

Effects of NPK Fertilizer and Farmyard Manure Rates on Millet Performance in Sudan and Sahel Savanna Soils Of Northeast Nigeria

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ABSTRACT

Field experiments were conducted in 2008 and 2009 rainy seasons at the Research and Demonstration Farms of Lake Chad Research Institute at Maiduguri and Gashua stations to study the effect of NPK fertilizer and farmyard manure rates on millet performance in Sudan and Sahel savannas of northeast Nigeria. The treatments consisted of factorial combinations of three levels of NPK fertilizer (NPK 0:0:0, 30:15:15 and 60:30:30 kg ha⁻¹) and four levels of farmyard manure (0, 2.5, 5.0 and 7.5 tonnes ha⁻¹). The experiments were laid out in a randomized complete block design (RCBD) and replicated three times. The parameters determined were plant height at 3, 6 and 9 weeks after sowing (WAS), straw, grain and above ground total biomass yields. The results of soil physico-chemical properties indicated low fertility status as typified by the low contents of N, P, Ca, Mg and low CEC, but moderate K. The application of NPK fertilizer and farmyard (FYM) manure either alone or in combination significantly influenced most of the parameters. The individual effect of NPK at half and full recommended rates were at par on most of the parameters, but significantly superior to the control. The individual effect of FYM was variable and more pronounced with the two higher rates of 5.0t and 7.5t FYM compared to the two lower rates of 0.0t and 2.5t FYM rates. Optimum millet growth and yield were superior with NPK 30:15:15, combined with 5.0t FYM more than other combination rates at early growth stage. At mid and late stage of growth, interaction of NPK 30:15:15 + 7.5t FYM produced significantly the tallest plants. Grain, straw and total biomass yield in Maiduguri were 129%, 71%, and 76% increase over the control, respectively. Similar results were obtained in Gashua, with higher yields at NPK 30:15:15 + 5.0t FYM. Based on the results it can be concluded that application of NPK 30:15:15 combined with 5.0t and 7.5t ha⁻¹ FYM could be viable management practice for sustained millet production in Sudan and Sahel savannas of northeast Nigeria.

Keywords: NPK fertilizer, Farmyard manure, Millet yield, Sudan and Sahel savannas.

1 Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is a staple food crop for about six million poor people in the most marginal agricultural lands of north-east Nigeria and therefore plays a critical role in food security (Elemo and Chube, 1995). These marginal lands are regions where the expanding desert is destroying the productivity of approximately 25 million hectares of land every year, creating conditions on which this crop can be cultivated but with low yields (Ikwele, 1998). In the drier and low resource agricultural situations of these regions where other sister crops such as corn cannot grow or often fail, this cereal will produce grain, but yields are low as a result of low and erratic rainfall, high temperature, low inherent soil fertility, and numerous biotic stresses. The yield of this crop was observed to be declining

in recent years. This was attributed to nutrient depletion relative to addition (Maiangwa, 2009) and has been reported to be one of the most important constraints leading to the decline in yield of the crop in these zones. In addition, blanket nutrient recommendations were made and applied based on estimates and there is paucity of information on soil-plant nutrient balance study and if available are mostly generalized.

Different strategies have been adopted over the years in order to assess the extent of nutrient losses and offer solutions to the problems. The ability of soils to provide nutrients for crop production is enhanced by systematic returns of nutrients. Maintenance of proper nutrient status in soil is a key factor for high yield production. In order to properly manage nutrient balance of a soil system in a sustainable way, it is necessary first to know the availability, depletion and balance of nutrient in a soil system (Myint *et al.*, 1997). It is recognized that sustainable high yield systems require both adequate nutrient supplies to growing crops as well as continual improvements to the soil's nutrient status and quality (De ren and Wan-fang, 1998). Innovative combinations of organic and inorganic nutrient sources must be used to increase inputs and to recycle the nutrients once they reach the soil. This suggests that part of the problem of nutrient deficiencies can be addressed through judicious use of organic inputs. Nyathi *et al.* (2003) while studying the efficacy of combinations of organic and inorganic sources of nutrients concluded that synergism existed only when combinations of inputs to sandy soil included organic fertilizers. Kwari *et al.* (1998) also recognized the beneficial effect of continuous application of FYM along with mineral fertilizers.

The essential aspect of maintaining soil fertility is making available in the upper layers of the soil (0-20 cm) sufficient nutrients in the right proportion to allow plants to absorb them, irrespective of total nutrient content. In order to restore soil fertility on a sustainable basis, the initial steps involved are the monitoring how soil fertility is being degraded and rate of degradation under continuous cropping. Application of mineral fertilizers in the soil of semi-arid region is a costly affair owing to their non-availability in sufficient quantity and if available, high cost (Brady and Weil, 2002). The characteristic of mineral fertilizers is that their beneficial effect is more in the short-run as compared to organic sources, though the availability of the later is also a constraint. Studies conducted around Sudan savanna region point to the direction that while the pronounced yield increase, consequent on mineral fertilizer application, is apparent in the short-run, their continuous use, however, tends to alter the physico-chemical properties of the soil, resulting in progressive decline in fertility (Rayar, 2000). If mineral fertilizers are used in conjunction with organic manures, the productivity of the soils is expected to improve significantly.

Increasing the productivity of these crops in such low-yielding and unpredictable environment, to keep pace with the increasing food demand of the growing population in the region is a task requiring concerted efforts. This calls for Integrated Nutrient Management (INM) as an approach in addressing soil fertility decline, especially in northeast Nigeria. The focus of this study is therefore to confirm the effects of FYM and NPK and to create new agronomy synergistic combinations for application to crops desirable for soil fertility management and sustainable crop production.

2 Materials and Methods

Rainy season field experiments were conducted in 2008 and 2009 in two different agro-ecological zones of north-east Nigeria. The locations are Research and Demonstration Farm of Lake Chad Research Institute, Maiduguri (11° 51'N, 13° 16'E), Borno state in Sudan savanna and at the Institute's experimental site, Gashua (12° 49' N, 11° 10'E), Yobe state in Sahel savanna of Nigeria as indicated in Figure 1. The soils of the experimental sites are characterized by aeolian sand formation, loosely

aggregated with a surface sandy loam texture (Chiroma *et al.*, 2003; Kwari and Bibinu, 2002). The soils are Typic Ustipsamment in Maiduguri (Rayar, 1988) and Psammentic Paleustalf in Gashua (Saidou *et al.*, 2010). The soils are low in organic carbon, total N, and available P and moderate K. Soil pH is slightly acidic in Gashua and neutral in Maiduguri (Table 1). Land development and use during the last forty years has been abusive and exploitative and resulted in degradation of soil and destruction of vegetation with resultant reduced productivity of both natural and managed ecosystem, leading to desert encroachment.

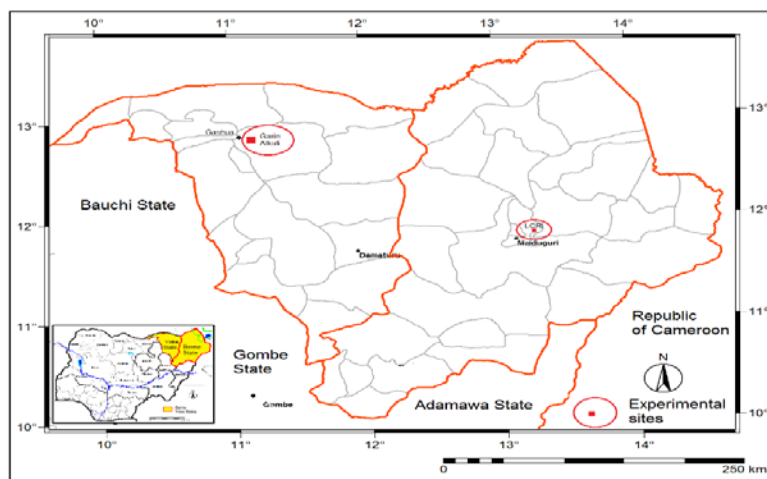


Figure 1: The study locations.

Source: Unimaid GEONETCast (2016).

2.1 Treatments and Experimental Design

The experiment consisted of factorial combinations of three levels of NPK fertilizer (NPK 0:0:0, 30:15:15 and 60:30:30 kg ha⁻¹) and four levels of farmyard manure (0, 2.5, 5.0 and 7.5 tonnes ha⁻¹) for millet as described by FPDD (1990) for high, medium and low fertility soils. The treatments were arranged in a randomized complete block design and replicated three times in plot sizes of 4.5 m × 5.25 m.

2.2 Experimental Procedure

The experimental fields were manually cleared, ploughed and harrowed to fine tilt with tractor in the first season and manually prepared by maintaining the previous plots the second season. Farmyard manure was applied two weeks before planting. One-third of nitrogen and full phosphorus and potassium were applied at planting using NPK 15-15-15, SSP (18% P₂O₅) and Urea (46% N). The remaining N were applied as micro-dose at 4 and 6 weeks after planting. Millet (SOSAT C-88) seeds obtained from Lake Chad Research Institute, were sown in the plots after treating the seeds with Apron plus (*metaxyl*) at the rate of 0.25 a. i. kg ha⁻¹. Weeds were controlled manually using hand hoe first at 3 WAS and subsequently at three week intervals. Millet and sorghum were harvested after reaching physiological maturity.

2.3 Collection of Data

2.3.1 Collection, preparation and analysis of soil samples

Three sets of six representative soil samples were collected from the experimental fields at a depth of 0 - 0.2 m in both locations before the experiments. The samples were air dried under shed, bulked, mixed

thoroughly to form composite samples. The samples were then dried in an oven at 105 °C for 24 hours, ground using pestle and mortar and passed through 2 mm mesh sieve and used for determination of selected physical and chemical properties. Particle size distribution was determined using Bouyoucos hydrometer method as described by Anderson and Ingram (1993). The textural class of the soils was determined using Marshall's Textural Triangle. Soil pH values were measured in 1:2.5 soil: water suspension ratios (Mc Clean, 1982). Electrical conductivity (EC) was determined on the soil-water suspension using electrical conductivity meter (Rhoades, 1982). Organic Carbon (OC) was determined using Walkley and Black method as described by Nelson and Sommers (1982). Organic matter (OM) was obtained by multiplying organic carbon by 1.724. Total N was determined using the micro Kjeldhal method (Bremner and Mulvaney, 1982); available P using Bray-1 method (Olsen and Sommers, 1982); cation exchange capacity (CEC) using 1N NH₄OAc (pH 7.0) saturation method (Chapman, 1965) and sum of exchangeable bases and exchange acidity using method described by Grant (1982). Bulk density (ρ) was determined on undisturbed soil core samples as described by Blake and Hartage (1986).

2.3.2 Measurement of plant parameters, collection and analysis of plant samples

Plant height at 3, 6 and 9 weeks after sowing (WAS), and straw and grain weight at harvest were measured per each plot and converted to kg ha⁻¹. Harvest index (HI) was determined by taking the ratio of grain yield to total dry matter as follows:

$$\text{Harvest Index} = \frac{\text{Grain yield per net plot}}{\text{Total dry matter per net plot}} \quad (1)$$

Straw and grain samples at harvest were collected for NPK content analysis. Plant and organic manure samples were digested by weighing 0.2 g of each of the samples into digestion tube and adding 10 ml of mixed ratio of 4% v/v perchloric acid in sulphuric acid. The mixture was heated on a digestion block until clear, colourless digest was obtained. The content was diluted to 100 ml with distilled water in a 100 ml flask. The digest was used to determine N by micro Kjeldhal and titration method; P by colorimetry using vanado-molybdate method with a spectrophotometer and K using flame photometer. The Ca and Mg were determined titrimetrically using Na₂ EDTA. Grains and vegetative parts were analyzed separately.

Data from field measurements and laboratory results were subjected to analysis of variance (ANOVA). All statistical analyses were performed using *Statistix 10.0* (analytical software for windows). Where differences between treatment means were significant, these differences were compared using Least Significant Difference (LSD) test or Duncan's Multiple Range Test (DMRT) where appropriate at 5% level of probability (Gomez and Gomez, 1984).

3 Results

3.1 Selected Physical and Chemical Properties

The soils are sandy loam in texture in both Maiduguri and Gashua (Table 1). The soils were slightly alkaline in Maiduguri to moderately alkaline in Gashua and free from salinity. The bulk densities were slightly higher in Maiduguri than in Gashua, all having moderate values. The soils have very low organic carbon in both locations, very low total N, and low available P contents. The K contents were moderate in both locations. The CEC were low but high in percentage base saturation. The chemical properties of the organic material used are presented in Table 2.

3.2 Effects of NPK and FYM on Millet Growth and Yield

3.2.1 Effects on plant height of millet in Maiduguri

Results of plant height of millet at various growth stages as influenced by application of NPK fertilizer and farmyard manure in Maiduguri is presented in Table 3a. Significant ($P < 0.05$) effects were observed with application of both NPK fertilizer and FYM. In Maiduguri plant height generally significantly increased with increasing rates of NPK fertilizer application at all the measurement stages. The only exception was at 6 WAS in the combined means and at 9 WAS in 2008. At 3 WAS in 2008, 2009 and their combined means, increase due to application of either NPK 30:15:15 or NPK 60:30:30 were significantly higher than when the fertilizers were not applied. The tallest plants were generally observed with the full recommended rate of NPK 60:30:30 in 2008, 2009 and their combined means. The increase over the NPK 0:0:0 (control) were 24.15% and 34.11% for half and full recommended rates in 2008, respectively. Similarly, the increase over control in 2009 were 37.41% and 49.76%, respectively for the half and full recommended rates, while in the means of the two years (combined means), 28.52% and 39.49% increase over control for the half and full recommended rates, respectively were observed. At 6 WAS significant differences were observed among the treatment means in both 2008 and 2009. In both years increases in plant heights due to application of NPK fertilizers were significant ($P < 0.05$) over the control, with NPK 30:15:15 producing the tallest plants in 2008, while in 2009 NPK 60:30:30 recorded the tallest plants. Their increases over the control were 37.8% and 29.715%, respectively. At 9 WAS application of NPK fertilizer did not produce significant increase in plant height in 2009, but in 2008 and their combined means, the effect was significant, with plots treated with fertilizer recorded taller plants than the control. In the combined means NPK 60:30:30 produced the tallest plants which were 24.62% taller than the plants produced by the control plots.

Farmyard manure application in Maiduguri had significant ($P < 0.05$) influence on millet plant height in all the three growth stages measured except at 3 and 6 WAS in the combined means, and at 9 WAS in 2009. Generally, plant height increased with increase in the application rates, though no significant differences between 5.0t and 7.5t FYM were observed in most cases. Initially, at 3 WAS in 2008, taller plants were obtained with 0.0t FYM, but later application of other rates of FYM were observed to produce taller plants. The treatment of 7.5t FYM in 2008 and the combined means produced significantly tallest plants in the late stage of growth, as compared to the early and mid-stages of growth.

There was significant interaction between NPK fertilizer and farmyard manure in Maiduguri at 3 WAS in 2008 and 2009, as well as 9 WAS in 2008, 2009 and the combined means (Table 4a). NPK 60:30:30 + 0.0t FYM produced the tallest plants at early stage of growth. At mid stage of growth, interaction of NPK 30:15:15 + 7.5t FYM in 2008 produced significantly the tallest plant height, while in 2009 and the combined means NPK 60:30:30 + 7.5t FYM was the best treatment. In both the two years and their combined means at all the stages of growth, shortest plants were obtained with interaction of NPK 0:0:0 and 0.0t FYM ha^{-1} .

3.2.2 Effects on plant height of millet in Gashua

In Gashua, application of NPK fertilizer significantly ($P < 0.05$) influenced plant height at the early and mid-stages of growth (Table 3b). However, the application did not result into any significant effect at later stage of growth (9 WAS). At 3 WAS in 2008 and the combined means, significant differences were obtained between the control plots and the treated plots, whereas at 6 WAS all the treated plots produced significantly taller plants than the control plots. In both cases the half and the full

recommended rates were at par with each other, Averaged across years, the height of plants grown under the fertilizer treatments significantly exceeded that of the control by 26.10% for the half and 26.71% for the full recommended rates at 3 WAS, 30.35% and 36.06% at 6 WAS, and 4.93% and 3.71% at 9 WAS, respectively.

Farmyard manure application considerably influenced plant height in Gashua, with significant effect at 3 WAS in 2008 and 2009; 6 WAS in 2008 only and at 9 WAS in 2008 and 2009. Increase in the application rates increased plant height at 3 WAS in 2008, with tallest plants recorded at the application of 7.5t FYM. Similarly, 7.5t FYM produced the tallest plants at 9 WAS in 2008, 2009 and their combined means.

In Gashua interactions of NPK fertilizer and farmyard manure were significant at 3 WAS in 2008 and 2009; at 6 WAS in 2008 and at 9 WAS in 2009 (Table 4b). At 3 WAS in 2008 and 2009, plant height obtained at NPK 60:30:30 + 0.0t FYM was the best whereas at 6 WAS in 2008 NPK 30:15:15 + 5.0t FYM produce the tallest plants. At 9 WAS in 2009, the tallest plants were observed with the interaction of NPK 0:0:0 + 7.5t FYM level.

3.2.3 Effects on yield and yield components of millet in Maiduguri

The individual effects of NPK fertilizer and farmyard manure on grain, straw, and total biomass yields of millet as well as on harvest index in Maiduguri are shown in Table 5a. Yields and yield component of millet were significantly ($P < 0.05$) influenced by application of both NPK fertilizer and FYM in both years and their combined means, except for harvest index in 2009. Millet grain yield generally increased with increasing NPK fertilizer rates in 2008, 2009 and the combined means. Fertilizer treated plots recorded significantly higher grain yield than the unfertilized plots. The differences in yield between NPK 30:15:15 and 60:30:30 were not significant. In 2009, NPK treatments recorded higher yield compared to their corresponding treatments in 2008. The increase over control with NPK 30:15:15 and 60:30:30 were 129% and 145%, respectively in 2008, while in 2009, the increases were 55% and 56%, respectively. Straw yield followed similar trend to that of grain yield, showing increase with increasing rate of NPK fertilizer in both years and the combined means. Similarly, fertilizer treated plots recorded significantly higher ($P < 0.05$) straw yield compared to the unfertilized plots. The yield increase over control in 2008, 2009 and combine means with NPK 60:30:30 were 107%, 49% and 71%, respectively. Total biomass yield was also significantly affected by the NPK fertilizer application rates. In 2008, application of NPK 60:30:30 produced significantly the higher biomass yield than either NPK 30:15:15 or 0:0:0 kg ha⁻¹. In 2009, there were no significant differences between biomass yield at NPK 30:15:15 and 60:30:30, but were significantly different from the value at NPK 0:0:0. Similarly, in the combined means significantly lower biomass yield was observed at NPK 0:0:0 compared to NPK 30:15:15 and 60:30:30 kg ha⁻¹. The latter two were not significantly different from each other. The yield increase over control at NPK 60:30:30 in 2008, 2009 and combined means were 121%, 152% and 76%, respectively. For harvest index, differences in values at NPK 30:15:15 and 60:30:30 rates were not significant, but were significantly higher than the value at NPK 0:0:0 rate in both 2008 and the combined means.

Application of FYM significantly increased grain, straw, and biomass yields and harvest index in 2008, 2009 and combined means in Maiduguri, except for straw yield and harvest index in 2009 (Table 5a). Among the different rates of FYM applied, there were significant difference in yields and yield component between 0.0t FYM and all other rates in 2008, whereas values at 5.0t and 7.5t FYM ha⁻¹ did not differ significantly. Rate of 5.0t FYM recorded the highest grain yield while the least was obtained at application of 0.0t FYM. In 2009, the rate of 5.0t FYM differ significantly from all other rates in yields and yield component. In the combine means 0.0t FYM produced the least yield which did not differ from the yield obtained with 2.5t FYM rate. The higher yield was obtained with 5.0t FYM ha⁻¹. For straw yield

in 2008, 5.0t and 7.5t FYM rates significantly increased yield relative to 0.0t and 2.5t FYM rates ha^{-1} . In the combined means, the manure treated plots were similar in yields, but vary with the control. Biomass yield and harvest index in 2008 and the combined means were increased significantly at 5.0t and 7.5t than at 0.0t and 2.5t FYM ha^{-1} .

The interaction effects of NPK and FYM were significant on all the yields and yield component of millet in Maiduguri (Table 6a). Generally, NPK 30:15:15 + 5.0t FYM recorded significantly higher yields and yield component values in both years and the combined means, whereas lower values were obtained at NPK 0:0:0 + 0.0t FYM ha^{-1} . At NPK 0:0:0: values increased with increase in FYM rates, with higher value at combination with 7.5t FYM. Interaction of either NPK 30:15:15 or 60:30:30 with FYM rates up to 5.0t FYM increased grain, straw and biomass yields as well as the harvest index, but decreased with further increase in FYM rate.

3.2.4 Effects on yield and yield components of millet in Gashua

In Gashua, the differences between the means of yields and yield component of millet recorded with application of various rates of NPK fertilizer were significant (Table 5b). For all the parameters measured, value at NPK 0:0:0 was significantly lower than values obtained at the two fertilizer treatments. No significant differences were observed between NPK 30:15:15 and 60:30:30 kg ha^{-1} . Treatment NPK 30:15:15 kg ha^{-1} recorded higher value in all the parameters.

Manure application rates in Gashua had significantly ($P < 0.05$) influenced all the yields and yield component measured in 2008, 2009 and the combined means, except for harvest index. In 2008, grain yield varied significantly between 0.0t FYM and all other rates. No observable differences among the treated plots were recorded. Similar trend was observed in 2009, but in the combined means, 5.0t and 7.5t ha^{-1} FYM rates recorded significantly higher grain yield than 0.0t FYM. Farmyard manure effect on straw yield was significant in 2008, with manure treated plots recording significantly higher yield than the non-treated plots. In 2009, 0.0t and 2.5t FYM did not differ in straw yield, but were significantly lower than 5.0t FYM rate. Biomass yield followed the same trend as that of straw yield, with yield significantly higher in all the FYM treated plots than in the control plots in 2008 cropping season and the combined means. In 2009, 5.0t FYM significantly affected biomass yield relative to 0.0t and 2.5t FYM ha^{-1} . For harvest index no significant difference was observed among the manure rates in both years and the combined means. Rate of 5.0t ha^{-1} FYM consistently gave the higher value.

In Gashua, the interaction effects were significant on grain yield in 2009 and the combined means, and straw yield and harvest index in 2009 only. Higher grain yield was consistently recorded at NPK 30:15:15 + 5.0t FYM ha^{-1} in all the parameters measured, except for harvest index which recorded greater values at NPK 30:15:15 + 2.5t ha^{-1} FYM. In 2009, at NPK 0:0:0 combined with different rates of FYM, grain yield did not differ significantly. At NPK 30:15:15 + 5.0t FYM grain yield was significantly higher compared with values at combination with all other manure rates. At NPK 60:30:30 combined with 0.0t FYM, grain yield was significantly lower than combination with 5.0t and 7.5t FYM, but similar when combined with 2.5t ha^{-1} FYM. Interaction of NPK 30:15:15 with various FYM rates did not differ significantly in straw yield. Similar observations were made at the interaction of NPK 60:30:30 with all the FYM rates. Interaction between NPK 30:15:15 and either 2.5t or 5.0t FYM in 2009 produced significantly higher harvest index values than all other interaction levels, except at NPK 0:0:0 + 0.0t, NPK 30:15:15 + 7.5t and NPK 60:30:30 with either 2.5t, 5.0t and 7.5t ha^{-1} FYM.

4 Discussion

4.1 Plant Height

The height of plant is an important growth character directly linked with the production of plant in terms of straw, grain and total dry matter yield. The two fertilizer treatments of NPK 60:30:30 and 30:15:15 generally show similar effect. The plant height increase with increasing fertilizer application lends credence to the report by Kwari and Bibinu (2002) that application of fertilizer had significant effect on plant height of millet. The increase in plant height with increasing fertilizer rates is expected because of addition of N and P into the soil through the fertilizer as these nutrients are essentially low in the soil. The lack of significant difference between the two NPK fertilizer rates may be due to leaching or volatilization of excess N added with the NPK 60:30:30 or slight fixation of excess P added with the higher rate or may be attributed to low phosphate sorption capacity of the soils (Kwari and Batey, 1988). Application of FYM resulted to variable responses in plant height of millet with significant effect at mid (6 WAS) and late (9 WAS) stages of growth due to complete decomposition and nutrient release at these stages. In most cases the significant increase in plant height occur with application of 5.0t and 7.5t ha⁻¹ FYM. At the initial stage there were no significant differences between control NPK and the various FYM treatments. This could be due to the fact that the FYM has not undergone substantial decomposition to bring about marked effect. Interaction effects due to application of inorganic fertilizer in combination with FYM showed significant effect only in the individual years. Plant height varied significantly as height increased with increase in combined rates of application. Initially, the NPK 60:30:30 + 0.0t FYM proved to be superior in enhancing plant height due to the nutrient supplied by the NPK fertilizer component. Subsequently, the interaction of the NPK 30:15:15 and either 5.0t or 7.5t ha⁻¹ FYM gave the best result. The combination of NPK 0:0:0 with various FYM rates showed tremendous decrease in height. The low response of millet plant to these fertilizer combinations might be due to insufficient available soil N for plant uptake since the N release during decomposition might have been fast utilized by the microorganisms carrying out the decomposition process, thus retarding growth at early stage. The result also suggests that poor growth of millet is expected without fertilizer application. On the other hand, the significant effect observed due to combined application of NPK fertilizer with FYM at higher rates, particularly at mid and late stages of growth, may be that NPK fertilizer supplied sufficient nutrients for both plants and microorganisms responsible for the decomposition of the added FYM (priming effect), thereby releasing more nutrients for uptake by plants as well as the release of nutrient at later stage by the FYM synchronized with the crop demand (Shah and Ahmad, 2006).

In Gashua NPK fertilizer enhanced plant height at early and mid-growth stages, but not at late stage. This may be due to the supply of nutrients from the NPK fertilizer. At later stage of growth, the NPK fertilizer might have been completely utilized thereby showing no effect among the treatments. The application of FYM also enhanced plant height. In most cases the height increased with increasing rates, but the increase was significant only between the control and the other rates. This is probably due to the improved soil conditions, thus making it conducive for good plant growth, in addition to the release of nutrients into the soil on decomposition of the FYM. Interaction effect was generally significant in the individual years but not across years. The significant interaction effect between the fertilizers indicates that at the various manure rates plant height tended to increase with increasing NPK fertilizer rates. This may be due to the nutrients added to the soil by the fertilizer. At mid and later stages of growth with different fertilizer rates, plant height increased with increasing FYM rates up to 5.0t ha⁻¹ FYM and then decrease further.

4.2 Yield and Yield Components

Application of NPK fertilizer significantly increased grain, straw and biomass yields and harvest index over control and the other fertilizer treatments over the two-year experiment. The increase was more than 85, 71, 76 and 16% from grain, straw, total biomass and harvest index, respectively over the control. The increase in yields and yield component with increasing NPK fertilizer clearly demonstrated that the nutrient supplied by the fertilizer had a tremendous beneficial effect in enhancing yield. This is because cereal crops demand high amount of N and P for improved yield since the soil of the study areas are inherently low in N and P contents. In general, application of FYM significantly increased yield. The two higher rates showed superiority over the two lower rate, but all were higher than the control. The yield increase with increasing manure rates shows that manure has a tremendous beneficial effect on the soil because of its contribution in improving soil physical properties, increased soil organic matter, CEC and exchangeable cations in addition to other plant nutrients. Similar finding was reported by Lawal *et al.* (2011) in Samaru Zaria. The interaction effects were significant for all yields and yield component parameters due to the combined application of NPK fertilizer and FYM. The result also revealed greater effect on grain yield due mainly to increasing NPK fertilizer rates than FYM, and that at the higher application rates of NPK 60:30:30 + 7.5t ha⁻¹ FYM, yields decreased. This may be as a result of luxury consumption which resulted in delayed maturity. Plants receiving NPK 30:15:15 + 5.0t FYM generally gave the higher yields, which corroborates the report of Kwari and Bibinu (2002) that sub-optimal rate of NPK 30:15:15 + 4.5t of manure may be beneficial for millet production in the regions. As earlier mentioned, soils in the savanna regions are low to very low in organic matter content and the clay fractions are predominantly low activity clay, consequently these soils are generally low in CEC and are poorly buffered (Table 1). This indicated that when NPK fertilizer alone is used the nutrients would be easily leached, thus making them unavailable for crop uptake and utilization as ascertained by Kwari *et al.* (1998). However, application of NPK fertilizer in combination with FYM would help reduce the quantity of inorganic fertilizer needed to meet crop demand as shown in this study. This indicates that manure has a tremendous beneficial effect in the soil because of its contribution to organic matter content and buffering capacity in addition to nutrients it supplies (Bationo and Mokwunye, 1991).

In Gashua, similar findings as in Maiduguri were observed, but in this case, NPK 30:15:15 gave slightly higher yields than the NPK 60:30:30. This means that the more porous sandy soil in Gashua might have influenced leaching of excess nutrients. Application of FYM significantly enhanced grain, straw and biomass yields than none application. Interaction effect was significant on grain yield, with NPK 30:15:15 + 5.0t FYM recording significantly higher yield than all other combination levels and the yield increase was over 215% compared with the control. The yield in the initial year was not significant. This means that the successive use of manure had a cumulative effect thereby enhancing grain yield in the subsequent years.

5 Conclusion

The study revealed increased millet performance with combined application of NPK and FYM fertilizers than their sole application. This was evidenced by the increased in growth and yields of millet with increased application rates. Half the recommended rate of NPK combined with either 5.0t or 7.5t FYM gave the tallest plants at all the three growth stages sampled in Maiduguri. Farmyard manure application at the rate of 5.0 or 7.5t /ha either alone or in combination enhanced plant height in Gashua. Combined application of NPK 30:15:15 plus 5.0t FYM to millet gave the highest millet grain yield of 3202 kg ha⁻¹ and total dry matter yield of 7962 kg ha⁻¹ in Sudan savanna and grain yield of 2136 kg ha⁻¹ and total dry

matter yield of 6397 kg ha⁻¹ in Sahel savanna. Hence it can be concluded that integrated application of half the recommended rates of NPK fertilizer for millet and either 5.0t or 7.5t FYM to soils of Maiduguri (Sudan savanna) and Gashua (Sahel savanna) will improved the physical and chemical condition of the soils and enhance millet performance for sustainable production.

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Table 1: Selected physical and chemical properties of the soil of the experimental sites

Properties	Maiduguri	Gashua
Particle size distribution (g kg⁻¹):		
Sand	716	815
Silt	146	72
Clay	138	113
Texture	Sandy loam	Sandy loam
Bulk density (g cm ⁻³)	1.74	1.68
pH _{1:2.5} (H ₂ O)	7.37	7.84
Electrical conductivity (dS m ⁻¹)	0.03	0.08
Organic matter (g kg ⁻¹)	2.84	2.57
Total nitrogen (g kg ⁻¹)	0.90	0.85
C:N ratio	1.85	1.75
Available Phosphorus (mg kg ⁻¹)	5.25	6.83
Exchangeable cations (cmol kg⁻¹):		
Potassium (K)	0.99	1.08
Sodium (Na)	0.31	0.29
Calcium (Ca)	1.90	0.80
Magnesium (Mg)	1.90	3.30
Exchangeable acidity (H + Al)	0.35	0.35
Cation Exchange Capacity (CEC)	5.44	5.82
Base saturation (%)	93.58	94.02

Table 2: Nutrients content of the farmyard manure used for the study

Nutrient	Value (%)
N	1.12
P	0.16
K	0.98
Ca	0.60
Mg	0.18

Table 3a: Effect of NPK fertilizer and farmyard manure on plant height of millet in Maiduguri

Treatments	3 WAS			6 WAS			9 WAS		
	2008	2009	Means	2008	2009	Means	2008	2009	Means
NPK fertilizer									
NPK 0:0:0	20.08	10.37	15.22	42.69	94.83	68.76	153.35	134.32	143.84
NPK 30:15:15	24.87	14.25	19.56	58.83	114.20	86.51	169.74	185.53	177.64
NPK 60:30:30	26.93	15.53	21.23	55.27	123.45	89.36	175.96	182.57	179.26
SE±	0.493	0.502	1.256	2.645	2.649	6.970	6.514	8.155	5.625
LSD	1.445	1.473	3.555	7.758	7.766	19.730	19.106	23.918	15.923
Farmyard manure									
0.0 t FYM	24.41	12.71	18.56	40.22	95.02	67.62	137.97	156.88	147.42
2.5 t FYM	22.14	12.09	17.12	50.01	106.36	78.13	163.00	156.38	159.69
5.0 t FYM	24.28	14.16	19.22	51.52	117.73	84.63	170.37	170.04	170.21
7.5 t FYM	24.99	14.58	19.78	67.29	124.20	95.74	194.07	186.60	190.33
SE±	0.569	0.580	1.450	3.055	3.057	8.048	7.522	9.417	6.495
LSD	1.668	1.700	4.104	8.959	8.967	22.783	22.061	27.618	18.387
Interaction									
NPK × FYM	**	*	NS	NS	NS	NS	**	*	***

*, **, *** significant at 5, 1 and 0.1% level of probability, respectively; NS = Not significant; WAS weeks after sowing.

Table 3b: Effect of NPK fertilizer and farmyard manure on plant height of millet in Gashua

Treatments	3 WAS			6 WAS			9 WAS		
	2008	2009	Means	2008	2009	Means	2008	2009	Means
NPK fertilizer									
NPK 0:0:0	15.13	17.68	16.40	60.59	95.63	78.11	218.37	129.68	174.03
NPK 30:15:15	23.72	17.63	20.68	84.58	119.17	101.82	234.59	130.63	182.61
NPK 60:30:30	24.50	17.10	20.78	90.74	121.82	106.28	227.01	133.96	180.48
SE±	0.712	0.745	1.878	3.503	5.617	4.986	9.444	4.589	11.924
LSD	2.087	9.026	5.825	10.273	4.294	3.982	27.700	18.221	11.267
Farmyard manure									
0.0 t FYM	19.30	20.18	20.37	62.98	108.80	85.89	208.09	115.50	161.79
2.5 t FYM	20.57	16.31	17.81	82.28	116.07	99.17	210.87	132.58	171.72
5.0 t FYM	21.63	16.11	18.87	87.14	112.00	99.57	240.53	136.91	188.72
7.5 t FYM	22.89	17.29	20.09	82.16	111.96	97.06	247.13	140.71	193.92
SE±	0.822	0.906	1.014	4.045	6.486	5.757	10.901	5.299	13.769
LSD	2.410	10.422	6.726	11.862	4.958	4.598	31.985	21.039	13.010
Interaction									
NPK × FYM	*	**	NS	*	NS	NS	NS	*	NS

*, **, *** significant at 5, 1 and 0.1% level of probability, respectively; NS = Not significant; WAS weeks after sowing.

Table 4a: Interaction effect of NPK fertilizer (kg ha⁻¹) and farmyard manure (t ha⁻¹) on plant height of millet in Maiduguri

Treatments	3 WAS			6 WAS			9 WAS		
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
NPK 0:0:0 + 0.0t	17.23 ^{g*}	8.40 ^g	12.82 ^g	36.27 ^f	73.60 ^g	54.93 ^f	79.97 ^d	98.37 ^d	89.17 ^d
NPK 0:0:0 + 2.5t	19.23 ^{fg}	9.47 ^{fg}	14.45 ^{fg}	41.77 ^{ef}	95.40 ^f	68.58 ^e	156.73 ^{bc}	160.00 ^{bc}	158.37 ^c
NPK 0:0:0 + 5.0t	20.97 ^{ef}	10.33 ^{efg}	15.65 ^{ef}	38.67 ^{ef}	98.33 ^{ef}	68.50 ^e	169.57 ^{abc}	130.60 ^{cd}	150.08 ^c
NPK 0:0:0 + 7.5t	22.87 ^{cde}	12.27 ^{cde}	17.97 ^{cd}	54.07 ^{cde}	112.00 ^{cde}	83.03 ^{cd}	207.13 ^a	148.33 ^c	177.73 ^{abc}
NPK 30:15:15 + 0.0t	26.53 ^b	17.47 ^{def}	19.40 ^{bc}	39.20 ^{ef}	99.33 ^{ef}	69.27 ^e	151.23 ^c	165.37 ^{bc}	158.55 ^c
NPK 30:15:15 + 2.5t	22.63 ^{de}	14.47 ^{def}	17.38 ^{de}	57.30 ^{bcd}	110.40 ^{def}	83.85 ^{cd}	166.83 ^{bc}	154.80 ^c	160.82 ^c
NPK 30:15:15 + 5.0t	24.70 ^{bcd}	15.40 ^{ab}	20.72 ^b	62.07 ^{abc}	128.60 ^{ab}	95.33 ^b	167.70 ^{bc}	215.07 ^a	191.38 ^{ab}
NPK 30:15:15 + 7.5t	25.60 ^{bc}	14.80 ^{abc}	20.73 ^b	76.73 ^a	118.47 ^{bcd}	97.60 ^{ab}	193.20 ^{ab}	206.40 ^{ab}	199.80 ^a
NPK 60:30:30 + 0.0t	29.47 ^a	12.13 ^a	23.47 ^a	45.20 ^{def}	112.13 ^{cde}	78.67 ^{de}	182.70 ^{abc}	206.40 ^{ab}	194.55 ^{ab}
NPK 60:30:30 + 2.5t	24.57 ^{bcd}	16.73 ^{bcd}	19.52 ^{bc}	50.97 ^{c-f}	113.27 ^{b-e}	82.12 ^{cd}	165.43 ^{bc}	154.33 ^c	159.88 ^c
NPK 60:30:30 + 5.0t	27.17 ^{ab}	15.87 ^{abc}	21.28 ^b	53.83 ^{cde}	126.27 ^{bc}	90.05 ^{bc}	173.83 ^{abc}	164.47 ^{bc}	169.15 ^{bc}
NPK 60:30:30 + 7.5t	26.50 ^b	1.004 ^{a-d}	20.65 ^b	71.07 ^{ab}	142.13 ^a	106.60 ^a	181.87 ^{abc}	205.07 ^{ab}	193.47 ^{ab}
SE±	0.985	1.004	0.704	5.291	5.296	3.781	13.028	16.310	10.412

*Means followed by the same letter(s) along the column are statistically not significantly different at 5% level of probability according to Duncan Multiple Range Test (DMRT).

Table 4b: Interaction effect of NPK fertilizer (kg ha⁻¹) and farmyard manure (t ha⁻¹) on plant height of millet in Gashua

Treatments	3 WAS			6 WAS			9 WAS		
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
NPK 0:0:0 + 0.0t	12.37 ^d	17.27 ^{bcd}	14.82 ^e	41.20 ^g	91.47 ^{bc}	66.33 ^g	183.10 ^{cd}	96.80 ^c	139.95 ^d
NPK 0:0:0 + 2.5t	13.60 ^d	18.67 ^{a-d}	16.13 ^{de}	74.30 ^{def}	99.60 ^{abc}	86.95 ^{ef}	173.40 ^d	125.40 ^b	149.40 ^{cd}
NPK 0:0:0 + 5.0t	14.53 ^d	18.60 ^{a-d}	16.57 ^{de}	56.77 ^{fg}	84.38 ^c	70.55 ^{fg}	243.87 ^{ab}	135.07 ^{ab}	189.47 ^{ab}
NPK 0:0:0 + 7.5t	20.00 ^c	16.20 ^{cd}	18.10 ^{cde}	70.10 ^{cef}	107.13 ^{abc}	88.62 ^{def}	273.10 ^a	161.47 ^a	217.28 ^a
NPK 30:15:15 + 0.0t	23.40 ^{abc}	21.27 ^{ab}	22.33 ^{abc}	76.73 ^{c-f}	117.53 ^{ab}	97.13 ^{b-e}	227.07 ^{a-d}	116.67 ^{bc}	171.87 ^{bc}
NPK 30:15:15 + 2.5t	23.20 ^{abc}	18.87 ^{a-d}	21.03 ^{abc}	68.97 ^{ef}	125.27 ^a	97.12 ^{b-e}	231.73 ^{ab}	142.00 ^{ab}	186.87 ^b
NPK 30:15:15 + 5.0t	25.43 ^a	15.27 ^{de}	20.35 ^{a-d}	107.43 ^a	126.27 ^a	116.85 ^a	248.33 ^{ab}	143.47 ^{ab}	195.90 ^{ab}
NPK 30:15:15 + 7.5t	22.83 ^{abc}	15.13 ^{de}	18.98 ^{b-e}	85.20 ^{b-e}	107.60 ^{abc}	96.40 ^{b-e}	231.23 ^{abc}	120.40 ^{bc}	175.82 ^{bc}
NPK 60:30:30 + 0.0t	25.93 ^a	22.00 ^a	23.97 ^a	71.00 ^{def}	117.40 ^{ab}	94.20 ^{cde}	214.10 ^{bcd}	133.03 ^b	173.57 ^{bc}
NPK 60:30:30 + 2.5t	21.10 ^{bc}	16.40 ^e	16.25 ^{de}	103.57 ^{ab}	123.33 ^{ab}	113.45 ^{ab}	227.47 ^{a-d}	130.33 ^b	178.90 ^b
NPK 60:30:30 + 5.0t	24.93 ^{ab}	14.47 ^{de}	19.70 ^{a-d}	97.23 ^{abc}	125.40 ^a	111.32 ^{abc}	229.40 ^{abc}	132.20 ^b	180.80 ^b
NPK 60:30:30 + 7.5t	25.83 ^a	20.53 ^{abc}	23.18 ^{ab}	91.17 ^{a-d}	121.13 ^{ab}	106.15 ^{a-d}	237.07 ^{abc}	140.27 ^{ab}	188.67 ^b
SE±	1.423	1.570	1.563	7.006	9.178	6.472	18.889	9.178	10.071

*Means followed by the same letter(s) along the column are statistically not significantly different at 5% level of probability according to Duncan Multiple Range Test (DMRT).

Table 5a: Effect of NPK fertilizer (kg ha⁻¹) and farmyard manure (t ha⁻¹) on yields and yield component of millet in Maiduguri

Treatments	Grain Yield (kg ha ⁻¹)			Straw Yield (kg ha ⁻¹)			Biomass Yield (kg ha ⁻¹)			Harvest Index		
	2008	2009	Means	2008	2009	Means	2008	2009	Means	2008	2009	Means
NPK fertilizer												
NPK 0:0:0	971	1956	1466	1767	2989	2376	2737	4945	3842	0.33	0.64	0.58
NPK 30:15:15	2221	3029	2425	3522	4354	3938	5744	7341	6542	0.39	0.70	0.67
NPK 60:30:30	2381	3052	2717	3663	4453	4058	6044	7505	6775	0.39	0.69	0.67
SE±	68.30	69.39	110.4	61.35	109.5	125.0	87.17	147.0	222.6	0.010	0.022	0.020
LSD	200.0	203.5	312.5	179.9	321.1	353.9	255.7	431.2	630.1	0.014	0.025	0.024
Farmyard manure												
0.0 t FYM	1436	2488	1962	2498	3662	3080	3934	6149	5042	0.34	0.66	0.59
2.5 t FYM	1669	2626	2148	2950	3914	3432	4619	6540	5580	0.34	0.67	0.60
5.0 t FYM	2236	2930	2583	3270	4134	3702	5506	7064	6285	0.41	0.71	0.70
7.5 t FYM	2089	2672	2381	3218	4017	3618	5307	6634	5971	0.40	0.68	0.67
SE±	78.86	80.12	127.5	70.84	126.4	144.3	100.7	169.8	257.0	0.011	0.025	0.023
LSD	231.3	235.0	360.8	207.8	370.7	408.6	295.2	497.9	727.6	0.032	0.029	0.027
Interaction												
NPK × FYM	***	**	**	***	*	*	***	***	*	***	**	***

*, **, *** significant at 5, 1 and 0.1% level of probability, respectively; NS = Not significant.

Table 5b: Effect of NPK fertilizer (kg ha⁻¹) and farmyard manure (t ha⁻¹) on yields and yield component of millet in Gashua

Treatments	Grain Yield (kg ha ⁻¹)			Straw Yield (kg ha ⁻¹)			Biomass Yield (kg ha ⁻¹)			Harvest Index		
	2008	2009	Mean s	2008	2009	Means	2008	2009	Mean s	2008	2009	Means
NPK fertilizer												
NPK 0:0:0	922	915	919	2584	3546	3065	3506	4461	3984b	0.26	0.22	0.24
NPK 30:15:15	1682	1754	1718	3125	4632	3878	4808	6386	5597a	0.35	0.27	0.31
NPK 60:30:30	1561	1619	1590	3030	4572	3801	4591	6191	5391a	0.34	0.26	0.30
SE±	61.35	67.26	46.00	104.6	175.2	183.7	124.1	195.5	192.9	0.012	0.014	0.012
LSD	179.9	197.3	130.2	306.7	513.8	520.1	363.8	573.4	545.5	0.034	0.042	0.035
Farmyard manure												
0.0 t FYM	139	1123	1131	2493	3694	3093	3632	4817	4225	0.30	0.25	0.28
2.5 t FYM	1421	1454	1438	2952	4093	3523	4374	5547	4961	0.32	0.26	0.29
5.0 t FYM	1544	1649	1597	3121	4717	3919	4665	6366	5516	0.33	0.25	0.29
7.5 t FYM	1449	1492	1471	3087	4495	3791	4536	5987	5261	0.32	0.25	0.28
SE±	70.84	77.66	53.11	120.8	202.3	212.9	143.2	225.7	222.5	0.013	0.016	0.014
LSD	207.8	227.8	150.4	354.1	593.3	600.5	420.1	662.1	629.9	0.039	0.048	0.041
Interaction												
IN. × ORG.	NS	*	**	NS	*	NS	NS	NS	NS	NS	**	NS

*, **, *** significant at 5, 1 and 0.1% level of probability, respectively; NS = Not significant.

Table 6a: Interaction effect of NPK fertilizer (kg ha⁻¹) and farmyard manure (t ha⁻¹) on yields (kg ha⁻¹) and yield component of millet in Maiduguri

Treatments	Grain Yield (kg ha ⁻¹)			Straw Yield (kg ha ⁻¹)			Biomass Yield (kg ha ⁻¹)			Harvest Index		
	2008	2009	Means	2008	2009	Means	2008	2009	Means	2008	2009	Means
NPK 0:0:0 + 0.0t	387 ^g	1258 ^f	822 ^f	1196 ^g	2502 ^e	1849 ^f	1583 ^h	3759 ^h	2671 ^f	0.25 ^e	0.34 ^c	0.29 ^e
NPK 0:0:0 + 2.5t	632 ^g	1831 ^e	1223 ^{ef}	1766 ^f	2904 ^{de}	2335 ^{ef}	2398 ^g	4717 ^g	3558 ^{ef}	0.26 ^e	0.39 ^{ab}	0.33 ^{de}
NPK 0:0:0 + 5.0t	1145 ^f	2115 ^e	1630 ^{de}	1794 ^f	3128 ^{de}	2461 ^{ef}	2940 ^f	5243 ^{fg}	4091 ^{de}	0.39 ^{a-d}	0.40 ^{ab}	0.40 ^{abc}
NPK 0:0:0 + 7.5t	1719 ^e	2638 ^{cd}	2179 ^{cd}	2310 ^e	3421 ^{cd}	2866 ^{de}	4030 ^e	6059 ^{ef}	5044 ^{cd}	0.42 ^{ab}	0.43 ^a	0.43 ^{ab}
NPK 30:15:15 + 0.0t	1952 ^{de}	2739 ^{cd}	2345 ^{bc}	2801 ^d	3959 ^{bc}	3380 ^{cd}	4753 ^d	6697 ^{de}	5725 ^{bc}	0.41 ^{abc}	0.41 ^a	0.41 ^{abc}
NPK 30:15:15 + 2.5t	1805 ^e	3045 ^{bc}	2425 ^{bc}	3435 ^c	4264 ^b	3849 ^{bc}	5240 ^{cd}	7309 ^{bcd}	6274 ^{bc}	0.35 ^d	0.42 ^a	0.38 ^{bc}
NPK 30:15:15 + 5.0t	2907 ^a	3497 ^a	3202 ^a	4465 ^a	5056 ^a	4761 ^a	7372 ^a	8552 ^a	7962 ^a	0.40 ^{a-d}	0.41 ^a	0.40 ^{abc}
NPK 30:15:15 + 7.5t	2222 ^{cd}	2834 ^{bcd}	2528 ^{bc}	3388 ^c	4138 ^b	3763 ^{bc}	5610 ^c	6805 ^{cde}	6208 ^{bc}	0.39 ^{a-d}	0.42 ^a	0.41 ^{abc}
NPK 60:30:30 + 0.0t	1969 ^{de}	3466 ^a	2718 ^{abc}	3496 ^c	4525 ^{ab}	4011 ^{bc}	5465 ^c	7991 ^{ab}	6728 ^{ab}	0.36 ^{cd}	0.43 ^a	0.40 ^{abc}
NPK 60:30:30 + 2.5t	2570 ^{abc}	3021 ^{bc}	2796 ^{abc}	3650 ^{bc}	4573 ^{ab}	4111 ^{ab}	6220 ^b	7594 ^{bc}	6907 ^{ab}	0.41 ^{ab}	0.40 ^a	0.41 ^{abc}
NPK 60:30:30 + 5.0t	2657 ^{ab}	3177 ^{ab}	2917 ^{ab}	3551 ^c	4219 ^b	3885 ^{bc}	6208 ^b	7396 ^{bcd}	6802 ^{ab}	0.43 ^a	0.43 ^a	0.43 ^a
NPK 60:30:30 + 7.5t	2327 ^{bcd}	2545 ^d	2436 ^{bc}	3955 ^b	4494 ^b	4225 ^{ab}	6282 ^b	7039 ^{cd}	6661 ^b	0.37 ^{bcd}	0.36 ^{bc}	0.37 ^{cd}
SE±	136.6	138.8	220.7	122.7	218.9	250.0	174.4	294.1	445.2	0.019	0.017	0.017

*Means followed by the same letter(s) along the column are statistically not significantly different at 5% level of probability according to Duncan Multiple Range Test (DMRT).

Table 6b: Interaction effect of NPK fertilizer (kg ha⁻¹) and farmyard manure (t ha⁻¹) on yields (kg ha⁻¹) and yield component of millet in Gashua

Treatments	Grain Yield (kg ha ⁻¹)			Straw Yield (kg ha ⁻¹)			Biomass Yield (kg ha ⁻¹)			Harvest Index		
	2008	2009	Means	2008	2009	Means	2008	2009	Means	2008	2009	Means
NPK 0:0:0 + 0.0t	556 ^f	800 ^e	678 ^g	1824 ^d	2008 ^c	1916 ^b	2380 ^e	2808 ^f	2594 ^f	0.24 ^c	0.28 ^{ab}	0.27 ^{b-e}
NPK 0:0:0 + 2.5t	903 ^{ef}	800 ^e	852 ^{fg}	2889 ^{abc}	3972 ^b	3450 ^a	3792 ^d	4772 ^e	4782 ^e	0.24 ^c	0.17 ^e	0.20 ^e
NPK 0:0:0 + 5.0t	1056 ^{de}	952 ^{de}	1004 ^{ef}	2855 ^{abc}	4130 ^{ab}	3492 ^a	3910 ^d	5081 ^{de}	4496 ^{de}	0.27 ^{bc}	0.19 ^{de}	0.23 ^{de}
NPK 0:0:0 + 7.5t	1174 ^{cde}	1110 ^{de}	1142 ^{de}	2770 ^{bc}	4073 ^{ab}	3422 ^a	3943 ^{cd}	5183 ^{cde}	4563 ^{cde}	0.30 ^{abc}	0.22 ^{cde}	0.26 ^{cde}
NPK 30:15:15 + 0.0t	1479 ^{bc}	1285 ^{cd}	1382 ^{cd}	3013 ^{abc}	4640 ^{ab}	3826 ^a	4492 ^{bcd}	5925 ^{bcd}	5209 ^{b-e}	0.33 ^{ab}	0.22 ^{cde}	0.28 ^{a-d}
NPK 30:15:15 + 2.5t	1632 ^{ab}	1903 ^b	1768 ^b	2810 ^{bc}	4038 ^{ab}	3424 ^a	4442 ^{bcd}	5941 ^{bcd}	5191 ^{b-e}	0.37 ^a	0.32 ^a	0.38 ^a
NPK 30:15:15 + 5.0t	1972 ^a	2300 ^a	2136 ^a	3464 ^a	5057 ^a	4261 ^a	5437 ^a	7357 ^a	6397 ^a	0.36 ^a	0.31 ^a	0.34 ^{ab}
NPK 30:15:15 + 7.5t	1646 ^{ab}	1528 ^{bc}	1587 ^{bc}	3214 ^{abc}	4792 ^{ab}	4003 ^a	4860 ^{ab}	6320 ^{abc}	5590 ^{abc}	0.34 ^{ab}	0.24 ^{a-e}	0.29 ^{a-d}
NPK 60:30:30 + 0.0t	1382 ^{bcd}	1285 ^{cd}	1334 ^{cd}	2642 ^c	4434 ^{ab}	3538 ^a	4024 ^{cd}	5719 ^{b-e}	4871 ^{b-e}	0.34 ^a	0.23 ^{b-e}	0.29 ^{a-d}
NPK 60:30:30 + 2.5t	1729 ^{ab}	1660 ^{bc}	1695 ^{bc}	3159 ^{abc}	4269 ^{ab}	3714 ^a	4888 ^{ab}	5929 ^{bcd}	5409 ^{a-d}	0.35 ^a	0.28 ^{abc}	0.32 ^{abc}
NPK 60:30:30 + 5.0t	1604 ^b	1695 ^b	1650 ^b	3045 ^{abc}	4965 ^{ab}	4005 ^a	4649 ^{bc}	6660 ^{ab}	5655 ^{ab}	0.35 ^a	0.25 ^{a-d}	0.30 ^{a-d}
NPK 60:30:30 + 7.5t	1528 ^{bc}	1838 ^b	1683 ^b	3276 ^{ab}	4619 ^{ab}	3948 ^a	4804 ^{ab}	6457 ^{ab}	5631 ^{abc}	0.32 ^{ab}	0.29 ^{abc}	0.30 ^{abc}
SE±	122.7	134.5	91.99	209.1	350.4	367.4	248.1	391.0	385.4	0.023	0.028	0.025

*Means followed by the same letter(s) along the column are statistically not significantly different at 5% level of probability according to Duncan Multiple Range Test (DMRT).