EFFECTS OF MICRO-DOSING OF ORGANIC AND INORGANIC FERTILIZERS AND INTRA-ROW SPACING ON GROWTH AND YIELD OF PEARL MILLET [*Pennisetum glaucum* (L.) R. Br] IN SUDAN SAVANNA OF NIGERIA

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A DISSERTATION SUBMITTED TO THE DEPARTMENT OF AGRONOMY, FACULTY OF AGRICULTURE, BAYERO UNIVERSITY, KANO, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE(M.Sc.) IN AGRONOMY (CROPS AND CROPPING SYSTEMS).

FEBRUARY, 2018

DECLARATION

"I hereby declare that this work is the product of my own research efforts; undertaken under the supervision of Dr. H. Ajeigbe and has not been presented and will not be presented elsewhere for the award of a degree or certificate. All sources have been duly acknowledged."

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CERTIFICATION

This is to certify that the research work for this dissertation and the subsequent preparation of this Thesis by (Ramat Alhaji Mohammed, SPS /13 /MAG /00023) were carried out under our supervision

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APPROVAL PAGE

This is to certify that the research work reported here titled "Effects of Micro-dosing of Organic and Inorganic Fertilizers and Intra-row Spacing on Growth and Yield of Pearl Millet [*Pennisetum glaucum* (L.) R. Br.] in Sudan Savanna of Nigeria" by RAMAT ALHAJI MOHAMMED (SPS/13/MAG/00023) has been examined and approved for the award of MASTER DEGREE IN AGRONOMY (Crops and Cropping Systems) by Bayero University, Kano.

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DEDICATION

I dedicated the entire work of this study and write up to the memory of my late mother ‘Maimuna Ali’. May her gentle soul rest in perfect peace,Ameen.

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ABSTRACT

A field experiment was conducted during the 2015 rainy season to compare the effects of micro-dosed organic and inorganic fertilizer and intra – row spacing on millet productivity. The trial was carried out at two locations; Wasai, Minjibir Local Government Area, Kano State, in the Sudan Savanna Ecological zone (Lat. 12°10`N and long. 8°39'E) and Gambawa, Gumel Local Government Area, Jigawa State, in the Sudano - Sahelian ecological zone (Lat. 12°61`N and long. 9°45'E). The experiment was laid out in split-plot design with four replications. The fertilizer treatment was assigned to the main plot and intra-row spacing the sub plot. The fertilizer treatments have ten levels; control, cow manure (100g), cow manure (50g) + poultry manure (50g), NPK micro-dose (3g), NPK 60:30:30, NPK micro-dose (3g) + cow manure (50g), NPK micro-dose (3g) + poultry manure (50g), poultry manure (50g), poultry manure (100g) and poultry manure (150g) while the two intra – row spacing were 50 and 100 cm. The result of the experiment indicated significant differences among the fertilizer treatments in leaf chlorophyll content (LCC), leaf area index (LAI), lodging, some yield attributes and grain yield. Significant differences were also observed on maturity, plant height and stand count and on stover yield. The intra-row spacing differed significantly in LCC, lodging, grain and stover yields and on stand count and 1000-grain weight. The result at Wasai indicated that NPK 60:30:30 recorded the highest grain yield (2479 kg ha^{-1}) while poultry manure (150g) gave the highest grain yield of (793 kg ha^{-1}) at Gambawa. The result indicated that intra-row spacing of 50 cm out yielded the 100 cm. The use of NPK micro-dose (3g) at Wasai-Minjibir and poultry manure (50g) at Gambawa were suggested for use by farmers at their respective locations.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Pearl millet [*Pennisetum glaucum*(L). R. Br.] has been grown for over 5000 years all over the Sahel and the tropical countries of West Africa and is the crop plant best adapted to arid and semi-arid zones. It is the major staple food crops for over 50 million of poor and vulnerable people in the Sahelian and Sudanian zones of West Africa (IRD, 2009). Nigeria has a world share of 4.5 % of the quantity of millet production (FAOSTAT; 2012).

1.1.1 Origin and Geographic Distribution of Millet

Millets are a group of small-grained cereal crops grown mostly in the arid, semi-arid and marginal soils. Chopra (2001) reported pearl millet as one of the most important dual purpose crop, and a staple food for millions of people in arid and semi-arid ecologies around the world. Pearl millet is the sixth most important cereal annually cultivated as rain fed crop in arid and semi-arid areas of Africa and the Indian sub-continent (FAO; 2007).

It has a large number of botanical species. The most important millets are pearl millet (*Pennisetum glaucum* (L) R. Br). Other important types include finger millet (*Eleusine coracana*), proso millet (*Panicum miliaceum*), and fox-tail millet (*Setaria italica*). Andrews and Kumar (2006) reported that pearl millet was domesticated in the Sahel 4000–5000 years ago from *Pennisetum violaceum* (Lam.) Rich. It spread to East Africa and from there to southern Africa, and about 3000 years ago, to the Indian subcontinent. It reached tropical America in the 18th century and the United States in the 19th century. It is also grown as a fodder crop in Brazil, the United States, South Africa and Australia. Pearl millet is known by a number of names; bulrush, cat-tail, and spiked millet in English; Bajra (Hindi), Dukhun (Arabic) and Mil á chandelles in most of west and North African countries Ibrahim (2015). Tabo, (1995) reported that, the crop is well adapted to growing in marginal areas characterized by drought, low fertility and high temperatures and could relatively perform better on soils with high salinity or low pH values, because of its tolerance to difficult growing conditions. It can be grown where other cereals such as maize or wheat would not survive. According to Izge (2006) pearl millet responds well to management inputs, therefore it has high potential of becoming an important component of intensive agriculture, especially in arid and semi-arid regions. Pearl millet mature early and are particularly important source of food supply to subsistence farmers. They ripen while the season is still wet but have a degree of resistance to grain mould diseases

In recent times, pearl millet has drawn a lot of attention as a replacement for maize and sorghum because of its ability to reliably produce grains on a wide range of soils and harsh production environment not suitable for maize (Dewey *et al*., 2012). The ability of pearl millet to grow in dry and marginal environments clearly makes it a crop with an important role in the future. It is extremely resistant to drought and well adapted to poor soils with high resistance to diseases. Pearl millet remains the only crop that has promise of food security for the growing world population under the changing climate. It seems likely to spring back as the world's best crop as the world gets hotter and drier. However, abiotic and biotic factors militate against meaningful millet production in Nigeria. Low and erratic rainfall leading to drought period of varying lengths, low water holding capacity, poor soil fertility and traditional practices such as low crop density were among the factors affecting millet production (Rai and Kumar, 1994).

For optimum plant growth, nutrients must be available in sufficient and balanced quantities. Earlier research has shown that applying needed nutrients is usually the limiting factor in pearl millet production, and that nutrient removal is greater than nutrient additions in semi-arid West Africa (Bationo and Mokwunye, 1991).

Smallholder farmers often use organic manure to supply essential nutrients for pearl millet production which are valuable source of soil organic matter. Response of crops to applied fertilizer depends on soil organic matter. The quantity of soil organic matter depends on the quantity of organic material which can be introduced into the soil either by natural returns through roots, stubbles, sloughed-off root nodules and root exudates or by artificial application in the form of organic fertilizer such as manure (Agboola and Omueti, 1982). Manures are important means of maintaining soil fertility. This is because nutrients contained in manures are released more slowly and are stored for a longer time in the soil, that ensuring residual effect (Sharma and Mittra, 1991). Organic fertilizers generally are very bulky, yet they manifest many important characteristics. They improve soil moisture and nutrient retention, stimulate root development, control weeds and soil erosion, minimize soil temperature fluctuation, improve soil porosity and enhance biological activities. To overcome the problems of bulkiness and slow release of nutrients associated with organic fertilizers, the use of inorganic fertilizers was introduced. When available, inorganic fertilizer use does not consume much labour, thus allowing time for other tasks. The amount of inorganic fertilizer used in most smallholder farming systems falls far below standard extension recommendations, due to poor purchasing power, risk aversion due to poor and unreliable rainfall, and lack of significant returns. There is also increased emphasis on the impact of environmental quality due to continuous use of chemical fertilizers. Thus, the focus of soil fertility research has now been shifted towards the combined application of organic resources and fertilizers as a way to arrest the problems associated with the sole use of organic or inorganic nutrient source (Vanlauwe *et al*., 2001). This is simply because experience has shown that the most rewarding benefits occur when different technologies are combined. Several researchers working in savanna region of Nigeria have demonstrated the benefits of complementary use of mineral fertilizers and manures (Tarfa *et al*., 2001; Yaro *et al*., 2003; Yusuf *et al*., 2003). When applying organic resources and mineral fertilizer simultaneously, one hardly ever observes negative interactions, indicating that even without clearly understanding the mechanisms underlying positive interactions, applying organic resources in combination with mineral inputs stands as an appropriate fertility management principle. For maximum fertilizer use efficiency instead of spreading fertilizer over the field, micro-dosing technique was introduced. The method emphasizes the application of small, affordable quantities of fertilizer with the seed at planting time or as top dressing 3 to 4 weeks after emergence. Dougbedji *et al.* (2011) reported that to help increase the rate of on-farm application of sources of nutrients, the fertilizer micro-dosing was developed especially to small-holder farmers with promising results. Hill application of manure combined with mineral fertilizer micro-dose is likely to optimize yield.

Plant spacing (both inter and intra-row spacing) plays an important role on growth, development and yield of cereal crops. Optimum plant density ensures that plants grow properly with their aerial and underground parts by utilizing more sunlight and soil nutrients (Miah *et al.* 1990). In a similar finding by Bhowmik *et al.* (2012) who stated that closer spacing hampers inter-cultural operations and in a densely populated crop the inter-plant competition for nutrients, air and light is very high, which usually results in mutual shading, lodging and thus favors more straw yield than grain yield. Though the yield per plant is lower at closer spacing, greater number of plants per ha^{-1} compensates the loss in the yield of individual plant (Balasubramaniyan and Palanlappan, 2007).

1.1.2 Environmental Conditions for Growth and Development of Pearl millet in Nigeria

Climate is one of the major threat in dryland agro-ecology of Nigeria posing low crop yields and serious environmental degradation- ranging from low soil water, erosion, droughts, and high temperatures which the resource poor farmers are not able to cope with as a result of poverty and low technological development. climatic factors that are of particular importance to pearl millet production are rainfall, air and soil temperatures, day length (photoperiod), radiation and wind. The impact of these variables is dependent on the developmental stage of the crop.

In Nigeria the climate of most pearl millet producing areas can typically be described as hot and dry. Millet production depends almost entirely on rainfall as its moisture supply, the amount and distribution of rainfall are important factors in determining the ultimate productivity of the crop. The optimum rainfall requirement of pearl millet ranges between 350 to 500mm and Chiroma *et al.* (2006) identified the boot and grain fill stages are important stages when pearl millet is particularly sensitive to water stress. Numerous studies have been carried out over the years on the effects of air and soil temperatures on the germination, growth and yield of pearl millet (Ong, 1983a; Ong, 1983b; Gregory, 1983). Soil temperatures influence all aspects of early vegetative development, the emergence of seedlings, the initiation, appearance and final number of leaves and tillers (Ong, 1993a). OMM (1993) stated that pearl millet requires temperatures between 22 and 36 ^{0}C for a good photosynthetic response, with an optimum range of 31 to 35 ^{o}C. Day length, or photoperiod, is a critical control in the initiation of the reproductive phase of the millet in many pearl millet cultivars. Photosensitive cultivars are grown as long season crops while non-photoperiodic cultivars are grown as short season crops (Syngenta Foundation, 2003). Ong (1983a) also found an optimum range of 22 to 35 ^{o}C for plant growth and a maximum of 45 to 40 ^{o}C. The optimum temperature for root elongation is 32 °C. However, one of the major constraints to crop production in the tropics is the inherent low fertility status of most soils, characterized by low activity clay, low level of organic matter, nitrogen, phosphorus, potassium and exchangeable bases (Osundare, 2008). Such constraints necessitated the search for many soils fertility improvement techniques such as adoption of appropriate and adequate fertilizer packages, involving the use of organic and/or inorganic fertilizers (Tankou, 2004). In northern Nigeria, especially the Sudano-sahelian savannas where fertilizer use was considered risky because of unreliable rainfall pattern and low buffering capacity of the soils, the use of mineral fertilizers on a continuous basis and at substantial quantities has always been of much concern. In the savanna agro-ecology, just like in other semi-arid regions of the tropics, most soils are poor because they are deeply weathered and have been leached for long, with little or no fertilizer and farm yard manure use. FAO (2011) reported that food crops give large responses to fertilizers on very poor soils and that there are similar increases in yields from the dressings of nitrogen, phosphorus and potassium sites. Pearl millet appears to have relatively fast root development, sending extensive roots both laterally and downward into the soil profile to take advantage of available moisture and nutrients. The crop yields best on fertile, well drained soils particularly when there are plenty of hot days. It is drought tolerant and has early maturity. Pearl millet can be considered a "low-input" crop, but does respond to fertile soil conditions and good management practices.

1.1.3 Production and Utilization

Millet production is distributed differentially among a large number of African countries; largest producers being in West Africa led by Nigeria (41%), Niger (16%), Burkina Faso (7%), Mali (6.4%), Senegal and Sudan (4.8% each) FAOSTAT (2011). Millets are extremely important in the African semi-arid tropics, produced in 18.50 million hectares by 28 countries covering 30% of the continent. There are nine species which form major sources of energy and protein for about 130 million people in sub-Saharan Africa. Among these, only four are produced significantly in Africa; including pearl millet (the most widely grown in 76% area), finger millet (19% area), Tef (9%) and fonio (4%).

Nkama (1998) stated the uses and traditional food preparations of pearl millet in Nigeria. The grain serves as food for the majority of people of dry land of Africa who utilize it in the form of thick porridge eaten with vegetable soup produced from flour called tuwo, a coarse millet flour known as " Biski" also eaten with soup, refreshing drink which is semi-boiled non-alcoholic beverage "Kunu", Flour from millet grain blended with tamarind powder, also boiled as 'kunun tsamiya', thick porridge consumed when mixed with milk "Fura," pap "Akamu", alcoholic or non-alcoholic beverage brewed from malted grain "Burkutu," 'dessert "dan wake" 'and palp "ogi", millet beer in Cameroon, and Millet flour called "Bajari" in western India. Recently millet flour is industrially blended with other cereals or grain legumes producing rich meals or supplements in packages such as "Soulfull", "Soulfull-choco-fills", "action meal" etc. Generally, the grain is produced for domestic consumption and has little commercial status. The stems are used for thatching, building fences and as a source of domestic fuel. Furthermore, the seed is a valuable food resource on account of its protein and lipids contents: 12% protein, 3% crude fibre and 4% fat (Ojediran, 2008). Trials in India have also shown that pearl millet is nutritionally superior for human growth when compared to maize and rice. The protein content of pearl millet is higher than maize and has a relatively high vitamin A content (Felch, 2006).

1.2 STATEMENT OF THE PROBLEM

The present low yield of pearl millet in Nigeria was attributed to many factors which include low soil fertility, low and erratic rainfall, improper spacing resulting to low plant population and lack of improved varieties. Farmers in the region have long been using the slow traditional fallow system to restore soil fertility and increase productivity. This trend has very low yield due to inherent low nutrient supply capacity of the system, coupled with poor management skills. Chemical fertilizers are scarce and expensive that the small-holder farmer cannot afford it. As a result, most farmers resort to the use of home refuse and farmyard manure with inadequate knowledge of exact application rate. Pearl millet growing in sandy soils of Northern Nigeria are mostly poor in nutrient and organic matter, as a result yield are always low and could not withstand the food security challenges that the nation is facing. In order to meet the increasing demand for food, the need for improved management techniques through efficient use of both manure and inorganic fertilizer, and to identify the optimum plant population suitable for high productivity should be overemphasized.

1.3 JUSTIFICATION OF THE STUDY

Researches have shown that application of mineral fertilizers and manure increase millet growth and yield. According to Maman *et al.* (2000), pearl millet grain and stover yields increased with application of a combination of cattle manure and P fertilizer. Organic manure can improve soil biophysical conditions thereby making the soil more productive and sustainable. Fertilizer point applications at planting (micro-dose) or to young seedlings can reduce phosphorus fixation in the soil, and promote stand establishment and early season growth. This includes increase in root and shoot growth, and enhance infection with vesicular arbuscular mycorrhizae further increasing nutrient uptake (Bagayoko *et al.*, 2000; Fatondji *et al.*,2001; Valluru *et al.,* 2010). which result in increased grain and stover yields (Dimes *et al*., 2003; Bagayoko *et al*., 2011). In-organic fertilizer on the other hand have high concentration of nutrients readily available to crops, but its use is hampered by its inaccessibility to majority of the farmers due to high cost and infrastructural problems in a developing country like Nigeria (Webber *et al.* 2001). It is therefore more economical to use sub-optimal of both the organic and inorganic fertilizers in form of micro-dosing so as to reduce cost while providing the optimum nutrients required for growth and productivity of millet.

1.4 OBJECTIVES OF THE STUDY

The objectives of the study were to:

i. determine the effects of organic and inorganic fertilizers micro-dosing on growth and yield of pearl millet,

ii. determine the effect of intra-row spacing on the growth and yield of pearl millet.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 EFFECTS OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH AND YIELD OF PEARL MIILET

2.1.1 Effects of Manure on Growth and Yield of Pearl Millet

Application of organic fertilizer is an important means of maintaining soil fertility and is found to be environmentally friendly. Organic matter contains varying amounts of plants nutrients, especially nitrogen, phosphorus and potassium, which are slowly released into the soil for plant uptake (Gachene and Gathiru, 2003). Kwari and Bibinu (2002) recommended a rate of 7.5 to 10.0 t/ha of animal manure for cereals in general. Significantly high crop yields were obtained in both short and long-term with the application of increasing rate of farmyard manure. The yield obtained was similar to that obtained with the application of inorganic fertilizer. The organic component of the mixture may give additional benefits in the longer term. Result of a study conducted by Agbede *et al*. (2008) on effect of poultry manure on growth of sorghum in Southern Nigeria showed that manure significantly increased plant height, leaf area, stem girth and 1000 seed weight and grain yield over the three years of study. The overall mean plant height, leaf area, stem girth, shoot dry weight, increased by 7.92%, 26.79%, 7.17%, and 30.36%, respectively. However, humus enhances the utilization of fertilizer nutrients by enhancing water retention ability of soil (Kwari and Bibinu, 2002) thus increasing yield and yield components of crops. The use of poultry manure had been reported to improve growth and yield of maize and improves the chemical and biological qualities of the soil which increases crop productivity than chemical fertilizers (Obi and Ebo, 1995; Ezeibekwe *et al*., 2009).Agbede *et al*. (2008) reported increased shoot and grain yields of sorghum with three years of poultry manure fertilization from 22.4-29.2t/ha and 1.14-1.57t/ha, respectively, while1000 seed weight and grain yield increased by 37.29% and 37.72%, respectively. In another study Ashiono *et al*. (2005) reported increased grain yield of sorghum with application of FYM up to 20 t/ha, which ranged from 7.2-12.64% over the non-application and increase in stover yield due to FYM ranged from 2.3 to 8.4%. Poultry manure is an important organic nutrient source used to increase pearl millet grain and stover yields. On-farm studies conducted in 2004 through 2006 by Maman and Mason (2013) in Niger indicated that application of 2 t ha^{-1} poultry manure increased pearl millet grain yield by 56% and stover yield by 53%.

2.1.2 Effects of Mineral Fertilizer on Growth and Yield of Pearl Millet

Chemical fertilizers are used in modern agriculture to correct known plant nutrient deficiencies; to provide high levels of nutrition, which aid plants in withstanding stress conditions; to maintain optimum soil fertility conditions; and to improve crop quality (Wapa *et al*. 2014). A study was carried out on the influence of mineral fertilizers on millet grain quality at Belarus by Lapa and Lomonos (2007). Their finding results established that application of NPK 90:40:0 had ensured maximal 1000 grain weight of 6.43g. The mineral fertilizer application promoted the increase of protein and amino acid contents of the grain by 10.4% and 11.7%, respectively. Research has indicated that pearl millet grain and stover yields increase with fertilizer application, but little adoption has occurred due to availability and cost of fertilizer, and low grain prices (Abdoulaye and Sanders, 2005; Vitale and Sanders, 2005). Grain yields of pearl millet can be reliably high when chemical fertilizers are applied to soils with sufficient moisture (Maman *et al*., 2000; Diseko, 2005). Saidou *et al*. (2010) while conducting research on the use of mineral fertilizer for millet production reported significant effect of fertilizer application on yield and biomass production. Grain yield increased with increase in the mineral fertilizer. Patil *et al*. (2015) while working with different rates of fertilizer and their application methods reported that the application of RDF (60:30:00 Kg NPK ha^{-1}) through briquettes was found significantly superior over RDF through fertilizers, 50 % RDF through briquettes, farmers practice and control treatments, however it was at par with the application of 75 % RDF through briquettes. Higher millet grain yield observed due to the briquette application might be due to reduction in leaching losses of nutrients and increase in the availability of nutrients. The influence of time of planting and fertilizer application on growth and yield of pearl millet was studied at the Teaching and Research Farm of the University of Agriculture Makurdi, Benue State, Nigeria (Agber *et al*., 2012). Their result indicated that application of 60:30:30 kg NPK/ha gave higher seed yield of 1517 and 1250 kg/ha in 2008 and 2009, respectively than other treatments.

Furthermore, a study was conducted to determine the grain and stover yield response of pearl millet to micro-dose fertilizer application alone, and micro-dose combined with N and P fertilizer application rates across years and locations in West Africa (Bagayoko *et al*., 2011). The result of the study indicated that micro-dose fertilizer application increased pearl millet grain yields by 240 to 300 kg ha^{-1} on sandy soils across a broad range of climatic and soil conditions in West Africa, while increasing pearl millet grain yields by 400 kg ha^{-1} on silty clay soils in Mali. Stover yield increases of pearl millet were 250 to 400 kg ha^{-1} on sandy soils and 500 to 2500 kg ha^{-1} on silty clay soils in Mali. Application of 20 kg P_2O_5 ha^{-1} and 30 kg N ha^{-1} in addition to micro-dose commonly increased grain yields by 140 to 180 kg ha^{-1} and stover yields by 600 to 1500 kg ha^{-1} over that of micro-dose application only. These results indicate that micro-dose in combination with 20 kg P_2O_5 ha^{-1} and 30 kg N ha^{-1} fertilizer application is required to optimize both grain and stover yield of pearl millet in West Africa to meet food, fuel and soil improvement needs of farmers.

2.1.3 Combined Effects of Organic and Inorganic Fertilizer on Growth and Yield of Pearl Millet

Combining application of organic manures and mineral fertilizers, the yield is expected to stabilize over the years, indicating substantial improvement in soil fertility. It was reported by Rayar (2000) that mineral fertilizer and organic manures whether separately or combined have beneficial effects upon soil and crop, their combined use is expected to yield rewarding dividends. The use of poultry manure droppings, cow dung and household wastes increase the efficiency of mineral fertilizers by providing the secondary and micro-nutrients not present in the mineral fertilizers (Wapa *et al*., 2014). Yamoah *et al*. (2002) reported that millet plots treated with a combination of crop residues and fertilizer yielded as much as 2160 kg ha^{-1} whereas their unfertilized plots produced only 210kg ha^{-1}. Phosphorus uptake in maize was increased with application of poultry manure droppings in combination with chemical fertilizer (Wapa *et al*., 2014). A tremendous response of maize to foliar application of boron in the presence of FYM was also recorded. Awotundun (2005), found increased height and grain yield of pop-corn with application of FYM and NPK fertilizers when applied in combination.

Several researchers working in Northern Nigeria have demonstrated the benefits of complementary use of mineral fertilizers and manures (Tarfa *et al*., 2001; Yaro *et al*., 2003; Yusuf *et al*., 2003). When applying organic resources and mineral fertilizer simultaneously, one hardly ever observes negative interactions, indicating that even without clearly understanding the mechanisms underlying positive interactions, applying organic resources in combination with mineral inputs stands as an appropriate fertility management principle. Bationo and Lompo (2003), reported significant increase in yield of maize with application of mineral fertilizer, but yield was higher when mineral fertilizer was combined with organic manure. Bationo *et al*. (2001) reported that efficient use of both organic and inorganic fertilizer is required to optimize crop yield to meet the food needs of a growing population and minimize soil degradation. In Samaru it was found that, in the absence of fertilizers, it required at least the application of 7.5 t ha^{-1} of manure to measure an increase in soil C and N. When fertilizers were added, the manure rate dropped to 5.0 t ha^{-1}. Iwuafor *et al*. (2002) reported a similar trend in maize yield on farmer-managed demonstration trials in the NGS of Nigeria. An ideal combination of organic and mineral fertilizers does not exist. The optimum combination depends on the targets and the situation of the particular farm. The major constraint to use of FYM is the large quantities required to satisfy crop need. For example, 100 kg of 10-0-10 fertilizer contains about the same amount of N-P-K as 2,000 kg of FYM. Thus FYM needs to be applied at very high rates to make up for their low nutrient content and to supply enough humus to improve the soil physical condition. Even then, availability of the nutrients to plants depends on the handling method used to conserve and store the manure before field application. Tremendous nutrient losses due to volatilization and leaching are encountered during storage and application if FYM are not properly handled. Therefore, combining the FYM with mineral fertilizer will reduce the nutrient losses. Balanced fertilization using both organic and chemical fertilizers is important for maintenance of soil organic matter content and long-term soil productivity in the tropics where soil organic matter content is low.

2.2 EFFECTS OF INTRA-ROW SPACING ON GROWTH AND YIELD OF PEARL MILLET

Plant spacing is an important agronomic attribute because it is believed to have effects on light interception during which photosynthesis takes place. Very close spacing make plants cluster together hence creating competition for available resources which affect the crop yield. Proper plant spacing gives the right plant density (Ibeawuchi *et al.,* 2008). The optimal plant densities for pearl millet production differ among geographic regions and research indicates that grain yield generally increases as plant density increases (Jones and Johnson, 1991; Heiniger *et al.*, 1997).

Selecting optimal row spacing is important to improve crop productivity as plants growing in too wide of a row may not efficiently utilize light, water, and nutrient resources. However, crops grown in too narrow rows may result in severe inter row competition and results in yield detrimental effects (Mashiqaa and Ngwako, 2011). Row spacing also modifies plant architecture, photosynthetic competence of leaves, and dry matter partitioning in several field crops (Hussain *et al.*, 2012). The impact of row spacing on cereal yield varies depending on the rainfall growing season, the time of sowing and the potential yield of the crop. The higher the yield potential, the greater the negative impact of wide rows on cereal yields.

Likewise, planting pearl millet in widely spaced rows and is perceived to be a practice that reduces pearl millet crop failure. There appears to be no justification, at least in terms of crop water use, to the use of wide spacing. Ijoyah *et al*. (2015) while studying the effects of intra-row spacing of pearl millet reported that early days to 50% flowering and maturity were recorded in closer intra-row spacing (15 cm and 20 cm), as compared to those recorded for wider intra-row spacing of 25 cm and 30 cm. This could be due to the higher population density and greater competition for nutrients at closer intra-row spacing. The stressed plants in closer intra-row spacing attained 50% flowering and maturity earlier than those from wider intra-row spacing. Two field experiments were conducted on two pearl millet landraces (Serere 6A and Tswana) during the 2009/2010 growing season in Sebele, Botswana to evaluate the response of the two landraces to different intra-row spacing (intra-row spacing of 15, 25 and 35 cm with a constant row spacing of 75 cm) were studied. The growth and development parameters (plant height, leaf area, number of leaves per plant, number of tillers per plant) showed a significant ($P<0.05$) treatment effects for wider plant spacing (35 × 75 cm) on plant height. Wider plant spacing revealed superior absolute numbers as compared to the narrower plant spacing. Leaf area of the two pearl millet landraces was significantly higher in the wider plant spacing (35 × 75 cm) compared to the narrower spacing. Leaf numbers per plant significantly increased ($P<0.05$) in the wider plant spacing. Based on their findings wider plant spacing outperformed the narrower plant spacing for all the measured growth and development parameters. Saba *et al*. (2015) studied three intra-row spacing (25 cm, 50 cm and 75 cm with an inter-row spacing of 75 cm) on growth and yield of pearl millet in Sokoto and the result indicated that spacing had significant effect on stand count with 25 cm recording the highest, tiller count at later stage with 75 cm having the highest tiller count. These spacing had no significant effect on plant height and panicle length in their study area. Kamal *et al*. (2013) while studying the effect of three plants spacing (50,70 and 90 cm), with 70 cm inter-row spacing in Zalingei area, Sudan, reported that plant spacing had no significant effect on most of growth parameters except one of the locations where 90 cm plant spacing recorded the highest leaf area (165.8 cm^2) whereas 50 cm plant spacing gave the lowest leaf area (136.4 cm^2).

High plant densities are used to increase crop yield per unit area while yield per plant decreases with increased plant densities. Total light interception by the canopy is maximized and total yield is increased. The high plant densities significantly increased leaf area, grain yield and harvest index in different maize cultivars compared with low plant densities. Wider spacing significantly promoted grain yield of maize crop compared with narrow rows (Muhammed *et al.* 2002). The best way to get uniform plant stands is to plant in regularly spaced rows and at regular intervals within the row (Faisul *et al*. 2013).Wailare (2010) studied the effect of intra-row spacing and variety on yield and yield components of millet and found that the three intra-rosw spacing of 30, 40 and 50 cm did not show statistically significant differences on plant height, 1000 grain weight, panicle length, panicle weight and number of panicles per plant and grain yield and stover weight, except panicle diameter which was significantly affected. Intra-row spacing density is a management variable that affects the production and quality of most crops. Though optimal plant densities for production differ among geographic regions, research indicates that grain yield generally increases as plant density increases. Saba *et al*. (2015) while studying the effect of three intra-row spacing on yield of pearl millet indicated significant stover yield and grain yield. The spacing of 25 cm and 50 cm out-performed the 75cm intra-row spacing. They concluded that excessively wide or narrow spacing leads to reduction in yield. Their findings also showed that wide spacing of 50 cm and 75 cm recorded higher 1000-grain weight than the narrow spacing of 25 cm. Also results of study in Sudan by Kamal *et al*. (2013) revealed that plant intra-row spacing of 50 cm, 70 cm and 90 cm by 75 cm inter-row spacing had no significant effect on yield parameters except on 1000-grain weight and yield. When Hassan and Abuelgasim (2006) studied the influence of inter-row spacing (75,100 and 150 cm and the intra-row spacing (50, 75 and 100 cm) on grain yield and its component of two pearl millet cultivars found that all traits were significantly affected by inter- row spacing in both seasons and intra-row spacing in the first season.

2.3 INTERACTION OF FERTILIZER AND INTRA-ROW SPACING ON GROWTH AND YIELD OF PEARL MILLET

One factor that appears to influence growth and yield of millet under different row spacing is the rate of fertilizer application. Ibrahim (2015) conducted a study on fertilizer and intra-row spacing on millet and found out significant interaction between fertilizer and spacing in which Intra-row spacing at 25 cm without fertilizer showed the highest number of days (86) to maturity while the lowest number of days (79) was recorded for micro-dose NPK + organic manure applied in combination with 150 cm intra-row spacing. He further stated that significant interactions existed on panicle length and stover yield in which NPK 60:30:30 applied at 150 cm intra-row spacing recorded the longest panicles (28.2 cm) while

25 cm intra-row spacing without fertilizer (control) recorded the shortest panicles (20 cm) and NPK 60:30:30 at 25 cm recorded highest stover yield (7, 772 kg ha^{-1}),

Barbieri *et al.* (2000) found a 14–21% greater grain yield at a 0.35 m spacing than at a 0.70 m spacing for well-fertilized maize, this improvement in grain yield rose to 27–43% for N-deficient maize. The narrow spacing improved yield by increasing both kernels per cob and cobs per hectare, compared to the wider spacing with low N treatment in their study. Ma *et al.* (2003) reported significant interactions between row spacing and N rates ($P < 0.01$); grain yield of Pioneer 38P06 Bt maize with the 80 kg N ha^{-1}fertilizer treatment was significantly greater (14.6%) at the 0.51 m row spacing than at the conventional 0.76 m row spacing, an advantage of narrow row spacing against conventional row spacing similar to those found in some areas of Argentina (Barbieri *et al*.2000).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL SITES

The field experiment was conducted in 2015 cropping season at two different locations namely: Wasai-Minjibir, in Minjibir local government area, Kano state. It is located in the Sudan savanna ecological zone with latitude12^{o}10’N and longitude 8^{o}39’E at an elevation of 442m above sea level and Farmers field at Gambawa village, Gumel Local government area, Jigawa state, in Sudano-Sahelian savanna ecological Zone at latitude 12^{o}61’N and longitude 9^{o}45’E with an elevation of 375m above sea level.

3.2 TREATMENTS AND EXPERIMENTAL DESIGN

The treatments consisted of a control, 9 levels of manure and inorganic fertilizers and two intra-row spacing (50 and 100 cm).

The experiment was laid out in a split plot design with four replications. The main plot consisted of organic and inorganic fertilizers (manure, mineral fertilizer and their combinations). The intra-row spacing treatments were allocated to the subplot. The gross plot size measuring 5 x 3 m (15 m^2) There was 1.5 m lee ways between replicates and 1.0m within replicate, while 1m alley in all borders. In general, the whole location was 15 m x 80 m =1200 m^2. The fertilizer micro-dose treatments were:

i. Control: - No fertilizer.

ii. Cow manure (50g) + poultry manure (50g): - A combination of two manure sources was applied per hill during planting in a hole of 5 cm and buried with soil.

iii. Cow manure (100 g hill^{-1}): - The cow dung manure was measured up to 100 g and was buried with the seeds in same hole during sowing. At 100 g hill^{-1}, one hectare required 1600 kg ha^{-1} and 2933.5 kg ha^{-1} when 24 and 44 hills per plot were used, respectively. When applied at the rate of 50 g hill^{-1}, it was half of the above stated rate.

iv. NPK (60:30:30): - This was drilled into the soil during planting and covered with soil. For the start NPK 30:30:30 was applied and the remaining 30 kg of N ha^{-1} was side-dressed in form of urea at 4 WAS.

v. NPK micro-dose (3g $hill^{-1}$): - After weighing 3g micro-dose of NPK, it was applied in a hole of 5 cm deep along with the seeds during planting. It was also applied in micro-doses of 3 g per hill where one hectare required 48kg using 24 hills per plot and 88 kg using 48 hills per plot, respectively.

vi. NPK microdose (3g) + cow manure (100 g): - The treatments were applied per hill together with the seeds during planting in a hole of 5 cm depth.

vii. NPK micro-dose (3g) + Poultry manure (100 g): -This combination of micro-doses was applied per hill in a hole of 5 cm depth during sowing.

viii. Poul+try manure (50 g $hill^{-1}$): - This was applied during planting in a hole of 5 cm with the seeds and buried with soil.

ix. Poultry manure (100g $hill^{-1}$): - A micro- dose of 100 g PM was buried with the seeds in a hole of 5 cm depth during sowing.

x. Poultry manure (150 g $hill^{-1}$): - This is a dose of 150 g PM that was applied per hill along with the seeds during planting into a hole of 5cm depth.

3.3 SOIL ANALYSIS

Soils from the experimental sites were collected at a depth of 0-30 cm prior to sowing. The samples were air dried at room temperature, ground and sieved before analyzed for physico-chemical properties. The analysis was carried out at the Soil Science Laboratory, Bayero University, Kano.

3.4 AGRONOMIC PRACTICES

3.4.1 Land Preparation

The land was first cleared, harrowed and ridged by tractor at a normal spacing of 75cm between ridges at Wasai-Minjibir. At Gambawa, draught bulls were used to carry out the ridging operation.

3.4.2 Seed Source/Variety

Seed supply for the field experiment was obtained from the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). Super SOSAT variety of millet was used.

3.4.3 Seed Treatment

The seeds were treated with Apron Star, at one (10 g) sachet to 3 kg of seeds.

3.4.4 Sowing and Thinning

Sowing at Wasai-Minjibir took place on 13/07/ 2015 and that of Gambawa took place on 20/07/2015. Five 5 seeds were sown alongside the fertilizer treatment in a hole, which were later thinned to two stands per hill at three weeks after sowing (WAS).

3.4.5 Weed Control

Weeds were controlled manually using hand hoe. Three different hoe weeding were carried out during the season at 3 ,6 and 9 WAS.

3.4.6 Harvesting and Threshing

Harvesting was carried out on 10/10/2015. The panicles were harvested at physiological maturity stage and sun dried to constant weight. These were later threshed manually and winnowed to separate the grains from the chaff. The activity was carried out separately for each net plot (1.5 m x 0.75 m).

3.5 DATA COLLECTION

3.5.1 Meteorological Data

Data on the weather conditions of the locations were obtained from ICRISAT's weather stations at Wasai, Minjibir local government area, Kano state (IAR Kano sub-station) at Wasai-Minjibir and Gambawa ICRISAT weather station, Gumel local government area, Jigawa state. The parameters recorded were maximum and minimum temperatures, rainfall and maximum and minimum relative humidity.

3.5.2 Crop Data

Data were collected from the plants within the net plot (two middle rows). The following data were taken into account:

i. Plant height: - The height of 5 plants chosen at random within the net plot were measured at maturity stage. Measurement begun from the ground level to the flag leaf on the stover near the panicle, using a meter rule.

ii. Leaf Chlorophyll content: - A digital leaf chlorophyll measuring meter/device was clamped to the leaf blade of the crop stands within the net plot, 5 different plants selected at random gave an average reading per net plot. Readings were taken at 3, 6 and 9 WAS.

iii. Leaf area index (LAI): - This was done by placing on the ground surface a leaf area reading instrument under the crop canopy of two rows in a net plot. A light sensor attached to it would automatically read the intensity of light shaded by the crop canopy. Readings were taken from 5 different stands chosen at random in the net plot at 6, 9 and 12 WAS.

iv. Number of days to 50% flowering: -This is the number of days from sowing to the time when 50% of the plants in each net plot had flowered and was recorded.

v. Number of days to maturity: -The number of days from sowing to the time when the millet became physiologically matured at least 95% of each plot. Maturity is exhibited by the presence of dark layer covering the lower part of the seed which would however be green at immature stage within the panicle.

vi. Total Stands at harvest: - This represented the number of plants and the total tillers both productive and unproductive in the net plots. They were counted at harvest and recorded. The total stands per plot were later extrapolated to per hectare basis.

vii. Plant lodging: -The number of stems that fell down in each net plot were counted and recorded prior to harvest.

viii. Number of panicles per plot: -The total number of panicles in the net plot were harvested, counted and recorded. The total number of panicles per net plot was later extrapolated to per hectare basis.

ix. Panicle length: -The length of 5 panicles randomly selected from the net plots were measured using meter rule calibrated in centimeter and the mean was recorded as the panicle length of the plant.

x. Grain yield (kg ha^{-1}): -The panicles in the net plot were cut and sun dried. The dried panicles were threshed, winnowed and the grains weighed using salter sensitive balance scale (model number 1036SVSSDR). The results taken were recorded accordingly and the per plot results were then extrapolated to per hectare basis.

xi. Stover yield (kg ha^{-1}): - The plants whose panicles were cut for grain weight were cut at the ground level. The stover was then rolled and left on the field for sun drying for twenty days after which the dried stover was weighed. The stover weight per plot was later extrapolated to per hectare.

xii. 1000-grain weight: This was counted using Numigral seed counter by Tripett and renaua and then weighed using Salter sensitive balance Scale and the weight recorded.

xiii. Harvest Index (HI%): - This is the percent proportion of the grain from the total above ground dry weight of the plant shoot at maturity (Deloughery and Rookston, 1979). It was calculated as follows: H I (%) = y/p^w x 100.

Where y is grain weight and p^w is the total above ground sun dry weight of the plant shoot. It represents the panicle weight and stover weight of each net plot.

xiv. Threshing Percentage (TH%): - This is the percent proportion of the dry grain weight out of the total panicle dry weight. It was determined for each net plot by: TH (%) = W^g/W^h x 100.

Where W^g is the sun dry grain weight and W^h is sun dry panicle weight.

3.6 DATA ANALYSIS

Data collected were subjected to analysis of variance (ANOVA) using Genstart Statistical package. Duncan Multiple Range Test (DMRT) was used in ranking treatment means.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Some Physical and Chemical Properties of the Soils

Results of the physical and chemical properties of soils at the two experimental sites were presented in Table 1. At Wasai-Minjibir, the soil pH in water (H_2O) was strongly acidic (5.22) and extremely acidic (4.43) in $CaCl_2$ solution. At Gambawa, the soil pH in water was slightly acidic (6.37) and strongly acidic (5.21) in presence of calcium chloride. The organic carbon content (OC) were low (< 0.3 gkg^{-1}) in both locations. The quantity of total nitrogen (N) at Wasai-Minjibir soil was low (0.1 gkg^{-1}) but very low at Gambawa (< 0.1 gkg^{-1}). Landon (1991) classified soils having total N of greater than 1.0% as very high, 0.5-1.0% high, 0.2-0.5% medium, 0.1-0.2% low and less than 0.1% as very low in total nitrogen content. Therefore, the soils of the experimental sites were low and very low in total nitrogen content. The soils available phosphorus (P) for both locations were low (<10gkg^{-1}). Likewise, Olsen *et al*. (1954) rating of available P soil test of >25, 18-25, 10-17, 5-9, <5 ppm were classified as very high, high, medium, low and very low, respectively. Thus, the soils of the study area fall under low category in its available P. The potassium (K) level of the soil in both location was high (>0.30 Cmol (+) kg^{-1}) but higher at Gambawa than Wasai-Minjibir. The exchangeable bases of calcium (Ca) and sodium (Na) were found to be low (< 2 Cmol (+) kg-^{1}) at Wasai-Minjibir site whereas magnesium was at medium range (> 0.3 Cmol (+) Kg^{-1}). At Gambawa, sodium (Na), magnesium (mg) and calcium (Ca) were in the order of low, medium and high, respectively. On the other hand, the Cation Exchange Capacity (CEC) were at low category (< 6 Cmol (+) kg^{-1}) in both locations. Landon (1991) who classified soils having CEC of >40, 25-40, 15-25, 5-15, <5

Table 1: Physico-Chemical Properties of Surface (0-30 cm) Soils of the Experimental Sites at Wasai Minjibir and Gambawa During the 2015 Rainy Season.

Property	**Wasai-Minjibir**	**Gambawa**
Physical (0--30cm)		
Sand (%)	88.64	80.64
Silt (%)	1.28	3.28
Clay (%)	10.08	16.08
Textural class	Loamy sand	Sandy loam
Chemical		
pH $_{1:2.5}$ in (H_2O)	5.2	6.4
pH $_{1:2.5}$ in ($CaCl_2$)	4.4	5.2
EC 1:5 (dSm^{-1})	0.08	0.02
Organic Carbon (g kg^{-1})	0.210	0.160
Total Nitrogen (g kg^{-1})	0.140	0.070
Available Phosphorus (mg kg^{-1})	4.478	4.104
Exchangeable bases		
Magnesium (Cmol kg^{-1})	0.345	1.019
Calcium (cmol kg^{-1})	0.896	1.609
Sodium (Cmol kg^{-1})	0.094	0.123
Potassium (cmol kg^{-1})	0.357	0.446

Source: Soil Science Laboratory, Bayero University Kano meq/100g as very high, high, medium, low and very low, respectively (Abdifarah, 2013). The electrical conductivity of the soil in both locations fall within low range (≤ 4.0 dSm^{-1}). According to this experiment, the soil from Wasai-Minjibir site was texturally classified as loamy sand while that of Gambawa site was sandy loam, with high percentage of sand than silt and clay.

4.1.2 Weather Condition of the Experimental Sites

The weather data obtained from the two experimental sites indicated monthly weather conditions during growing season (May- October) as presented in Appendix I. At Wasai-Minjibir, a total of 545mm of rainfall was received with a peak of 325mm rainfall recorded in August indicating about 60% of annual total received in a single month. Average monthly minimum temperature varied from 22 to 25.4 ^{0}C while maximum temperature ranges from 31.5 to 41^{0}C. Also average monthly relative humidity varied from 56 to 96 % for maximum while minimum varied from 10.5 to 56%. On the contrary, the monthly peak rainfall was received in July (170.7 mm) at Gambawa, with a total rainfall of 401 mm recorded for the growing season. Average monthly minimum temperature varied from 20 to 25.1 ^{0}C while maximum temperature ranges from 33 to 42^{0}C. Also average monthly relative humidity varied from 45 to 99 % for maximum while minimum varied from 7.9 to 54%.

4.1.3 Effects of Fertilizer Treatment and Intra-Row Spacing on Growth and Yield of Pearl Millet at Wasai-Minjibir and Gambawa During the 2015 Rainy Season

Stands count at harvest ha^{-1}

The main effects of fertilizer treatments and intra-row spacing on number of stands count per ha^{-1} in Minijibir and Gambawa is presented in Table 2. There were no significant differences among the fertilizer treatments at Wasai-Minjibir.

Table 2: Effects of Fertilizer Treatments and Intra-Row Spacing on Number of Stand counts at harvest, Days to 50% Flowering and Days to Maturity of millet at Wasai-Minjibir and Gambawa During the 2015 Rainy Season.

	Wasai-Minjibir			Gambawa		
Treatments	**No. of Stands ha^{-1}**	**Days to 50% Flowering**	**Days to Maturity**	**No. of Stands ha^{-1}**	**Days to 50% Flowering**	**Days to Maturity**
Fertilizer (F)						
Control	49,700	60.8 a	86.0 a	20,400 bc	60.1	84.6 abc
Cow manure(50g) + poultry Manure(50g)	53,500	60.3 ab	85.0 ab	25,500 ab	60.1	84.8 abc
Cow manure(100g)	54,130	60.4 ab	86.0 a	12,400 c	60.1	84.3 bc
NPK 60:30:30	57,500	60.3 ab	85.5 a	33,300 a	60.0	84.0 bc
NPK micro-dose (3g)	55,700	59.9 ab	85.0 ab	29,900 ab	60.4	83.5 c
NPK micro-dose (3g) + cow manure (100g)	51,500	59.6 b	84.4 b	34,000 a	60.4	84.0 bc
NPK microdose (3g) + Poultry manure (100g)	53,100	60.1 ab	85.8 a	26,100 ab	60.3	84.9 abc
Poultry manure (50g)	53,300	60.6 ab	85.3 ab	30,400ab	60.5	85.00 abc
Poultry manure (100g)	51,300	60.1 ab	85.3 ab	30,800 a	60.5	85.6 ab
Poultry manure (150g)	50,800	60.8 a	86.0 a	29,300 ab	60.3	86.4 a
SE±	4,870	0.520	0.508	5,068	0.450	0.864
Spacing (cm)						
100	46,440 b	60.45	85.70	23,200 b	60.500	84.78
50	59,700 a	60.10	85.13	31,300 a	60.025	84.63
SE±	1,640	0.172	0.197	1,520	0.175	0.187
F x S	*****	**NS**	**NS**	**NS**	**NS**	**NS**

Means within the same treatment and column followed by same letter(s) are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT). NS = not significant, * = significant at 5% level

The highest mean stand count (57,500) was obtained with application of NPK 60:30:30 which was not significantly different from the means obtained with other fertilizer treatments. At Gambawa, significant differences were observed among the fertilizer treatments. The highest number of stands (34,000) was recorded with the application of NPK micro-dose (3g) + cow manure (100g). The difference between this mean and the means obtained with cow manure (100g) and the control were significant ($P \leq 0.05$). Generally, the mean stand counts were lower at Gambawa compared to Wasai-Minjibir. The interaction between fertilizer treatments and intra-row spacing on stand counts at harvest was significant at Wasai-Minjibir (Table 3). At 50 cm intra-row spacing no significant difference observed among fertilizer levels. At 100 cm intra-row spacing however, significant differences exist between control and some treatments. At various fertilizer levels, 50 cm intra-row spacing resulted to high stands count than 100 cm intra-row spacing.

Number of days to 50% flowering

The effects of fertilizer treatments and intra-row spacing on days to 50% flowering is shown in Table 2. Number of days to 50% flowering was significantly affected at Wasai-Minjibir only. At Wasai-Minjibir, the control and poultry manure(150g) took longer days to attain days to 50% flowering that were statistically similar with other fertilizer levels except NPK micro-dose (3g) + cow manure (100g) that took shorter days to attain 50% flowering. At Gambawa, the differences among the fertilizer treatments were statistically not significant ($P \geq 0.05$). The effects of intra-row spacing on days to 50% flowering was not significant in both locations. The interaction between fertilizer treatments and intra-row spacing on days to 50% flowering was not significant at both locations.

Table 3: Interaction between Fertilizer Treatments and Spacing on Stand counts at Harvest of Millet at Wasai-Minjibir During 2015 Rainy Season.

	Spacing	
Fertilizer(F)	50cm	100cm
Control	63700 a	35,730 h
Cow manure (50g) + poultry manure (50g)	64,000 a	43,100 fgh
Cow manure (100g)	59,700 abcd	48,700 c-g
NPK 60:30:30	61,300 ab	53,700 a-f
NPK microdose (3g)	62,000 a	49,300 b-g
NPK microdose 3g) + cow manure(100g)	62,670 a	40,400 gh
NPK microdose (3g) + Poultry manure (100g)	57,700 a-e	48,400 defg
Poultry manure (50g)	54,400 a-f	52,400 a-g
Poultry manure (100g)	55,300 a-e	37,300 efgh
Poultry manure(150g)	56,000 a-e	45,700 efgh
SE±	6,097	

Means followed by the same letter(s) are not significantly different at 5% level of probability using Duncan Multiple Range Test DMRT.

Number of days to maturity

The means of treatments for number of days to maturity at both locations are presented in Table 2. At Wasai-Minjibir, the influence of fertilizer treatments on number of days to maturity were observed at both locations where only NPK micro-dose (3g) + cow manure (100g) recorded the least number of days to maturity (84) as against 86 days obtained among other fertilizer treatments. At Gambawa less number of days to maturity (84days) were recorded by NPK micro-dose (3g) which was statistically at par with results obtained from NPK 60:30:30, NPK micro dose (3g) + cow manure (100g) and cow manure (100g). More number of days (86) were obtained from plots fertilized with poultry manure (150g) at both locations. No Significant difference was observed between the two intra-row spacing. The interaction between fertilizer and spacing was not significant at both locations.

Plant height(m)

The means of treatments for plant height are presented in Table 4. The differences between the means of fertilizer treatment were not significant at Wasai-Minjibir, but significant ($P<0.05$) at Gambawa. At Gambawa, NPK 60:30:30 produced significantly taller plants (1.63 m), but was not significantly different from the heights obtained at NPK micro-dose (3g) + poultry manure (100g). Significantly shorter plants were obtained at the control treatment (1.09 m). There was no significant difference observed between the two intra-row spacings at both locations. The interaction between the fertilizer treatments and spacing at both locations were also not significant.

Plant lodging %

The main effects of fertilizer treatments and intra-row spacing on plant lodging is presented in Table 4. Significant treatments effects were observed at both locations. At Wasai-Minjibir, highest number of plant lodging (19.0) was obtained in plots treated with

Table 4: Effects of Fertilizer Treatment and Intra-Row Spacing on Plant Height and Plant Lodging of Millet at Wasai Minjibir and Gambawa During the 2015 Rainy Season.

	Wasai Minjibir		**Gambawa**	
Treatments	Plant height (m)	Plant lodging %	Plant height (m)	Plant lodging %
Fertilizer (F)				
Control	1.79	17 ab	1.09 d	8 d
cow manure (50g) + poultry manure	1.83	16 ab	1.43 abc	20 abc
Cow manure(100g)	1.77	10 bc	1.32 bcd	7 d
NPK 60:30:30	1.76	19 a	1.63 a	16 ab
NPK microdose (3g)	1.71	16 ab	1.28 cd	17 abc
NPK microdose (3g) + cow manure (100g)	1.76	15 ab	1.19 d	20 a
NPK microdose (3g) + Poultry manure (100g)	1.88	9 bc	1.60 a	8 c-d
Poultry manure (50g)	1.80	5 c	1.29 cd	10 bcd
Poultry manure(100g)	1.87	11bc	1.55 ab	11 bcd
Poultry manure (150g)	1.85	4 c	1.56 a	13 abcd
SE±	0.124	1.719	0.114	1.166
Spacing (cm)				
100	1.801	13	1.413	13
50	1.804	12	1.373	14
SE±	0.035	0.868	0.053	0.378
F x S	NS	NS	NS	NS

Means within the same treatment and column followed by same letter(s) are significantly not different at 5% level of probability using Duncan multiple range test (DMRT). NS = not significant, * = significant at 5% level of probability

NPK 60:30:30, the difference between the means of NPK 60:30:30 and those of NPK micro-dose (3g) + poultry manure (100g), poultry manure (150g) and poultry manure (50g) were statistically similar. Lower number of plant lodging was recorded in plots treated with poultry manure (150g) and poultry manure (50g). At Gambawa, highest number of plant lodging (20.0) was obtained in plots treated with NPK micro-dose (3g) + cow manure (100g) and cow manure(50g) + poultry manure(50g) although not statistically different from the values recorded by NPK microdose (3g) while the least value was obtained with cow manure (100g) and control. Effect of spacing on number of plant lodging was only significant at Gambawa. It was observed that 50cm spacing had the highest number of plant lodging compared to 100cm spacing. The interaction between the fertilizer treatments and intra-row spacing on number of plant lodging was not significant at both locations.

Number of panicles ha^{-1}

Significant differences were observed among the fertilizer treatments in number of panicles ha^{-1} in both locations (Table 5). At Wasai-Minjibir, NPK micro-dose (3g) + poultry manure (100g) produced the highest number of panicles ha^{-1} that were not significantly different with some fertilizer rates. The least number of panicles ha^{-1} was produced by poultry manure at 50g and 100g. At Gambawa, the highest number of panicles ha^{-1} was recorded with application of NPK micro-dose (3g) + cow manure (100g) and NPK 60:30:30 but were statistically similar with other rates. The differences between the means of this treatment with those of control, cow manure (50g) + poultry manure (50g) and cow manure (100g) was significant ($P \leq 0.05$). The least number of panicles ha^{-1} was produced by control and cow dung.

The intra-row spacing treatments showed significant differences ($P \leq 0.05$) at both locations. Higher number of panicles were obtained with 50 cm spacing at both locations.

Table 5: Effects of Fertilizer Treatment and Intra-row Spacing on Number of Panicles and Panicle Length of Millet at Wasai Minjibir and Gambawa During the 2015 Raining Season.

	Wasai Minjibir		**Gambawa**	
Treatments	Number of Panicles ha^{-1}	Panicle length(cm)	Number of Panicles ha^{-1}	Panicle length(cm)
Fertilizer (F)				
Control	53,900 abc	26.4	15,300 c	23.3 abc
cow manure (50g) + poultry manure (50g)	54,500 abc	27.1	20,800 bc	24.4 abc
Cow manure(100g)	55,100 abc	27.4	14,100 c	21.4 c
NPK 60:30:30	56,100 abc	26.7	30,000 a	26.0 a
NPK microdose (3g)	57,500 ab	26.2	28,400 ab	22.7 bc
NPK microdose (3g) + cow manure (100g)	49,500 abc	27.0	33,700 a	22.4 bc
NPK microdose (3g) + Poultry manure (100g)	58,700 a	26.3	25,300 ab	26.5 a
Poultry manure (50g)	47,200 c	26.5	27,300 ab	24.8 abc
Poultry manure(100g)	47,700 c	27.7	28,500 ab	25.4 ab
Poultry manure (150g)	48,800 bc	27.0	26,000 ab	24.7 abc
SE±	4,489	0.864	4,353	1.828
Spacing (cm)				
100	46,300 b	27.16	21,700 b	23.54
50	59,500 a	26.51	28,000 a	23.79
SE±	2017	0.444	1897	0.620
F x S	*	NS	NS	NS

Means within the same treatment and column followed by same letter(s) are significantly not different at 5% level of probability using Duncan multiple range test (DMRT). NS = not significant, * = significant at 5% level of probability

Interaction between fertilizer treatments and intra-row spacing on number of panicles ha^{-1} at Wasai-Minjibir is presented in Table 6. Looking at various fertilizer levels at 50cm intra-row spacing poultry manure (100g) produced least number of panicles ha^{-1} than the other levels that were statistically at par. At 100cm NPK microdose (3g) + cow manure (100g) and poultry manure 150g produced least of this parameter than others that were at par. At various levels of NPK fertilizer, intra-row spacing of 50cm significantly produced more of number of panicles ha^{-1}.

Panicle length (cm)

The effects of fertilizer treatment and intra-row spacing on panicle length is presented in Table 5. The difference between fertilizer treatment means was not significant on panicle length at Wasai-Minjibir but was significant at Gambawa. Plots treated with cow manure (100g) at Gambawa recorded generally lower mean panicle length than the other treatments, except with control. NPK micro-dose (3g) + cow manure (100g) and NPK 60:30:30 significantly produced longer panicles that were at par with other fertilizer levels. The effect of spacing on panicle length was not significant at both locations. The interaction of fertilizer versus intra-row spacing was also not significant at both locations.

Leaf chlorophyll content (LCC)

The effects of treatments on LCC are presented in Table 7. At Wasai-Minjibir, the influence of treatments was significant only at 3 and 6 WAS. At 3 WAS poultry manure(100g) significantly produced high LCC than some fertilizer levels that were at par while cow manure(50g) + poultry manner (50g) produced least LCC. At 6 WAS, NPK micro-dose (3g) + poultry manure(100g) significantly produced higher LCC than some fertilizer levels that were statistically similar. The lowest LCC was produced by the control,

Table 6: Interaction between Fertilizer Treatments and intra-row Spacing on Number of Panicles ha^{-1} of Millet at Wasai-Minjibir During the 2015 Rainy Season.

Means followed by same letter(s) are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT)

	Spacing	
Fertilizer (F)	50cm	100cm
Control	67,330 a	40,400 d
Cow manure (50g) + Poultry manure (50g)	64,660 a	44,400 cd
Cow manure (100g)	63,730 a	46,400 bcd
NPK 60:30:30	57,330 ab	55,066 abc
NPK microdose (3g)	64,660 a	50,400 bcd
NPK microdose (3g) + cow manure (100g)	57,330 ab	41,730 d
NPK micro-dose (3g) + Poultry manure (100g)	67,330 a	50,000 bcd
Poultry manure (50g)	49,060 bcd	45,330 bcd
Poultry manure(100g)	45,730 bcd	49,730 bcd
Poultry manure (150g)	58,000 ab	39,730 d
SE±	6360	

Table 7: Effects of Fertilizer Treatment and Intra-Row Spacing on Leaf Chlorophyll Content of Millet at Wasai-Minjibir and Gambawa During the 2015 Rainy Season.

	Minjibir			Gambawa		
	Chlorophyll Content (WAS)			Chlorophyll Content (WAS)		
Treatments	3	6	9	3	6	9
<u>Fertilizer (F)</u>						
Control	34.20 bc	46.69 b	56.41	26.64	38.51	53.90 a
Cow manure(50g) + Poultry manure (50g)	34.10 c	48.39 ab	56.19	30.43	38.14	40.86 c
Cow manure (100g)	34.52 bc	47.11 b	56.42	25.11	36.56	44.84 abc
NPK 60:30:30	37.97 ab	48.46 ab	58.02	33.64	42.92	51.35 ab
NPK microdose (3g)	37.94 abc	48.26 ab	53.15	29.08	39.27	41.91 bc
NPK microdose (3g) + Cow manure(100g)	37.97 ab	47.12 b	57.24	31.79	40.14	44.74 a-c
NPK micro-dose (3g) + Poultry manure (100g)	37.64 abc	50.70 a	60.51	35.95	42.84	40.15 c
Poultry manure (50g)	36.57 abc	49.40 ab	55.55	32.55	42.54	44.49 abc
Poultry manure(100g)	39.06 a	49.74 ab	57.47	31.35	43.89	44.83 abc
Poultry manure (150g)	35.90 abc	48.24 ab	58.47	33.15	43.60	37.66 c
SE±	1.883	1.616	3.755	2.061	3.322	4.617
<u>Spacing (cm)</u>						
100	37.01	48.96	56.64	31.49	43.04	45.77
50	36.16	47.86	57.24	30.44	38.64	43.17
SE±	0.640	0.645	0.897	0.980	1.245	1.615
F x S	NS	NS	NS	NS	NS	NS

Means within the same treatment and column followed by same letter(s) are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT). NS = not significant, * = significant at 5% level of probability. WAS = weeks after sowing.

cow manure at 100g and NPK micro-dose (3g) + cow manure (100g). At Gambawa, it was significant only at 9 WAS. The highest LCC was produced by the control but was at par with some levels of fertilizer. The least LCC was produced by poultry manure(150g) and other two levels of fertilizer. Varying intra-raw spacing had no significant influence on LCC at both sites and at all the sampling periods. Similarly, none of the treatments interaction on LCC were significant.

Leaf area index (LAI)

The means of leaf area index (LAI) at 6, 9 and 12 WAS as affected by fertilizer treatments and intra-row spacing are given in Table 8. At Wasai-Minjibir, significant differences ($P \leq 0.05$) were observed among fertilizer treatments at 6 WAS where the highest LAI (2.01) value was obtained at NPK micro-dose (3g) which were statistically similar with other levels and the lowest (1.32) by control and poultry manure (150g). The effect of intra-row spacing on LAI at 6WAS was significant at Wasai where a high value of (1.78) was obtained at 50 cm, which was significantly different from the value (1.38) obtained at 100cm spacing. The interaction between fertilizer and intra-row spacing on LAI at 6 WAS was not significant. At Gambawa, NPK micro-dose (3g) + poultry manure (100g) produced the highest LAI (0.92) at 9WAS, that was similar with the results of other fertilizer levels. The result was significant when compared with the mean obtained with poultry manure (100g). The effects of intra-row spacing on LAI at 9 WAS was not significant at both locations and there were no significant interactions too.

The effect of fertilizer and intra-row spacing on LAI at 12 WAS were recorded at Wasai-Minjibir but was not determined at Gambawa due to unfavourable weather conditions; such that the crops were not photosynthetically green during that period of the season and most of their leaves dried up. The

Table 8: Effects of Fertilizer Treatment and Intra-Row spacing on Leaf Area Index (LAI) of Millet at Wasai-Minjibir and Gambawa During the 2015 Rainy Season.

Means within the same treatment and column followed by same letter(s) are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT). NS = not significant, * = significant at 5% level of probability. WAS= weeks after sowing

	Wasai-Minjibir			**Gambawa**	
	Leaf	area	Index (WAS)	Leaf area	Index(WAS)
Treatments	**6**	**9**	**12**	**6**	**9**
Fertilizer (F)					
Control	1.32 c	1.33	0.46	1.93	0.81 ab
Cow manure(50g) + Poultry manure (50g)	1.64 abc	2.17	0.48	2.24	0.58 ab
Cow manure (100g)	1.59 bc	1.99	0.48	1.65	0.52 b
NPK 60:30:30	1.64 abc	1.83	0.49	2.32	0.59 ab
NPK microdose (3g)	2.01 a	1.96	0.49	1.96	0.59 ab
NPK microdose (3g) + Cow manure (100g)	1.61 bc	1.85	0.38	2.12	0.59 ab
NPK microdose (3g) + Poultry manure (100g)	1.53 bc	2.03	0.49	2.76	0.92 a
Poultry manure (50g)	1.78 ab	1.869	0.49	2.11	0.80 ab
Poultry manure (100g)	1.65 abc	2.07	0.51	2.72	0.47 b
Poultry manure (150g)	1.38 c	2.01	0.47	2.92	0.74 ab
SE±	0.187	0.208	0.072	0.281	0.170
Spacing (cm)					
100	1.384 b	1.994	0.4690	2.283	0.673
50	1.781 a	1.830	0.4785	2.262	0.651
SE±	0.078	0.129	0.018	0.094	0.049
F x S	NS	NS	**	NS	NS

fertilizer treatment effects on the mean values of LAI were not significant. The effects of intra-row spacing on LAI at 12 WAS were also not significant.

The interaction of fertilizer and intra-row spacing on LAI at 12WAS is presented on Table 9. At 100cm intra-row spacing considering all fertilizer levels been constant, poultry manure 100g produced the highest (0.588) LAI value. And the least results were also produced at same spacing by NPK microdose (3g) + cow manure (100g). All remaining values were at par with each other.

Grain yield (kg ha^{-1})

The effects of fertilizer treatments and intra-row spacing on yield at Wasai-Minjibir and Gambawa are presented in Table 10. Significant differences ($P \leq 0.05$) were observed among treatment means. At Wasai-Minjibir plots fertilized with NPK 60:30:30 recorded the highest mean grain yield (2479 kg ha^{-1}), which was significantly not different from the mean values obtained by cow manure (50g) + poultry manure (50g), NPK micro-dose (3g), cow manure (100g), NPK micro-dose(3g) + poultry manure(100g) and poultry manure(150g). Poultry manure(100g) recorded a significantly lower value when compared with the yield recorded by NPK 60:30:30. At Gambawa, poultry manure(150g) recorded the highest grain yield which was significantly not different from the values recorded by poultry manure (100g) and NPK micro-dose (3g) + poultry manure(100g). The lowest yield was recorded from control treatment which have similar result with cow manure (100g). The yield obtained with poultry manure (100g), NPK micro-dose (3g) + poultry manure (100g) and poultry manure (150g) were significantly higher than cow manure (100g) and control. There was no significant difference between the two intra-row spacing at Gambawa but only at Wasai, where the 50 cm intra-row spacing significantly ($P \leq 0.05$) produced the highest grain yield. The interaction was not significant at both locations.

Table 9: Interaction between Fertilizer and Intra-Row Spacing on Leaf Area Index of millet at 12 WAS at Wasai-Minjibir in the 2015 Rainy Season

	Spacing	
Fertilizer (F)	100cm	50cm
Control	0.488 a-d	0.440b-e
Cow manure (50g) + Poultry manure (50g)	0.440 b-e	0.520 abc
Cow manure (100g)	0.498 a-d	0.480 a-d
NPK 60:30:30	0.453 a-d	0.518 abc
NPK micro-dose (3g)	0.495 a-d	0.488 a-d
NPK micro-dose (3g) + Cow manure (100g)	0.333 e	0.423 c-e
NPK microdose (3g) + Poultry manure(100g)	0.538 abc	0.433 b-e
Poultry manure (50g)	0.480 a-d	0.505 a-d
Poultry manure(100g)	0.588 a	0.428 b-e
Poultry manure (150g)	0.380 de	0.553 ab
SE±	0.082	

Means followed by same letter(s) are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT). NS = not significant, * = significant at 5% level of probability.

Table 10: Effects of Fertilizer Treatment and Intra-Row Spacing on Grain and Stover Yield of Millet at Wasai-Minjibir and Gambawa During the 2015 Rainy Season.

	Wasai-Minjibir		**Gambawa**	
Treatments	Grain Yield (kg ha^{-1})	Stover Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})	Stover Yield (kg ha^{-1})
Fertilizer (F)				
Control	1930 bc	3583 b	188 c	1200 cd
Cow manure (50g) + Poultry manure (50g)	2072 abc	4383 ab	407 bc	1017 cd
Cow manure (100g)	2269 abc	4683 a	185 c	883 d
NPK 60:30:30	2479 a	5000 a	635 ab	1717 ab
NPK micro-dose(3g)	2093 abc	4650 a	405 bc	983 cd
NPK micro-dose (3g) + Cow manure(100g)	1903 bc	4517 ab	597 ab	1367 bcd
NPK micro-dose (3g) + Poultry manure (100g)	2413 ab	5017 a	725 ab	1450 abc
Poultry manure (50g)	1927 bc	4383 ab	483 abc	1867 a
Poultry manure (100g)	1867 c	4233 ab	743 a	1417 abc
Poultry manure (150g)	2057 abc	4500 ab	793 a	1750 ab
SE±	265.9	507.6	156.0	237.4
Spacing (cm)				
100	1933 b	4133 b	465	1287
50	2269 a	4857 a	548	1443
SE±	86.5	196.8	46.2	91.8
F x S	NS	NS	NS	*

Means within the same treatment and column followed by same letter(s) are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT). NS = not significant, * = significant at 5% level of probability.

Stover Yield (kg ha^{-1})

The effects of fertilizer treatments and intra-row spacing on stover yield was observed at Wasai-Minjibir and Gambawa as presented in Table 10. At Wasai-Minjibir the highest stover yield was obtained at plots treated with NPK micro-dose(3g) + poultry manure (100g), though statistically not different from other fertilizer levels except the control which gave the least stover weight. The differences between the means obtained with NPK micro-dose (3g) + poultry manure (100g) was significant when compared with the means of control only. NPK micro-dose (3g) + Poultry manure(100g) gave similar mean value with that obtained by NPK 60:30:30. At Gambawa, significant differences were observed among the fertilizer treatments levels. The highest mean stover yield was recorded with application of poultry manure (50g) but statistically at par with other fertilizer levels except cow manure 100g which yielded the least stover weight.

The effect of spacing on stover weight is significant at Wasai-Minjibir. The spacing of 50 cm gave higher mean stover weight than the 100 cm intra-row spacing. Interaction between fertilizer treatments and intra-raw spacing was significant at Gambawa (Table 11). At constant fertilizer levels, considering intra-row spacings, indicated 50cm to produce high Stover yield at poultry manure(150g) though statistically similar with each other. The least stover yield was produced by cow manure (100g) at 100cm intra-row spacing.

1000-Grain Weight (g)

The effects of fertilizer treatments and intra-row spacing on 1000-grain weight of millet at Wasai-Minjibir and Gambawa is presented in Table 12. There were no significant differences between the fertilizer treatments as well as intra row spacing at both locations. At Gambawa the highest 1000-grain weight was obtained with poultry manure (150g), which was at par with other fertilizer levels. The least value was obtained with control. The

Table 11: Interaction Between Fertilizer Treatment and intra-row Spacing on Stover Yield (kg ha^{-1}) of Millet at Gambawa During the 2015 Rainy Season.

	Spacing	
Fertilizer	50cm	100cm
Control	1000 fgh	1400 b-g
Cow manure (50g) + Poultry manure (50g)	1033 fgh	1000 fgh
Cow manure (100g)	1200 defg	567 h
NPK 60:30:30	1633 a-f	1900 abc
NPK microdose (3g)	900 gh	1067 efgh
NPK microdose (3g) + Cow manure (100g)	1367 c-g	1367 c-g
NPK micro-dose (3g) + Poultry manure (100g)	1867 abc	1033 fgh
Poultry manure (50g)	1733 abcd	2000 ab
Poultry manure (100g)	1667 a-e	1167 d-h
Poultry manure (150g)	2133 a	1367 c-g
SE±		313.9

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

Table 12. Effects of Fertilizer Treatments and Intra-Row Spacing on Yield Components of Millet at Wasai-Minjibir and Gambawa During the 2015 Rainy Season.

	Wasai-Minjibir			**Gambawa**		
Treatments	1000-grain weight (g)	Harvest Index%	Threshing %	1000-grain Weight (g)	Harvest Index%	Threshing %
Fertilizer (F)						
Control	9.49	0.30	70.13	6.85	0.10	53.3
Cow manure (50g) + Poultry manure (50g	9.92	0.29	72.83	7.14	0.20	62.6
Cow manure (100g)	9.66	0.30	75.58	7.79	0.10	50.9
NPK 60:30:30	10.30	0.29	73.51	8.66	0.20	60.7
NPK microdose (3g)	9.54	0.28	69.62	7.00	0.20	50.5
NPK microdose (3g) + Cow manure (100g)	9.36	0.27	72.38	7.15	0.20	61.8
NPK microdose (3g) + Poultry manure(100g)	9.99	0.29	72.24	8.57	0.30	68.3
Poultry manure (50g)	9.40	0.27	71.85	7.21	0.20	50.8
Poultry manure(100g)	9.25	0.27	71.22	7.75	0.30	63.5
Poultry manure (150g)	10.29	0.28	72.66	8.82	0.3	67.7
SE±	0.55	0.02	2.11	0.85	0.04	8.02
Spacing (cm)						
100	9.98	0.29	72.10	8.08	0.20	61.1
50	9.46	0.28	72.30	7.30	0.20	56.9
SE±	0.24	0.01	0.82	0.32	0.01	2.39
F x S	NS	NS	NS	NS	NS	NS

Means within the same treatment and column followed by same letter(s) are not significantly different at 5% level of probability using Duncan multiple range test. NS = not significant.

100 cm spacing yielded higher weight values across the locations than does the 50 cm. The interaction between fertilizer treatment and intra-row spacing was not significant at both locations.

Harvest Index (HI %)

The effects of fertilizer and intra-row spacing treatments on harvest index of millet at Wasai-Minjibir and Gambawa is presented in Table 12. There were no significant differences among the treatment means at Wasai-Minjibir as opposed to the treatment means at Gambawa. At Gambawa, poultry manure 100g and 150g and NPK microdose(3g) + poultry manure (100g) produced high HI that were statistically similar with other fertilizer levels. The control produced least HI. The effect of intra-row spacing on harvest index of millet at both locations was not significant. In the same vein, the interaction between fertilizer treatment and intra-row spacing on harvest index was not significant.

Threshing Percentage (TH%)

There were no significant differences among the fertilizer treatments at Wasai-Minjibir and Gambawa (Table 12). At Wasai-Minjibir, the highest mean value of threshing percentage (75.58%) was obtained at plots treated with cow manure (100g) which was statistically similar with some treatment levels while the least value was obtained with NPK micro-dose (3g), poultry manure (100g) and the control. At Gambawa, the highest mean threshing percentage was recorded at plots treated with NPK micro-dose (3g) + poultry manure (100g) that was at par with some fertilizer levels while the least was obtained with poultry manure (50g) and two other levels. Likewise, the effects of intra-row spacing treatment on threshing percentage was not significant at both locations. There were no significant interactions at both locations.

4.2 DISCUSSION

4.2.1 Soil Properties and Climatic Condition

The results of soil analysis obtained from the two locations is an indication that pearl millet is tolerant to sandy acidic soils. This is in agreement with Tabo (1995) who reported that pearl millet is well adapted to growing in marginal areas characterized by drought, low fertility and high temperatures and could relatively perform better on soils with high salinity or low pH values, because of its tolerance to difficult growing conditions. It can be grown where other cereals such as maize or wheat would not survive. The nitrogen content of the soil, the organic carbon content and phosphorus were low in both locations and this confirms the low yield obtained in the control plots at the two locations. However, higher yield was obtained at Wasai-Minjibir compared to Gambawa which can be attributed to higher organic carbon and nitrogen content of the soil at Wasai-Minjibir. Similarly, the phosphorus content of the soils was low($<10gkg^{-1}$) at both locations. Due to better soil conditions and the level of residuals in nitrogen and phosphorus the soil at Wasai-Minjibir will support crops better than the soil at Gambawa. Maman *et al.* (2000) reported that pearl millet grain and stover yields were increased with application of a combination of cattle manure and P fertilizer. The result also showed that the exchangeable potassium at Gambawa is high than at Wasai-Minjibir. The soil in the two locations are classified as loamy sand and sandy loam which was good for pearl millet production. Also, the high rainfall received during growth development at Wasai-Minjibir compared to Gambawa justified the higher grain yield achieved at Wasai-Minjibir. The highest rainfall of 325mm was received in August at Wasai-Minjibir and only 170.70mm at Gambawa in the same month. It is therefore evident that the amount and distribution pattern of rainfall determined the growth and yield of pearl millet across the two locations.

4.2.2 Effects of Organic and Inorganic Fertilizers on Growth and Yield of Pearl Millet

The fertilizer treatments did not show any significant effect on leaf chlorophyll content at 3, 6 and 9WAS at both locations where only at Gambawa NPK micro-dose (3g) + Poultry manure (100g) had shown some significance between means at week 3. This combined form of fertilizer is a rich source of nitrogen fertilizer and that nitrogen is an important component in chlorophyll and leaf formation. In contrast, the control recorded the highest mean LCC value at Gambawa. Poultry manure (150g) recorded the least result at Gambawa and that could be attributed to high volatilization losses and leaching encountered during storage and application. At the same time the highest LCC achieved by control might be due to the inherent soil nitrogen that was present prior to seed germination. Unlike that of the manure where the nitrogen was lost to volatilization and some other factors.

At Wasai-Minjibir, the highest leaf area index (LAI) at 6 weeks after sowing(WAS) was obtained in plots fertilized with NPK micro-dose (3g) while the least from plots without fertilizer (control). As a usual phenomenon, crops treated with fertilizer must look nourished with good growth and development unlike their counterparts that were lacking. At 9 WAS, the highest LAI value was recorded from cow manure (50g) + poultry manure (50g) and the least obtained from the control all at Wasai-Minjibir. At Gambawa, the highest LAI value was obtained from poultry manure (100g) + NPK micro dose(3g). Fertilizer combinations gave outstanding performance in the two locations on LAI at 9WAS because of its richness in providing needed nutrients for good growth in millet. The effect of fertilizer and intra-row spacing on LAI at 12 weeks after sowing (WAS) was recorded at Wasai-Minjibir only while Gambawa was not determined due to unfavorable weather conditions.

The results from both Wasai-Minjibir and Gambawa showed that NPK micro-dose (3g) + cow manure (100g) produced the least number of days to 50% flowering and number of days to maturity though the treatments values were statistically similar at both locations. That was due to optimum fertilization obtained from combined form of fertilizer which supplied essential nutrients needed for fast growth, early flowering and maturity.

Fertilizer treatments on plant height did not show any difference at Wasai-Minjibir but only at Gambawa where NPK 60:30:30 produced taller plants. Shorter plants were obtained at the control plots. This is expected as the fertilizer treated plots support plant growth thereby increasing plant height unlike in control where nutrients through fertilizers were not applied.

Plots treated with NPK 60:30:30 recorded the highest figure on stands count at harvest at Wasai-Minjibir, although the result was at par with other fertilizer treatments. Such development was related to high amount of residuals obtained from previous nutrients additions to the soil at Wasai. At Gambawa, the highest number of stands count were recorded from NPK micro-dose (3g) + cow manure (100g). Since P is generally known for growth and development of strong stems in cereals it was a clear testimony that the fertilizer provided enough P for this role.

In fertilizer application, poultry manure (150g $hill^{-1}$) recorded the least figure on plant lodging at Wasai-Minjibir because the optimum level of plant nutrients found in the organic manure were responsible for growth and development of strong stems in millet especially macro- and micronutrients. At Gambawa the least number of lodged plants were recorded from plots fertilized with cow manure (100g $hill^{-1}$). Plots treated with manure fertilizer recorded least figure on lodged plants whereas those from NPK 60:30:30 recorded the highest number of lodged plants in both locations. The reason was due to high N content present in NPK fertilizer which results to fast stem elongation and subsequent bending. High wind speed could be another factor for increased number of lodged plants.

Increase in the number of panicles per ha^{-1} was obtained when the combined form of fertilizer, NPK micro-dose (3g) + poultry manure (100g) and NPK micro dose + cow manure (100g) were used at both sites. This result was supported by findings from Bationo and Lompo (2003), who reported significant increases in yield of maize with application of mineral fertilizer combined with organic manure.

Fertilizer treatment results on panicle length were at par in Wasai Minjibir. Their effect was only noticed at gambawa where NPK 60:30:30 and NPK microdose (3g) + Cow manure (100g) significantly produced longer panicles thu the treatment result was similar with each other.

Application of fertilizers had significant effect on grain yield at Wasai-Minjibir and Gambawa. The result indicated that NPK 60:30:30 produced the highest grain yield as compared with other fertilizer treatments which were at par with other treatment results. The result is in harmony with the findings of Maman *et al.* (2000) and Diseko, (2005) that millet grain yield can be reliably high when chemical fertilizers are applied to soils. This was attributed to supply of readily available plant nutrients for uptake. However, at Gambawa poultry manure (150g $hill^{-1}$) recorded significantly the highest grain yield but when compared with the grain yield of NPK 60:30:30 they gave similar effect. This might be as a result of high nutrients supplied by the high rate of poultry manure (150g $hill^{-1}$) as well as the benefit of organic matter in improving the sandy soils of Gambawa. Similar findings by Saidou *et al.* (2010) showed significant effect of fertilizer application on yield and biomass production on sandy soils. The yields values obtained at Wasai-Minjibir was much higher than at Gambawa, which could be attributed to higher level of precipitation and better soil condition at Wasai-Minjibir (Table 1& appendix1). The lower yield at Gambawa may be attributed to poor condition of sandy soil. Application of the fertilizers through micro-dose compared favorably well in both locations. Bagayoko *et al*., (2011) reported increased millet grain yield with micro-dose application over the other methods as this minimize nutrient loss and maximize efficiency.

Findings from this study showed that NPK 60:30:30 had the heaviest 1000-grain weight in both locations. Similar effect was also observed with poultry manure (150g $hill^{-1}$) compared to other treatments. This might be due to the supply of readily available plant nutrients from rich nutrient sources as compared to the non-application. Agbede *et al.* (2008) reported increased 1000-grain weight with poultry manure application over three years since the manure is an important organic nutrient source. This increase in 1000-grain weight by NPK 60:30:30 might be due to increase in available nutrient which were readily taken up and transformed into assimilates for grain formation.

The highest harvest index of (30%)was recorded by cow manure (100g $hill^{-1}$) and the control at Wasai-Minjibir. At Gambawa, poultry manure (100g), NPK micro-dose (3g) + poultry manure (100g) and poultry manure (150g) obtained same statistical result (30%) each. At both locations, a harvest ratio of 0.30 remained same, which implied that the various manures yielded 30% grain out of the total net biomass at harvest. This result corroborates with the statements of Ezeibekwe *et al*., (2009), Obi and Ebo, (1995) that use of poultry manure had been reported to improve growth and yield of maize and improves the chemical and biological qualities of the soil which increase crop productivity than chemical fertilizers. The control was able to show similar result at Wasai-Minjibir which was attributed to favourable conditions and some residual effect from the soil at that site. This result agrees with the findings of Kwari and Bibinu (1994) that humus enhances the utilization of fertilizer nutrients by enhancing water retention ability of the soil, thus, increasing yield and yield components of crops.

The highest threshing percentage (76%) was recorded from plots treated with cow manure (100g hill^{-1}) at Wasai-Minjibir. Gambawa have the highest threshing percentage recorded by NPK micro-dose (3g) + poultry manure (100g). This is in conformity with the work of Bationo and Lompo (2003) who recorded significant increase in yield of maize with application of mineral fertilizer but yield was higher when mineral fertilizer was combined with organic manure. It could also be attributed to the high status of P in the soils of both locations thus increasing grain size and proportion. The high threshing percentage obtained at Wasai-Minjibir compared to Gambawa might be due to the level of organic matter and favorable environmental conditions found at Wasai-Minjibir. In another study Ashiono *et al.* (2005) reported increased grain yield of sorghum with application of FYM up to 20t ha^{-1} which ranged from 7.2-12.64% over the non-application and increase in stover yield due to FYM ranged from 2.3 to 8.4%.

4.2.3 Effect of Intra-Row Spacing on Growth and Yield of Pearl Millet

The highest LAI result produced by the close intra-row spacing of 50 cm at Wasai-minjibir and not Gambawa contradicted the findings of Kamal *et al.*, (2013) that the wider intra-row spacing had significant effect on leaf area index.

The spacing treatment did not reflect any effect at Wasai-Minjibir but only at Gambawa where 50 cm spacing alone, recorded less number of days than 100 cm. This development was due to high population density and greater competition for nutrients at closer intra-row spacing. The stressed plants in closer intra-row spacing attained 50% flowering and maturity earlier than those from wider intra-row spacing. This is in agreement with Ijoyah *et al.* (2015) while studying the effect of intra-row spacing of pearl millet reported that early days to 50% flowering and maturity were recorded in closer intra-row spacing as compared to those recorded for wider intra-row spacing. Although there was no significant difference observed between the two intra row spacing, the narrow spacing of 50cm recorded more stand count at harvest compared to the wider spacing. This is an ideal phenomenon in which the closer intra-row spacing has greater number of plant population than does the wider spacing.

The 100cm intra-row spacing had the least number of plant lodging than the 50cm spacing because the closer intra-row spacing outnumbered the wider spacing in terms of population. The closely spaced millets were stressed due to competition for resources and were therefore not strongly formed. Such stems could easily bend and fall down. The figure is high at Wasai because of high amount of nitrogen (N) at Wasai-Minjibir soil than Gambawa (Table 4).

According to the result, the 50cm intra-row spacing gave the highest significant values on number of panicles at both locations. This is because increase in plant population gave a corresponding increase in number of panicles per plot and consequently per hectare. This result was however, contrary to the report of Wailare (2010) who studied the effect of intra-row spacing and variety on yield and yield components of millet and found that the three intra-row spacing of 30, 40 and 50cm did not show statistically different in plant height, 1000 grain weight, panicle length, panicle weight and panicle number except panicle diameter which was statistically affected.

The intra-row spacing showed a significant effect on grain yield at Wasai-Minjibir, which implied that the closer the spacing the higher the grain yield. The yield decreased with increasing intra-row spacing. At Gambawa, though no significant difference was observed between the two intra-row spacing, higher yield was obtained with high planting density. The differences in grain yield obtained from both sites might be attributed to the differences in environmental conditions and initial soil organic carbon and nitrogen. The results were in contrast with the finding of Muhammad *et al*. (2002) who stated that wider spacing in millet significantly promoted grain yield than the narrower spacing. However, the intra-row spacing had a significant effect on stover yield at Wasai only. The result of intra-row spacing effect on stover yield was significant at Wasai. The narrower spacing 50 cm resulted in highest stover yield than the wider spacing of 100cm. This might be attributed to increase in tiller counts in close spacing. Ibrahim (2015) also observed higher stover yield in the same environment. Saba *et al.* (2015) also observed that excessively wide or narrow spacing leads to reduction in yield.

Sowing pearl millet at 100cm spacing produced significantly heavier 1000-grain weight. The lighter 1000-grain weight obtained by 50cm spacing might be due to high competition at narrower spacing than at wider spacing. The competition for growth and yield factors such as light, nutrients, and water in the narrower spacing might have decreased 1000-grain weight. The result was in contrast with the findings of Wailare (2010). who stated that intra-row spacing does not have effect on 1000-grain weight, but kamal *et al*., (2013) revealed significant effect of 50, 70 and 90 cm x 75 cm spacing on 1000-grain weight of millet in Sudan.

4.2.4 Interaction

Looking at the result on Table 8, the different rates of poultry manure produced a significant result on LAI at 12WAS at Wasai with both spacings showing that poultry manure as a fertilizer nutrient have high potential for increased assimilates production and leaves canopy formation. The organic fertilizer of cow manure(50g) + poultry manure(50g) versus 50cm spacing recorded the highest number on stand count at harvest than the result obtained from 100 cm (Table 3). The interaction result obtained from the control with 100cm spacing had the least value. This is because the combined form of organic and inorganic favoured the close spacing producing more stand count at harvest than it was with the 100cm. This result contradicted the findings of Kamal *et al.* (2013) that plant spacing had no significant effect on most of growth parameters.

Higher number of panicles were obtained with the narrow spacing of 50cm at NPK Microdose (3g) + poultry manure (100g) though the result obtained was at par with the values recorded by other fertilizer levels. Ma *et al.* (2003) reported significant interactions between row spacing and N rates ($P < 0.01$); grain yield of Pioneer 38P06 Bt maize with the 80 kg N ha^{-1} fertilizer treatment was significantly greater (14.6%) at the 0.51 m row spacing than at the conventional 0.76 m row spacing, an advantage of narrow row spacing against conventional row spacing similar to those found in some areas of Argentina (Barbieri *et al*.2000).

A higher stover weight value was obtained when poultry manure (150g) was applied to the 50cm intra-row spacing and which indicated the close spacing favours stover yield than the wider spacing, although the 100cm produced a result similar to that of the close spacing in its interaction with some of the fertilizer treatment levels. The result conforms with the findings of Ibrahim (2015) who conducted a study on fertilizer and intra-row spacing on millet and found out significant interaction between fertilizer and spacing in which NPK 60:30:30 at 25 cm recorded highest stover yield (7, 772 kg ha^{-1}). Barbieri *et al.* (2000) found a 14–21% greater grain yield at a 0.35 m spacing than at a 0.70 m spacing for well-fertilized maize, this improvement in grain yield rose to 27–43% for N-deficient maize. The narrow spacing improved yield by increasing both kernels per cob and cobs per hectare, compared to the wider spacing with low N treatment in their study.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

A field experiment was conducted to evaluate the effects of intra-row spacing and micro-dose application of manure and mineral fertilizers for growth and yield performance of millet in Sudan Savannah of Nigeria. The experiment was conducted at two different locations, namely; ICRISAT's research field at Wasai-Minjibir, Minjibir Local Government area of Kano State, in Sudan Savannah ecological zone. The other location was at farmers' field, at Gambawa village, Gumel Local Government area, Jigawa state, in Sudano-Sahelian ecological zone. The field experiment was laid out in a split plot design with four replications. The main plot consists of manure and mineral fertilizer, in ten (10) micro-dose levels. Namely; control, cow manure (50g) + poultry manure (50g), cow manure (100g), NPK 60: 30: 30, NPK micro-dose (3g), NPK microdose (3g) + cow manure (100g), NPK microdose (3g) + poultry manure (100g), poultry manure (50g), poultry manure (100g), poultry manure (150g). The sup-plot treatment consists of two intra-row spacing: 50 and 100 cm. The results showed that significant differences were recorded from fertilizers on growth and yield characters in LCC, LAI, number of days to maturity, plant height, stand count at harvest, lodging, panicle number and grain yield at varying periods and locations and at both locations, also on 1000-grain weight at both locations and Harvest index at Gambawa only. In the intra-row spacing however, significant differences were observed on parameters such as LCC, stand count at harvest, lodging, grain and stover yield, and on 1000-grain weight at varying periods and locations as well as at both locations. Significant interactions were observed on traits such as LAI at 12 WAS, on stand count at harvest and panicle number at Wasai-Minjibir and on stover weight (Gambawa only). The result at Wasai indicated that NPK 60:30:30 recorded the highest grain yield

(2479 kg ha^{-1}) which was statistically not different from the results obtained by some of the fertilizer levels. while the least value (1867 kg ha^{-1}) was recorded by poultry manure (100g hill^{-1}). The application of poultry manure (150g) gave the highest grain yield (793 kg ha^{-1}) at Gambawa, though statistically similar to the values obtained at some fertilizer rates. while cow manure (100g hill^{-1}) recorded the least grain yield (185 kg ha^{-1}). The results also showed that intra-row spacing of 50 cm out yielded the 100 cm intra-row spacing.

5.2 CONCLUSION

For good growth and yield of pearl millet, the application of NPK microdose (3g hill^{-1}) with 50 cm intra-row spacing at Wasai-Minjibir and use of poultry manure (50g hill^{-1}) with 50 cm intra-row spacing at Gambawa are recommended for adoption by farmers at their respective locations.

5.3 RECOMMENDATIONS

- For better millet productivity, farmers at Wasai-Minjibir should adopt to the use of NPK micro-dose (3g) as recommended fertilizer.
- Millet farmers in the Sudano-Sahelian zone especially Gambawa should adopt to the new micro-dose application method through the use of poultry manure (50g hill^{-1}) for better growth and yield of millet.
- The close- spacing of 50 cm x 75 cm is much recommended for millet production for better grain and stover yields.

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APPENDIX I

Appendix I: Meteorological Data of the Experimental Sites at Wasai-Minjibir and Gambawa during 2015 growing Season.

	WASAI-MINJIBIR					GAMBAWA				
Months	**Rainfall (mm)**	**Relative Humidity (%)**		**Temperature (ºC)**		**Rainfall (mm)**	**Relative Humidity (%)**		**Temperature (ºC)**	
		Max.	**Min.**	**Max.**	**Min.**		**Max.**	**Min.**	**Max.**	**Min.**
May	0	56	10.5	41	25.4	0	45	7.9	42	25.1
June	51	78	31	37	24.7	82.81	76	25	39	23.4
July	135	89	45.1	33.5	23	170.70	89	40	35	23.4
August	325	96	56	31.5	22	78.05	98	53.7	33	22
September	34	95	51.4	32	21.8	62.23	98.6	46.6	34	21.7
October	20	88	30	36	22	7.37	91	23	38	20
Total	**545**					**401.16**				