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Performance of pearl millet [*Pennisetum glaucum* (L.) R. Br.]top cross hybrid under varying plant density and fertilizer micro-dosing

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Abstract
The effect of population density and fertilizer micro dosing grain yield and its related characters were studied in nine pearl millet genotypes. The experimental was laid in a split-split plot design with three replications at Bengou and N'dounga in 2017 and 2018 cropping seasons. Significant differences were observed on plant height, days to 50% flowering, number of tillers per plant, thousand grain weight and grain yield due to population density and fertilizer application. The plant density of 15 000 hills ha-1and fertiliser micro dosing rate of 4 g of NPK + 2 g of urea.

Key Word: *population density and fertilizer micro dosing and top cross*

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I. Introduction

Pearl millet (*Pennisetum glaucum* (L.) R. Br.),belongs to the family of poaceae and the genus of *Pennisetum* contains about 140 species (USDA and NRCS, 2006). Pearl millet is a diploid crop (2n =14), protogeneous, and highly cross-pollinated with outcrossing rates of more than 85%. It is of paramount important cereal crops of the semi-arid regions of Africa and India (Oumar*et al.*, 2008). The crop is the most drought and heat tolerant among cereals and it has the highest water use efficiency under drought stress. It can be grown in areas where other cereals like maize and sorghum would not produce. Pearl millet is capable to give reasonable yield under rainfall of 200 to 250 mm (Basavaraj*et al.*, 2010).

Pearl millet is the world's sixth most important cereal grain and is grown extensively in Africa and Asia. According to FAO (2020), over the word, Africa produced 15 867 785 t (51.15%), Asia 14 381 318 t (46.36%), Europe 405 530 t (1.31%), America 328 815 t (1.06%) and Oceania 35 922 t (0.12%). Niger is the second country pearl millet producer after India. The three top pearl millet producer over the world are: India 11 640 000 t, Niger 3 3856 344 t and Nigeria 2 240 744 t. In Niger Republic the area harvested is estimated to 7 033 751 ha in 2018 (FAO, 2020). Pearl millet is considered as a staple source of nutrition for millions of people.

Pearl millet provides 63.2% of total cereal production in Niger and more than 66% of total per capita cereal food consumption (FAO, 2019). Pearl millet grain exceeds most other cereals in protein quality and content of key mineral micronutrients including zinc and iron (Gulia*et al.*, 2007; Govindaraj*et al.*, 2013). In Niger, pearl millet is the first staple food for the majority of people. Alternative uses of pearl millet grain include modern processed foods and feed for livestock including poultry and fish (Gulia*et al.*, 2007). The grains are transformed into various local food for human consumption. Millet is also used in traditional Pharmacopeia for a lot of remedies. The stem is used to enhance soil fertility and it is also used as fodder in dry season for feeding livestock and as materials for fencing and as fuel (Camara*et al.*, 2006).

So far, it was observed that lower population density and inappropriate fertilizer rate are among factors which could influence pearl millet crop production. Farmers used large spacing both intra and inter row spacing which result in very low population density. Similarly, Batiano*et al.* (1992) reported that usually farmers plant pearl millet at low plant populations of approximately 5000 hills. ha^{-1} (2-5 plants $hill^{-1}$) supposing the method reduced the risk of yield loss from water stress and permits plant to exploit large soil volumes for the limited nutrients available.

So also, land degradation was the foundation cause of food insecurity and poverty in Niger (https://www.icrisat.org) and low soil fertility is the one of the most limiting factor for agriculture production.

The soil is predominantly sandy, which are poor in major nutrients, principally phosphorus (P) and nitrogen (N) and it is also reported by earlier researchers from evaluation of soil nutrient status that crop nutrient removal is greater than nutrient import (Batiano*et al.*, 1998; Bachir, 2015). Even though this crop has a potential to adapt to harsh conditions, particularly low soil fertility, its yield is often very low with an average of 400 kg ha^{-1} (Sivakumar and Saalam, 1999). The inheritance of low soil fertility combined with inappropriate soil fertility management are main causes underlying the low millet production in the sahelian zone of Niger (Stoovogel and Smaling, 1990; Graef and Haigis, 2001 and Schelecht*et al.*, 2006).
The objective of this study is to found out how population density and fertilizer application could improve pearl millet production in Niger Republic.

II. Materials And Methods

2.1 EXPERIMENTAL SITES

The experiment was conducted at Bengou and N'dounga both in the National Institute for Agronomic Research of Niger (INRAN) station in 2017 and 2018 rainy seasons. Bengou is situated in Sahelo-Sudanian zone of Niger (11^o 58' 44'' North and 03^o33'25''East) where the annual rainfall is usually exceeding 700mm, which normally starts from June to the end of September. N'dounga is located in the Sahelian zone of Niger (13^o 22' 23''North and 2^o 14' 50''East) with rainfall ranges from 400 to 600mm start from June to the end of September.

2.2 TREATMENTS AND EXPERIMENTAL DESIGN

Three factors and their respective levels were studied in the experiment: Pearl millet genotypes, fertilizer rate and population density. Plant population density of 10 000 hills ha^{-1}, 15 000 hills ha^{-1} and 27 000 hills ha^{-1}.F_1 = 0 g NPK + 0 g urea; F_2 = 4 g NPK+ 2 g urea and F_3 = 6 g NPK + 4g urea. Nine (9) pearl millet genotypes were investigated in this study: (A-9 x HK, A-9 x Moro, A-99 x HK, A99 x Moro, A-9, A-99, HK, Moro and improved check "HKP"). The experiment was made of 81 treatments which were the combination of three population densities, three fertilizer rates and nine pearl millet genotypes arranged in a Split –Split Plot design with three replications.
-The main plots were allocated for the population density;
-The sub plots were occupied by the fertilizer rate;
-The sub-sub plots received pearl millet genotypes.

2.3 DATA COLLECTION AND ANALYSIS

2.3.1 Agronomic Data

Data were collected on six characters: Plant height, Days to 50% flowering, Number of tillers $plant^{-1}$, Grain yield and thousand grains weight.

2.3.2 Data Analysis

Data were subjected to the analysis of variance (ANOVA) to sort out significant difference among treatments. The effect of the studied factors on all the agronomic characters were evaluated. Data were analysis with the computer package JMP Pro 14^{th} Edition and mean comparison was performed using SNK t-test. In order to describe commutatively the variation and correlation among characters of genotypes.

III. Results

3.1 Plant Height

Data on plant height of pearl millet as influenced by plant density in 2017 and 2018 at Bengou and N'dounga are presented in figure 1. The analysis of variance indicated that plant densities of pearl millet differed significantly ($p<0.01$) in plant height in 2018 at both locations and at N'dounga in 2017. Taller plants were observed with plant density of 15,000 hills ha^{-1} in 2018 at Bengou while the shortest plants were found with plant density of 27,000 hills ha^{-1}. Similarly, at N'dounga in 2017, the tallest plants were produced at lower plant density of 10,000 hills ha^{-1} while plant growing with higher plant density of 27,000 hills ha^{-1} recorded the shortest. In 2018, the plant density of 27,000 hills ha^{-1} produced the tallest plants followed by 15,000 hills ha^{-1} and the lowest was found with 10,000 hills ha^{-1}.

Ideal plant is among the most important aspects of agronomic practices that influence the general field performance of pearl millet production in Sahelian region. Variable responses to different plant densities was observed across the plant characters, years and locations. The higher plant growth performance was noted with 10,000 plant density. This might be as result of sufficient spacing under different soil conditions which enable the plant to explore available soil nutrients, moisture stored within the soil capillary, soil air, Co_2, solar radiation capture and other weather elements to express its phenotypic potential. This finding supports the results of Pandey*et al.*(2000); Tajul *et al.*(2013); Faramarzi *et al.* (2015) ; Kumari *et al.* (2017)who reported that sparsely populated plant with sufficient nutrient in the soil produced tallest plants, while densely populated plants with lower fertilizer rate were shorter.

Furthermore, plant height was highly significantly ($p<0.0001$) affected by fertilizer micro-dosing treatment across the study locations and seasons combined (figure 2). With exception of control treatment, all the varied levels of fertilizer micro-dosing produced taller plants with statistically similar values across all the levels of observations. The significant effect of mineral fertilizer micro-dosing on plant height of pearl millet at both sites could be due to the positive influence of nitrogen for stimulation of meristematic cell division and its rapid elongation at the apex. Furthermore, synthesis of amino acids could increase growth characters like plant height. Although there were no statistical differences among the treatments, both treatments are similar indicating that, the application of 4 g hill^{-1} NPK + 2 g hill^{-1} Urea were sufficient to achieve optimum plant height. The result is in concordance with the findings of Ayub*et al*. (2009); Ali (2010) and Bhuva and Detroja (2018)who observed that application of 60 kg N ha^{-1} recorded significant higher plant height and number of tillers than the control in pearl millet.

Nitrogen (N) plays important role in plant metabolism system and all vital processes related with protein, of which nitrogen is an indispensable constituent. as reported by Laghari *et al*. (2016) and Bhuva and Detroja (2018). Nitrogen promotes leaf and stem growth rapidly which consequently increase the yield and its quality to get better crop production. Significant increase in plant height with application of fertilizer micro-dosing at varying rates might be attributed to the positive effect of fertilizer to significantly influence, physiological, biochemical and metabolic process of the plant.

In addition, the genotypic influence on plant height produced significantly higher ($p<0.0001$) values with variable responses across all locations (figure 3). Better performances were achieved with HK, Moro and HKP. Also, others that exhibited higher plant height include A-9 x HK and A-9 x Moro when combined in 2017 and were mostly observed at N'dounga compared with the rest. The result showed that A-99 produced the shorter plants at all locations except in 2017 where these were statistically at par with A-9.

The tallest plants observed from HK, were developed with a few lines from the base population of the local improved variety HKP. Taller plants are desired in restorer lines to facilitate naturel pollination in hybrid production. This also indicates higher genetic variability within the open pollinated variety HKP which was widely cultivated by farmers and well adapted across the study area. This might be attributed to the genetic potential of HK genotype in developing taller plants, among others. Generally, taller plants were recorded in 2018 than in 2017 at Bengou and might be due to the sufficient rainfall pattern recorded during the 2018 cropping season and other favourable climatic conditions. Sufficient rainfall distribution led to adequate soil moisture content that increased the solubility of soil nutrients and in turn facilitated nutrient availability, thereby resulting in rapid crop growth. The results supported the findings of Pasternak *et al*. (2012).

Significant interaction between plant density x fertilizer micro-dosing on plant height was obtained in 2017 at Bengou. When no fertilizer was applied all plant densities produced statistically similar plant height. The treated plots with 6 g of NKP + 4 g of urea produced significantly taller plant at higher plant densities.

Tallest plants observed from higher plant density and lower dose of 4 g hill^{-1} NPK + 2 g hill^{-1} urea could be attributed to the fact that at higher plant density, plant tend to produce lower number of tillers and set the gradient for essentials nutrients (nitrogen, potassium and phosphorus) efficient absorption used for apical growth. At Bengou experimental site, lack of significance observed throughout the treatment at 27,000 hill^{-1} proved that at higher plant density, irrespective of the treatments plant responded to rapid apical elongation rather than increasing the number of productive tillers. It could probable that the response to rapid apical elongation at higher plant density in this study area was attributed to increasing competition for space, limited moisture and canopy effects that retarded tillering of individual stem. Thus, the response was redirected towards interception of adequate solar radiation to increase the rate of photosynthesis production for the plant survival. These are in line with the finding of Kipkurui, (2019) who reported ineffective interaction between plant density and fertilizer application on growth and yield variables for finger millet.

Lack of significance interaction of plant density x fertilizer application at N'dounga on plant height might be due to irregularity of rainfall coupled with high temperature during the growth period which probably hid the interaction effects.

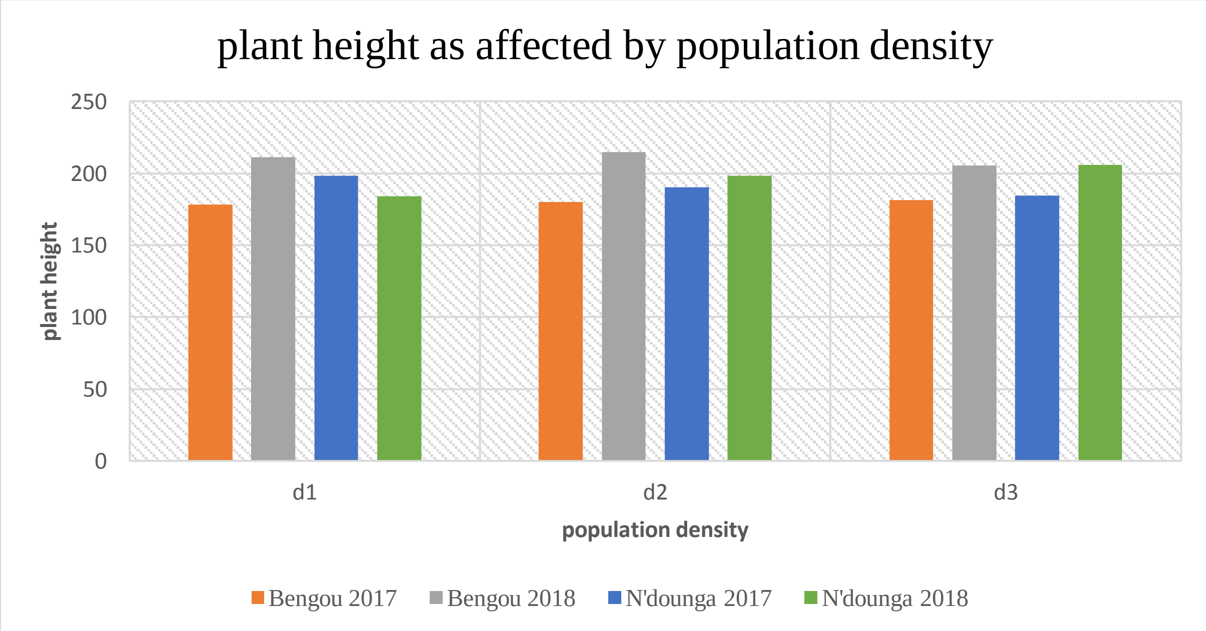

Figure 1: plant height as affected by population density

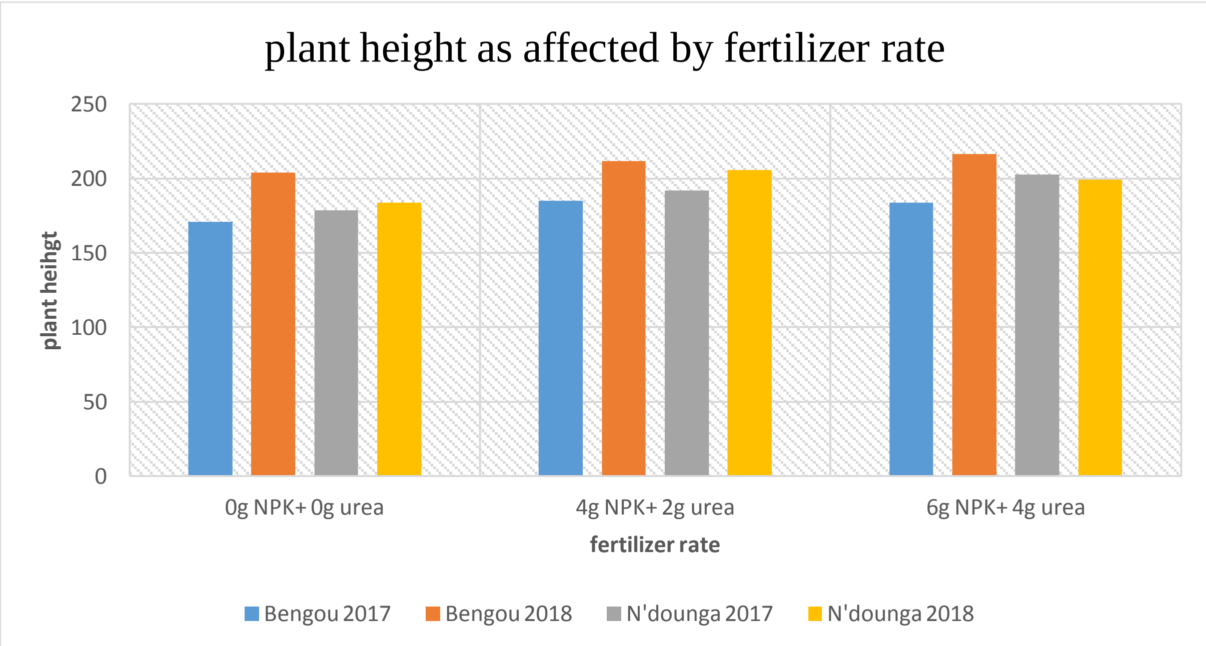

Figure 2: plant height as affected by fertilizer rate

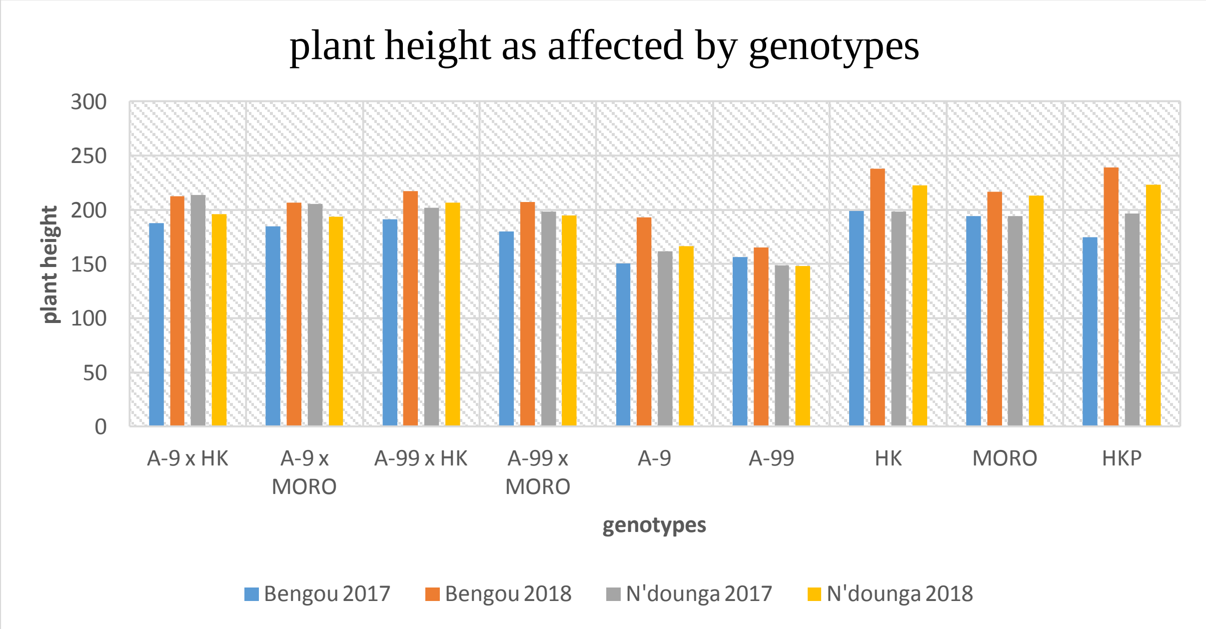

Figure 3: plant height as affected by genotypes

3.2 Days to 50% Flowering

The results of data analysis for number of days to 50% flowering of pearl millet genotypes as affected by plant density in 2017 and 2018 at Bengou and N'dounga are presented in figure 4

At Bengou experimental site, plant density had significantly ($p < 0.05$) influenced the number of days to 50% flowering. In 2017 cropping seasons, 27,000 plants ha^{-1} treatment recorded higher number of days to 50% flowering (61.9 days). The plant density of 15,000 and 10,000 hills ha^{-1} produced the earliest plants. In 2018, genotypes under 10,000 and 27,000 hills ha^{-1} took longer time to achieve 50% flowering (61.5 days). In combined seasons at Bengou, the results revealed that higher number of days (61.7 days) to 50% flowering was found with plant density of 27,000 hills ha^{-1}. In 2017 cropping season at N'dounga, plant density showed no significant influence on days to 50% flowering. Pearl millet takes more time to accomplish days to 50% flowering with plant density of 10,000 hills ha^{-1} in 2018 while the earliest plants were obtained with 27,000 hills ha^{-1}.

Invariably, the variability in number of days to 50% flowering observed from different plant density might probably be associated with environmental effect such as rainfall distribution, soil fertility and temperature. This corresponds with similar findings of Hamidi and Dabbagh (1995) and Ajeigbe *et al.* (2019) who noted pearl millet responses to plant population in the semi-arid environments of Nigeria.

In 2017 at both locations, fertilizer micro-dosing showed no significant effect on number of days to 50% flowering. Days to 50% flowering was highly significantly ($p<0.0001$) influenced by fertilizer micro-dosing at both locations in 2018 (figure 5). Longer time to 50% flowering was observed from the control while the plants treated with 6 g of NPK + 4 g of urea or 4 g of NPK + 2 g of urea recorded the lowest values which were significantly at par. Pearl millet genotypes differed significantly ($p<0.0001$) for days to 50% flowering in both sites.

The results of this study further revealed that decrease rate of micro-dosing application significantly influenced days to 50% flowering of pearl millet at both locations by hastening the vegetative growth rate to produce inflorescence earlier than unfertilized plots. This might be attributed to the positive effect of the primary mean nutrients in stimulating normal plant physiological, biological synthesis and metabolic process. Early flowering of pearl millet is an important trait in plant adaptation to drought prone agrology. This is in line with the finding of Wafula *et al.* (2016). In contrary, Kumar *et al.* (2012) and Tiwana*et al.* (2012) reported positive correlation between days to 50% flowering and rate of fertilizer applied. Nitrogen and phosphorus provide energy to plants for photosynthesis, meristem and elongation initiation, nutrients translocation and respiration (Wilson *et al.*, 2005) and are essential for the growth and formation of seed and ultimately enhance early flowering. This is also in line with the findings of Ausiku*et al.* (2020) who observed that time to flowering prolonged with limited nitrogen, compared to well fertilized plots.

At Bengou location in 2017, HK, Moro and A-99 were the latest flowering with 64.0, 63.9 and 63.8 days, respectively (figure 5). The earliest genotype to 50% flowering was A-99 x Moro (58.1 days). In 2018, three genotypes showed longer time to accomplish days to 50% flowering, which were A-9, A-99 and HK while the earlier genotype in 2018 was A-9 x HK (58.8 days). At N'dounga in 2017, longer time to 50% flowering in pearl millet was observed with HK (64.0 days) and HKP (63.6 days) while the earliest genotypes were A-9 x Moro (58.7 days) and Moro (58.7 days). In 2018, A-9 (61.3 days) was the latest genotype to reach 50% flowering whereas A-9 x HK, A-9 x Moro and A-99 x Moro were the earliest. Four genotypes A-9 (61.0 days), A-99 (61.0 days), HK (61.9 days) and HKP (60.4 days) showed longer time to attain 50% flowering and the lowest was recorded with A-9 x Moro.

The expression of earliness across locations showed by the hybrid A-9 x HK and A-9 x Moro might be due to the genetic inheritance from the male parent (HK and Moro) of the gene controlling the character. A similar result was reported by earlier investigators Navales*et al.* (1991) that 50% flowering was highly heritable character.

The interaction between plant density x fertilizer micro-dosing on number of days 50% flowering indicated significant effects in 2018 at Bengou and in 2017 at N'dounga. At Bengou 2018, when no fertilizer micro-dosing was applied the latest plants to achieve 50% flowering were observed irrespective of plant density. At N'dounga 2017, significantly higher number of days to accomplished 50% flowering was observed with plant densities of 10,000 and 15,000 hills ha^{-1}, compared to 27,000 hills ha^{-1}. At N'dounga 2017 cropping seasons, pearl millet genotypes flowered earlier with 4 g of NPK + 2 g of urea treatment at 27,000 hills ha^{-1} (plant density) while the latest plants were observed between fertilizer control and 10,000 hills ha^{-1}.

The shortest number of days to 50% flowering observed between plant density of 15,000 hill ha^{-1} and 6 g hill^{-1} + 4 g hill^{-1} urea interaction explained that the gene controlling this character was highly influenced by the environmental condition and agronomic practices. This might be due to the positive effect of micro dose nutrients balance rate and its ability to stimulate rapid growth of pearl millet and probably induced early flowering in the environment

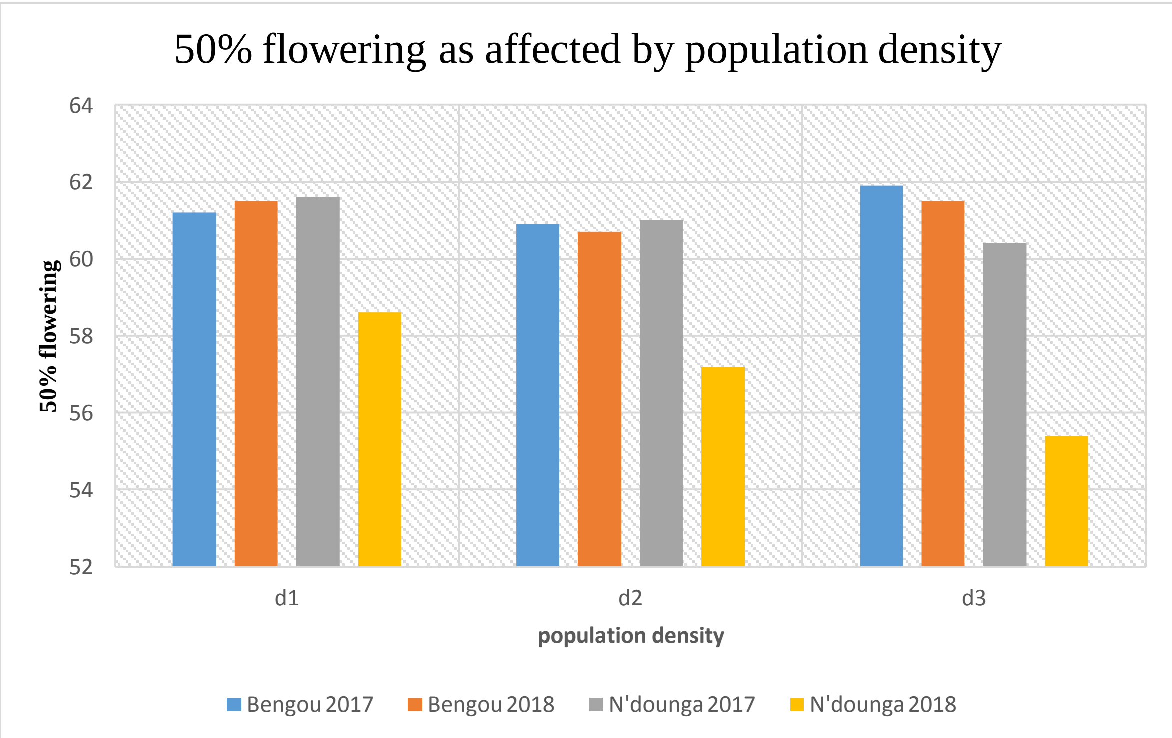

Figure 4: 50% flowering as affected by population density

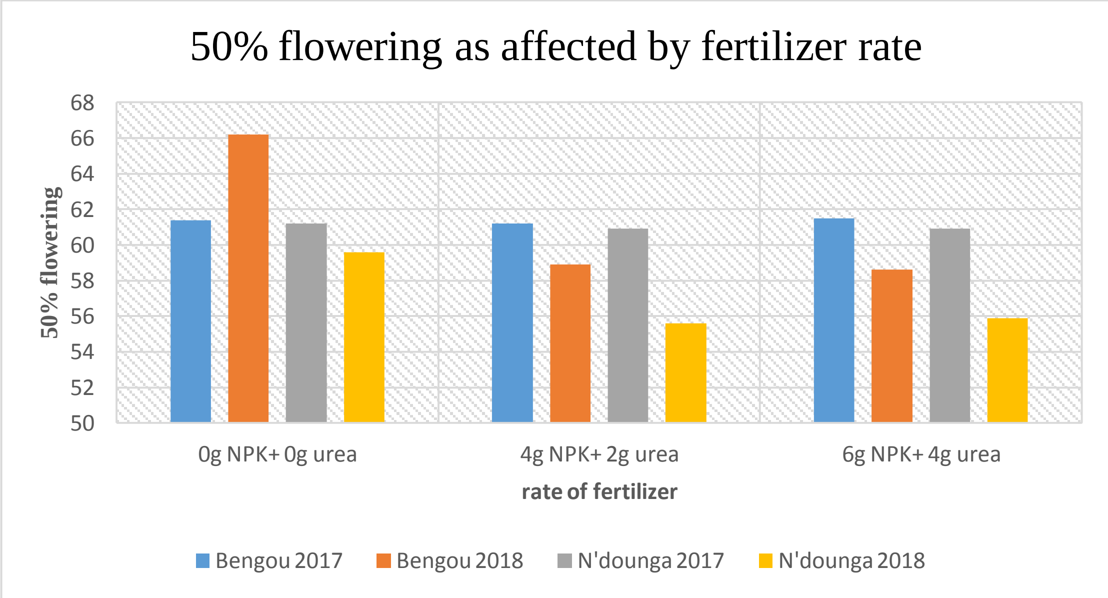

Figure 5: 50% flowering as affected by fertilizer rate

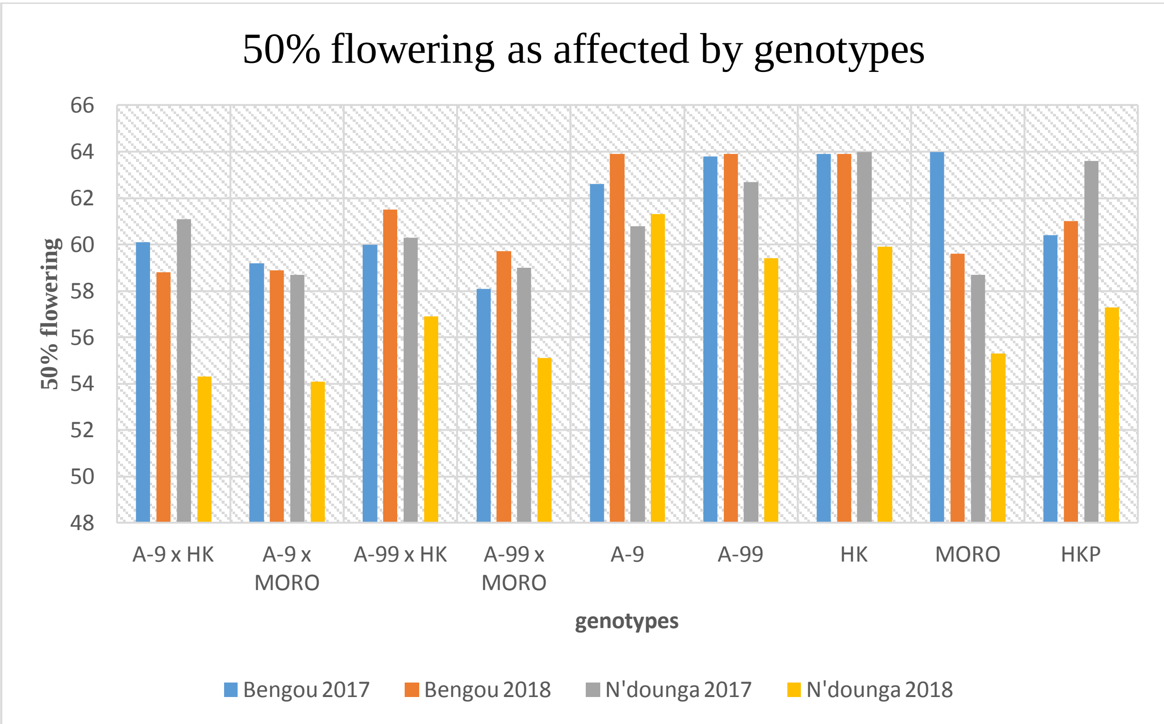

Figure 6: 50% flowering as affected by genotypes

3.3 Number of tillers / plant

Number of tillers per plant as affected by plant density at Bengou and N'dounga in 2017 and 2018 are presented in figure 7. The results of the 2017 cropping seasons indicated that plant density showed no significant differences on number of tillers per plant. However, number of tillers per plant of pearl millet was highly significantly ($p<0.0001$) affected by plant density in 2018 at Bengou. Furthermore, increase in plant density significantly decrease number of tillers per plant in 2018 at both locations. The results showed clearly greater number of tillers per plant at N'dounga than at Bengou. The lowest value was recorded with the higher plant density.

Furthermore, the higher number of tillers produced with lower plant density of (10,000 hill ha^{-1}) might have indicated that at lower plant density stems of pearl millet have the opportunity to develop a greater number of tillers probably owing to less competition among growing plants in terms of surface area for root elongation, moisture, mutual canopy effect, nutrients and sunlight. The result is in line with findings of Azam*et al.*(1984);

Agha and Eshaq (2008), Kalaraju*et al*. (2009) and Ajeigbe *et al*. (2019). But this is not in agreement with the findings of Kumari *et al*. (2017) who reported that narrow row spacing intercept more radiation than wider row spacing owing to proper utilization of nutrients as well as moisture under optimum plant on pearl millet. Conversely, the lower number of tillers per plant observed at Bengou could be due to the heavy rainfall received which probably affect Fertilizer micro-dosing particularly N for its higher soil mobility through leaching process associated with less solar radiation at vegetative stage which reduce the number of tillers per plant.

Number of tillers per plant was not significantly affected by fertilizer application in 2017 at both locations (figure 8). In 2018 cropping seasons, plants treated with fertilizer micro-dosing produced statistically ($p<0.0001$) higher number of tillers per plant except at N'dounga 2018 where 6 g hill^{-1} of NPK + 4 g hill^{-1} of urea showed highest number of tillers per plant than plants which received 4 g hill^{-1} of NPK + 2 g hill^{-1} of urea.

The high number of tillers/plant observed with application of 4 g hill^{-1} of NPK+2 g hill^{-1} of urea fertilizer micro-dosing on pearl millet at both sites was probably due to the significant effects of nitrogen as it is the major component of nucleic acid, purines, pyrimidines, porphyrins which are constituent for many proteins (Fatondji *et al.*, 2006). Moreover, it also encourages the micro-dosing uptake of other nutrient such as phosphorous and potassium. Similarly, proper fertilizer application could promote higher rooting system capable of accessing sufficient soil nutrient and water. This facilitates tillers opportunity to grow well up to maturity and become productive. The result was in conformity with those obtained by Maniaji and Benson (2018) who reported higher number of tillers/plant with the application of balance phosphorus fertilizer in finger millet. He further attributed the results to the strong rooting network that phosphorus has on cereals.

Pearl millet genotypes differed significantly ($p<0.01$) on number of tillers per plant at both locations (figure 9). At Bengou in 2017, high number of tillers (4.2 and 4.1) were produced by A-99 x HK and Moro while the lowest values were recorded on A-9 x HK, A-9 x Moro and HKP. In 2018 cropping seasons, four genotypes exhibited higher number of tillers per plant, and these include A-9 x Moro, A-99 x HK, A-9 and A-99 which were statistically similar. The lowest values were observed with A-99 x Moro, HK and Moro. In general, higher number of tillers were noted in 2018 than in 2017 at Bengou. In combined seasons, A-99 x HK produced the highest value, while the lowest was recorded by HKP. At N'dounga in 2018 and combined seasons, A-9 x HK and A-9 x Moro showed the highest values for number of tillers per plant while the lowest were observed by HK and HKP. In general, the results of this study showed that higher number of tillers per plant were recorded at lower plant density.

The highest number of tillers recorded with the genotype A-9 x HK at N'dounga could be attributed to the excellent seedling vigour and high tillering ability of the female parent. During the selection process, the first three characters which directed the choice of the sterile line were high tillering, length and compactness of the panicle. This confirmed the inheritance of the trait from the female parent to the offspring. The result is in agreement with the findings of Nassir and Ariyo (2011) andAcharya *et al.* (2017) who reported that hybrid perform better and produce higher number of tillers per plant compared to their parents.

The interaction between plant density and fertilizer application showed high significant differences (<0.0001) on number of tillers per plant in 2018 at Bengou and N'dounga. At Bengou 2018, the results obtained showed that plant density of 27,000 hills ha^{-1} produced least number of tiller per plant at Bengou and progressive increase was observed from higher density to lower irrespective of fertilizer micro-dosing. At 10,000 and 15,000 hills ha^{-1}, the control produced least number of tillers compared to the rest. At N'dounga, plant density of 10,000 hills ha^{-1}produced statistically higher number of tillers irrespective of micro-dosing treatment. At 15,000 and 27,000 hills ha^{-1}, the number of tillers increase slightly from the control to higher micro-dosing.

The highest number of productive tillers observed between lower plant density of 10,000 hill ha^{-1} and 4 g hill^{-1} + 2 g hill^{-1} urea at Bengou and with 6 g hill^{-1} + 4 g hill^{-1} urea at N'dounga might be due to the variable effects of soil nutrients within varied environments grown with less plant competition. In fact, lower plant density of 10,000 hill^{-1}might haveprovided sufficient root density which facilitated pearl millet ability to absorb satisfactorily the nutrients available leading to increased number of productive tillers. This result is in line with the findings of Ayub *et al*. (2007) who reported higher growth character in lower plant density and fertilizer application interaction.

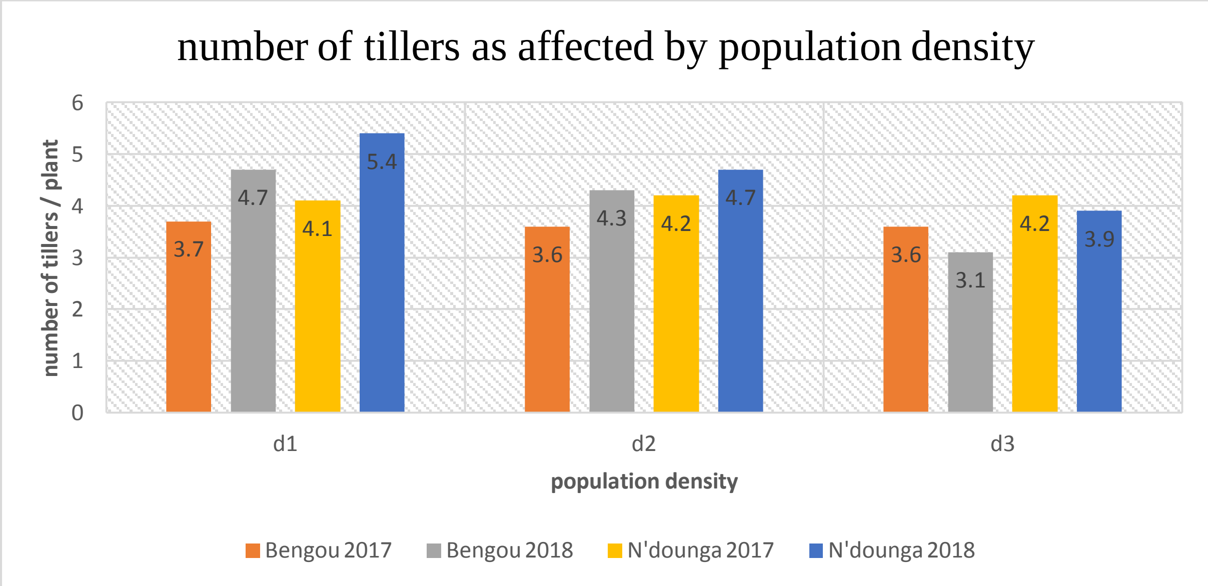

Figure 7: number of tillers as affected by population density

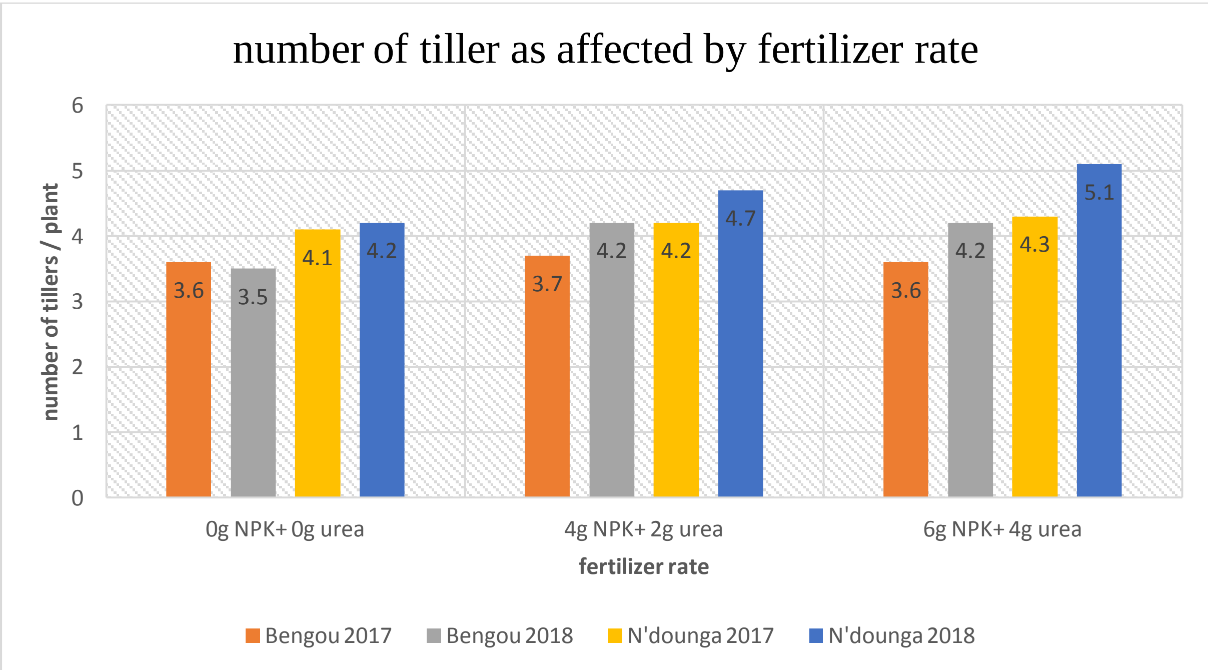

Figure 8: number of tiller as affected by fertilizer rate

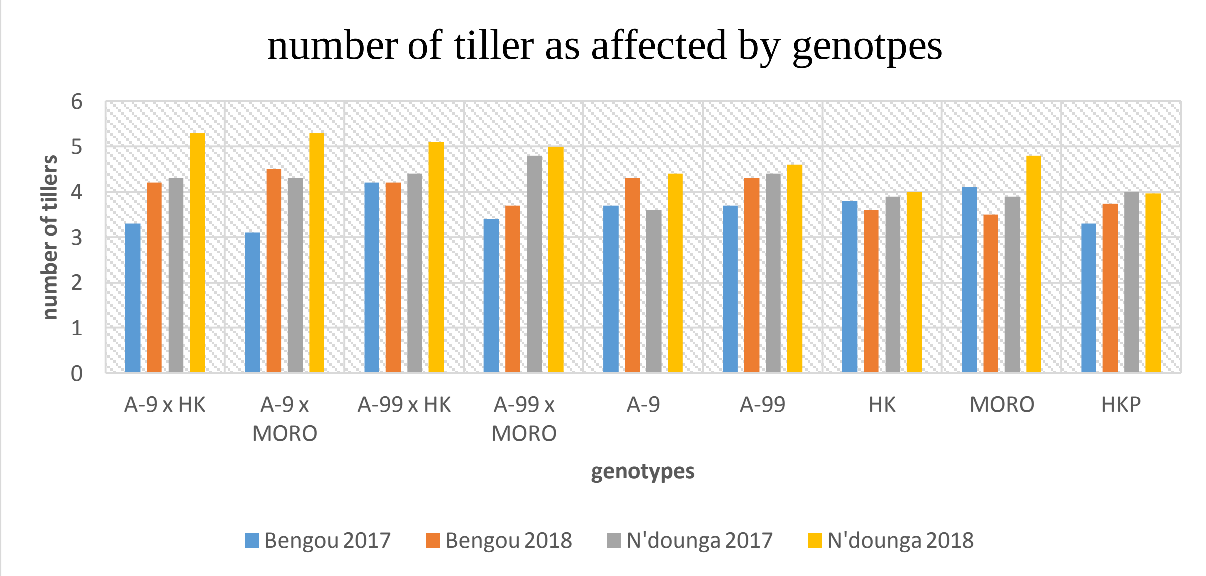

Figure 9: number of tiller as affected by genotypes

3.4 Thousand Grain Weight

The effects of plant density on 1000 grain weight of pearl millet genotypes at Bengou and N'dounga in 2017 and 2018 cropping season are presented in figure 10. The results indicated that the plant density did not produce any statistically significant effects on 1000 grain weight at Bengou in 2017. However highly significant ($p<0.01$) effect was observed in 2018 and combined seasons at Bengou. At this experimental site, 10,000 hills ha^{-1} and 15,000 hills ha^{-1} recorded the highest thousand grain weight which were at par. Also, the results indicated that plant density showed no significant effects on 1000 grain weight at N'dounga in both cropping seasons.

The fertilizer treatment was significantly affected 1000 grain weight at both locations and year ($p<0.05$) as presented in figure 11.

The application of 4 g hill^{-1} of NKP +2 g hill^{-1} of urea and 6 g of NKP + 4 g of urea produced the heaviest 1000 grain weight across the year at Bengou although both treatments were statistically similar. At N'dounga fertilizer treatments showed similar effect in 2018.

Thousand grain weight was significantly ($p<0.0001$) affected by pearl millet genotypes at both locations (figure 12). Furthermore, A-9 x HK and A-9 x Moro produced heavier 1000 grain weight in 2017 at Bengou.

In 2018, five genotypes exhibited higher 1000 grain values and these include A-9 x HK, A-9 x Moro, A-99 x HK, A-9 and A- 99 which were statistically similar. At N'dounga 2018 the genotypes with the highest 1000 grain weight were A-9 x HK, A-9 x Moro and A-9, whereas in 2017 A-9 x HK stood out with the highest 1000 grain weight.

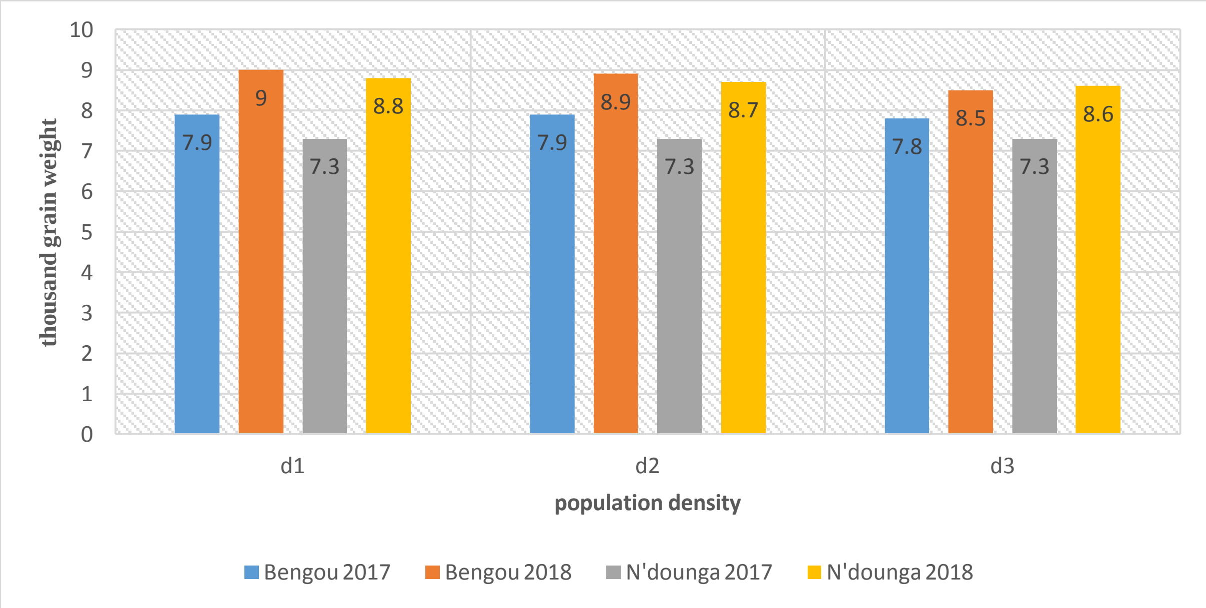

Figure 10: thousand grain weight as affected by population density

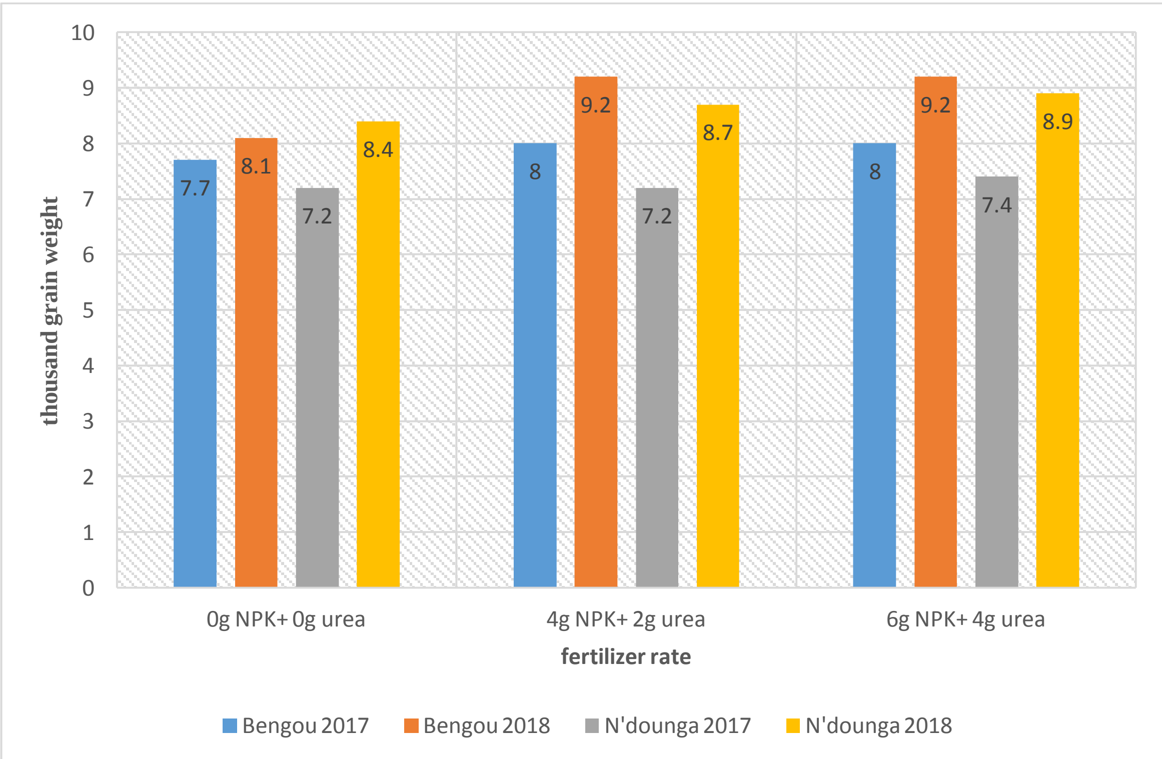

Figure 11: thousand grain weight as affected by fertilizer rate

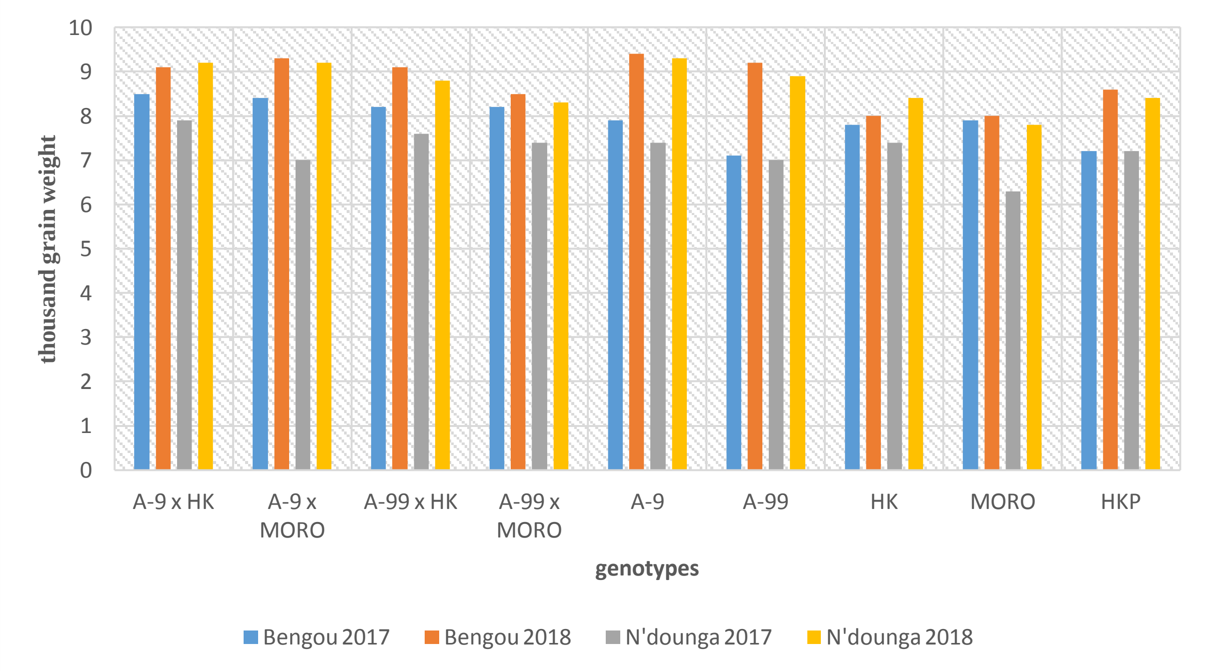

Figure 12: thousand grain weight as affected by genotypes

3.5 Grain Yield (kg/ha)

The effects of plant density on grain yield of pearl millet genotypes at Bengou and N'dounga in 2017 and 2018 cropping seasons are presented in figure 13. At Bengou experimental site, the results showed that plant density showed highly significant ($p<0.01$) effect on grain yield of pearl millet in both cropping seasons. In 2017 at Bengou the highest grain yield was achieved from plant density of 15,000 hills ha^{-1} while the lowest was obtained with 27,000 hills ha^{-1}. In 2018, the plants grown under 15,000 hills ha^{-1} treatmentproduced the highest grain yield followed by 10,000 hills ha^{-1} while the lowest was recorded at 27,000 hills ha^{-1} plant density. In 2017 at N'dounga as well, plant density of 27,000 hills ha^{-1} produced the highest grain yield, while sparsely plants treatment (10,000 hills ha^{-1} and 15,000 hills ha^{-1}) were statistically similar and produced the lowest grain yield. In 2018 seasons the highest grain yield was observed with 15,000 hills ha^{-1} while the others were statistically similar.

Generally, higher grain yield of pearl millet was observed from plant density of 15,000 hill ha^{-1} across the locations except in 2017 at N'dounga. The increase of 24% of grain yield observed at Bengou over the recommended plant density of 10,000 hill ha^{-1} could be due to the inherent genetic ability of the most outstanding genotypes' to efficiently optimize resources utilization to produce higher grain yield. Conversely, the lack of significant increase of grain yield beyond 15,000 hill ha^{-1} might be due to the fact that plant produced lower yield when plant density exceeded the maximum capacity of available resources: solar radiation, spaces, nutrients, moisture etc. leading to poor panicle production. This is in agreement with the findings of Pasternak *et al*. (2012);Faramarzi *et al*. (2015), and Ajeigbe *et al.* (2019) who reported higher grain yield with higher plant density compared to lower plant densities. The lower grain yield noted with 27,000 hill ha^{-1} at Bengou might be due to higher competition effects probably resulted from higher density of above ground biomass for insufficient resources at the grain formation stage of the plant development thus caused lower yield. In contrast to Bengou, lower grain yield at 10,000 hill ha^{-1} was produced at N'dounga experimental site, and this could probably be due to variation in response mechanisms to environmental effect such as intense temperature that might have influenced nutrients uptake.

Grain yield was significantly ($p<0.01$) affected by fertilizer application at both sites (figure 14). The plants treated with 6 g $hill^{-1}$ of NPK + 4 g $hill^{-1}$ of urea and 4 g $hill^{-1}$ of NPK + 2 g $hill^{-1}$ of urea micro-dosing recorded the highest grain yield in 2017 and 2018 at Bengou while the control produced the lowest. Interestingly, fertilizer application produced similar tendency as at Bengou experimental site from which highest grain yield was recorded. It was observed that 6 g $hill^{-1}$ of NPK + 4 g $hill^{-1}$ of urea and 4 g $hill^{-1}$ of NPK + 2 g $hill^{-1}$ of urea treatments showed similar effects.

Significant differences observed on panicle weight and grain yield might be due to the positive effect of fertilizer micro-dosing applied. Balance application of nitrogen, phosphorus and potassium induced increase in yield attributive characters and are the key nutrients in pearl millet production by acting on growth character and filling grain. The fertilizer micro-dosing of 6 g $hill^{-1}$ NPK + 4 g $hill^{-1}$ urea and 4 g $hill^{-1}$ NPK + 2 g $hill^{-1}$ urea were statistically similar, indicating that the later dose was economical and sufficient to increase pearl millet hybrid production in the study areas. This is line with the findings of earlier workers on fertilizer micro dosing in West Africa (Bationo and Buerkert 2001, Hayashi *et al*., 2008, Tabo*et al*., 2011, Abdou *et al.*, 2012, Ibrahim *et al*., 2014, Ibrahim *et al*., 2016 and Blessing *et al*., 2017), who reported that, fertilizer micro-dosing application could meet pearl millet primary nutrients demand for better growth that subsequently promote better grain production. In this study 4 g hill^{-1} + 2 g hill^{-1} urea micro-dosing was the most ideal combined rate in both cropping seasons. This might be due to the fact that NPK micro-dose fertilizer is essential for normal growth, maturity, photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement, cell elongation, physiological, biochemical and metabolic process. Similar response of the two treatments might be due to the fact that they are not different from one another to produce significant variation. Therefore, the fertilizer micro-dosing of 4 g hill^{-1} + 2 g hill^{-1} is sufficient for optimum pearl millet production.

The genotypes of pearl millet differed significantly ($p<0.01$) on grain yield at both locations (figure 15). In 2017 at Bengou, A-99 x HK (2463 kg ha^{-1}) genotype produced the highest grain yield followed by A-9 x HK (2307 kg ha^{-1}) whereas the least productive genotypes were A-9 (1355 kg ha^{-1}), A-99 (1178 kg ha^{-1}) and HKP (1123 kg ha^{-1}). In 2018 cropping seasons, the most productive genotype was A-99 x HK (1733 kg ha^{-1}) followed by A-9 x Moro (1578 kg ha^{-1}) while A-9 recorded the lowest grain yield. In 2017 at N'dounga location, the result indicated that the best performing genotype was A-99 x HK (2427 kg ha^{-1}) followed by A-9 x Moro (2116 kg ha^{-1}) whereas A-9 (1152 kg ha^{-1}) was the least. Also, in 2018 A-99 x HK (2448 kg ha^{-1}) recorded the highest grain yield followed by A-9 x Moro (2202 kg ha^{-1}) and the lowest was A-99 (1427 kg ha^{-1}).

A differential effect of pearl millet genotypes on grain yield and yield components indicated was inherent genetic variation among the studied genotypes. The hybrid A-9 x HK performed better than the other genotypes for grain yield which was likely due to its distinguished genetic behaviour. The result was in agreement with the finding of Vetriventhan*et al.* (2008) and Gami (2019) who reported higher growth performance of the hybrids over open pollinated varieties.

The interaction between plant density and fertilizer micro-dosing was significant in 2017 and 2018 at Bengou experimental site. In 2017 cropping seasons, irrespective of plant density the control produced the lowest grain yield while plots receiving fertilizer micro dosing were statistically similar. In 2018 also, the control produced lower grain yield irrespective of plant density and the treated plots produced the highest.

The significant interaction observed for grain yield at Bengou in 2017 and 2018, may be due to the effect of the important amount of rainfall on pearl millet production. The finding is in conformity with the work of Bationo and Mokwunye (1991) who reported significant interaction between plant density and fertilizer application when adequate rainfall was received in a study conducted over three years in southern Niger Republic.

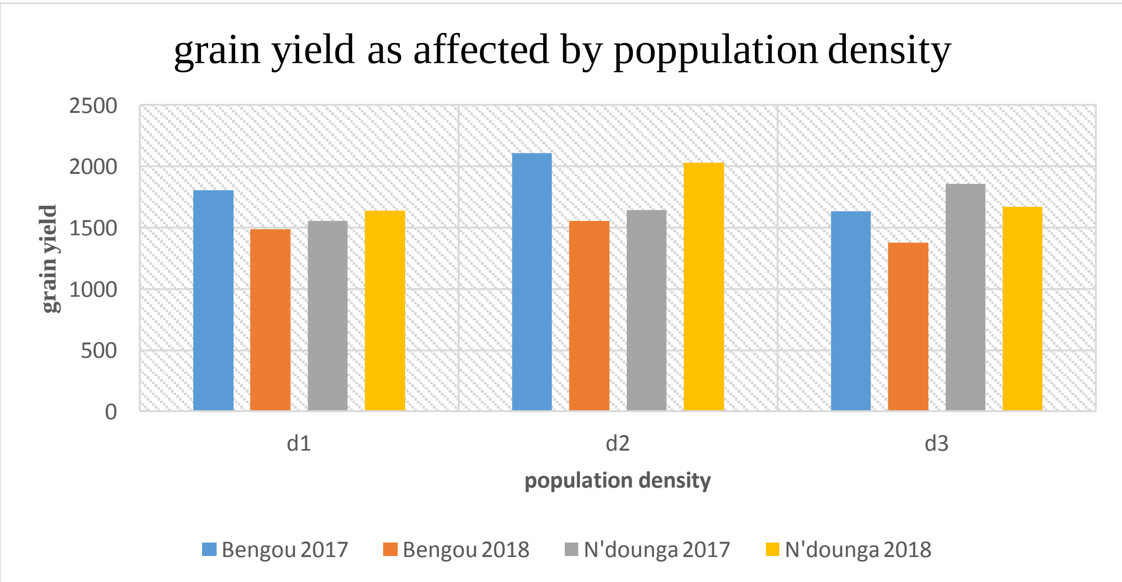

Figure 13: grain yield as affected by population density

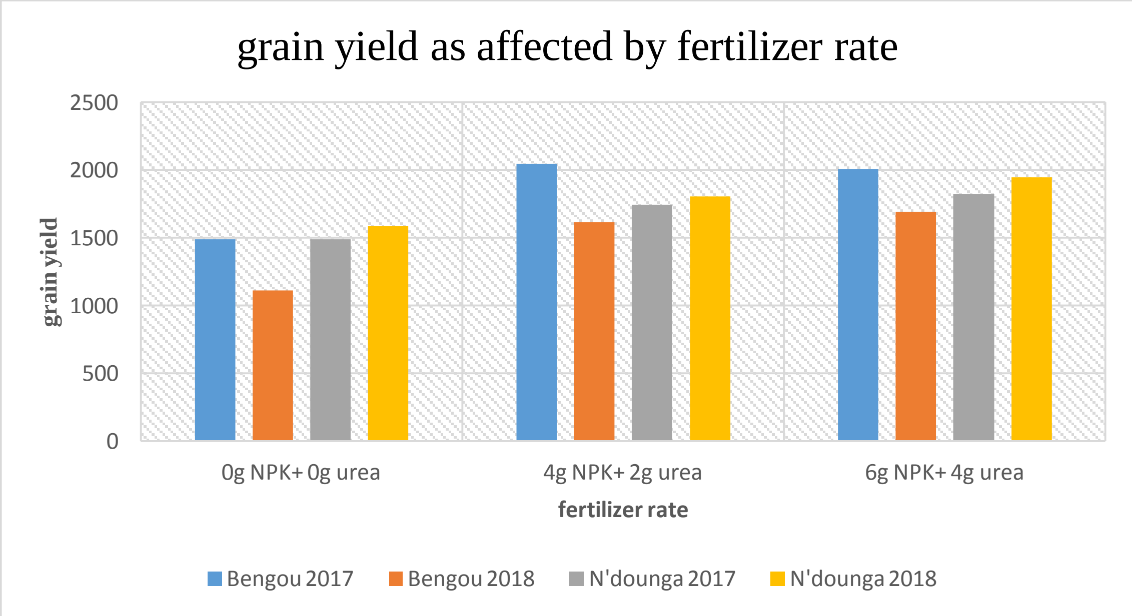

Figure 14: grain yield as affected by fertilizer rate

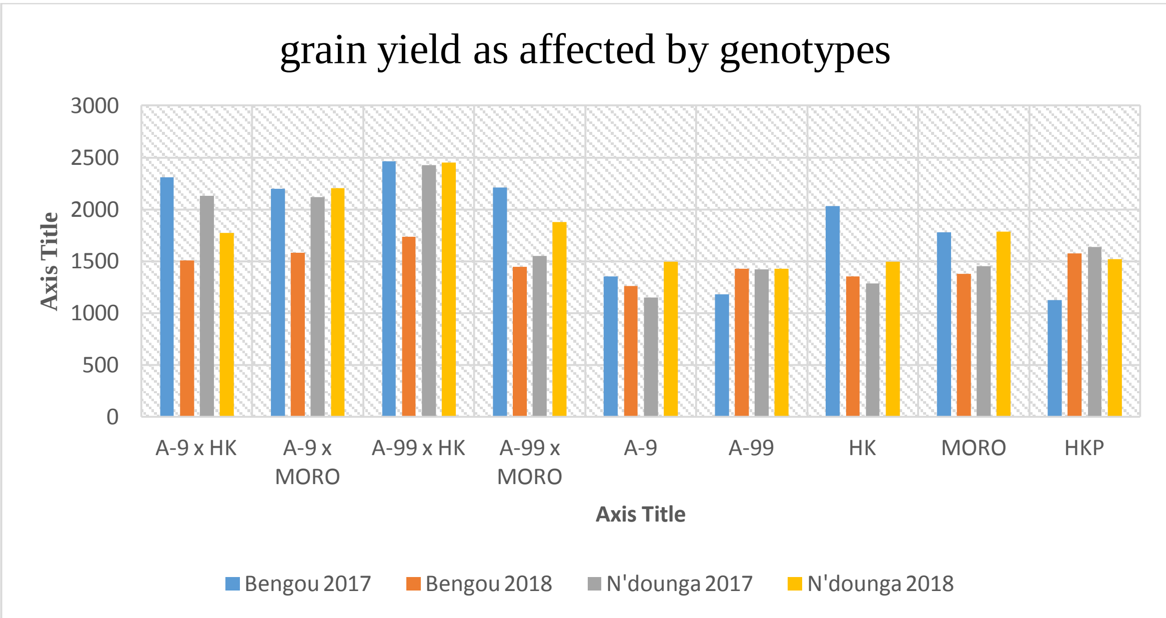

Figure 15: grain yield as affected by genotypes

IV. Conclusion

In conclusion, the results of this study showed that growth characters and yield components of pearl millet genotypes were significantly influenced by plant density and fertilizer micro-dosing in the study area. The plant density of 15,000 hill ha^{-1} resulted in higher plant height, grain yield and thousand grain yield across locations. At N'dounga, leaf area, panicle diameter, panicle length and thousand grain weight were not influenced by plant density probably due to the irregularity of rainfall and effect of high temperature. The inconsistency of the treatment observed on number of days to 50% flowering indicated that the character was likely influenced by the environment. Growth and yield characters responded significantly with the application of 4 g $hill^{-1}$ ofNPK+ 2 g $hill^{-1}$ of urea fertilizer micro-dosing.

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