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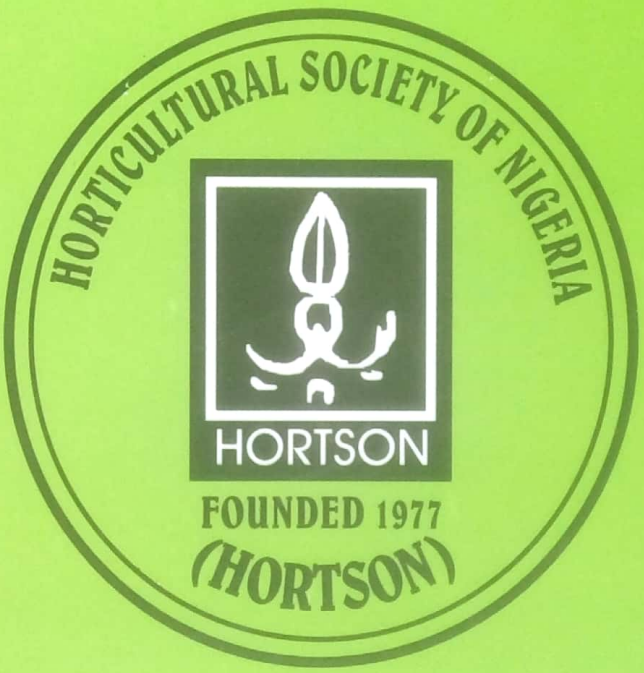

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EFFECTS OF NITROGEN FERTILIZER RATES ON VEGETATIVE GROWTH AND YIELD OF LETTUCE CULTIVARS (*LACTUCA SATIVA* L.) AT KADAWA, SUDAN AGRO-ECOLOGICAL ZONE OF NIGERIA

***Ibrahim, H.[1], Ichi, J. O.[2], Adediran, O. A.[1], Osunde, A. O.[3] Odofin, A. J.[3], and Bala, A.**
[1]Federal University of Technology, School of Agriculture and Agricultural Technology, Department of Crop Production, Minna, Nigeria,
[2]Ahmadu Bello University, Institute for Agricultural Research, Department of Agricultural and Bio-Resources Engineering, Zaria, Ngeria
[3]Federal University of Technology, School of Agriculture and Agricultural Technology, Department of Soil Science, Minna, Nigeria.
*Corresponding author email: harunamokwa@futminna.edu.ng; Telephone: +234-8036970843

ABSTRACT
The study was carried out to evaluate effects of nitrogen fertilizer on vegetative growth and yield of lettuce (*Lactuca sativa* L.) cultivars under irrigated conditions during 2016/2017 and 2017/2018 dry seasons in a semi-arid ecology of Northern Nigeria at Irrigation Research Sub-Station farm (IRS) of the Institute for Agricultural Research, Ahmadu Bello University at Kadawa, in Nigeria. Treatments were factorial combinations of five nitrogen rates (0, 30, 60, 90 and120 kg N ha^{-1}) using urea (46% N) and three lettuce cultivars (Great Lake, Lettuce Slaai and Baby leaf mix) laid out in a complete randomized block design (RCBD) with three replicates. The results indicated that different levels of nitrogen fertilizer rates on all growth and yield characteristics were significant with the highest nitrogen level of 120 kg ha^{-1} recording the highest yield of 10.0 and 11.9 tonnes ha^{-1} in 2016/2017 and 2017/2018 seasons respectively while the control recorded least yield of 4.0 and 5.3 tonnes ha^{-1} in both seasons. Application of 120 kg N ha^{-1} significantly increased yield of lettuce in the tune of 52.7% compared to control treatment. Cultivar had a significant effect on growth characters like fresh weights, number of leaves, canopy spread and vegetative yield but not on stem diameter and root length. Great Lake significantly out yielded the other two cultivars. The highest yield was obtained with 120 kg ha^{-1} treatment with Great Lake.

Keywords: *Nitrogen, Growth, Vegetative Yield, Lettuce,*

INTRODUCTION
Nitrogen is the most yield limiting nutrient, hence its management is critical for optimum yield and quality in lettuce. It plays a role in chlorophyll synthesis and hence the process of photosynthesis and carbon dioxide assimilation (Jasso-Chaverria, *et al.*, 2005). It promotes vigorous growth, and increases number of leaves. It is also necessary for reproduction and promotes the uptake of phosphorus and potassium by the plant (Basel and Atif, 2008). Plants under low levels of nitrogen develop an elevated root: shoot ratio with shortened lateral branches. Konstantopoulou *et al.*, (2010) reported that nitrogen application not only results in higher yield but also affects quality features such as nitrate, vitamin C and chlorophyll content in the leaves of lettuce. In addition, its application rate has been reported to affect various growth parameters such as

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photosynthesis and transpiration rate and stomatal conductance (Khah *et al*.,.2012). Many investigators such as Chen Hai Yan *et al*. (2009) and Zhang *et al*. (2010) reported that the addition of nitrogen fertilizer had a major effect on plant growth in different crop and quality of sweet pepper (Akande *et al*., 2007). Mohammad *et al*. (2010) have also reported that increasing rates of nitrogen significantly affected plant vegetative growth (plant height, lateral stem number, and leaf chlorophyll content).

Lettuce (*Lactuca sativa* L.) is a popular crop amongst the salad vegetables (Shaheen *et al*., 2010). It ranked fourth in terms of consumption rate and 26th among vegetables and fruits in terms of nutritive value. World production of lettuce in 2010 was 24.8 metric tonnes. According to FAO (2013) estimates, China produced about 13.5 metric tonnes, United States of America (USA) produced 3.5 metric tonnes while India produced about 1,1 metric tonnes of lettuce. China's production is consumed locally. While Spain is the world's largest exporter of lettuce, with the United States of America (USA) ranking second. Niger is the highest producer in Africa with about 1.74 metric tonnes (FAO, 2015). Lettuce is most often used for salads. But is also used in other dishes such as soup, sandwiches and wraps (Zohany *et al*., 2012). It is usually consumed individually as salad or shredded in mixed salad of onion, tomato, cheese and basil (Asaduzzaman *et al*. 2010). Lettuce is rich in vitamin A (carotene), vitamin C (ascorbic acid) and calcium iron (Ananda and Ahundeniya, 2012). According to Hoque *et al*. (2010) the antioxidants contained in lettuce may protect against serious diseases, including cardio-vascular disease and certain cancers. Cultivars have a significant effect on growth, yield and characteristic of plants and consequently causing variation in size, form, leaf shape, color and taste. The choice of lettuce variety for increased yield was based mainly on the vegetative growth and resistance to bolting in hot weather (Masarirambi *et al*., 2012). Selection of cultivar has been noted to be among the factors that contributed to the realization of a successful cropping (Bello and Awwal, 2008). Many varieties of lettuce exist with varying shapes, sizes and colour of leaves. These variations could be as a result of genetic constitution or environmental factors. The production of lettuce is constrained by low soil fertility due to continued cultivation without replenishment (Nagaz *et al*., 2013). This challenge, coupled with continued decline in soil fertility in most small holder farms due to little or no fertilizer application has led to reduction of crop yields in Kadawa region (Amkha *et al*., 2006). Nitrogen fertilizers should be applied in such a way to prevent the excessive supply of this nutrient without limiting the yield potential of different crop genotypes. Therefore, the aim of this study was to evaluate the response of inorganic nitrogen fertilizer on growth and yield of three lettuce cultivars.

MATERIALS AND METHODS

The field experiment was conducted for two consecutive dry seasons of 2016/2017 and 2017/2018 at Irrigation Research Sub-Station Farm (IRS) of the Institute for Agricultural Research, Ahmadu Bello University at Kadawa, (11°C, 39 inches North, 080 °C 027 ¨ East and 500 m above sea level) in the Sudan Savanna Ecological Zone of Nigeria. The area has a cool dry season that has the north-eastern winds, which are cool and contain dust blown from the Sahara Desert. The minimum temperature ranges between 11°C and 18°C in the cool months (November to March) with maximum temperatures of 40 °C in the warmer months (April to October) which is ideal for cultivation of wide variety of crops in the dry season. The soils are, in general, moderately deep and well drained with sandy loam textured surface and sandy clay loam textured subsoil.

A composite soil sample was taken using soil auger at different locations from the field at 0-15 cm and 15- 30 cm depth before land preparation, bulked for physical and chemical analysis each year using standard procedures. The soil samples were air dried, gently crushed and passed through 2 mm sieve, before routine physical and chemical analyses using Sparks (1996) method. This was done before the establishment of the experiment.

The lettuce cultivars used were:

Great Lake: This variety produces tasty large heads, ideal for dry harvest. The seed takes about 5 to 10 days to germinate. It produces crisp, bright green leaved heads and matures in 50-60 days. The plant can resist bolting during hot dry weather (Davey *et al*., 2007). It grows to a height of 20 cm. This cultivar is most common in Nigeria (figure 1).

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Slaai: This variety forms a crisp head with strong resistance to bolting in hot weather. It takes about 70 days to maturity (Davey *et al.*, 2007). Lettuce Slaai was sourced from SAKATA SEED, South Africa (Pty) Ltd (figure 2).

Baby Leaf Mix: Germination takes about 7 to 14 days and the plant matures in 35 to 45 days. This type does not form hearts and comes in different colours with various types of mottling or patterns; and it is considered the easiest type of lettuce to grow (Zohany *et al.*, 2012). This sample, Baby leaf mix lettuce was sourced from Starke Ayres (Pty) Ltd, Gauteng South Africa (figure 3). The field experiment consisted of five rates (0, 30, 60, 90 and 120 kg ha^{-1}) of nitrogen fertilizer using urea (46% N) and the three selected lettuce cultivars, giving a total of 15 treatments per replication. The treatment was combined in a factorial arrangement and laid out in a randomized complete block design with three replications. A distance of 1m between replicates and 0.5 m between plots was left as intervals. The plot size was 2 m x 2 m, while the net plot was 0.6m x 2 m. Seeds of the three cultivars were sown separately on a well prepared nursery bed by drilling method. The beds were mulched after sowing and irrigated daily with watering can. The mulch was removed after seedling emergence and rearranged between drill-rows of the emerged seedlings. The experimental sites were cleared, ploughed, harrowed and later made into sunking beds (plots) to create a favourable condition for seedling establishment. Two weeks to transplanting, the seedlings were hardened up by irrigating the nursery at two days' intervals. After 33 days of sowing at the nursery when seedlings had produced an average of five to six true leaves, they were transplanted at 30 cm x 30 cm intra and inter–row spacing. This was done in the evening to reduce transplanting shock on the seedlings. Surface irrigation method was used in the two seasons. Water was released from the canal into the lateral ditches which serviced the basins. During land preparation 50 kg P_2O_5, and 50 kg K_2O per hectare using single superphosphate (SSP) and muriate of potash (MOP) respectively, was applied to the entire plots. Nitrogen using urea (46% N) was applied at the rate of 0, 30, 60, 90 and 120 kg ha^{-1} to the designated plots in two splits; during transplanting and the other half was applied at 3 weeks after transplanting. The plots were weeded manually using a hand hoe as found necessary. Lettuce was manually harvested by cutting the head above ground level. This was done when the varieties had attained harvest maturity (60,70 and 45 days) respectively according to cultivar. Three plants per net-plot were randomly picked and tagged at 4 WAT for the purpose of measuring the following growth and yield parameters. Plant height was taken from tagged plants at 6 and 8 WAT. This was done by measuring the height (cm) of the plant from base to tip of the terminal leaf, with a meter rule, and the mean was determined. Number of leaves per plant was determined at 6 and 8 WAT from which the mean was computed. Fresh weight per plant (g) was calculated at 6 and 8 WAT by harvesting three plants randomly, weighed using electronic weighing balance and mean was determined. Leaf canopy spread was taken at 8 and 10 WAT by measuring the leaf width of the tagged plants with tape rule and mean was determined. Stem diameter was taken at 8 and 10 WAT with veneer caliper and the mean was recorded. Root length was taken at 8 and 10 WAT by means of meter rules and average was recorded. Fresh yield ha^{-1} was determined by harvesting all the net plots separately and taking their weight (g), and expressed in kg ha^{-1}. Data collected were subjected to analysis of variance using General Linear Model Procedure of SAS and treatment means was separated using Duncan Multiple Range Test (DMRT) at 5% level of probability (Duncan (1955).

RESULTS

The results of the soil analysis for the experimental site for 2016/2017 and 2017/2018 are presented in Table 1. The dominant soil texture was loam. The chemical properties of the soils following critical values of soil nutrients showed that the pH in the location was moderately acidic. The total nitrogen, available phosphorus, calcium, magnesium, potassium and sodium were generally moderate while the organic matter was low.

Effect of nitrogen rate on number of leaves plant^{-1}.

The effect of nitrogen fertilizer rates on number of leaves is presented in Table 2. Nitrogen fertilizer application rates significantly ($p< 0.05$) affected leaf number. The highest number of leaves was recorded at the highest N treatment (120 kg N ha^{-1}) while the lowest was related to

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the control treatment. However, in 2016/2017 at 8 WAT application of N rate from control to 60 kg ha^{-1} were not significant. The same trend was observed at 10 WAT with the application of 90 and 120 kg N ha^{-1}. Cultivar significantly affected number of leaves per plant throughout the period of 2016/2017 while 2017/2018 season cultivar did not show any significant effect on number of leaves. Table 3 shows the effect of nitrogen rates on leaf fresh weight, canopy spread and stem diameter in 2016/2017 and 2017/2018 dry seasons.

Effect of nitrogen rate on plant height.

The effect of nitrogen fertilizer rate on plant height is presented in Table 2. Nitrogen fertilizer application significantly ($p< 0.05$) increased plant height. The highest level of nitrogen fertilizer (120 kg N ha^{-1}) produced the tallest plants while the shortest plants as obtained in the control (without N). However, no significant difference was found between the three other treatments (control, 30 and 60 kg ha^{-1}) at 6 and 8 WAT in 2016/2017 (Table 2). In 2017/2018, increasing nitrogen level from 90 to 120 kg ha^{-1} had no significant difference which recorded the tallest plants. In the first stages (6 and 8 WAT) of growth differences between nitrogen levels were not significant because the plants were in early stage and growth of plants was typically low at this stage. Cultivar had no significant effect on plant height throughout the sampling period except at 6 WAT in 2016/2017. Among the cultivars, Baby leaf significantly produced taller plants than the other two cultivars used. Slaai and Great Lake, which were not significantly different from each other. Interaction effect between nitrogen and cultivar on plant height was not significant throughout the period of experimentation.

Effect of nitrogen fertilizer rate on fresh weight plant^{-1}

Table 3 shows the effect of nitrogen rates on leaf fresh weight, canopy spread and stem diameter in 2016/2017 and 2017/2018 dry seasons. The effect of nitrogen fertilizer rate on the fresh weight of leaves was significant ($p< 0.05$) throughout the sampling period. The lowest fresh leaf weight was recorded in the control treatment and the highest leaf fresh weight was in 120 kg N ha^{-1}. In 2016/2017, nitrogen rates had significant ($p < 0.5\%$) effect on fresh weight throughout the sampling period. Application rate of 120 kg N ha^{-1} significantly recorded the highest fresh weight per plant throughout the season.

However, in 2017/2018, nitrogen rate nitrogen rate had significant ($p< 0.05$) effect on fresh weight of leaves except at 10 WAT. Application rate of 120 kg N ha^{-1} significantly recorded the highest fresh weight per plant throughout the season, but at 8 WAT increasing nitrogen from zero to 30 kg N ha^{-1} had no significant effect on fresh weight of lettuce while further increase above 60 kg N ha^{-1} up to the highest rate of 120 kg N ha^{-1}, produced the highest but statistically similar fresh weight. Cultivar had significant ($p< 0.05$) effect on fresh weight per plant only at 6 WAT in 2016/2017 dry season. At 6 WAT, Great Lake produced heavier fresh weight than the other cultivars which had similar fresh weight, all the other sampling periods shows no significant difference in fresh weight with respect to cultivar.

Effect of nitrogen fertilizer rates on leaf canopy spread.

Application of nitrogen rates had significant ($p< 0.05$) effect on canopy spread in 2016/2017 and 2017/2018 study periods. Generally, application of 120 kg N ha^{-1} rates of nitrogen significantly produced plant with widest leaves throughout the study periods. In 2016/2017, increasing rates of nitrogen up till 60 kg N ha^{-1} did not affect canopy spread significantly at 8 and 10 WAT, further increase to 120 kg N ha produced significant difference between the former and the later in canopy spread. However, canopy spread at 90 and 120 kg ha-1 N application were similar. In 2017/2018 at 8 and 10 WAT, increasing nitrogen up till 90 kg N ha^{-1} did not influenced canopy spread significantly, however, further increase of 120 kg N ha^{-1} resulted in significantly widest canopy spread compared with the control treatment. Cultivar variations was significant at 8 and 10 WAT in 2016/2017 cropping season. Baby Leaf Mix produced significantly plants with narrow canopy compared with that produced by Great Lake and Slaai throughout the study periods.

Effect of nitrogen fertilizer rate on lettuce stem diameter.

Application of nitrogen fertilizer significantly ($p< 0.05$) affected stem diameter throughout the experimental period. In 2016/2017 the highest nitrogen rate of 120 kg N ha^{-1} produced thickest stem diameter than control and the other rates. In 2017/2018, however, increasing nitrogen rate from zero to 30kg ha^{-1} had at 8 WAT did

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notsignificantly affect the stem diameter, but further increase to the highest rate of 120kg ha^{-1} were although statistically at par but better than control and 30kg ha^{-1}. At 10 WAT the highest N rate of 120 kg ha^{-1}recorded significantly widest stem than the other treatments. Cultivar had no significant effect on stem diameter throughout the sampling periods. Interaction between nitrogen and cultivar on fresh weight per plant was also not significant.

Effect of nitrogen fertilizer rate on root length.

Table 4 shows the effect of nitrogen rates on root length and fresh yield ha-1 in 2016/2017 and 2017/2018 dry seasons. Response of lettuce cultivar to nitrogen fertilizer rate on root length at Kadawa in 2016/2017 and 2017/2018 is shown on Table 4. At 8 and 10 WAT only in 2016/2017, increasing nitrogen fertilizer from zero to 60 kg N ha^{-1} increased root length but further increase of nitrogen above 60kg N ha^{-1} did not significantly affected stem diameter. However, in 2017/2018 at 10 WAT, N fertilizer rates ha significant effect on root length of lettuce. Root length was highest at the N application of 120 kg N ha^{-1} and least at the control. All other treatments were not significantly different Variation in cultivar had no significant effect on root length in both years, and interaction between nitrogen and cultivar was also not significant throughout the sampling periods.

Effect of nitrogen fertilizer rate on yield of lettuce.

The response of lettuce cultivar to nitrogen fertilizer on fresh yield at Kadawa in 2016/2017and 2017/2018 is shown in Table 4. In 2016/2017, there were significant ($p< 0.05$) differences amon nitrogen rates. Application of the highest rate of nitrogen (120 kg N ha^{-1}) gave the heaviest fresh yield per hectare, while control recorded the least yield per hectare. In 2018 the significantly heavier (11.2 t ha^{-1}) fresh yield was recorded with the application of 120 kg N ha^{-1} compared to the yield values of between 5.3 and 9.1 t ha^{-1} obtained from other fertilizer treatments. Variation in cultivar had no significant effect on vegetative yield per hectare in 2017/2018 experimental periods. However, in 2016/2017, Baby Leaf Mix recorded the lowest (7.67 %) fresh yield compared with Great Lake and Slaai which were statistically the same.

DISCUSSION

The growth components of lettuce cultivars were significantly influenced by nitrogen application rates. The observed increase on growth and vegetative yield characters like plant height, leaf numbers, canopy spread, fresh weight per plant, stem diameter, root length and fresh yield per nitrogen fertilizer application due to higher nitrogen content which induced higher plant height, number of leaves, fresh weight, dry weight. This result is in agreement with Boroujerdnia *et al.* (2007) who reported that increments in leaf fresh weight may be due to a combination of nitrogen with plant matter produced during photosynthesis such as glucose, ascorbic acid, amino acids and protein. Cultivar Great Lake performed better than Slaai and Baby Mix Leaf in this experiment. These variations could be as a result of genetical composition of the cultivars. The present result agrees with findings of Maryam and Naser (2007) who reported that cultivar was significant on fresh weight, 'PichAhwazi', had a higher fresh weight than 'PichVaramini'.

CONCLUSION

Based on the results obtained, it can be concluded that application of nitrogen fertilizer to lettuce leads to successive increase in growth, yield and yield related parameters. Application of 120 kg N ha^{-1} significantly increased yield of lettuce in the tune of 52.7 % compared to control treatment. Therefore, productivity of lettuce under irrigation can be maximized by application of 120 kg N ha^{-1} while cultivar Great Lake was superior to Slaai and Baby Mix Leaf in this regard.

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