ISSN:2321-1156

International Journal of Innovative Research in Technology & Science(IJIRTS)

Mineral composition of maize (*Zea mays L.*) in response to neem seed crush blended urea in a sandy loam of Maiduguri, Nigeria

[1]Makinta, G., [1]Kwari, J. D., [1]Ngala, A. L., [1]Buji, I. B., and [1]Adamu, I., [1] Department of Soil Science, Faculty of Agriculture, University of Maiduguri

Abstract

A field experiment was conducted in a sandy loam (*Typic Ustipsamment*) at the University of Maiduguri Faculty of Agriculture Teaching and Research Farm to determine the effect of neem (*Azadirachta indica, J*.) seed crush blended urea on the nutrient concentration and uptake by maize. The experiment was a 4 x 3 factorial, laid out in a randomized complete block design with three replicates. The factors and treatments comprised four levels of nitrogen (0, 50, 100 and 150 kg N/ha) in form of urea and three levels of neem seed crush (0, 15 and 30% by weight of urea-N applied). The results indicated that fertilizer N singularly or in combination with neem seed crush (NSC) significantly influenced the concentration and uptake of N, P, K and Ca both in maize grain and stover. However, Magnesium was not significantly affected by treatment combinations both in maize grain and stover. NSC treatment levels did not significantly affect mineral accumulation both in maize grain and stover. The highest nutrient accumulation and uptake by maize were recorded by the treatment combination of 150 kg N/ha and NSC at 30% by weight of urea-N used. The results generally indicated that nitrification inhibitory properties of the neem material enhanced nutrient concentration and uptake in maize crop resulting in better dry matter accumulation.

Key Words: Nitrogen fertilizer, nitrification inhibitor, N losses, nutrient concentration, sandy loam

Introduction

The uptake and distribution of nutrients to different parts of maize plant have been found to vary with the native fertility of the soil, application of fertilizers, the growth stage of the plant and environmental conditions (Kogbe and Adediran, 2003 [1]). Several workers have found that fertilization with N increased concentration of N and P in the plant system (Selles *et al*., 1995 [2], Hussaini *et al*., 2008 [3]). Chemical analysis of plant nutrients showed some relationship of plant nutrient supply and yield of plants. As there is synergy between N supply and uptake and accumulation of other nutrients in plants, (Marschrer, 1997 [4]) application of N fertilizers should boost maximum yield of crops including maize.

However, the low N use efficiency of crops due to N dynamics seriously undermined the attainment of maximum yield potential by field crops. The low N efficiency is attributed to rapid nitrification and subsequent loss of N by leaching and denitrification (Havlin *et al.*, 2005 [5]). Such losses constitute an economic set back to the farmer due to the high cost of N fertilizer. Also, loss of N either by leaching as NO_3^- or denitrification as N_2O may pollute ground water by excess NO_3^- or deplete the ozone layer by N_2O contributing to global warming (Malla *et al*., 2005 [6]). To improve the N use efficiency agronomists devised application of nitrification inhibitors along with fertilizer N sources to curtail N loses (Hermann *et al*., 2007 [7]; Yu *et al*., 2007 [8]). Nitrification inhibitors were found to suppress microbial enzymes responsible for conversion of NH_4^+ to NO_3^- thereby slowing down the formation of NO_3^- which is easily lost through leaching (Prasad and Parmer, 1995 [9]). This results in preponderance of NH_4^+ over NO_3^- in the soil and root zone, since NH_4^+ gets fixed in the cation exchange complex. This influences N uptake by plants, N nutrition and yield (Majumdar, 2007 [10]).

Various chemically synthesized substances have been introduced as nitrification inhibitors and their efficacy in N conservation and increasing crop yield had been demonstrated Prasad and Parmer, 1995 [9]). However the large scale use of these chemicals is seriously limited by cost implications, availability and regulatory control (Majumdar, 2007 [10]). Recently, botanical inhibitors of non-edible oil seeds have been prepared and tested for their efficacy in crop production Morhaty *et al*., 2008 [11]).

Among the non-edible oil seeds, neem (*Azadirachta Indica J.*) and Karanja (*Pongamia Pinnata, Pierre*) and their isolates have been evaluated and found to be effective in retarding nitrification in soil (Majumdar, 2002 [12]; Sahrawat and Parmer, 1975 [13]). This study is therefore designed to assess the effect of neem seed crush blended urea fertilizer on mineral nutrient uptake and accumulation in maize in a sandy loam semi-arid soil

.

Materials and Methods

A field experiment was conducted in the University of Maiduguri Faculty of Agriculture Teaching and Research Farm to evaluate the effect of neem seed crush treated urea on mineral composition of maize in a sandy loam in semi-arid, Nigeria. The site was located at $11^0$50'N and $12^0$15'E, with an altitude of 345m above sea level. Annual rainfall and monthly temperature ranges from 440-866mm and 28.5-32.8 ^{O}C, respectively. The soil of the trial site had been classified as *Typic Ustipsamment* according to the USDA classification (USDA Soil Survey Staff 2003 [14]).

Soil sample collection and analysis

Representative soil samples were taken at the depth of 0-15cm from ten different locations and analyzed for physico-chemical properties before treatment application. The soil samples were air-dried crushed and passed through 2-mm sieve and kept in air-tight bags before analysis. Exchangeable K, Na, Ca and Mg were extracted with a neutral solution of 1N NH_4OAc (pH 7.0). Potassium, and Na were determined by flame photometer, Ca and Mg by the atomic absorption spectrophometer (AAS). Soil pH was measured in 1:2.5 soil: H_2O suspension using glass electrode digital pH meter. Particle size distribution was determined by Bouyoucos hydrometer model No. 4427 ASTM 152H according to the procedure described by Gee and Orr, 2002 [15]. The field capacity was determined by the procedure described by Black (Dane and Topp, 2002[16]).

Preparation of the neem seed crush

Mature neem seeds were collected and thoroughly dried in a shade. The seeds were crushed and winnowed to separate shells from the kernels. Care was taken to ensure that only brown kernels were used and those not of this colour sorted out and removed. The kernels were then ground to fine powder using clean mortar and pestle. The neem kernel powder was passed through 1mm-sieve and weighed at rates of 0, 15 and 30% by weight of urea applied. The treatments were kept in polythene bags ready for field application. To obtain a fine neem powder and urea fertilizer blend, acetone was applied to the mixture at the rate of 2 ml/100 g of urea.

Treatments and experimental design

A 4 x 3 factorial experiment was arranged in a randomized complete block design with three replicates. The factors and treatment levels were N (0, 50, 100, and 150 kg/ha), in the form of urea and neem seed crush (0, 15 and 30% by weight of urea used). Phosphorus and potassium were applied at the rates of 60 kg P_2O_5 and 30 kg K_2O per hectare in the form of single superphosphate and muriate of potash, respectively as a basal dose at planting. The net plot size was 5 m x 4 m with an alley of 1 m between plots. The maize variety, DMR-ESR (W) was chosen as the test crop for its good adaptability to the semi-arid agro ecological zone (FPDD, 1989 [17]).

Plant sample collection and analysis

Samples for plant tissue analysis were taken from each plot, dissected into grains, cobs and stover and oven-dried at 70 ^{O}C to constant weight before grinding with a Wiley mill and passed through 0.5 mm sieve. The samples were chemically analyzed to determine their contents of nitrogen, phosphorus, potassium, calcium and magnesium. Concentrations of all the elements were expressed on a dry weight basis and the nutrient uptake and accumulation were calculated using the respective dry weights.

Total nitrogen concentration was determined by the micro-Kjeldhal method. For the determination of the remaining elements, plant samples were first subjected to wet digestion. From the digest, various elements were read using appropriate procedures. Phosphorus content was determined colometrically on spectrophotometer using the Vanado-Molybdate yellow method. A flame photometer was used to determine K, while Ca and Mg were determined using atomic absorption spectrophotometer (AAS).

Statistical analysis

Data collected from field observations were subjected to the analysis of variance (ANOVA). The treatment means were compared using the least significant difference and the Duncan multiple range test (DMRT) methods. The statistical analyses were conducted based on the procedure described by Gomez and Gomez, 1984 [18].

Results and Discussion

Soil physical and chemical properties

The physico-chemical properties of the soils of the experimental site was presented in Table 1. The soil of the trial site was sandy loam in texture and of neutral reaction. The organic carbon and total N contents were low, probably due to low turnover of plant biomass and high rate of organic matter mineralization as suggested by Chiroma *et al.* (2002[19]). The C : N ratio was narrow apparently due to high rate of organic matter oxidation. The low CEC of the soils may be due to predominant sandy fraction of the soil. Rayar and Haruna, (1988 [20]) observed that the general low organic matter content and low N status of these sandy soils markedly affected their productivity.

Effect of nitrogen rates and neem seed crush levels on nutrient concentration in maize grain

The result on the main effects of nitrogen and neem seed crush (NSC) on nutrient concentration of maize grain is presented in Table 2. The result shows that there is a significant ($P < 0.05$) effect of N treatment levels on the nutrient concentration. N levels at 150 kg N ha^{-1} recorded an increase in N, P, K, Ca and Mg content of 138.4, 239.0, 28.0, 67.0 and 30.0% over the control, respectively. At the 100 kg N ha^{-1} level increase in nutrient contents were 69.0, 115, 68, 100 and 35 % over the control for N, P, K, Ca and Mg, respectively. The N level at 50 kg ha^{-1} which is also significantly ($P < 0.05$) higher than the control, recorded N, P, K, Ca and Mg content of 67.0, 108.0, 43.0, 67 and 15% increase over the control. The results clearly showed that great degree of synergy existed between N application and accumulation of other mineral nutrients in maize grain. This may be due to production of small roots and root hairs which increase the surface area for absorption of nutrients by maize as opined by Eltelib *et al*. (2006 [21]).

Table 1: Physico-chemical properties of the experimental soil

Properties	**Value**
pH (1:2.5) H_20	6.85
EC (dSm^{-1})	7.5×10^{-3}
Organic carbon (g/kg)	4.40
Total N (g/kg)	0.80
C:N ratio	5.50
Available P(Bray II, mg/kg)	5.30
Exchangeable, Na (Cmol (+)/kg)	1.20
Exchangeable, K (Cmol (+)/kg)	0.29
Exchangeable, Ca (Cmol (+)/kg)	4.27
Exchangeable, Mg (Cmol (+)/kg)	2.18
Exchangeable, acidity (Cmol (+)/kg)	0.30
ECEC (Cmol (+)/kg)	8.24
Field capacity (%)	38.45
Particle size analysis (g/kg)	
Sand	701
Silt	153
Clay	146
Textural class	Sandy loam

The main effect of nitrogen rates and neem seed crush (NSC) levels on the nutrient concentration in maize grain is indicated in Table 2. NSC levels only significantly influenced N and P content of maize grain. The concentrations of K, Ca and Mg are not significantly affected by NSC additions. At the 15% NSC level the N and P contents increased by 16.10 and 4.0% over the control, while at the 30% NSC level, N and P contents of maize grain were increased by 5.1 and 28.0% over the control, respectively. The effect of NSC may not be unconnected with the nitrification inhibitory properties of NSC to conserve the added N which is utilized by maize crop for better root function and absorption of N and P, thus concurring with the findings of Schwab and Murdock (2010 [22]) and Goos (2008 [23]).

Table 2: Effect of nitrogen rates and neem seed crush levels on nutrient concentration (g/kg) in maize grain

Treatments	**N**	**P**	**K**	**Ca**	**Mg**
N rate (kg/ha)					
0	13.80	1.30	14.00	3.00	20.00
50	23.10	2.70	20.00	5.00	23.00
100	23.30	2.80	23.50	6.00	27.00
150	32.90	4.40	31.90	5.00	26.00
SE±	0.73	0.35	0.30	0.70	0.60
$LSD_{(0.05)}$	1.53	0.73	0.60	1.68	1.83
NSC level (%)					
0	21.80	2.50	24.10	0.40	28.00
15	25.30	2.60	23.80	0.50	22.00
30	24.20	2.20	23.00	0.60	26.00
SE±	1.10	0.32	0.22	0.10	0.40
$LSD_{(0.05)}$	2.30	0.68	ns	ns	ns

ns = not significant.

Effect of nitrogen rates and neem seed crush levels on nutrient concentration in maize stover

The result in Table 3 shows the main effects of N and NSC on nutrient concentration in maize stover. The N treatment levels significantly ($P < 0.05$) affected the concentration of nutrients in maize stover. The response generated by N levels was linearly increased from the lowest to the highest treatment levels. The highest percent increase over the control was recorded by 150 kg N ha^{-1}. The magnitude of the increase for N, P, K, Ca and Mg were 65.2, 193.3, 66.0, 61.0 and 36.4% over the control, respectively. The N level at 100 kg ha^{-1} also significantly ($P < 0.05$) increased the nutrient content of maize stover. The percent increase over control were 26.0, 86.7, 55.0, 56.52 and 27.30% for N, P, K, Ca and Mg contents, respectively. The positive effect of N fertilization on nutrient concentration and uptake by maize was corroborated by Yu *et al*. (2007 [8]).

The NSC levels also significantly (P < 0.05) influenced N, P. K concentration of maize stover, while Ca and Mg contents of stover were not significantly affected. The NSC at 30% increased maize stover concentration of N, P, K, by 25.4, 28.0 and 4.50% over the control, respectively. This shows that the neem material have enhanced N supply to maize crop, resulting in increased nutrient concentration by reducing N losses as opined by Frye (2006 [24]).

Table 3: Effect of nitrogen rates and neem seed crush levels on nutrients concentration (g/kg) in maize stover

Treatments	**N**	**P**	**K**	**Ca**	**Mg**
N rate (kg/ha)					
0	1.47	0.14	11.49	0.32	2.13
50	13.76	1.61	11.91	2.98	13.70
100	27.24	3.27	27.50	7.01	31.56
150	47.35	6.33	45.92	7.02	37.42
SE±	0.73	0.25	4.30	0.70	0.60
$LSD_{(0.05)}$	1.53	0.72	8.60	1.52	1.53
NSC level (%)					
0	16.05	1.84	17.75	0.30	20.62
15	21.50	2.21	20.22	0.42	18.70
30	18.76	2.50	17.83	0.47	20.16
SE±	1.10	0.32	0.22	0.10	0.40
$LSD_{(0.05)}$	3.72	0.50	0.60	0.36	ns

ns = not significant

Effect of nitrogen rates and neem seed crush levels on maize grain nutrient uptake

The main effects of N and NSC levels on nutrient uptake and accumulation by maize grain were presented in Table 4. The results showed that N levels significantly (P < 0.05) affected the nutrient uptake by maize grain. The N levels at 150 kg N ha^{-1} generated highest nutrient uptake values with corresponding increase in N, P, K, Ca and Mg contents by over 3-fold compared with the control treatment. At the 50 kg N ha^{-1} level, the uptake of N, P, K, Ca and Mg increased by 83.61, 105, 3.60, 83.13 and 54.31% over the control treatment. The trend of the increase is linear from the control to the highest N treatment level. Similarly, the NSC treatment levels significantly (P < 0.05) increased the nutrient uptake by maize as presented in Table 4. However, Mg uptake by maize was not significantly affected by the NSC treatments. The results demonstrated that the botanical material, neem seed crush blended with the urea fertilizer treatments improve the efficiency of urea N as suggested by Sa'ad *et al*. (1996 [25] and Majumdar (2007 [10]).

Table 4: Effect of nitrogen rates and neem seed crush levels on maize grain nutrient uptake (kg/ha)

Treatments	**N**	**P**	**K**	**Ca**	**Mg**
N rate (kg/ha)					
0	15.80	1.50	10.00	2.30	1.10
50	17.60	2.70	12.50	2.10	1.30
100	19.90	2.80	15.50	3.60	1.40
150	26.10	4.40	16.60	3.70	1.50
SE±	0.72	0.25	2.10	0.50	0.20
$LSD_{(0.05)}$	1.51	0.53	4.70	1.10	0.40
NSC (level %)					
0	19.70	2.50	13.10	3.00	1.20
15	19.10	2.60	13.30	3.10	1.40
30	20.20	3.20	14.60	3.50	1.50
SE±	0.70	0.20	0.60	0.53	0.20
$LSD_{(0.05)}$	1.50	0.50	1.30	ns	ns

ns = not significant

Effect of nitrogen rates and neem seed crush levels on maize stover nutrient uptake

The results in Table 5 indicate the main effect of N and NSC levels on nutrient uptake in maize stover. N levels showed significant (P < 0.01) effect on the nutrient uptake in maize stover. N level at 50 kg/ha recorded 116, 249, 74.61, 77.15 and 129 % increases in nutrient uptake of N, P, K, Ca and Mg over the control, respectively. N levels at 100 and 150 kg/ha recorded even higher significant increases in nutrient uptake of maize stover than that at 50 kg N/ha level. This great response was due to low N contents of these soils as reported by Rayar and Haruna (1988 [20]). This indicates that these soils require N application to achieve maximum crop production potential in field crops. The NSC levels significantly affected the N, P, K uptake by maize stover while Ca and Mg were not significantly affected.

Effect of nitrogen rates and neem seed crush levels on maize total biomass nutrient uptake

The main effects of N and NSC on the total above-ground nutrient uptake by maize is indicated in Table 6. The results on N levels showed a highly significant (P < 0.01) effect on the total above-ground nutrient uptake by maize. The total nutrient uptake tremendously increased with increasing N levels, with the highest values recorded by N at 150 kg ha^{-1}. The other N levels of 50 kg N ha^{-1} and 100 kg N ha^{-1} equally recorded highly significant (P < 0.01) effects on the total above- ground nutrient uptake of maize. The positive effect of N application on total nutrient uptake of maize was earlier reported by Ibrahim (1995 [26]) who observed that N addition had enhanced N supply and uptake of nitrogen and other mineral nutrients.

Table 5: Effect of nitrogen and neem seed crush levels on nutrient uptake in maize stover (kg/ha)

Treatment	**N**	**P**	**K**	**Ca**	**Mg**
N (kg/ha)					
0	18.34	1.74	16.11	2.67	1.28
50	39.60	6.08	28.13	4.73	2.93
100	59.82	8.42	46.59	10.82	4.21
150	90.60	15.27	57.62	12.84	5.20
SE	4.30	0.35	2.10	0.50	0.20
LSD $_{(0.05)}$	8.86	0.73	4.70	1.10	0.45
NSC (%)					
0	48.12	6.40	32.00	7.33	2.90
15	48.90	6.65	34.02	7.93	3.60
30	48.86	7.74	35.32	8.50	3.63
SE	0.70	0.20	0.60	0.61	0.20
LSD $_{(0.05)}$	ns	0.50	1.30	ns	ns

ns = not significant.

Table 6: Effect of nitrogen rates and neem seed crush levels on maize total above-ground biomass nutrient uptake (kg/ha)

Treatment	**N**	**P**	**K**	**Ca**	**Mg**
N rate (kg/ha)					
0	19.81	1.88	17.60	2.99	3.41
50	53.36	7.69	40.04	7.71	16.63
100	87.06	11.09	74.09	17.83	35.77
150	138.15	21.60	103.5	20.04	42.62
SE±	3.20	0.70	8.40	1.20	0.80
LSD $_{(0.05)}$	6.73	1.43	13.30	2.78	1.53
NSC level (%)					
0	64.17	8.30	49.75	7.63	23.32
15	70.40	8.86	54.24	8.35	22.30
30	67.53	10.24	53.15	8.97	23.79
SE±	7.41	0.52	0.82	0.70	0.68
LSD $_{(0.05)}$	ns	1.84	1.93	ns	ns

ns = not significant.

The NSC treatment levels significantly ($P < 0.05$) affected P and K uptake by maize but failed to impact a significant uptake on N, Ca and Mg. Ibrahim (1995 [26]) found that N application enhanced N and P uptake remarkably. A similar effect of neem cake treated N application on N, P and K uptake was reported by Rayar and Bello (1990 [27]) on wheat crop. The increased uptake by corn was due to increased N supply and improved physiological capacity of corn to absorb nutrients (Teyker, 2006 [28]).

Effect of combined application levels of nitrogen and neem seed crush on nutrient concentration and total uptake by maize

The results on the effect of combined application of nitrogen (N) and neem seed crush (NSC) on nutrient concentration in maize grain is presented in Table 7. The interaction of N and NSC levels significantly ($P < 0.01$) affected nitrogen, phosphorus, potassium and calcium concentrations in maize grain but failed to influence the magnesium concentration. The increase in the mineral content showed a linear trend across the treatments from the lowest to the highest levels. The highest combined treatment level of 150 kg Nha^{-1} and NSC at 30% applied N recorded the greatest increases in the mineral concentration of maize grain. At this combined level, increases in N, P. K and Ca contents were 111.0, 336, 101.91 and 100.0% over the control respectively. Similarly, the 100 kg N ha^{-1} with various levels of NSC both at 15 and 30% recorded significant responses in mineral nutrient concentration in maize grain. The increases due to the combined application resulted from the enhanced ammonium supply to maize crop which stimulated growth of extensive rooting system leading to increased absorption of mineral nutrient by maize. A similar finding was reported on wheat crop by Rayar and Bello (1990 [27]) and Bundy (2004 [29]) on maize crop.

Table 7: Effect of combined levels of nitrogen and neem seed crush on nutrient concentration (g/kg) in maize grain

N × NSC	**N**	**P**	**K**	**Ca**	**Mg**
0 × 0	11.40^{d}	1.10^{e}	14.20^{g}	0.30^{d}	2.80
0 × 15	14.70^{d}	1.60^{d}	13.70^{g}	0.30^{d}	2.00
0 × 30	15.30^{d}	1.80^{d}	14.00^{g}	0.30^{d}	3.10
50 × 0	23.80^{bc}	2.30^{cd}	20.20^{de}	0.40^{c}	2.00
50 × 15	28.30^{b}	3.40^{bc}	20.60^{d}	0.50^{b}	2.00
50 × 30	23.10^{bc}	2.40^{cd}	19.30^{f}	0.40^{c}	2.10
100 × 0	20.70^{bc}	2.60^{c}	20.80^{cd}	0.50^{b}	2.00
100 × 15	25.30^{b}	2.50^{cd}	21.10^{c}	0.50^{b}	2.10
100 × 30	23.90^{bc}	3.40^{bc}	22.40^{bc}	0.60^{a}	2.20
150 × 0	34.30^{a}	4.00^{b}	25.40^{b}	0.50^{b}	3.10
150 × 15	33.30^{ab}	4.10^{ab}	27.70^{ab}	0.60^{a}	2.40
150 × 30	37.40^{a}	5.00^{a}	28.50^{a}	0.60^{a}	2.70
SE±	1.70	0.40	0.48	0.02	ns

Means followed by the same letter within a column are not significantly different at 5% level of probability (DMRT).

The results in Table 8 also indicate the effect of combined levels of N and NSC on nutrient content of maize stover. These results also show a significant effect on N, P, K and Ca contents of stover while Mg concentration is not significantly affected. As expected, the mineral concentration of stover increased with increasing levels of combined treatments. The magnitude of increase for N, P, K and Ca were 97.22, 355, 100 and 95% over the control, respectively. The increase in nutrient concentration is not unconnected with the preponderance of NH_4-N in the root zone which stimulated the root's capacity to absorb mineral nutrients as opined by Marshner (1997 [30]) and Teyker (2006 [28]).

Table 8: Effect of combined application of N and NSC on nutrient concentration of maize stover (g/kg)

N × NSC	N	P	K	Ca	Mg
0 × 0	14.40^{e}	0.50^{f}	9.8^{b}	2.20^{c}	1.02
0 × 15	16.20^{d}	0.60^{f}	10.0^{b}	2.30^{b}	1.20
0 × 30	16.80^{d}	1.90^{e}	10.2^{b}	2.50^{bc}	1.20
50 × 0	9.60^{cd}	1.30^{de}	12.2^{b}	3.00^{b}	1.30
50 × 15	16.00^{de}	3.30^{c}	12.40^{a}	3.00^{b}	1.40
50 × 30	17.20^{d}	2.70^{d}	13.00^{a}	3.30^{b}	1.30
100 × 0	20.60^{bc}	3.60^{b}	14.10^{a}	3.50^{ab}	1.20
100 × 15	20.80^{bc}	2.90^{bc}	14.60^{a}	3.40^{ab}	1.40
100 × 30	18.40^{cd}	3.90^{ab}	17.70^{a}	3.80^{ab}	1.60
150 × 0	24.20^{bc}	2.80^{bc}	16.30^{a}	3.10^{ab}	1.40
150 × 15	25.80^{ab}	3.20^{b}	16.20^{a}	3.60^{ab}	1.50
150 × 30	28.40^{a}	4.00^{a}	17.40^{a}	4.20^{a}	1.50
SE±	2.60	0.31	1.50	1.00	Ns

Means followed by the same letter within a column are not significantly different at 5% level of probability (DMRT).

The interaction effects of N and NSC on maize grain nutrient uptake is presented in Table 9. The N and NSC combined levels significantly influenced nutrient uptake by maize grain. The increase is linear from the lowest to the highest treatment levels. Although the highest combined treatment of 150 kg N ha^{-1} and NSC at 30% recorded the highest mineral uptake by maize grain, the N at 100 kg ha^{-1} level combined with NSC at 30% generated a comparable response by recording a greater uptake per unit urea – N applied. These results again showed the nitrification inhibitory properties of the neem product which enhanced N and other nutrients uptake by maize as corroborated the findings of Alofe and Obigbesan (1995 [31]) and Laijawala (2010 [32]). The inhibiting nitrification of applied N is important because the NH_4^-N form is held tightly by soil particles and not subject to leaching and denitrification losses resulting in better uptake by maize crop Schwab and Murdock (2010 [22]).

The results in Table 10 showed that combined application of N and NSC levels significantly influenced the mineral nutrient uptake by maize stover. A linear response in nutrient uptake was discernible due to the increasing combined N and NSC treatments. The highest nutrient uptake by maize stover was recorded by 150 kg N ha^{-1} and NSC at 30%. A similar result was recorded by Rayar and Bello (1990 [27]) who reported tremendous uptake of nutrients by wheat crop supplied with neem cake coated urea – N. The levels of nutrient accumulation in maize stover however declined in plots with zero nitrogen treatments with increasing NSC levels. This was attributed to biological immobilization triggered by the neem material Ashworth (1986 [33]).

Table 9: Effect of combined levels of N and NSC on nutrient uptake by maize grain (kg/ha)

N × NSC	N	P	K	Ca	Mg
0 × 0	1.56^{d}	0.15^{f}	1.95^{f}	0.04^{f}	0.25^{d}
0 × 15	1.93^{d}	0.21^{f}	1.80^{f}	0.04^{f}	0.26^{d}
0 × 30	0.76^{d}	0.09^{f}	0.70^{f}	0.02^{f}	0.10^{d}
50 × 0	14.06^{c}	1.44^{de}	12.63^{e}	0.25^{e}	1.25^{c}
50 × 15	14.71^{c}	2.15^{d}	13.01^{de}	0.32^{de}	1.26^{c}
50 × 30	12.26^{c}	1.27^{e}	10.24^{e}	0.21^{e}	1.12^{c}
100 × 0	17.50^{c}	2.23^{cd}	17.84^{d}	0.43^{d}	1.72^{c}
100 × 15	31.47^{b}	2.86^{c}	26.25^{c}	0.62^{cd}	2.61^{b}
100 × 30	35.22^{a}	4.50^{b}	29.55^{bc}	0.80^{ab}	2.90^{b}
150 × 0	32.20^{ab}	4.37^{bc}	33.70^{b}	0.66^{c}	4.11^{a}
150 × 15	39.10^{a}	6.12^{ab}	41.33^{a}	0.50^{a}	3.60^{ab}
150 × 30	41.13^{a}	7.21^{a}	42.80^{a}	0.90^{a}	4.05^{a}
SE±	3.92	0.92	2.10	0.05	0.28

Means followed by the same letter within a column are not significantly different at 5% level of probability (DMRT).

Table 10: Effect of combined levels of nitrogen and neem seed crush on nutrient uptake by maize stover (kg/ha)

N × NSC	N	P	K	Ca	Mg
0 × 0	21.13^{fg}	1.61^{g}	14.40^{g}	3.23^{c}	1.47^{b}
0 × 15	17.01^{g}	1.70^{g}	10.50^{g}	2.42^{c}	1.26^{b}
0 × 30	16.24^{g}	1.74^{g}	9.86^{g}	2.43^{c}	1.16^{b}
50 × 0	40.18^{de}	4.72^{f}	25.01^{f}	6.15^{bc}	2.67^{b}
50 × 15	43.50^{d}	9.24^{c}	33.72^{de}	8.20^{b}	3.81^{ab}
50 × 30	34.11^{ef}	4.76^{f}	25.78^{ef}	6.54^{b}	2.58^{b}
100 × 0	58.03^{c}	7.32^{e}	39.72^{cd}	9.86^{b}	3.38^{ab}
100 × 15	67.95^{bc}	8.17^{de}	47.70^{bc}	11.43^{ab}	4.57^{a}
100 × 30	54.00^{de}	9.97^{c}	51.91^{b}	11.15^{ab}	4.70^{a}
150 × 0	83.10^{b}	13.73^{b}	55.96^{b}	10.64^{ab}	4.81^{a}
150 × 15	82.50^{b}	13.11^{b}	51.80^{b}	11.51^{ab}	4.80^{a}
150 × 30	107.7^{a}	18.96^{a}	65.98^{a}	15.93^{a}	5.70^{a}
SE±	5.91	0.71	3.50	2.50	1.15

Means followed by the same letter within a column are not significantly different at 5% level of probability (DMRT)

The interaction effect of N and NSC application showed significant ($P < 0.05$) effect on the total nutrient uptake by maize (Table 11). The highest nutrient uptake by maize was recorded by the combined rate of 150 kg N and NSC at 30% which showed tremendous increase in N, P, K, Ca and Mg uptake by maize crop. This is attributed to mobilization of large portion of N and P and smaller portions of other nutrients for grain development. Apart from the spectacular increases recorded by 150 kg N and NSC at 30% level, the combinations of 100 kg N with NSC at 15% and 30% both showed comparable responses to that of 150 kg N application alone, showing that there is accrued benefit when neem material is applied along with the urea fertilizer. The result generally confirmed the conjecture that applying fertilizer N with inhibitors improve the N use efficiency of crops by enhancing N supply Nelson and Huber (2001 [34]) and Laijawala (2007 [32]). Consequently, urea N is judiciously utilized by maize crop to achieve maximum production, and save cost on fertilizer N inputs.

Table 11: Effect of combined levels of nitrogen and neem seed crush on maize total above-ground nutrient uptake (kg/ha)

N × NSC	N	P	K	Ca	Mg
0 × 0	22.13^{g}	1.76^{f}	16.35^{f}	3.27e	1.72^{d}
0 × 15	18.94^{g}	1.91^{f}	12.30^{f}	2.46e	1.52^{d}
0 × 30	17.04^{g}	1.83^{f}	10.56^{f}	2.43^{e}	1.26^{d}
50 × 0	54.24^{ef}	6.16^{e}	37.64^{e}	6.40^{d}	3.92^{c}
50 × 15	58.21^{e}	11.39^{cd}	46.73^{de}	8.52^{cd}	5.07^{c}
50 × 30	46.37^{f}	6.05^{e}	36.02^{e}	6.75^{d}	3.70^{c}
100 × 0	75.53^{d}	9.55^{d}	57.56^{d}	10.29^{bc}	5.10^{c}
100 × 15	99.42^{c}	11.03^{d}	73.95^{c}	12.05^{b}	7.18^{b}
100 × 30	89.22^{c}	14.47^{c}	81.46^{bc}	11.95^{b}	7.60^{b}
150 × 0	115.3^{b}	18.10^{b}	89.66^{b}	11.30^{bc}	8.92^{ab}
150 × 15	121.6^{b}	19.23^{b}	93.13^{b}	12.41^{b}	8.40^{ab}
150 × 30	148.8^{a}	26.17^{a}	108.8^{a}	16.83^{a}	9.75^{a}
SE±	4.93	1.32	5.08	1.22	0.73

Means followed by the same letter within a column are not significantly different at 5% level of probability (DMRT).

Conclusion

The study indicated that N application alone and in combination with neem seed crush increased the mineral nutrient concentration in grain and stover and the total above ground uptake by maize. The nutrient accumulation in maize grain was greater than that of the stover. The result demonstrated that 100 kg N ha^{-1} and NSC at 30% recorded better nutrient uptake than N at 150 kg ha^{-1} alone. Combined application of N and NSC at 150 kg ha^{-1} and NSC at 30% was the best as this interaction increased N, P, K and Ca concentration and uptake in maize. This shows that the botanical inhibitor treated N was better utilized by maize plant.

Acknowledgments

The authors are thankful to the University of Maiduguri for the support to develop this document.

References

[1] J. O. S. Kogbe and J. A. Adediran. Influence of nitrogen, phosphorus and potassium on the yield of maize in the Savanna zone of Nigeria. African Journal of Biotechnology. Vol. 2(10) pp 345-349. 2003.

[2] F.C. Selles, A. Campbell and R. P. Zeutner. Effect of cropping and fertilization on plant and soil phosphorus. Soil Science Society of American journal 359: 140-145. 1995.

[3] M. A. Hussaini, N. B. Ogunlela, A. A. Ramalan, and A. M. Falaki, Mineral composition of Dry Season Maize (*Zea mays L.*) in Response to varying levels of Nitrogen, Phosphorus and Irrigation. *World J. Agric. Sci*., 2008. 4(6): 775-780.

[4] H. Marschner. Mineral Nutrition of Higher Plants. 2nd Ed. Academic Press. Hacourt Brace and Company, London. 1997.

[5] J. L. Havlin, J. D. Beaton, S.L. Tisdale and L. Nelson. Soil Fertlity and Fertilizers: An introduction to nutrient management (Seventh edition) Pearson Education (Pubs.) 2007. Pp.75.

[6] G. Malla, A. Bhatia, H. Pathak, S. Prasad, M. C. Jain, and J. Singh. Mitigating nitrous oxide and methane emissions from soil in rice-wheat system of the Indo-Gangetic chemisphere, 2005, 58:141-147.

[7] A. M. Hermann, E. Witter, and T. Katterer. Use of acetylene as a nitrification inhibitor to reduce biases in gross N transformation rates in a soil showing rapid disappearance of added ammonium. *Soil Biol. Biochem*. 2007, 39:2390-2400.

[8] O. Yu, Y. Chen, X. Ye, O. Zhang, Z. Zhang, and P. Tian, Evaluation of nitrification inhibitor 3,4-dimethyl Pyrozole phosphate on nitrogen leaching in undisturbed soil columns. *Chemosphere*, 2007, 67: 872-878.

[9] R. Prasad and J. F. Parmar. Nitrification inhibitors for the agriculture, health and environment. *Adv. Agron*. 1995, 54: 233-281.

[10] D. Majumdar. Unexploited botanical nitrification inhibitors prepared from Karanja plant. *Natural Product Radiance*, 2007, Vol.7 (1): pp.58 – 67.

[11] S. Moharty, A. K. Patra, and P. K. Chhonkar. Neem (*Azadirachta Indica, J.*) Seed kernel powder retards urease and nitrification activities in different soils at contrasting moisture and temperature regimes. *Biores. Technol*. 2008, 99(4): 894-899.

[12] D.Majumdar. Suppression of nitrification and N_2O emission by karanjin – a nitrification inhibitor prepared from Karanja (Pongamia globra vent). *Chemisphere*, 2002, 47(8): 845 – 850.

[13] K. L. Sahrawat and B. S. Parmar. Alcohol extract of "neem" seed as nitrification inhibitor. *J. Indian Soc. Soil Sci.* 1975, 23:131-14.

[14] USDA Soil Survey Staff. Keys to Soil Taxonomy (9th Ed.). United State Department of Agriculture, WRSC, Washington D.C. 2003.

[15] G. W. Gee and D. Orr. Particle size analysis. In: Dane, J. H. and Topp, G. C. (Eds.). Methods of soil analysis, part II, physical methods. Soil Science

Society of America Book Series No. 5, ASA and SSSA Madison, WI pp225-273. 2002.

[16] J. H. Dane and G. C. Topp. Methods of soil analysis, physical methods. Soil Science Society of America Book Series No. 5, ASA and SSSA Madison, WI pp274-298. 2002.

[17] FPDD. Fertilizer use and Management for Crops in Nigeria. Fertilizer Procurement and Distribution Division. Federal Ministry of Water Resources and Rural Development, Lagos, 163 pp. 1989.

[18] K. A. Gomez and A. A. Gomez. Statistical Procedures for Agricultural Research 2nd.Edn. John Wiley and Sons, New York. 1984. Pp. 679.

[19] A. M. Chiroma, J. D. Kwari and A. B. Alhassan. Effect of different management practices on selected soil fertility parameters in a sandy soil in a north eastern Nigeria. *Journal of sustainable Agriculture and Environment*. 2002, 4(2): 264-274.

[20] A. J. Rayar and B. U. Haruna. Studies on distribution of total and available nitrogen in the soils of South Chad Irrigation area of Borno state. *Annals of Borno*. 1988, 2: 105.

[21] H. A. Eltelib, M. A. Hamad and E. E., Ali. The effect of nitrogen and phosphorus fertilization on growth, yield and quality of forage maize (*Zea mays. L*.) *J. Agron*, 2006, 5(3): 515-518.

[22] G. J. Schwab and L. W. Murdock. Nitrogen transformation inhibitors and controlled Release urea. Cooperative Extension Service. University of Kentucky, Lexington, KY, 40546. 2010.

[23] R. Goos. Effect of Nutrisphere-N on urea hydrolysis, nitrification and volatilization In: Proceedings of the 38th North Central Extension-Soil Fertility conference, 24: 89-96, Nov., 12-13, Des Mornes, I. A. 2008.

[24] W. Frye. Nitrification Inhibition for nitrogen efficiency and environment protection. IFA International Workshop on Enhanced-Efficiency Fertilizers, Frankfurt, Germany, 2006.

[25] L. O. Sa'ad, S. Lehmann and R. Conrad. Influence of thiosulfate on nitrification, denitrification and production of nitric oxide and nitrous oxide in soil. *Boil. Fert. Soils*, 1996, 21:152-159.

[26] A. Ibrahim. Effect of Nitrogen Fertilizer and Farmyard Manure Application on Yield and nutrient uptake of Maize (*Zea mays L.*) in a Semi-arid soil. M.Sc. Thesis. Department of Soil Science, University of Maiduguri. Pp.65. 1995.

[27] A. J. Rayar and D. R. Bello. Effect of neem seed crush treated urea on yield and nitrogen use efficiency of wheat. In: Proceedings of the First National Conference on Wheat Production, Feb. 1990, Maiduguri, Nigeria, 1990.

[28] R. H. Teyker. Influence of Nitrogen and potassium sources on corn yield and xylem Exudate composition. *J. Plant Nutr*. 2006, 14:79-85.

[29] L. G. Bundy. Corn Fertilization. University of Wisconsin Cooperative Extension Pub., A3340. Lake St. Rm 103, Madison, WI, 53706, 2004.

[30] C. O. Alofe, and O. Obigbesan. Nitrogen concentration in maize as affected by cropping history and time of application of N fertilizers. *Samaru J. Agric. Res*., 1995, 11:80-86.

[31] K. Laijawala. Neem as a Nitrification inhibitor. International Conference on Enhanced–Efficiency Fertilizers. IFA, 23-24, March, 2010, Miami, FL. USA, 2010.

[32] J. Ashworth. Comments on nitrification inhibition by nitrapyrin and volatile compounds. *Soil Sci. Soc. Am. J.*, 1986, 50:268-268.

[33] D. W. Nelson and D. Huber. Nitrogen inhibitor for corn production. National corn Handbook (NCH-55). Cooperative Extension Service. Iowa State University, Ames, USA. 2001.

Biographies

GONI MAKINTA received the B.Sc. degree in Agriculture from the University of Maiduguri, Maiduguri, Borno State, in 1983 and the M.Sc. degree in Soil Science from the University of Maiduguri, Maiduguri, Borno State, in 2002. Currently, He is a Lecturer II at the University of Maiduguri. His teaching and research areas include soil fertility and plant nutrition.

JOSHUA DANKASA KWARI received the B.Sc. degree in Agriculture from the University of Maiduguri, Maiduguri, Borno State, in 1982 and the Ph.D. degree in Soil Chemistry, Fertility and Management from the University of Aberdeen, Aberdeen, Scotland in 1987. Currently, He is a Professor of Soil Science at University of Maiduguri. His teaching and research areas include soil chemistry, fertility, management and plant nutrition.

ADAM LAWAN NGALA received the B.Sc. degree in Soil Science from the University of Maiduguri, Maiduguri, Borno State, in 1998, the M.Sc. degree in Soil Science from the University of Maiduguri, Maiduguri, Borno State, in 2007, and the Ph.D. degree in Soil Fertility and Plant Nutrition from the University of Maiduguri, Maiduguri, Borno State in 2015, respectively. Currently, He is a Senior Lecturer at the University of Maiduguri. His teaching and research areas include Soil fertility and plant nutrition and soil nutrient balance..

IBRAHIM BABAGANA BUJI received the B. Agriculture degree in Agriculture from the University of Maiduguri, Maiduguri, Borno State, in 2008 and the M.Sc. degree in Agronomy from the University of Ibadan, Ibadan, Oyo State, in 2015, respectively. Currently, He is an Assistant Lecturer at University of Maiduguri. His teaching and research areas include Soil Survey, Soil classification, and Land Use Planning

IBRAHIM ADAMU received the B. Agriculture degree in Soil Science from the University of Maiduguri, Maiduguri, Borno State, in 2008 and the M.Sc. degree in Agronomy from the University of Ibadan, Ibadan, Oyo State, in 2015, respectively. Currently, He is an assistant Lecturer of Soil Science at University of Maiduguri. His teaching and research areas include Soil Survey, Soil classification, and Land Use Planning.