leads to death of germinating seedling of parasites and therefore depletion of their seed bank in the soil. Varieties of cowpea, soybean and cotton with very high *Striga* seeds germination stimulation have been identified (Carsky *et al.,* 1994). These non- host, if identified for various productions and cropping systems, would reduce soil seed bank and the spreadof *Striga.*

Intercropping:Intercropping is a practice which has been widely used in the tropics for many years which offers substantial advantages compared with sole cropping. Numerous reasons have been advanced for farmers practicing inter cropping one of the strategies of weed control. Kureh *et al.* (1999) reported that inter cropping maize with soybean supported lower incidence and infestation of *Striga* and exhibited significantly lower crop syndrome reaction score than sole maize. They further indicated that emerged *Striga* plants in the inter crop

were etiolated in growth and died earlier than Strigain the sole crop, probably as a result of the smothering effect of soybeans.

Use of high rate of fertilizer: Lagoke *et al*. (1994) indicated that the application of nitrogenous fertilizer has been observed to reduce the severity of *Striga* attack and increase yield of the affected host crop.Carsky *et al*, (1994) stressed that the effectiveness of nitrogen fertilizer in reducing *Striga* infestation would depend on its time of application, soil fertility level and crop variety. Esilaba *et al.* (2000) reported that, the greatest reduction in the mean *Striga* density, across all treatments was obtained with 120KgN ha^{-1} and 20 t ha^{-1} manure for maize.

Resistant varieties: Are plants within a certain group that are less vulnerable to attack by pest or disease. The use of resistant varieties is the primary control measure for small scale farmers but it must be supported with the cultural practices, however, reliance on host resistance against *Striga* cannot be attained through breeding and usually the newly developed varieties may not fulfil farmers preference traits(Adunga, 2007).

Crop rotation: This is a cultural practice indicated by Akobundu, (2016) which provides diversity in the species of crops that are available and reduces the severity of *Striga* infestation. Certain weeds tend to associate with given crops and if same host crop is grown continuously for several seasons, associated weeds may reach high populations(Akobundu, 2016).

2.7 Effect of Organic Manure on Nutrients Availability, Uptake and Concentration in Sorghum

Soil amendment with green manure has been demonstrated to increased soil organic C,total N and available P (Lee *et al*., 2007). Incorporation of green manure into the soil promoted transformation and mineralization of less-labile inorganic and organic P into labile- P in the lithosphere, which resulted in higher root P concentration and higher total P up take by plants (Makinde *et al*., 2001). Nitrogen content and P uptake were two to three times greater than those of the other three winter cover crops, P uptake differed slightly among the other winter cover crops but sorghum P uptake was not correlated to winter cover crop P uptake (Lee*et al.*,2007). They further found that organic fertilization increased N mineralization and uptake from recently added solid cattle manure but this effect is not dominant. Lelei *et al.* (2009) reported that a single application of cow dung might have increased the organic matter content of the soil well below 2.5cm depth, and for a period exceeding three years. The organic fertilizers might have raised the level of organic carbon and loss on ignition in the 0-5cm layer by increasing the growth of pasture roots. The rate of nitrogen supplied by the dung to the actual dung spot were 900-1200 kgha^{1}, but only 125-165kgha^{1} on the basis of 619cm square (Lelei *et al*., 2009). About 30% or more of the N applied in the dung may have been in the top soil three years later. There was also evidence that dung increased the proportion of grasses compared with other treatments. The total apparent recoveries of calcium in the herbage and top soil were higher in the dung treatments than in the superphosphate treatments. They also reported that dung increased the capacity of the soil to absorbed cations due probably to increases in pH and organic manure probably for this reason the apparent recoveries of calcium was much higher under dung than under superphosphate. They further reported that three years after the application of dung there was still pronounced effects on total N and organic matter on the top 2.5cm of the soil. On the

other hand topdressing with phosphate and potassium, while markedly increasing the yield of N, did not influence the level of N in the soil and only slightly raised that of organic carbon. This suggested that dung plays the key role in the accumulation of N and soil organic matter after pasture improvement. It was found that when dung was incorporated into the soil, 70% of the total P was available to plants but this proportion was reduced to only 13-20% when it was applied to the surface. The substantial amount of nutrients that are contained in a cattle dung can potentially be recycled back to the soil in an available form. It has been estimated for example, that in grazed grassland the return of animal excreta contributes 150 - 300 $kgNha^{-1}$to the soil (Murwira *et al*., 1993).

2.8Interaction of Organic and Nitrogen Fertilizers in Sorghum

The long-run effects of the combined application of organic and inorganic fertilizers in improving soil fertility and crop yield have been demonstrated (Bundy *et al*., 2005). The increase in yield of sorghum with organic and inorganic fertilizer applications was probably due to higher number of leaves per plant, plant height and leaf area per plant. Results were similar with findings of Lee *et al*. (2007) who also reported significant effect of N application on green fodder yield of sorghum. Application of organic and inorganic fertilizer in combination produced significantly taller plants when compared with application of organic matter alone but statistically lower than plant height treated with inorganic fertilizer Although it is widely accepted that organic matter additions are essential in maintaining soil health, it is doubtful whether organic input alone will be able to compensate for the continuing removal of plant nutrients in harvested products (Ali, 2000).

Wang *et al.* (2001) reported that, organic and inorganic fertilizers showed great benefits not only by the increase in N uptake by crop plants, but also improvement of fodder yield. Maize performed best in terms of growth and yield with complementary application of organic and inorganic fertilizers. Titiloye (1982), reported that, the most satisfactory method of increasing maize yield was by the judicious combination of organic wastes and inorganic fertilizers.

Makinde *et al*. (2001) has earlier reported that, maize yield from sole organic application and a mixture of organic and inorganic fertilizers application were similar and were significantly higher than yields from organic fertilizer application alone. Murwira *et al.* (1993) observed that, nutrients use efficiency was increased through a combined application of organic and inorganic fertilizer. Maize yields with complementary organic and mineral fertilizers and with the sole inorganic fertilizer treatment were comparable because nutrients were readily released from the inorganic fertilizer and maize, being an aggressive feeder, was able to utilize it for its growth and yield (Makinde *et al*., 2001). The control plots that had no fertilizers gave lowest maize dry matter yield values in the first and the second years, respectively, while the highest values were obtained from plots treated with complementary inorganic and organic fertilizers. They were not significantly higher than that realized than from sole inorganic fertilizer application.

2.9Decomposition of Organic Materials

Plant nitrogen availability from solid cattle manure (SCM) when applied to the surface of cultivated grassland varied widely (Bergstrom *et al.*, 2004) in a number of experiments the apparent herbage N recovery from SCM ranged from 20-50% in the first year. Since the

major part of N present in SCM is organically bound. Its net availability for plant uptake largely depends on the balance between decomposition, mineralization, and immobilization. These processes are influenced by environmental conditions (temperature and moisture), edaphic factors such as soil pH and clay content, chemical composition of the applied organic matter and the composition of the soil decomposer community (bacteria, fungi and invertebrates) (Cassman*et al.*, 2003).

Globally, the observed variation in the decomposition of organic matter in terrestrial ecosystem is 70% influenced by different environmental conditions, together with the chemical composition of organic matter (Cassman*et al.*, 2003). The remaining 30% is influenced by other factors like soil decomposer community and their interaction with specific characteristics of the added organic matter together with local soil chemical and physical properties (Bergstrom*et al.*, 2004). However, the strength of these factors and their interactions vary among ecosystems and biomass (Wall,2008). In case of significant interactions, the chemical composition (lignin : N, or carbon : N ratio) of the organic inputs was found to determine the composition of the associated decomposer communities and the route and rate of the decomposition processes at local scale. Such an association has been reported to explain why decomposition commonly occurs more rapidly when organic matter is applied to its home habitat than when it is applied elsewhere, an effect called home field advantage (AHF). The AHF is generally stronger where the organic matter quality is lower. Solid cattle manure (SCM) varies greatly in its composition and quality (lignin : N and C : N ratio) because of differences in animal origin, feed ration, bedding materials and manure handling as well as processing systems. Bouldin(1988) observed that repeated application of cattle dung to grassland increased the soil fauna biomass as well as its activity. Ayoola *et al.*

(2006) also reported organic matter amendments boosted the activity of enzymes that were important in the decomposition process.

Decomposition rates of incorporated green manure (G.M) differed less between seasons and locations than for mulched G.M (Myers *et al.*,1994). Incorporated residues are in a generally favourable environment for microbial decomposition which result in close soil contact, adequate soil moisture, among others. Fast initial decomposition of soyabean in both seasons at Asian Vegetable Research and Development Centre (AVRDC) matches findings of Bergstrom*et al.* (2004) where incorporated soyabean residues lost 68% of their total biomass within 32 days. Green manure decomposition and subsequent N release depended largely on residue quality and quantity, soil moisture and temperature and specific soil factors such as texture, minerology and acidity, biological activity, and the presence of other nutrients (Myers *et al.*, 1994). Decomposition and mineralisation studies conducted by Fillery,(2001) showed that N was released rapidly from green manure during the first 2-3 weeks after incorporation and then slowed down. About 25-30% of cereals residues and 40-50% from legume residues can decompose in a month. While Azraful-Haq*et al.* (2001) reported earlier that, it takes about 3 - 6 weeks for organic matter to adequately decompose in the tropics. Legume residues commonly have C: N ratio less than 30:1 and therefore tend to release N and decompose rapidly. Hence, this residue make nutrients available for the succeeding crops.

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Experimental Site

A field trial was conducted during each of the wet seasons of 2013 and 2014 to investigate the effects of nitrogen and organic manure. The manure consisted of *Cassia obtusifolia* L. green manure and cowdung on two varieties of sorghum grown on *Striga*-infested fields.The locations were the farms of the Institute for Agricultural Research, Samaru (Lat. 11^0 11"N7^0 38 E; 686m above sea level), in the Northern Guinea Savanna zone and the Experimental farm of Hassan Usman Katsina Polytechnic, Katsina (12^0 56 "N, 7^0 36 E; 465m above sea level) in the Sudan Savanna zone of Nigeria. Details of meteorological data at the two locations and seasons were recorded and presented in Appendices 1 - 4.

3.2 Soil, *Cassia* Green manure and Cowdung Analyses

Prior to land preparation in each season, soil samples were collected randomly from each experimental site at 0-30cm depth using a soil auger. The soil samples from each location were bulked, air dried, ground and sieved using a 2mm wire mesh before being subjected to laboratory analysis for physical and chemical properties using standard procedures as described by Black (1965). The results of analysis are presented in Table 2. The chemical properties of C. *obtusifolia* green manure from Katsina and Samaru in 2013 and 2014 were determined by the standard procedure and are presented in Table 3. Similarly, the percentage N, P and K properties of cowdung used in both locations was also determined by standard procedure and are presented in Table 4.

3. 3 Treatments, Experimental Design and Plot Size

The Experiment in each location consisted of two sorghum varieties (SAMSORG-40 and SAMSORG-41), four levels of organic manure (*Cassia* green manure at 0, 7.5 and 15t ha^{-1} and cowdung at 10t ha^{-1}) and three nitrogen levels (0, 40 and 80kgNha^{-1}). The experiment was laid out in a Split Plot Design, with nitrogen levels assigned to main plots and factorial combinations of organic manure levels and variety assigned to the sub-plots. The treatments were replicated thrice. The gross plot size consisted of six ridges,75cm apart, each 3m long giving an area of 13.5m^2, while the net plot consisted of the two ridges, giving an area of 4.5m^2.

Description of *C. obtusifolia* L.

C. obtusifolia(L.) belongs to the family Leguminoseae, *Caesalpinioideae.* It is an erect, branched and bushy annual or perennial dicotyledonous plant, up to 90cm high, that reproduces by seed. The stem is branched, cylindrical, hairless or sparingly hairy. The leaves are alternate, pinnate, 2.5- 7.5cm long. The flower is yellow, 2-3 cm across and borne on pedicel in the leaf axils. The fruit is cylindrical, 10 - 20cm long and 5-6mm wide, curved and beaked. The seed is about 5mm long and 2mm wide, some what rhomboid, brown and smooth. It is a pan-tropic weed of road sides, grass lands and cultivated fields, common near settlements and widespread in West Africa. (Akobundu *et al*., 2016).

SorghumVarietal Description :

SAMSORG- 40(ICSV111) Morphologically, it is semi-dwarf and semi-compact with cream coloured seed. The variety was released by IAR, Samaru, Zaria. It is adapted to Sudan and Sahel Savanna Zones. It is an early maturing variety (75 - 80 days). It is nonlodging, and non senescent variety with good response to fertilization. The potential yield is 1500 – 2000kgha^{-1} and grows to a height of 300 – 350cm. The leaves turn brown at maturity but is tolerant tomost leaf diseases and *Striga*(Anon., 2015).

SAMSORG- 41 (ICSV400) It is non lodging, drought tolerant, and non senescent variety with good response to fertilization. It is an improved medium maturing variety, adaptable toboth Sudan savanna and Sahel ecological zones. Seed colour is cream and hashard grains which make good local food quality. It is high yielding, and *Striga* tolerant. The variety grows to a height of 300-350 cm. It matures within 90-110 days. It was developed and released Institute for Agricultural Research (IAR), Zaria. Its yield potential is 1000-2800kgha-^{1} (Anon., 2015).

Cultural Practices

Land preparation and manure incorporation.

In each trial and season, the land was harrowed to a fine tilth and ridged, 75cm apart. The site was marked into plots and replications. Alley path ways of one meter across and one ridge along the ridges were allowed as borders between the plots, while replications were separated by two ridges along and 1m across the ridges. C. *obtusifolia* plantswere harvested at five weeks after emergence from near by fields where it is growing wild in both locations. The green manure and crushed cow dung were uniformly

appliedaccording to treatment and incorporated into the soil two weeks before sowing for full decomposition. The incorporation was done by opening the center of each ridge to about 15cm depth, and applying cow dung or burying *cassia* plants according to treatments, after which, each was covered with soil.

***Striga* seeds inoculation**

The *Striga* seeds was obtained from the cereal research programme IAR, Zaria. Each experimental site was inoculated with *Striga* seeds, a day to sowing. This was done by using 25g of *Striga* seeds per 1kg of fine sand to inoculate each field. The inoculants was uniformly applied by broadcasting immediately after ridging and prior to manure application. The inoculation was done to boost the *Striga* level of the infested fields.

Planting

Apron plus was used to dress the seed of each crop variety at the rate of 10g per sachet 3.0kg of seeds. Dressed seeds of Sorghum was sown on June 20th and 15th in 2013 and 2014, respectively at Katsina and June 25thand 20^{th} in 2013 and 2014, respectively at Samaru using 4 - 5 seeds per hill at a spacing of 35cm on 75cm ridges. Sorghum seedlings were thinned to two plants per stand at three weeks after sowing (WAS) so as to allow the vigorous to grow.

Fertilizer application

Nitrogen in the form of Urea (46%N) was applied in two split doses as per treatment (0, 40 and 80kgNha^{-1}) at 3 and 6 WAS by side dressing. N P and K compound fertilizer (15:15:15) was applied basally to supply 30 kg $P_2 0_5$ha^{-1}and $K_2 0$ ha^{-1} using SSP and MOP as source of P & K, respectively.

Weed Control

Paraquat as Gramazon 27 / L was applied on each experimental field prior to land preparation to control emerged weeds. Weeds were controlled by hoe weeding at 3WAS. Subsequent weed control was done by hand pulling as the need arose, to avoid *Striga* plants destruction.

Harvesting

Sorghum was harvested when the panicles had attained physiological maturity observed by the development of black layer at grain placental region. The stalks were cut at ground level, panicles from stalks and sun-dried for one week before threshing. Threshing was carried out using mortar and pestle grains winnowed with the air to remove chaff, further dried and weighed on a mettle balance.

1. 3. 4 Observations and Data Collection

3.4.1 *Striga* parameters

Number of days to first *Striga* emergence

This was determined by counting days from date of seed sowing to when *Striga* shoot started emerging in each plot.

***Striga* shoot count**

The number of emerged *Striga* shoots was determined by counting within a square quadrat of 0.5m by 0.5m placed randomly on each plot and recorded. The number of *Striga* per meter square was computed.

Number of *Striga* infested sorghum stands.

The number of sorghum stands infested by *Striga* was determined per net plot at harvest and recorded.

Crop *Striga* reaction score

The reaction of Sorghum to *Striga* in each plot was assessed at 6,9 and 12 WAS. The factors considered for sorghum reaction score include yellowing of leaves, stunting of plants and leaf scorching or necrosis. These were assessed using scale of 1 to 5, where 1 represented normal, healthy and vigorous crop growth and scale 5 represented scorched and dying or dead plants (Appendix v).

3.4.2 Crop Growth and Yield Parameters.

Stand count

The stand count of sorghum was taken at 3 WAS after thinning and at harvest by counting the stands in each plot. The sorghum were thinned to two plants per stand at one 1 WAS.

Plant height (cm).

Five stands were randomly selected and tagged in each net plot for the purpose of collecting data. Plant height was obtained by measuring the height of each plant using meter rule from base of topmost leaf to the ground level. The parameter was taken at 3, 6, 9, 12 WAS and at harvest. Average heights of all the plants in the five stands was computed and recorded.

Number of leaves per plant

The leaves on the five tagged stands were counted at 3, 6 ,9 and 12 WAS for each net plot. The average number of leaves per plant was computed to get number of leaves per plant, which was also recorded.

Shoot dry weight (g)

The dry matter per plant was determined at 3, 6, 9 and 12 WAS by randomly selecting and uprooting five plants from the discard in each plot. The plant samples were cleaned of soil, oven-dried at 70^{o}C to constant weight, weighed and mean weight computed and recorded.

Leaf area (LA) and Leaf area index (LAI).

The L A was determined at 3, 6 ,9 and 12 WAS as follows:

L A = L x W x 0.75

Where L = Length of leaf,

W = Maximum width

0.75 = Crop factor

Leaf area/ net plot (PLA) = L x W x 0.75 x n x N

Where n = Number of leaves measured per plant

N = Number of leaves measured per plot

PLA = Leaf area/ plot

LAI = PLA/ Net plot area

Crop Growth Rate (CGR)

The CGR express the increment of dry matter on plant material per unit area of ground per unit of time. It was calculated as suggested by Watson (1958) as follows :

$$\boldsymbol{CGR = \frac{W2-W1}{T2-T1} g/m^2/wk}$$

Where W^2 and W^1 refers to dry weight of plant material per unit area of ground at times T_2 and T_1 respectively.

Relative Growth Rate (RGR).

The RGR expresses the cumulative dry matter increment per unit of time. It was computed as described by Blackman (1919) using the formula

$$\boldsymbol{RGR = \frac{W2 - InW1}{T2 - T1} mg/g/wk}$$

WhereIn refers to Log, W2 and W1 refers to total and dry weight plant^{-1} at times $T_2$and T_1 respectively.

Stover yield at harvest.

At harvest, each plant in the net plot was cut at ground level and panicles were separated from the stalk. The stover (stalk and leaves) was dried and weighed to determine stover yield, which was expressed in Kgha^{-1}.

Panicle weight (g).

The panicles from the tagged plants in the net plot were harvested, sun-dried, weighed, and their means recorded as panicle weight per plant.

Panicle length (cm)

The panicle length per plant were obtained by measuring the length of 10 randomly selected panicles from each net plot using a metre rule, and mean length computed and recorded.

Grain weight per panicle (g)

Panicles of tagged plants in the net plots were sun-dried, threshed and seeds weighed and mean computed.recorded per panicle.

100-Grain weight (g)

One hundred seeds were randomly countedfrom each net plot and weighed and the weight was recorded as 100-grain weight.

Sorghum grain yield ($kgha^{-1}$)

Panicle from each net plot were harvested, dried, threshed and winnowed. The grains obtained were weighed and expressed as yield in kilograms per hectare ($kgha^{-1}$).

3.5 Data Analysis

Data collected were subjected to analysis of variance,(ANOVA) to test the significance of differences between treatment means using the F-test as described by Snedecor and Cochran (1967). The treatment means were compared using the Duncan Multiple Range Test (Duncan, 1955). Correlation coefficients between some growth and yield parameters on one hand, and *Striga* parameters on the other were computed to determine their relationship as described by (Little and Hills, 1978).

3.6Regression Analysis: Regression was done to determine response of sorghum to N, Cowdung and C. *obtusifolia* green manure levels. Path coefficient analysis was carried out to determine the direct and indirect effects on crop yield percentage contribution of individual paired growth yield parameters to yield.

3. 7Partial Economic Analysis

Grain yield data was subjected to partial economic analysis where returns and variable costs were computed to determine the gross margin. Gross margin was calculated as described by Olukosi and Erhabor (1988) as follows :

GM = TR-TVC

Where : GM = gross margin

TR = total revenue/ha

TVC = total variable cost

CHAPTER FOUR

4. 0RESULTS

4. 1 Soil Analyses

The results of soil analysis at the experimental site are presented in Table 1. The soils at Katsina and Samaru were sandy loam and loam respectively. The soil pH at Katsina was higher than at Samaru in each situation and season. The total carbon content and CEC of the soil were higher in 2013 than 2014 in both locations, while available P content was greater at Katsina than at Samaru in 2013 only.

4. 2 Post harvest chemical analyses of soil per treatment bases at Katsina and Samaru in 2013 and 2014.

The results of postharvest analysis of the soil on the basis of organic manure and N levels are presented in Table 2. Nitrogen level slightly increased with *Cassia* green manure rate from 0-15 t ha^{-1} in both years and locations. In most cases, N level by 15 t ha^{-1} *Cassia* green manure was similar to cow dung at 10 t ha^{-1} . The soil available P level was not consistent among the various treatments in both years and locations, while variation in exchangeable K was very slight.

Table : 1 Physical and chemical characteristic of soil samples (0-30cm) taken from the experimental sites during 2013 and 2014 at Katsina and Samaru.

Soil properties	Katsina		Samaru	
	2013	2014	2013	2014
Physical properties				
Sand (%)	80.0	76.0	19.8	25.0
Silt (%)	6.00	8.5	13.2	16.6
Clay (%)	14.0	16.4	67.0	58.4
Textural class	Sandy loam	Sandy loam	Loam	Loam
Chemical properties				
pH in water (1:2.5)	6.35	6.45	6.30	6.05
pH in 0.01m $CaCl_2$	5.82	5.08	5.61	5.08
Organic carbon (%)	0.70	0.41	0.80	0.41
Total Nitrogen (%)	0.24	0.50	0.58	0.50
Available P mg/kg	3.08	4.30	2.10	4.30
Exchangeable cation (Cmol/kg)				
K	0.12	1.23	1.40	1.20
Mg	0.91	1.52	1.80	1.50
Ca	2.00	4.03	4.30	3.03
Na	0.41	0.21	0.41	0.58
CEC (meq/100g)	6.40	5.27	2.40	5.27

Soil chemical laboratory, Department of Agronomy, Ahmadu Bello University, Zaria.

Table : 2 Physical and chemical properties of soil samples from experimental sites on the basis of manure and N treatments at post harvest in 2013 and 2014 wet seasons at Katsina and Samaru.

Treatments	2013			2014		
	Katsina					
	Nitrogen (%)	Available Phosphorus. (mg/kg)	Exchangeable Potassium (meq/100g)	Nitrogen (%)	Available Phosphorus. (mg/kg)	Exchangeable Potassium (meq/100g)
M_0	0.26	14.98	0.04	0.32	13.29	0.04
M_1	0.39	19.10	0.08	0.44	13.81	0.04
M_2	0.52	15.61	0.07	0.66	16.29	0.05
M_3	0.59	15.77	0.07	0.75	20.33	0.06
N_0	0.33	14.86	0.05	0.45	14.56	0.05
N_1	0.44	13.26	0.05	0.48	15.11	0.04
N_2	0.43	20.96	0.05	0.57	18.10	0.06
			Samaru			
M_0	0.28	18.23	0.05	0.36	16.12	0.04
M_1	0.38	21.22	0.05	0.50	20.20	0.05
M_2	0.58	18.13	0.05	0.79	18.72	0.07
M_3	0.59	13.78	0.05	0.73	21.33	0.06
N_0	0.41	19.44	0.05	0.50	15.45	0.05
N_1	0.48	15.76	0.06	0.64	22.06	0.05
N_2	0.48	19.61	0.05	0.64	19.76	0.06

Source : Soil chemical Laboratory of the Department of Agronomy, Ahmadu Bello University, Zaria.

M_0 = 0 t ha^{-1} Organic manure.

M_1 = 7.5 t ha^{-1} Green manure.

M_2 = 15 t ha^{-1} Green manure

M_3 = 10 t ha^{-1} Cow dung.

N_0 = 0 Kg N ha^{-1}

N_1 = 40 Kg N ha^{-1}

N_2 = 80 Kg N ha^{-1}

4. 3 Nutrients contents of *Cassiaobtusifolia* green manure and cow dung used.

The nutrient content of *Cassia*plants and cow dung are in Tables 3 and 4. The N, P and K content of cow dung used in Samaru was slightly higher than at Katsina in both years. Similarly, *Cassia* green manure plants from Samaru contained slightly higher percentages of N, P andK compared to that sourced atKatsina.

Table : 3 Percentage N, P and K contents of *Cassia* green manure used at Katsina and Samaru in 2013 and 2014 wet seasons.

Nutrients (%)	Katsina		Samaru	
	2013	2014	2013	2014
Total N	1.57	1.78	1.75	22.78
Available P	1.45	1.50	1.60	1.96
Available K	0.52	0.61	0.56	0.63

Source : Soil chemical Laboratory of the Department of Agronomy, Ahmadu Bello University, Zaria.

Table : 4 Percentage N, P and K contents of cow dung manure used at Katsina and Samaru in 2013 and 2014 wet seasons.

Nutrients (%)	Katsina		Samaru	
	2013	2014	2013	2014
Total N	1.70	1.85	1.88	2.10
Available P	1.56	1.43	1.63	2.40
Available K	0.65	0.70	0.61	0.78

Source : Soil chemical Laboratory of the Department of Agronomy, Ahmadu Bello University, Zaria.

4. 4*Striga*Related Parameters

4. 4 .1 Number of Days to first *Striga*Shoot Emergence

The number of days to *Striga* shoot emergence was not significantly influenced by crop variety and organic manure at all the sampling periods and mean data in Katsina(Table 5). In 2014, Application of 40 and 80kgN ha^{-1} resulted in similar but shorter periods of*Striga*shoot emergence than the untreated control.There is no significant interaction between all the treatments across the locations and years under study. In Samaru, crop variety, organic manure and nitrogen significantly influenced the number of days by *Striga* shoot emergence. SAMSORG-40 had longer period to *Striga* shoot emergence than SAMSORG-41 in 2013, 2014 and the mean. In 2013,*Striga* shoot emergence in *Cassia* green manure at 15t ha^{-1} and cowdung at 10t ha^{-1} emerged earliercompared to untreated control and lower rate (7.5 t ha^{-1}) of green manure. In 2014, the untreated control and green manure at 15t ha^{-1} gave shorter days to *Striga* shoot emergence than the other treatments. In the mean, green manure at 15t ha^{-1} reduced the number of days to *Striga* shoot emergence compared to all other treatments. In 2013, the untreated control had the lower number of days to *Striga* shoot emergence compared to 40 and 80kgN ha^{-1}.However, in 2014, application of 80kgN ha^{-1} resulted in shorter period to *Striga* emergence than the lower rates.

4. 4. 2 *Striga* Shoot Count at Harvest

The effects of variety, *Cassia* green manure and nitrogen on *Striga* shoots are presented in Tables 6. The number of *Striga* shoots was not affected by crop variety throughout the study period and locations, except in 2013 at Samaru. In Katsina, green manure at 15 t ha^{-1} and

Table : 5 Effects of variety, organic manure and nitrogen rates on the number of days to *Striga* emergence in 2013, 2014 and mean during the wet seasons at Katsina and Samaru.

Treatments	Number of days to *Striga* emergence					
	Katsina			Samaru		
	2013	2014	mean	2013	2014	Mean
Variety (V).						
SAMSORG- 40	102	93	97	107.0a	105.0a	106.0a
SAMSORG- 41	102	93	97	96.0b	95.2b	95.6b
SE (±)	0.2	0.1	0.1	0.17	0.15	0.16
Manure (M). ($t\ ha^{-1}$)						
0	102	93	97	106.0a	93.7b	99.9ab
Cassia[1] at 7.5	102	92	97	103.0ab	109a	106.0a
Cassia at 15	101	93	97	91.7b	92.2b	91.9b
Cow dung at 10	102	93	96	92.2b	102.2a	97.6ab
SE (±)	0.2	0.2	0.2	0.19	0.17	0.20
Nitrogen (N). ($kg\ ha^{-1}$)						
0	105	94	99	90.0b	91.3a	102.0a
40	101	92	96	101.0a	91.3a	101.0ab
80	103	92	97	86.7a	66.3b	76.5b
SE (±)	0.2	0.2	0.2	0.15	0.14	0.19
Interactions.						
V x M	NS	NS	NS	NS[2]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using test DMRT.

1.*Cassia* = Green manure**.**

2. = Not significant at 5% level of probability.

Table: 6 Effects of variety, organic manure and nitrogen rates on *Striga* shoot count at Katsina and Samaru in 2013, 2014 wet seasons and mean.

Treatments	*Striga* shoot count at harvest (No.)					
	Katsina			Samaru		
	2013	2014	mean	2013	2014	Mean
Variety (V).						
SAMSORG- 40	0.92	1.11	1.02	1.44a	0.64b	1.04
SAMSORG- 41	0.56	1.03	0.80	0.42b	0.86a	0.64
SE (±)	0.160	0.280	0.160	0.353	0.162	0.195
Manure (M). ($t\ ha^{-1}$)						
0	0.94ab	1.50	1.22a	0.67	0.67b	0.67
Cassia[1] at 7.5	1.22a	1.17	1.20ab	1.33	0.61b	0.97
Cassia at 15	0.44b	1.11	0.78b	1.17	1.33a	1.27
Cow dung at 10	0.33c	0.50	0.42c	0.55	0.34ab	0.47
SE (±)	0.221	0.402	0.234	0.532	0.221	0.272
Nitrogen (N). ($kg\ ha^{-1}$)						
0	1.25a	1.71a	1.48a	1.46	1.75	1.00a
40	0.67ab	0.71b	0.69b	0.33	0.39	0.13b
80	0.29b	0.80b	0.55b	1.05	0.21	0.63ab
SE (±)	0.220	0.131	0.201	0.464	0.440	0.243
Interactions.						
V x M	NS	NS	NS	NS[2]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1., *Cassia* = Green manure

2. NS. = Not significant at 5% level of probability..

cow dung at 10 t ha^{-1} supported lower number of *Striga* shoots than green manure at 7.5 t ha^{-1}

The untreated control was at par with each of the other treatments (Table 6). In the combined data, cowdung at 10t ha^{-1} gave lower *Striga* shoots than green manure at 0 and 7.5t ha^{-1}, which in turn were at par with each other and also with15t ha^{-1}. In 2013 in Katsina, the use of 80KgNha^{-1} reduced the number of *Striga* shoots over the untreated control only. In 2014 and the combined data, 40 and 80kgNha^{-1} reduced *Striga* shoots over the untreated control.

In Samaru, SAMSORG-41 supported less *Striga* shoots than SAMSORG-40 in 2013. In 2014, green manure at non manure and 7.5t ha^{-1} resulted in less *Striga* shoots than the 15t ha^{-1} level. Cowdung treatment was at par to all the other treatments. In the combined data, application of 80kgNha^{-1}reduced *Striga* shoot count compared to the untreated control. However, N at 40KgNha^{-1} was similar to the control and the higher level. The interactions of variety, green manure and N on *Striga* shoot count were not significant at both locations and seasons and the mean data.

4. 4. 3 Number of *Striga* Infested Sorghum Stands per plot

Effects of variety, organic manure and nitrogen on the number of *Striga* infected sorghum stands par plot at harvest in 2013, 2014 and combined mean in Katsina and Samaru are presented in Table 7. At both locations and seasons, crop variety and organic manure did not influence the number of *Striga* infested sorghum stands. However, N influenced this parameter in both years and the mean data at Katsina and in 2014 only in Samaru. At Katsina, application of 80 Kg N ha^{-1} in 2013 and 40 and 80 kg N ha^{-1} in 2014 and the mean data suppressed the number of infested Sorghum stand compared to the untreated control.

Table : 7Effects of variety, organic manure and nitrogen rates on the number of sorghum stand infested with *Striga* at harvest in Katsina and Samaru in 2013, 2014 wet seasons and mean.

Treatments	Number of plants infested with *Striga* (No.)					
	Katsina			Samaru		
	2013	2014	mean	2013	2014	Mean
Variety (V).						
SAMSORG- 40	0.50	0.84	0.67	1.08	0.39	0.74
SAMSORG- 41	0.50	0.75	0.63	0.53	0.36	0.44
SE(±)	0.001	0.016	0.001	0.392	0.112	0.204
Manure (M). ($t\ ha^{-1}$)						
0	0.83	0.94	0.89	0.94	0.44	0.69
Cassia[1] at 7.5	0.52	0.72	0.61	1.33	0.33	0.83
Cassia at 15	0.39	0.67	0.53	0.67	0.50	0.58
Cow dung at 10	0.28	0.85	0.56	0.28	0.22	0.25
SE (±)	0.223	0.226	0.140	0.560	0.162	0.292
Nitrogen (N). ($kg\ ha^{-1}$)						
0	0.88a	1.89a	1.38a	1.04	1.00a	1.02
40	0.42ab	0.33b	0.38b	0.38	0.13ab	0.25
80	0.21c	0.17c	0.19c	1.00	0.00b	0.53
SE (±)	0.154	0.151	0.122	0.423	0.240	0.245
Interactions.						
V x M	NS[2]	NS	NS	NS[2]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. .*Cassia* = Green manure

2. = Not significant at 5% level of probability

The values by 40 and 80KgNha^{-1} were similar in 2014 and the means. There was no interaction recorded on this parameters across the locations and years.

4. 4. 4 Crop- *Striga* Reaction Score

The influence of manure and nitrogen rates on sorghum reaction score in 2013 and 2014at Katsina and Samaru are presented in Tables 8 and 9 respectively. At Katsina (Table 8) crop reaction to *Striga* was not significantly influenced by crop variety at 3 WAS across the locations, but at 6 WAS significanteffect was recorded by variety and manure at 6 and 9 WAS in 2013SAMSORG-40 was more affected by *Striga* than SAMSORG-41at 6 WAS. Sorghum reaction to *Striga* attackat 6 WAS was more severe in the control treatment without application of manure. All other treatments were similar. Crop reaction was greater with cowdung at 10t ha^{-1} than all the other treatments, including the untreated control. Nitrogen did not influence crop reaction to *Striga.*In 2014, variety shows influence on crop reaction score only at 6 WAS where crop reaction was higher with SAMSORG-40. On the other hand no significant influence was recorded on crop reaction by both manure and nitrogen treatments.

At Samaru (Table 9) variety at 6 WAS did not influence crop reaction to *Striga* in both seasons, however, crop reaction with green manure. at 7.5 t ha^{-1} was reduced compared to untreated control at 6 and 9 WAS. Green manure at 15 t ha^{-1} and cow dung at 10 t ha^{-1} resulted in crop reaction values that were similar to both the control and the lowest by 7.5 t ha^{-1} green manure at this period. In 2014, sorghum reaction score was only recorded by organic manure treatments only at 3 WAS where application of 0- 7.5 t ha^{-1} resulted in similar reaction to *Striga* compared to the lowest recorded by cow dung.

Table :8 Effects of variety organic manure and nitrogen rates on crop reaction score at 3, 6 and 9 WAS 2013, 2014 wet seasons.

Treatments	Crop reaction score at (WAS)					
	20132014					
	3	6	9	3	6	9
Variety (V).						
SAMSORG- 40	4.4	4.3a	4.5	1.5	4.4a	5.0
SAMSORG- 41	4.5	3.9b	5.2	1.5	3.8b	5.0
SE (±)	0.11	0.02	0.39	0.02	0.18	0.29
Manure (M). ($t\ ha^{-1}$)						
0	4.5	4.73a	3.6b	1.5	4.1	5.0
Cassia[1] at 7.5	4.2	4.02b	4.7b	1.6	4.3	5.0
Cassia at 15	4.6	3.71b	1.6c	1.4	4.0	5.0
Cow dung at 10	4.5	3.71b	5.0a	1.5	3.9	5.0
SE (±)	0.27	0.18	0.55	0.02	0.17	1.40
Nitrogen (N). ($kg\ ha^{-1}$)						
0	4.33	4.37	3.9	1.6	4.0	5.0
40	4.37	4.17	5.5	1.6	4.1	5.0
80	4.47	3.83	5.1	1.3	4.0	5.0
SE (±)	0.18	0.20	0.88	0.02	0.23	1.74
Interactions.						
V x M	NS[2]	NS	NS	NS[2]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. .*Cassia* = Green manure

2.NS = Not significant at 5% level of probability.

Scale 1-5, 1 = Normal plants, 5 = Dead plants

Table : 9 Effects of variety, organic manure and nitrogen rates on crop reaction score at 3, 6 and 9 WAS 2013, 2014 wet seasons at Samaru.

Treatments	Crop reaction score. at (WAS)					
	2013			2014		
	3	6	9	3	6	9
Variety (V).						
SAMSORG- 40	1.7	6.9	4.5	1.61	3.91	3.91
SAMSORG- 41	1.9	6.8	4.5	1.58	3.85	3.85
SE (±)	0.10	0.14	0.10	0.08	0.12	0.12
Manure (M). ($t\ ha^{-1}$)						
0	2.5a	6.9	4.7a	1.87a	3.93	3.93
Cassia[1] at 7.5	2.1b	7.0	4.3b	1.81a	3.90	3.90
Cassia at 15	1.4c	6.6	4.5ab	1.42b	3.90	3.90
Cow dung at 10	1.2c	6.8	4.5ab	1.28c	3.79	3.79
SE (±)	0.14	0.20	0.14	0.11	0.17	0.17
Nitrogen (N). **(**$Kg\ ha^{-1}$)						
0	2.0a	7.0	4.4	1.58	3.82	3.82
40	1.8ab	6.4	4.5	1.54	3.81	3.81
80	1.7b	7.0	4.6	1.66	4.02	4.02
SE (±)	0.10	0.34	0.15	0.09	0.09	0.09
Interactions.						
V x M	NS[2]	NS	NS	NS[2]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1..*Cassia* = Green manure

2.NS = Not significant at 5% level of probability.

Scale 1-5, 1 = Normal plants, 5 = Dead plants

The interaction of variety, manure and nitrogen on crop reaction score were not significant throughout the study period and locations.

4. 5 Crop Growth Parameters

4. 5. 1. Stand count

Effects of variety, organic manure and nitrogen on sorghum stand count at Katsina and Samaru are presented in Tables 10 and 11 respectively. In 2013 (Table 10)Sorghum stand count was significantly influenced by crop variety at harvest such that SAMSORG-40 was significantly more populated than the other at Katsina. At Katsina, SAMSORG-40 gave higher stand count than SAMSORG-41 at harvest in 2013.At 3WAS and harvest cowdung manure at 10and 15 t ha^{-1}gave statistically similar sorghum stand count which was at par with the values from the control treatment. Application of 40 and 80 kg N ha^{-1} gave the highest stand count at 3 WAS and at harvest, respectively. SAMSORG-41 produced the highest sorghum stands at harvest in 2014 than the other variety. The higher crop stand count obtained in cow dung at 3 WAS in 2014 was at par than stand count at 15 t ha^{-1} at harvest. Application of 40 and 80kgN ha^{-1} gave similar stand count, and each was higher than the control at 3 WAS and harvest. In Samaru (Table 11) at 3 WAS and at harvest in 2013 with varieties stand count were similar across the sampling the periods, while with manure rates significant effect was only recorded at 3 WAS where cow dungmanure resulted in higher stand count than 7.5 t ha^{-1}. The other treatments were

statistically similar to the highest and lowest stand count in the trial. Comparable sorghum stand count were recorded both at 3 WAS and harvest in 40 and 80 kg N ha^{-1} with the lowest obtained in 0 kg N ha^{-1}.

Table: 10 Effects of variety, organic manure and nitrogen on stand count of sorghum at 3 WAS and harvest at Katsina in 2013 and 2014 wet seasons.

Treatments (Net plot).	Stand count			
	2013		2014	
	3WAS[1]	Harvest	3WAS	Harvest
Variety (V).				
SAMSORG – 40	77.8	70.3a	78.2	68.8b
SAMSORG – 41	76.1	68.0b	77.5	72.4a
SE (±)	0.59	0.63	0.61	1.16
Manure (M). **(**t ha^{-1})				
0	75.4b	67.9b	78.0ab	65.9c
Cassia[2]at 7.5	76.7ab	68.3b	76.6b	74.1a
Cassia at 15	77.1ab	69.1ab	77.4ab	69.0b
Cowdung at 10	78.6a	71.3a	79.5a	73.3a
SE(±)	0.83	0.90	0.86	1.65
Nitrogen (N). **(**kg ha^{-1})				
0	73.1b	65.0b	73.6b	66.1b
40	79.4a	70.6a	79.8a	71.7a
80	78.3a	71.8a	80.2a	74.1a
SE (±)	0.66	0.83	0.10	1.11
Interactions.				
V x M	NS[3]	NS	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using the DMRT.

1.WAS = Weeks after sowing

2.Cassia = Green manure

3.NS = Not significant at 5% level of probability.

Table : 11 Effects of variety, organic manure and nitrogen on the stand count of Sorghum at 3WAS and harvest at Samaru in 2013 and 2014 wet seasons.

TreatmentsStand count (Net plot).	2013		2014	
	3 WAS[1]	Harvest	3WAS	Harvest
Variety (V).				
SAMSORG – 40	78.2	70.4	81.5	74.0
SAMSORG – 41	77.5	70.3	80.7	71.6
SE (±)	0.61	0.75	0.65	1.01
Manure (M). **(**t ha^{-1})				
0	78.0ab	71.1	79.7b	71.4
Cassia[2]at 7.5	76.6b	69.3	80.8ab	74.7
Cassia at 15	77.4ab	70.6	83.1a	71.7
Cowdung at 10	79.5a	70.3	80.7ab	73.5
SE(±)	0.86	1.06	0.97	1.11
Nitrogen (N) **(**kg ha^{-1})				
0	73.6b	66.3b	76.2b	68.6b
40	79.8a	72.2a	83.5a	74.7a
80	80.2a	72.5a	83.6a	75.1a
SE (±)	0.10	0.82	0.92	1.43
Interactions				
V x M	NS[3]	NS	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letterwithin a column of each treatment group are not significantly different at 5% level of probability using the DMRT.

1..WAS = Weeks after sowing

2..Cassia = Green manure

3..NS = Not significant at 5% of probability.

In 2014 SAMSORG-40 and 41 resulted in similar sorghum stand count in all the sampling periods. Sorghum stand count was significantly influenced with manure rates only at 3 WAS. *Cassia* green manure at 15t ha^{-1} was significantly more populated than the other rates of organic manure. Fewer sorghum stands were recorded from the untreated control compared to significantly more populated sorghum stands obtained in 40 and 80 kg N ha^{-1}.

The interactions of crop variety, manure and nitrogen rates on stand count were not significant at 3WAS and harvest in both locations and years.

4.5.2 Plant height

At Katsina, plant height of Sorghum was not influenced by variety in all the sampling periods in 2013 (Table 12).Plant height increased with *Cassia* green manure from 0-15 t ha^{-1},at all the sampling periods in 2013 and 2014. Incorporation of 15 t ha^{-1} of *Cassia* green manure was comparable to 10 t ha^{-1} of cow dung at 3,9 and 12 WAS in this year. Nitrogen at 40 Kg N ha^{-1} resulted in taller plants than the untreated control, and 80KgNha^{-1} rate was similar to 0 and 40KgNha^{-1} rates at 9 WAS in 2013. SAMSORG-40 resulted in taller plants than SAMSORG-41 at 3 WAS. In 2014, at Katsina, SAMSORG-40 gave taller plantsthan SAMSORG-41 at 3 WAS only (Table 13). Application 15 t ha^{-1} of *Cassia* green manure gave plant height comparable to 10 t ha^{-1} of cow dung at of cross all the sampling periods in 2014 except at 6 WAS. Similarly, *Cassia* green manure at 7.5 t ha^{-1} gave similar plant height to 10 t ha^{-1} of cow dung at 9 and 12 WAS. In 2014, plant height increased with N from 0- 80 kg N ha^{-1} at 6 WAS and 0-40 kg N ha^{-1} at 9 WAS. At 12 WAS, 80 kg N ha^{-1} resulted in taller plants than the untreated control. Plant height by 40 kg N ha^{-1} was similar to those by the lowest with the control and the highest by 80 kg N ha^{-1}.

Table : 12 Effects of variety, organic manure and nitrogen on sorghum plant height at 3, 6, 9 and 12 WAS in 2013 wet season at Katsina.

Treatments	Plant height (cm)			
	At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	33.2	61.4	91.2	118.2
SAMSORG- 41	34.1	66.4	91.3	126.1
SE (±)	1.34	1.82	3.40	3.01
Manure (M). (t ha^{-1})				
0	20.1c	30.8d	61.2c	86.4c
Cassia[2] at 7.5	34.4b	65.7c	93.4b	124.7b
Cassia at 15	36.2a	76.1b	102.4ab	141.3a
Cowdung at 10	45.2a	83.9a	108.2a	136.2ab
SE (±)	1.90	2.57	4.80	4.25
Nitrogen (N). (kg ha^{-1})				
0	32.4	61.4	87.3b	115.2
40	33.6	64.1	94.7a	124.7
80	36.4	66.8	91.9ab	126.5
SE (±)	1.15	1.86	1.43	3.90
Interactions				
V x M	NS[3]	NS	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. *Cassia* = green manure

3. NS = Not significant at 5% level of probability

Table :13 Effects of variety, organic manure and nitrogen on sorghum plant height at 3, 6, 9 and 12 WAS in 2014 wet season at Katsina.

Treatments	Plant height (cm)			
	At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	31.1a	71.6	97.8	113
SAMSORG- 41	27.5b	68.6	92.9	107
SE (±)	1.24	2.01	2.15	2.31
Manure (M). ($t\ ha^{-1}$)				
0	22.4c	48.1c	72.6b	84.5b
Cassia[2] at 7.5	28.3b	71.1b	100a	116a
Cassia at 15	31.9ab	82.7a	106a	123a
Cowdung at 10	34.6a	78.4ab	102a	118a
SE (±)	1.76	2.85	3.04	3.26
Nitrogen (N). ($kg\ ha^{-1}$)				
0	26.8	65.4c	88.3b	101.9b
40	30.4	70.1b	96.2a	112.3ab
80	30.8	74.7a	101.5a	117.2a
SE (±)	1.12	0.95	1.86	2.67
Interactions.				
V x M	NS[3]	NS	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. Cassia = Green manure

3. NS = Not significant at 5% level of probability

At Samaru, Sorghum plant height was not influenced by crop variety at 3-12 WAS in 2013. In 2013, plant height increased with *cassia* green manure rate from 0-15 t ha^{-1} in all the sampling periods. The tallest plants were produced in *cassia* green 15 t ha^{-1} at 3, 6 and 9 WAS except at 12 WAS where the tallest plants was in cow dung . In this year, at 3 WAS, 80 Kg N ha^{-1} resulted in taller plants than 0 and 40 kg N ha^{-1}. At 6 and 12 WAS, 40 and 80 Kg N ha^{-1} resulted in similar plant height and each was greater than the untreated control but at 9 WAS 80 kg N ha^{-1} produced plants taller than by the control. In 2014, significant effect on plant height was only recorded at 12 WAS with SAMSORG-40 resulted in taller plants than the other variety. Plant height increased with green manure rates from 0-7.5 t ha^{-1} at 3 – 12 WAS. At 3 - 12 WAS, green manure at 15 t ha^{-1} and cow dung at 10 t ha^{-1} resulted in similar and taller plants than the untreated control.

The tallest plants were consistently by cow dung at 10 t ha^{-1}, while the control consistently gave the shortest plants in the trial. At 3 and 12 WAS, plant height increased with N-rates from 0-80 Kg N $ha.^{-1}$ However, at 6 and 9 WAS, 0 and 40 Kg N ha^{-1} resulted in similar, shorter plants than 80 Kg N ha^{-1} treatment. The interactions of variety, manure and nitrogen on plant height were not significant throughout the Sampling period in both locations.

4. 5. 3 Number of leaves per plant

Effects of variety, organic manure and nitrogen on number of leaves per plant are presented in Tables 16-17. At Katsina there was no significant influence by variety on the number of leaves per plant across the sampling period in 2013 and 2014 (Tables 16 and 17). The number of leaves per plant was significantly influenced by manure level at all the sampling periods except at 12 WAS at Katsina

Table :14 Effects of variety, organic manure and nitrogen on Sorghum plant height at 3, 6, 9 and 12 WAS in 2013 wet season at Samaru.

Treatments	Plant height (cm)			
At (WAS)				
	3	6	9	12
Variety (V).				
SAMSORG- 40	42.3	84.4	101.0	139.0
SAMSORG- 41	39.2	86.2	102.0	142.0
SE (±)	1.34	2.34	2.74	3.34
Manure (M). ($t\ ha^{-1}$)				
0	28.3c	59.3c	75.4d	111.0c
Cassia[2] at 7.5	40.8b	82.6b	99.6c	140.0b
Cassia at 15	49.9a	103.0a	122.0a	153.0ab
Cow dung at 10	43.9b	95.8a	110.0b	159.0a
SE(±)	1.89	3.31	3.87	4.72
Nitrogen (N). ($kg\ ha^{-1}$)				
0	35.5b	75.6b	90.9b	127.0b
40	40.0b	86.2a	103ab	144.0a
80	46.7a	94.1a	111.0a	150.0a
SE (±)	1.68	2.27	3.55	3.86
Interactions.				
V x M	NS[3]	NS	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. *Cassia* = Green manure

3. NS = Not significant at 5% level of probability

Table :15 Effects of variety, organic manure and nitrogen on Sorghum plant height at 3, 6, 9 and 12 WAS in 2014 wet season at Samaru.

Treatments	Plant height (cm)			
	At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	49.6	112.0	145.0	175.1a
SAMSORG- 41	47.3	107.0	142.0	166.2b
SE(±)	1.32	2.64	2.92	2.51
Manure (M). ($t\ ha^{-1}$)				
0	36.9c	82.9b	121c	148.0b
Cassia[2] at 7.5	49.9b	114a	143b	174.0a
Cassia at 15	51.2ab	123a	153ab	175.1a
Cow dung at 10	55.9a	119a	158a	184.0a
SE (±)	1.86	3.73	4.12	3.56
Nitrogen (N). ($kg\ ha^{-1}$)				
0	43.9c	103.0b	130.1b	156.2c
40	49.0b	107.0b	142.5b	171.1b
80	52.5a	118.0a	158.0a	184.0a
SE±	0.88	1.84	3.02	1.50
Interactions.				
V x M	NS[3]	NS	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. *Cassia* = Green manure

3. NS = Not significant at 5% level of probability

At 3 WAS, cow dung gave higher number of leaves per plant than the untreated control, while 7.5 and 15 t ha^{-1} of *Cassia* green manure were at par with the cow dung treatment.

Application of both *Cassia* green manure and cow dung gave statistically similar but higher number of leaves per plant than the untreated control, irrespective of green manure rate at 6 and 9 WAS (Table 16). Application of nitrogen at all the rates under study did not influence number of leaves at 3 and 6 WAS. However, at 9 and 12 WAS, application of 80 kg N ha^{-1} produced more leaves statistically similar to 40 kg N ha^{-1} than the control. In 2014 at katsina location, no significant influence was recorded by the varieties on this parameters. Application of *Cassia* greenmanure at all the rates and cow dung at 10 t ha^{-1} resulted in similar leaf numbers, and each was higher than by the untreated control at 3 and 9 WAS (Table 17). At 6 WAS, number of leaves increased with green manure level from 0 – 15 t ha^{-1} and the highest was at par with 10 t ha^{-1}. In 2014 at katsina, application of 40 and 80 Kg N ha^{-1} gave similar numbers of leaves and each was higher than by control at 6 WAS. At 9 WAS, number of leaves, increased with N rate from 0 – 80 kg N ha^{-1}. At 12 WAS, 80 kg N ha^{-1} gave higher leaf number than the control, while 40 kg N ha^{-1} was similar to both 0 and 80 Kg N ha^{-1}.

At Samaru in 2013, SAMSORG-40 resulted in more number of leavesper plant than SAMSORG-41 at 3-12 WAS. In this year, *Cassia* green manure and cow dung at 10 t ha^{-1} recorded statistically similar number of leaves and each was more than by the untreated control at 6 WAS (Table 18). At 9 WAS, the number of leaves increased with green manure rate from 0 – 15 t ha^{-1} and the highest was at par with that by 10 t ha^{-1} cow dung. At 3 – 9 WAS, the number of leaves increased with N rate from 0 – 80 kg N ha^{-1} .

Table : 16 Effects of variety, organic manure and nitrogen on the number of sorghum leaves per plant at 3, 6, 9 and 12 WAS in 2013 wet season at Katsina.

Treatments	Number of leaves/ plant At (WAS)			
	3	6	9	9
Variety (V).				
SAMSORG- 40	5.4	5.1	6.1	
SAMSORG- 41	4.0	5.4	6.3	11.4
SE (±)	0.99	0.15	0.19	0.13
Manure (M).				
(t ha^{-1})				
0	2.8b	3.34b	4.91b	11.5
Cassia[2] at 7.5	4.3ab	5.7a	6.3a	11.2
Cassia at 15	4.3ab	5.8a	6.8a	11.7
Cowdung at 10	7.4a	6.2a	6.9a	11.5
SE (±)	1.39	0.21	0.27	0.18
Nitrogen (N).				
(kg ha^{-1})				
0	4.1	5.1	5.7b	11.0
40	4.0	5.2	6.2ab	11.4ab
80	6.1	5.5	6.7a	12.0a
SE (±)	1.12	0.20	0.22	0.20
Interactions.				
V x M	NS[3]	NS	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. *Cassia* = Green manure

3. NS = Not significant at 5% level of probability

Table : 17 Effects of variety, organic manure and nitrogen on the number of sorghum leaves per plant at 3, 6, 9 and 12 WAS in 2014 wet season at Katsina.

Treatments	Number of leaves / plant At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	4.4	6.4	8.0	11.6
SAMSORG- 41	4.3	6.5	8.3	11.4
SE (±)	0.11	0.13	0.12	0.13
Manure (M). ($t\ ha^{-1}$)				
0	3.8b	5.3d	7.1b	11.5
Cassia[2] at 7.5	4.3a	6.3c	8.3a	11.2
Cassia at 15	4.7a	7.5a	8.6a	11.7
Cowdung at 10	4.6a	6.9a	8.4a	11.5
SE (±)	0.15	0.19	0.17	0.18
Nitrogen (N). ($kg\ ha^{-1}$)				
0	3.9	5.6b	7.3c	11.0
40	4.4	6.6a	8.3b	11.4ab
80	4.8	7.2a	8.9a	12.0a
SE (±)	0.27	0.19	0.09	0.20
Interactions.				
V x M	NS[3]	NS	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. *Cassia* = Green manure

3. NS = Not significant at 5% level of probability

Table : 18 Effects of variety, organic manure and nitrogen on the number of sorghum leaves per plant at 3, 6, 9 and 12 WAS in 2013 wet season at Samaru.

Treatments	Number of leaves / plant At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	3.7a	7.0a	8.6a	12.2a
SAMSORG- 41	3.5b	6.4b	8.0b	11.7b
SE (±)	0.06	0.18	0.14	0.09
Manure (M).				
(t ha^{-1})				
0	3.6	5.2b	7.4c	11.9
Cassia2 at 7.5	3.5	6.82a	8.1b	12.0
Cassia at 15	3.6	7.2a	8.9a	12.1
Cowdung at 10	3.5	7.5a	8.8a	11.8
SE (±)	0.09	0.25	0.20	0.13
Nitrogen (N.)				
(kg ha^{-1})				
0	3.3c	6.1c	7.5c	10.9b
40	3.7b	6.7b	8.4b	12.2a
80	3.9a	7.4a	9.1a	12.8a
SE (±)	0.05	0.10	0.18	0.07
Interaction.				
V x M	NS[3]	NS	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using (DMRT).

1. WAS = Weeks after sowing

2. *Cassia* = Green manure

3. NS = Not significant at 5% level of probability

At 12 WAS, application of 40 and 80 Kg N ha^{-1} resulted in similar and higher leaves numbers than the untreated control.

InSamaru, at 3 WAS both varieties produced similar number of leaves. Similarly, application of *Cassia* green manure at 7.5 and 15t ha^{-1} and cowdung at 10t ha^{-1} resulted in similar leaf numbers, and each level was higher than untreated control at 3 and 12 WAS (Table 19). At 6 WAS, cowdung gave higher leaf number than the control and green manure at 7.5t ha^{-1}. At 9 WAS, green manure at 15t ha^{-1} and cowdung at 10t ha^{-1} resulted in similar number of leaves and each was higher than by the untreated control which was in turn similar to *cassia* manure at 7.5 t ha^{-1}.

There was no significant interactions between the various the treatment groups across the sampling periods, locations and years of study.

4. 5.4 Leaf area index (LAI)

Significant differences among varieties in LAI was observed in Katsina in 2013 and at 6 WAS, whereSAMSORG-40 produced significantly higher LAI than SAMSORG-41 (Table20). LAI increased with green manure rate from 0-15t ha^{-1} at 3WAS in 2013 (Table 20), and 6-12 WAS in 2014 (Table 21). *Cassia* green manure at 15 t ha^{-1} had greater LAI at 6 WAS than 0-7.5 t ha^{-1} and the untreated control at 12 WAS in 2013 and at 6 WAS in 2014. In either case, cow dung at 10 t ha^{-1} consistently resulted in the highest LAI, which was only comparable to green manure at 15 t ha^{-1} at 9 and 12 WAS in 2013. Nitrogen at 40 and 80 Kg N ha^{-1} at 3 WAS in 2013 and 6 WAS in 2014 resulted in similar and higher LAI than untreated control. At 6 WAS in 2013 and 9 WAS in

Table : 19 Effects of variety, organic manure and nitrogen on the number of sorghum leaves per plant at 3, 6, 9 and 12 WAS in 2014 wet season at Samaru.

Treatments	Number of leaves/ plant At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	5.2	8.9a	10.9a	12.9a
SAMSORG- 41	5.1	8.5b	10.4b	12.5b
SE (±)	0.07	0.09	0.01	0.08
Manure (M). ($t\ ha^{-1}$)				
0	4.7b	8.19c	10.3b	12.9b
Cassia[2] at 7.5	5.4a	8.54bc	10.6ab	12.7a
Cassia at 15	5.3a	8.92ab	10.9a	12.9a
Cow dung at 10	5.5a	9.06a	10.9a	12.9a
SE (±)	0.10	0.13	0.14	0.11
Nitrogen (N). ($kg\ ha^{-1}$)				
0	5.1	8.2b	10.2b	12.2b
40	5.3	8.7a	10.9ab	12.8ab
80	5.3	9.1a	11.0a	13.8a
SE (±)	0.08	0.10	0.19	0.17
Interactions.				
V x M	NS[3]	NS	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. *Cassia* = Green manure

3. NS = Not significant at 5% level of probability

Table : 20 Effects of variety, organic manure and nitrogen rates on Leaf area index (LAI) per plant at 3, 6, 9 and 12 WAS in 2013 wet season at Katsina.

Treatments	Leaf area index (LAI) At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	0.4	1.5a	2.4	2.3
SAMSORG- 41	0.4	1.1b	2.4	2.3
SE (±)	0.01	0.07	0.11	0.13
Manure (M). (t ha^{-1})				
0	0.3b	2.2c	2.4b	2.1b
Cassia[2] at 7.5	0.5a	2.3c	2.3b	2.2ab
Cassia at 15	0.5a	2.4b	3.5a	2.3a
Cow dung at 10	0.5a	3.1a	3.5a	2.4a
SE (±)	0.02	0.01	0.16	0.14
Nitrogen (N). (kg ha^{-1})				
0	0.4b	2.6c	2.8c	2.2
40	0.4a	2.8b	3.2b	2.2
80	0.5a	3.1a	3.3a	2.3
SE (±)	0.01	0.01	0.11	0.19
Interactions.				
V x M	NS[3]	*	*	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using (DMRT).*= Significant

1. WAS = Weeks after sowing
2. *Cassia* = Green manure
3. NS = Not significant at 5% level of probability.

..*= Significant

Table : 21 Effects of variety, organic manure and nitrogen rates on Leaf area index (LAI) per plant at 3, 6, 9 and 12 WAS in 2014 wet season at Katsina.

Treatments	Leaf area index (LAI) At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	0.5a	1.5a	2.5a	2.2a
SAMSORG- 41	0.4b	1.4b	2.2b	2.1b
SE (±)	0.01	0.06	0.06	0.05
Manure (M). ($t\ ha^{-1}$)				
0	0.3c	2.6c	2.9d	2.2c
Cassia[2] at 7.5	0.5b	2.6c	3.1c	2.3b
Cassia at 15	0.5b	2.8b	3.3b	2.5a
Cow dung at 10	0.5a	3.3a	3.5a	2.5a
SE (±)	0.01	0.08	0.09	0.16
Nitrogen (N). ($kg\ ha^{-1}$)				
0	0.44b	2.8b	2.8c	2.3
40	0.46ab	3.0a	3.3b	2.3
80	0.49a	3.2a	3.5a	2.3
SE (±)	0.01	0.07	0.05	0.17
Interactions.				
V x M	NS[3]	*	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. *Cassia* = Green manure

3. NS = Not significant at 5% level of probability.

*= Significant

both years LAI increased with N rate from 0 – 80 kg N ha^{-1}. At 3 WAS in 2013, 80 kg N ha^{-1} produced greater LAI than untreated control.

In 2013 at Samaru, SAMSORG-40 produced greater LAI than SAMSORG-41 at 3-12 WAS (Table 22). At 3 and 12 WAS, green manure at 7.5 and 15 t ha^{-1} produced greater LAI than the zero t ha^{-1}. At 6 WAS, application of 15 t ha^{-1} green manure produced greater LAI than the lower rates, while LAI increased with green manure rate from 0 – 15 t ha^{-1} green manure at 9 WAS. Cow dung at 10 t ha^{-1} consistently resulted in higher LAI and was only comparable to green manure at 15 t ha^{-1} at 3, 9 and 12WAS. Application of N at 40 and 80 kg N ha^{-1} gave greater LAI than the untreated control at 3 and 12 WAS (Table 23). However, LAI increased with N rate from 0 – 80 kg N ha^{-1} at 6 and 9 WAS. In 2014, SAMSORG-40 also gave higher LAI than SAMSORG-41 at 3 – 9 WAS. At these periods, LAI increased with green manure at 0 – 15 t ha^{-1}. The LAI by green manure at 15 t ha^{-1} was comparable to the highest from cow dung at 10 t ha^{-1} at 3 and 9 WAS.

There was significant interaction of variety and manure at 6 and 9 WAS in 2013 and 6 WAS in 2014 at Katsina and 9 WAS in 2013 at Samaru (Table 24).

In Katsina 2013 trial, crop variety did not influence LAI throughout the sampling periods except at 6WAS. But with green manure at 15 t ha^{-1} and cow dung at 10 t ha^{-1} , gave statistically comparable LAI with cow dung at 3 WAS, and at par with those in 0-7.5 t ha^{-1} at 6 and 9 WAS. SAMSORG-40 gave higher LAI than SAMSORG-41. On the other hand, LAI increased with green manure rate from 7.5-15 t ha^{-1} under SAMSORG-40 and 0—15 t ha^{-1} under SAMSORG-41. With SAMSORG-40, LAI by the highest available green manure

Table : 22 Effects of variety, organic manure and nitrogen rates on Leaf area index (LAI) per plant at 3, 6, 9 and 12 WAS in 2013 wet season at Samaru.

Treatments	Leaf area index (LAI) At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	0.5a	2.1a	2.5a	2.2a
SAMSORG- 41	0.4b	1.3b	2.3b	1.5b
SE (±)	0.01	0.09	0.06	0.10
Manure (M). ($t\ ha^{-1}$)				
0	0.3c	2.3c	2.3c	7.0b
Cassia[2] at 7.5	0.5b	2.3c	2.5b	8.0a
Cassia at 15	0.5b	3.2b	3.3a	8.2a
Cow dung at 10	0.5a	3.4a	3.6a	8.2a
SE (±)	0.01	0.12	0.02	0.02
Nitrogen (N). ($kg\ ha^{-1}$)				
0	0.4b	2.8c	3.1c	2.5b
40	0.5a	3.2b	3.3b	3.0a
80	0.5a	3.4a	3.5a	3.1a
SE±	0.01	0.01	0.07	0.01
Interactions.				
V x M	NS[3]	NS	*	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing
2. *Cassia* = Green manure
3. NS = Not significant, at 5% level of probability.
4. * = Significant at 5% level of probability.

Table : 23 Effects of variety, organic manure and nitrogen rates on Leaf area index (LAI) per plant at 3, 6, 9 and 12 WAS in 2014 wet season at Samaru.

Treatments	Leaf area index (LAI) At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	0.5	2.2a	3.1a	3.1a
SAMSORG- 41	0.5	2.1b	2.3b	2.3b
SE (±)	0.01	0.08	0.07	0.08
Manure (M). (t ha^{-1})				
0	0.4c	2.3d	2.40c	2.1
***Cassia*[2] at 7.5**	0.5b	2.6c	3.23b	2.2
***Cassia* at 15**	0.5a	3.3b	3.45a	2.2
Cow dung at 10	0.6a	3.71a	4.05a	2.2
SE (±)	0.01	0.11	0.10	0.09
Nitrogen (N). (kg ha^{-1})				
0	0.5	2.8c	2.9c	2.3
40	0.5	3.3b	3.4b	2.3
80	0.5	3.5a	3.8a	2.3
SE (±)	0.06	0.09	0.06	0.06
Interactions.				
V x M	NS[3]	NS	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. *Cassia* = Green manure,

3. NS = Not significant at 5% level of probability. .

. . * = Significant at 5% level of probability

Table : 24 Interaction of variety and organic manure on leaf area index at 6 and 9 WAS in 2013at Katsina, 6 WAS in 2014 at Katsina and 9 WASin 2013 atSamaru.

Manure rate (t ha^{-1})	Variety	
	6 WAS in 2013 at katsina	
	SAMSORG-40	SAMSORG-41
0	1.4e	1.2e
7.5	1.5de	1.5d
15	2.3a	2.1b
10	2.7a	2.1c
SE±	0.14	
	9 WAS in 2013 at Katsina	
0	2.1cd	2.0e
7.5	2.2c	2.1d
15	2.5b	2.4b
10	2.3c	3.12a
SE±	0.22	
	6 WAS in 2014 at Katsina.	
0	1.56d	1.67c
7.5	2.32d	2.45d
15	2.64b	2.42c
10	3.05a	2.35c
SE±	0.123	
	9 WAS in 2013 at Samaru	
0	2.2e	1.1f
7.5	2.3c	2.2d
15	2.4a	2.3b
10	3.1a	2.5b
SE±	0.12	

Means followed by same letterare not significantly different at 5% level of probability using DMRT.

level and cow dung were similar, but the former was higher than the latter with SAMSORG-41. At 9 WAS in katsina, SAMSORG-40 gave higher LAI than SAMSORG-41 when supplied with 0-7.5t ha^{-1} green manure. At 15t ha^{-1} green manure there was no difference in LAI among the two the two varieties. However, with cow dung at 10t ha^{-1} , SAMSORG-41 gave higher LAI than the other manure treatments, including cow dung. With SAMSORG-41, LAI increased with green manure rate from 0-15t ha^{-1}, and LAI by cow dung was higher than each level of green manure.

The interaction of variety and organic manure on the LAI at 6 WAS in Katsina. Holding SAMSORG-40 constant, increase of green manure from 0-7.5 t ha^{-1} gave statistically comparable LAI while at 15 t ha^{-1} was lower than the highest at 10 t ha^{-1} of cow dung. With SAMSORG-41 there was similar LAI by zero t ha^{-1}, 15 t ha^{-1} green manure and 10t ha^{-1} cow dung.

Significant interaction of variety and organic manure on LAI was recorded amongst the two varieties at 9 WAS at Samaru in 2013. In either case, LAI increased with green manure from 0-15 t ha^{-1} in both varieties. Similarly, 10 t ha^{-1} cow dung gave comparable LAI to 15 t ha^{-1} green manure in both varieties which were higher than the LAI of other manure rates.

4. 5.5 Shoot dry weight (g).

Effects of variety, organic manure and nitrogen rate on shoot dry weight (dwt) in the wet seasons of 2013 and 2014 at Katsina and Samaru are presented in Tables 25-28. Tables 25 and,26 at 3WAS in both seasons and 12WAS in 2014, SAMSORG-40 gave greater shoot dry weight than SAMSORG-41. In 2013, shoot dwt increased with *Cassia* green manure

Table: 25 Effects of variety, organic manure and nitrogen rates on shoot dry weight per plant at 3, 6, 9 and 12 WAS in 2013 wet season at Katsina.

Treatments	Shoot dry weight (g / plant) At (WAS)			
	3	6	9	12
Variety (V)				
SAMSORG- 40	8.3a	15.4	26.5	39.3
SAMSORG- 41	7.4b	15.3	23.6	36.6
SE (±)	0.16	0.80	1.35	1.51
Manure (M). (t ha^{-1})				
0	5.3d	11.0c	18.8c	33.3b
Cassia[2] at 7.5	6.8c	15.2b	21.7bc	37.5ab
Cassia at 15	8.5b	14.8b	26.7b	42.8a
Cow dung at 10	10.7a	20.1a	33.0a	38.2ab
SE (±)	0.22	1.13	1.91	2.14
Nitrogen (N). (kg $ha^{-1)}$				
0	6.9c	12.6b	20.0b	30.7c
40	8.0b	16.5a	26.2a	39.7b
80	8.6a	16.9a	29.0a	43.5a
SE (±)	0.16	0.32	0.81	0.61
Interactions.				
V x M	*	NS	NS	NS
V x N	NS[3]	NS	NS	NS
M x N	NS	*	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. *Cassia* = Green manure

3. NS = Not significant at 5% level of probability.

. *= Significant at 5% level of probability.

Table : 26 Effects of variety, organic manure and nitrogen rates on shoot dry weight per plant at 3, 6, 9 and 12 WAS in 2014 wet season at Katsina.

Treatments	Shoot dry weight (g / plant) At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	8.9a	22.4	35.5	50.5a
SAMSORG- 41	8.0b	21.2	32.1	44.2b
SE (±)	0.14	1.03	1.29	1.40
Manure (M). ($t\ ha^{-1}$)				
0	5.7d	12.5c	24.5c	40.8b
Cassia[2] at 7.5	7.6c	18.6b	31.0b	46.9a
Cassia at 15	9.1a	26.1a	35.4b	51.5a
Cow dung at 10	11.6a	30.1a	44.2a	50.4a
SE (±)	0.20	1.03	1.83	1.98
Nitrogen (N). ($kg\ ha^{-1}$)				
0	7.5b	16.8b	26.2b	38.9b
40	8.5a	22.7ab	35.2a	50.8a
80	9.2a	25.9a	39.9a	52.5a
SE (±)	0.19	1.52	1.65	0.81
Interactions.				
V x M	NS[3]	NS	NS	NS
V x N	NS	NS	NS	NS
M x N	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. *Cassia* = Green manure

3. NS = Not significant at 5% level of probability.

from 0-15 t ha^{-1} at 3WAS and 0-7.5 t ha^{-1} at 6 WAS. At 9 and 12 WAS, green manure at 15 t ha^{-1} gave higher shoot dwt than the untreated control and 7.5 t ha^{-1} was at par with the control and 15 t ha^{-1} treatment.At 3-9 WAS, cow dung resulted in greater shoot dwt than each level of green manure (Table 25). At 12 WAS, the highest shoot dwt was by green manure at 15 t ha^{-1}, and this was only comparable to values by cow dung at 10 t ha^{-1} and green manure at 7.5 t ha^{-1}. Furthermore, in 2013, in Katsina shoot dwt increased with N rate from 0 – 80 kg N ha^{-1} at 3 and 12 WAS (Table 25). At 6 and 9 WAS, 40 and 80 kg N ha^{-1} gave similar values of shoot dwt, and each was higher than that by the control.

In 2014, shoot dwt increased with green manure rate from 0-15 t ha^{-1} at 3 and 6 WAS and at 9 and 12 WAS, values by 7.5 and 15 t ha^{-1} were similar, and higher than by the control (Table 26). Cow dung at 10 t ha^{-1} consistently gave the highest shoot dwt, and was only comparable to green manure applied at 15 t ha^{-1} at 3, 6 and 12 WAS and 7.5 t ha^{-1} at 12 WAS. Application of N at 40 and 80 kg N ha^{-1} resulted in similar but higher shoot dwt than the zero N level at 3, 9 and 12 WAS. At 6 WAS, 80 kg N ha^{-1} gave higher shoot dwt than the control, but the value by 7.5 t ha^{-1} of green manure was similar to the 0 and 80 kg N levels.

At 3, 6 and 12 WAS in 2013 and 3-9 WAS in 2014, SAMSORG-40 resulted in higher shoot dwt than SAMSORG-41. (Tables 27 & 28). In 2013, shoot dwt increased with green manure level from 0-15 t ha^{-1} from 3-12 WAS. At each sampling period, cow dung gave the highest shoot dwt which was only comparable to 15 t ha^{-1} green manure at 12 WAS. In 2014, shoot dry weight increased with green manure rate from 0-15 t ha^{-1} at 3 and 6 WAS and 7.5 t ha^{-1} at 9 WAS (Table 28). Shoot dry weight was higher and similar by cow dung treatments at 3- 9 WAS. Shoot dwt increased with N level from 0 – 80 kg N ha^{-1} at 3 WAS

Table: 27 Effects of variety, organic manure and nitrogen rates on shoot dry weight per plant at 3, 6, 9 and 12 WAS in 2013 wet season at Samaru.

Treatments	Shoot dry weight (g / plant) At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	8.9a	22.1a	34.4	50.6a
SAMSORG- 41	8.0b	29.9b	32.5	44.2b
SE (±)	0.15	0.75	0.98	1.08
Manure (M). ($t\ ha^{-1}$)				
0	5.7d	12.5d	24.2d	40.2c
Cassia[2] at 7.5	7.3c	18.1c	31.2c	46.7b
Cassia at 15	9.1b	23.5b	36.7b	51.6a
Cow dung at 10	11.6a	30.1a	42.3a	51.6a
SE (±)	0.21	1.06	1.38	1.52
Nitrogen (N). ($kg\ ha^{-1}$)				
0	7.46c	15.5b	24.7b	38.1b
40	8.53b	21.9b	35.2a	48.0b
80	9.25a	25.7a	40.9a	56.1a
SE (±)	0.15	0.41	1.46	1.01
Interactions.				
V x M	*	NS	NS	NS
V x N	NS[3]	NS	NS	NS
M x N	NS	*	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. *Cassia* = Green manure

3. NS = Not significant at 5% level of probability.

.4. * =Significant at 5%. level of probability

Table : 28Effects of variety, organic manure and nitrogen rates on shoot dry weight per plant at 3, 6, 9 and 12 WAS in 2014 wet season at Samaru.

Treatments	Shoot dry weight (g / plant) At (WAS)			
	3	6	9	12
Variety (V).				
SAMSORG- 40	10.0a	19.4a	30.5a	31.9
SAMSORG- 41	9.0b	17.5b	29.4b	33.6
SE (±)	0.18	0.44	1.10	2.61
Manure (M). ($t\ ha^{-1}$)				
0	5.9d	11.2d	16.8b	26.1
Cassia[2] at 7.5	8.1c	16.2c	24.7b	33.2
Cassia at 15	10.5b	24.4a	35.8a	35.3
Cow dung at 10	13.5a	26.1b	42.1a	36.6
SE (±)	0.25	0.62	2.28	3.69
Nitrogen (N). ($kg\ ha^{-1}$)				
0	8.14c	15.7c	25.8	29.3
40	9.73b	18.1b	31.4	35.3
80	10.7a	21.6a	32.8	33.8
SE (±)	0.11	0.46	3.84	2.70
Interactions.				
V x M	*	NS	NS	NS
V x N	NS[3]	NS	NS	NS
M x N	NS	*	NS	NS
V x M x N	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing

2. *Cassia* = Green manure

3. NS = Not significant, at 5%. level of probability * =Significant at 5%. level of probability

.* =Significant at 5%. level of probability

(Table 27) at this location. At 6 and 12 WAS, 80 kg N ha^{-1} resulted in higher shoot dwt than the lower rates which values were similar. At 9 WAS, 40 and 80 kg N ha^{-1} gave similar values, and each was greater than the value by the untreated control. In 2014 at Samaru, shoot dwt increased with green manure rate from 0-15 t ha^{-1} and N rate from 0-80 kg N ha^{-1} both at 3-6 WAS (Table 28). Shoot dwt value by green manure at 15 t ha^{-1} at 9 WAS was similar to cow dung and each was higher than by the lower rate of green manure at 9WAS. At 3 WAS in 2013 at Katsina, crop variety did not significantly influence shoot dwt with the application of 0-7.5 t ha^{-1} of green manure rate and cow dung rate at 10 t ha^{-1} . With green manure rate at 15 t ha^{-1} , SAMSORG-40 resulted in higher shoot dwt than SAMSORG-41. With use of SAMSORG-40 shoot dwt increased with green manure rate from 0-15 t ha^{-1}, and 0-7.5 t ha^{-1} with SAMSORG-41. In each variety, cow dung at 10 t ha^{-1} resulted in higher shoot dwt than each green manure rate with SAMSORG-41, but with SAMSORG-40, cow dung was at par with green manure treatment.

In Samaru, in 2013, the shoot dwt was significantly influenced by the two varieties across all the sampling periods except at 9 WAS (Table 27). The heaviest shoot was resulted by SAMSORG-40 which was at par than SAMSORG-41. Shoot dwt increased with green manure rate from 0-15 t ha^{-1} at 3, 6, 9 and 12 WAS but the highest was obtained in cow dung. Application of 0-80 kg N ha^{-1} consistently resulted in heavier shoot dwt with the highest in 80 kg N ha^{-1}. In 2014, Table 28 SAMSORG-40 resulted in heavier shoot dwt compared to the other variety. In manure treatments, in each case, cow dung gave the highest shoot dwt at 3, 6 and 9 WAS. Sorghum shoot dwt were significantly influenced by N rates except at 9 WAS. Heavier shoot dwt was recorded by the use of 80 kg N ha^{-1} which significantly out weighed 40 kg N ha^{-1} and control treatment respectively. There was significant interaction of

variety and manure at 3 WAS in 2013 at Katsina and 2013 and 2014 at Samaru (Table 29), and manure and nitrogen at 6 WAS in 2013 at Katsina and 2013 and 2014 in Samaru (Table 30).

In the interaction of manure and nitrogen rates at 6 WAS in Katsina trial in 2013, 80 kg N ha^{-1} resulted in higher shoot dwt than the lower rates when applied in conjunction with the untreated control and 10 t ha^{-1} cow dung (Table 30). With 7.5 t ha^{-1} of green manure, N did not influence this parameter, but with 15 t ha^{-1} green manure, 40 and 80 kg N ha^{-1} gave similar shoot dwt values, and each was higher than by the control. At 0 kg N ha^{-1} , *Cassia* green manure at 7.5 and 15 t ha^{-1} and cow dung at 10 t ha^{-1} gave similar values, each of which was higher than by the untreated control. Shoot dwt increased with green manure rate from 0-15 t ha^{-1} with 40 kg N ha^{-1}, and 7.5 t ha^{-1} when applied along with 80 kg N ha^{-1}. The highest shoot dwt was obtained by 15 t ha^{-1} when applied in conjunction with 40 or 80 kg N ha^{-1}. At 6 WAS in 2013 at Samaru, nitrogen did not influence shoot dwt when applied without manure (Table 30). However, cow dung in conjunction with 80 kg N ha^{-1} gave greater shoot dwt that was statistically similar to cow dung with 40 kg N ha^{-1} but at per with the untreated control. On the other hand, shoot dwt increased with green manure rate from 0-7.5 t ha^{-1} under 0 kg N ha^{-1}, 0-15 t ha^{-1} under green manure 7.5 and 15 t ha^{-1}. With 40 and 80 kg N ha^{-1}, cow dung at 10 t ha^{-1} gave higher shoot dwt than the other combinations. At Samaru in 2014, shoot dwt increased with green manure rate from 0-15 t ha^{-1} when applied in conjunction with 0 and 80 kg N ha^{-1} and 0-7.5 t ha^{-1} when with 40 kg N ha^{-1} (Table 30).

Table : 29Interaction of variety and organic manure on shoot dry weight at 3 WAS in 2013 wet season at Katsina and Samaru and 3 WAS in 2014 wet season at Samaru.

Manure rate (t ha^{-1})	Variety.	
3 WAS in 2013 at katsina		
	SAMSORG-40	SAMSORG-41
0	5.5c	5.1c
7.5	7.0b	6.6b
15	9.9a	7.1b
10	10.8a	10.5a
SE±	0.10	
	3 WAS in 2013 at Samaru.	
0	5.8d	5.6c
7.5	7.5c	7.1b
15	10.1b	7.6b
10	11.6a	11.6a
SE±	0.26	
	3 WAS in 2014 at Samaru	
0	6.1d	5.8c
7.5	8.6b	7.6b
15	12.4a	8.7b
10	13.1a	13.9a
SE±	0.44	

Means followed by same letterare not significantly different at 5% level of probability using DMRT.

Table : 30Interaction of organic manure and nitrogen on shoot dry weight at 6 WAS in 2013 wet season at Katsina and Samaru at 6 WAS in 2014 wet season at Samaru.

Nitrogen rates (kgN ha^{-1})	Manure ($t\ ha^{-1}$).			
	2013 at Katsina			
	0	7.5	15	10
0	10.4d	15.8c	13.3c	10.9c
40	10.3d	15.9c	23.6a	16.3c
80	12.2c	13.9c	24.6a	17.2b
SE (±)		1.96		
	2013 at Samaru			
0	10.3f	16.6e	16.0ef	19.6de
40	12.9f	17.3e	24.5cd	32.5ab
80	14.4ef	20.6d	29.7bc	38.1a
SE (±)		1.83		
	2014 at Samaru			
0	11.0g	13.7f	15.4e	21.7b
40	13.3fg	16.9de	20.0cd	22.1b
80	14.4ef	17.9d	24.7b	29.3a
SE (±)		1.07		

Means followed by same letterare not significantly different at 5% level of probability using DMRT.

In either case, cowdung treatment resulted in higher shoot dwt than green manure rates. On the other hand, 40 and 80kgN ha^{-1}in conjunction with cow dung gave similar and higher shoot dwt than when applied along with green manure at 0 and 15t ha^{-1}. The lowest shoot dwt was recorded across all the treatments by 0 kg N ha^{-1} along with 0 t ha^{-1} .

4. 5. 6 Crop Growth Rate (CGR).

At Katsina, the effects of varieties CGR at 3-6, 6-9, and 9-12 WAS in 2013 was similar (Table 31). In 2013, at Katsina, CGR by cow dung was lower than by green manure rates,

including the untreated control which was comparable to 40 kg N ha^{-1}.at 9-12 WAS while at 6-9 WAS CGR was statistically similar by same treatments. In this location, 80 kg N ha^{-1} gave higher CGR at 6-9 and 9-12 WAS but all were higher than the untreated control. In 2014, at Katsina, no significant effect was observed by variety on CGR throughout the sampling periods. In either case, application of 0-10 t ha^{-1} organic manure at 3-6 WAS all were at per with CGR in the control treatment. At 9-12 WAS CGR reduced in cow dung compared to 0-15 t ha^{-1} . Application 80 kg N ha^{-1} resulted in highest CGR but comparable to CGR in 40 kg N ha^{-1}.In 2013, 2014 at Samaru, CGR was similar by the variety across all the sampling periods (Table 32). Increasing green manure rates from 0-15 t ha^{-1} at 3-6 and 9-12 WAS in 2013 and at 9-12 WAS in 2014 gave a corresponding increase in CGR and all the treatments.

Application of 40-80 kg N ha^{-1} produced the highest and similar CGR at 6-9 WAS except at 3-6 WAS where CGR reduced but at per with the untreated control. On the other hand, similar CGR was recorded in the nitrogen treatments across the sampling periods. There was no significant interaction on CGR between all the treatments throughout the study periods

Table: 31 Effects of variety, organic manure and nitrogen on crop growth rate at 3-6,6-9, and 9-12 WAS at Katsina in 2013, 2014 wet seasons.

Treatments	Crop Growth Rate (g/ m^2/ wk)					
	At WAS					
20132014	3-6	6-9	9-12	3-6	6-9	9-12
Variety (V).						
SAMSORG- 40	2.5	3.7	4.3	4.5	4.4	5.0
SAMSORG- 41	2.6	2.8	4.3	4.4	3.6	4.0
SE (±)	0.22	0.55	0.57	0.34	0.61	0.65
Manure (M). ($t\ ha^{-1}$)						
0	2.0	2.6	4.8a	2.3c	4.0	5.4a
Cassia[2] at 7.5	2.3	2.2	5.3a	3.7b	4.1	5.3a
Cassia at 15	2.90	4.0	5.3a	5.7a	3.7	5.4a
Cow dung at 10	3.0	4.2	1.7b	6.2a	4.7	2.1b
SE (±)	0.33	0.78	0.80	0.48	0.86	0.92
Nitrogen (N). ($kg\ ha^{-1}$)						
0	2.2	2.5b	3.6b	3.1b	3.1b	4.2
40	2.5	3.2ab	4.5a	4.7ab	4.2ab	5.2
80	2.9	4.0a	4.9a	5.6a	4.7a	4.2
SE (±)	0.35	0.29	0.18	0.55	0.34	0.31
Interactions.						
V x M	NS[3]	NS	NS	NS[3]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing,
2. *Cassia* = Green manure.
3. NS = Not significant,at 5% level of probability

Table :32 Effects of variety, organic manure and nitrogen on crop growth rate (CGR) at 3, 6, 9 and 12 WAS at Samaru in 2013, 2014 wet seasons.

Treatments	Crop Growth Rate (g/ m^2/ wk)					
	At WAS					
2013	2014					
	3-6	6-9	9-12	3-6	6-9	9-12
Variety (V).						
SAMSORG- 40	4.4	4.2	5.3	2.5	3.2	2.8
SAMSORG- 41	4.0	4.2	3.9	2.6	3.7	4.3
SE (±)	0.25	0.40	0.48	0.22	0.27	0.68
Manure (M). ($t\ ha^{-1}$)						
0	2.27d	3.91	2.9b	2.1	1.1b	4.4
[2]*Cassia* at 7.5	3.58c	4.37	5.2a	2.3	3.3a	3.3
Cassia at 15	6.15a	4.08	5.2a	2.9	4.2a	3.8
Cow dung at 10	4.81b	4.40	5.0a	2.9	4.4a	2.7
SE (±)	0.35	0.57	0.68	0.31	0.74	0.96
Nitrogen (N). ($kg\ ha^{-1}$)						
0	2.7c	3.1b	4.5	2.2	2.6	4.08
40	4.4b	4.5ab	4.3	2.5	3.8	3.79
80	5.5a	5.1a	5.1	2.9	3.4	2.75
SE (±)	0.11	0.42	0.30	0.35	0.64	0.78
Interactions.						
V x M	NS[3]	NS	NS	NS[3]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing,

2. *Cassia* = Green manure

3. NS = Not significant, at 5% level of probability.

4. 5.7 Relative Growth Rate (RGR).

The effects of variety, manure and nitrogen on RGR in both locations and years are presented in Tables 33 – 34. Crop variety did not significantly affect RGR in both seasons and locations. In Katsina, RGR was influenced by manure and N throughout the period of sampling in both years , except at 9-12 WAS in 2014 (Table 33). At 3-6 WAS in 2013, green manure at 7.5t ha^{-1}gave lower RGR than cowdung and15t ha^{-1}, which in 2014, the parameter increased with green manure rate from 0-15t ha^{-1}, and cowdung at 10t ha^{-1} was similar to the highest level of green manure. At 6-9 WAS, cowdung at 10t ha^{-1} gave higher RGR than 0-7.5t ha^{-1} of green manure and the control in 2013, but in 2014, the use of cowdung at 10t ha^{-1} gave higher values than each of the green manure treatments. At 3-6 WAS in 2013 and 6-9 WAS in 2014, application of 40 and 80kgN ha^{-1}resulted in higher RGR than the untreated control (Table 34). At 6-9 WAS in 2013 and 3-6 WAS in 2014, 80kgN ha^{-1}, gave higher value than the untreated control, and was at par with 40kgN ha^{-1}. At Samaru, RGR was influenced by manure 3-6 WAS and 6-9 WAS in both years and N throughout sampling period in 2013.At 3 WAS in 2013, RGR increased with green manure rate from 0-15 t ha^{-1}, and non of the treatments was comparable to the highest value by cow

dung at 10 t ha^{-1}. At 6-9 WAS RGR by cow dung was higher than by the green manure at 0 and 7.5 t ha^{-1}, followed by green manure at 15 t ha^{-1} which was in turn greater than by the untreated control. In 2014, RGR by 15 and 10 t ha^{-1} green manure and cow dung , respectively at 3-6 WAS as well as green manure at 7.5- 15 t ha^{-1} and cow dung at 10 t ha^{-1} at 6-9 WAS, were higher than by the other treatment (s). In 2013 at Samaru, RGR increased with N rate from 0-80 kg N ha^{-1} at 3-9 WAS and 0-40 kg N ha^{-1} at 6-9 WAS.

Table : 33 Effects of variety, organic manure and nitrogen on Relative growth rate (RGR) at 3-6, 6-9 and 9-12 WAS in 2013, 2014 wet seasons.

Treatments	Relative Growth Rate (mg /m^2/wk)					
	At WAS					
2013				2014		
	3-6	6-9	9-12	3-6	6-9	9-12
Variety (V).						
SAMSORG- 40	1.74	2.34	2.56	2.30	2.49	2.72
SAMSORG- 41	1.83	2.19	2.55	2.27	2.43	2.63
SE (±)	0.080	0.061	0.042	0.042	0.050	0.032
Manure (M). ($t\ ha^{-1}$)						
0	1.81ab	2.13b	2.52ab	1.93c	2.35b	2.64
Cassia[2] at 7.5	2.06a	2.12b	2.59ab	2.25b	2.42b	2.73
Cassia at 15	1.58b	2.26ab	2.67a	2.44a	2.44b	2.74
Cow dung at 10	1.73b	2.48a	2.44b	2.53a	2.65a	2.63
SE (±)	0.060	0.090	0.061	0.060	0.070	0.052
Nitrogen (N). ($kg\ ha^{-1}$)						
0	1.69b	2.09b	2.42b	2.10b	2.30b	2.57
40	1.85a	2.28ab	2.60a	2.33ab	2.50a	2.74
80	1.85a	2.36a	2.65a	2.43a	2.59a	2.57
SE (±)	0.032	0.052	0.021	0.062	0.040	0.011
Interactions.						
V x M	NS[3]	NS	NS	NS[3]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing,
2. *Cassia* = Green manure
3. NS = Not significant, at 5% level of probability.

Table : 34 Effects of variety, organic manure and nitrogen on Relative growth rate (RGR) at 3-6, 6-9 and 9-12 WAS at Samaru in 2013, 2014 wet seasons.

Treatments	Relative Growth Rate (mg/ g / wk)					
	At WAS					
	2013			2014		
	3-6	6-9	9-12	3-6	6-9	9-12
Variety (V).						
SAMSORG- 40	2.29	2.48	2.73	2.05	2.26	2.41
SAMSORG- 41	2.23	2.47	2.63	2.07	2.25	2.53
SE (±)	0.050	0.062	0.030	0.020	0.041	0.030
Manure (M). ($t\ ha^{-1}$)						
0	1.93d	2.34c	2.63	1.89b	1.88b	2.35
Cassia[2] at 7.5	2.22c	2.44bc	2.69	1.97b	2.26a	2.41
Cassia at 15	2.35b	2.52ab	2.73	2.16a	2.40a	2.57
Cow dung at 10	2.53a	2.60a	2.66	2.22a	2.48a	2.54
SE (±)	0.060	0.080	0.052	0.070	0.063	0.054
Nitrogen (N). ($kg\ ha^{-1}$)						
0	2.04c	2.28b	2.57c	1.97	2.15	2.43
40	2.31b	2.53a	2.68b	2.07	2.32	2.53
80	2.43a	2.61a	2.79a	2.13	2.29	2.44
SE (±)	0.030	0.052	0.064	0.040	0.052	0.030
Interactions.						
V x M	NS[3]	NS	NS	NS[3]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing,

2. Cassia = Green manure

3. NS = Not significant, at 5% level of probability.

The interaction of variety, organic manure and nitrogen were not significant throughout the period of investigation in both years and locations.

4. 5.8 Net Assimilation Rate (NAR).

The effects of variety, manure and nitrogen on net assimilation rate of sorghum in both locations and years are presented in Tables 35-36. Effect of crop variety, on net assimilation rate (NAR) was not significant in both locations and years. In Katsina, effect of manure was significant at 3-6 and 9-12WAS in both years (Tables 35). At 3-6WAS in both years, green manure at 15t ha^{-1} and cowdung at 10t ha^{-1} resulted in similar NAR values, and each was higher than by green manure at 0 and 7.5t ha^{-1}. At 9-12WAS, green manure at 15t ha^{-1} resulted in lower NAR than the lower, rates and cowdung at 10t ha^{-1} all of which were similar . At 9-12 WAS in 2014, the untreated control recorded higher NAR than the higher N rate. In Samaru, No significant effect was observed by SAMSORG-40 and 41 on NAR, while NAR was influenced by manure only at 9-12 WAS in 2013 and 2014 respectively. In bothyears and nitrogen at 3-6 WAS in both years (Tables 36). In both locations and at 9-12 WAS, green manure at 15 t ha^{-1} and cow dung at 10 t ha^{-1} gave similar NAR, and each was lower than by the lower rates of green manure. Application of 40-80 Kg N ha^{-1} resulted in higher NAR than the untreated control at 3-6 WAS in both locations.

4. 5. 9 Number of days to 50% panicle production

The effect of crop variety, manure and N on the number of days to 50% panicle are presented in Table 37. At Katsina, the number of days to 50% heading was significantly influenced by variety and manure in 2013 and the mean, and nitrogen in 2014.

Table : 35 Effects of variety, organic manure and nitrogen rates on Net assimilation rate (NAR) at Katsina in 2013, 2014 wet seasons.

Treatments	Net Assimilation Rate (g cm-^{2} wk^{-1})					
	At WAS					
	2013			2014		
	3-6	6-9	9-12	3-6	6-9	9-12
Variety (V).						
SAMSORG- 40	0.05	0.09	0.09	0.05	0.01	0.01
SAMSORG- 41	0.03	0.08	0.09	0.04	0.01	0.01
SE (±)	0.001	0.001	0.001	0.001	0.001	0.001
Manure (M). (t ha^{-1})						
0	0.01b	0.01	0.01a	0.01b	0.01	0.01a
Cassia[2] at 7.5	0.01b	0.01	0.01a	0.01b	0.01	0.01a
Cassia at 15	0.10a	0.01	0.00b	0.11a	0.01	0.00b
Cow dung at 10	0.11a	0.01	0.01a	0.10a	0.01	0.01a
SE (±)	0.003	0.001	0.001	0.003	0.001	0.001
Nitrogen (N). (kg ha^{-1})						
0	0.04	0.01	0.01	0.04	0.08	0.09a
40	0.05	0.01	0.01	0.05	0.01	0.01b
80	0.05	0.01	0.01	0.05	0.01	0.01b
SE (±)	0.001	0.001	0.034	0.001	0.001	0.001
Interactions.						
V x M	NS[3]	NS	NS	NS[3]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using Duncan's multiple range test (DMRT).

1. WAS = Weeks after sowing,

2. *Cassia* = Green manure.

3. NS = Not significant at 5% level of probability

Table : 36 Effects of organic manure and nitrogen rates on net assimilation rate (NAR) at 3-6, 6-9 and 9-12 WAS at Samaru in 2013, 2014 wet seasons.

Treatments	Net Assimilation Rate (g cm-^{2} wk^{-1})					
	At WAS					
2013	2014					
	3-6	6-9	9-12	3-6	6-9	9-12
Variety (V).						
SAMSORG- 40	0.01	0.09	0.01	0.01	0.09	0.01
SAMSORG- 41	0.01	0.01	0.09	0.01	0.01	0.09
SE (±)	0.001	0.001	0.001	0.001	0.001	0.001
Manure (M). (t ha^{-1})						
0	0.01	0.01	0.01a	0.01	0.01	0.01a
Cassia[2] at 7.5	0.01	0.01	0.01a	0.01	0.01	0.01a
Cassia at 15	0.01	0.01	0.00b	0.01	0.01	0.00b
Cow dung at 10	0.01	0.01	0.00b	0.01	0.01	0.00b
SE (±)	0.001	0.001	0.001	0.001	0.001	0.001
Nitrogen (N). (kg ha^{-1})						
0	0.01b	0.08	0.01	0.01b	0.00	0.01
40	0.01a	0.01	0.00	0.01a	0.01	0.00
80	0.01a	0.01	0.00	0.01a	0.01	0.00
SE (±)	0.036	0.001	0.006	0.036	0.001	0.001
Interactions.						
V x M	NS[3]	NS	NS	NS[3]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. WAS = Weeks after sowing,

2. *Cassia* = Green manure.

3. NS = Not significant at 5% level of probability.

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Table : 37 Effects of variety, organic manure and nitrogen rates on the number of days to 50% heading in 2013, 2014 wet seasons and combined at Katsina and Samaru.

Treatments	Number of days to 50% heading					
	Katsina			Samaru		
	2013	2014	Mean	2013	2014	Mean
Variety (V).						
SAMSORG- 40	71.2a	59.6	65.4a	60.8a	58.9a	59.8a
SAMSORG- 41	69.0b	59.3	64.1b	59.9b	58.4b	59.1b
SE (±)	0.38	0.23	0.36	0.28	0.15	0.16
Manure (M). ($t\ ha^{-1}$)						
0	70.9ab	59.7	65.3ab	60.8a	58.7b	59.6a
Cassia[1] at 7.5	68.6b	59.1	63.8b	60.7a	58.7b	59.7a
Cassia at 15	78.7b	59.7	66.0a	61.1a	59.5a	60.3a
Cow dung at 10	72.28a	59.67	63.9b	58.8b	57.7c	58.2b
SE (±)	0.57	0.33	0.51	0.35	0.21	0.22
Nitrogen (N). ($kg\ ha^{-1}$)						
0	70.3	60.9a	65.6	60.1	58.8	59.5
40	69.8	58.8b	64.3	60.1	58.3	59.2
80	70.2	58.6b	64.4	60.8	58.8	59.8
SE (±)	0.33	0.42	0.44	0.35	0.21	0.20
Interactions.						
V x M	NS[2]	NS	NS	NS[2]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. *Cassia* = Green manure

2. NS = Not significant at 5% level of probability.

In 2013 SAMSORG-40 took a longer period to attain 50% heading than SAMSORG-41. In 2013, green manure at 7.5 and 15t ha^{-1} resulted in shorter period to 50% heading than cowdung at 10t ha^{-1} while the control was at par with each of these treatments. In the mean, green manure of 7.5t ha^{-1} and cowdung at 10t ha^{-1} resulted in less number of days to 50% heading. In 2014 in this location, application of 40 and 80KgNha^{-1} gave similar period to 50% heading, and each was less than the value by the untreated control, this might be due to the effect of nitrogen fertilizers.

At Samaru, the number of days to 50% heading of Sorghum was significantly influenced by variety and manure in both years and the mean data (Table 37). In each case, SAMSORG-40 took a longer period to attain 50% heading than SAMSORG-41. In 2013 and the mean data, green manure at 0-15t ha^{-1} took a longer period to attain 50% heading than cowdung at 10t ha^{-1}. In 2014, green manure at 15t ha^{-1} resulted in more number of days to 50% heading than lower rates, each of which was in turn more than the least by cow dung at 10 t ha^{-1}. Nitrogen did not influence the number of days to 50% heading in the two years and mean data.

Interactions of variety, manure and nitrogen levels on the number of days to 50% heading were not significant in both years and the combined data, and locations.

4. 5.10 Number of days to physiological maturity

In Katsina, the effect of variety on number of days to physiological maturity of sorghum was not significant in the two years and the mean, while manure in 2014 and nitrogen in the two years and the mean significantly influenced this parameter (Table 38). In 2014, cowdung at 10t ha^{-1} resulted in more number of days to physiological maturity which was statistically similar to the other treatments, except 7.5t ha^{-1} *Cassia* green manure, which was the least in

Table: 38 Effects of variety, organic manure and nitrogen rates on the number of days to physiological maturity at Katsina and Samaru in 2013, 2014 wet seasons and mean.

Treatments	Number of days to physiological maturity					
	Katsina			Samaru		
	2013	2014	Mean	2013	2014	Mean
Variety (V).						
SAMSORG- 40	102.0	93.5	98.1	98.4	90.5b	94.5
SAMSORG- 41	102.0	93.2	97.8	98.2	90.8a	94.5
SE (±)	3.35	0.13	0.21	0.10	0.09	0.08
Manure (M). ($t\ ha^{-1}$)						
0	102.1	93.5ab	98.0	97.7b	90.6	94.1b
Cassia[1] at 7.5	103.2	92.9b	98.2	98.7a	90.6	94.5a
Cassia at 15	101.3	93.5ab	97.7	98.3a	90.6	94.4a
Cow dung at 10	102.0	93.5a	98.0	98.6a	90.8	94.7a
SE (±)	4.74	0.19	1.80	0.21	0.12	0.12
Nitrogen (N). ($kg\ ha^{-1}$)						
0	105.2a	94.5a	99.8a	98.4	91.3a	94.9a
40	101.0b	92.6b	97.0b	98.4	90.2b	94.4ab
80	101.0b	92.9b	97.0b	98.5	90.3b	94.1b
SE (±)	7.96	0.14	0.26	0.34	0.11	0.18
Interactions.						
V x M	NS[2]	NS	NS	NS[2]	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	*	NS	NS	*	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1.*Cassia* = Green manure.

2.NS = Not significant at 5% level of probability

.* = . significant at 5% level of probability

the trial. Nitrogen at 40 and 80kgNha^{-1} attained 50% maturity earlier than the untreated control in the two years and the combined data. In Samaru, the number of days to physiological maturity was significantly influenced by variety in 2014, manure in 2013 and the data and nitrogen in 2014 and the mean data (Table 38). In 2014, SAMSORG-40 took a shorter period to attain physiological maturity than SAMSORG-41. Also application of 40 and 80KgNha^{-1} led to early crop maturity than the control. In the combined data, 80KgN ha^{-1} hastened crop maturity compared to the control, and the value by 40KgNha^{-1} was similar to both the control and the 80KgN ha^{-1} N rate.

In both locations, the interaction of manure and nitrogen levels on the number of days to crop maturity was significant in 2013 (Tables39& 40). In Katsina the number of days to sorghum crop maturity increased with green manure rate from 7.5- 15t ha^{-1} when applied in conjunction with 0 N Kg N ha^{-1} (Table 39). At each N level, the plot without manure resulted in early crop maturity, which was only comparable to green manure at 7.5 t ha^{-1} when applied along with 40 or 80 Kg N ha^{-1} .

Table : 39 Interaction of organic manure and nitrogen on the number of days to physiological maturity during 2013 wet season at Katsina.

Nitrogen rates (KgN ha^{-1})	*Cassia* green manure rates (t ha^{-1}).			Cow dung (t ha^{-1}).
	0	7.5	15	10
0	102.0c	104.0ab	106.2a	106.1a
40	102.0bc	103.1b	99.5d	99.3d
80	102.0c	101.0c	99.7d	100c
SE±		0.98		

Means followed by same letterare not significantly different at 5% level of probability using DMRT.

The crop supplied with 10t ha^{-1} of cowdung gave comparable number of days to maturity to green manure at 15t ha^{-1} when combined with 0 or 40kgNha^{-1}. N did not influence crop maturity period under the untreated control but with green manure at 7.5t ha^{-1}, 80KgNha^{-1} reduced maturity period compared to the lower rates, while with 15t ha^{-1} , 40 and 80KgNha^{-1} gave equal crop maturity period, each of which was less than the value by the untreated control. However, the parameter increased with N rate from 0 – 80KgNha^{-1} when in conjunction with 10t ha^{-1} cowdung.

At Samaru, number of days to crop maturity increased with N rate from 0 – 80KgNha^{-1} , when applied without any manure (Table 40). With 7.5t ha^{-1} of green manure, 40 and 80kgNha^{-1} resulted in less number of days to maturity, while with green manure at 15t ha^{-1} and cowdung at 10t ha^{-1} N did not influence crop maturity. On the other hand, with N 0 and 40KgNha^{-1}, applied manure prolonged crop maturity period compared to the untreated control. However, at 80KgN ha^{-1}, manure level recorded similar days of crop maturity.

Table : 40 Interaction of organic manure and nitrogen on the number of days to physiological maturity during 2013 wet season at Samaru.

Nitrogen rates (KgN ha^{-1})	*Cassia* green manure rates (t ha^{-1})			Cow dung (t ha^{-1}).
	0	7.5	15	10
0	96.9d	99.2c	98.7b	99.0ab
40	197.5a	98.2b	98.0b	98.2b
80	98.7b	98.8b	98.2b	98.5b
SE±		0.34		

Means followed by same letterare not significantly different at 5% level of probability using DMRT.

4.6 Crop Yield and Yield Component

4.6.1 Stover yield

Sorghum stover yield was influenced by variety, organic manure and nitrogen rates in the two years and combined data at Katsina, (Table 41) and nitrogen in 2013 and the combined data respectively at Samaru. Atkatsina, SAMSORG – 40 yielded more stover than SAMSORG – 41 in the two years and the combined data. Stover yield increased withmanure rate from 0 – 7.5t ha^{-1} of green manure, beyond which there was no further response in 2013. Stover yield increased with green manure rate from 0 – 15t ha^{-1} in 2014 and the combined data. In the two years and the mean data, cow dung gave the highest yield value, and was only comparable to green manure at 15 t ha^{-1} in 2013. In the two years, application of 80 kg N ha^{-1} resulted in higher stover yield than the untreated control, and 40 kg N ha^{-1} was similar to both treatments. In the combined data, stover yield increased with N rate from 0-80 kg N ha^{-1}.

In Samaru, stover yield was affected by manure in 2013 and nitrogen in the mean data only (Table 41). *Cassia* green manure at 7.5 t ha^{-1} and 15 t ha^{-1} and cow dung at 10 t ha^{-1} resulted in similar and higher stover yield, than untreated control in 2013. In the mean nitrogen at 80 kg N ha^{-1} recorded higher stover yield than the untreated control, and application of 40 kg N ha^{-1} which gave stover yield that was similar to both treatments.

The interaction of variety and manure was significant on stover yield in 2013 at Samaru (Table 42). With SAMSORG-40, green manure at 7.5 and 15 t ha^{-1} resulted in higher stover than the untreated control and each was at par with cow dung at 10 t ha^{-1}.

Table : 41 Effects of variety, organic manure and nitrogen rates on sorghum stover yield at Katsina and Samaru in 2013, 2014 wet seasons and combined.

TreatmentsStover yield (kg ha^{-1})	Katsina			Samaru		
	2013	2014	mean	2013	2014	mean
Variety (V).						
SAMSORG- 40	1003a	1047a	1025a	1045	1146	1095
SAMSORG- 41	923b	961b	942b	963	1264	1114
SE (±)	25.7	25.1	18.0	34.2	16.5	84.2
Manure (M). (t ha^{-1})						
0	764c	782d	773.d	784.b	1261	1022
Cassia[1] at 7.5	959b	962c	961c	1010a	1074	1042
Cassia at 15	1014ab	1084b	1049b	1099a	1182	1141
Cow dung at 10	1114a	1188a	1151a	1123a	1303	1213
SE (±)	36.27	35.55	25.40	48.3	23.3	11.9
Nitrogen (N) (kg ha^{-1})						
0	881b	907b	894c	945	974	960b
40	972ab	1010ab	991b	1021	1107	1064ab
80	1036a	1095a	1065a	1046	1533	1290a
SE (±)	26.7	30.3	22.0	31.9	17.8	92.5
Interactions.						
V x M	NS[2]	NS	NS	*	NS	NS
V x N	NS	NS	NS	NS[2]	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. *Cassia* = Green manure

2.NS = Not significant at 5% level of probability.

Table : 42 Interaction of variety and organic manure on sorghum stover yield in 2013 wet season at Samaru.

Manure rate	Variety.	
(t ha^{-1})	SAMSORG-40	SAMSORG-41
0	787c	5781c
7.5	1092a	928bc
15	1230a	968b
10	1069ab	1177a
SE±	68.3	

Means followed by same letterare not significantly different at 5% level of probability using DMRT.

However, SAMSORG-41, cowdung at 10t ha^{-1} gave higher stover yield than all the green manure treatments. On the other hand, variety did not influence stover yield, when in conjunction with 0t ha^{-1} green manure and 10t ha^{-1} cowdung. However, with green manure at 7.5 and 15t ha^{-1} SAMSORG-40 yielded greater stover than SAMSORG-41.

4.6.2 Panicle Length (cm).

In 2013 at Katsina, sorghum panicle length was not influenced by the two varieties of sorghum throughout the sampling periods (Table 43). Application of cowdung resulted in longer panicles than green manure treatments, which were similar. In the mean data, cowdung gave longer panicles than the untreated control, and 7.5t ha^{-1} and 15t ha^{-1} of green manure gave similar panicle length, each of which was at par with values by the control and cowdung at 10t ha^{-1}. Also, the use of 40 and 80kgNha^{-1} resulted in similar and longer panicles than the untreated control. At Samaru, SAMSORG-40 gave longer panicles than SAMSORG-41 in 2013. Furthermore, green manure at 7.5 and 15t ha^{-1} and cowdung at 10t ha^{-1} gave similar panicle lengths and each was longer than by the untreated control.

Table : 43 Effects of variety, organic manure and nitrogen rates on sorghum panicle length at Katsina and Samaru in 2013, 2014 wet seasonsand mean.

TreatmentsPanicle length (cm)

	Katsina			Samaru		
	2013	2014	mean	2013	2014	mean
Variety (V).						
SAMSORG- 40	14.5	29.0	21.7	22.8a	24.2	22.9
SAMSORG- 41	15.2	27.7	21.4	19.9b	23.1	22.1
SE (±)	0.40	0.99	0.53	0.43	3.47	1.75
Manure (M). ($t\ ha^{-1}$)						
0	13.6b	27.5ab	20.5b	17.8b	27.7	22.7
Cassia[1] at 7.5	14.7b	27.9ab	21.3ab	22.0a	21.4	21.7
Cassia at 15	14.6b	28.4a	21.5ab	22.0a	22.6	22.3
Cow dung at 10	16.5a	16.5a	23.0a	22.0a	22.6	22.3
SE (±)	0.55	1.40	0.75	0.61	4.91	2.47
Nitrogen (N). ($kg\ ha^{-1}$)						
0	13.9	26.0	19.9b	19.9	20.1	20.0
40	15.5	30.2	22.9a	20.9	21.0	21.0
80	15.1	28.8	22.0a	23.3	29.7	26.5
SE (±)	0.88	1.74	0.65	1.08	3.96	2.05
Interactions.						
V x M	NS[2]	NS	NS	*	NS	NS
V x N	NS	NS	NS	NS[2]	NS	NS
M x N	*	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

significant at 5% level of probability..

1. *Cassia* green manure

2.NS = Not significant at 5% level of probability.

* = significant at 5% level of probability..

There was significant interaction of manure and nitrogen at Katsina and variety and manure at Samaru on sorghum panicle length in 2013, (Tables 44 & 45).

At Katsina, Nitrogen did not influence panicle length when applied in conjunction without manure (Table 44). However, with 7.5 t ha^{-1} green manure, N at 80 Kg N ha^{-1} resulted in longer panicles than the lower rates, but with 15 t ha^{-1} green manure, at 40 kg N ha^{-1} gave longer panicles than the higher rate which followed and the shortest by the untreated control. On the other hand, with 0 Kg N ha^{-1} , green manure at 7.5 t ha^{-1} gave longer panicles than the 15 t ha^{-1} level, while with 40 kg N ha^{-1} green manure at 15 t ha^{-1} and cow dung at 10 t ha^{-1} resulted in longer panicles than 0 and 7.5 t ha^{-1} green manure. When in conjunction with 80 Kg N ha^{-1} green manure at 7.5 t ha^{-1} and cow dung at 10 t ha^{-1} with application of 40 kg N ha^{-1} resulted in similar panicle lengths, each of which was longer than by the untreated control and 15 t ha^{-1} green manure, which were at par.

Table : 44 Interction of organic manure and nitrogen on panicle length of sorghum during 2013 wet season at Katsina.

Nitrogen rates	*Cassia* green manure rates (t ha^{-1}).		Cow dung (t ha^{-1}).	
(KgN ha^{-1})	0	7.5	15	10
0	13.2bc	15.0b	11.7c	15.6ab
40	13.8b	13.3b	18.4a	16.6a
80	13.7b	15.8a	13.6b	17.3b
SE±		0.96		

Means followed by same letterare not significantly different at 5% level of probability using Duncan multiple range test (DMRT).

Application of 0 Kg N ha^{-1} produced the shortest sorghum panicles when applied in conjunction with 0 t ha^{-1} organic manure (Table 44). However, with 7.5 t ha^{-1} green manure, N at 80 Kg N ha^{-1} resulted in longer panicles than the lower rates, but with 15 t ha^{-1} green manure, at 40 kg N ha^{-1} gave longer panicles than the higher rate which followed and the shortest by the untreated control. On the other hand, with 0 Kg N ha^{-1} , green manure at 7.5 t ha^{-1} gave longer panicles than the 15 t ha^{-1} level, while with 40 kg N ha^{-1} green manure at 15 t ha^{-1} and cow dung at 10 t ha^{-1} resulted in longer panicles than 0 and 7.5 t ha^{-1} green manure. When in conjunction with 80 Kg N ha^{-1}, green manure at 7.5 t ha^{-1} resulted in similar panicle lengths with each panicles treated with 40 Kg N ha^{-1} along side with 15 t ha^{-1} green manure and cow dung at 10 t ha^{-1}.

At Samaru, panicles length increased with green manure from 0 – 7.5 t ha^{-1} when in conjunction with SAMSORG-40 and 0-15 t ha^{-1} with SAMSORG-41(Table 45). With SAMSORG-40, cow dung at 10 t ha^{-1} gave longer panicles than the untreated control only. However, with SAMSORG-41, resulted in longer panicles than green manure at 0 – 15 t ha^{-1} . On the other hand, SAMSORG-40 resulted in longer panicles than SAMSORG-41, when green manure was applied at 0-15 t ha^{-1} . But with cow dung, the two varieties produced similar panicle lengths.

Table : 45 Interaction of variety and organic manure on sorghum panicle length during 2013wet season at Samaru.

Manure rate (t ha^{-1})	Variety.	
	SAMSORG-40	SAMSORG-41
0	20.1bc	15.4d
7.5	24.9a	19.1c
15	22.3ab	21.7b
10	23.8a	23.5a
SE±	0.86	

4.6. 3 Panicle Weight (g).

Table 46. In both trials and locations, the weight of panicle in Katsina across the sampling periods was more by SAMSORG – 40 than by SAMSORG-41 (Table 46). In both years and the mean, panicle weight increased with green manure rate from 0 – 15 t ha^{-1} in both locations, except in Samaru where green manure at 7.5 and 15 t ha^{-1} produced similar values, each of which was greater than by the control in 2013. Cow dung at 10 t ha^{-1} consistently produced heavier panicles than the green manure treatment in both locations and years, except at Samaru when the value by this treatment was at par with those by 7.5 and 15 t ha^{-1} green manure in 2013. In 2013 and 2014, nitrogen at 40 and 80 Kg N ha^{-1} gave similar and heavier panicles than the untreated control at Katsina. However, panicle weight increased with N rate 0 – 80 Kg N ha^{-1} in the mean data in both locations and 2014 at Samaru.

There were significant interactions of crop variety and manure; and manure and nitrogen in 2013 and the combined data (Tables 47 and 48). When Sorghum was grown with green manure at 0-15 t ha^{-1} in 2013 and without any manure in the mean data, SAMSORG-40 gave heavier panicles than SAMSORG-41 (Table 47). But with 7.5-15 t ha^{-1} of green manure in the combined data and 10 t ha^{-1} of cow dung in both situations there was no difference between panicle weights of the two varieties. On the other hand, SAMSORG-40, gave heavier panicles than SAMSORG-41 in conjunction with green manure rate from 0 – 15 t ha^{-1} in 2013 and the untreated control in the mean data.

Table : 46 Effects of variety, organic manure and nitrogen rates on sorghum panicle weight at Katsina and Samaru in 2013, 2014wet seasons and mean.

TreatmentsPanicle weight (g)

	Katsina			Samaru		
	2013	2014	mean	2013	2014	mean
Variety (V).						
SAMSORG- 40	119.0a	128.0a	123.0a	124.4a	124.5a	124.4a
SAMSORG- 41	96.1b	106.0b	101.0b	97.1b	98.9b	98.0b
SE(±)	2.06	5.47	2.92	3.60	4.08	0.33
Manure (M). ($t\ ha^{-1}$)						
0	74.5d	76.6d	75.5d	17.8b	73.0d	73.8d
Cassia[1] at 7.5	90.3c	105.5c	97.9c	22.0a	94.3c	94.6c
Cassia at 15	123.1b	130.0b	127.3b	22.0a	124.6b	124.4b
Cow dung at 10	141.4a	157.2a	149.2a	23.7a	156.5a	152.4a
SE (±)	2.91	7.73	4.13	5.09	5.77	3.84
Nitrogen (N). ($kg\ ha^{-1}$)						
0	85.6b	99.0b	92.3c	19.9	94.9c	93.4c
40	114.5a	119.2a	117.0b	20.9	110.4b	113.0b
80	122.5a	134.0a	128.2a	23.3	130.5a	126.5a
SE (±)	5.55	4.93	3.58	6.51	2.91	3.56
Interactions.						
V x M	*	NS	*	[2]NS	NS	NS
V x N	NS[2]	NS	NS	NS	NS	NS
M x N	*	NS	*	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. *Cassia* = Green manure

2. NS = Not significant at 5% level of probability.

* = significant at 5% level of probability

Table : 47 Interaction of variety and organic manure on sorghum panicle weight in 2013 wet season and mean dataat Katsina.

Manure rates ($t\ ha^{-1}$)	Variety	
	2013 wet season	
	SAMSORG-40	SAMSORG-41
0	96.7d	52.3f
7.5	96.9d	83.7e
15	150.4a	132.5b
10	131.2bc	115.4c
SE±	4.11	
	Combined	
0	97.7c	53.4d
7.5	101.0c	94.2c
15	133.4b	121.4b
10	162.0a	137.5ab
SE±	5.84	

Means followed by same letterare not significantly different at 5% level of probability using DMRT.

In the interaction of manure and N at Katsina in 2013 (Table 48), green manure at 15 t ha^{-1} and cow dung at 10 t ha^{-1} resulted in similar panicle weight, and each value was higher than by 0 and 7.5 t ha^{-1} green manure when in conjunction with 0 kg N ha^{-1} . With 40 Kg N ha^{-1} , panicle length increased with green manure level from 0-15 t ha^{-1} , while the value by cow dung treatments was higher than by the green manure treatments (Table 48). With 80 kg N ha^{-1} , manure at 15 t ha^{-1} resulted in heavier panicles than lower rates, while cow dung treatment gave heavier panicles than each of the green manure treatments. On the other hand, application of N at 40 and 80 Kg N ha^{-1} resulted in heavier panicles than the untreated control when in conjunction with 0 – 15 t ha^{-1} of green manure and 10 t ha^{-1} of cow dung.

In the combined data green manure at 15 t ha^{-1} gave heavier panicles than lower rates, and cow dung at the given rate recorded higher value than all the green manure levels when

Table : 48 Interaction of organic manure and nitrogen on panicle weight of sorghum during 2013 wet season and mean data at Katsina.

Nitrogen rates (k g N ha^{-1})	*Cassia* green manure rates (t ha^{-1}).		Cow dung (t ha^{-1}).	
	0	7.5	15	10
0	66.0g	72.3fg	98.3d	105.5d
40	74.2f	101.7d	130.3c	152.5ab
80	83.3ef	96.8de	142.3bc	167a
SE±		5.04		
		Combined		
0	67.4e	82.0e	103.9d	115.6c
40	74.4e	106.2cd	127.0c	160.0ab
80	84.6de	104.5d	150.2b	174.1a
SE±		7.15		

Means followed by same letterare not significantly different at 5% level of probability using DMRT.

applied with 0 and 80kgNha^{-1}. With 40KgNha^{-1} , green manure at 7.5 and 15t ha^{-1} gave higher panicle weight than the untreated controls, while cowdung at 10t ha^{-1} maintained the lead. On the other hand, N did not influence panicle length when no manure was applied to the crop. With 7.5t ha^{-1}, 40 and 80KgNha^{-1} gave heavier panicles than the control, while with 15t ha^{-1} of green manure, panicle weight increased with N level. With cowdung at 10t ha^{-1}, 40 and 80KgNha^{-1} gave similar panicle weight and each was higher than the value by the control.

4.6. 4 Grain weight per plant.

Effects of variety, organic manure and nitrogen rates on sorghum grain weight par plant are presented in Table49. Each of these treatments significantly influenced sorghum seed weight across the locations, years and the combined means. SAMSORG-40 gave heavier seeds per

plant than SAMSORG-41. At both locations, years and the grain weight per plant increased with green manure rate from 0-15t ha^{-1}**.** However, in each case, cowdung at 10 t ha^{-1}gave higher grain weight per plant all the rate of *Cassia* green manure. In this location, application of N at 40 and 80KgNha^{-1} resulted in similar grain weight values, each of which was higher than the untreated control in 2013 and 2014. In the grain weight per plant increased with N rate from 0-80 Kg N ha^{-1}. At Samaru, the use of 80 Kg N ha^{-1} resulted in higher grain weight than the control, and 40 Kg N ha^{-1} resulted in a value that was at par with the control and the higher N level in 2013. In 2014, 80 Kg N ha^{-1} gave higher grain weight than 0 and 40 Kg N ha^{-1} . But in the mean data at katsina location, grain weight increased with N rate from 0-80 Kg N ha^{-1}. The interaction of variety and organic manure was significant in 2013 and the mean data at Katsina (Table 50). In 2013, and with SAMSORG-40, cow dung at 10 t ha^{-1} resulted in higher grain weight than all the green manure treatments. Green manure at 15 t ha^{-1} resulted in higher grain weight than the lower rates. When SAMSORG-41 was used, grain weight increased with green manure rate from 0-15 t ha^{-1} , and the highest levels was at par with grain weight value by cow dung at 10t ha^{-1}

In the mean data, with SAMSORG-40, cow dung gave the highest seed weight value, which was higher than at values by each green manure level. This was followed by green manure at 15 t ha^{-1} , which in turn had higher value than the lower rates. When SAMSORG-41 was used, grain weight increased with green manure rate from 0-15 t ha^{-1} , and the value by the highest green manure rate was similar to that by cow dung at 10 t ha^{-1} which value was highest. Similarly, as at Katsina, SAMSORG-40 gave higher seed weight than SAMSORG-

Table :49 Effects of variety, organic manure and nitrogen rates on sorghum grain weight per plant at Katsina and Samaru in 2013, 2014 wet seasons and mean.

Treatments	Grain weight (g/ plant)					
	Katsina			Samaru		
	2013	2014	mean	2013	2014	mean
Variety (V).						
SAMSORG- 40	108.4a	118.6a	113.4a	112.7a	110.6a	111.4a
SAMSORG- 41	84.9b	97.6b	91.3b	85.5b	89.1b	87.3b
SE (±)	2.11	5.42	2.91	3.49	3.40	2.65
Manure (M). ($t\ ha^{-1}$)						
0	62.9d	69.7d	66.3d	65.8d	64.2d	65.0d
Cassia[1] at 7.5	81.4c	97.4c	89.4c	86.3c	86.0c	86.2c
Cassia at 15	113.5b	120.2b	117.3b	112.5b	113.4b	113.2b
Cow dung at 10	128.4a	143.6a	136.3a	132.5a	136.4a	134.2a
SE (±)	2.98	7.66	4.11	4.94	5.66	3.76
Nitrogen (N). ($kg\ ha^{-1}$)						
0	75.0b	89.3b	82.1c	81.4b	84.5b	82.9c
40	104.2a	109.4a	106.3b	104.4ab	96.3b	100.4b
80	110.0a	124.3a	117.1a	112.3a	117.5a	114.6a
SE(±)	5.57	4.68	3.56	6.93	4.73	4.19
Interactions.						
V x M	*	NS	*	NS[2]	NS	NS
V x N	NS[2]	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1. *Cassia* = Green manure.

2. NS= Not significant at 5% level of probability.

. * = significant at 5% level of probability.

Table : 50 Interaction between variety and organic manure on sorghum grain weight per plant during the wet season 2013 and meanat Katsina.

Manure rate ($t\ ha^{-1}$)	Grain weight (g) 2013 wet season	
	SAMSORG-40	SAMSORG-41
0	87.3d	38.6f
7.5	96.9d	75.4e
15	131.0b	115.0c
10	150.3a	119.4bc
SE±	4.22	
	Mean data	
0	89.4c	43.3e
7.5	92.7c	86.1d
15	121.5b	113.4b
10	149.3a	122.5b
SE±	5.82	

Means followed by same letterare not significantly different at 5% level of probability using DMRT.

41 when combined with either of the green manure levels as well as cowdung treatment.. In both scenarios, the combination of cowdung at 10t ha^{-1} and SAMSORG-40 resulted in the highest grain weight.This was followed by combinations of SAMSORG-40 and green manure at 15t ha^{-1} in 2013 and SAMSORG-41 and cowdung at 10t ha^{-1} in the combined data.

4. 6. 5 100-grain weight

At Katsina, 100 – grain weight was significantly affected by variety in the combined data such that SAMSORG 40 resulted in heavier grains than SAMSORG-41(Table 51). In 2013, 2014 and mean of the years green manure at 15 t ha^{-1} and cow dung at 10t ha^{-1} gave similar 100-grain weights, and each value was higher than by the untreated control. In each season, SAMSORG-40 grain weight was greater than by the other variety, and 100-grain weight

Table : 51Effects of variety, organic manure and nitrogen rates on 100- grain weightof sorghum at Katsina and Samaru in 2013, 2014 wet seasons and mean.

Treatments 100-grain weight (g)

	Katsina			Samaru		
	2013	2014	mean	2013	2014	mean
Variety (V).						
SAMSORG- 40	3.28	3.30	3.28a	112.8a	110.9a	111.9a
SAMSORG- 41	3.02	3.16	3.02b	85.5b	89.1b	87.3b
SE (±)	0.10	0.10	0.07	3.49	3.41	2.65
Manure (M). ($t\ ha^{-1}$)						
0	2.76b	2.77b	2.77c	65.8d	64.2d	65.0d
Cassia[1] at 7.5	3.06ab	3.42a	3.06b	86.3c	86.0c	86.2c
Cassia at 15	3.42a	3.06a	3.42a	132.2a	136.1a	134.1a
Cow dung at 10	3.37a	3.40a	3.37a	112.3b	113.7b	113.0b
				4.94	5.66	3.76
SE (±)	0.14	0.14	0.10			
Nitrogen (N). ($kg\ ha^{-1}$)				81.4b	84.5b	83.0c
0	2.73b	2.79b	2.73b	104.1ab	96.3b	100.9b
40	3.30a	3.35a	3.30a	112.0a	117.8a	114.9a
80	3.43a	3.52a	3.43a	6.93	4.73	4.19
SE (±)	0.09	0.09	0.09			
Interactions.						
V x M	NS[2]	NS	NS	NS	NS	NS
V x N	NS	NS	NS	NS	NS	NS
M x N	NS	NS	NS	NS	NS	NS
V x M x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using Duncan's multiple range test (DMRT).

1.*Cassia* = Green manure

2. = Not significant

increased with green manure rate to 15 t ha^{-1}. The 100-grain weight values by green manure at 15 t ha^{-1} was higher than by cow dung treatment, which in turn was higher than the lower rates of green manure. Grain weight by 80 Kg N ha^{-1} was greater than by the untreated control in 2013 and the control and 40 Kg N ha^{-1} in 2014. In the mean, 100-grain weight increased with N from 0-80 Kg N ha^{-1}.

The interactions of variety, organic manure and nitrogen on 100-grain weight were not significant in the two years and the mean.

4.6.6 Grain yield

Crop variety, organic manures and nitrogen significantly affected sorghum grain yield in both years and the combined data at Katsina and Samaru (Tables 52). In both locations and seasons, SAMSORG-40 out yielded SAMSORG-41. Also in each case, grain yield increased with green manure from 0-15t ha^{-1}. The use of 15t ha^{-1} green manure resulted in higher grain yield than cow dung at 10t ha^{-1} in both locations and seasons, except in 2013 at Katsina. Similarly, in both locations and seasons and their combined means, grain yield increased with nitrogen from 0-80kgNha^{-1}.

There were significant interactions of crop varieties and organic manure in 2014 and combined atkatsina, 2013and 2014 at Samaru, variety and nitrogen in 2014 at Katsina and 2013 and 2014 at Samaru, manure and nitrogen in 2014 at Katsina and in 2013 at Samaru respectively (Tables 53 - 57).Interaction of variety and manure rates on Sorghum grain yield at Katsina in 2014 is presented in Table 53.

Table : 52 Effects of variety, organic manure and nitrogen rates on sorghum grain yield at Katsina and Samaru in 2013, 2014 wet seasons and mean.

. Treatments	Grain yield (kg ha^{-1})					
	Katsina			Samaru		
	2013	2014	mean	2013	2014	mean
Variety (V).						
SAMSORG- 40	1715a	1815a	1765a	2000a	2149a	2074a
SAMSORG- 41	1608b	1688b	1648b	1809b	1980b	1894b
SE (±)	12.2	2.4	6.2	9.7	18.7	1.8
Manure (M). (t ha^{-1})						
0	1289d	1429d	1359d	1516d	1698d	1607d
***Cassia*[1] at 7.5**	1526c	1683c	1605c	1815c	2039c	1927c
***Cassia* at 15**	1888b	2056a	1972a	2166a	2289a	2228a
Cow dung at 10	1940a	1839b	1890b	2120b	2233b	2176b
SE (±)	17.2	3.5	8.8	13.7	26.5	2.6
Nitrogen (N). (kg ha^{-1})						
0	1554c	1650c	1602c	1753c	1868c	1811c
40	1644b	1745b	1694b	1914b	2113b	2013b
80	1785a	1861a	1823a	2046a	2213a	2129a
SE (±)	5.6	6.0	7.6	6.6	8.6	2.0
Interactions.						
V x M	NS[2]	*	*	*	*	NS
V x N	NS	*	NS	*	*	NS
M x N	NS	*	NS	*	NS	NS
V x M x N	NS	NS	NS	NS[2]	NS	NS

Means followed by the same letter within a column of each treatment group are not significantly different at 5% level of probability using DMRT.

1.*Cassia* = Green manure.

2.NS Not significant at 5% level of probability.

* = significant at 5% level of probability.

In 2014 and the combined means and with each manure level, SAMSORG-40 resulted in higher grain yield than SAMSORG-41, except the cow dung treatment. Holding each variety constant, grain yield increased with green manure rate from

Table : 53 Interaction of variety and organic manure sorghum grain yield during 2014 wet season and mean in Katsina.

Manure rate ($t\ ha^{-1}$)	Variety	
	2014 wet season	
	SAMSORG-40	SAMSORG-41
0	1466f	1392g
7.5	1780d	1585e
15	2143a	1969b
10	1805c	1807c
SE±	4.9	
	Mean data	
	SAMSORG-40	SAMSORG-41
0	1406g	1312h
7.5	1675e	1534f
15	2049a	1895c
10	1930b	1850b
SE±	2.9	

Means followed by same letterare not significantly different at 5% level of probability using DMRT.

0-15 t ha^{-1} in both varieties. In each case green manure at 15 t ha^{-1} gave higher grain yield than cow dung at 10 t ha^{-1} , which in turn was higher than lower rates of green manure.

At Samaru, grain yield increased with green manure from 0-15t ha^{-1} under SAMSORG-40 in 2013 and SAMSORG-41 in 2014 and 7.5 -15 t ha^{-1} under SAMSORG-40 in 2014 (Table 54). With each variety in 2014, green manure at 15 t ha^{-1} had higher yield over cow dung at 10 t ha^{-1}. At each level of green manure, SAMSORG-40 out yielded the other variety.

Table : 54Interaction of variety and organic manure sorghum grain yield during 2013 and 2014 wet seasons at Samaru.

Manure rate (t ha^{-1})	Variety	
	2013 wet season	
	SAMSORG-40	SAMSORG-41
0	1605f	1427g
7.5	1882d	1749e
15	2302a	2031c
10	2211b	2029c
SE±	5.0	
	2014 wet season	
0	1769c	1627f
7.5	2137c	1940d
15	2365a	2140c
10	2325b	1940d
SE±	5.2	

Means followed by same letterare not significantly different at 5% level of probability using DMRT.

Table 55: shows the significant interaction of variety and nitrogen rate on the grain yield of Sorghum at Katsina in 2014, Samaru in 2013 and 2014. Holding each variety constant, each level of nitrogen from 0-80 kg N ha^{-1} gave a corresponding increase in yield. In each case, application of 80 kg N ha^{-1} under SAMSORG-40 gave higher grain yield than all other treatment combinations. With each level of organic manure, SAMSORG-40 resulted in higher grain yield than SAMSORG-41. Interactions effect of organic manure and nitrogen rate on grain yield at Katsina in 2014 and Samaru in 2013 are presented in Tables 56 & 57. Grain yield increased with N from 0-80 kg N ha^{-1} at each level of organic manure in each location. Highest grain yield was obtained at 80 kg N ha^{-1} in conjunction with green manure at 15 t ha^{-1} at Katsina and cow dung at 10 t ha^{-1} at Samaru. On the other hand, grain yield increased with green manure rate fro 0-15 t ha^{-1} in both locations. With N at 0- 80 kg N ha^{-1} at Katsina

Table :55 Interaction of variety and nitrogen on sorghum grain yield in 2014 wet season at Katsina, 2013, 2014 at Samaru.

Nitrogen rate (Kg N ha^{-1}).	Variety SAMSORG-40	SAMSORG-41
0	1708c	1591e
40	1821b	1668d
801917a		1806b
SE (±)	4.5	

Nitrogen rate. (KgN ha^{-1})	Variety SAMSORG-40	SAMSORG-41
0	1834d	1673f
40	2025b	1802e
80	2141a	1951c
SE (±)	4.4	

Nitrogen rate (KgN ha^{-1})	Variety. SAMSORG-40	SAMSORG-41
0	1930e	1806f
40	2218b	2008d
802299a		2127c
SE (±)	4.5	

Means followed by same letterare not significantly different at 5% level of probability using t DMRT.

and 0-40 kg N ha^{-1} at Samaru green manure at 15 t ha^{-1} out yielded the cow dung treatment.

In Samaru, cow dung at the given rate out yield green manure at 15 t ha^{-1} when applied in conjunction with 80 kg N ha^{-1}.

Table : 56 Interaction of organic manure and nitrogen on sorghum grain yield in 2014 wet season at Katsina.

Nitrogen rates ($t\ ha^{-1}$). ($KgN\ ha^{-1}$)	Manure rates 0	7.5	15	cow dung ($t\ ha^{-1}$). 10
0	1307i	1553g	1924c	1813e
40	1412h	1692f	2045b	1829e
80	1568g	1802e	2199a	1876d
SE (±)		6.0		

Means followed by same letterare not significantly different at 5% level of probability using DMRT

Table : 57 Interaction of organic manure and nitrogen on sorghum grain yield in 2013 wet season at Samaru.

Nitrogen rates ($KgN\ ha^{-1}$)	Manure rates ($t\ ha^{-1}$) 0	7.5	15	Cow dung ($t\ ha^{-1}$) 10
0	1355k	1641i	2075e	1942f
40	1521j	1851g	2061c	2123d
80	1671h	1954f	2264b	2294a
SE (±)		6.2		

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4. 7 Correlations

Tables58 & 59 show the correlation matrixbetween sorghum grain yield, yield attributes, growth characters and *Striga* shoot count inthe combined data at Katsina and Samaru. At Katsina (Table58), sorghum grain yield strongly and positively correlated with all the observed parameters, except with *Striga* shoot count and stover yield,which were moderately and highly negatively correlated with yield respectively. This stressed the dependence of the parameters on yield, growth and yield characters in Sorghum . The inter relationships that existed between stand count, number of leaves, shoot dry weight and 100-

grain weight were positive and significant, and moderately significant with all other parameters except plant height and panicle length, which showed no significant correlation. Stand count was moderately and negatively correlated with *Striga* shoot count. Positive and significant relationship was observed between plant height and all other parameters, except *Striga* count and panicle length. Number of leaves was significantly correlated with LAI, shoot dry weight and stover yield, moderately related to panicle length, panicle weight, grainweight and 100-grain weight.Leaf area indexwas strongly correlated with panicle weight, grainweight and 100-grain weight and moderately so with shoot dwt and stover yield The correlation between LAI and *Striga* shoot count was moderate and positive.Positive and significant correlations were observed between shoot dwt on one hand and panicle length, panicle weight, grain weight and 100-grain weight. *Striga* shoot count was moderately correlated with panicle weight and grain yield. Stover yield was strongly and positively correlated with panicle weight, grain yield and 100- grain weight. Moderate correlation were recorded between panicle length and panicle and grain weights. Strong positive and correlations were observed between panicle weight and grain weight and 100-grain weight and between grain weight and 100-grain weight.

At Samaru (Table 59), grain yield was strongly and positively correlated with stand count, plant height and number of leaves and moderately so with panicle weight, grain weight and 100-grai weight. The correlation of yield with shoot dry weight was moderate and negative. Similarly, stand count was only strongly and positively correlated with plant height and number of leaves, and moderately so with panicle weight, grain yield and 100-grain weight. Plant height showed strong and positive relationship with number of leaves and grain weight and moderate relationship with 100-grain weight. Number of leaves was strongly

correlated with panicle weight, grain weight and 100-grain weight. Moderate and negative correlations were recorded between shoot dry weight and *Striga* count. The former was significantly correlated with panicle weight and grain weight. Stover yield was strongly correlated with panicle length, while panicle length was strongly correlated with panicle weight. There was significant strong and positive correlation between panicle weight and grain weight and 100-grain weight. Grain weight was strongly and positively correlated with 100-grain weight.

Table : 58 Correlation matrix between grain yield and growth attributes of sorghum and *Striga* shoot count at Katsina site. (Mean data).

1	2	3	4	5	6	7	8	9	10	11	12
1. 1.00											
2. 0.315**	1.00										
3. 0.622**	0.165^{NS}	1.00									
4. 0.281**	0.350**	156^{NS}	1.00								
5. 0.570**	0.200*	0.369**	0.267**	1.00							
6. 0.467**	0.378**	0.302**	0.371**	0.406*	1.00						
7. -0.244*	-0.196*	0.084^{NS}	0.150^{NS}	-0.199*	0.159^{NS}	1.00					
8. -0.674**	0.233*	0.493**	0.243**	0.545*	0.416**	0.194^{NS}	1.00				
9. 0.228**	0.141^{NS}	0.170^{NS}	0.202*	0.094^{NS}	0.368**	0.043^{NS}	0.180	1.00			
10. 0.679**	0.232*	0.503**	0.210*	0.466**	0.440**	0.198*	0.641**	0.213*	1.00		
11. 0.672**	0.235*	0.509**	0.218*	0.464**	0.445**	0.196*	0.647**	0.223*	0.435**	1.00	
12. 0.450**	0.365**	0.383**	0.235*	0.259**	0.410**	0.161^{NS}	0.360**	0.089^{NS}	0.677**	0.435**	1.00

1. Grain yield. 2. Stand count. 3. Plant height. 4. Number of leaves. 5. LAI 6. Shoot dry weight. 7.Striga shoot count. 8. Stover yield. 9. Panicle length. 10. Panicle weight. 11. Grain weight. 12. 100-grain weight.

* = significant at 5% level of probability (r= 0.195), **= significant at 1% level of probability (r= 0.254).

Table : 59 Correlation matrix between grain yield and growth attributes of sorghum and *Striga* shoot count at Samaru site. (Mean data).

	1	2	3	4	5	6	7	8	9	10	11	12
1.	1.00											
2.	0.306**	1.00										
3.	0.632**	0.316**	1.00									
4.	0.522**	0.288**	0.508**	1.00								
5.	0.091^{NS}	-0.061^{NS}	0.182^{NS}	0.069^{NS}	1.00							
6.	-0.227*	0.108^{NS}	0.103^{NS}	0.062^{NS}	0.175^{NS}	1.00						
7.	-0.05^{NS}	-0.157^{NS}	0.116^{NS}	0.122^{NS}	-0.04^{NS}	-0.203*	1.00					
8.	0.174^{NS}	-0.011^{NS}	-0.19^{NS}	0.177^{NS}	0.023^{NS}	0.002^{NS}	0.002^{NS}	1.00				
9.	0.086^{NS}	-0.036^{NS}	0.106^{NS}	0.137^{NS}	0.018^{NS}	-0.01^{NS}	0.048^{NS}	0.937**	1.00			
10.	0.737*	0.199*	0.418	0.340**	0.050^{NS}	0.311**	0.122^{NS}	0.152^{NS}	-0.14^{NS}	1.00		
11.	0.725*	0.215*	0.390**	0.356**	0.049^{NS}	0.323**	-0.12^{NS}	0.147^{NS}	0.937**	0.968**	1.00	
12.	0.401*	0.219*	0.226*	0.293*	-0.07^{NS}	-0.07^{NS}	0.333**	0.047^{NS}	0.152^{NS}	0.318**	0.310**	1.00

1. Grain yield. 2. Stand count. 3. Plant height. 4. Number of leaves. 5. LAI 6. Shoot dry weight. 7.Striga count. 8. Stover yield. 9. Panicle length. 10. Panicle weight. 11. Seed weight. 12. 100-grain weight

* = significant at 5% level of probability (r= 0.195), **= significant at 1% level of probability (r= 0.254).

4. 8 Path Coefficient Analysis

4. 8. 1 Direct and indirect effects of some growth and yield attributes on sorghum grain yield.

The direct and indirect effects of different growth and yield components on grain yield in 2013, 2014 and mean at katsina are presented in Table 60. In 2013, panicle weight plant^{-1} gave the highest direct positive effect 0.969 on grain yield, followed by plant height and100-grain weight in the declining order. On the other hand, shoot dry weight and grain weight gave negative direct effects on yield. The highest positive indirect effect on grain yield resulted from grain weight via panicle weight followed by 100-grain weight, panicle weight and plant height and panicle weight and shoot dry weight via panicle weight. The least indirect effect on grain yield was by Panicle weight via grain weight. All the indirect effects on grain yield via shoot dry weight and grain weight were negative.

In 2014, plant height had the greatest direct effects on grain yield, followed by shoot dry weight, grain weight and number of leaves in that order. The least direct effect was recorded by 100-grain weight. The indirect effect on yield was highest with panicle weight via plant height followed by grain weight and 100-grain weight via plant height. The lowest indirect effect was by grain weight via 100- grain weight. All the other parameters had indirect, only grain weight had the indirect negative effect on yield via 100-grain weight.

Table : 60 Direct and indirect effects of growth and yield components of sorghum grain yield in 2013 and 2014 wet seasons and combined at Katsina.

			Effect through				
Yield attributes	Plant height	Number of leaves	Shoot dwt	Panicle wt	Grain wt	100-grain wt	**Total correlation**
			2013				
Plant height	**0.291**	0.002	-0.005	0.479	-0188	0.034	0.613
No.of leaves	0.036	**0.017**	-0.006	0.274	-0.105	0.017	0.234
Shoot dwt	0.080	0.006	**-0.018**	0.439	-0.169	0.044	0.381
Panicle wt	0.144	0.005	-0.008	**0.969**	-0.371	0.055	0.794
Grain wt	0.147	0.005	-0.008	0.963	**-0.373**	0.056	0.789
100-grain wt	0.097	0.003	-0.008	0.519	-0.205	**0.103**	0.508
			2014				
Plant height	**0.492**	0.017	0.082	0.039	0.075	-0.013	0.692
No.of leaves	0.084	**0.100**	0.081	0.009	0.018	-0.009	0.283
Shoot dwt	0.160	0.032	**0.253**	0.030	0.057	-0.013	0.519
Panicle wt	0.266	0.012	0.105	**0.072**	0.139	-0.010	0.584
Grain wt	0.265	0.013	0.104	0.071	**0.139**	-0.027	0.566
100-grain wt	0.230	0.031	0.117	0.025	0.133	**-0.028**	0.508
			Combined				
Plant height	**0.225**	0.013	0.018	0.234	0.194	-0.061	0.622
No.of leaves	0.035	**0.080**	0.023	0.098	0.083	-0.038	0.281
Shoot dwt	0.070	0.030	**0.061**	0.205	0.170	-0.066	0.467
Panicle wt	0.113	0.017	0.027	**0.465**	0.165	-0.109	0.679
Grain wt	0.114	0.018	0.027	0.202	**0.380**	-0.070	0.672
100-grain wt	0.086	0.019	0.025	0.315	0165	**-0.161**	0.450

dwt =dry weight, wt =weight.

In the combined data, the highest direct effect came from panicle weight followed by seed weight and plant height accordingly. The least direct effect was recorded 100-grainweight. On the other hand, the greatest indirect effect was by 100-grain weight via panicle weight, followed by plant height via panicle weight. The least indirect effect on grain yield resulted from panicle weight via 100-grain weight were negative. The indirect effect of all parameters via 100-grain weight were negative.

4. 8.2 Percent contributions ofsome growth and yield characters to grain yield at katsina.

Table : 61 shows the percent contribution of individual and combined growth and yield parameters of sorghum to grain yield at Katsina in 2013, 2014 andthe combined mean. The highest individual percent contribution to yield was by grainweight in 2013 and the mean, while in 2014,plant height had the highest contribution to yield. The least individual contribution to yield was obtained from number of leaves and shoot dry weight in the combined mean. On the other hand, the combined contributions differed significantly across the years under study. In 2013, the highest percent combined contribution was by plant height and panicle weight, followed by panicle weight and 100- grain weight. In 2014, the highest percent joint contribution was by plant height and shoot dry weight, followed by plant height and grain weight. Across the years, the highest combined contribution was by plant height and panicle weight. The residual (un accounted contributions) were generally high, amounting to 44.82% in 2013, 35.6% in 2014 and 34.38% in the two years mean data.

Table : 61 Path coefficient and percentage contribution of growth and yield parameters of sorghum to grain yield in 2013, 2014 wet seasons and combined mean at Katsina

Treatment	2013	2014	Mean
Individual contribution			
Plant height	8.47	24.20	5.06
Number of leaves	0.03	1.00	0.65
Shoot dry weight	0.03	6.41	0.37
Panicle weight	3.12	3.00	6.12
Grain weight	13.93	1.94	14.46
100-grain weight	1.06	0.08	2.58
Combined contribution			
Plant height + Number of leaves	0.12	1.68	0.56
Plant height + shoot dwt	-0.30	8.09	0.83
Plant height + Panicle wt	27.87	3.81	10.53
Plant height + grain wt	-10.95	7.39	8.70
Plant height +100-grain wt	1.99	-1.29	-2.77
Number of leaves + dwt	-0.02	1.62	0.36
Number of leaves + Panicle wt	0.94	0.17	1.57
Number of leaves + Grain wt	0.36	0.36	1.33
Number of leaves + 100-grain wt	0.06	-0.17	-0.61
dwt+ Panicle weight	-1.63	1.51	2.50
dwt + Grain weight	0.63	2.90	2.07
dwt + 100-grain wt	-0.06	-0.44	-0.46
Panicle wt + grain wt	3.10	3.02	6.12
Panicle wt + 100-grain wt	10.65	-0.14	-10.12
Grain wt +100-seed wt	-4.22	-0.74	-5.31
Residual	**44.82**	**35.6**	**34.38**
Total	100.00	100.00	100.00

dwt = dry weight, wt = weight

4. 8. 3 Direct and indirect effects of some growth and yield attributes on sorghum grain yield at Samaru.

The direct and indirect effects of some growth and yield attributes of sorghum on grain yield are presented in Table 62. In the 2013, the highest direct effect on yield was by panicle weight, followed by plant height and shoot dry weight, and the lowest by grain weight. For the indirect effect, the highest was by grain weight via panicle weight, followed by shoot weight via panicle weight and plant height via panicle weight. Negative direct effect was recorded by all parameters via grain weight. In 2014, 100-grain weight gave the highest direct effect on yield, followed by panicle weight, grain weight and plant height in descending order. Grain weight via panicle weight gave the highest indirect effect on grain yield, followed by panicle weight via grain weight. The least indirect effect was recorded by number of leaves via shoot dwt followed by followed by panicle weight, grain weight and 100-grain weight via shoot dwt each.

In the combined data of the two years under study, the highest direct effect on grain yield was recorded from grain weight, followed by plant height, panicle weight, 100-grain weight in the descending order, and the lowest was by shoot dry weight. For the indirect effect, panicle weight via grain weight gave the highest effect followed by plant height via grain weight, number of leaves via grain weight and shoot dwt via grain weight. The least indirect effect was by grain weight via panicle weight, which was negative. The indirect effects of each of each parameter via panicle weight and shoot dwt via plant height were negative.

Table : 62 Direct and indirect effect of growth and yield components of sorghum grain yield in 2013 and 2014 wet seasons at Samaru.

			Effect through				
Yield attributes	Plant height	No. of leaves	Shoot dwt	Panicle wt	Grain wt	100-grain wt	**Total correlation**
			2013				
Plant height	**0.281**	0.015	0.123	0.369	-0109	0.001	0.679
No. of leaves	0.094	**0.044**	0.165	0.189	-0.059	0.001	0.433
Shoot dwt	0.125	0.026	**0.278**	0.372	-0.120	0.001	0.680
Panicle wt	0.164	0.013	0.163	**0.634**	-0.193	0.001	0.780
Grain wt	0.156	0.013	0.170	0.622	**-0.197**	0.001	0.763
100-grain wt	0.042	0.011	0.060	0.164	-0.005	**0.006**	0.221
			2014				
Plant height	**0.186**	0.037	0.002	0.125	0.100	0.122	0.572
No. of leaves	0.078	**0.087**	0.001	0.125	0.121	0.134	0.545
Shoot dwt	0.028	0.004	**0.015**	0.058	0.049	0.062	0.215
Panicle wt	0.087	0.041	0.003	**0.268**	0.222	0.119	0.740
Grain wt	0.080	0.045	0.003	0.256	**0.232**	0.116	0.733
100-grain wt	0.072	0.037	0.003	0.101	0.085	**0.317**	0.614
			Combined				
Plant height	**0.352**	0.060	-0.005	-0.064	0.262	0.027	0.632
No. of leaves	0.179	**0.118**	0.003	-0.052	0.239	0.035	0.522
Shoot d wt	-0.036	0.007	**0.046**	-0.048	0.217	0.020	-0.277
Panicle wt	0.147	0.040	0.014	**-0.153**	0.650	0.038	0.737
Grain wt	0.137	0.042	-0.015	-0.148	**0.672**	0.037	0.725
100-grain wt	0.079	0.035	0.008	-0.049	0.203	**0.120**	0.401

dwt = dry weight, wt = weight.

4. 8. 4 Percent contributionsof some growth and yield characters to sorghum grain yield at Samaru.

The percent contributions of growth and yield characters of sorghum to grain yield at Samaru are presented in Table 63. Shoot dry weight gave the highest individual contribution in 2013 while in 2014 and combined datanumber of leaves gave the highest contribution. The least individual contribution was recorded by leaves number in 2013 and the combined means and shoot dry weight in 2014.In 2013, shoot dry weight and grain weight had the highest joint contribution to yield followed by plant height and grain weight, whilein 2014 and combined mean, the highest contribution to yield was by panicle weight and grain weight, followed by panicle weight and 100-grain weight in 2014 and plant height and grain weight in the combined mean. The least combined contribution to grain yield was by plant height and leaves in 2013 and the combined mean and plant height plus shoot dwt in 2014.

4. 9 Regression.

Regression curves of green manure and nitrogen rates against sorghum grain yield at Katsina and Samaru during 2013, 2014 wet seasons and the combined data are presented in Figures 1- 4, respectively. In Katsina, (Figure 1). In Katsina the response of sorghum grain yield to green manure was linear, with these equations : as $y= -10.63x^2 + 278.9x + 117.31$ in 2013, $y= 0.698x^2+ 31.859x +1426.3$ in 2014 and $y= -0.3333x^2 + 47.98x + 1348.4$ in the combined data (Figure 1). In Samaru (Figure 2), the yield response to green manure are presented by these equations : $y= -1.088x^2 + 61.979x + 1504.4$ in 2013, $y= -1.3413x^2 + 63.279x + 1598.2$ in 2014 and $y= -1.685x^2 + 66.475x + 1683$ in the combined data.

Table : 63 Path coefficient and percentage contribution of different growth and yield components of sorghum to grain yield in 2013, 2014 wet seasons and mean at Samaru

Treatment	2013	2014	Mean
Individual contribution			
Plant height	6.92	3.45	5.19
Number of leaves	0.25	0.76	0.51
Shoot dwt	7.76	0.02	3.89
Panicle wt	4.16	7.17	5.67
Grain wt	3.88	5.40	4.64
100-grain wt	3.10	7.02	5.31
Combined contribution			
Plant height + Number of leaves	0.83	1.36	1.10
Plant height + shoot dwt	5.42	0.10	2.76
Plant height + Panicle wt	2.80	4.65	3.73
Plant height + grain wt	6.15	3.72	4.94
Plant height + 100-grain wt	2.05	4.45	3.50
Number of leaves + shoot dwt	1.47	2.12	1.82
Number of leaves + Panicle wt	1.68	2.19	1.94
Number of leaves + Grain wt	2.52	2.11	2.32
Number of leaves + 100-grain wt	3.50	2.32	2.91
Shoot dwt + Panicle wt	2.72	1.17	1.95
Shoot dwt + Grain wt	6.70	0.14	3.42
Shoot dry weight + 100-grain wt	2.10	0.39	1.50
Panicle weight + grain wt	4.48	11.90	8.19
Panicle weight +100-grain wt	0.18	6.39	3.29
Grain weight + 100-grain wt	3.06	5.40	4.48
Residual	**25.75**	**27.76**	**26.76**
Total	100.00	100.00	100.00

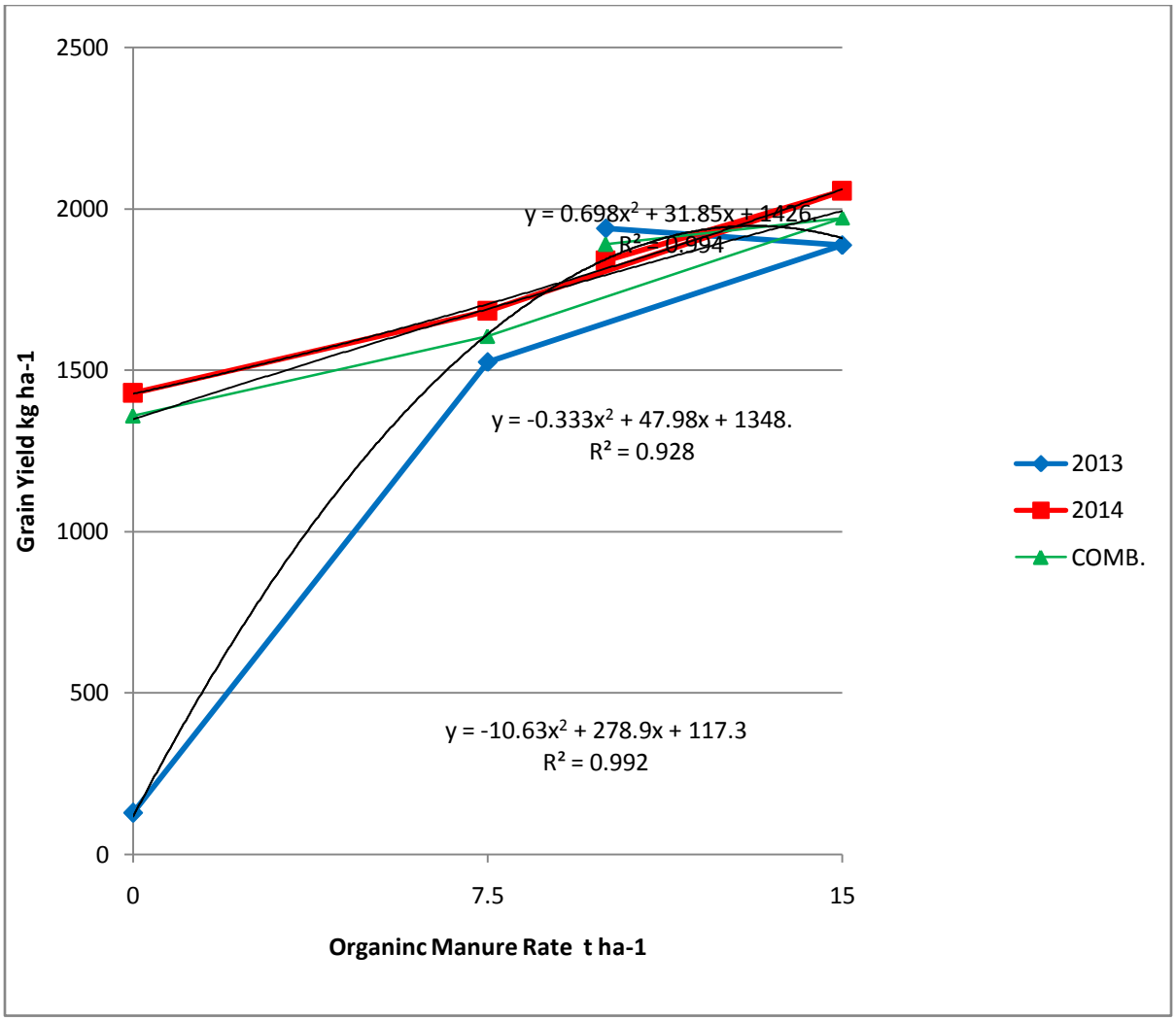


Figure 1: Regression of organic manure rates against grain yield of sorghum in 2013, 2014 and combined at Katsina.

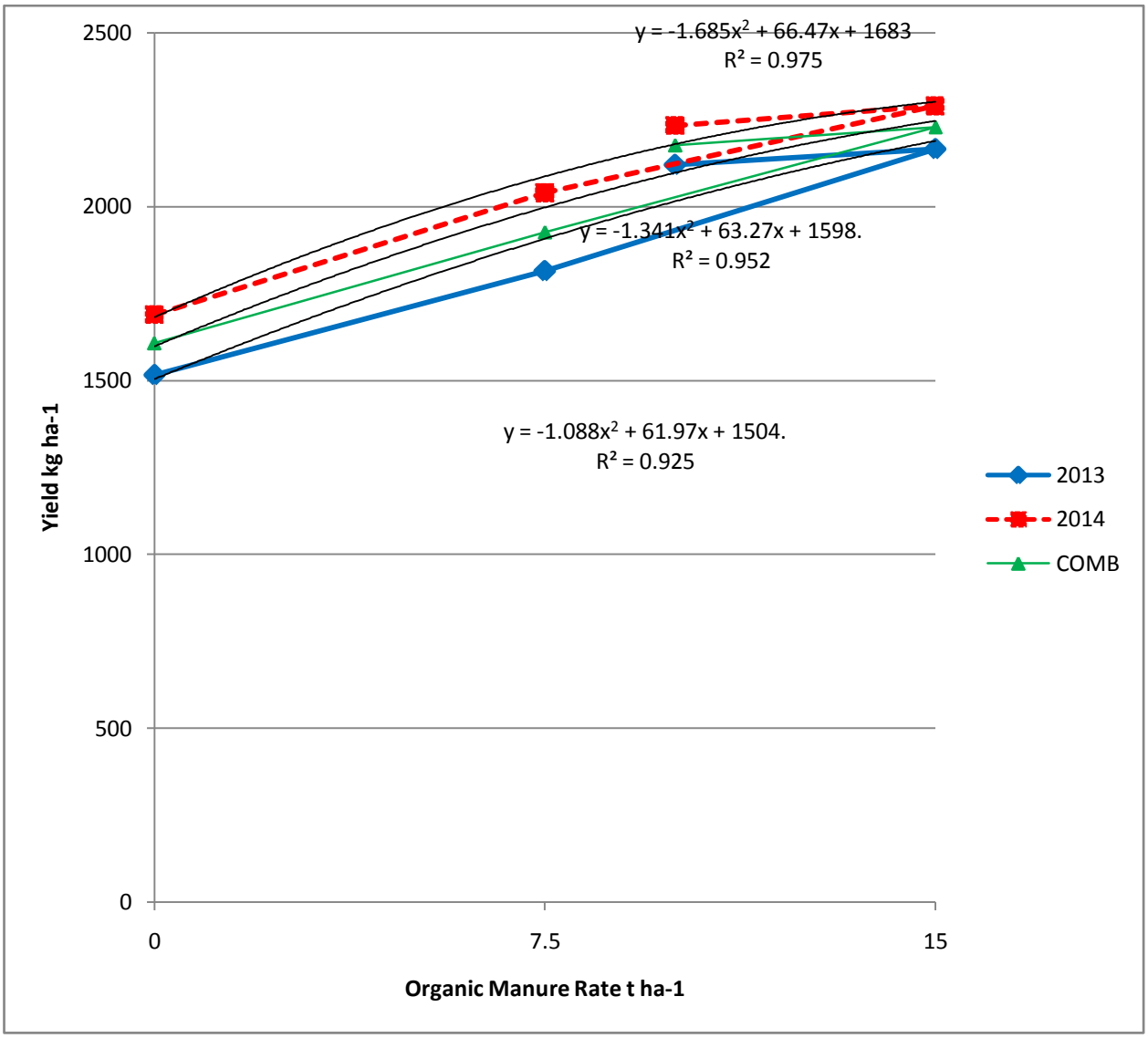


Figure 2: Regression of organic manure rates against grain yield of sorghum in 2013, 2014 and combined at Samaru..

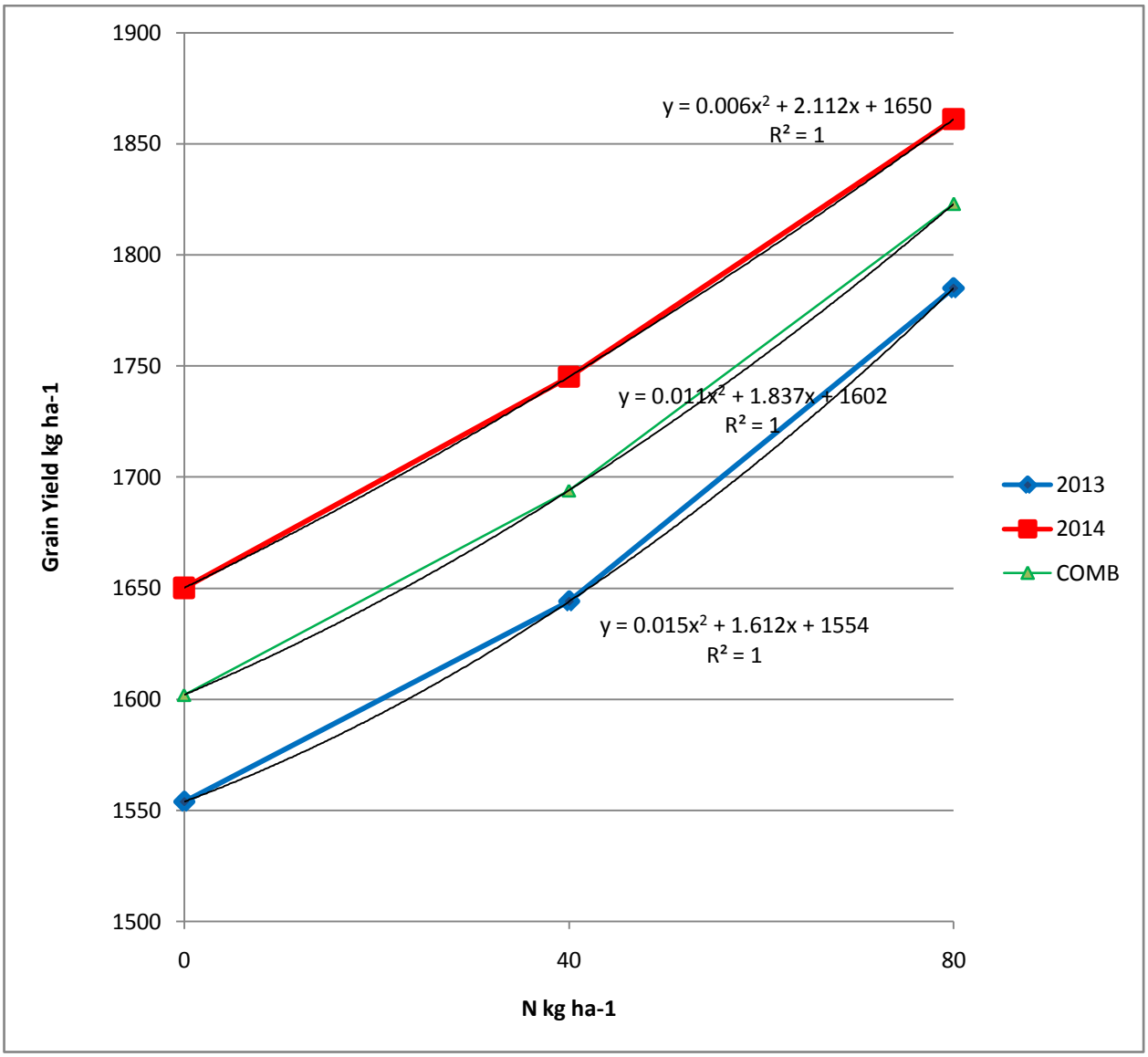


Figure 3: Regression of nitrogen rates against grain yield of sorghum in 2013, 2014 and combined at Katsina.

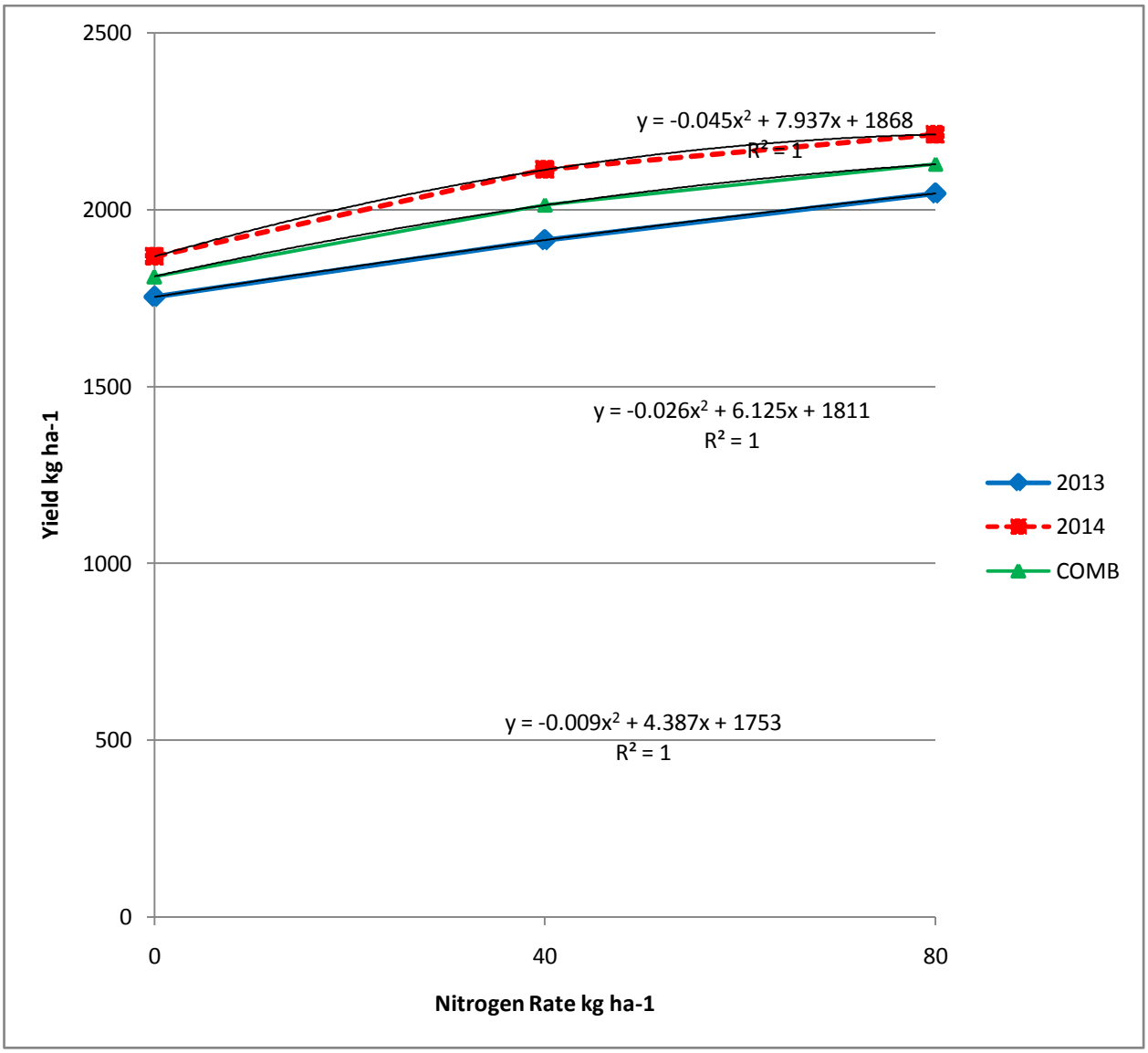


Figure 4: Regression of nitrogen rates against grain yield of sorghum in 2013, 2014 and combined at Samaru.

The optimum yield was not attained in all cases. Application of green manure at 15 t ha^{-1} resulted in the highest grain yields of 1843.3, 2060.3 and 1992 kg ha^{-1} in 2013, 2014 and the combined mean.

The regression nitrogen against grain yield in Katsina (Figure 3) indicated that grain yield response to nitrogen fertilizer rates was quadratic and represented by equations as y- $0.015x^2$ + 1.612x + 1554, in 2013, y= $0.006x^2$+ 2.112 + 1650 in 2014 and y= $0.011x^2$+ 1.837x 1602 in the combined data. In Samaru, (Figure 4), the responses represented by these equations : y= $-1.088x^2$ + 61.87x + 1504 in 2013, y= $-1.685x^2$ + 66.47x + 1683 in 2014 and y= $-1.341x^2$ + 63.27x + 1598 in the combined data. Optimum green manure level was not attained in the two years and the combined data. The highest nitrogen level of 80 kg N ha^{-1} resulted in the highest grain yield. In each case, the response to N was also quadratic. The highest grain yield was 15t ha^{-1}, with the yields of 2188.8 kg ha^{-1} in 2013, 2300.92 kg ha^{-1} in 2014 and by 2245.3 kg ha^{-1}in the combined data.

Similarly, with nitrogen against grain yield of sorghum, it was depicted equationally by y= -$0.009x^2$ + 4.387x + 1753 in 2013, y= -$0.045x^2$ + 7.937x +1868 in 2014 and y= -$0.026x^2$ + 6.125x + 1811 in the combined data, an indication of linear response too.

The highest nitrogen rate for grain yield was at 80kgN ha^{-1}, which gave maximum grain yields of 2046.4, 2214.96 and 2134.6 kgha^{-1} in 2013, 2014 and combined mean, respectively.

4. 10 Partial Economic Analysis of Yield.

The economic evaluation of integrating variety, organic manure and nitrogen rates in the production of sorghum in the two- years combined at Katsina and Samaru are presented in Tables 64 -67. Tables 64 and 65 show the values of inputs and total variable cost (TVC), of sorghum production, in Katsina and Samaru, respectively, while Tables 66 and 67 show gross revenue, total variable cost, gross margin per Naira in the use of agronomic practices in sorghum production in the respective locations. At Katsina, the highest TVC was by the complementary application of *Cassia* green manure at 15t ha^{-1} with 80kgN ha^{-1} on SAMSORG-40(Table 64), followed by SAMSORG-41 treated with15t ha^{-1} and the higher rate of nitrogen. The least TVC was recorded by SAMSORG-41 from the non- fertilized plots. In Samaru,Table 65 showthe highest TVC was by SAMSORG-41 treated with 15t ha^{-1} green manure and 80kgN ha^{-1} followed by SAMSORG-40 with 15t ha^{-1} and 80kgN ha^{-1} while the least TVC was by SAMSORG-41 from untreated control.

The highest gross revenue and gross margin per naira invested in Katsina were achieved by SAMSORG-40 (Table 66). The highest gross revenue was recorded in SAMSORG-40 under 10t ha^{-1} cowdung and 80kgN ha^{-1} . Similarly, the highest gross margin per Naira invested was by SAMSORG-40 from untreated control. In Samaru, (Table 67) application of cowdung at 10t ha^{-1} with 80kgN ha^{-1} to SAMSORG-40 resulted in highest gross revenue, while SAMSORG-40 treated with 10t ha^{-1} cowdung and zero nitrogen level recorded the highest gross margin. The highest gross margin per nairawas by SAMSORG-40 grown with zero organic manure and 40kgN ha^{-1}while the least gross margin per naira was resulted by SAMSORG-40 using 15t ha^{-1} green manure and 80kgN ha^{-1} .

Table : 64 Contributions to total variable cost (TVC) on the production of sorghum under different nitrogen and organic manure ratesin 2013 and 2014 wet seasons at Katsina.

TREAT.	SD (₦)	SW (₦)	O.M (₦)	FERT. (₦)	INC. (₦)	APP. (₦)	INOC. (₦))	WC. (₦)	HV. (₦)	THRES. (₦)	TP. (₦)	TVC. (₦)
$M_0V_1N_0$	6259	11573	-	-	-	-	34722	13888	30864	37037	154	97952
$M_0V_1N_1$	6259	11573	-	51441	-	30864	34722	13888	30864	37037	921	217569
$M_0V_1N_2$	6259	11573	-	102879	-	30864	34722	13888	30864	37037	946	269032
$M_0V_2N_0$	6259	11573	-	-	-	-	34722	13888	30864	37037	159	134502
$M_0V_2N_1$	6259	11573	-	51441	-	30864	34722	13888	30864	37037	1700	218348
$M_0V_2N_2$	6259	11573	-	102879	-	30864	34722	13888	30864	37037	1800	269886
$M_1V_1N_0$	6259	11573	49383	-	37037	-	34722	13888	40123	43209	2045	238239
$M_1V_1N_1$	6259	11573	49383	51441	37037	30864	34722	13888	40123	43209	2400	320899
$M_1V_1N_2$	6259	11573	49383	102879	37037	30864	34722	13888	40123	43209	2500	372437
$M_1V_2N_0$	6259	11573	49383	-	37037	-	34722	13888	40123	43209	2364	238558
$M_1V_2N_1$	6259	11573	49383	51441	37037	30864	34722	13888	40123	43209	2400	320899
$M_1V_2N_2$	6259	11573	49383	102879	37037	30864	34722	13888	40123	43209	2600	329328
$M_2V_1N_0$	6259	11573	98765	-	37037	-	34722	13888	40123	43209	2400	287976
$M_2V_1N_1$	6259	11573	98765	51441	37037	30864	34722	13888	40123	43209	2500	370381
$M_2V_1N_2$	6259	11573	98765	102879	37037	30864	34722	13888	40123	43209	2700	422019
$M_2V_2N_0$	6259	11573	98765	-	37037	-	34722	13888	40123	43209	2500	288076
$M_2V_2N_1$	6259	11573	98765	51441	37037	30864	34722	13888	40123	43209	2600	370481
$M_2V_2N_2$	6259	11573	98765	102879	37037	30864	34722	13888	40123	43209	2900	422219
$M_3V_1N_0$	6259	11573	61728	-	37037	-	34722	13888	40123	43209	2600	251139
$M_3V_1N_1$	6259	11573	61728	51441	37037	30864	34722	13888	40123	43209	2700	267958
$M_3V_1N_2$	6259	11573	61728	102879	37037	30864	34722	13888	40123	43209	2900	385182
$M_3V_2N_0$	6259	11573	61728	-	37037	-	34722	13888	40123	43209	2700	237351
$M_3V_2N_1$	6259	11573	61728	51441	37037	30864	34722	13888	40123	43209	2800	293521
$M_3V_2N_2$	6259	11573	61728	102879	37037	30864	34722	13888	40123	43209	3000	385282

- = Not applicable, Labour= ₦ 200/man day, Nitrogen = 5000, Seeds = 200/kg, *Striga* seeds = N 500, C.D = N 1000/100kg, *Cassia* = N800/100kg, SW= Sowing,,INC.= incorporation, INOC.= inoculation,APP= application, HV= harvesting, THRES= threshing.

Table : 65 Contributions to total variable cost (TVC) on the production of sorghum under different nitrogen and organic manure rates in 2013 and 2014 wet seasons at Samaru.

TREAT.	SD (₦)	SW (₦)	O.M (₦)	NITR. (₦)	INC. (₦)	APP. (₦)	INOC. (₦))	WC. (₦)	HV. (₦)	THRES. (₦)	TP. (₦)	TVC. (₦)
$M_0V_1N_0$	6259	11573	-	-	-	-	34722	13888	30864	30864	167	128337
$M_0V_1N_1$	6259	11573	-	56583	-	30864	34722	13888	30864	30864	1700	217317
$M_0V_1N_2$	6259	11573	-	113169	-	30864	34722	13888	30864	30864	1900	275894
$M_0V_2N_0$	6259	11573	-	-	-	-	34722	13888	30864	30864	1700	129870
$M_0V_2N_1$	6259	11573	-	56583	-	30864	34722	13888	30864	30864	1800	217417
$M_0V_2N_2$	6259	11573	-	113169	-	30864	34722	13888	30864	30864	1900	274103
$M_1V_1N_0$	6259	11573	61728	-	30864	-	34722	13888	37037	37037	2400	235508
$M_1V_1N_1$	6259	11573	61728	56583	30864	30864	34722	13888	37037	37037	2500	320805
$M_1V_1N_2$	6259	11573	61728	113169	30864	30864	34722	13888	37037	37037	2600	379741
$M_1V_2N_0$	6259	11573	61728	-	30864	-	34722	13888	37037	37037	2500	235608
$M_1V_2N_1$	6259	11573	61728	56583	30864	30864	34722	13888	37037	37037	2600	323155
$M_1V_2N_2$	6259	11573	61728	113169	30864	30864	34722	13888	37037	37037	2600	266572
$M_2V_1N_0$	6259	11573	123456	-	30864	-	34722	13888	37037	37037	2600	297436
$M_2V_1N_1$	6259	11573	123456	56583	30864	30864	34722	13888	37037	37037	2700	384983
$M_2V_1N_2$	6259	11573	123456	113169	30864	30864	34722	13888	37037	37037	2800	441669
$M_2V_2N_0$	6259	11573	123456	-	30864	-	34722	13888	37037	37037	2700	297536
$M_2V_2N_1$	6259	11573	123456	56583	30864	30864	34722	13888	37037	37037	2800	385083
$M_2V_2N_2$	6259	11573	123456	113169	30864	30864	34722	13888	37037	37037	2500	441369
$M_3V_1N_0$	6259	11573	61728	-	30864	-	34722	13888	37037	37037	2700	235808
$M_3V_1N_1$	6259	11573	61728	56583	30864	30864	34722	13888	37037	37037	2800	323355
$M_3V_1N_2$	6259	11573	61728	113169	30864	30864	34722	13888	37037	37037	2900	380041
$M_3V_2N_0$	6259	11573	61728	-	30864	-	34722	13888	37037	37037	2800	235908
$M_3V_2N_1$	6259	11573	61728	56583	30864	30864	34722	13888	37037	37037	2800	323353
$M_3V_2N_2$	6259	11573	61728	113169	30864	30864	34722	13888	37037	37037	2900	380041

- = Not applicable, Labour= ₦ 200/man day, Nitrogen = 5500, Seeds = 200/kg, *Striga* seeds = N 500, C.D = N 1000/100kg, *Cassia* = N1000/100kg, SW= Sowing, INC.= incorporation, INOC.= inoculation,APP= application, HV= harvesting, THRES= threshing.

Table:66 Partial economic analysis of variety, nitrogen and organic manure rates on the production of sorghum in 2013, 2014 wet seasons and combined at Katsina.

Treatment	Grain yield (Kg ha^{-1})	Average yield / $Kgha^{-1}$	Gross Revenue (GR)	Total Variable Cost (TVC)	Gross margin (GR-TVC)	Gross margin per Naira invested.
$M_0V_1N_0$	1549	200	309800	97952	211848	**0.69**
$M_0V_1N_1$	921	200	190200	217569	-27369	-0.14
$M_0V_1N_2$	946	200	189200	269032	-79832	0.42
$M_0V_2N_0$	1598	200	319600	134502	185098	0.59
$M_0V_2N_1$	1695	200	339000	218348	120652	0.36
$M_0V_2N_2$	1799	200	359800	269886	89914	0.25
$M_1V_1N_0$	1945	200	389000	238239	150761	0.39
$M_1V_1N_1$	2396	200	479200	320899	158301	0.34
$M_1V_1N_2$	2517	200	503400	372437	130963	0.27
$M_1V_2N_0$	2364	200	472800	238558	234242	0.50
$M_1V_2N_1$	2496	200	499200	320899	178301	0.36
$M_1V_2N_2$	2571	200	514200	329328	184872	0.36
$M_2V_1N_0$	2408	200	481600	287976	193624	0.41
$M_2V_1N_1$	2532	200	506400	370381	136019	0.27
$M_2V_1N_2$	2677	200	535400	422019	113381	0.22
$M_2V_2N_0$	2490	200	498000	288076	209924	0.43
$M_2V_2N_1$	2631	200	526200	370481	155719	0.30
$M_2V_2N_2$	2886	200	577200	422219	154981	0.27
$M_3V_1N_0$	2594	200	518800	251139	267661	0.54
$M_3V_1N_1$	2716	200	543200	267958	275242	0.05
$M_3V_1N_2$	2862	200	572400	385182	187218	0.33
$M_3V_2N_0$	2669	200	533800	237351	296449	0.56
$M_3V_2N_1$	2773	200	554600	293521	261079	0.48
$M_3V_2N_2$	2947	200	589400	385282	204118	0.35

Nitrogen (Kg N ha^{-1}),Organic manure (t ha^{-1}),

Table : 67 Partial economic analysis of variety, nitrogen and organic manure rates on the production of sorghum In 2013, 2014 wet seasons and combined at Samaru.

Treatment	Grain yield (Kg ha^{-1})	Average yield/ $Kgha^{-1}$	Gross Revenue (GR)	Total Variable Cost (TVC)	Gross margin (GR-TVC)	Gross margin per Naira invested.
$M_0V_1N_0$	1674	200	334800	128337	206463	0.62
$M_0V_1N_1$	1764	200	352800	217317	135483	0.48
$M_0V_1N_2$	1872	200	374400	275894	98506	0.27
$M_0V_2N_0$	1733	200	346600	129870	216730	0.63
$M_0V_2N_1$	1794	200	358800	217417	141383	**0.66**
$M_0V_2N_2$	1885	200	377000	274103	102897	0.28
$M_1V_1N_0$	2414	200	482800	235508	274292	0.57
$M_1V_1N_1$	2521	200	504200	320805	183395	0.37
$M_1V_1N_2$	2630	200	526000	379741	146259	0.28
$M_1V_2N_0$	2485	200	497000	235608	261392	0.53
$M_1V_2N_1$	2550	200	510000	323155	186845	0.37
$M_1V_2N_2$	2646	200	529200	266572	262628	0.50
$M_2V_1N_0$	2578	200	515600	297436	218164	0.43
$M_2V_1N_1$	2685	200	537000	384983	152017	0.28
$M_2V_1N_2$	2820	200	564000	441669	122331	0.22
$M_2V_2N_0$	2728	200	545600	297536	248064	0.46
$M_2V_2N_1$	2758	200	551600	385083	166517	0.31
$M_2V_2N_2$	2526	200	505200	441369	63831	0.13
$M_3V_1N_0$	2717	200	543400	235808	307592	0.57
$M_3V_1N_1$	2763	200	552600	323355	229245	0.42
$M_3V_1N_2$	2925	200	585000	380041	204959	0.36
$M_3V_2N_0$	2767	200	553400	235908	317492	0.58
$M_3V_2N_1$	2838	200	567600	323353	244247	0.44
$M_3V_2N_2$	2946	200	589200	380041	209159	0.36

Nitrogen (kg N ha^{-1}), Organic manure (t ha^{-1})

5. 0 DISCUSSIONS

5. 1. Influence of *Striga* on sorghum variety Growth and Yield Parameters.

SAMSORG-40 and SAMSORG 41 are known to be tolerant to *Striga* infestation and may each delay the emergence of *Striga* (Kureh *et al.,* 1999). The non significant effect of variety to *Striga* shoot count in Katsina location might also be due to both varieties being tolerant to *Striga*. The two varieties can tolerate some levels of *Striga* attack,while in Samaru, the lower shoot counts of *Striga* in SAMSORG-41 might be brought about as a result of the reduction of witchweed seeds density induced by native soil N and then at Katsina more favourable condition to the variety than SAMSORG-40 (Appendix 5). The use of mineral nitrogen and organic manure such as farm yard manure and compost have been reported to reduce *Striga* infestations (Piterse, 1996).

The influence of variety on LAI showed that SAMSORG-40 had larger LAI than SAMSORG-41. This could be that SAMSORG-40 grew taller and formed more leaves than the later, which enhanced greater photosynthesis and robust growth. The higher shoot dry weight by SAMSORG-40 was proportionately reflected in taller plants than was the case with SAMSORG-41. The difference in yield amongst the varieties at both locations and seasons may be related to the differences in the growth characters by the respective varieties. SAMSORG-40 outweighed SAMSORG-41 with the respect to plant height, number of leaves, establishment count, leaf area index and shoot dry weight, which are attributes of can be transformed into yield. The differences in the number of days to 50% heading between the two locations showed SAMSORG-40 took more days to head, than SAMSORG-41. This shows the ability of SAMSORG-41 variety to utilize the resources like nutrients, water and space effectively than SAMSORG-40. With number of days to maturity, SAMSORG-40

had less number of days to become physiologically matured when compared to SAMSORG-41 in Samaru, may be due the high level of nitrogen, which enhanced vegetative growth, unlike in the Katsina site where nitrogen was moderately available to the crops.The difference of Panicle length in 2013 showed that, SAMSORG-40 had the longest panicles than SAMSORG-41 with the shortest panicles. This may be related to genetic make of the variety. SAMSORG-40 had longer stalks and hence panicle length was at par with that of SAMSORG-41 which shows relatively shorter leaves, panicles and stalks respectively. The heaviest panicles recorded by SAMSORG-40 across the locations and periods of study showed that, enhanced growth attributes such as number of leaves, plant height, stand count and LAI in this variety were transformed into yield and yield attributes. Heaviest grain weight per stand couple with 100-grain weight observed in SAMSORG-40 over SAMSORG-41 could be due to the highest growth components already exhibited by later variety. The highest values of stover yield obtained from SAMSORG-40 over SAMSORG-41 might be related to genetic superiority of the variety which was reflected in the production of taller plants and greater number of leaves, and leaf area index. The greater values of yield by SAMSORG-40 over SAMSORG-41 in both locations might be as a result of the cumulative effect of growth, and yield attributes on the final grain yield of sorghum. Abdullahi *et al.* (2011) reported that SAMSORG-40 had significant number of yield attributes and yield over the Kano fara-fara, a local variety.

Another reason for the differences in yield amongst the varieties in both locations and seasons might be related to the differences in yield components by the varieties. SAMSORG-40 outweighed SAMSORG-41 with the respect to plant height, number of leaves, establishment count, leaf area index and shoot dry weight which can be transformed

into yield. The higher stand count in Katsina at harvest 2014 may be attributed to the adequate rainfall experienced at the onset of sowing, which supported seed germination and emergence, despite the lower fertility status of the soil of the experimental siteas shown in Appendices 5 and 6, where nitrogen soil content was low. This indicated the role of rainfall in seedling emergence.

5. 2 Influence of Green Manure on *Striga,* Sorghum Growth and Yield Parameters in Sorghum.

At Katsina in 2013, *Striga* shoots were rarely recorded when higher doses of organic manures were used. The high manure level enhanced vigorous crop growth and leaf spread (LAI), which smothered emerged *Striga* shoots, leading to dieback. The non significant effect of the varying rates of organic manure on *Striga* shoot count at Katsina in 2014 and Samaru in both years might be attributed to early *Striga* emergence before the mineralization of organic materials, and therefore, provided insufficient amount of nitrogen that is required to suppress the parasitic weed in relation to the untreated control and the lower rates of green manure.

On the other hand at Samaru, the consistently early emergence of *Striga* seedlings in green manure at 15t ha^{-1} might be an indication that the manure provided plant nutrients which supported crop growth and induced *Striga* seed germination which could not withstand the more vigorous sorghum plants, but died back as earlier indicated. This finding is in harmony with the earlier reports made by Gworgwor (1993), who reported that, delay in *Striga* emergence might be due to low stimulant production by sorghum. In the sorghum crop with organic manure application, *Striga* shoots were scarcely recorded when higher dose of the manure and cowdung were used. This might probably be caused by crop growth and

reduction of *Striga* shoots Piterse (1996) reported that, *Striga* infestation was ameliorated by the use of organic manure and nitrogen. Application of varying rates of organic manure did not show significant influence on *Striga* incidence on sorghum stands at harvest in both locations. This might be due to the inadequate amount of available N to suppress the weed. At this stage, organic manures had not completely decomposed, to release N that could reduce *Striga* infestation to crop plants even with higher organic manure levels. The high *Striga* count recorded on the untreated control could be due to the low amount of nitrogen that increased crop susceptivility to *Striga* attack. At higher levels of green manure and the cow dung at 10t ha^{-1}, crop growth increased and this facilitated its tolerance to *Striga*, under which some *Striga* plants did not survive. The similar response to 15t ha^{-1} *Cassia* green manure and 10 t ha^{-1} cowdung on stand count of sorghum in Katsina showed that, the available moisture during planting promote seed germination and seedling emergence, even though at this stage the manures had not decomposed to release nutrients. In Samaru, at 3WAS and harvest green manure had no significant effect on the stand count, at that time, rainfall was not adequate to supply moisture for seed germination, even though the soil was rich in N, and this might brought about the differences on the stand count. Similar finding was reported by Theodora *et al.* (2003) who found out that application of farm yard manure did not affect the stand count of sorghum. Taller plants were as a result of increased green manure from 0- 15t ha^{-1} and cowdung at 10t ha^{-1}in both sites indicating that increasing green manure and cowdung at the given rates had pronounced effect on vegetative growth of sorghum plants. The effect might be due to the improvement in the soil properties as well as nutrient content following fertilization with *Cassia* green manure and cowdung. This is in agreement with a report by Benefeldt (2002), who pointed to the potential uses of poultry

manure as a fertilizer and soil amendments. Similarly, Mahadi, (2011) reported that application of 8 and 12t ha^{-1} of cowdung promoted plant height of maize. The comparable leaf numbers per plant with cowdung and *Cassia* green manure recorded in both years in Katsina indicate that, similar amounts of N were supplied by 7.5-15t ha^{-1} green manure and 10t ha^{-1} of cowdung. The greater LAI by 7.5-15t ha^{-1} *Cassia* green manure and 10t ha^{-1} of cowdung revealed the significant contribution of the manures in promoting the vegetative growth of crop, which contributed significantly to crop canopy formation and spread.

The generally larger LAI recorded in 2014 at Samaru when compared to Katsina site, might be attributed to the fertility level of soil at Samaru where available N was found to be high both at pre and post harvest soil analysis. However, the lowest LAI across the untreated control might be, due to the absence of the supplied N organic manure. A similar trend was recorded by shoot dwt. Heavy rainfall was experienced in Katsina, especially during 2013 wet season, and this probably affect crop growth compared to Samaru. The reason might be that heavy rainfall caused run-off which washes nutrients away and leaching to make them less available to crop plants the reverse was the case in 2014.

Sorghum grain yield increased with increase in green manure rates and by the cowdung treatment. This is because nutrients in the manure were possibly released toward the post-anthesis stage. Nutrients such as N and P are important for grain formation and yield development. The application of manure provides other essential nutrients that are limiting in mineral fertilizers, and this could increase grain yield of sorghum even under *Striga* pressure as observed by Parker and Riches (1993). The finding showed that *Cassia* green manure significantly increased growth and yield of sorghum, probably due to improved soil physical and chemical properties. Organic matter is known to improve porosity and moisture

holding capacity, of soil and enhances root growth, water and nutrient uptake capability. Apart from the fact that nutrients released from the green manure has direct effect on growth and yield. The importance of N in organic matter in improving sorghum performance has been highlighted by Arunah *et al*. (2006), who found that poultry manure was superior to the applied N in promoting yield of sorghum. With varying rates of organic manures the panicle length recorded in 2013 in both locations, 2014 and combined in Katsina, was proportional to the rate. Enhancement in crop growth obviously improved assimilate production and translocation to the sink, including the reproduction portion which is explained by heavier panicles.

5. 3Effect of Nitrogen on *Striga*and Sorghum Growth and Yield inKatsina and Samaru.

With nitrogen at varying rates, *Striga* shoots were rarely recorded when higher doses of nitrogen were used and this probably caused etiolated growth of *Striga* shoots, which eventually died. Esilaba *et al.* (2000) reported that the greatest reduction in the mean *Striga* density across all the treatments was obtained with 120kgNha^{-1} and 20t ha^{-1} organicmanure in maize. The least *Striga* shoot count was under higher rate of 80kgNha^{-1}. Indeed there was a general decline in infestation with increasing N rates in Katsina and Samaru and their combined means. These results are in agreement with the reports by Mumera and Bello (1993) who found that *Striga* infestation declined with increasing N availability and the impact depended on the severity of infestation. However,high *Striga* infestation was recorded from the untreated control compared to plots that were treated with N in Katsina and Samaru in 2014. Nitrogen at the rate of 40-80kgNha^{-1} markedly reduced *Striga* infestation. Similar report was made by Lagoke *et al*. (1994) that application of certain levels

of nitrogenous fertilizer reduced the severity of *Striga* attack and increased yield of the affected host crop. The positive influence on crop reaction score recorded from nitrogen treatment at 3 WAS in 2013 at Samaru showed that, the lowest crop reaction score was witnessed when 80kgN ha^{-1} was used, indicating that sufficient amount of N can lower sorghum crop reaction to *Striga* with consequent increase in yield. This is because nutrients were available and released toward the post-anthesis stage, and made available for the development of the site of photosynthesis, there by aiding yield development of the crop. Another reason might be due to enhanced P uptake since the native P level was good as shown at pre and post harvest soil physical and chemical analysis in Katsina and Samaru respectively. These results affirm that, application of nitrogenous fertilizers, provided that other essential nutrients are not limiting, can increase grain yield of sorghum even under high *Striga* infestation as reported by Parker and Riches (1993).

The least grain yield was obtained from the untreated plots. This describes the role of nitrogen as the single most important nutrient for cereal crop production. The use of high rate of nitrogen increased the performance of sorghum in *Striga* infested field. This is because nitrogen can reduce the severity of *Striga* attack and at the same time increase the performance of the host crop (Lagoke and Isah, 2010). Padwick (1983) had observed that many tropical soils showed nutrient deficiency problems and decrease in crop yield after only a short period of cultivation. Another reason for the low yield recorded at Katsina in 2013 when compared to the yield at Samaru, despite the heavy rainfall experienced during the vegetative growth, might be as a result of the erratic supply of rains towards the grainfilling stage. This can be testified in the Samaru location, where the highest grain yield was obtained, because of the adequate rains experienced during the periods of grain filling.

5.4 Interactions

There was interaction of manure and nitrogen on shoot dry weight at both locations in 2013 and 2014 wet seasons, in which the maximum dry weight accumulation plant^{-1} was recorded with application of *Cassia* green manure at 15 t ha^{-1} and 10 t ha^{-1} of cow dung each with nitrogen at 80 kg N ha^{-1}. This might be probably due to thesufficient amount of N which met the requirement of the crop. Lagoke and Isah (2010) observed that, nitrogen application reduced the severity of *Striga* and improve host crop performance. By integrating nitrogen fertilizer with organic manure, the higher shoot dry weight recorded, might be attributed to the higher N input from the synthetic fertilizer plus the slow release of N from the organic source of manure which provided the element at the later stage of crop growth and development. Organic manure takes some time to be mineralized. Patel *et al.* (1994) reported that dry matter yield increases with nitrogen application from 40-160 kg ha^{-1}. There was interaction of manure and nitrogen on the early physiological maturity in Katsina and Samaru in 2013 and 2014 wet seasons. Integrating *Cassia* green manure and cow dung probably provided some nutrients essential for the early physiological maturity of the crop. This was in line with earlier suggestion that nutrients were released by the integrated fertilizers and poultry manure towards post-anthesis stage (Esilaba *et al*., 2000) Thus, the nutrients were available to develop the site of photosynthesis, thereby aiding rapid yield development of the crop plants (Olayinka *et al*., 2007).

In the significant interaction of organic manure and mineral fertilizer on panicle weight of Sorghum in 2013 and the combined data in Katsina, the heaviest panicles were produced by integrating the highest available rates of both organic and mineral fertilizers. This indicates the high demand of growth factors such as nutrients by sorghum. As the crop grew older its

demand for environmental resources increased, the competition for growth factor became intense and the effect of varying rates of organic and mineral fertilizer became very clear. Thus, creating a significant variations in panicle weight between the rates of manure and fertilizer.

Interaction of crop variety and organic manure on panicle length of sorghum at Samaru 2013 wet season showed SAMSORG-40 had a greater response to organic manure application than SAMSORG-41, as panicle length increased with green manure rate from 0-15 t ha^{-1}. This indicates that SAMSORG-40 might use the available nutrient from the manure judiciously than the other variety. SAMSORG-40 grows vigorously to exploit available nutrients at the expense of other variety.

There was significant interaction of variety and organic manure on sorghum grain yield in 2014 and the combined data in Katsina and in 2013 and 2014 in Samaru. The interaction revealed that grain yield increased with increased in green manure rates from 0-15 t ha^{-1} and cow dung at 10 t ha^{-1}. This might be nutrients like N and P from the manure werereleased toward the post anthesis stage for grain filling and yield development. This was in harmony with the findings of Esilaba*et al*,(2000), who reported that among the manure treatments of 10-30 t ha^{-1} significantly improved maize yield as compared to untreated control. As the crop grew older, its demand for environmental resources increased, the competition for growth factors became intense and effect of varying rates of organic and mineral fertilizer became very clear, thus, creating a significant variation in grain yield between the combined levels. The SAMSORG-40 in conjunction with 15 t ha^{-1} of *Cassia* green manure produced the highest grain yield across the locations and sampling periods

hence, this indicate that, nutrients like N & P requirement for maximum yield production were better utilized in grain production at the highest green manure level of 15 t ha^{-1}.

The Interaction of organic and mineral fertilizer on the grain yield of sorghum in 2014 at Katsina and 2013 in Samaru shows that yield was greaterwith complementary application of 80kgN $ha^{-1}$and 15t ha^{-1} green manure in Katsina,followed by 80kgNha^{-1} plus 10t ha^{-1} cowdung. This result indicated that integrating organic and mineral fertilizer is a better nutrientsource compared with sole organic and inorganic fertilizers. This might be due to mineral nutrientsthat was first provided to the growing crop during the early vegetative growth stages, while the organic components provided nutrients at the later stage of the crop development.This is in agreement with the earlier reports that the most satisfactory method of increasing yield was by judicious combination of organic wastes and inorganic fertilizers (Makinde *et al*., 2001; Titiloye, 1983).

5. 5 Relationships Between *Striga* and Crop Growthand yield Parameters.

The moderate and positivesignificant correlation between the yield and all the observed parameters, except *Striga* count and panicle length stressed the dependence of yield on them parameters. It further shows the importance of producing taller plants and more leaves with larger leaf area that is required to intercept light for high assimilate production which transmitted into grain formation. Taller plants with more leavesand large assimilatory area stand the chance of intercepting more light and competing more effectively against weeds. This result corroborates the one earlier reported by Olabanji(2001),who observed significant and positive relationship between growth and yield characters.

Higher number and heavier panicles and grain weights were significantly positively correlated to grain yield in both locations, This is quite expected because panicle size and grain weight are yieldattributing factors in cereal production. Olabanji (2001) has earlier observed a positive and significant relationship between grain yield and yield parameters such as panicle weight, grain weight and 100-grain weight. Production of leaves with large leaf let means high light interception and hence, more production of Stover yield and shoot dry weight that formed the final grain yield. This was further proved by the strong and positive relationship between shoot dry weight and grain yield.

In Samaru, grain yield was moderate and negatively correlated with shoot dry weight and significantly correlated with all the other parameters except LAI, *Striga* count, Stover yield and panicle length, which revealed non significant relationships. Moderate and negative relationship was recorded between shoot dry weight and *Striga*shoot count.N significant correlation was recorded between *Striga* shoot count and all the parameters, except 100-grain weight, which was negative and significant. Thisshows the detrimental effect of *Striga* parasitism on the host crop, which affects crop and markedly altered shoot development,stunting the plants, thereby affecting dry matter production. In extreme cases, there was total collapse of the plants and yield reduction of 20-100% as reported by Dogget (1965).

The direct and indirect effects by both the growth and yield attributes on yield were recorded in the two locations and yearsof study. In both locations, the greatest effect by panicle weight on yield showed that panicle weight greatly influenced yield. The heavier the panicle the more yield would be realized. The direct effectsof some growth parameters to yield such as by plant height, shoot dry weight, number of leaves,as some of the primary determinants

for yield may be attributed to the impact of complementary application of green manure, cowdungand the high rates of N-fertilizer which improved crop growth and eventually led to heavier panicles, 100-grain weight and grain weight that constituted the yield.

The individual and combined contributions of panicle weight to yield recorded over the years and the mean, showed that sorghum panicle weight has direct bearing ongrain yield.The highest combined contributions of panicle weight via shoot dry weight, is not surprising because all of them are major determinants of yield. Grain weight usually determines the weight of the panicle and panicle weight can be used to estimate yield per plant. Therefore, any factor that may directly or indirectly affect any of the two would equally affect theultimate grain yield.

5.6 Regression

Regression of green manure against yield in the two years and locations showed that the response to green manure was linear and the optimum yield was not attained even at value of 15t ha^{-1}green manure.The results revealed that an optimum yield of either of the two sorghum varieties could be attained by the use of green manure at a rate above the current maximum of 15tha^{-1} green manure in both locations, even though soil differed with respect to nutrients status from one place to another and even in the same location from time to time. Olabanji (2001) reported that optimum yield of sorghum was attained by the use of 20 t ha^{-1} green manure compared to 5-15 t ha^{-1}. The lower values of yield attained at Katsina by the use of 15tha^{-1} green manure when compared to that of Samaru might be due to the differences in the rainfall distribution and native fertility status of soil. In Samaru, adequate rainfall was witnessed during the post anthesis stage andthesoil was more fertile both at pre

and post harvest periods, as indicated in Appendices I and II. Another reason may be due to the difference in the quality and N, P and K contentsof green manure plantmaterials sourcedfrom Samaru were at par with those obtained and used in Katsina site.

Similarly, the yield response to N was linear in both locations. The maximum expected grain yieldin Katsina wasalso significantly lower than that obtained in Samaru. In addition to each situation, the heavier rainfall in the month of September might have caused run off and leaching of some soil nutrients, thereby reducing their availability to sorghum crop during the reproductive phase at Katsina location. The result from the soil analysis both at pre and post-harvest revealed that more available P and N was found at Samaru location than Katsina. Similarly, *Cassia obtusifolia* green manure and cowdung applied to sorghum in Samaru contained more N and P when compared to those used in Katsina.Possibly, another reason might be due to the differences in soil physical characteristics: Katsina site had a sandy loam soil with low organic matter content which encouraged greater leaching of nutrients than in Samaru where the soil was loamy, richer in organic matter, hence able to retain adequate moisture and nutrients for plant growth and development.

5. 7 Partial Economic Analysis of Sorghum Production.

The Total Variable Cost (TVC) recorded from both sites of the study differed significantly among themselves. The TVC incurred for producing sorghum in Samaru outweighed that in Katsina. The reasons for this difference may be attributed to the differences in the cost price of some inputs such as fertilizers, *Cassia obtusifolia* and coupled with the lower cost of labour for the cultural operationsdone on the farm in the two locations during both

production and processing periods. The difference on TVC in both locations showed that things are relatively cheaper in Katsina compared to Samaru.

Highest gross margin recorded in Katsina by the use of SAMSORG-40 treated with 10t ha^{-1} cowdung and 0kgN ha^{-1} and the highest gross margin per naira by SAMSORG-41under controlshowed that, although grain yield was high by 15t ha^{-1}green manure and 80kgN ha^{-1}. The cost of production was high and so the profit was maximized by growing SAMSORG-41without fertilizer input, that is, with less capital investment. Lowest TVC was obtained by production of millet without fertilizer application compared to the use of N even at the lower rates of 40 kg N ha^{-1}(Gani, 2015). Similarly, in Samaru,highest gross marginwas realized by SAMSORG-40 grown under similar treatment as obtained in Katsina, while, the highest gross margin per naira invested was obtained from SAMSORG-40 with zero application of organic manure and 40kgN ha^{-1}. The highest gross return and profit may be practically recorded due to the reduced cost incurred for non use of green manure at both sites. With variety, SAMSORG-40 showed that application of 10t ha^{-1} cowdung alone without fertilizer can give maximum yield with the less capital investment.

CHAPTER SIX

6.0 SUMMARY AND CONCLUSIONS

Two field trials were conducted in the wet seasons of 2013, 2014, one at the Institute for Agricultural Research Farm, Samaru (11 11 N 7^0 38 E; 686m above sea level) in the northern Guinea Savanna, and the other at Experimental Farm of Hassan Usman Katsina Polytechnic, Katsina (12 56 N, 7^0 36 E; 465m above sea level) in the Sudan Savanna of Nigeria to investigate the effects of variety, *Cassia* green manure and nitrogen on sorghum grown on *Striga*- infested field. The treatments consisted of two sorghum varieties (SAMSORG-40 and SAMSORG 41), four levels of organic manure (*Cassia* green manure at 0, 7.5, 15t ha^{-1} and cowdung at 10t ha^{-1}) and three levels of nitrogen (0, 40 and 80kgNha^{-1}). The experiment was laid in a split plot design and replicated thrice, with nitrogen assigned to the main plots and the factorial combinations of organic manure levels and varieties assigned to the sub-plots. The test site soils were *Striga*- infested, and were low in organic matter, N, and available P. Analysis of soil of the experimental locations after harvest showed that complementary application of green manure at 15t $ha^{-1}$and nitrogen at 80kg Nha^{-1}improved N, availableP and exchangeable K status of the soil.

With variety, SAMSORG-40 had an edge over SAMSORG-41 with respect to *Striga*shoot count even though both varieties were tolerant to *Striga,* yet*Striga* density wasmore higher in SAMSORG-41. Similarly,amongst the two varieties tested, SAMSORG-40 recorded more plant height, number of leaves, LAI, shoot dry weight than SAMSORG-41.SAMSORG-40 exhibited more positive response to yield and yield attributes when compared to the other variety in both locations andyears ofstudy.

*Striga*shoot count and infestation on sorghum was not significantly affected by the used of green manure and cowdung when compared to the untreated control. This shows the effect of organic N in reducing the impact of *Striga* density and infestation. Application of *Cassia* green manure at 15t ha^{-1}resulted in highergrowth components such as plant height, number of leaves and LAI when compared to both application of 0,7.5-10t ha^{-1} of green manure and cowdung. This contributed significantly to not only crop yield, but helped in replenishing the lost nutrients to the soil of the experimental lands. Influence of green manure at 15t ha^{-1} on thefinal grain yield of sorghum was superior to all other treatments, sampling periods and locations. Application of 10t ha^{-1} cowdung was at par with 0- 7.5t ha^{-1} green manure with respect to yield.

With nitrogen application at 80kgN ha^{-1},*Striga* count, number of*Striga* infested plants and *Striga* crop reaction score were found to be significantlylower when compared to the untreated control. Similarly,plant height, numbers of leaves, LAI, shoot dry weight weregreater at 80kgN ha^{-1} compared to 0- 40kgN ha^{-1}.Yield attributes and yield were significantly greater with the application of 80kgN ha^{-1}than40kgNha^{-1} in both sites and years of study.

Integrating green manure at 15t ha^{-1} with 80kgN ha^{-1} showedsignificant improvements on shoot dry weight and days to physiological maturity of sorghum plants. Similarly, integrating 80kgN ha^{-1} and 15t ha^{-1}gave greater panicle length and weight. Complementary application of 15t ha^{-1} green manure with 80kgN ha^{-1} resulted in the highest grain yield of sorghum.

Positive and significant relationship was recorded in Katsina between sorghum grain yield and stand count, number of leaves, LAI, shoot dry weight, panicle weight, 100- grain weight, grain weight, stover yield, as the primary determinants for yield. In Samaru, grain yield was negatively and not significantly correlated to LAI, shoot dry weight, *Striga*shoot count,stover yield and panicle length.In both locations, panicle weight showed greater direct effect on grain yield. Growth parameters such as plant height, shoot dry weight, number of leaves, showed both direct effect to yield. The individual percent contributions to grain yieldwas by panicle weight and the highest combined contributions was also by panicle weight and shoot dry weight.

Sorghum grain yield showed linear response to applied green manure from 0 – 15t ha^{-1} and N from 0 – 80kgha^{-1}, an indication that optimum levels were not attained or reached.Therefore, further application of both organic manure and mineral nitrogen above the rates used in this study couldbe applied to attain the optimum yield of sorghum. The total variable cost (TVC) of sorghum production in Samaru was higher when compared to the TVC in Katsina across the years of study.

In both locations, the highest gross margin was recorded by SAMSORG-40 under 10t ha^{-1} with 0kgN ha^{-1}(₦ 0.69), while the gross margin per naira invested was by SAMSORG-41without fertilization input in Katsina, and SAMSORG-40 with 0t ha^{-1}organic manure and 40kg Nha^{-1} in Samaru.

In conclusion, the study revealed that, the highest grain yield of sorghum was by the application of 15 t ha^{-1} green manureand 80 kg N ha^{-1} with SAMSORG-40 grown on *Striga*infested field, irrespective of location. Improving soil fertility, especially N will reduce

the effect of *Striga*on sorghum. Application of 15 t ha^{-1} green manure delayed *Striga* emergence at Samaru and reduced *Striga* shoot count and crop reaction score at Katsina. In contrast, grain yield was insignificantly and negatively correlated to *Striga* shoot count at Samaru. Panicle weight and panicle weight via shoot dry weight gave the highest percent contribution to sorghum grain yield. Grain yield showed linear response to the applied green manure from 0- 15 t ha^{-1} and from 0- 80 kg N ha^{-1}, an indication that work still needs to be carried out in order to determine their optimum levels. The highest returns per Naira invested was obtained with SAMSORG-40 supplied with *Cassia* green manure at 15 t ha^{-1} and 80 kg N ha^{-1} at Katsina; and SAMSORG-40 supplied with 10 t ha^{-1} of cowdung, without any N input.

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APPENDICES

Appendix I: Meteorological data of monthly rainfall, temperature, relative humidity, sunshine hours at Katsina, Nigeria for 2013 and 2014 wet seasons.

		2013			
Months	Rainfall (mm)	Temperature (^{0}C) Max.	Min	Relative humidity (%)	Sunshine (Hr)
June	307.1	36.0	26.2	51.0	7.6
July	270.0	32.0	24.1	72.1	7.5
August	606.8	30.0	22.2	76.2	7.1
September	147.1	34.0	25.2	69.0	8.1
October	25.0	38.0	24.0	45.1	9.7
November	0.0	36.0	21.0	21.0	10.0
December	0.0	36.0	18.2	18.1	11.1
Total	1331.03				
		2014			
June	207.8	36.0	26.2	51.0	8.2
July	262.0	35.1	25.1	59.1	7.1
August	298.9	31.0	23.0	75.0	6.9
September	72.8	33.1	23.2	69.1	7.2
October	6.5	37.0	21.1	40.0	9.3
November	0.0	35.2	16.0	20.0	9.5
December	0.0	32.0	13.2	21.2	10.4
Total	848				

Source : Meteorological station, Umaru Musa University, Katsina.

Appendix II: Meteorological data of monthly rainfall, temperature, relative humidity, sunshine hours at Samaru, Nigeria for 2013 and 2014 wet seasons.

Months	Rainfall (mm)	Temperature (^{0}C) Max.	Min	Relative humidity (%)	Sunshine (Hr)
		2013			
May	57.2	35.6	17.4	67.4	7.1
June	102.5	31.0	13.0	76.6	6.9
July	193.9	30.8	20.0	79.6	6.3
August	230.0	30.0	19.6	83.0	4.7
September	113.3	32.0	18.9	78.5	6.5
October	54.0	34.1	18.2	73.5	6.6
November	0.0	34.2	15.9	34.8	8.9
December	0.0	29.0	15.2	24.8	5.2
Total	946.3				
		2014			
May	35.0	35.1	22.2	48.3	6.3
June	98.3	32.1	21.2	55.5	6.4
July	205.0	31.4	20.1	66.2	6.3
August	303.0	30.1	20.1	75.2	6.1
September	206.7	31.1	21.2	66.2	6.3
October	151.7	33.9	19.1	62.1	6.2
November	0.0	30.1	14.0	38.0	6.9
December	0.0	26.2	13.2	23.1	5.9
Total	999.7				

Source : Meteorological Unit Institute for Agricultural Research (IAR), Samaru ABU, Zaria.

Appendix III: Scales for *Striga* Crop reaction Score

Rating	Description
1. Normal plants	
2.	Slight discolouration and necrotic spots.
3.	Definite growth reduction, severe toxicity symptoms
4	Distinguishable inhibition of growth.
5	Completely killed or dead plants.

Biography

NAME _ Rabi'u ABDULLAHI

DATE OF BIRTH _ 3rdOctober, 1970

PLACE OF BIRTH _ Katsina

LOCAL GOVT. AREA _ Katsina

STATE _ Katsina

MARITAL STATUS _ Married

CONTACT ADDRES: Department of Agricultural Science Education, Federal College of Education, Katsina,

INSTITUTIONS ATTENDED WITH DATES :

1. Gidado Primary School Katsina 1976-1982
2. Katsina Teachers College, Katsina. 1982-1987
3. Federal College of Education, Katsina. 1990-1993
4. UsmanuDanfodio University, Sokoto. 1993-1998
5. Ahmadu Bello University, Zaria. 2008-2011
6. Ahmadu Bello University, Zaria. 2013-date.

WORKING EXPERIENCE

Organization	From	To	Position
1. Government Day Secondary School, Katsina.	1999	2005	Senior Master II
2. Federal College of Education, Katsina.	2005	date.	Lecturer I

Year of Admission for Postgraduate studies: 2012/2013

Admission Number: Ph. D/AGRIC./46862/12-13

Ph.D THESIS TITLE: "**INTEGRATING NITROGEN FERTILIZER AND ORGANIC MANURE ON SORGHUM (*Sorghum bicolor* (L.) *Moench*) VARIETIES GROWN ON STRIGA (*Striga hermonthica*(Del.) Benth) INFESTED FIELDS IN NIGERIAN SAVANNA''.**

THESIS Supervisory Committee:

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