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Influence of Nitrogen Levels and Planting Architecture on Grain Amaranth in Kenya

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ABSTRACT

Due to the stated unique seed composition, grain amaranth has certainly a potential to become a more considerable non-wheat material in composite flours used for fortified food production. In Kenya, the crop is grown in small plots and has not been fully utilized. Because of the many advantages it has there is need to improve on its production and adoption among the farmers. To achieve these there should be proper recommendations on the best agronomic practices for the crop. The study was carried out at Kenyatta University Farm, Main Campus during short and long rains cropping seasons of 2015 and 2016. It was laid out in a randomized complete block design (RCBD) with two arrangements (Conventional and Diagonal Offset) and three N rates (0 Kg/ha, 50 Kg/ha and 100 Kg/ha) and replicated thrice. Data collected were subjected to Analysis of Variance using SAS computer software and Fischer's Protected LSD test was used to separate treatment means at 95% confidence level. The root weight increased with increasing nitrogen rate application with those under the 50 kg/ha rate having the highest on the diagonal offset arrangement. The root length was significantly influenced by application of nitrogen with the 50 kg/ha N showing the longest roots(22 cm) with no application having the shortest(15 cm) from week 5 after planting through to week 8. The highest leaf weight (63.4 g) was exhibited in the highest nitrogen rate during the first season while the lowest(23 g) was on the control. The grain yield per plant was highest(52g) under the diagonal offset planting architecture on the two highest rates of nitrogen fertilizer for both seasons. It is therefore recommended that the diagonal offset planting arrangement is suitable for grain amaranth at a rate of 50 kg/ha N.

Keywords: grain amaranth, production, diagonal offset, architecture, adoption.

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ABSTRACT

*Due to the stated unique seed composition, grain amaranth has certainly a potential to become a more considerable non-wheat material in composite flours used for fortified food production. In Kenya, the crop is grown in small plots and has not been fully utilized. Because of the many advantages it has there is need to improve on its production and adoption among the farmers. To achieve these there should be proper recommendations on the best agronomic practices for the crop. The study was carried out at Kenyatta University Farm, Main Campus during short and long rains cropping seasons of 2015 and 2016. It was laid out in a randomized complete block design (RCBD) with two arrangements (Conventional and Diagonal Offset) and three N rates (0 Kg/ha, 50 Kg/ha and 100 Kg/ha) and replicated thrice. Data collected were subjected to Analysis of Variance using SAS computer software and Fischer's Protected LSD test was used to separate treatment means at 95% confidence level. The root weight increased with increasing nitrogen rate application with those under the 50 kg/ha rate having the highest on the diagonal offset arrangement. The root length was significantly influenced by application of nitrogen with the 50 kg/ha N showing the longest roots(22 cm) with no application having the shortest(15 cm) from week 5 after planting through to week 8. The highest leaf weight (*63.4 g*) was exhibited in the highest nitrogen rate during the first season while the lowest(23 g) was on the control. The grain yield per plant was highest(52g) under the diagonal offset planting architecture on the two highest rates of nitrogen fertilizer for both seasons. It is therefore recommended that the diagonal offset planting arrangement is suitable for grain amaranth at a rate of 50 kg/ha N.*

Keywords: grain amaranth, production, diagonal offset, architecture, adoption.

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I. INTRODUCTION

Grain amaranth is an herbaceous annual plant belonging to the family Amaranthaceae with green or red or brown leaves and branched flower stalks (heads) bearing small seeds. It is known to be a native of tropical America, but it is now very widely distributed throughout the tropics (Palada and Chang, 2003). Grain amaranth can be used as a high protein grain or as a leafy vegetable. The seeds are eaten as a cereal grain. They are ground into flour, popped like popcorn or cooked into porridge. The seeds can be germinated into nutritious sprouts (AVRDC, 2003). A seed of grain amaranth is on average composed of 13.1 to 21.0% of crude protein; 5.6 to 10.9% of crude fat; 48 to 69% of starch; 3.1 to 5.0% of dietary fibre and 2.5 to 4.4% of ash. The seed of grain amaranth is a rich source of iron (72-174 ppm), calcium (1300-2850 ppm), sodium (160-480 ppm), magnesium (2300-3360 ppm) and zinc (36.2-40 ppm) as well as vitamin riboflavin (0.19-0.23 mg/100g of flour) and ascorbic acid (4.5 mg/100 gm of flour), niacin (1.17-1.45 mg/100 g of flour), thiamine (0.07-0.1 mg/100 g of flour) and other microelements (Becker *et al*., 1981). Amaranth leaves are cooked alone or combined with other local vegetables such as pumpkin. The leaves are rich in calcium phosphorus, folic acid, potassium, iron and vitamins A, B and C but fairly low in carbohydrate (Okpara *et al*., 2013).

Due to the stated unique seed composition, grain amaranth has certainly a potential to become a more considerable non-wheat material in composite flours used for fortified food production (FAO, 2005). Amaranth was recognized as gluten-free and is therefore suitable for diets of celiac disease patients (Thompson, 2001). Moreover, it is less prone to disease attacks and it can be grown on a wide range of soils but, it grows best in loam or silt-loam soils with good water holding capacity and it can also tolerate a soil pH of 4.5 to 8. In Kenya, the crop is grown in small plots and has not been fully utilized. Because of the many advantages it has there is need to improve on its production and adoption among the farmers. To achieve these there should be proper recommendations on the best agronomic practices for the crop. It has an under-exploited potential to contribute to food security, nutrition, health, income generation and environmental services in Kenya. Amaranth has become important in urban and peri-urban vegetable industry, which brings more attention to improving its productivity. The vegetable intake of the Sub- Sahara Africa (SSA) populace is far below the worlds WHO and FAO recommendations (WHO, 2008; FAO, 2005; Bhargava et al., 2006).

The narrowing of the number of crops upon which global food security and economic growth depend has placed the future supply of food and rural incomes at risk. The mentioned facts with profound environmental consequences and concern for loss of crop varieties stimulate organizations and scientists worldwide in retrieving, researching and disseminating the knowledge in production and utilization of neglected, disregarded, underexploited and new plant species, or so called alternative crops like Amaranth. A remarkable feature of Amaranth plants is their ability to respond plastically to changes in their environment (Givnish, 2002). Few studies have investigated the effects of resource availability on the contribution of plant-level plasticity and productivity. Despite their importance, the local vegetables have generally received little research attention. Therefore, their productivity has remained relatively low or is unknown (Schippers and Budd, 1997). There is inadequate research activities and dissemination of knowledge on production and utilization of this neglected and disregarded alternative crop. Information is lacking on how its yields can be increased through better fertilization and plant arrangement to meet the high demand and reach its potential and also be considered as an important vegetable crop in the country.

II. MATERIAL AND METHODS

2.1 Sites description

The field experiment was conducted at The Kenyatta University main campus which is located in Kiambu County. It is approximately 20 kilometers by road, northeast of Nairobi City Centre. The campus lies along the Nairobi-Thika Super Highway. The coordinates of Kenyatta University main campus are: Latitude: -1.183056; Longitude: 36.926111 and at an elevation of 1520 m above sea level. The County enjoys a warm climate with temperatures ranging between 12°C and 18.7°C. The rainfall aggregate for the county is 1000mm each year. The cool climate makes it a conducive for farming. June and July rank as the coldest months while January-March and September-October are the hottest months.

2.2 Experimental design and treatments

The experiment was laid out in a randomized complete block design in factorial arrangement consisting of three N rates of 0 kg N/ha, 50 kg N/ha and 100 kg N/ha and 2 planting architectures of Conventional row planting and Diagonal offset arrangement. The source of N was Calcium-Ammonium Nitrate (CAN). The treatments were then replicated three times. The seed sourced from Simlaw Seeds Company was planted directly to the experimental plots of size 2m by 1m. Thinning was done just before applying the N fertilizer and two hand weedings followed thereafter. Disease and pest control was done in the case of their respective incidences.

2.3 Data collection and analysis

Data was collected after application of nitrogen at weekly interval, four weeks after emergence. The following growth and yield components were measured and recorded: Plant height (cm), root length (cm), stem diameter (cm), number of leaves per plant, leaf area (cm2), 1000-seed weight (g) and grain yield (g). Dried heads were threshed and the grains obtained were sundried for about three days. The weight of the grains were recorded and used to estimate the grain weight per plot, which was later converted to grain yield per plant by dividing by the stand count. The data collected was summarized using Ms. Excel package and subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) version 9.0 and their individual treatment means compared using Fischer's Protected least significant difference (LSD) test at 5% level of probability.

III. RESULTS AND DISCUSSION

3.1 Root weight

Root weight varied significantly ($p \leq 0.05$) due to the nitrogen rates and row arrangements interactions during in season 1 at the 8 week (Fig.1). Root weight increased with increasing rates under both the conventional and diagonal offset row spacing architectures with the highest rate of 100kg/ha N recording the heaviest root weight under conventional which was closely followed by the same rate under conventional arrangement (though the differences were not significantly different at $p \leq 0.05$). At 50kg/ha N the same trend was observed with conventional recording the highest root weight which was followed by diagonal arrangement. These differences, unlike under 100kg N were statistically significant ($p \leq 0.05$). The control treatment recorded the lowest root weight under both arrangements with the diagonal recording the least.

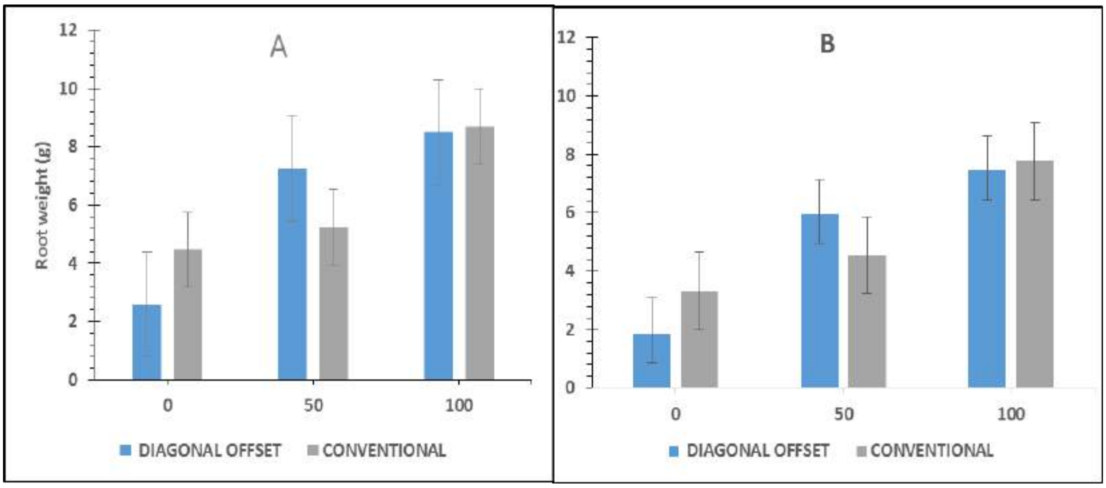

Figure 1: The root weight of grain amaranth as influenced by nitrogen rates and planting architecture during the first (A) and second (B) seasons at Kenyatta University

The increase in root weight in N applied treatments over the control confirm the role of N vegetative growth which result in increased photosynthetic activity leading to the heaviest root weight. This result showed that both nitrogen and row arrangement favored the growth, yield and plasticity of grain amaranth hence leading to differential root weight accumulation depending on N supply. It is clear that the plant expressed plasticity in terms of roots depending on N under different densities (conventional and off-set arrangement). When there was no N and of course no competition, then off-set was superior unlike under 50kg N when there was superiority with conventional arrangement.

3.2 Root length

Root length varied significantly due to the different levels of nitrogen rates at the different stages of growth at weeks, 5, 6, 7 and 8 as shown by (Fig.4.12). At week five the longest root was found with the highest nitrogen rate of 100 kg/ha N which was statistically similar to the nitrogen rate of 50kg/ha N. The control treatment recorded the least root length. At 6 WAP the longest root was recorded from the nitrogen rate of 50kg/ha N which was followed by the nitrogen rate of 100 kg/ha N treatment. The lowest root length was elicited from the treatment with no N application. The same trend was observed at 7 and 8 WAP. The 50kg/ha N showed consistent significant increase of root length in the different stages of growth. This rate was found to be the best rate for the production of grain amaranth. These results showed that nitrogen rates influenced growth, yield and plasticity of grain amaranth resulting in varied root lengths. The increasing root length with increasing N rates revealed the importance of N in the growth of grain amaranth hence leading to the longest root length. Amaranthus is a C4 plant that requires high levels of nitrogen (Masvanhise, 2015). Nitrogen (N) nutrition enhanced metabolic processes that influences the physicochemical environment at the soil-root interface, modifies rhizosphere conditions.

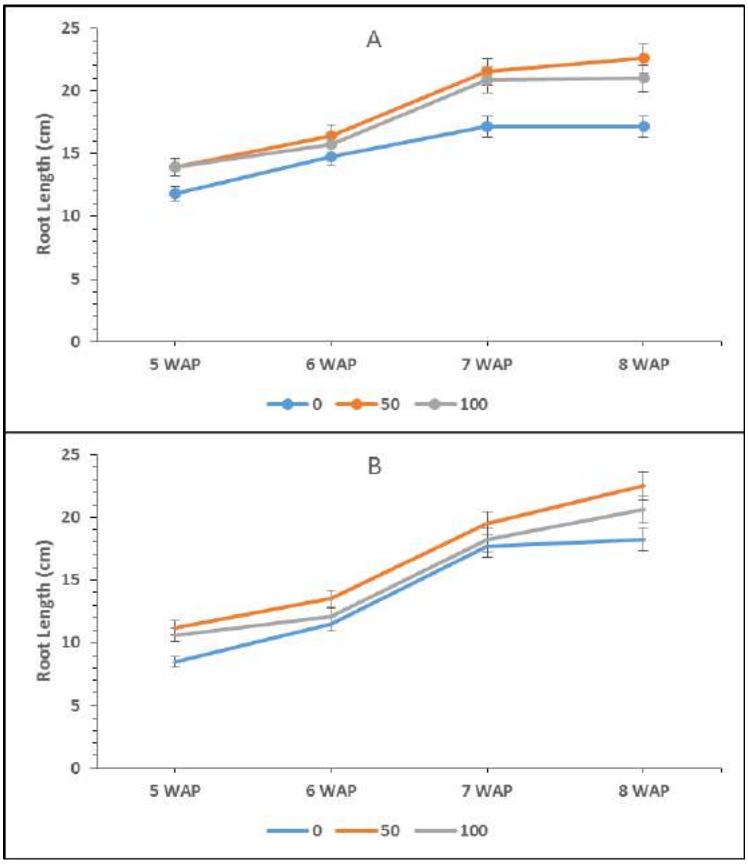

Figure 2: The influence of nitrogen rates on root length of grain amaranth during the first season (A) and second season (B) at Kenyatta University

3.3 Leaf fresh weight

Leaf weight per plant showed significant differences due to application of different levels of nitrogen at different stages of growth of grain amaranth week 4,5.6.7 and 8 in both seasons (Table 1). The highest leaf fresh weight of the grain was seen from the highest nitrogen rate of 100 kg/ha N which was followed significantly by the

50 kg /ha N and the lowest leaf weight was from the no N application treatment in season 1 week four .The same trend was observed in season 2 though at a significantly lower rate except in week 4 where the 50 kg/ha N had the most with 23.4 g. Season 1 was superior to season 2 probably due to long rains at the time of the study which ensured maximum availability of moisture and nutrient absorption hence good growth of the crop.

Table 1: Effect of nitrogen levels on the leaf fresh weight of grain amaranth during the two seasons at Kenyatta University

	Week 5		Week 6		Week 7		Week 8	
Nitrogen Rates	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
0	16.3a	4.03c	11.7a	7.9a	41.4a	7.7c	9.1c	12.1c
50	22.4a	6.9b	30.0a	10.2a	44.2a	12.4b	44.8b	23.4a
100	27.7a	10.0a	18.6a	8.4a	63.4a	18.7a	61.5a	18.2b
LSD	12.6	2.42	17.1	5.23	25.6	4.33	10.8	3.95
P-Value	0.051	0.007	0.052	0.492	0.125	0.03	<.001	0.003

Values in columns followed by the same letter are not statistically significant ($p<0.05$)

These results showed that nitrogen rates influenced growth, yield and plasticity of grain amaranth resulting in varied leaf fresh weight. Increased leaf fresh weight in N applied treatments over no N applied treatments confirmed the importance of N in increases vegetative growth such as leaves of the crop which enhances high photosynthesis hence heavy leaf weight was produced. N is a constituent of chlorophyll and as such encourages healthy green leaves with maximum weigh. Amaranth has a C-4 photosynthetic pathway which enable it to be uniquely efficient in utilizing sunlight and nutrients (Mwangi, 2003), this could have been the reason for the production of the observed heavy leaves with the highest rate having the most. These results are in tandem with those of Majumder (2007) who also reported the highest leaf weight (51.26g) from the highest N rate and the least leaf weight (40.02 cm) from the control treatment. Also in close similarity with these results were the findings by (Toungos et al., 2015) who reported highest leaf fresh weight from the highest N rate of 120 kg/ha. Nitrogenous fertilization treatments have favorably influenced the growth and yield of several *Amaranthus* species (Nie *et al.*, 2004) including plant height, number of leaves, leaf area, fresh and dry weights in addition to N and P uptake. This agrees with the results of the present study. Also in conformity with the results of the present study is the work which was done by Materechera and Medupe (2006) who reported that the addition of nitrogen either as chemical fertilizer or manure significantly improved the growth and yields of amaranth.

3.4 Grain Yield

The combined effects of N application rates with row arrangement had significant influence on grain yields in both seasons (Fig. 3). The highest grain yield(52g) in season one(A) was found in both harvest 1 and harvest 2 from the combinations of the highest N rate of 100kg/ha with diagonal row arrangement which was followed by the combinations of the 50kg/ha N and the same row arrangement whereas the least grain yield was obtained from the control combinations. The same trend was observed from the combinations between the different N rates and the conventional row arrangement although at some significantly lower yields and the lowest yield was recorded from the control interactions.

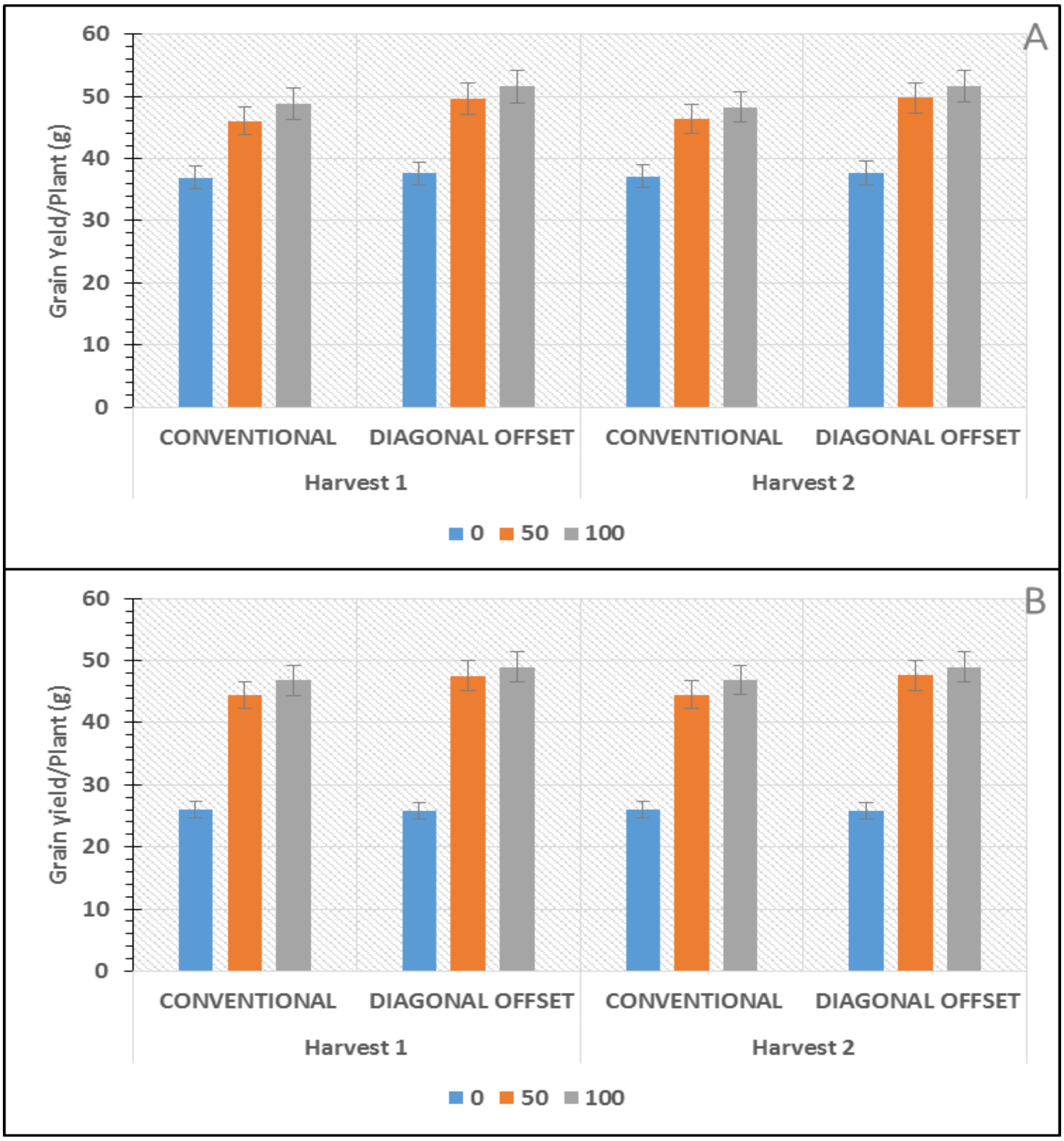

Figure 3: The grain yield per plant of amaranth influenced by planting architecture during the first (A) and second (B) seasons at Kenyatta University

These results confirmed that N rates and row arrangements influenced the growth, grain yields and plasticity of amaranth resulting in differential grain yields. From this study, it was clear that plasticity was observed in terms of yields due to plastic responses to intense competition of available N in the soil because of dense plant densities under diagonal row arrangement. This arrangement was superior because the competitive effect which was higher due to high plant density was reduced when nitrogen fertilizer was applied at 50 kg/ha and 100 kg/ha N. Also, because of high number of plants due to narrow row spacing resulting in the production of highest grain yield. As observed earlier diagonal offset led in most growth, yield and plastic parameters studied; plant height, root length, number of buds and leaves, leaf area, stems diameter and leaf senescence enhancing photosynthetic activities and nutrient absorption, ultimately the highest yields. There was no significant difference between the mean values obtained from 100kg/ha and 50kg/ha but the later led in most parameters studied. On the other hand, conventional row arrangements registered slightly lower yields both at 100kg/ha and 50kg/ha than diagonal row arrangement due low competition over the available N because of low plant density therefore when the fertilizer was applied competition was further reduced and this could be the reason of low yields observed. Amaranth grain yield reported in the literature exhibited a large degree of variability depending on such factors as soil chemical and physical properties, climate, planting density, the variety and level of fertilization (FSNP, (2007).

IV. CONCLUSION

The nitrogen application rates had considerable influence on the growth of amaranth with 50 kg N ha^{-1} having the most influence on the growth parameters while 100 kg N ha^{-1} topped on some at different stages. The combination between the diagonal offset and 50 kg N ha^{-1} was superior on most stages for both seasons on all parameters studied and it therefore recommended.

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Competing Interests

Authors have declared that no competing interests exist.

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