Original Research

Science Vision 16 (2)
April-June
ISSN (print) 0975-6175
ISSN (online) 2229-6026

Effect of NPK fertilizer on growth and yield of maize under different jhum cycles in Mizoram

Lalrammuanpuia Hnamte*, C. Lalrammawia and B. Gopichand

Department of Forestry, Mizoram University, Aizawl 796004, India

Received 25 May 2016 | Revised 1 June 2016 | Accepted 2 June 2016

Abstract

Intensive jhum cultivation is the biggest ecological threat due to its associated problems such as biodiversity loss, deforestation, soil erosion and the gradual reduction of land productivity in Mizoram. The intrinsic practice of jhum cultivation still dominated the farming system in Mizoram to a large margin. Four levels of nitrogen, phosphorus and potassium soil fertilizer application in local maize variety was conducted in 2 years, 3 years and 5 years jhum cycles. Strong significant ($P<0.05$) response to fertilizer application occurred in the growth and yield performance of maize. Different period of jhum cycles also had significant ($P<0.05$) effect in growth and yield with highest productivity in longest jhum cycle. Taking account of the poor soil nutrient content and the acidic soil in Mizoram, application of urea at lower rate under longer jhum cycle may be adopted.

Key words: Fertilizer; grain yield; jhum cycle; nitrogen; phosphorus; potassium; Zea mays.

Introduction

Jhum cultivation, in which natural vegetation is cut down and burnt for use as non-permanent agricultural land, has been a common agricultural practice for many rural populations throughout the tropics.[1] It is the most traditional and dominant land use system in the hilly regions of northeastern India. Shifting cultivation in its more traditional and cultural integrated form is an ecological and economically viable system agriculture as long as population densities are low and jhum cycles are long enough to maintain soil fertility.[2] The intervening period for which a jhum land is abandoned is known as Jhum cycle.[3]

In the past 25 years, the common jhum cycle in Mizoram was 4-6 years cycles,[4] but currently the jhum cycles ranged mostly from 2-5 years as a result of the drastic reduction of land availability for agriculture. This is mainly due to population pressure and the continual practice of jhum cultivation which resulted in the conversion of fertile land into unsustainable marginal lands.[5]

In Mizoram, maize (*Zea mays* L.) is the second most important cereal crop next to rice in

Corresponding author: Hnamte
Phone: : +91-9436190370
E-mail: muanpuiahnamte75@gmail.com

jhum areas and where it is grown predominantly during summer as a kharif crop.[6] At present, the maize production only met the requirement for human consumption and the booming poultry farming has intensified the demand for maize as poultry feed.

The present investigation was undertaken to study the effect of fertilizers on growth and yield of the most productive local maize variety called '*mimpui'* under different jhum cycles aiming the optimization of the balance between jhum cycle and fertilizer application.

Materials and Methods

Experimental site

The experiment was conducted at Edenthar area (Fig 1) which is at the outskirt of Aizawl, the capital city of Mizoram state. The altitude is about 943 above msl with geographical coordinates of 23.754149° N and 92.714610°E. The hill slopes have the soil orders of ultisols with sandy clay loam texture. The average annual rainfall in this area is 2150 cm.

Prior to land preparation, soil samples from 0 to 20 cm depth were collected from each jhum cycles and air dried. For soil texture analysis, soil sample was mixed with 50ml water and shaken vigorously in a graduated cylinder. The suspended soil was allowed to settle overnight. The soil texture was analyzed from its volumetric content of sand, silt and clay. Soil pH was determined using pH meter by taking soil and water in the ratio of 1:1, Organic carbon (OC) was determined by Walkey Black wet oxidation method[7], total nitrogen was determined using CHNS/O analyzer (Euro Vector, Model: EuroEA3000), available phosphorus (P_2O_5) by Bray P2 method,[8] and available potassium (K_2O) by Jackson (1973),[9] before land preparation for the experiment. The three jhum plots were slashed and burnt before the experiment as in Table 1.

Experimental design and treatment

Three jhum cycle sites *viz.* 2 years jhum cycle (2JC), 3 years jhum cycle (3JC) and 5 years jhum cycle (5JC) were selected which located adjacent to each other within an area of 2 acres to rule out the difference in environmental parameters. Four levels of nitrogen (N), phosphorus (P) and potassium (K) fertilizer doses were applied as shown in Table 2.

Seeds of *mimpui* variety of maize were purchased from Department of Agriculture, Government of Mizoram, Aizawl. The experimental layout was randomized block design (RBD) with

Figure 1. The experimental site at Edenthar showing site location and fertilizer application plots under difference jhum cycles.

Table 1. Properties of top soil of 2JC, 3JC and 5JC before land preparation.

Jhum cycles	pH	OC (%)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Total N (%)	Soil texture
2 JC	6.15	1.38	7.56	120	0.26	Sandy clay loam
3 JC	6.18	1.67	9.32	145	0.32	Sandy clay loam
5 JC	6.24	3.11	11.33	180	0.47	Sandy clay loam

Table 2. Table showing four fertilizer plots with their respective rates of nitrogen (N), phosphorus (P) and potassium (K) application.

Treatment	Nitrogen (N) kg/ha	Phosphorus (P) kg/ha	Potassium (K) kg/ha
To	0	0	0
T1	80	40	20
T2	100	50	30
T3	120	60	40

three replications. Each treatment plot was 4 x 3 m containing 80 plants at the spacing of 75 x 20 cm (66,666 plants/hectare) and two adjacent plots were separated by 1m buffer zone. Sowing of seeds was done on 24th March, 2010. Application of nitrogen, phosphorus and potassium in the form of urea, single superphosphate (SSP) and murate of potash (MOP) respectively was carried at split doses with the first application as broadcasting during soil tilling before sowing and the second dose at 30 days after sowing (DAS) as basal treatment.

Growth parameters

Measurement of height (in cm) using measuring tape and counting of leaves were conducted at 15, 30, 45 and 60 DAS. Plant biomass was determined at the time of harvest. Plant aboveground biomass of all the above ground parts except the grain were oven dried at 70°C until it reached constant weight and then the dry weight was recorded using digital weighing balance.

Yield parameters

Number of cob, length of cob (cm), number of kernel row per cob, number of kernels per row and test weight were recorded after maturity harvest. Grain yield was extrapolated from yield of the sampled area. Test weight was measured by taking the oven dry weight of randomly selected 1000 kernels. Harvest index was calculated as kernel dry weight divided by aboveground dry weight of the plant.

Statistical analysis

Data obtained from all the observations was analyzed using Sigma Stat 4.0 and Microsoft Excel.

Results and Discussion

Soil properties

Soil properties of the three jhum sites sampled before the land preparation for the experiment (Table 2) showed soil pH ranging from 6.15 in 2 years jhum to 6.24 in 5 years jhum. Similar trend with lowest values in 2 years jhum and highest 5 years jhum was also observed in other soil parameters ranging from 1.38 to 3.11 kg/ha in soil OC content, 7.56 to 11.33 kg/ha in available phosphate, 120 to 180 kg/ha in available potassium and 0.26 to 0.4 % in total nitrogen content (Table 2). Although slightly higher value in pH and higher content of OC, available phosphate, available potash and total nitrogen content occurred in longer jhum periods, all the soil in the three jhum cycles represent poor nutrient content for annual crop plantation.

Growth parameters

The measurement of plant height at 15, 30, 45 and 60 DAS showed significant variations among the fertilizer plots in all the three jhum cycles (Table 3). At the initial stage of growth observed at 15 DAS, there were less significant variations among the fertilizer plots as well as among the three jhum cycles. As the growth progressed, the increased in the range of plant height between the *T0* plots and the *T3* plots indicated the strong influence of fertilizer input. Vigorous growth occurred between 30 to 60 DAS and the maximum range between control plot and *T3* plot was recorded at 45 DAS. At 60 DAS the plant height between *T0* and *T3* plots ranged from 165.50±1.27 cm to 181.36±2.81 cm in 2JC, 172.63±0.34 cm to 212.70±0.75 cm in 3JC and 185.33±5.88 cm to 217.80±1.76 which accounted for 9.6%, 14.7% and 17.5% increase from their respective control plots.

Among the jhum cycles, the comparison of plots having the same level of fertilizer application showed lowest value in 2JC and highest value in 5JC (Table 3). Highest variation in each fertilizer plots occurred at the 45 DAS measurement. At 60 DAS, the range between the minimum value in 2JC and the maximum value in 5JC accounted for 11.98% in *T0*, 8.41% in *T1*, 32.33% in T2 and 20.09% in *T3*.

Similar to plant height, the number of leaves per plant also showed less significant variations among the fertilizer plots as well as the jhum cycles. Higher level of significance in number leaves per plant occurred at the 45 and 60 DAS measurements. Lower leaf production coincided with the lower level of fertilizer input and highest leaf production in highest level of fertilizer application.

Fertilizer application induced highly significant increase in aboveground biomass production showing similar trend with height and number of leaves (Table 3). The increase in aboveground biomass production from the minimum values in control plots to *T3* plots accounted for 27.76% in 2JC, 25.19% in 3JC and 24.00% in 5JC.

Significant response to the difference jhum cycles was observed with lowest aboveground biomass production in the most frequent jhum cycle of 2JC and highest production in the longest jhum cycle of 5JC. The aboveground biomass production in each of the fertilizer plots of 2JC was more comparable to their corresponding plots in 3JC than 5JC. The increase in aboveground biomass production from 2JC to 5JC was 14.52%, 17.25%, 18.70% and 11.15% in *T0*, *T1, T2* and *T3* plots respectively (Fig. 2).

Figure 2. Maize plant of different fertilizer plots of 5JC at 30 DAS.

Yield parameters

Number of cobs per plant was counted and

Table 3. Growth performance of maize plant under different levels of soil NPK fertilizer application in 2JC, 3JC and 5JC. Mean ± SE.

Parameter	Jhum cycle	To	T1	T2	T3	P <0.05	LSD (P<0.05)
Height 15 DAS (cm)	2J	13.87±0.26	14.56±0.23	15.43±0.14	15.70±0.17	***	0.70
	3J	14.33±0.41	15.20±0.20	15.63±0.08	16.00±0.15	**	0.86
	5J	14.96±0.17	16.50±0.55	16.26±0.23	16.36±0.24	*	1.30
		ns	*	*	Ns		
			1.30	0.63			
Height 30 DAS (cm)	2J	40.73±4.01	50.33±0.72	58.36±0.58	68.63±2.09	***	9.60
	3J	67.90±1.95	58.66±1.79	64.16±3.04	72.20±1.38	***	8.03
	5J	62.76±2.03	75.43±2.53	81.56±1.08	88.30±1.17	***	6.13
		**	***	***	***		
		14.86	8.33	17.40	16.13		
Height 45 DAS (cm)	2J	63.83±1.62	81.26±4.04	99.93±5.00	149.53±3.10	***	17.43
	3J	87.93±5.73	138.73±0.27	149.70±1.26	170.96±2.94	***	10.96
	5J	117±0.99	128.80±1.04	167.50±1.89	196.60±6.31	***	11.03
		***	***	***	***		
		21.41	57.46	17.80	21.43		
Height 60 DAS (cm)	2J	165.50±1.27	170.97±0.66	157.80±1.30	181.36±2.81	***	7.70
	3J	172.63±0.34	175.37±0.99	185.63±2.64	222.70±0.75	**	12.30
	5J	185.33±5.88	184.36±4.80	208.83±2.74	217.80±1.76	***	23.50
		*	*	***	**		
		12.70	13.40	23.20	16.56		
No. of leaves 15 DAS	2J	4.83±0.03	5.23±0.03	5.30±0.06	5.67±0.09	***	0.36
	3J	5.17±0.07	5.50±0.15	5.43±0.03	5.97±0.07	**	0.33
	5J	5.10±0.06	5.63±0.08	5.56±0.03	5.93±0.35	ns	
		*	NS	*	ns		
		0.26		0.20			
No. of leaves 30 DAS	2J	8.83±0.03	8.43±0.08	8.33±0.03	8.73±0.04	**	0.30
	3J	8.20±0.50	9.32±0.61	9.61±0.49	9.20±0.06	***	0.30
	5J	8.40±0.30	9.07±0.12	9.70±0.05	10.21±0.06	***	0.63
		ns	**	***	***		
			0.63	1.26	0.46		
No. of leaves 45 DAS	2J	9.97±0.09	10.27±0.15	11.07±0.09	11.73±0.09	***	0.66
	3J	10.10±0.06	10.53±0.15	12.30±0.06	12.46±0.08	***	0.43
	5J	11.90±0.06	11.94±0.05	12.23±0.09	13.33±0.23	***	1.06
		***	***	***	**		
		1.80	1.36	1.16	0.73		

No. of leaves 60 DAS	2J	11.83±0.09	12.30±0.06	12.16±0.08	12.47±0.09	**	0.30
	3J	12.37±0.09	12.23±0.03	12.83±0.07	13.50±0.06	***	0.46
	5J	12.57±0.03	12.87±0.12	13.50±0.12	13.80±0.06	***	0.32
		**	**	***	***		
		0.53	0.56	0.66	0.30		
Biomass at harvest dry. Wt. (kg)	2J	252.48±2.08	259.47±5.86	273.55±1.06	334.99±6.06	*	
	3J	276.21±0.54	280.59±1.58	297.01±4.22	348.69±2.26	ns	
	5J	353.81±6.90	323.47±1.99	300.32±2.75	285.33±4.60	ns	
		ns	ns	ns	ns		

ns = non significant value; * = <0.05; **= <0.01; *** = <0.001; LSD = Least significant difference of mean.

Table 4. Yield parameters under different levels of NPK fertilizer application in 2JC, 3JC and 5JC. Mean ± SE.

Parameter	Jhum cycle	To	T1	T2	T3	P<0.05	LSD (P<0.05)
Length of Cob (cm)	2J	17.43±0.23	18.57±0.22	19.47±0.03	19.7±0.31	*	1.23
	3J	18.70±0.25	19.93±0.15	20.07±0.15	20.60±0.12	***	1.13
	5J	20.63±0.18	21.07±0.30	21.20±0.15	21.93±0.30	*	0.8
		***	***	***	**		
LSD		1.26	1.13	0.6	0.9		
Kernel's row per cob	2J	12.07±0.15	12.60±0.17	12.77±0.09	13.17±0.15	**	0.567
	3J	12.93±0.18	13.33±0.12	13.53±0.09	13.80±0.06	**	0.40
	5J	13.60±0.12	13.90±0.06	13.97±0.12	14.03±0.12	ns	
		**	***	**	NS		
LSD		0.66	0.56	0.43	0.63		
Kernels per row	2J	24.87±1.20	27.53±1.43	28.90±0.06	30.50±0.89	*	4.03
	3J	27.90±0.38	28.93±0.72	29.67±0.47	31.73±1.16	*	2.80
	5J	33.57±0.34	34.10±0.46	35.40±0.55	35.50±0.21	**	1.40
		***	***	**	**		
		3.03	5.16	5.73	3.76		
Kernels Per cob	2J	301.56±17.93	342.97±25.16	360.29±2.06	397±11.58	*	54.02
	3J	367.13±9.39	394.12±3.39	401.69±13.17	493.12±18.25	*	44.99
	5J	445.45±12.24	482.05±11.30	494.40±10.65	496.95±4.89	**	36.59
LSD		65.57	87.92	41.40	57.83		
Grain yield (kg)	2J	6198.9±441.0	6953.0±359.5	7330.2±296.5	8157.6±354.4	*	1204.59
	3J	7538.9±224.1	7935.7±155.5	8477.4±83.5	9071.8±164.2	***	541.70
	5J	9058.0±84.4	9337.7±41.5	9689.0±217.7	9795.6±185.2	*	631.03
		**	***	**	***		
LSD		1339.09	982.71	1147.19	914.26		

Test weight (kg)	2J	304.36±6.25	305.07±7.76	305.07±10.58	308.00±5.08	ns
	3J	305.14±5.83	302.13±7.76	312.20±1.94	309.89±0.89	ns
	5J	315.28±5.85	305.47±4.63	308.48±4.82	308.25±8.77	ns
		ns	ns	ns	ns	
Harvest Index	2J	0.37±0.02	0.40±0.02	0.41±0.02	0.36±0.02	ns
	3J	0.39±0.02	0.44±0.02	0.40±0.01	0.41±0.01	ns
	5J	0.43±0.02	0.46±0.00	0.49±0.01	0.48±0.01	ns
		ns	ns	ns	ns	

ns = non significant value; * = <0.05; **= <0.01; *** = <0.001; LSD = Least significant difference of mean.

all the plants irrespective of difference levels of fertilizer application and jhum cycles produce only one harvestable cob, and the second cob, if produced, was under-developed and had no commercial value. So, only the first cob was considered in the yield parameters.

The length of cobs measured after harvest showed significant difference among the fertilizer plots in each jhum cycle (Table 4). Similar trend with shortest length of cob in *T0* plots and highest length in high fertilizer plots (*T2* & *T3*) was observed in all the three jhum cycles. The highest range in length of cob from 17.43±0.23 cm in (*T0*) to 19.70±0.31cm (*T3*) occurred in 2JC, and 5JC showed lowest ranged of 20.63±0.18 cm (*T0*) to 21.93±0.30 cm (*T3*). Significant difference of lowest value in 2JC and highest value in 5JC was also observed in each fertilizer plots among the three jhum cycles.

Number of kernel row per cob showed highly significant variation among the fertilizer treatment plots with lowest value in *T0* plot and highest value in *T3* plot ranging from 12.07±0.15 to 13.17±0.15 in 2JC, 12.93±0.18 to 13.80±0.06 in 3JC and, 13.60±0.12 to 14.03±0.12 in 5JC (Table 3). The comparison of the number of kernel row per cob of each fertilizer plot among the three jhum cycles also showed significant increase from 2JC to 5JC except in *T3* plots.

The average number of kernel per row also showed similar trend of lowest number in control plots (*T0*) and reaching maximum number in plot with highest level of fertilizer application (Table 4). Except 3JC, fertilizer application induced significant effect on number of kernel per row. The inter jhum comparison of each corresponding fertilizer plot showed highly significant variation in number of kernel per row.

The number of kernels per cob showed significant difference among the fertilizer plots which increases with the increase in fertilizer application (Table 4). The difference between the minimum and maximum values of kernels per cob accounted for an increase in 31.65%, 19.60% and 11.56% from their minimum value in 2JC, 3JC and 5JC respectively.

The dry grain yield extrapolated to a hectare area showed highly significant difference among the different fertilizer plots. *T0* plots represented lowest dry grain yield in all the three jhum cycles and the maximum grain yield coincided with maximum fertilizer input (*T3*) (Table 4). The increase from the minimum and maximum yield ranged from 6198.90±441.05 kg/ha to 8157.60±354.49 kg/ha in 2JC, 7538±224.14 kg/ha to 9071.87±164.22 kg/ha in 3JC and, 9058.04±84.41 kg/ha to 9795.66±185.29 kg/ha in 5JC accounted for 31.59%, 20.34% and 8.14% increase from their respective minimum values in 2JC, 3JC and 5JC.

Highly significant difference occurred in the grain yield among the different jhum cycles (Table 4). Lowest grain yield occurred in 2JC followed by 3JC and highest in 5JC. The maximum grain yield of 8157.60±354.49 kg/ha in 2JC was lower than the minimum yield of 9058.04±84.41 kg/ha in the control plot of 5JC.

The difference in yield between 2JC and 5JC in each fertilizer plot was 46.12%, 34.29%, 32.17% and 20.08% in *T0, T1, T2* and *T3* respectively.

The comparison of test weight among the fertilizer plots as well as each fertilizer plot of different jhum cycles showed no significant variations. Although comparatively higher value of harvest index (HI) was observed in 5JC, there were no statistically significant variations among the fertilizer plots and among each plot of the jhum cycles (Table 4).

From the result of the analysis of growth parameters and the yield parameters under different level of fertilizer application and different jhum cycles, it is evident that the soil NPK fertilizer input and the frequency of jhum cycle had profound effect in growth performance as well as in yield characteristics of the local '*mimpui*' variety of maize in Mizoram. Similar observation of improvement of growth and yield by soil fertilizer application was reported in Maize[10-12] and that omission of P or K fertilizer reduce maize yield by 17% and 19%.[13] The less significant variations in plant height and number of leaves at the initial stage of growth may be attributed to availability of nutrient in the germinating seed and the low nutrient requirement for the seedling growth which was met by the available soil nutrient even in the control plots.

The increase in length of cob with increasing level of fertilizer application indicated that soil nutrient availability is one of the crucial determining factors in yield parameters. The highest ranged in length of cob in 2JC followed by 3JC and 5JC indicated that the effect of fertilizer input was highest in the most intensive jhum cycle of 2JC.

The range in growth and yield parameters between the control plots and the high fertilizer application plots increasing from 5JC to 3JC and highest in 2JC implies that in the most frequent jhum cycle of 2JC, the low soil nutrient content was a strong limiting factor for growth and yield whereas the comparative lower range in 5JC indicated the lesser effect of soil fertilizer amendment in longer jhum cycle.

From this observation, it is obvious that under current practice of frequent jhum cycles, poor soil nutrient content is a strong limiting factor for the growth and yield of the *mimpui* maize variety. This may probably be attributed to NPK being part of the essential nutrients required for the promotion of vigorous above and below ground growth which enhances plant biomass production etc., thus leading to an efficient absorption and translocation of water and nutrients and, better interception of solar radiation and assimilation of carbon dioxide by photosynthetic tissues. Previous report stated the enhancement of N uptake by K application and that the girth of maize which is a determinant factor to withstand lodging against strong wind was positively influenced by the availability of soil K.[14]

The non-significant variation in test weight among fertilizer plots as well as among jhum cycles indicated that the fertilizer application or period of jhum cycles did not induce significant increase in kernel weight. The non-significant value of harvest index among fertilizer plots as well as among the jhum cycles implies that the biomass production corresponded with the grain yield. The length of cob, kernel row per cob, and kernels per row which eventually increased the number of kernels per cob were the determinants of grain yield rather than kernel weight under fertilizer application and longer jhum cycles.

The minimum grain yield of 6198 kg/ha of *mimpui* variety in this experiment is comparable to the previously reported maximum grain yield of 6300kg/ha under NPK treatment in dry savannah of Benin.[11] Other reports on productivity of maize showed much lower yield of <5000kg/ha in NPK treatment,[15] <4000kg/ha in ultisols soil of south eastern Nigeria,[16] <2000 kg/ha under shifting cultivation in Somotillo, Nicaragua.[17]

Maize is a nutrient demanding crop and due to its high uptake rate of available nitrogen, phosphorus and potassium from soil,[11] fertilizer application in the successive cropping season may be prerequisite in similar jhum cycles to supplement the nutrient removal of the previous crop. Also due to the acidic condition of the soil, careful monitoring in application of acidic fertilizer like urea needed to be conducted to prevent setting up of unfavourable soil condition such as aluminium toxicity.[18]

From this experiment, it is observed that the *mimpui* is a high yielding variety that could be promoted for commercial corn production. Considering the strong effect of NPK fertilizer in grain yield and at the same time the delicate soil condition under jhum cultivation, it is suggested 5 years jhum cycle with lower rate of fertilizer application (80:40:20 NPK kg/ha) may be adopted.

References

1. Grogan P, Lalnunmawia F & Tripati SK (2012). Shifting cultivation in steeply sloped regions: a, review of management options and research priorities for Mizoram state, Northeast India. *Agrofor Syst,* **84**, 163–177.
2. Saha R, Chaudhary RS & Somasundaram J (2012). Soil health management under hill agroecosystem of North East India. *AESS*, 1–9.
3. Bam M (2015). Jhum cultivation practices of the Galo of Arunachal Pradesh, *IJCR,* **7**, 20326–20329.
4. Tawnenga Uma S & Tripathi RS (1996). Evaluating second year cropping on jhum fallows in Mizoram, north-eastern India - Phytomass dynamics and primary productivity. *J Biosci*, **21**, 563–575.
5. Devi LN & Choudhury BU (2013). Soil fertility status in relation to fallow cycles and lasnuse practices in shifting cultivated areas of Chandel district Manipur, India. *IOSR-JAVS*, **4**, 1–9.
6. Anonymous (2007). Statistical Abstract, 2005–06, Department of Agriculture & Minor Irrigation, Government of Mizoram. Published by Directorate of Agriculture & Minor Irrigation, Mizoram, Aizawl.
7. Walkley A & Black IA (1934). An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci*, **37,** 29–37.
8. Bray RH & Kurtz (1945). Determination of total organic and available forms of phosphorus in oils. *Soil Sci*, **59**, 39–45.
9. Jackson ML (1973) *Soil Chemical Analysis*. 1st edn. Prentice Hall of Indian Pvt. Ltd. London, pp. 255–300.
10. Onasanya RO, Aiyelari OP, Onasanya A, Oikeh S, Nwilene FE & Oyelakin OO (2009). Growth and yield response of maize (*Zea mays* L.) to different rates of nitrogen and phosphorus fertilizers in Southern Nigeria. *WJAS,* **5**, 400–407.
11. Bashir N, Malik SA, Mahmood S, Mahmood-ul-Hassan, Athar H & Athar M (2012). Influence of urea application on growth, yield and mineral uptake in two corn (*Zea mays* L.) cultivars. *Afr J Biotechnol*, **11**, 10494–10503.
12. Admas H, Gebrekidan H, Bedadi B & Adgo E (2015) Effect of organic and inorganic fertilizers on yield and yield components of Maize at Wujiraba watershed, north-western highlands of Ethiopia. *Am J Plant Nutr Fert Technol*, **5**, 1–9.
13. He H, Li W & Tu S (2012). Balanced fertilizer promoted yield and quality of waxy Maize in Chongqing. *Better crops,* **96**, 17–19.
14. Brar, MS, Sharma P, Singh A & Saandhu SS (2012). Nitrogen Use Efficiency (NUE), Growth, Yield Parameters and Yield of Maize (*Zea mays* L.) as Affected by K Application. *Res Fin*, **30**, 1–25.
15. Egbe EA, Fonge BA, Mokake SE, Besong M & Fongod AN (2012). The effects of green manure and NPK fertilizer on the growth and yield of maize (*Zea mays* L) in the mount Cameroon region. *Agric Biol J N Am*, **3**, 82–92.
16. Okonkwo CI, Onyibe C, Nwite J, Igwe TS, Njoku C & Mbah CN (2012). Physical characteristics and maize grain yield in an ultisol in south eastern Nigeria amended with four animal manures. *IRJAS*, **2**, 77–80.
17. FAO (2016), Save and Grow in practice: maize, rice, wheat. A guide to sustainable cereal production. ISBN 978-92-5-108519-6 : http://www.fao.org/3/a-i4009e.pdf
18. Marschner H (1995). The soil root interface (rhizosphere) in relation to mineral nutrition. In: *Mineral Nutrition of Higher Plants*. 2nd ed. New York (USA): Academic Press Inc. pp. 537–594.