EFFECT OF WEED CONTROL AND NPK FERTILIZER RATES ON THE PERFORMANCE OF FINGER MILLET (*Eleusine coracana* (L.) Gaertn.) IN THE NIGERIAN SAVANNA

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTERS OF SCIENCE IN AGRONOMY

DEPARTMENT OF AGRONOMY,
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JUNE, 2021

DECLARATION

I declare that the work in this dissertation entitled “Effect of Weed Control and NPK Fertilizer Rates on the Performance of Finger millet (*Eleusine coracana* (L.) Gaertn.) in the Nigerian Savanna” has been carried out by me in the Department of Agronomy under the supervision of Profs. S. A. Dadari and B. A. Babaji. The information derived from the literature is duly acknowledged in the text and list of references provided. No part of this dissertation has been previously presented for another degree or diploma in any University.

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Prof. S. A. Dadari (Date)
(Chairman, Supervisory Committee)

CERTIFICATION

The dissertation entitled "Effect of Weed Control and NPK Fertilizer Rates on the Performance of Finger millet (*Eleusine coracana* (L.) Gaertn.) in the Nigerian Savanna" by MUSA Luqman meets the regulations governing the award of the degree of M.Sc. Agronomy of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This research work is dedicated to my mother, Haj. Aishatu Isah, who has been the pillar of my educational pursuit, and my source of inspiration.

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ABSTRACT

Field trials were conducted during the rainy season of 2019 at the research farms of the Institute for Agricultural Research, Samaru, in the Northern Guinea savanna, and the National Institute for Horticultural Research, Bagauda sub-station, in the Sudan savanna agro-ecological zone of Nigeria to assess the performance of finger millet (*Eleusine coracana* (L.) Gaertn.) as influenced by weed control and NPK fertilizer rates. Treatments consisted of six weed control treatments (Atrazine at 2.0 and 3.0 kg a.i ha^{-1};2,4-D at 0.6 and 0.8 kg a.i ha^{-1}; hoe weeding at 3 and 6 WAS and weedy check) and four levels of NPK (control (0:0:0), 30:15:15, 60:30:30, and 90:45:45 kg $N:P_2O_5:K_2O$ ha^{-1}) fertilizer. The factorial combination of the treatments were laid in a randomized complete block design (RCBD) replicated three times. Application of herbicides generally enhanced the performance of finger millet, though the hoe weeded control performed better in terms of crop growth and yield attributes of finger millet, where it resulted in early crop emergence and better crop establishment, subsequently resulting in reduced weed cover score, cumulative weed density and weed dry weights respectively. The hoe weeded control resulted in the most vigorous and less injured crops with wider assimilatory leaf area, higher values for number of tillers, plant dry weights, crop growth and relative growth rates. Other parameters that were enhanced by the hoe weeded control include number of days to physiological maturity, number of fingers per panicle, panicle weight per plant, threshing percentage and grain yield. However, among the herbicides evaluated, application of 2,4-D at 0.8 kg a.i. ha^{-1} gave better weed control over the weedy check with yield increase of 52.7 and 57.3% in Samaru and Bagauda, respectively. Generally, the crop responded positively to application of NPK fertilizer where application of 90:45:45 kg NPK ha^{-1} resulted in higher values for all the measured growth and yield characters of finger millet in both locations. Similarly, the same highest rate of NPK fertilizer application also recorded high values for cumulative weed density and weed dry weight at both locations. There was a positive and highly significant correlation between grain yield and growth and yield parameters such as plant height, LAI, plant dry weight, panicle weight and threshing percentage. Grain yield was, however, negatively correlated with cumulative weed dry weight. The regression of finger millet grain yield against NPK fertilizer rates showed a linear response in both locations. Hoe weeded control gave more effective season long weed control than all the herbicide control treatments. Application of 90:45:45 kg NPK ha^{-1} enhanced the performance of finger millet in terms of crop growth, yield attributes and grain yield more than all other fertilizer treatments evaluated at both locations. Combination of either hoe weeding or application of 2,4-D at 0.8 kg a.i. ha^{-1} with 90:45:45 kg NPK ha^{-1} gave the highest grain yield of finger millet at both locations.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Botany, Production and Distribution

Finger millet (*Eleusine coracana* (L.) Geartn.) belongs to the family Poaceae. It is a native of the highlands of Uganda and Ethiopia. It is an annual herbaceous plant with an erect, compressed and glabrous stem with a height of about 40-150 cm. The crop is capable of producing many tillers and nodal branches. The leaf blade is linear and taper to an acute point with ciliated margins. The panicle consists of a group of spikes called fingers. The spikelets are made up of 4-10 florets arranged on the finger. The crop is about 97-99% self-pollinating, with spikelets producing globose and smooth seeds. The seeds could be brown, black, purple, orange or white in colour. The crop matures in about 3-6 months (Dida *et al.*, 2007).

The world annual production of finger millet is 4.5 million metric tonnes of grain out of which Africa produced 2.0 million metric tonnes from an estimated land area of 19 million hectares (Dida *et al*., 2007), and it accounts for 8% of the land area and 11% of all millets production worldwide (Glew *et al.*,2008). However, Asian production keeps growing (by 50% in India during the last fifty years and by 8% per year in Nepal) while African production remains unchanged (Styslinger, 2011). Finger millet is widely cultivated in drier parts of the world mainly Asia and Africa. In West Africa, finger millet is cultivated in a wide geographical zone stretching from Senegal, Niger and Northern Nigeria (Burkill, 1985). In Jos, Nigeria, Glew *et al.* (2008) reported that finger millet otherwise called Black millet or Tamba in Hausa is cultivated on the highland areas of the Plateau, and parts of Kaduna state.

1.1 Soil and Climatic Requirements

Finger millet is an important dry land crop due to its resilience and ability to withstand aberrant weather conditions and generally grown in soils with poor nutrient levels and water holding capacity. The wide adaptability of finger millet can be attributed to its ability to assimilate CO_2 via C_4 di-carboxylic acid pathway (Holt, 2000). The crop thrives at higher elevations of 2500m and tolerates salinity better than most cereals. It is grown preferably on a well-drained sandy loam soil. It is generally suited to less fertile soils and poorer growing conditions, such as intense heat and low rainfall (Baker, 2003). It grows best in an environment with rainfall of about 500-1000mm distributed across the growing season (Dida *et al.,* 2007). Temperature range of 11 to 27°C and a soil pH of 5.0 to 8.0 are ideal for finger millet production. It can also tolerate cool climates and appears to be photoperiod sensitive with the optimum being 12 hours (Anon., 1996). These finger millet attributes combine to make it a suitable crop for ensuring food security in drought prone areas.

1.2 Nutritional Value, Uses and Importance

Finger millet is a superior crop compared to some major cereal crops especially polished rice. Among the other millets, finger millet has a high amount of calcium (0.38%), fiber (18%), phenolic compounds (0.3%–3%), and sulphur containing amino acids (Singh and Raghuvanshi, 2012; Rurinda, *et al.,* 2014; Devi *et al.,* 2014). It contains 9.2% protein, 1.29% fat, 76.32% carbohydrate, 2.24% minerals and 3.9% ash besides vitamin A and B. The grains are rich in phosphorus, potassium and amino acid. It is also a rich source of calcium (410mg/ 100g grain) for growing children and aged people (Tomar *et al*., 2011). The grain is easy to digest and does not contain gluten; it is therefore a cereal of choice for people who are sensitive to gluten in their diet. In addition to its nutritive value, the straw is used as feed for animals and for roof thatching.

Finger millet has no major storage pest problems and can be stored cheaply for long periods, provided it is well dried to low moisture content.

The importance of finger millet is due to its significance as a medicinal crop, high industrial potential and its nutritive value, which makes the crop a good constituent for balance diet more than most cereal crops consumed by man and animals (Vanderjagt, *et al*.,2001; Thacher *et al*., 2002; Vanderjagt *et al.*, 2007). These researchers further reported that finger millet has been found to have high levels of methionine, tryptophan, vitamin B, fibres and minerals such as phosphorus, iron with its calcium level 40 times more than that found in maize (*Zea mays* L.) and rice (*Oryza sativa* L.), 10 times more than that found in wheat (*Triticum aestivum* L.). This makes the crop a good source for balance diet formulations for malnourished, diabetic and HIV/AIDS patients. The crop is also beneficial for children, pregnant women and nursing mothers (Thacher *et al*., 2002 and Vanderjagt *et al.*, 2007).

The high level of iron and calcium content of finger millet has been found to be relevant to populations inhabiting northern Nigeria where the incidence of iron deficiency causes anemia particularly in pregnant women and calcium deficiency causes rickets in young children. The ability of the crop to grow in water-deficit regions, the long storability of the seed for consumption and planting (estimated to be viable for over ten years), the resistance of the grain against moulds and insects make it a viable emergency food (Burkill, 1985; Styslinger,2003).

In Africa, finger millet can be processed into many dishes such as porridge, bread, malt, traditional beer etc. Anon. (1996) reported that, finger millet straw makes good fodder containing up to 61% total digestible nutrients better than pearl millet (*Pennisetum glaucum* (L.) R. Brown.), wheat or sorghum (*Sorghum bicolor* (L) Moench). Interestingly, new food products made from finger millets are also becoming popular among younger people, including noodles, pasta, vermicelli, sweet products, snacks, and different bakery products (Verma *et al.*, 2013).

1.3 Justification and Objectives

Finger millet has not been given much attention by national and international research centres particularly in the Sub-Saharan Africa, where the crop is an important food and feed material. This results in low yields across producing countries in the region, in the tune of 500-750 kg ha^{-1} (Mitaru *et al.*, 1993; Takan *et al*.,2002) as against 1000-2000 kg ha^{-1} in other parts of the world, where the crop is of less economic importance. The area under finger millet production has decreased because most local farmers jettison/abandon it for production of other more economically lucrative cereal crops (Oduori, 2005). The low yields reported by the farmers in Nigeria and elsewhere in Africa have been attributed to poor agronomic management practices. One of the major constraints in finger millet production as in other cultivated crops, is poor weed management practices (Anon.1998).

The conventional weed control methods used by farmers include manual hoe weeding and hand pulling which are laborious, time consuming and expensive, especially in fields with *Eleusine indica* and *Eleusine africana*. It is difficult to distinguish seedlings of these grassy weeds from finger millet at early stage of growth because of their vegetative mimicry and distinguishable only when they flower.

Herbicides provide weed control at initial growth stage thereby giving the crop an advantage of good growth from beginning, which results in a competitive edge over the later emerging weeds. A lot of herbicides have been developed and are being used in different field crops. Unfortunately, very limited herbicides have been used in Nigeria and elsewhere for weed management in finger millet. Hence, there is a need to investigate and determine suitable herbicides to manage mixed weed flora in finger millet.

In spite of the crop importance, information on weed management practices and fertilizer application in finger millet is limited. Therefore, the need to carry out research on alternative weed control methods, such as the use of appropriate dose of suitable herbicides that can selectively give season long weed control, and fertilizer rates that produces optimum yield of finger millet, necessitated this research.

This study was therefore conceived with the following objectives:

1. To evaluate and determine the suitable weed control strategy for growth and yield of finger millet.
2. To determine the optimum NPK fertilizer rate for growth and yield of finger millet.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Effect of Weed Competition on the Performance of Finger Millet

Weeds are non-value plants, which grow out of place, cover the ground and hinder the growth and establishment of other plants at a particular space and time. The greatest loss in a crop yield due to weed competition occurs during the critical period of weed competition which is the period of the crop growth when it is most susceptible to weed competition (Lagoke, *et al.*, 1986). Pearl millet is very sensitive to weed competition during the early stage of growth (Lagoke *et al.*, 1981). Weeding in finger millet requires high labour and drudgery with hand pulling in broadcast fields (Das, 2008). Weeds usually absorb mineral nutrients faster than many of the crop plants and accumulate them in their tissues in relatively large amount and therefore, derive greater benefit (Gupta, 1998).

Weeds having similar characteristics as those of crop plants are often more serious competitors than weeds of dissimilar habits (Das, 2008). Weeding in finger millet is problematic because the dominant weeds in Africa's finger millet fields are similar to the crop and are difficult to differentiate from the crop at early crop's life during weeding (Styslinger, 2003). The critical period of crop-weed competition in finger millet has been observed to be from 25-45 days after sowing (Das, 2008). Finger millet is less susceptible to pests and diseases than other cereal crops, blast being the only major disease, but it has a poor ability to compete with weeds (Van and Gericke 2000). In many developing countries, half of the effort devoted to crop production is spent on weed control (Culpepper and York, 2000). A well pulverized seedbed is highly essential for good germination and higher initial plant stand of finger millet which in turn reduces weed competition (Das, 2008).

Significant decrease in yield of finger millet was observed due to delayed weeding from 15-65 days after sowing (Gosh, 2000). It was reported that finger millet productivity is low since weeds pose one of the major constraints in the production of the crop owing to initial slow growth rate of the crop, which favour weed growth and causes more competition for sunlight, nutrient and water in early stages of growth (Das, 2008). Unchecked weed growth in millet throughout its life cycle has been reported to affect growth and cause between 44 and 53% grain yield reduction in Savanna ecological zones of Nigeria (Lagoke, 1984 and Lagoke *et al.*, 1988). It was reported that the effect of weeds on the growth and yield of crop varies with weed species, density and duration of the crop exposure to weeds (Dawson, 1970). However, hoe-weeding twice at 3 and 6 or 7 weeks after sowing achieved good crop growth and grain yield in pearl millet (*Pennisetum glaucum*) in the absence of herbicide was recommended by Lagoke *et al.*, (1988).

A yield loss finger millet due to uncontrolled weeds in the first six (6) weeks of millet growth was reported to be about 54% Bulus (2002). Finger millet has very poor competitive ability with weeds due to its initial slow growth. A single method of weed control is not able to control all weeds up to the desired level, therefore integration of weed control methods and fertilizer application can be an effective weed control strategy (Nyende *et al.*, 2001; Pradhan *et al.*, 2010).

2.2 Effect of Herbicides on the Performance of Finger Millet

Herbicides are chemical substances that injure or kill weed plants. Chemical weed control options are limited for millet production. Joshua and Gworgwor (2001) reported that atrazine at 2.0-3.0 kg active ingredient (a.i. ha^{-1}), Primextra (Atrazine + Metorlachlor) at 2.0-2.5 kg a.i. ha^{-1} controlled weeds more effectively but reduced yields in millet and cowpea mixture. The higher herbicide rates were phytotoxic to millet and consequently reduced grain yields. Also grain yield of millet was highest under 1:1 cropping pattern and atrazine at 1.5kg a.i. ha^{-1} in 1998 and under

2:1 cropping pattern and atrazine at 1.5 kg a.i. ha^{-1} in 1999. Naik *et al*. (1999) from Bangalore reported that application of butachlor, diuron, 2,4-D and Isoproturon with or without earthing up were effective in controlling different weed flora.

Rao (2000) reported that pre-emergence application of Pendimenthalin at 0.75-1.5kg a.i. ha^{-1} gave good control for wide species of weeds in finger millet and pearl millet fields. This was followed by post emergence application of 2,4-D at 0.25-0.50 kg a.i. ha^{-1} which controlled most of the late emerging broadleaved weeds and some annual grasses. Yadav (1971) observed that atrazine applied at the rate of 1 kg a.i. ha^{-1} as pre-emergence reduced the dry weight of weeds by 67% and increased the grain yield of sorghum by 103%. Hand weeding and 0.5 kg a.i. ha^{-1} of atrazine were next best, giving increases in yield of 95 and 91%, respectively.

Singh *et al*. (1973) after three years trial obtained the most consistent broad spectrum weed control with atrazine rates. Some works with atrazine alone and in mixtures have reported very good weed control especially on Cyperus spp. and other sedges. Baker, (2003) reported that Formula 40® (Alkanolamine salt of 2,4-D) is labeled for control of broadleaf weeds in millet. The researcher further reported that for good weed control in pearl millet production, atrazine as a pre-plant incorporated or pre-emergence treatment at rates of 0.5–1 kg a.i. ha^{-1} gave best weed control. They also found that atrazine applied at 1.5 kg a.i. ha^{-1} and higher reduced both grain and stover yield. The reduction was greater in post emergence treatments. It has been reported that pearl millet was injured due to pre-emergence application of atrazine and simazine, but their post-emergence application appeared safe (Kasasian, 1971). Rao *et al.* (1971) presoaked seeds of pearl millet in distilled water for 12 hours and then treated with 1000 ppm aqueous solutions of atrazine, simanzine and 2,4-D for 12 and 24 hours separately with an additional treatment of distilled water as a control.

2.3 Description of Herbicide Used

2.3.1 Atrazine

Atrazine (2-chloro-4 ethylamino-6-isopropylamino-s-triazine) is a white, crystalline solid, with a water solubility of 70 ppm at 25℃ and acute oral lethal dose 50 (LD_{50}) for rats of 3,080 mg/kg active ingredient (a.i). It is a pre-emergence herbicide formulated either as wettable powder, flowable liquid suspension or granules (Anon, 2015). Atrazine is widely used for selective control of broadleaf and grassy weeds in crops such as millet, sorghum, maize and sugarcane. Under dry condition, a shallow incorporation of atrazine may increase the degree of weed control as it persists longer in the soil.

2.3.2 2,4-D

The herbicide 2,4-D (2,4-Dichlorophenoxy acetic acid) belongs to chlorinated phenoxy group of herbicides. Both inorganic salt amine and ester formulations are available either in solid or liquid form. Its acute oral LD_{50} for rat is 300 to 1000 mg/kg body weight. It is a post emergence systemic herbicide which is widely used to controlled broadleaved weeds in cereal crops, turf pastures and non-crop land. Most dicotyledonous plants are susceptible at normal herbicide application rates, and it is normally applied at the rate of 0.5 to 1.5 kg a.i. ha^{-1} (Akobundu, 1987). Plant roots absorb polar (salt) forms of 2,4-D most readily, while leaves absorb non-polar (ester) form most readily. The ester of 2,4-D tends to resist washing from plants and are rapidly converted to acid by plants. Following foliar absorption, 2,4-D is translocated within the phloem probably in the photosynthates. Following root absorption, it may move upwards in the transpiration stream (xylem). The translocation is influenced by the growth status of the plant. Accumulation of the herbicide occurs principally at their meristematic regions of the shoots and the roots. 2,4-D causes abnormal growth response and affect respiration, food reserves and cell division in susceptible plants.

2.4 Effects of NPK Fertilizer on the Performance of Finger Millet

2.4.1 Nitrogen (N)

Inorganic fertilizers have high concentration of nutrients which are readily available to crops. Nitrogen plays a central role in plant biochemistry as an essential constituent of cell wall, cytoplasmic protein, nucleic acid, chlorophyll and vast array of cell components (Shen *et al.*, 2005). In Finger millet high nitrogen rate was reported to lead to rapid leaf area development, prolonged leaf life, improved leaf area duration after flowering and increased yield (Parmer, 2007). Finger millet production is limited by nitrogen deficiency more often than by any other nutrient, and also dry matter production of 40 days old plants increased with increasing nitrogen rate (Mani, 1991). It was also observed that peak demand for nitrogen occurred during the period from three weeks before and two weeks after panicle initiation (Sunitha *et al.*, 2006). Nitrogen has been known to affect the number of days to 50% panicle initiation and silking. The researchers further observed a decrease in the number of days to 50% panicle, with increasing nitrogen rates. The variable response in the number of days to 50% panicle and silking to increase in nitrogen fertilization should be attributed to location effect, crop variety and the prevailing climatic conditions. The higher nitrogen rate increased number of active leaves per plant, dry weights of stem and leaf sheaths, panicle weight, total plant dry weight and leaf area (Parmer, 2007).

Opiyo (2004) observed that nitrogen application increased the number of days to 50% panicle initiation and also observed increase in grain yield and nitrogen use efficiency with nitrogen rate. Finger millet was grown and with 0, 60, 90 or 120 kgNha^{-1} under field experiment results revealed that yield was highest with 60 $kgNha^{-1}$, increasing by one tonnes per hectare over the control, but water use efficiency was not significantly influenced with increase in nitrogen rate (Malleshi, 2007). Nitrogen deficiency in finger millet is indicated by dwarf growth and pale yellowish leaves (Parmer, 2007). The response of finger millet to nitrogen fertilizer is known to be related to the level of soil inorganic matter, total nitrogen content of the soil, the texture of the soil and crop variety used.

Finger millet responds well to N application (Gupta *et al.*, 2012; Roy *et al.*, 2001), since many of the soils in the semi-arid regions are deficient in N (Rao *et al.*, 2012). Studies concerning N management in finger millet are mainly focused on the amount of N applied, timing of application, and varietal responses to N. Rao *et al*. (1989) reported increases in yield and grain protein content in finger millet due to N fertilizer application rates of up to 40 kg N ha^{-1}in India. The authors claimed that the economic optimum rate of N fertilizer for finger millet was 43.5 kg ha^{-1} under rainfed conditions. Hegde and Gowda (1986) reported that finger millet grain yield was 23.1 kg per kg N at 20 kg N ha^{-1}, while the yield benefit declined to 19.9 kg per kg N at 60 kg N ha^{-1}. These results suggest that application of the correct dose of N fertilizer is important in order to maximize the profits of poor finger millet farmers.

It is also important to note that the application of inorganic N fertilizer can delay flowering and physiological maturity by 1-2 weeks (Tenywa *et al.*, 1999), which can affect the final yield. The latter study also found that application of inorganic N alone (22.5–45 kg N ha^{-1}) did not increase the grain yield compared to the no fertilizer application under conditions of seed broadcasting and row planting. Therefore, the researchers claimed that N application alone is not economical in finger millet cultivation. Based on a long-term field experiment with finger millet, Hemalatha and Chellamuthu (2013) found that continuous application of inorganic N fertilizer alone reduced the soil organic carbon level due to low dry matter production and reduced return of crop residues to the field. In addition to the amount of N supplied, the timing of N application is also important for finger millet.

The importance of applying N starts with seed germination, a challenge for small seeded crops like finger millet especially under nutrient deficient conditions. The application of inorganic N fertilizer at the time of planting stimulates better crop emergence especially in N deficient soil (Rurinda *et al.,* 2014). Hegde and Gowda (1986) also claimed that incorporation of N fertilizer during seeding enhanced finger millet yield by 30% compared to broadcasted fertilizer. Synchronizing N supply with crop N demand is essential to maximize yield and N use efficiency. These researchers further reported that application of N on sandy loam soils at 50 kg ha^{-1} produced a finger millet grain yield of 2430 kg when applied at planting, whereas the yield increased to 2650 kg ha^{-1} when the application time was split (at planting and 25-30 days after planting). Therefore, split application of N fertilizer enhances finger millet yield production and possibly reduces N losses as well.

2.4.2 Phosphorus (P)

The application of phosphorus to soil in available form promotes root growth in finger millet, stimulates tillering and hastens maturity (Anon. 1996). The effect of phosphorus on shoot dry weight and root surface area during the vegetative period appeared to be related to the effect on crop development. Leaf area index was also observed to increase by 8-12% when phosphorus was increased from 0-18kg per hectare (Shen *et al.,* 2005). Shoot growth rate was retarded by phosphorus limitation and the formation of reproductive organs and flower initiation was delayed with limitation in phosphorus availability (Parmer, 2007). Premature senescence of leaves occurred in phosphorus-deficient plants and seed formation was particularly restricted (Parmer, 2007). In finger millet, plant suffering from phosphorus deficiency exhibited reduction in leaf expansion and surface area, and number of leaves were the most striking effect (Gani, 2012).

The rate of phosphorus to be applied to finger millet crop for optimum yield depends on the phosphorus sorption capacity of the soil, as soil with higher sorption capacity require high level of phosphorus fertilizer when they are phosphorus deficient (Gani,2012).Furthermore, under conditions of low phosphorus buffering capacity and low inherent phosphorus, it is beneficial to supply large initial dose of phosphorus to the soil to build up the phosphorus levels to sustain good yield (Kumar, 1993).Although P is one of the macronutrients required by finger millet, limited research has been conducted to evaluate the significance of P on finger millet growth and yield. Nevertheless, P is one of the highly limited nutrients in farmers' fields in semi-arid regions (Rao *et al.,* 2012).

In a multi-location field experiments conducted in Eastern Uganda, Tenywa *et al*. (1999) found that application of P fertilizer (20-40 kg P_2O_5 ha^{-1}) increased the growth and yield of finger millet compared to the no fertilizer control under row planting conditions. However, Hedge and Gowda (1986) reported a reduction in finger millet grain yields from 16.3 to 14.7 kg per kg P_2O_5 when the P application rate was increased from 30 to 60 kg ha^{-1} P_2O_5. Similar to inorganic N, this result suggests that application of excess P does not improve yield, but rather that application of balanced fertilizer is crucial. Organic practices have been shown to be important for P nutrition in finger millet.

2.4.3 Potassium (K)

Potassium is required for the activation of over 80 enzymes throughout the plant (Kumara *et al.*, 2007). It is important for plant ability to withstand extreme cold and hot temperatures, drought, pest and lodging, mostly in finger millet. Potassium increases water use efficiency and transforms sugar to starch in the grain-filling process (Rangaraj *et al.,* 2007). There was inverse relationship between potassium status and crop dry matter response to potassium application. The lower the potassium status of the soil, the higher the response to potassium application and vice versa (Opiyo, 2004). When potassium was deficient, growth was retarded and net re-translocation of potassium ion (K^+) from mature leaves and stems was enhanced, and under severe deficiency, these organs become chlorotic and necrotic (Shen *et al.,* 2005). High potassium rate delayed leaf senescence and increased the total area and number of leaves in millet (Kumar, 1993). The increasing soil potassium rate increased the shoot and the root dry weights (Opiyo, 2004).

2.4.4 NPK Nutrition

Finger millet requires relatively high soil nutrient levels especially nitrogen, phosphorus and potassium (Gani, 2012). Current fertilizer recommendation for finger millet production is based on genotype and agro-ecological zones (Sunitha *et al.,* 2006). Balanced fertilization ensures that the plant has access to adequate amount of each nutrient that is vital for optimum yield (Kumara *et al.,* 2007). An observation by deWet (2006) revealed that when finger millet was given 0-100kg N, 0-50kg P_2O_s and 0-50kg K_2O per hectare, over 70% lodging was observed without NPK or with N and P only. Increasing nitrogen rate increased lodging susceptibility, whereas increasing phosphorus and especially potassium rate reduced lodging (Murwira and Kirchmann, 1993). Kumar, (1993) showed that maximum leaf area and duration was increased by NPK application, and leaf senescence was higher when no NPK was applied.

Murthy and Hegde (1981) observed that the rain-fed finger millet grown with NPK at the rate of 50:50:25 $N:P_2O_5:K_2O$ ha^{-1}gave the highest yield of 3.13 ton ha^{-1}. The yield decreased to 2.62 ton ha^{-1} with 50% decrease in NPK rates and to 2.14 ton with no fertilizer application. The highest grain yields of finger millet was obtained with application of 120 kg N + 60 kg P_2O_5 + 60 Kg K_2O ha^{-1} (Purushotham and Sadashivaiah, 1993). Application of NPK at 60:30:30 kg NPK ha^{-1} recorded the greatest dry matter yield, leaf area index and crop growth rate. This treatment also increased fingers ear^{-1} and grain weight $earhead^{-1}$ compared with the lower rates, and resulted in higher yield of finger millet under sole and intercropping systems (Maithra *et al.,* 2001).

NPK has been shown to be important for early establishment of finger millet, based on a well-planned, three-year study conducted in farmers' fields in Eastern Zimbabwe by Rurinda *et al*., (2014). The data suggests that application of manure alone may not be beneficial to finger millet, perhaps because the nutrients are not readily available to the seedling. The researchers also found that agronomic N use efficiency (kg grain yield produced per kg N applied) decreases at high NPK rates, thus identification of the optimum fertilizer requirement is very important in order to maximize crop productivity. Hegde and Gowda (1986) reported that the required NPK fertilizer rate depends on whether the conditions are wet or dry, with a higher rate of fertilizer required under irrigated conditions (100:50:50 kg $N:P_2O_5:K_2O$) compared to arid conditions (50:37.5:25 kg $N:P_2O_5:K_2O$) in order to achieve respective growing condition and yield potentials (*i.e.*, there is more biomass produced under wet conditions). Similarly, Sankar *et al*., (2011) found that the benefit of applying inorganic fertilizer (NPK) increased under high moisture condition compared to low moisture condition (<500 mm).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Sites

The experiment was conducted during the 2019 rainy season at the research farm of the Institute for Agricultural Research, Ahmadu Bello University, Samaru (latitude 11^{0} 11^{1} N, longitude 07^{0} 38^{1} E, 686m above sea level) in the Northern Guinea Savanna and the National Institute for Horticultural Research, Bagauda sub-station (latitude $11^{0}37^{1}$ N, longitude $08^{0}23^{1}$ E, 500m above sea level), in the Sudan Savanna of Nigeria

3.2 Herbicides Screening

Four pre-emergence herbicides (Pendimentalin, 2,4-D, Atrazine and Butachlor) were screened at the orchard of Department of Agronomy, each at two different rates (recommended rates and 75% recommended rates for millet). The experiment was laid out in a randomized complete block design (RCBD) and replicated three times, using pots of 254.5 cm^{3} volume. The seeds of finger millet were planted in each pot, and seedlings later thinned to two plants per stand at two weeks after emergence. The pots were watered to field capacity for three days before planting, then once daily after planting. Data taken include number of days to emergence, weed compositions (grasses, broad leaves and sedges) and crop injury score. The level of finger millet tolerance to the herbicides and the effect of the herbicides on weeds (weed control) was observed and compared with the weedy check. The result obtained was analyzed to identify which herbicide was more promising. This informed the choice of herbicide type and rates that were further evaluated in the field, for this study.

3.3 Treatments and Experimental Design

The treatments consisted of six weed control strategies (Atrazine at 2.0 and 3.0 kg a.i. ha^{-1}, 2,4-D at 0.6 and 0.8 kg a.i. ha^{-1}, hoe weeding at 3 and 6 WAS, and a weedy check) and four levels of NPK fertilizer (0:0:0, 30:15:15, 60:30:30, and 90:45:45 kg $N:P_2O_5:K_2O$ ha^{-1}). The factorial combination of treatments was laid in a randomized complete block design (RCBD) and replicated three times.

3.4 Soil Sampling

Soil samples were randomly collected from fifteen (15) points at each experimental site at the depth of 0-30cm using an auger (10 cm diameter). Samples collected were thoroughly mixed and a composite sample was taken, dried and sieved using a 2 mm mesh, and subjected to physical and chemical analysis. Particle size distribution was determined using the hydrometer method with Calgon as a dispersing agent and the soil textural class was determined (Okalebo *et al.*, 1993). The soil pH in 1:1 soil:water ratio and 1:2 soil:0.01 M $CaCl_2$ was determined using electrometric method (Okalebo *et al.,* 1993). Organic carbon was determined by Black's wet oxidation method. Total nitrogen was determined by macro Kjedahl's oxidation method involving digestion and distillation (Jackson, 1967). The readily acid-soluble forms of phosphorus as extracted with hydrochloric acid and ammonium fluoride mixture called Bray No. 2 and phosphorus in the extract was determined by colorimetric procedure as described by Okalebo *et al.* (1993). Exchangeable cations were extracted with an excess ammonium acetate solution, potassium and sodium were determined using flame photometer while magnesium and calcium by atomic absorption spectrophotometer (Sparks, 1996). The analysis was conducted in the analytical laboratory of the Department of Agronomy, A.B.U. Zaria.

3.5 Meteorological Data

Meteorological data on temperature, sunshine hours, rainfall and relative humidity were collected from the Meteorological Units of the Institute for Agricultural Research, Samaru, and the National Institute for Horticultural Research, Bagauda sub-station during the 2019 cropping season and are presented in Appendices I and II.

3.6 Cultural Practices

3.6.1 Land preparation

The land was harrowed twice to a fine tilth and later made into ridges 75 cm apart. The field was marked into 72 plots. Gross plot size was 12 m^2 (3 m × 4 m) constituting four (4) ridges, while the net plot size was 6 m^2 (1.5 m × 4 m). The border between plots and replicates was 0.5 m and 1 m, respectively.

3.6.2 Test material

Local finger millet cultivar Jengre red (Ex-Jos) was used in this experiment. It is a small seeded, reddish brown in colour, with yield potential of about 1 ton ha^{-1} and matures in 120-140 days (Bulus 2002; Gani, 2012). It was purchased from Jengre market, Jos, Plateau state.

3.6.3 Crop protection

Finger millet seeds were treated with Apron star (Methylthiram + Metalaxyl + Carboxin) at the rate of 10 g per 4 kg of seed before planting, to protect the seeds against attack by soil borne pests and pathogens.

3.6.4 Seed sowing

Seed sowing was done on 2nd July, 2019 at Samaru, and 3rd July, 2019 at Bagauda. The seeds were dibbled two rows on a ridge (20 cm apart) and intra row spacing of 20 cm. Seedlings were later thinned to two plants per stand at 2 weeks after sowing (WAS).

3.6.5 Herbicide application

The pre-emergence herbicide, Atrazine and 2,4-D were applied immediately after sowing on treatment basis. Herbicide application was done using a calibrated CP3 Knapsack sprayer fitted with a green deflector nozzle and set at a pressure of 2.1 kg cm^{-2}, which delivered spray volume of 200 L ha^{-1}.

3.6.6 Weeding

Hoe weeding was done on the hoe weeded control plots at 3 and 6 WAS in order to control weeds at both locations.

3.6.7 Fertilizer application

NPK 15:15:15 was applied basally (at planting) to supply half dose of nitrogen and full dose of phosphorus and potassium, thereafter at 5 WAS, top dressing was done using urea (46% N) to supply the other half dose of nitrogen. The fertilizers were applied using band placement method.

3.6.8 Harvesting

The crop was harvested at physiological maturity when the panicle had turned brownish in colour, indicated by free threshing of the grains when the panicles are robbed by hand. The plant was cut about 5cm below the panicle using a sickle, dried for 3 days before threshing on polythene sack by beating with sticks and thereafter winnowed to remove the straw, foreign materials and unfilled grains. This was done separately for each plot.

3.7 Observations and Data Collection

3.7.1 Weed parameters

3.7.1.1 Weed composition

The types of weed species observed in the field were identified, and classified into grasses, broad-leaves and sedges accordingly. Their level of occurrence was also recorded for each plot.

3.7.1.2 Weed cover score

Weed cover score was taken and recorded for each treatment at 3 and 6 WAS by visual observation using a scale of 1-9; where 1 represents weed-free and 9 represents the highest weed covered plot.

3.7.1.3 Weed density

Weed count was taken using 50 cm x 50 cm quadrant placed randomly in each plot at 3, 6 and 9 WAS. Weed samples were uprooted and separated into species then counted as density of individual weed species. The sum of all the species recorded at each sampling period were taken as the total weed density per plot.

3.7.1.4 Weed dry weight (g)

Weed samples obtained from the net plot using a quadrat at 3, 6 and 9 WAS were cleaned, and oven dried at 70^{o}C to a constant weight. The dry weights were taken using Metler-P 1210 balance and recorded accordingly for each treatment.

3.7.2 Crop growth parameters

3.7.2.1 Days to emergence

The number of days between sowing and 50% seedling emergence on each net plot were taken and recorded for each treatment.

3.7.2.2 Emergence count

The number of emerged stands viz-a-viz the total number of expected/planted stands per net plot were taken at 2 WAS and recorded.

3.7.2.3 Crop injury score

The crop injury score for each treatment combination was assessed visually at 3 and 6 WAS using a scale of 1-9, where 1 represents least crop injury and 9 represents most injured/completely dead plants/plot.

3.7.2.4 Crop vigor score

The crop vigor score for each plot was visually assessed at 3 and 6 WAS using a scale of 1-9, where 1 represents the least vigorous plants while 9 represents healthiest plants.

3.7.2.5 Plant height (cm)

The plant height of finger millet from each net plot were taken at 6, 9 and 12 WAS using a meter rule by measuring the height of five randomly selected and tagged plants from the base of culm to the apex. The average plant height was recorded accordingly and expressed as in cm per plant.

3.7.2.6 Leaf area index (LAI)

The leaf area index of a canopy is the total leaf area of a plant material per unit area occupied by the plant. LAI is the ratio of leaf surface area per unit land surface. Non-destructive LAI data was measured for each treatment at 6, 9 and 12 WAS using Ceptometer (Model tp-at). The sensor of the Ceptometer was placed diagonally across the two inner rows, such that the end of the sensor coincided with the line of the plants in each row. The displayed LAI for each plot was recorded accordingly. All LAI measurements were made under cloud free conditions between 12:00 and 14:00 hours.

3.7.2.7 Number of tillers per plant

The number of tillers from the five tagged plants were counted and the average tillers per plant was recorded for each of the net plot at 9 and 12 WAS.

3.7.2.8 Shoot dry weight (g/plant)

Five plants were cut at the base from area outside the net plot and border rows in each plot at 6, 9 and 12 WAS, thereafter placed in labelled envelopes and oven dried at 70^{o}C to a constant weight determined by using Metler-P 1210 balance. The average weight was later computed and recorded for each treatment combination.

3.7.2.9 Crop growth rate (CGR)

The crop growth rate of a plant is simply the measure of the rate of increase in weight at a given time. CGR from each plot was calculated and recorded at 6, 9 and 12WAS, using the formula described by Watson (1952).

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \; g / wk$$

Where, W_1 is plant dry weight at time T_1 and W_2 is plant dry weight at time T_2. Values obtained were later recorded for each plot.

3.7.2.10 Relative growth rate (RGR)

The relative growth rate of a plant at an instance in time is defined as the increase in plant material per unit of plant material present per unit of time. RGR for each treatment combination were calculated and recorded at 6, 9, and 12 WAS.

$$RGR = \frac{\log_e W_2 - \log_e W_1}{T_2 - T_1} \; g / g / wk$$

Where, W_1 is plant dry weight at time T_1, and W_2 is plant dry weight at time T_2. The computed values were thereafter recorded for each treatment combination.

3.7.2.11 Number of days to 50% heading

The number of days to 50% heading of finger millet from each plot was determined by counting and recording the number of days from sowing to the day when 50% of the panicle extruded in each plot.

3.7.2.12 Stand count at harvest

The number of stands of finger millet per net plot were counted and recorded at harvest.

3.7.2.13 Days to physiological maturity

The number of days to physiological maturity for each plot was determined by counting and recording number of days from sowing when 90% of the panicle turned from green to golden brown.

3.7.3 Yield and yield components

3.7.3.1 Panicle length (cm)

The panicle length of five tagged plants from each net plot were measured from the base of the panicle to the distal end using a meter rule, thereafter the average panicle length per plant was determined and recorded in cm.

3.7.3.2 Number of fingers panicle^{-1}

The number of fingers per panicles of the five tagged plant in each plot were counted and the average computed and recorded.

3.7.3.3 Panicle weight plant^{-1}(g)

The panicle weight per plant from the five tagged plants at harvest prior to threshing in each net plot was determined by weighing the panicles using Metler-P 1210 balance and later the average computed and recorded in g per plant.

3.7.3.4 Grain weight plant^{-1}(g)

The average weight of grain from the five tagged plants were determined after threshing by weighing the winnowed grains from each plot using a Metler-P 1210 weighing balance and values obtained were averaged and the mean grain weight per plant recorded.

3.7.3.5 1000-Grain weight (g)

Three sets of 1000-grain per net plot were counted using seed counter, weighed using Metler-P 1210 weighing balance, and mean values recorded and expressed in g.

3.7.3.6 Grain yield (kg ha^{-1})

The threshed and winnowed grain from each net plot was weighed using a Metler-P 1210 balance. The values obtained were later converted and recorded in kg ha^{-1} for each of the treatment combination.

3.7.3.7 Threshing percentage (%)

The threshing percentage was determined from each plot by taking the ratio of grain weight to panicle weight. Panicles from the five tagged plants were used and the values for each plot were expressed and recorded in percentage.

$$\text{Threshing percentage} = \frac{\text{Grain weight after threshing}}{\text{Panicle weight (un-threshed)}} \times 100$$

3.7.3.8 Harvest index (HI)

HI was determined and recorded by dividing the grain yields by the total biomass in each net plot.

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.8 Statistical Analysis

The data collected were subjected to statistical analysis using the General Linear Model (GLM) procedure of Statistical Analysis Software (SAS) package, version 9.4. The treatment means were compared using Duncan's Multiple Range Test (DMRT) (Duncan, 1955) at 5% level of probability. The magnitude and type of relationship between grain yield and other parameters were determined by simple correlation analysis (Little and Hills, 1978). Regression of grain yield against NPK fertilizer was also carried out as described by Steel and Torrie (1987).

CHAPTER FOUR

4.0 RESULTS

4.1 Physical and Chemical Properties of the Soil

Table 1 shows the physical and chemical properties of the soils at the experimental sites during the 2019 rainy season. At Samaru, the textural class of the soil was loam, moderately acidic (5.51) with low organic carbon (1.02 g kg^{-1}) and total nitrogen (0.95 g kg^{-1}). Available phosphorus (10.54 mg kg^{-1}), calcium (2.61 cmol kg^{-1}), magnesium (0.36 cmol kg^{-1}), potassium (0.18 cmol kg^{-1}) and sodium (0.21 cmol kg^{-1}) contents were medium, cation exchange capacity of the soil was low (3.65). At Bagauda, the soil was classified as sandy loam and soil pH was moderately acidic (5.84). Organic carbon (1.22 g kg^{-1}), total nitrogen (1.18 g kg^{-1}) and available phosphorus (6.26 mg kg^{-1}) contents were low, while calcium (3.15 cmol kg^{-1}), magnesium (0.56 cmol kg^{-1}), potassium (0.18 cmol kg^{-1}) and sodium (1.18 cmol kg^{-1}) contents were all medium, cation exchange capacity of the soil was low (4.32).

4.2 Weed Species Composition and their Level of Occurrence

The weed species composition and their level of occurrence at both experimental sites during the 2019 rainy season were taken at 12 WAS and classified into grasses, broadleaves and sedges as presented in Table 2. At both locations, high level of *Cynodon dactylon, Digitaria horizontalis, Ageratum conyzoides, Cyperus esculentus* and *Cyperus rotundus,* were observed. Also, moderate level of occurrence *Eleucine indica, Panicum maximum, Rottboellia cochinchinensis, Commelina benghalensis, Euphorbia hirta* L. and *Portulaca oleracea*were observed. At Samaru, *Setaria barbata* Lam. occurred at high level while *Achanthospermum hispidum* was observed to be moderate. However, at Bagauda, *Echinochloa colona* L., *Amaranthus spinosus,* and *Senna obtusifolia* occurred at moderate levels.

Table 1: Physical and chemical properties of soils at the experimental sites during the 2019 rainy season

Soil Composition	Depth of Soil (0 – 30cm)	
Particle size distribution (g kg^{-1})	**Samaru**	**Bagauda**
Sand	416	640
Silt	460	280
Clay	124	80
Textural class	Loam	Sandy loam
Chemical properties		
pH in H_2O (1:2.5)	5.51	5.84
pH in 0.01M $CaCl_2$ (1:2.5)	4.67	4.15
Organic Carbon (g kg^{-1})	1.02	1.22
Total Nitrogen (g kg^{-1})	0.95	1.18
Available Phosphorus (mg kg^{-1})	10.54	6.26
Exchangeable cations (cmol kg^{-1})		
Calcium (Ca^{2+})	2.61	3.15
Magnesium (Mg^{2+})	0.36	0.56
Potassium (K^+)	0.18	0.18
Sodium (Na^+)	0.21	1.18
Aluminium and Hydrogen ($Al^{3+} + H^+$)	0.29	0.25
Cation Exchange Capacity (C.E.C)	3.65	4.32

Analysed at the Department of Agronomy, Ahmadu Bello University, Zaria (2019)

Table 2: Weed species composition and level of occurrence identified at 12 WAS at the experimental sites during the 2019 rainy season

Weed Species	Common Name	Level of occurrence	
		Samaru	**Bagauda**
Grasses			
Cynodon dactylon (Linn.) Pers.	Bermuda grass	**	**
Digitaria horizontalis Willd.	Crabgrass	**	**
Echinochloa colona (Linn.) Link	Jungle-rice	-	*
Eleucine indica (L.) Gaertn.	Goose-grass	*	*
Panicum maximum Jacq.	Guinea-grass	*	*
Pennisetum pedicellatum Trin.	Feather pennisetum	*	**
Rottboellia cochinchinensis (Lour.) Clayton	Corn-grass	*	*
Setaria barbata (Lam.) Kunth	Foxtail-grass	**	-
Broadleaves			
Achanthospermum hispidum DC.	Bristly starbur	*	-
Ageratum conyzoides Linn.	Goat-weed	**	**
Amaranthus spinosus Linn.	Spiny amaranth	-	*
Senna obtusifolia L.	Sickle pod	-	*
Commelina benghalensis L.	Tropical spiderwort	**	*
Euphorbia hirta Linn.	Garden spurge	*	*
Portulaca oleracea Linn.	Hog weed	*	**
Sedges			
Cyperus esculentus Linn.	Yellow nutsedge	**	**
Cyperus rotundus Linn.	Purple nutsedge, nut-grass	**	**

Keys: ** = High weed infestation (>40%) and * = Low weed infestation (1- 39%)

4.3 Weed Cover Score

Table 3 shows the effect of weed control treatments and NPK fertilizer rates on the weed cover score in finger millet during the 2019 rainy season at Samaru and Bagauda. Weedy check recorded significantly higher weed cover score throughout the sampling periods in both locations. This was statistically comparable to the various herbicide treatments during the course of the trial. Hoe weeded control plots however consistently had the least weed cover score at both sampling periods and locations.

The effect of varying NPK fertilizer rates on weed cover score was significant at both sampling periods and locations except at 6 WAS in Samaru. No-fertilizer treatment recorded the least weed cover score at 3 in Samaru and 6 WAS Bagauda. However, at 3 WAS in Bagauda, the untreated control had significantly higher weed cover score than plots receiving fertilizer at higher rates of 60:30:30 and90:45:45 kg ha^{-1}but comparable to treatments with 30:15:15 kg ha^{-1}.

The interaction of weed control treatments and NPK fertilizer rates on weed cover score was not significant at both sampling periods and locations.

4.4 Weed Density

The effects of weed control treatments and NPK fertilizer rates on weed density in plots of finger millet in Samaru and Bagauda during the 2019 cropping season is shown in Table 4. The effect of weed control strategies on weed density was not significant throughout the growing season at Bagauda, while at Samaru, highest and least weed density were recorded by the weedy check and hoe weeded control respectively.

Table 3: Effect of weed control treatments and NPK fertilizer rates on weed cover score in finger millet in Samaru and Bagauda during the 2019 rainy season

	Weed Cover Score			
	Samaru		Bagauda	
Treatments	3 WAS[1]	6 WAS	3 WAS	6 WAS
Weed Control (W)				
Atrazine at 2.0 kg a.i. ha^{-1}	6.0bc[2]	6.9a	5.5bc	8.3a
Atrazine at 3.0 kg a.i. ha^{-1}	6.7ab	6.8a	5.8bc	8.3a
2,4-D at 0.6 kg a.i. ha^{-1}	5.4bc	6.5a	5.2c	7.9ab
2,4-D at 0.8 kg a.i. ha^{-1}	4.8c	6.6a	6.3ab	7.2b
Hoe weeded control	1.1d	1.0b	1.9d	1.3c
Weedy check	7.8a	5.9a	7.0a	7.6ab
SE±	0.49	0.49	0.34	0.33
NPK kg ha^{-1} (N)				
0:0:0	4.7b	4.8	6.0a	5.9c
30:15:15	5.1ab	6.1	5.3ab	6.6bc
60:30:30	5.3ab	5.6	4.9b	7.1ab
90:45:45	6.1a	6.1	4.9b	7.5a
SE±	0.40	0.40	0.28	0.27
Interaction				
W x N	NS[3]	NS	NS	NS

[2]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[3]NS = Not Significant
[1]WAS = Weeks After Sowing

Table 4: Effect of weed control treatments and NPK fertilizer rates on weed density in finger millet in Samaru and Bagauda during the 2019 rainy season

	Weed Density					
	Samaru			Bagauda		
Treatments	3 WAS[1]	6 WAS	9 WAS	3 WAS	6 WAS	9 WAS
Weed Control (W)						
Atrazine at 2.0 kg a.i. ha^{-1}	25.3c	30.0c	23.7c	15.3	25.1	16.7
Atrazine at 3.0 kg a.i. ha^{-1}	32.5b	37.1b	26.8b	15.9	23.3	16.8
2,4-D at 0.6 kg a.i. ha^{-1}	14.0e	18.8e	17.4e	14.4	21.3	15.9
2,4-D at 0.8 kg a.i. ha^{-1}	18.7d	25.4d	20.1d	13.9	21.1	16.0
Hoe weeded control	14.0e	10.5f	12.3f	13.3	18.7	13.7
Weedy check	41.8a	49.2a	33.7a	18.9	26.7	19.3
SE±	1.10	0.82	0.50	2.04	2.20	2.12
NPK kg ha^{-1} (N)						
0:0:0	24.5b	27.9	20.7c	13.1	19.4	13.9
30:15:15	23.7ab	28.2	21.6c	14.6	21.6	15.7
60:30:30	24.4ab	27.9	22.8b	16.1	23.2	17.3
90:45:45	26.1a	29.3	24.2a	17.5	24.6	18.6
SE±	0.90	0.67	0.41	1.66	1.80	1.73
Interaction						
W x N	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
NS = Not Significant
[1]WAS = Weeks After Sowing

Similarly, varying NPK fertilizer significantly affected weed density only at 3 and 9 WAS in Samaru where plots treated with highest NPK fertilizer rates recorded the highest values for weed density which in turn was not significantly different from the lower applied rates.

Interactions observed between weed treatment and NPK fertilizer treatments on weed density were not significant at all sampling periods in both locations

4.5 Weed Dry Weight

Table 5 shows the effects of weed control treatments and NPK fertilizer on the weed dry weight of finger millet at 3, 6 and 9 WAS during the 2019 rainy season in Samaru and Bagauda respectively. Across all the sampling period and locations, weed control treatments significantly reduced weed dry weight when compared with the weedy check that consistently had the highest values of weed dry weight that was statistically at par with all except Atrazine at 3.0 kg a.i. $ha^{-1}$and hoe weeded control at 3 and 6 WAS, and 2,4-Dat 0.8 kg a.i. ha^{-1} at 3 WAS in Bagauda. Hoe weeded control consistently gave the least weed dry weights across all the sampling periods in both locations, subsequently followed by application of 2,4-Dat 0.6 kg a.i. ha^{-1}, 2,4-Dat 0.8 kg a.i. ha^{-1}, Atrazine at 2.0 kg a.i. ha^{-1} and least chemical control was from Atrazine at 3.0 kg a.i. ha^{-1}at all the sampling periods in Samaru.

Application of NPK fertilizer significantly affected weed dry weights across all the sampling periods in both locations. At 6 and 9 WAS in Samaru and all the sampling periods in Bagauda, NPK fertilizer rate of 90:45:45 kg NPK ha^{-1}resulted in the highest weed dry weight that was statistically similar to that of 60:30:30 kg NPK ha^{-1}at 3 WAS in Samaru and in all the sampling weeks in Bagauda, as well as 30:15:15 kg NPK ha^{-1}at 9 WAS in Bagauda only. At 9 WAS in Samaru, the control had the heaviest weed dry weight that was statistically similar to that of 30:15:15 kg NPK ha^{-1} but more than that recorded by 90:45:45 and 60:30:30 kg NPK ha^{-1}. At all

Table 5: Effect of weed control treatments and NPK fertilizer rates on weed dry weight (g) in finger millet at Samaru and Bagauda during the 2019 rainy season

	Weed Dry Weight (g)					
	Samaru			Bagauda		
Treatments	3 WAS[1]	6 WAS	9 WAS	3 WAS	6 WAS	9 WAS
Weed Control (W)						
Atrazine at 2.0 kg a.i. ha^{-1}	60.5c[2]	97.2c	94.1c	74.4a	89.1a	63.6a
Atrazine at 3.0 kg a.i. ha^{-1}	75.7b	110.9b	118.4b	45.1c	72.0b	62.3a
2,4-D at 0.6 kg a.i. ha^{-1}	28.2e	58.9e	66.2e	62.7ab	77.7ab	68.7a
2,4-D at 0.8 kg a.i. ha^{-1}	45.2d	80.0d	84.2d	53.1bc	78.0ab	64.6a
Hoe weeded control	4.1f	17.9f	21.3f	21.4d	17.9c	24.3b
Weedy check	100.7a	144.3a	145.2a	69.8a	88.7a	70.6a
SE±	2.88	2.47	4.88	4.90	4.47	6.72
NPK kg ha^{-1} (N)						
0:0:0	44.9c	78.1c	98.4a	44.1b	58.3b	51.5b
30:15:15	50.5bc	83.5bc	89.7ab	46.5b	65.1b	58.6ab
60:30:30	55.2ab	85.5b	85.1b	59.4a	75.6a	56.8ab
90:45:45	59.0a	92.3a	79.8b	67.6a	83.3a	69.1a
SE±	2.35	2.02	3.98	4.00	3.65	5.48
Interaction						
W x N	NS[3]	NS	NS	NS	*	NS

[2]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[3]NS = Not Significant
[1]WAS = Weeks After Sowing
*Significant at 5% level of probability

but 9 WAS in Samaru, the control had the least value for weed dry weight that was at par with that of 30:15:15 kg NPK ha^{-1}.

Significant interaction of weed control treatments and NPK fertilizer rates on weed dry weight was observed at 9 WAS in Bagauda as presented on Table 6. Generally, weedy check had the highest while hoe weeded control significantly reduced weed dry weight. This is however followed by application of Atrazine at 3.0 kg a.i. ha^{-1}. All other herbicides weed control treatments had moderately reduced weed dry weights in a statistically similar manner. Varying the NPK fertilizer rates had no significant effect on weed dry weight when 0.6 kg a.i. ha^{-1} of 2,4-D or hoe weeding was used. In the case of other weed control strategies employed, 90:45:45 kg NPK ha^{-1}produced the heaviest weed dry weights that was statistically the same with 60:30:30kg NPK ha^{-1} as for the use of 2,4-D herbicide and weedy check, and 0:0:0 and 30:15:15 kg NPK $ha^{-1}$when Atrazine at 2.0kg a.i. $ha^{-1}$was applied. With the exception of the latter mentioned herbicide treatments all other weed control strategies had their lowest value for weed dry weight when no NPK fertilizer was used. The highest weed dry weight value was from the combination of weedy check and 90:45:45 kg NPK ha^{-1} while the least value was from hoe weeded control and 0:0:0kg NPK ha^{-1}.

Table 6: Interaction of weed control and NPK fertilizer on weed dry weight (g) in finger millet during the 2019 rainy season at 9 WAS[1] in Bagauda

NPK kg ha^{-1}	Weed Control					
	Atrazine (kg a.i. ha^{-1})		2,4-D (kg a.i. ha^{-1})		HW Control	Weedy Check
	2.0	3.0	0.6	0.8		
0:0:0	82.8ab[2]	49.5de	70.7bcd	64.9bcd	10.0f	72.1bc
30:15:15	107.4a	65.1bcd	75.3bc	53.1cd	15.2f	74.7bc
60:30:30	71.6bcd	79.4b	82.4ab	98.6a	20.8f	100.6a
90:45:45	94.7a	94.2a	82.4ab	95.3a	25.5ef	107.5a
SE±			8.94			

[2]Means followed by the same letter(s) within a column in each treatment do not significantly differ at 5% level of probability using Duncan Multiple Range Test (DMRT).
HW = Hoe weeded control

4.6 Days to Emergence

The effects of weed control treatments and NPK fertilizer on the number of days to emergence of finger millet during the 2019 rainy season at both locations is shown on Table 7. Weed control treatments significantly affected the number of days to emergence of finger millet. In both location, application of Atrazine at 3.0 kg a.i. ha^{-1} and 2,4-D at 0.8 kg a.i. ha^{-1} significantly delay emergence of finger millet. This is followed by application of Atrazine at 2.0 kg a.i. ha^{-1} and 2,4-Dat 0.6 kg a.i. ha^{-1} which were statistically at par with 2,4-D at 0.8 kg a.i. ha^{-1}. Hoe weeded control and weedy check however emerged faster than all other weed control treatments.

Application of NPK fertilizer rates significantly affected number of days to emergence, where increase in the rates of NPK fertilizer from 0:0:0 to 90:45:45 kg ha^{-1} resulted in corresponding decrease in number of days to emergence, although application of 60:30:30 kg ha^{-1}in Samaru and 30:15:15 and 60:30:30 kg ha^{-1} in Bagauda resulted to similar number of days to emergence.

The interaction of weed control treatments and NPK fertilizer on the number of days to emergence of finger millet was not significant.

4.7 Emergence Count

Table 7 shows the significant difference observed in the emergence count of finger millet as a result of use of different weed control strategies during the 2019 rainy season at both locations. At Samaru, hoe weeded control gave statistically higher emergence count, that was comparable with that of 2,4-D at 0.6 kg a.i. ha^{-1} followed by application of Atrazine at 2.0 kg a.i. $ha^{-1}$and the weedy check which were at par. Application of Atrazine at 3.0 kg a.i. ha^{-1} and 2,4-D at 0.8 kg a.i. ha^{-1} gave the least emergence count which were statistically similar with application of Atrazine at 2.0 kg a.i. ha^{-1} and the weedy check. Hoe weeded control gave significantly higher emergence

Table 7: Effect of weed control treatments and NPK fertilizer rates on number of days to emergence and emergence count of finger millet in Samaru and Bagauda during the 2019 rainy season

	No. of Days to Emergence		Emergence Count	
Treatments	Samaru	Bagauda	Samaru	Bagauda
Weed Control (W)				
Atrazine at 2.0 kg a.i. ha^{-1}	5.6b	5.7b	74.3bc[1]	74.3b
Atrazine at 3.0 kg a.i. ha^{-1}	6.0a	6.3a	73.3c	74.8b
2,4-D at 0.6 kg a.i. ha^{-1}	5.6b	5.4b	75.5ab	74.4b
2,4-D at 0.8 kg a.i. ha^{-1}	5.8ab	5.8ab	73.3c	74.5b
Hoe weeded control	4.7c	3.9c	76.6a	77.0a
Weedy check	4.8c	3.8c	74.6bc	74.6b
SE±	0.63	0.17	0.63	0.71
NPK kg ha^{-1} (N)				
0:0:0	6.1a	5.7a	72.3b	73.7b
30:15:15	5.7b	5.2b	74.6a	75.1ab
60:30:30	5.1c	5.1b	75.4a	75.3ab
90:45:45	4.8c	4.6c	76.1a	75.7a
SE±	0.11	0.14	0.51	0.58
Interaction				
W x N	NS[3]	NS	NS	NS

[1]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan Multiple Range Test (DMRT).
[2]WAS = Weeks After Sowing [3]NS = Not Significant

count followed by the lower values recorded by the remaining weed control treatments at Bagauda.

All the applied NPK fertilizer rates produced significantly higher and similar values for emergence count than the control at Samaru. At Bagauda, application of NPK 90:45:45 kg ha^{-1} gave higher emergence count though statistically similar with the other two applied lower NPK rates. Control gave the least emergence count which was statistically comparable with application of 30:15:15 and 60:30:30 kg ha^{-1}.

Interaction of weed control and NPK fertilizer treatments was not significant at both locations.

4.8 Crop Injury Score

Crop injury score of finger millet as influenced by weed control treatments and NPK fertilizer rates at 3 and 6 WAS during the 2019 cropping season at Samaru and Bagauda is presented on Table 8. Weed control strategies significantly affected crop injury score across all the sampling periods at both locations. Hoe weeded control generally had the least injury on the finger millet crop when compared to other treatments across sampling periods and locations. All the herbicide weed control treatments statistically caused similar and higher injury to finger millet crop similar statistically to weedy check at all except 6 WAS in Samaru when it caused less injury to the crop.

Application of NPK fertilizer treatments significantly affected the crop injury score of finger millet where increase in the rates of NPK fertilizer from up to 60:30:30 kg NPK ha^{-1}resulted in corresponding decrease in crop injury score beyond which no significant response was recorded except at 3 WAS in Bagauda where 90:45:45 kg ha^{-1}had less injury on the crop.

Interaction between weed control treatments and NPK fertilizer rates on crop injury score was significant at 3 WAS in both locations and at 6 WAS in Samaru which were presented on Table 9.Regardless of the NPK fertilizer rate hoe weeded control generally had the least injured crops when compared with all other herbicide weed control treatments at all the sampling periods and locations., while use of the highest rate of Atrazine or any of the 2,4-D herbicide rates caused more injury to the finger millet in same like manner with weedy check at 3 WAS in both locations.

Table 8: Effect of weed control treatments and NPK fertilizer rates on crop injury score of finger millet in Samaru and Bagauda during the 2019 rainy season

	Crop Injury Score			
	Samaru		Bagauda	
Treatments	3 WAS[1]	6 WAS	3 WAS	6 WAS
Weed Control (W)				
Atrazine at 2.0 kg a.i. ha^{-1}	3.8a[2]	2.9bc	3.4b	1.7a
Atrazine at 3.0 kg a.i. ha^{-1}	4.4a	3.4ab	3.7ab	2.0a
2,4-D at 0.6 kg a.i. ha^{-1}	4.9a	4.2a	3.4b	1.9a
2,4-D at 0.8 kg a.i. ha^{-1}	4.3a	3.7ab	3.3b	2.1a
Hoe weeded control	1.0b	1.1d	1.3c	1.1b
Weedy check	4.2a	2.5c	4.1a	1.6ab
SE±	0.43	0.29	0.19	0.18
NPK kg ha^{-1} (N)				
0:0:0	5.9a	4.4a	5.3a	2.7a
30:15:15	3.9b	3.2b	3.3b	1.8b
60:30:30	2.9c	2.4c	2.3c	1.3c
90:45:45	2.3c	1.8c	1.8d	1.1c
SE±	0.35	0.23	0.16	0.14
Interaction				
W x N	*	*	*	NS[3]

[2]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[3]NS = Not Significant [1]WAS = Weeks After Sowing *Significant at 5% level of probability

Table 9: Interaction of weed control and NPK fertilizer on crop injury score of finger millet in Samaru and Bagauda during the 2019 rainy season

NPK kg ha^{-1}	Weed Control					
	Atrazine (kg a.i. ha^{-1})		2,4-D (kg a.i. ha^{-1})		HW Control	Weedy Check
	2.0	3.0	0.6	0.8		
Bagauda 3 WAS[2]						
0:0:0	6.3ab[1]	6.7a	5.3bc	5.3bc	1.7fgh	6.7a
30:15:15	3.3de	3.3de	3.7d	3.3de	1.3gh	4.7c
60:30:30	2.3efg	2.7def	2.7def	2.3efg	1.3gh	2.7def
90:45:45	1.7fgh	2.0fgh	2.0fgh	2.0fgh	1.0h	2.3efg
SE±	0.38					
Samaru 3 WAS						
0:0:0	4.0cde	7.3ab	8.0a	7.3ab	1.0f	7.3ab
30:15:15	4.7cd	5.3bc	5.0bcd	3.7cde	1.0f	4.0cde
60:30:30	3.3c-f	3.3c-f	4.0cde	2.7def	1.0f	3.0c-f
90:45:45	3.3c-f	1.7ef	2.7def	3.3c-f	1.0f	2.0ef
SE±	0.86					
Samaru 6 WAS						
0:0:0	2.7e-h	5.3abc	6.3ab	6.7a	1.3hi	4.3cd
30:15:15	3.3d-g	4.0cde	4.7bcd	3.3d-g	1.0i	2.7e-h
60:30:30	2.7e-h	3.0efg	3.7c-f	2.3f-i	1.0i	1.7ghi
90:45:45	3.0efg	1.3hi	2.0ghi	2.3f-i	1.0i	1.3hi
SE±	0.57					

[1]Means followed by the same letter(s) within a column in each treatment do not significantly differ at 5% level of probability using Duncan Multiple Range Test (DMRT).
[2]WAS = Weeks After Sowing   HW = Hoe weeded control

4.9 Crop Vigour Score

Table 10 shows the effects of weed control treatments and NPK fertilizer rates on crop vigour score of finger millet during the 2019 cropping season at both locations. Weed control treatments significantly affected the crop vigour of finger millet in both locations. It was observed that hoe weeded control significantly and consistently recorded the most vigorous crops across the sampling periods at both location that was comparable statistically with application of Atrazine at 2.0 kg a.i. ha^{-1} at 3 WAS and weedy check in Samaru, 2,4-D at 0.6 and 0.8 kg a.i. ha^{-1} at 3 WAS and 3 WAS and 6 WAS in Bagauda, and weedy check at 3 was in Samaru. All other herbicide treatments reduced the vigour of finger millet crop.

Application of NPK fertilizer had significant effect on crop vigour score. At 3 WAS in both locations, increasing the rates of NPK fertilizer led to corresponding increase in crop vigour. Application of 30:15:15 kg ha^{-1} and the control had the least crop vigour and were statistically at par at 6 WAS in Samaru. This was followed by application of 60:30:30 kg $ha^{-1}$and 90:45:45 kg ha^{-1} which gave the highest values for crop vigour. At 6 WAS in Bagauda, control had the least crop vigour, followed by 30:15:15 kg ha^{-1} which is statistically the same with 60:30:30 kg ha^{-1} that had higher value. Application of 90:45:45 kg ha^{-1} resulted to most vigorous plants statistically similar to 60:30:30 kg ha^{-1}.

Interaction of treatments on crop vigour score was not significant across the sampling periods at both locations.

Table 10: Effect of weed control treatments and NPK fertilizer rates on crop vigour score of finger millet in Samaru and Bagauda during the 2019 rainy season

	Crop Vigour Score			
	Samaru		Bagauda	
Treatments	3 WAS[1]	6 WAS	3 WAS	6 WAS
Weed Control (W)				
Atrazine at 2.0 kg a.i. ha^{-1}	5.4ab[2]	5.3b	5.2b	7.3b
Atrazine at 3.0 kg a.i. ha^{-1}	4.9b	3.9b	5.0b	7.5b
2,4-D at 0.6 kg a.i. ha^{-1}	4.8b	4.4b	5.8a	7.4b
2,4-D at 0.8 kg a.i. ha^{-1}	4.7b	4.2b	6.1a	8.1ab
Hoe weeded control	6.0a	7.0a	6.3a	8.5a
Weedy check	5.3ab	4.6b	4.6b	7.5b
SE±	0.29	0.44	0.20	0.26
NPK kg ha^{-1} (N)				
0:0:0	2.6d	3.5c	3.4d	6.1c
30:15:15	4.9c	4.2c	5.1c	7.8b
60:30:30	6.2b	5.3b	6.3b	8.3ab
90:45:45	7.1a	6.6a	7.2a	8.6a
SE±	0.24	0.36	0.16	0.21
Interaction				
W x N	NS[3]	NS	NS	NS

[2]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[3]NS = Not Significant
[1]WAS = Weeks After Sowing

4.10 Plant Height

The effects of weed control treatments and NPK fertilizer rates on the plant height of finger millet at both locations during the 2019 rainy season is presented on Table 11. Weed control significantly affected plant height across the sampling periods and locations except at 9 WAS in Bagauda. Across all the sampling periods in Samaru and 6 WAS in Bagauda, application of Atrazine at 2.0 and 3.0 kg a.i. ha^{-1}, 2,4-D at 0.8 kg a.i. ha^{-1}, hoe weeded control and weedy check gave statistically similar and taller plants than for plants that received 2,4-D at 0.6 kg a.i. ha^{-1}. At 12 WAS in Bagauda, hoe weeded control and 2,4-D at 0.6 and 0.8 kg a.i. ha^{-1} had the tallest plants that were statistically similar with that from plots that received Atrazine at 3.0 kg a.i. ha^{-1} but taller plants than for Atrazine at 2.0 kg a.i. ha^{-1} and the weedy check that had the shortest plants.

Application of NPK fertilizer significantly affected plant height at all the sampling periods in both locations. It was observed that the highest NPK rate of 90:45:45 kg ha^{-1}generally resulted in the tallest plants that did not differ statistically from those plots that received 60:30:30 kg NPK ha^{-1}at 9 WAS in both locations only. The no-NPK treatment consistently recorded the shortest plants.

Interaction of factors on plant height of finger millet was not significant at all the sampling periods in both locations.

Table 11: Effect of weed control treatments and NPK fertilizer rates on plant height (cm) of finger millet in Samaru and Bagauda during the 2019 rainy season

	Plant Height (cm)					
	Samaru			Bagauda		
Treatments	6 WAS[1]	9 WAS	12WAS	6 WAS	9 WAS	12WAS
Weed Control (W)						
Atrazine at 2.0 kg a.i. ha^{-1}	42.5a[2]	51.6ab	80.0a	33.9a	57.9	64.2bc
Atrazine at 3.0 kg a.i. ha^{-1}	41.2ab	52.7ab	78.2a	3.8ab	61.3	67.9ab
2,4-D at 0.6 kg a.i. ha^{-1}	37.6b	46.9b	69.3b	29.6b	57.2	71.0a
2,4-D at 0.8 kg a.i. ha^{-1}	39.7ab	55.5a	78.3a	31.6ab	58.8	66.3abc
Hoe weeded control	42.2a	55.8a	85.9a	34.1a	62.3	71.6a
Weedy check	38.6ab	49.5ab	80.8a	32.6a	58.8	61.8c
SE±	1.27	2.06	2.86	0.85	1.78	1.92
NPK kg ha^{-1} (N)						
0:0:0	31.4c	41.7c	59.2d	25.9c	46.1c	51.3d
30:15:15	40.1b	52.7b	75.2c	32.5b	60.3b	66.1c
60:30:30	42.2b	54.7ab	86.7b	33.1b	63.6ab	72.6b
90:45:45	47.4a	58.8a	93.8a	37.7a	67.4a	78.4a
SE±	1.04	1.68	2.34	0.69	1.45	1.57
Interaction						
W x N	NS[3]	NS	NS	NS	NS	NS

[2]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[3]NS = Not Significant[1]WAS = Weeks After Sowing *Significant at 5% level of probability

4.11 Leaf Area Index

Table 12 shows the effects of weed control treatments and NPK fertilizer rates on the leaf area index (LAI) of finger millet at 6, 9 and 12 WAS during the 2019 rainy season in both locations. Weed control had no significant effect on LAI at 6 WAS in both locations. At 9 and 12 WAS in both locations, hoe weeded control resulted in the highest LAI values that was statistically comparable with that of Atrazine at 2.0 kg a.i ha^{-}1, 2,4-D at 0.6 kg a.i ha^{-1}and weedy check in Samaru location only. It was followed by LAI from application of Atrazine at 3.0 kg a.i ha^{-1}, although statistically comparable with application of Atrazine at 2.0 kg a.i ha^{-1}, 2,4-D at 0.6 kg a.i ha^{-1}, and weedy check; the least LAI value was from 2,4-D at 0.8 kg a.i ha^{-1}at Samaru. On the other hand, all the remaining weed control treatments had statistically similar lower LAI than hoe weeded control.

The effect of NPK fertilizer rates on LAI was observed to be significant throughout the sampling periods at both locations. Across all the sampling periods at Samaru, increasing the rate of NPK fertilizer from 0:0:0 to 30:15:15 significantly resulted in a corresponding increase in LAI. Further increase in NPK fertilizer rate to 60:30:30 kg NPK ha^{-1} increased LAI at 6 and 9 WAS in Samaru. The 30:15:15 and 60:30:30 kg NPK ha^{-1} had statistically similar LAI at 6 WAS in Samaru and all the sampling stages in Bagauda. Further increase to 90:45:45 kg ha^{-1} did not significantly affect LAI at Samaru but increased the parameter in Bagauda.

Interaction of weed control treatments and NPK fertilizer rates on LAI was generally not significant.

Table 12: Effect of weed control treatments and NPK fertilizer rates on leaf area index of finger millet in Samaru and Bagauda during the 2019 rainy season

	Leaf Area Index					
	Samaru			Bagauda		
Treatments	6 WAS[1]	9 WAS	12WAS	6 WAS	9 WAS	12WAS
Weed Control (W)						
Atrazine at 2.0 kg a.i. ha^{-1}	1.65	2.88abc[2]	4.13abc	1.49	3.34b	4.46b
Atrazine at 3.0 kg a.i. ha^{-1}	1.72	2.65bc	3.90bc	1.54	3.68b	4.80b
2,4-D at 0.6 kg a.i. ha^{-1}	1.74	3.02ab	4.27ab	1.55	3.45b	4.57b
2,4-D at 0.8 kg a.i. ha^{-1}	1.65	2.54c	3.79c	1.50	3.48b	4.60b
Hoe weeded control	1.59	3.20a	4.45a	1.81	4.32a	5.44a
Weedy check	1.48	2.85abc	4.10abc	1.59	3.45b	4.46b
SE±	0.146	0.146	0.146	0.108	0.188	0.188
NPK kg ha^{-1} (N)						
0:0:0	0.83c	1.85c	3.10c	1.33b	2.42c	3.53c
30:15:15	1.58b	2.75b	4.00b	1.57b	3.47b	4.59b
60:30:30	1.92ab	3.28a	4.53a	1.56b	3.90b	5.02b
90:45:45	2.23a	3.55a	4.80a	1.86a	4.68a	5.80a
SE±	0.119	0.119	0.119	0.088	0.153	0.154
Interaction						
W x N	NS[3]	NS	NS	NS	NS	NS

[2]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[3]NS = Not Significant[1]WAS = Weeks After Sowing

4.12 Number of Tillers per Plant

Table 13 shows the effects of weed control treatments and NPK fertilizer rates on the number of tillers per plant of finger millet. Weed control significantly affected number of tillers per plant in both locations. Hoe weeded control consistently gave significantly higher number of tillers throughout the sampling periods at both locations that was statistically similar to that from other weed control strategies employed except for plots left weedy at both sampling weeks and locations and 2,4-D at 0.8 kg a.i. ha^{-1} at 12 WAS in Samaru and both sampling weeks in Bagauda. Weedy check consistently gave the least values for number of tillers across the sampling periods and locations.

Application of NPK fertilizer significantly affected number of tillers of finger millet in both locations. The highest rate of NPK fertilizer consistently had the highest number of tillers per plant only similar statistically with that of 60:30:30 kg NPK ha^{-1} at Samaru. The 30:15:15 kg NPK ha^{-1} fertilizer rate had more tillers only than for the least generally recorded by 0:0:0 kg ha^{-1}.

Interaction of weed control treatments and NPK fertilizer had no significant effect on the number of tillers per plant of finger millet at both sampling weeks and locations.

Table 13: Effect of weed control treatments and NPK fertilizer rates on number of tillers per plant of finger millet in Samaru and Bagauda during the 2019 rainy season

	Number of Tillers			
	Samaru		Bagauda	
Treatments	9 WAS[1]	12WAS	9 WAS	12WAS
Weed Control (W)				
Atrazine at 2.0 kg a.i. ha^{-1}	2.1a[2]	2.5ab	1.9ab	2.8abc
Atrazine at 3.0 kg a.i. ha^{-1}	2.3a	2.6ab	2.2a	3.1ab
2,4-D at 0.6 kg a.i. ha^{-1}	1.9ab	2.5ab	1.9ab	2.6bc
2,4-D at 0.8 kg a.i. ha^{-1}	1.8ab	2.3b	1.6b	2.4c
Hoe weeded control	2.3a	2.9a	2.3a	3.3a
Weedy check	1.5b	1.8c	1.1c	1.8d
SE±	0.18	0.15	0.14	0.17
NPK kg ha^{-1}(N)				
0:0:0	1.2c	1.6c	0.9d	1.8d
30:15:15	1.9b	2.3b	1.6c	2.5c
60:30:30	2.3ab	2.8a	2.1b	3.1b
90:45:45	2.6a	3.1a	2.7a	3.5a
SE±	0.14	0.12	0.12	0.14
Interaction				
W x N	NS[3]	NS	NS	NS

[2]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[3]NS = Not Significant[1]WAS = Weeks After Sowing

4.13 Shoot dry weight

Dry weights per plant of finger millet as influenced by weed control treatments and NPK fertilizer rates at the two experimental sites during the 2019 rainy season are shown on Table 14. The difference in plant dry weight among the imposed weed control treatment were observed to be statistically significant across the sampling periods in both locations. It was observed that hoe weeded control did not differ statistically with application of the two rates of 2,4-D and Atrazine at 2.0 kg a.i. ha^{-1} at 12 WAS in Samaru and both Atrazine rates, 0.6 kg a.i. ha^{-1} of 2,4-D and weedy check at 6 WAS in Bagauda. The weedy check at all the sampling periods of both location except at 6 WAS in Bagauda recorded the least values for plant dry weights.

Application of NPK fertilizer significantly influenced accumulation of plant dry matter at both locations. It was observed that increasing the rate of NPK fertilizer from 0:0:0 to 30:15:15 and further to 60:30:30 and 90:45:45 kg NPK ha^{-1} significantly resulted in a corresponding increase in dry matter production across all the sampling periods at both locations, although 30:15:15 and 60:30:30 kg NPK ha^{-1} had statistically similar plant dry weight at 12 WAS in Bagauda only.

Interaction of factors did not significantly affect plant dry weights of finger millet throughout the sampling periods in both locations.

Table 14: Effect of weed control treatments and NPK fertilizer rates on plant dry weight (g) of finger millet in Samaru and Bagauda during the 2019 rainy season

	Plant Dry Weight (g)					
	Samaru			Bagauda		
Treatments	6 WAS[1]	9 WAS	12WAS	6 WAS	9 WAS	12WAS
Weed Control (W)						
Atrazine at 2.0 kg a.i. ha^{-1}	2.8b[2]	8.7b	15.9a	4.5a	9.0b	13.6bc
Atrazine at 3.0 kg a.i. ha^{-1}	2.6bc	8.1b	11.8b	4.5a	8.6b	11.0cd
2,4-D at 0.6 kg a.i. ha^{-1}	2.1c	9.4b	16.6a	3.9ab	6.4c	14.2b
2,4-D at 0.8 kg a.i. ha^{-1}	2.0c	9.4b	17.1a	3.3b	7.7bc	15.1b
Hoe weeded control	3.6a	12.5a	19.0a	4.8a	13.3a	24.1a
Weedy check	2.4bc	8.0b	11.2b	4.2ab	6.4c	8.5d
SE±	0.21	0.68	1.13	0.31	0.57	0.99
NPK kg ha^{-1} (N)						
0:0:0	1.3d	5.2d	9.6d	2.2d	3.9d	8.7c
30:15:15	2.2c	7.6c	13.7c	3.4c	8.0c	13.9b
60:30:30	2.8b	10.2b	16.9b	4.9b	9.8b	15.8b
90:45:45	4.1a	14.4a	20.9a	6.3a	12.6a	19.3a
SE±	0.18	0.56	0.92	0.25	0.47	0.81
Interaction						
W x N	NS[3]	NS	NS	NS	NS	NS

[2]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[3]NS = Not Significant[1]WAS = Weeks After Sowing

4.14 Crop Growth Rate

The effects of weed control treatments and NPK fertilizer rates on crop growth rate CGR of finger millet at Samaru and Bagauda during the 2019 rainy season is presented on Table 15. Weed control treatments significantly influenced CGR across the sampling periods at both locations. Hoe weeded control consistently had the highest CGR values in both locations while weedy check consistently had the least. The highest value of CGR recorded did not differ statistically from that of 2,4-D at both rates at 9 and 12 WAS in Samaru. Atrazine at both rates, 2,4-D at 0.6 kg a.i. ha^{-1} and weedy check had the least values of CGR at all except 6 WAS in Bagauda.

Application of NPK fertilizer had significant effect on CGR of finger millet only at 6 and 9 WAS in both locations where increase in the rates of fertilizer significantly resulted in corresponding increase in CGR, although the CGR for control and NPK rate of 30:15:15 kg ha^{-1}at 9 WAS in Samaru were at par while further increase to 60:30:30 kg ha^{-1} did not significantly affect CGR. There was no significant difference in CGR between the fertilizer treatments at 12 WAS in both locations.

Generally, interaction of the two factors on CGR of finger millet was not significant.

Table 15: Effect of weed control treatments and NPK fertilizer rates on crop growth rate of finger millet in Samaru and Bagauda during the 2019 rainy season

	Crop Growth Rate (gwk^{-1})					
	Samaru			Bagauda		
Treatments	6 WAS[1]	9 WAS	12WAS	6 WAS	9 WAS	12WAS
Weed Control (W)						
Atrazine at 2.0 kg a.i. ha^{-1}	0.46b[2]	1.97b	2.41ab	0.74a	1.51b	1.54c
Atrazine at 3.0 kg a.i. ha^{-1}	0.44bc	1.83b	1.24bc	0.76a	1.34bc	0.82c
2,4-D at 0.6 kg a.i. ha^{-1}	0.34c	2.44ab	2.42ab	0.65ab	0.83c	2.59b
2,4-D at 0.8 kg a.i. ha^{-1}	0.34c	2.45ab	2.57a	0.55b	1.45b	2.48b
Hoe weeded control	0.60a	2.98a	2.15abc	0.79a	2.84a	3.63a
Weedy check	0.39bc	1.87b	1.08c	0.70ab	0.75c	0.69c
SE±	0.037	0.235	0.409	0.051	0.205	0.325
NPK kg ha^{-1} (N)						
0:0:0	0.21d	1.31c	1.48	0.37d	0.56c	2.56
30:15:15	0.36c	1.80c	2.04	0.55c	1.54b	1.98
60:30:30	0.46b	2.46b	2.26	0.82b	1.64ab	1.99
90:45:45	0.68a	3.46a	2.15	1.05a	2.08a	1.59
SE±	0.030	0.192	0.334	0.042	0.168	0.265
Interaction						
W x N	NS[3]	NS	NS	NS	NS	NS

[2]Means followed by the same letter(s) within a column in each treatment do not differ significantlyat 5% level of probability using Duncan's Multiple Range Test (DMRT)
[3]NS = Not Significant[1]WAS = Weeks After Sowing

4.15 Relative Growth Rate

Table 16 shows the effects of weed control treatments and NPK fertilizer rates on the relative growth rate (RGR) of finger millet during the 2019 rainy season at the two experimental sites. At 6 WAS at both locations and at 9 WAS in Bagauda, only the hoe weeded control had the highest RGR values not statistically different from that of Atrazine at both rates at 6 WAS in both locations and 2,4-D at 0.8 kg a.i. ha^{-1} at 9 WAS in Bagauda. Application of 2,4-D at either 0.6 or 0.8 kg a.i. ha^{-1} at 6 WAS in both locations and weedy check at 9 WAS in Bagauda had the lowest RGR values. At 9 WAS in Samaru and 12 WAS in Bagauda, application of 2,4-D at either rate had the highest RGR statistically similar to that of hoe weeded control at 12 WAS in Bagauda only. Atrazine at both rates and weedy check at these sampling periods had the lowest RGR values. Variation in strategies employed to control weeds in finger millet did not affect RGR statistically at 12 WAS in Samaru.

NPK fertilizer treatments had significant effect on RGR of finger millet only at 6 WAS in Samaru and at each of the sampling periods at Bagauda. At 6 WAS in both locations, increasing the rate of NPK fertilizer from 0:0:0 to 90:45:45 kg NPK ha^{-1} significantly resulted in corresponding increase in RGR. At 9 WAS in Bagauda, application of 30:15:15 kg NPK ha^{-1} had higher RGR values not statistically different from that of the higher rates but more than for the control, although the control is statistically at par with application of 30:15:15 kg ha^{-1}. The control had higher RGR value than for NPK fertilizer treatments of 60:30:30 and 90:45:45 kg NPK ha^{-1} but statistically not different from that of 30:15:15 kg NPK ha^{-1}.

Interaction of weed control and NPK fertilizer treatments on RGR was not significant at all the sampling periods in both locations.

Table 16: Effect of weed control treatments and NPK fertilizer rates on relative growth rate of finger millet in Samaru and Bagauda during the 2019 rainy season

	Relative Growth Rate ($gg^{-1}wk^{-1}$)					
	Samaru			Bagauda		
Treatments	6 WAS[1]	9 WAS	12WAS	6 WAS	9 WAS	12WAS
Weed Control (W)						
Atrazine at 2.0 kg a.i. ha^{-1}	0.15ab[2]	0.38b	0.22	0.23ab	0.24bc	0.16bc
Atrazine at 3.0 kg a.i. ha^{-1}	0.14ab	0.38b	0.14	0.23ab	0.21bc	0.11c
2,4-D at 0.6 kg a.i. ha^{-1}	0.07c	0.58a	0.18	0.21bc	0.17cd	0.26a
2,4-D at 0.8 kg a.i. ha^{-1}	0.06c	0.59a	0.21	0.18c	0.28ab	0.23ab
Hoe weeded control	0.20a	0.40b	0.14	0.25a	0.34a	0.21ab
Weedy check	0.12bc	0.39b	0.15	0.22ab	0.15d	0.11c
SE±	0.022	0.044	0.036	0.012	0.027	0.026
NPK kg ha^{-1} (N)						
0:0:0	0.00d	0.51	0.19	0.13d	0.20b	0.24a
30:15:15	0.11c	0.45	0.20	0.20c	0.27a	0.19ab
60:30:30	0.16b	0.44	0.17	0.26b	0.22ab	0.16b
90:45:45	0.23a	0.41	0.13	0.30a	0.23ab	0.13b
SE±	0.018	0.036	0.029	0.010	0.022	0.022
Interaction						
W x N	NS[3]	NS	NS	NS	NS	NS

[2]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[3]NS = Not Significant
[1]WAS = Weeks After Sowing

4.16 Number of Days to 50 % Heading

The effects of weed control treatments and NPK fertilizer rates on the number of days to 50% heading of finger millet at the experimental sites during the 2019 rainy season are shown on Table 17. The difference in the number of days to 50% heading of finger millet among weed control treatments used were observed to be statistically significant at both locations. At Samaru, application of Atrazine at 3.0 kg a.i. ha^{-1}, 2,4-D at 0.6 and 0.8 kg a.i. ha^{-1} and weedy check significantly delay anthesis, followed by application of Atrazine at 2.0 kg a.i. ha^{-1} which was comparable with Atrazine at 3.0 kg a.i. ha^{-1} and 2,4-D at 0.6 and 0.8 kg a.i. ha^{-1}. Hoe weeded control however resulted in early anthesis. At Bagauda, all chemical weed control treatments and weedy check significantly delayed days to 50% heading in similar like manner while the hoe weeded control caused early heading.

Similarly, application of NPK fertilizer also had significant effect on number of days to 50 % heading of finger millet where increase in NPK fertilizer rates consistently resulted in corresponding decrease in the number of days to anthesis at both locations, although application of 30:15:15 kg NPK ha^{-1} and control had statistically similar values at days to 50% heading at Bagauda. Factors interaction did not significantly affect number of days to 50% heading.

Table 17: Effect of weed control treatments and NPK fertilizer rates on number of days to 50% heading of finger millet in Samaru and Bagauda during the 2019 rainy season

Treatments	Number of Days to 50 % Heading	
	Samaru	Bagauda
Weed Control (W)		
Atrazine at 2.0 kg a.i. ha^{-1}	94.0b[1]	105.5a
Atrazine at 3.0 kg a.i. ha^{-1}	94.7ab	104.3a
2,4-D at 0.6 kg a.i. ha^{-1}	95.6ab	104.3a
2,4-D at 0.8 kg a.i. ha^{-1}	94.8ab	105.2a
Hoe weeded control	91.8c	102.8b
Weedy check	96.1a	105.0a
SE±	0.556	0.46
NPK kg ha^{-1} (N)		
0:0:0	99.1a	106.6a
30:15:15	95.1b	105.7a
60:30:30	93.3c	103.9b
90:45:45	90.5d	102.2c
SE±	0.45	0.38
Interaction		
W x N	NS[2]	NS

[1]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[2]NS = Not Significant

4.17 Stand Count at Harvest

The effects of weed control treatments and NPK fertilizer rates on the stand count at harvest of finger millet at the experimental sites during the 2019 rainy season are shown on Table 18. Weed control treatments significantly influenced stand count at harvest statistically at both locations. At Samaru, application of 2,4-Dat either rate and hoe weeded control significantly had a greater number of stands which was followed by treatments that received Atrazine at 2.0 and 3.0 kg a.i. ha^{-1} although statistically at par with 2,4-Dat 0.8 kg a.i.ha^{-1}. Weedy check however had the least number of stands. At Bagauda, Atrazine 3.0 kg a.i. ha^{-1}, 2,4-D at either rate and hoe weeded control had statistically similar but greater number of stands than the weedy check. The higher stand count recorded by these treatments was followed by that of Atrazine 2.0 kg a.i. ha^{-1} which in turn was statistically at par with the other chemical weed control treatments.

Application of NPK fertilizer had no significant effect on stand count at both locations. Similarly, interaction of factors on stand count at harvest was also not significant.

4.18 Days to Physiological Maturity

The effects of weed control treatments and NPK fertilizer rates on the number of days to physiological maturity of finger millet at the two experimental sites during the 2019 rainy season is presented on Table 18. At both locations, weed control treatments was observed to have statistically similar effect on number of days to physiological maturity, although, hoe weeded control delayed maturity in similar like manner as the application of Atrazine at 3.0 kg a.i. ha^{-1} and 2,4-D at 0.6 and 0.8 kg a.i. ha^{-1}. This closely followed by Atrazine at 2.0 kg a.i. ha^{-1} which in turn was also comparable with application of Atrazine at 3.0 kg a.i. $ha^{-1}$and 2,4-D at 0.6 and 0.8 kg a.i. ha^{-1}. However, weedy check took fewer number of days to physiological maturity.

Table 18: Effect of weed control treatments and NPK fertilizer rates on stand count at harvest and number of days to physiological maturity of finger millet in Samaru and Bagauda during the 2019 rainy season

	Stand Count at Harvest		Days to Physiological Maturity	
Treatments	Samaru	Bagauda	Samaru	Bagauda
Weed Control (W)				
Atrazine at 2.0 kg a.i. ha^{-1}	69.7b[1]	68.9a	133.6b	129.6b
Atrazine at 3.0 kg a.i. ha^{-1}	69.3b	70.2a	134.9ab	130.9ab
2,4-D at 0.6 kg a.i. ha^{-1}	73.1a	72.5a	135.8ab	131.8ab
2,4-D at 0.8 kg a.i. ha^{-1}	72.0ab	70.4a	135.6ab	131.6ab
Hoe weeded control	74.8a	73.6a	136.4a	132.4a
Weedy check	60.5c	58.8b	130.1c	126.1c
SE±	1.09	1.76	0.85	0.85
NPK kg ha^{-1} (N)				
0:0:0	69.4	67.3	127.9d	123.9d
30:15:15	69.7	69.2	133.4c	129.4c
60:30:30	69.3	68.8	135.7b	131.7b
90:45:45	71.2	70.9	140.6a	136.6a
SE±	0.89	1.44	0.70	0.70
Interaction				
W x N	NS[2]	NS	NS	NS

[1]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[2]NS = Not Significant

The application of NPK fertilizer significantly affected number of days to physiological maturity in both locations where each increase in fertilizer rates from 0:0:0 to 90:45:45 kg NPK ha^{-1} significantly resulted in corresponding distinct delay in days to physiological maturity, with no-NPK treatment maturing much earlier than any other treatments while application of 90:45:45 kg NPK ha^{-1} resulted to late maturity.

Interaction of weed control treatments and NPK fertilizer rates on number of days to physiological maturity was not significant in both locations.

4.19 Panicle Length

Table 19 shows the effects of weed control treatments and NPK fertilizer rates on the panicle length of finger millet at harvest during the 2019 rainy season at Samaru and Bagauda. It was observed that weed control significantly affected panicle length only at Bagauda, where hoe weeded control, weedy check 2,4-D at 0.6 and 0.8 kg a.i. ha^{-1} and Atrazine at 2.0 kg a.i. ha^{-1}resulted in statistically similar but longer panicles than for plots that received Atrazine at 3.0 kg a.i. ha^{-1}only which produced shorter panicles.

Application of NPK fertilizer significantly influenced the length of finger millet panicles in both locations. At Samaru, all fertilizer treatments resulted in statistically similar but longer panicles than for control which gave shorter panicles. While in Bagauda, application of 90:45:45 kg NPK ha^{-1} had statistically similar panicle length with 60:30:30 kg NPK ha^{-1}but longer panicles than application of 30:15:15 kg ha^{-1} and control. Likewise, the length of panicles from 60:30:30 kg NPK ha^{-1} did not differ statistically from that of 30:15:15 kg NPK ha^{-1} and control.

Factors interaction had no significant effect on panicle length in both locations.

Table 19: Effect of weed control treatments and NPK fertilizer rates on panicle length (cm) and number of fingers per panicle of finger millet in Samaru and Bagauda during the 2019 rainy season

	Panicle Length (cm)		Number of Fingers per Panicle	
Treatments	Samaru	Bagauda	Samaru	Bagauda
Weed Control (W)				
Atrazine at 2.0 kg a.i. ha^{-1}	12.0	12.3a[1]	7.5bc	7.3a
Atrazine at 3.0 kg a.i. ha^{-1}	11.6	11.0b	7.4bc	6.3b
2,4-D at 0.6 kg a.i. ha^{-1}	11.2	12.0a	6.7c	7.2a
2,4-D at 0.8 kg a.i. ha^{-1}	11.9	12.4a	7.8b	7.3a
Hoe weeded control	12.0	12.2a	8.8a	7.3a
Weedy check	11.1	12.2a	6.9bc	6.8ab
SE±	0.47	0.28	0.30	0.24
NPK kg ha^{-1} (N)				
0:0:0	10.0b	11.7b	5.8c	6.6b
30:15:15	11.6a	11.8b	7.6b	6.9b
60:30:30	12.3a	12.1ab	8.0b	6.9b
90:45:45	12.6a	12.5a	8.7a	7.7a
SE±	0.37	0.23	0.25	0.19
Interaction				
W x N	NS[2]	NS	NS	NS

[1]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[2]NS = Not Significant

4.20 Number of Fingers per Panicle

The effects of weed control treatments and NPK fertilizer rates on the number of fingers per panicle of finger millet in Samaru and Bagauda during the 2019 rainy season are also presented on Table 19. The response of number of fingers per panicle to weed control treatments were observed to be statistically significant at both locations. In both locations, the hoe weeded plots had greater number of fingers per panicle that did not differ statistically with that of the other weed control treatments except Atrazine at 3.0 kg a.i. ha^{-1} that had fewer fingers at Bagauda only. In Samaru, the lowest number of fingers was when 2,4-D was applied at 0.6 kg a.i. ha^{-1} which in turn was statistically similar with that of Atrazine at 2.0 or 3.0 kg a.i. ha^{-1}.

The application of NPK fertilizer significantly affected number of fingers per panicle at both locations. In Samaru and Bagauda, application of 90:45:45 kg NPK ha^{-1} produced the highest number of fingers per panicle, followed by that from 60:30:30 and 30:15:15 kg NPK ha^{-1} which when compared to the control was statistically the same at Bagauda and more in Samaru.

Factor interactions did not significantly affect number of fingers per panicle in both locations.

4.21 Panicle Weight per Plant

The effects of weed control treatments and NPK fertilizer rates on the panicle weight per plant of finger millet at the experimental sites during the 2019 rainy season are presented on Table 20. The response of panicle weight per plant to weed control treatments were observed to be statistically significant at both locations. At both locations, hoe weeded control significantly outweighs all other weed control treatments. It closely followed by 2,4-D at 0.6 and 0.8 kg a.i. ha^{-1} at both locations and Atrazine at 3.0 kg a.i. ha^{-1} at Samaru only. Application of Atrazine at 2.0 kg a.i. ha^{-1} had resulted in lower panicle weight that was comparable statistically with weedy check only in Samaru.

Application of NPK fertilizer rates significantly affected panicle weight per plant of finger millet at both locations. At both, increasing the rate of NPK fertilizer from 0:0:0 to 60:30:30 kg ha^{-1} significantly resulted in corresponding increase in panicle weight, even though the difference in panicle weight between 30:15:15 and 60:30:30 kg ha^{-1} at Bagauda was not significant. Further increase in NPK rate from 60:30:30 to 90:45:45 kg ha^{-1} significantly increased panicle weight at both locations.

Interaction of weed control and NPK fertilizer treatments on panicle weight per plant was not significant at both locations.

4.22 Grain Weight per Plant

Table 20 also represents the effects of weed control treatments and NPK fertilizer rates on grain weight per plant of finger millet during the 2019 rainy season in both experimental sites. It was observed that weed control significantly affected grain weight in both locations where hoe weeded control produced the heaviest grain weights of finger millet that was more for weedy check but statistically similar to all the chemical weed control treatments at Bagauda only. In

Samaru, the highest value recorded by the hoe weeded was closely followed by that of 2,4-D at 0.8 kg a.i. ha^{-1} and Atrazine at 2.0 kg a.i. ha^{-1}, then 2,4-D at 0.6 kg a.i. ha^{-1} and Atrazine at 3.0 kg a.i. ha^{-1}, while the least was from the weedy check.

Application of NPK fertilizer rates significantly affected grain weight of finger only in Samaru location where it was observed that increase in NPK fertilizer from 0:0:0 to 30:15:15 and 60:30:30 kg NPK ha^{-1} increased grain weight, although 30:15:15 and 60:30:30 kg NPK ha^{-1} were statistically at par. Further increase to 90:45:45 NPK kg ha^{-1} had no significant effect on grain weight of finger millet.

Interaction of factors on grain weight per plant of finger millet was not significant in both locations.

Table 20: Effect of weed control treatments and NPK fertilizer rates on panicle weight (g) and grain weight (g) per plant of finger millet in Samaru and Bagauda during the 2019 rainy season

Treatments	Panicle Weight per Plant (g)		Grain Weight per Plant (g)	
	Samaru	Bagauda	Samaru	Bagauda
Weed Control (W)				
Atrazine at 2.0 kg a.i. ha^{-1}	9.6cd[1]	9.7c	5.1bc	5.8ab
Atrazine at 3.0 kg a.i. ha^{-1}	10.1bc	9.0c	4.1d	5.7ab
2,4-D at 0.6 kg a.i. ha^{-1}	11.4bc	11.6b	4.7cd	6.2ab
2,4-D at 0.8 kg a.i. ha^{-1}	12.1b	11.0b	5.5b	5.9ab
Hoe weeded control	16.0a	13.8a	10.5a	7.5a
Weedy check	8.0d	7.0d	2.3e	5.0b
SE±	0.76	0.41	0.25	0.65
NPK kg ha^{-1} (N)				
0:0:0	7.0d	5.2c	4.7c	5.9
30:15:15	10.0c	11.3b	5.1b	6.0
60:30:30	12.4b	11.8b	5.5ab	6.0
90:45:45	15.5a	13.1a	6.0a	6.2
SE±	0.62	0.33	0.20	0.53
Interaction				
W x N	NS[2]	*	NS	NS

[1]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[2]NS = Not Significant*Significant at 5% level of probability

4.23 1000-grain weight

The 1000-grain weight of finger millet as influenced by weed control treatments and NPK fertilizer rates during the 2019 cropping season in Samaru and Bagauda is presented on Table 21. The result shows that weed control strategies used significantly affected 1000-grain weight in both locations where hoe weeded control had the heaviest 1000-grains of finger millet, followed by application of 2,4-D at 0.8 kg a.i. $ha^{-1}$and Atrazine at 2.0 kg a.i. ha^{-1} which were statistically at par, and then 2,4-D at 0.6 kg a.i. ha^{-1} and Atrazine at 3.0 kg a.i. ha^{-1}though statistically same; in Samaru location only. In Bagauda, all herbicide treatments were statistically at par with the hoe weeded control. Weedy check however gave the least grain weights in both locations, though statistically same with all herbicide treatments only in Bagauda.

The 1000-grain weight of finger millet was significantly influenced by application of NPK fertilizer rates in Samaru only where increase in the rates of NPK fertilizer from 0:0:0 to 30:15:15 then 60:30:30 kg NPK ha^{-1} increased 1000-grain weight. Although no-NPK treatment and 30:15:15 kg NPK ha^{-1} were statistically similar. Further increase to 90:45:45 kg NPK ha^{-1} had no significant effect on 1000-grain weight of finger millet.

The interaction of weed control treatments and NPK fertilizer rates on 1000-grain weight was not significant in both locations.

Table 21: Effect of weed control treatments and NPK fertilizer rates on 1000-grain weight (g) of finger millet in Samaru and Bagauda during the 2019 rainy season

	1000-grain Weight (g)	
Treatments	Samaru	Bagauda
Weed Control (W)		
Atrazine at 2.0 kg a.i. ha^{-1}	2.0bc[1]	2.3ab
Atrazine at 3.0 kg a.i. ha^{-1}	1.65d	2.3ab
2,4-D at 0.6 kg a.i. ha^{-1}	1.9cd	2.5ab
2,4-D at 0.8 kg a.i. ha^{-1}	2.2b	2.4ab
Hoe weeded control	4.2a	3.0a
Weedy check	0.9e	2.0b
SE±	0.10	0.26
NPK kg ha^{-1} (N)		
0:0:0	1.9c	2.4
30:15:15	2.1bc	2.4
60:30:30	2.2ab	2.4
90:45:45	2.4a	2.5
SE±	0.08	0.21
Interaction		
W x N	NS[2]	NS

[1]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
[2]NS = Not Significant

4.24 Grain Yield per Hectare

The effects of weed control treatments and NPK fertilizer rates on the grain yield per hectare of finger millet at Samaru and Bagauda during the 2019 rainy season are shown on Table 22. The response of grain yield to weed control treatments were observed to be statistically significant at both locations. Hoe weeded control significantly out-yielded all other weed control while weedy check had the lowest yield consistently at both locations. In both locations, hoe weeded control was closely followed by application of Atrazine at 3.0 kg a.i. ha^{-1} and 2,4-Dat 0.8 kg a.i. ha^{-1}, as well as 2,4-D at 0.6 kg a.i. ha^{-1}in Bagauda only. The latter out yielded Atrazine at 2.0 kg a.i. ha^{-1} in Samaru only.

Similarly, the application of NPK fertilizer treatments significantly influenced grain yield of finger millet in both locations. It was observed that increase in the rates of NPK fertilizer from 0:0:0 to 30:15:15 and further to 60:30:30 and 90:45:45 kg NPK ha^{-1} respectively, significantly resulted in a corresponding increase in grain yield of finger millet in both locations.

The interaction of weed control strategies and NPK fertilizer rates on grain yield of finger millet $ha^{-1}$was significant in both locations (Table 23). In Samaru and Bagauda, regardless of the NPK fertilizer rate, the hoe weeded control gave the highest yield value which did not differ statistically from any of the chemical weed control measures employed only when no fertilizer was applied at Bagauda. Increasing the NPK fertilizer level from 0:0:0 to 30:15:15 kg NPK ha^{-1} and further to 60:30:30 and 90:45:45 kg NPK ha^{-1} had led to a corresponding increase in finger millet grain yield for each of the weed control treatments; the differences in grain yield were not significant to treatment with 0:0:0 and 30:15:15 kg NPK ha^{-1} when 0.8 kg a.i. ha^{-1} of 2,4-D was applied at Samaru and weedy check at Bagauda, 30:15:15 and 60:30:30 kg NPK ha^{-1} for weedy

Table 22: Effect of weed control treatments and NPK fertilizer rates on grain yield ($kgha^{-1}$) of finger millet in Samaru and Bagauda during the 2019 rainy season

	Grain yield ($kg\ ha^{-1}$)	
Treatments	Samaru	Bagauda
Weed Control (W)		
Atrazine at 2.0 kg a.i. ha^{-1}	356d[1]	371c
Atrazine at 3.0 kg a.i. ha^{-1}	516b	419b
2,4-D at 0.6 kg a.i. ha^{-1}	431c	379bc
2,4-D at 0.8 kg a.i. ha^{-1}	531b	420b
Hoe weeded control	874a	565a
Weedy check	253e	179d
SE±	18.2	14.6
NPK kg ha^{-1} (N)		
0:0:0	140d	112d
30:15:15	397c	308c
60:30:30	570b	486b
90:45:45	866a	650a
SE±	14.8	11.9
Interaction		
W x N	*	*

[1]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
*Significant at 5% level of probability

Table 23: Interaction of weed control strategies and NPK fertilizer rates on grain yield (kg ha^{-1}) of finger millet in Samaru and Bagauda during the 2019 rainy season

NPK kg ha^{-1}	Weed Control					
	Atrazine (kg a.i. ha^{-1})		2,4-D (kg a.i. ha^{-1})		HW Control	Weedy Check
	2.0	3.0	0.6	0.8		
Samaru						
0:0:0	153ij[1]	87j	97j	159ij	273h	71j
30:15:15	313gh	415fg	285h	244hi	841d	237hi
60:30:30	426f	623e	475f	590e	1071c	283h
90:45:45	533e	937d	866d	1130b	1311a	419f
SE±				36.3		
Bagauda						
0:0:0	106ij	132i	92ij	109ij	159i	71j
30:15:15	344gh	302gh	352fg	293gh	475de	84ij
60:30:30	526d	430ef	534d	462de	694bc	268h
90:45:45	619c	651bc	699bc	704b	932a	294gh
SE±				29.1		

[1]Means followed by the same letter(s) within a column in each treatment do not differ significantly at 5% level of probability using Duncan's Multiple Range Test (DMRT)
HW = Hoe weeded control

check at Bagauda. Combination of 90:45:45 kg NPK ha^{-1} and hoe weeding gave the highest grain yield of finger millet at both locations. It was followed by combination of 0.8 kg a.i. ha^{-1} of 2,4-D in both locations. While no NPK and weedy check gave the least grain yield values in both locations.

4.25 Threshing Percentage

Table 24 shows the effects of weed control treatments and NPK fertilizer rates on threshing percentage of finger millet during the 2019 rainy season at both experimental sites. At Samaru, application of Atrazine at 3.0 kg a.i. ha^{-1}, 2,4-D at 0.8 kg a.i. ha^{-1}, hoe weeded control and weedy check resulted in significantly higher threshing percentage than Atrazine at 2.0 kg a.i. ha^{-1} which was comparable with Atrazine at 3.0 kg a.i. ha^{-1}, 2,4-D at 0.8 kg a.i. ha^{-1} and weedy check, and in turn similar with 2,4-D at 0.6 kg a.i. ha^{-1} that had very low threshing percentage. At Bagauda, application of Atrazine at either 2.0 or 3.0 kg a.i. ha^{-1} and hoe weeded control resulted in statistically similar but higher threshing percentage for This is followed by application of 2,4-D at 0.6 and 0.8 kg a.i. ha^{-1} which is comparable with weedy check that had the least threshing percentage.

Application of NPK fertilizer rates significantly affected threshing percentage of finger millet at both locations. At Samaru, increasing the rate of NPK fertilizer from 0:0:0 to 30:15:15 kg ha^{-1} increased threshing percentage. Application of 30:15:15 and 60:30:30 kg ha^{-1} significantly resulted in similar threshing percentage, further increase to 90:45:45 kg ha^{-1} did not significantly affect threshing percentage. At Bagauda, increasing the rate of NPK fertilizer from 30:15:15 to 60:30:30 and further to 90:45:45 kg ha^{-1} resulted in corresponding increase in threshing percentage, however application of 30:15:15 kg ha^{-1} and control were statistically the same.

All factor interactions did not affect threshing percentage at both locations.

Table 24: Effect of weed control treatments and NPK fertilizer rates on threshing percentage and harvest index of finger millet in Samaru and Bagauda during the 2019 rainy season

	Threshing Percentage		Harvest Index	
Treatments	Samaru	Bagauda	Samaru	Bagauda
Weed Control (W)				
Atrazine at 2.0 kg a.i. ha^{-1}	31.3bc[1]	35.7a	38.4	41.2ab
Atrazine at 3.0 kg a.i. ha^{-1}	40.9ab	34.0a	46.4	45.0a
2,4-D at 0.6 kg a.i. ha^{-1}	31.0c	28.5bc	41.5	45.6a
2,4-D at 0.8 kg a.i. ha^{-1}	34.4abc	28.1bc	42.5	43.1a
Hoe weeded control	42.5a	31.5ab	45.3	37.1b
Weedy check	33.9abc	25.4c	41.3	44.4a
SE±	3.13	1.86	2.75	2.02
NPK kg ha^{-1} (N)				
0:0:0	18.5c	19.5c	44.9	40.2b
30:15:15	37.6b	22.9c	40.8	45.9a
60:30:30	40.5ab	36.9b	41.7	43.6ab
90:45:45	46.1a	42.8a	42.9	41.2ab
SE±	2.55	1.51	2.24	1.65
Interaction				
W x N	NS[2]	NS	NS	NS

[1]Means followed by the same letter(s) within a column in each treatment do not significantly different at 5% probability level using Duncan's Multiple Range Test (DMRT)
[2]NS = Not Significant

4.26 Harvest index

The effects of weed control treatments and NPK fertilizer rates on harvest index of finger millet at the experimental sites during the 2019 rainy season are shown on Table 24. The response of harvest index to weed control treatments were observed to be statistically significant only at Bagauda where all weed control treatments resulted in similar higher harvest index than hoe weeded control which gave lower harvest index that is similar to application of Atrazine at 2.0 kg a.i. ha^{-1}.

NPK fertilizer treatments did not significantly influence harvest index of finger millet at Samaru. However, at Bagauda, all fertilizer treatments significantly resulted in higher harvest index than the control, although the control was statistically at par with values from application of 60:30:30 and 90:45:45 kg ha^{-1}.

Interaction of weed control and NPK fertilizer treatments on harvest index was not significant at both locations.

4.27 Correlation Analysis in Samaru

The relationship between grain yield, weed parameters, and crop growth and yield parameters of finger millet during the 2019 rainy season in Samaru is presented on Table 25. There was a positive and highly significant correlation between grain yield and growth and yield parameters such as plant height, LAI, crop dry weight, panicle weight, 1000-grain weight and threshing percentage and only a positive significant correlation with CGR and number of tillers. However, grain yield had a negative and highly relationship with cumulative weed dry weight but negative and not significant correlation with cumulative weed density.

4.28 Correlation Analysis in Bagauda

The result of correlation analyses of grain yield, weed parameters, as well as crop growth and yield parameters of finger millet during the 2019 rainy season in Bagauda is shown on Table 26. A positive and highly significant correlation between grain yield and growth and yield parameters such as plant height, LAI, crop dry weight, numbers of tillers, numbers of tillers, panicle weight and threshing percentage were recorded while a positive and significant relationship between grain yield and CGR was observed. The correlation between grain yield, cumulative weed dry weight and weed density was negative and not significant.

Table 25: Matrix of correlation coefficient between grain yield, weed parameters, growth and yield components of finger millet during the 2019 rainy season at Samaru

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.000											
2	0.110	1.000										
3	0.665**	-0.374*	1.000									
4	0.596**	0.114	0.192	1.000								
5	0.810**	0.424**	0.196	0.603**	1.000							
6	0.393*	-0.071	0.486**	0.275	0.534**	1.000						
7	0.393*	0.062	0.144	0.554**	0.317	0.347	1.000					
8	0.604**	-0.158	0.468**	0.382*	0.567**	0.446**	0.094	1.000				
9	0.654**	-0.430**	0.412**	0.475**	0.584**	0.572**	0.285	0.616**	1.000			
10	0.651**	-0.139	0.572**	0.288	0.528**	0.476**	0.058	-0.466**	-0.136	1.000		
11	-0.536**	-0.099	-0.144	-0.688**	-0.576**	-0.414*	-0.600**	-0.205	-0.466*	-0.136	1.000	
12	-0.285	-0.105	0.025	-0.748**	-0.325	-0.109	-0.738**	-0.042	-0.247	0.117	0.744**	1.000

DF = (n-2) = 70, r = 0.232 [1]*Significant at 5% level of probability ** Significant at 1% level of probability
1 = Grain yield per ha 2 = Harvest index 3 = Threshing percentage 4 = 1000-grain weight 5 = Panicle weight 6 = Number of tillers 7 = Crop growth rate
8 = Leaf area index 9 = Crop dry weight 10 = Plant height 11 = Weed dry weight 12 = Weed density

Table 26: Matrix of correlation coefficient between grain yield, weed parameters, growth and yield components of finger millet during the 2019 rainy season at Bagauda

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.000											
2	0.115	1.000										
3	0.780**	-0.279	1.000									
4	0.184	0.247	0.344	1.000								
5	0.806**	0.259	0.344	0.367*	1.000							
6	0.805**	-0.069	0.641**	0.132	0.650**	1.000						
7	0.430*	-0.567**	0.202	0.174	0.395*	0.276	1.000					
8	0.735**	-0.045	0.546**	0.135	0.640**	0.644**	0.289*	1.000				
9	0.778**	-0.514**	0.504**	0.181	0.658**	0.564**	0.813**	0.574**	1.000			
10	0.795**	-0.006	0.628**	0.160	0.710**	0.743**	0.346	0.721**	0.611**	1.000		
11	-0.002	0.316	0.127	0.048	-0.014	0.158	-0.299	-0.048	-0.274	0.068	1.000	
12	-0.084	0.340	0.018	-0.476**	0.139	0.071	-0.411	0.124	-0.225	0.099	0.112	1.000

DF = (n-2) = 70, r = 0.232 *Significant at 5% level of probability ** Significant at 1% level of probability
1 = Grain yield per ha 2 = Harvest index 3 = Threshing percentage 4 = 1000-grain weight 5 = Panicle weight 6 = Number of tillers 7 = Crop growth rate 8 = Leaf area index 9 = Crop dry weight 10 = Plant height 11 = Weed dry weight 12 = Weed density

4.29 Regression Analysis

The response of grain yield of finger to NPK fertilizer application at Samaru and Bagauda are shown on figure 1. The result indicated that grain yields responses were both linear with the equations **y = 140.61 + 2.3511x** at Samaru and **y = 119.99 + 1.7919x** at Bagauda respectively.

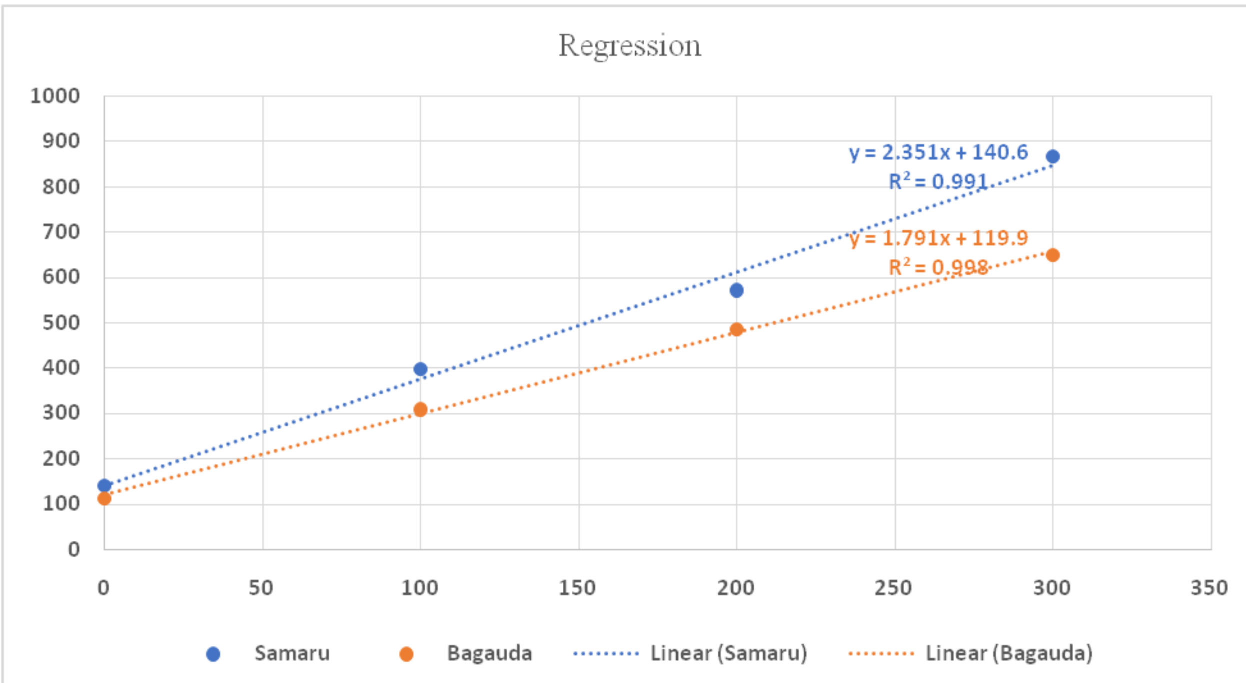

Figure 1: *Regression of Finger millet grain yield against rates of NPK fertilizer during the 2019 rainy season at Samaru and Bagauda*

CHAPTER FIVE

5.0 DISCUSSION

Generally, the performance of finger millet in terms of growth and yield components was better at Samaru than at Bagauda. The higher grain yield (21.1% more) obtained at Samaru (averaged at 493 kg ha^{-1}) compared to Bagauda (averaged at 388 kg ha^{-1}) could be attributed to differences in the soil type (loam in Samaru as against sandy loam in Bagauda), higher soil organic matter content with higher nutrients such as nitrogen in Samaru. In Samaru, finger millet must have had access to more nitrogen (N) during early growth thereby leading to better plant growth. The soil fertility advantage coupled with favorable weather conditions could be responsible for the better performance of finger millet in terms of growth and yields at Samaru than at Bagauda. This agrees with the findings of Reddy and Reddi (2010) who reported that environmental factors are responsible for 50 % effect on crop growth and yield patterns of crop plants. The lower yield at Bagauda could also be attributed to inefficiency of the weed control measures employed to control weeds in the crop. Lower soil nutrient levels and higher weed infestation lowered the productivity of finger millet due to competition for growth factors, such as moisture, light, nutrients and space.

5.1 Effect of Weed Control Treatments on Weeds

The existence of measures to suppress and control weeds make it possible to obtain good crop growth and yield, including growth and yield of finger millet as observed in this present study. All weed management practices significantly reduced weed cover score, total weed density, and weed dry weight at both locations, with hoe weeded control at 3 and 6 WAS being the best. The reduction in weed cover score, weed density and weed dry weight could be due to effectiveness of the weed control measures employed at the early stage of their emergence, giving the crop full advantage for harnessing the scarce resources necessary for growth, thus allowing rapid seedling growth, strengthening the crop to be able to better compete at later growth stages, through better established root system that will source nutrient, moisture and improve anchorage while allowing shoot to later develop and photosynthesize for better competition with other plants. This is evident in the improved growth that greatly assisted in smothering the weeds at early stage of growth, thereby decreasing weed infestation. This result is in line with the findings of Amare and Etagegnehu (2016) who reported that least weed density and weed biomass was from weeding twice at 3 and 6 WAS which consequently resulted in the highest grain yield as compared to other control practices.

Similarly, Tuti *et al*. (2016) reported that, all the weed control measures significantly reduced total weed dry weight and weed index as compared to that of weedy check, but weeding at 3 and 6 WAS significantly lowered the total weed dry weight respectively. Emeghara *et al.* (2013) reported that weed competitions in crops depends on four factors which include; crop growth stage, amount of weed present, the degree of water and nutrient stress, and the weed species that are found in the field. Ishaya *et al.* (2008) also observed that weeds in greater densities are a serious challenge to the growth and development of crops.

5.2 Response of Finger millet to Weed Control Measures

Finger millet like other crops responds to environmental factors such as moisture, solar radiation and nutrients for good growth and development. Most often competition set in for these growth factors thereby causing stunted growth, which in turn lead to reduction in growth and yield factors such as plant height, leaf area index and grain yield. Andrade *et al*. (2002) reported a decrease in dry matter accumulation as a result of poor plant growth caused by competition from weeds which in turn influenced the final kernel set. The delay in number of days to emergence of finger millet seedlings observed with application of Atrazine 2.0 and 3.0 kg a.i. ha^{-1}, and 2,4-D at 0.6 and 0.8 kg a.i. ha^{-1}, as pre-emergence weed control treatments at both locations, could be due to the slow hypocotyl and radicle elongation normally influenced by pre-emergence herbicides, especially on small seeded crops. Competition for growth resources between weeds and crop plant usually retards growth and development of most crops, and may be attributed to stronger competitive ability of weeds which invariably emerged and established faster than the finger millet crop. Kamble (2006) reported a gradual inhibition of hypocotyl and radicle elongation of seedlings due to actions of pre-emergence herbicides. Similarly, crop parameters such as leaf area index, plant dry matter, CGR and RGR were significantly improved as weeds were controlled due to imposition of weed control measures. This could probably be due to weed suppression by weed control treatments couple with the ability of the finger millet to grow faster and smoother weeds under this condition, as a result of reduced competition for resources between the weeds and finger millet crop.

The significantly higher values for leaf area index in both locations from plots weeded twice could be attributed to the absence of competition between the weeds and crop, thereby providing a conducive atmosphere for the crop to access more growth resources and produced larger leaf canopy. Larger assimilatory leaf area means higher light interception that led to higher dry matter production that made up various plant parts. The same observation was made by Basavaraj and Reddy (2014) who reported that hoe weeding twice produced significantly higher growth parameters viz., taller plants, higher LAI, greater number of tillers $hill^{-1}$ and higher dry matter accumulation than the other treatments. Lagoke *et al.* (1988) also reported that two hoe-weedings at 3 and 6 or 7 weeks after sowing (WAS) was recommended to achieve good crop growth and grain yield in pearl millet. In both locations, weedy check resulted in shorter plant, least leaf area index and lower dry matter accumulation than all other weed control treatments evaluated. This could be related to the fact that intensive competition from weeds for the growth resources usually retards growth and development of companion crop(s).

The higher number of tillers obtained at both locations as a result of hoe weeding at 3 and 6 WAS and application of herbicides was an indication that these weed control strategies were able to control weeds effectively. This is in conformity with the findings of Prithvi *et al.* (2015), who reported that application of oxadiargyl 100 gha^{-1} followed by inter-cultivation at 20 days after transplanting (DAT), recorded higher values for plant height, crop dry weight, grain weight per panicle and highest grain yield.

The significantly higher number of fingers $panicle^{-1}$, panicle weight $plant^{-1}$ 1000-grain weight, grain yield $hectare^{-1}$ and harvest index at both locations were observed with hoe weeded control at 3 and 6 WAS. This could be attributed to efficient weed control provided by this treatment which reduced weeds/crop competition and thus a sound ground for nutrient absorption and utilization, hence resulting in good crop growth. Naik *et al*. (2000) observed an increase in grain yield in treated plots of finger millet due to reduced weed pressure as a result of increase uptake of major nutrients. It could also be due to reduced weed-crop competition and increased availability of resources which paved way for increased leaf area and consequently increased dry matter production and accumulation, which translated to higher crop yield. This result agrees with the findings of Tuti *et al.* (2016) who reported that the grain yield of finger millet was significantly higher in hand weeding twice than the other method of weed control employed.

Similarly, Pradhan *et al*. (2010) also observed that weeding twice resulted in the highest grain yield, straw yield and harvest index of finger millet. Also, Kumara *et al*. (2007) observed that weeding twice at 20 and 40 DAT (days after transplanting) or the use of butachlor at 0.75 kg ha^{-1} + 2,4 D Na salt 0.75 kg ha^{-1} recorded significantly higher grain yield of finger millet as compared to un-weeded control treatment. Similarly, Pradhan *et al*. (2010) conducted research for nine years consecutively and concluded that two hand weeding and application of butachlor at the rate of 0.75 kg ha^{-1} were similar and gave the highest grain yield of finger millet. The weed free environment thus created helped the crop to put forth better growth due to absence of competition from weeds for sunlight, space, water and nutrient which in turn resulted in higher grain yield of the crop.

Weedy check resulted in lower number of tillers, number of fingers $plant^{-1}$, panicle weight $plant^{-1}$, 1000-grain weight, grain yield $hectare^{-1}$, and lower harvest index than all other weed control treatments evaluated. This is expected because weed competition would usually suppress plant growth and development, increase tiller mortality and decreased grain production. This result is in line with the findings of Pandey *et al*. (2018) who observed that the weed management practices employed significantly improved the growth and yield attributes of finger millet over the weedy check. Siddiqui *et al.* (2010) also observed that weeds were competitive and caused substantial reduction in the vegetative growth and grain yield of the crop. Similarly, Singh *et al*. (2002) observed that maintaining weed free environment till maturity recorded significantly higher grain yield of crops.

5.3 Response of Finger millet to NPK Fertilization

From this study, the improvement of growth and yield of finger millet as a result of fertilizer application could be attributed to initial low fertility status of the soils at the experimental sites as indicated by the result of soil analysis. NPK fertilizer supplied the major essential nutrients which improved the fertility of the soil that resulted in subsequent increase in crop performance in terms of growth and yield attributes. The initial use of food reserve stored in the cotyledon as source of early plant nutrients for the development of the radicle and plumule, to enable the germination of seedlings and foray water and nutrient, accompanied by the early dependence on inherent soil nutrients and initial slow uptake as a result of young and developing roots, therefore could be responsible for the lack of response for applied nutrients and therefore non-significant of parameters difference among the NPK fertilizer rates at early vegetative stages (0-6 WAS) in this study. Almodares *et al*. (2006), suggested that it may be too early to evaluate growth parameters at this stage. Upon development of necessary apparatuses for effective photosynthesis, the effect of applied nutrient became apparent and continue throughout the crop's active growth phase, leading up to the reproductive phase, as a result, all growth and yield parameters were eventually significantly affected by NPK fertilizer application.

The increase in growth parameters such as plant height, LAI and number of tillers per plant recorded as a result of increase in NPK fertilizer rates up to 90:45:45 kg ha^{-1} could be attributed to making these major nutrients available for absorption and used for cell division and elongation, proteins and chlorophyll syntheses, which accelerated meristematic activity of plant that led to progressive increase in internodes length and photosynthetic area. These results agree with the findings of Redei *et al.* (2018) and Muhammad *et al*. (2018), who reported significant increase in growth parameters with increase in NPK dosage in sorghum.

The production of taller plants with larger assimilatory leaf area due to NPK fertilization might have resulted to interception of more light leading to higher dry matter production and thus heavier plant dry weight. The significant increase in plant dry weight might be due to efficient use of N, P and K that might have lead to production and accumulation of more assimilates by the various plant parts. These results were in conformity with finding of Almodares *et al.* (2006;

2008) and Abou-amer and Kewan (2014). Similarly, Wadsworth (2002) reported that increased dry matter production with increase in fertilizer application was due to the role of N in increasing biomass production. Deficiency of these nutrients may reduce the sunshine use efficiency or ability of crop to photosynthesize and this could account for the overall poor performance of unfertilized plants such as 0 kg NPK ha^{-1} in this study.

The improvement in growth as well as photosynthetic parameter due to addition of NPK could be attributed to better interception and utilization of radiant energy leading to higher production of photosynthates and therefore better crop growth and development. Mansab *et al*. (2003), Valdabadi and Farahani (2010), observed similar trend in increased LAI value with increase in N level. Furthermore, CGR and RGR increased with the advancement of growth (6-9 WAS) and then further declined toward maturity (12 WAS) in line with normal sigmoid growth curve as similarly observed by Goma (2011) in grain sorghum. CGR increased significantly with increasing rate of soil fertility in successive growth stages. This may be due to higher rate of dry matter production and accumulation with increasing rates of NPK fertilizers.

Application of NPK fertilizer resulted to early anthesis (heading) when compared with the control plots (without NPK). This could be attributed to the roles played by of P and K in synthesis of higher molecular weight substances and translocation of assimilates, which favors faster differentiation of tissues and subsequent transformation into reproductive phase. Mishra *et al.* (2014) and Redai *et al.* (2018) also reported similar observation on the effect of inorganic fertilizers on number of days to heading. Panicle weight, panicle length, 1000-grain weight, number of fingers per panicle and grain yield of finger millet were increased with increase in NPK fertilizer rates. This is due to role played by N in enhancing dry matter production; P through efficient transformation of solar energy into chemical energy that could increase carbohydrate content; and K whose role is in transportation of sink assimilate by influencing electron transport in the transport chain of the crop (Leghari *et al.*, 2018; Malhotra *et al.*, 2018; and Prajapati *et al.*, 2012). This finding is in conformity with the report of Abbas and Sayyed Hassan (2016), Muhammad *et al*. (2018), and Redei *et al*. (2018), that indicated that supply of inorganic fertilizers results in higher net assimilation rate and increased yield and its components.

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION

Field trials were conducted during the 2019 rainy season at the Institute for Agricultural Research, Samaru (latitude 11^0 11^1 N, longitude 07^0 38^1 E, 686m above sea level) in the Northern Guinea savanna, and the National Institute for Horticultural Research, Bagauda (latitude $11^0 37^1$ N, longitude $08^0 23^1$ E, 500m above sea level), in the Sudan savanna agro-ecological zone of Nigeria to assess the effect weed control and NPK fertilizer rates on the performance of finger millet. Treatments consisted of six weed control strategies (Atrazine at 2.0 and 3.0 kg a.i ha^{-1}, 2,4-D at 0.6 and 0.8 kg a.i ha^{-1}, hoe weeded control at 3 and 6 WAS, and weedy check) and four levels of NPK fertilizer (0:0:0, 30:15:15, 60:30:30, and 90:45:45 kg $N:P_2O_5:K_2O$ ha^{-1}). The factorial combinations of these treatments were laid out in a randomized complete block design (RCBD) and replicated three times.

Application of herbicides generally affected the performance of finger millet. Hoe weeded control performed better in terms of crop growth and yield attributes of finger millet, where it resulted in early seedling emergence and gave more crop stands at emergence, which subsequently resulted to reduced weed cover score, cumulative weed density and weed dry weights. The hoe weeded control consequently resulted to the most vigorous and less injured finger millet plants with larger assimilatory leaf area, higher values for number of tillers, plant dry weights, crop growth and relative growth rates. Other parameters that were enhanced by the hoe weeded control included number of days to physiological maturity, number of fingers per panicle, panicle weight per plant, grain yield per hectare, and threshing percentage.

The crop generally responded to application of NPK fertilizer. Application of 90:45:45 kg NPK ha^{-1} resulted in higher values for cumulative weed density and weed dry weights at both locations, and number of emerged stands and crop vigor score, but recorded least number of injured crops. This rate consistently resulted in taller plants, higher values for leaf area index, tillers per plant, plant dry weights, crop growth rate and increased days to physiological maturity. Likewise, it consequently resulted in distinctly longer panicles and higher values for number of fingers per panicle, panicle weight, grain weight per plant, grain yield per hectare as well as threshing percentage across the two locations. In both locations, there was a positive highly significant correlation between grain yield and growth and yield parameters such as plant height, LAI, crop dry weight, numbers of tillers (Bagauda only), panicle weight, 1000-grain weight (Samaru only) and threshing percentage. Grain yield was negatively and highly significantly correlated with cumulative weed dry weight. The regression of finger millet grain yield against NPK fertilizer rates showed a linear response at both locations.

Based on the results obtained from this study, it can be concluded that;

1. In the case of herbicide application, 2,4-D at 0.8 kg a.i. ha^{-1} or Atrazine at 3.0 kg a.i. ha^{-1} gave better weed control over weedy check with yield increase of 52.7 and 51.0% in Samaru; 57.4 and 57.3% in Bagauda respectively. However, at both locations, hoe weeding gave better and season long weed control with 71.1% yield increase.

2. Application of 90:45:45 kg NPK ha^{-1}enhanced the performance of finger millet in terms of crop growth, yield and yield components when compared with the lower rates and unfertilized treatment in both locations.

3. In both locations, application of 2,4-D at 0.8 kg a.i. ha^{-1}combined with 90:45:45 kg NPK ha^{-1} gave the highest grain yield of finger millet over all other herbicide weed control and NPK fertilizer treatment combinations.

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APPENDICES

Appendix I: Meteorological data showing monthly rainfall, temperature, relative humidity and evaporation at Samaru during 2019 rainy season

Month	**Rainfall**	**Temperature (^0C)**		**Relative humidity**		**Evaporation**
	(mm)	**Max**	**Min**	**10 a.m**	**4 p.m**	**(mm/day)**
May	146.7	35.8	24.5	61.5	54.7	
June	110.3	30.4	23.1	78.8	72.2	4.5
July	314.2	28.8	22.8	81.4	74.8	3.3
August	243.2	28.3	22.2	83.3	79.1	3.3
September	237.4	30.4	23.0	76.9	69.9	2.9
October	217.4	29.8	22.5	77.9	74.8	4.0
November	0.0	32.3	17.9	35.4	30.7	5.0
TOTAL	**1269.2**					

Source: IAR Meteorological Unit, Ahmadu Bello University, Zaria, Nigeria (2019)

Appendix II: Meteorological data showing monthly rainfall, temperature, relative humidity and evaporation at Bagauda during 2019 rainy season

Month	**Rainfall**	**Temperature (^0C)**		**Relative humidity**		**Evaporation**
	(mm)	**Max**	**Min**	**10 a.m**	**4 p.m**	**(mm/day)**
May	93.80	36.70	26.80	40.50	34.2	NA
June	107.00	28.50	24.20	45.90	44.0	NA
July	343.00	26.40	22.00	56.80	50.1	NA
August	241.00	29.80	20.50	59.50	52.2	NA
September	209.00	32.80	23.40	50.20	43.7	NA
October	55.00	34.50	28.10	42.50	36.4	NA
TOTAL	**1048.8**					

Key: NA = Not Available
Source: NIHORT Meteorological Unit, Bagauda sub-station, Kano, Nigeria (2019)

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