HORTICULTURAL SOCIETY OF NIGERIA (HORTSON) BOOK OF PROCEEDINGS OF THE 37TH ANNUAL CONFERENCE

Theme: ‘‘Horticultural Production: A Panacea for Sustainable Economic Growth and Development”

Editors:
Adesina, J. M., Iwala, O. S. Kekere, O. Ajayi, A. J., Ajayi E. O. & Idowu-Agida O.O.

Correct Citation:
In: Adesina, J. M., Iwala, O. S., Kekere, O. and Ajayi, A. J. Ajayi E. O. & Idowu-Agida O.O. (2019). Horticultural Production for Sustainable Economic Growth and Development. Book of Proceedings of the 37th Annual Conference of Horticultural Society of Nigeria, Faculty of Agricultural Technology, Rufus Giwa Polytechnic, Owo, Ondo State Nigeria. 18th – 22nd November, 2019,

ISSN 978-978-977-709-9

Effects of nitrogen fertilizer rates on vegetative growth and yield of lettuce cultivars (*Lactuca sativa* L.) at Kadawa, Sudan agro-ecological zone of Nigeria

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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. Treatments were factorial combinations of five nitrogen (urea 46% N) rates (0, 30, 60, 90 and120 kg N ha^{-1}) 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 (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 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 photosynthesis and transpiration rate and stomatal conductance (Khah *et al*.,2012). Many researchers 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 its quality. (Akande *et al.* (2007) and Mohammad *et al.* (2010) have also reported that increasing rates of nitrogen significantly affected plant vegetative growth 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, (11^0 39/ N, 080^0 027/ E 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 ^oC and 18 ^oC in the cool months (November to March) with maximum temperatures of 40 ^oC in the warmer months (April to October) which is ideal for cultivation of wide variety of crops in the dry season.

The field experiment consisted of five rates (0, 30, 60, 90 and 120 kg ha^{-1}) of nitrogen fertilizer (urea 46% N) and three lettuce cultivars (Great Lake, Lettuce Slaai and Baby leaf mix), giving a total of 15 treatments per replication. The treatment was combined in a 5 x 3 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. 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.

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 (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 3 weeks after transplanting (WAT). 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, number of leaves, fresh leaf weight, leaf canopy spread, stem diameter, root length and fresh yield at 6 and WAT, 8 and 10 WAT and at harvest respectively using standard procedures.

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 and Discussion

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 shows that it was moderately acidic. The total N, available P, Ca, Mg, K and Na were generally moderate while the organic carbon was low.

Effect of nitrogen rate on number of leaves plant and plant height (cm).

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 and plant height. The highest number of leaves and plant height was recorded at the highest N treatment (120 kg N ha^{-1}) while the lowest and shortest plant was obtained from the control treatment. However, in 2016/2017 at 8 WAT application of N rate from control to 60 kg ha^{-1} were not significant in terms of number of leaves produced. While non-significant difference was also observed between control, 30 and 60 kg ha^{-1} at 6 and 8 WAT in 2016/2017 (Table 2). The same trend was observed at 10 WAT with the application of 90 and 120 kg N ha^{-1}. In 2017/2018, increasing nitrogen level had no significant effect on plant height. Cultivar significantly affected number of leaves per plant throughout the period of 2016/2017 while in 2017/2018 season cultivar did not show any significant effect on number of leaves, same as for plant height except at 6 WAT in 2016/2017. Interaction effect between nitrogen and cultivar on plant height was not significant throughout the period of experimentation (Table 2).

Effect of nitrogen rate on plant height (cm).

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 (Table 2).

Effect of nitrogen rate on fresh leaf weight plant' canopy spread and stem diameter.

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 leaves fresh weight, canopy spread and stem diameter was significant ($p< 0.05$) throughout the sampling period for both seasons. The lowest parameters were recorded in the control treatment and the highest was in 120 kg N ha^{-1}. In 2017/2018, nitrogen rates had significant ($p < 0.5\%$) effect on fresh weight of leaves except at 10 WAT. Increasing nitrogen rate from zero to 90 kg N ha^{-1} had no significant effect on the various growth parameters of lettuce, but those treated with 120 kg N ha^{-1} recorded significant effect compared with control (Table 3). Similar trend was observed for canopy spread.

Cultivar had significant ($p< 0.05$) effect on fresh leaf, canopy spread at 6, 8 and 10 WAT respectively in 2016/2017 dry season. While cultivars do not have significant effect on stem diameter. Great Lake and Baby Leaf Mix produced heavier fresh weight and canopy spread compared to other cultivars. Interaction between nitrogen and cultivar on fresh weight per plant was also not significant.

Effect of nitrogen rate on root length (cm) and yield of lettuce (ha^{-1}).

Response of lettuce cultivar to nitrogen fertilizer rate on root length and yield in 2016/2017and 2017/2018 is shown on Table 4. In both season, there were significant ($p< 0.05$) differences in yield recorded among nitrogen rate. Application of the highest rate of 120kg N ha^{-1} gave the heaviest fresh yield per hectare, while control recorded the least per hectare. At 8 and 10 WAT in 2016/2017 application of 30 and 60 kg N ha^{-1} did not significantly affected root length at 8 and 10 WAT, similar trend was observed in 2017/2018 season. Non-significant increase in root length was recorded at 8 WAT in 2017/2018 season. 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 root length. However, in both season root length was highest at the N application of 120kg N ha^{-1} and least at the control.

Variation in cultivar had no significant effect on root length and vegetative yield per hectare in both years and interaction between nitrogen and cultivar was also not significant throughout the sampling periods. However, in 2016/2017, Baby Leaf Mix recorded the lowest (7.67 %) fresh yield compared with Great Lake and Slaai which are statiscally the same.

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 hectare were significant. The influenced of nitrogen rates on growth parameters of lettuce indicated the role it plays in plants biochemistry, as an essential constituent of chlorophyll, increasing crops vegetative ability, such that application of nitrogen fertilizer stimulated vegetative growth by increasing the number of leaves. Boroujerdnia and Ansari (2007) reported that increasing the nitrogen rate increased the number of growth characters such as plant height, number of leaves dry weight and leave area. Jones *et al*. (2007) also reported a significant difference in the number of leaves of cucumber among nitrogen levels and that the highest leaf number was obtained with 200 kg N ha^{-1}. Among the major nutrient required by crops, nitrogen is perhaps the most important of the nutrients because of its biological roles and because it is required in large quantities by the plants. The significant response on lettuce could be attributed to increase in leaf number, broader leaves of plants that were supplied with nitrogen compared to control which reduced significantly all the growth characters. Lettuce plants were taller in those plots that received 90 and 120 N kg ha^{-1} than those that received lower rates of 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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Table 1: - Physio-chemical properties of the experimental soil

Soil Compositions	2015/2016		2016/2017	
	0-15	15-30	0-15	15-30
Physical Properties				
Clay	18	23	18	21
Silt	45	38	40	37
Sand	37	39	40	42
Textural class	Loam	Loam	Loam	Loam
Chemical Compositions				
pH in H_2O(1:2.5)	7.40	7.30	7.00	7.10
pH in $CaCl_2$(0.01m)	6.90	6.90	6.20	6.30
Organic Carbon (kg^{-1})	4.20	2.40	5.3	3.0
Total Nitrogen (kg^{-1})	0.52	0.30	5.3	3.5
Available Phosphorus(mg kg^{-1})	9.28	5.95	10.00	8.75
Exchangeable bases (cmol (+)kg^{-1})				
Ca	3.80	4.20	4.10	5.10
Mg	1.03	1.13	1.41	2.34
K	0.11	0.14	0.14	0.15
Na	0.10	0.13	0.45	0.63
CEC	6.33	6.72	7.30	9.70

Source: Soil Science Department, Ahmadu Bello University, Zaria.

Proceedings of 37th Annual Conference of the Horticultural Society of Nigeria (HORTSON) "OWO MADE 2019"
THEME: Horticultural Production: A Panacea for Sustainable Economic Growth and Development
MONDAY 18TH – FRIDAY 22ND NOVEMBER, 2019

Table 2: Response of lettuce cultivars to nitrogen fertilizer on plant height and number of leaves per plant at Kadawa in 2016/2017 and 2017/2018 seasons.

	Number of leaves						Plant height (cm)					
	2016/2017			2017/2018			2016/2017			2017/2018		
Treatment	6WAT	8 WAT	10 WAT	6WAT	8 WAT	10 WAT	6WAT	8 WAT	10 WAT	6WAT	8 WAT	10 WAT
Nitrogen (kg ha^{-1})												
Control	10c	14c	13b	24c	29	36c	5.8b	7.7b	6.2c	8.9b	11.7b	24.1
30	12b	15bc	14b	26bc	29	39c	6.3b	7.0b	7.1c	11.1ab	13.4ab	24.7
60	13ab	16abc	18ab	29abc	32	43abc	6.4b	8.1b	8.7bc	11.8ab	13.5ab	28.4
90	12b	16ab	17ab	30.ab	34	46ab	7.7a	9.7a	11.0b	12.3ab	14.5ab	29.9
120	14a	19a	19a	33a	35	49a	8.1a	11.0a	15.0a	13.2a	15.5a	29.9
SE±	0.4	0.6	1.6	2.0	2.0	3.0	0.39	0.50	0.93	1.12	1.09	2.70
Cultivar												
Great Lake	11b	14c	12b	28	32	44	6.3b	8.5	9.0	11.4	13.1	27.6
Slaai	16b	15b	16b	29	33	41	6.7b	8.5	9.1	12.2	13.9	27.4
Baby leaf Mix	13a	18a	20a	28	31	43	7.6a	8.9	10.3	10.8	14.1	27.0
SE±	0.32	0.4	1.2	1.6	1.5	2.3	0.30	0.39	0.72	0.90	0.84	2.09
Interaction												
N x C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means within each column and factor followed by same letter is statistically similar ($p>0.05$) using DMRT. NS: Not significant, WAT: weeks after transplanting

Table 3: Response of lettuce cultivars to nitrogen fertilizer on leaf fresh weight, canopy spread and stem diameter at Kadawa in 2016/2017 and 2017/2018 seasons

	Fresh leaf weight (g)						Canopy spread (cm)				Stem diameter (cm)			
Treatment	**2016/2017**			**2017/2018**			**2016/2017**		**2017/2018**		**2016/2017**		**2017/2018**	
	6 WAT	8 WAT	10 WAT	6 WAT	8 WAT	10 WAT	8 WAT	10 WAT	8 WAT	10 WAT	8 WAT	10 WAT	8 WAT	10 WAT
Nitrogen (kg ha^{-1})														
Control	21.0c	51.5c	79.1c	136.3b	162.6c	387.3	13.8b	12.1c	34.0b	45.1b	5.66c	7.25c	9.19b	9.32c
30	23.5c	71.4bc	92.7c	113.7b	176.2c	399.5	13.3b	12.6c	36.1ab	46.6b	6.81b	7.69bc	9.41b	9.62bc
60	30.8bc	97.5b	133.5bc	129.9b	213.6abc	456.9	15.3b	14.1bc	38.4ab	48.7b	6.89b	7.60ab	10.04ab	10.18bc
90	39.1b	99.9b	161.5b	145.2ab	257.7ab	443.5	16.6ab	16.1b	40.2ab	50.0ab	6.74b	8.64ab	10.39ab	10.97bc
120	60.7a	151.5a	220.5a	212.5a	271.2a	760.1	21.0a	19.2a	41.6a	55.1a	8.76a	9.59a	11.55a	12.01a
SE±	3.99	12.91	17.98	23.12	29.67	124.43	1.65	0.79	2.12	1.81	0.445	0.386	0.575	0.505
Cultivar														
Great Lake	41.5a	111.0	147.9	143.6	228.5	578.8	19.6a	18.3a	39.9	50.3	19.6a	18.3a	39.9	50.3
Slaai	32.0b	86.8	134.4	139.9	232.3	437.3	14.7b	13.7ab	37.8	49.6	14.7b	13.7	37.8	49.6
Baby leaf Mix	29.4b	80.6	123.7	155.2	182.0	430.3	13.2b	12.1b	36.1	46.8	13.2b	12.1b	36.1	46.8
SE±	3.09	10.00	13.93	17.91	22.98	96.38	1.28	0.59	1.64	1.41	1.28	0.59	1.64	1.41
Interaction														
N x C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means within each column and factor followed by same letter is statistically similar ($p>0.05$) using DMRT. NS: Not significant. WAT: weeks after transplanting.

Table 4: Response of lettuce cultivars to nitrogen fertilizer on root length and fresh yield ha^{-1} at Kadawa

	Root length (cm)				Fresh yield (kg ha^{-1})	
Treatment	**2016/2017**		**2017/2018**			
Nitrogen (kg ha^{-1})	8WAT	10WAT	8WAT	10WAT	**2016/2017**	**2017/2018**
Control	6.62b	5.98c	8.84	8.31b	40463e	52870d
30	6.37b	6.79bc	8.36	8.61ab	51389d	69352c
60	7.51ab	7.07abc	8.65	8.97ab	66944c	86204b
90	7.11ab	7.76ab	9.02	9.11ab	86204b	91019b
120	7.87a	8.21a	9.95	9.86a	100000a	111875a
SE±	0.363	0.370	0.533	0.414	2120.8	2891.8
Cultivar						
Lettuce Great Lake	7.06	7.44	8.79	9.03	70333a	80500
Lettuce Slaai	7.29	7.22	8.79	8.82	69389ab	83889
Baby leaf Mix	6.85	6.74	9.26	9.00	64940b	80298
SE±	0.281	0.286	0.413	0.321	1642.7	2240.0
Interaction						
N x C	NS	NS	NS	NS	NS	NS

Means within each column and factor followed by same letter is statistically similar ($p>0.05$) using DMRT. NS: Not significant. WAT: weeks after transplanting