Residual soil fertility status as influenced by Mn and Zn fertilizers in sesame based cropping system on lithosols of northern guinea savanna of Nigeria

H. E. Shehu

Department of Crop Science, Adamawa State University, Mubi, Adamawa State, Nigeria.
Email: harushe2003@gmail.com

Abstract: A study was carried out to assess the influence of Mn and Zn fertilizers on residual soil N, P, K, Mn and Zn in sesame (Sesamum indicum L.) based cropping system during the 2005 and 2006 rainy season, at the Food and Agriculture Organisation/Tree Crop Programme (FAO/TCP) Teaching and Research farm of the Adamawa State University, Mubi, northern guinea savanna of Nigeria. The experiment consisted of 2 Mn rates (0.5 and 1 kg ha^{-1}) and 2 Zn rates (0.5 and 1 kg ha^{-1}) with various treatment combinations added to nitrogen (75 kg ha^{-1}), phosphorus (45 kg ha^{-1}) and potassium (22.5 kg ha^{-1}) as basal, laid out in a randomized complete block design (RCBD), replicated three times. The results showed that Mn at 1 kg ha^{-1} increased soil N by 0.01%, P, Mn and Zn by 1.35, 20.14, and 1.47 mg kg^{-1}, respectively. Zn application at 0.5 kg ha^{-1} increased soil build up of N by 0.17%, K by 0.02 cmol kg^{-1} while at 1 kg Zn ha^{-1} soil P, Mn and Zn increased by 2.35, 14.34 and 4.89 mg kg^{-1}, respectively. Agronomic efficiencies of both Mn and Zn were 25 and 61, respectively at 0.5 kg Mn and Zn ha^{-1}. Uptake of N and K is related to soil Mn and Zn balance.

[Shehu HE. **Residual soil fertility status as influenced by Mn and Zn fertilizers in sesame based cropping system on lithosols of northern guinea savanna of Nigeria.** *Nat Sci* 2017;15(1):34-41]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature. 6. doi:10.7537/marsnsj150117.06.

Keywords: Nitrogen, Phosphorus, potassium, Manganese, Zinc, Sesame

1. Introduction

The judicious management and conservation of the soil to guide against decreased crop yields and negative effect on the environment under intensive cropping have become a major area of agronomic study. It has been observed that many African soils show deficiency problems after only a short period of cultivation because of their nature as well as prevailing environmental conditions (Padwick, 1983). The general agreement that all the nutrient amendments made to soil had and still by far the most important effects in terms of increasing crop production (Cakmak *et al*., 2010). It is for these reasons that farmers have sought to furnish additional nutrient by applying chemical fertilizers (McVickar and Walker, 1978) so that the yield of crops will no longer be limited by the amount of plant nutrients inherent in the soils.

Researches on the nutrition of sesame have shown significant yield increases in the tropics (Daulay and Singh, 1982; Kalaisevan, 2002 and Malik, 2003) and especially on lithosols of the savanna region of Nigeria (Shehu *et al*., 2014) due to nitrogen, phosphorus and potassium additions.

However, there are paucities of information about the effects of the fertilizer treatments on nutrients after cropping. Therefore, this study aimed to assess the changes in some nutrients under Mn and Zn fertilizer treatments in sesame based cropping system.

2. Materials and Methods

Experimental Site

Two year field study were conducted during the 2005 and 2006 rainy seasons at the Food and Agricultural Organisation of the United Nations/Tree.

Crop Project (FAO/TCP) Teaching and Research farm of the Adamawa State University, Mubi (10^{o} 11' N: 13^{o} 19' E, altitude 594 m above sea level) Northern Guinea savanna of Nigeria. The mean annual rainfall ranges from 700 mm to 1,050 mm (Adebayo, 2004). The Vegetation is of typical Northern Guinea savanna. The soils of the experimental site have been classified as Entisols (SSS, 1975) or lithosols, (FAO/UNESCO classification).

Soil Sampling and Analysis

Soil samples were collected at 0-15 cm depths from 10 randomly selected points in the experimental field and a composite was made before land preparation using auger. Samples collected were air dried, crushed and sieved through a two mm screen for analysis prior to the beginning of the experiment. Standard methods were used to analyze the samples as follows: Soil reaction (pH) were determined in the supernatant of 1:2.5 soil-water with a pH meter; Particle size distribution by the hydrometer method (Bouyoucos, 1962); total nitrogen by a modified Kjeldahl method (Bremner and Mulvaney 1982); Available phosphorus was extracted by Bray P1 method (Bray and Kurtz, 1945) and determined by spectrometry; Exchangeable cations were extracted in 1M NH_4OAc buffered at pH 7 (Page *et al.,* 1982).

Calcium and magnesium were determined by atomic absorption spectrophotometer, and K and Na by flame photometer. Effective cation exchange capacity was estimated by summation of exchangeable bases (Rhodes, 1982) and exchange acidity by KCl extraction method (Mclean, 1965). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934) while Zn and Mn as described by Lindsayand Norvell (1978). The results of the analyses are shown in Table 1.

Table 1. Some physical and chemical properties of the experimental soil

Parameter	**Value**
Sand (g kg^{-1})	536
Silt (g kg^{-1})	302
Clay (g kg^{-1})	162
Textural Class	Sandy loam
pH (1:2.5, H_2O)	6.2
Organic Carbon (g kg^{-1})	6.44
Organic matter (g kg^{-1})	0.75
Total Nitrogen (g kg^{-1})	0.15
Available P (mg kg-1)	2.1
Exchangeable K (Cmol kg^{-1})	0.33
Exchangeable Ca (Cmol kg^{-1})	4.8
Exchangeable Mg (Cmol kg^{-1})	2.27
Exchangeable Na (Cmol kg^{-1})	0.98
Available Zn (mg kg^{-1})	2.26
Mn (mg kg^{-1})	37.83

Experimental design and treatments

The experiments were laid out in a randomized complete block design with two fertilizer types: Mn (0.5 and 1 kg Mn ha^{-1}) and Zn (0.5 and 1 kg Zn ha^{-1}) with various treatment combinations. Nitrogen (75 kg N ha^{-1}), phosphorus (45 kg P_2O_5 ha^{-1}) and potassium.

(22.5 kg K_2O ha^{-1}) were supplied as basal for sesame crop.

Agronomic efficiencies were calculated as follows:

$$Agronomic\ Efficiency\ (AE) = \frac{Grain\ yield_f - Grain\ yield_c}{Fertilizer\ \ applied}\ kg/kg$$

Where the indices, *f* and *c* denote ‘fertilized crop’ and ‘unfertilized controls’ respectively (Crasswel and Godwin, 1984: Mengel and Kirby, 2006).

2.4. Data analysis

Data collected was subjected to analysis of variance (ANOVA) using SAS 9.1.3 (2010). Duncan’s Multiple Range Test (DMRT) was used for mean separation where differences were significant, at 5% level of probability.

3. Results

Nitrogen, P, and K uptake by sesame

The effect of Mn and Zn fertilizer on N uptake is presented in Table 2. Highest N uptake (24.2 kg ha^{-1}) was realized when NPK + 0.5 kg Zn ha^{-1} was applied in 2005. In 2006, NPK + 1 kg Zn ha^{-1} gave the highest N uptake of 27.91 kg ha^{-1}. The combined analysis revealed that 25.33 kg ha^{-1} N obtained from the application of NPK + 1 kg ha^{-1} was the highest.

Table 2: Effects of Mn and Zn fertilizers on the uptake of N, P and K by sesame

	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
Treatment	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
0-0-0	5.00	$5.53^{b\dagger}$	5.27^{c}	3.43	0.56^{b}	0.41^{b}	$9.65^{d\dagger}$	7.26^{b}	8.46^{c}
NPK	21.26	20.40^{ab}	20.83^{ab}	4.89	1.60^{ab}	1.85^{a}	29.18^{a}	27.29^{a}	28.24^{a}
NPK + 0.5Mn	9.42	16.87^{ab}	13.15^{ab}	5.35	2.24^{a}	1.47^{a}	22.82^{ab}	29.86^{a}	26.34^{ab}
NPK + 0.5Zn	24.20	19.54^{ab}	21.87^{ab}	5.13	2.52^{a}	1.90^{a}	20.20^{a-c}	29.21^{a}	24.71^{ab}
NPK + 1Mn	10.61	23.96^{a}	17.29^{ab}	5.76	2.54^{a}	1.64^{a}	28.18^{a}	25.55^{a}	26.86^{ab}
NPK + 1Zn	22.76	27.91^{a}	25.33^{a}	5.85	2.00^{a}	1.37^{ab}	16.94^{b-d}	28.44^{a}	22.69^{ab}
NPK + 0.5Mn + 0.5Zn	11.29	16.54^{ab}	13.92^{a-c}	3.27	1.95^{a}	1.57^{a}	15.22^{b-d}	21.24^{a}	18.23^{b}
NPK + 1Mn+ 1Zn	15.09	18.47^{ab}	16.78^{ab}	5.05	1.59^{ab}	1.65^{a}	12.62^{cd}	24.65^{a}	18.64^{b}
SE(±)	5.71	4.52	5.04	1.32	0.39	0.34	2.81	3.69	3.79

$^{\dagger=}$Means followed by same letter(s) in subscript are not significantly different at 5% level of probability using Duncan’s multiple range test.

The uptake of P as influenced by Mn and Zn fertilizer additions is presented in Table 2. The amount of P uptake showed no significant difference between 0 kg ha^{-1}, NPK and NPK +1 kg ha^{-1} each of Mn and Zn with a corresponding P uptake of 0.56, 1.60 and 1.59 kg ha^{-1} respectively. The highest P uptake in 2005 was recorded with NPK+1 kg Mn ha^{-1} application which gave 2.54 kg ha^{-1} P uptake. In 2006, application of NPK + 0.5 kg Zn ha^{-1} produced the highest P uptake of 1.90 kg ha^{-1} which was statistically at par with values from all treatments except the control. The highest P uptake was recorded when 0.5 kg Zn ha^{-1} was added to NPK where uptake of 2.21 kg ha^{-1} was recorded. While P uptake increased with increase in Mn rate (1.85 to 2.09 kg ha^{-1}), increase in Zn rate decreased P uptake (2.21 to 1.69 kg ha^{-1}). The effect of Mn and Zn fertilizer on the uptake of K on sesame is shown in Table 2. In 2005, combinations of Mn and Zn at both 0.5 and 1 kg ha^{-1} gave lower K uptake compared to where they were added separately. In 2006, all rates produced K uptake values that were statistically at par except for the 0 kg ha^{-1}. In the combined analysis, the highest K uptake (28.24 kg ha^{-1}) was recorded where no Mn and Zn were added to NPK.

Mn and Zn uptake by sesame

The effect of Mn and Zn fertilizers on the uptake of Mn is presented in Table 3. In 2005, all rates produced Mn uptake values that were statistically at par except for the 0 kg ha^{-1}. In 2006, Mn uptake was highest (0.57 kg ha^{-1}) when NPK + 1 kg ha^{-1} Mn was applied. This did not produce a significantly different Mn uptake from NPK + 0.5 kg Mn ha^{-1}, NPK + 0.5 kg Zn ha^{-1} and NPK + 0.5 kg Mn + 0.5 kg Zn ha^{-1} with corresponding Mn uptake of 0.43, 0.44 and 0.38 kg ha^{-1}, respectively. In the combined analysis, treatment NPK + 1 kg Mn ha^{-1} had the highest Mn uptake of 0.47 kg ha^{-1}. Uptake of 0.34, 0.42, and 0.36 kg ha^{-1} from application of NPK + 0.5 kg Mn, NPK + 0.5 kg Zn and NPK + 1 kg Zn ha^{-1} respectively were not significantly different.

Table 3: Effect of Mn and Zn on the uptake of Mn and Zn by sesame

	Mn uptake (kg ha^{-1})			Zn uptake (kg ha^{-1})		
Treatment	2005	2006	Mean	2005	2006	Mean
0 0-0	$0.08^{b†}$	0.15^{c}	0.12^{c}	0.003^{b}	0.003^{c}	0.003^{c}
NPK	0.27^{a}	0.32^{bc}	0.30^{b}	0.011^{b}	0.016^{ab}	0.013^{ab}
NPK + 0.5Mn	0.25^{a}	0.43^{ab}	0.34^{ab}	0.013^{b}	0.013^{a-c}	0.013^{ab}
NPK + 0.5Zn	0.40^{a}	0.44^{ab}	0.42^{ab}	0.016^{b}	0.015^{ab}	0.016^{ab}
NPK + 1Mn	0.38^{a}	0.57^{a}	0.47^{a}	0.012^{b}	0.011^{a-c}	0.012^{a-c}
NPK + 1Zn	0.40^{a}	0.32^{bc}	0.36^{ab}	0.013^{b}	0.019^{a}	0.016^{ab}
NPK + 0.5Mn + 0.5Zn	0.29^{a}	0.38^{ab}	0.33^{b}	0.034^{a}	0.008^{bc}	0.021^{a}
NPK + 1Mn+ 1Zn	0.37^{a}	0.29^{bc}	0.33^{b}	0.009^{b}	0.007^{bc}	0.008^{bc}
SE(±)	0.05	0.06	0.06	0.004	0.003	0.004

†=Means followed by same letter(s) in subscript are not significantly different at 5% level of probability using Duncan's multiple range test.

The effect of Mn and Zn fertilizers on the uptake of Zn is presented in Table 3. The two years of study and the combined analysis revealed significant responses of Zn uptake to Mn and Zn fertilizer application. In 2005, highest Zn uptake was recorded from the application NPK + 1 kg Zn ha^{-1} of 0.40 kg ha^{-1} while in 2006. The highest was obtained with NPK + 1 kg Mn ha^{-1} of 0.57 kg ha^{-1}. The lowest uptake was from soils that did not receive any fertilizer application. In the combined analysis, highest Zn uptake came from application of NPK + 0.5 kg Mn + 0.5 kg Zn ha^{-1}. This was not significantly different from uptake recorded at NPK + 0.5 kg Mn ha^{-1}, NPK + 0.5 kg Zn ha^{-1}, NPK +1 kgMn ha^{-1} and NPK + 1 kg Zn ha^{-1} with corresponding uptake of 0.013, 0.013, 0.016, 0.016 and 0.12 kg ha^{-1} respectively. The lowest Zn uptake of 0.003 kg ha^{-1} was from control.

Table 4: Effect of Mn and Zn fertilizers on residual soil N, P, and K

	Soil N (%)			Soil P (mg kg^{-1})			Soil K (Cmol kg^{-1})		
Treatment	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
0-0-0	$0.07^{c†}$	0.04^{b}	0.05^{b}	3.43	1.52^{c}	2.48^{b}	0.21	$0.17^{b†}$	0.19^{b}
NPK	0.15^{bc}	0.06^{ab}	0.10^{b}	4.89	1.82^{c}	3.36^{ab}	0.28	0.43^{a}	0.35^{ab}
NPK + 0.5Mn	0.15^{bc}	0.05^{ab}	0.10^{b}	5.35	2.03^{bc}	3.69^{ab}	0.24	0.44^{a}	0.34^{ab}
NPK + 0.5Zn	0.55^{a}	0.09^{a}	0.32^{a}	5.13	2.36^{bc}	3.75^{ab}	0.20	0.51^{a}	0.35^{ab}
NPK + 1Mn	0.26^{bc}	0.07^{ab}	0.16^{ab}	5.76	3.13^{a-c}	4.45^{ab}	0.23	0.39^{ab}	0.31^{ab}
NPK + 1Zn	0.39^{bc}	0.06^{ab}	0.22^{ab}	5.85	5.05^{a}	5.45^{a}	0.23	0.36^{ab}	0.29^{ab}
NPK + 0.5Mn + 0.5Zn	0.13^{bc}	0.05^{ab}	0.09^{b}	3.27	3.96^{ab}	3.62^{ab}	0.34	0.43^{a}	0.38^{a}
NPK + 1Mn+ 1Zn	0.14^{bc}	0.05^{ab}	0.10^{b}	5.05	4.35^{a}	4.70^{ab}	0.23	0.38^{ab}	0.30^{ab}
SE(±)	0.09	0.00	0.09	1.32	0.60	1.16	0.05	0.07	0.08

†=Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using Duncan Multiple Range Test.

Residual soil N, P, and K

In 2005, 2006 and combined analysis, NPK + 0.5 kg Zn ha^{-1} had higher residual soil N than NPK, NPK + 0.5 Mn kg ha^{-1}, NPK + 1 kg Mn ha^{-1}, NPK + 1 kg Zn ha^{-1}, NPK + 0.5 and 1 kg Mn and Zn ha^{-1} (Table 4). In both years, Zn had significant effect on residual soil N than with Mn and Mn and Zn combinations. The with residual soil N of 0.32% was the highest. This was combined analysis indicated that NPK + 0.5 kg Zn ha^{-1} at par with NPK + 1 kg Mn ha^{-1} and NPK + 0.5 kg Zn ha^{-1} with corresponding residual soil N of 0.16 and 0.22, respectively. All other rates were significantly low. The influence of Mn and Zn on residual soil P after sesame cultivation was not significant in 2005. In 2006 and in the combined analysis, residual soil P was highest at NPK + 1 kg Zn ha^{-1} application which gave a residual soil P of 5.45 mg kg^{-1}. All other values were not significantly different from the residual soil P recorded at 0 kg ha^{-1}. Application of Mn and Zn fertilizers did not show significant effect on residual soil K in 2005. In 2006 and in the combined analysis, NPK + 0.5 kg Mn + 0.5 kg Zn ha^{-1} had the highest residual soil K of 0.43 and 0.38 Cmol kg^{-1} respectively. In both analysis, except for the 0 kg ha^{-1} all other rates were not significantly different from one another.

Residual soil Mn and Zn

The effect of Mn and Zn on residual soil Mn is presented in Table 5. There was no significant influence on residual soil Mn in 2005. In 2006, NPK + 1 kg Mn ha^{-1} recorded the highest residual soil Mn of 70.0 mg kg^{-1}. However, this value was only significantly different from 43 mg kg^{-1} Mn recorded from 0 kg ha^{-1} rate. The combined analysis did not show any significant influence on residual soil Mn. However, soil Mn increased by 14.2 and 20.14 mg kg^{-1} from addition of 0.5 and 1 kg Mn ha^{-1} after cropping (Table 6).

Table 5: Effect of Mn and Zn fertilizers on residual soil Mn and Zn in sesame

	Soil Mn (mg kg^{-1})			Soil Zn (mg kg^{-1})		
Treatment	2005	2006	Mean	2005	2006	Mean
0 0-0	36.73	43^{b†}	39.87	1.94	2.50	2.22
NPK	46.73	56.67^{ab}	51.7	1.94	2.73	2.33
NPK + 0.5Mn	38.73	65.33^{ab}	52.03	2.13	2.65	2.39
NPK + 0.5Zn	45.33	53.33^{ab}	49.3	7.91	6.02	6.96
NPK + 1Mn	45.93	70.00^{a}	57.97	4.45	2.99	3.72
NPK + 1Zn	38.00	66.33^{ab}	52.17	5.35	8.95	7.15
NPK + 0.5Mn + 0.5Zn	37.37	58.33^{ab}	47.85	2.73	4.99	3.86
NPK + 1Mn+ 1Zn	40.40	48.00^{ab}	44.15	2.61	8.82	5.71
SE(±)	7.12	7.20	8.71	2.12	2.58	2.29

$^{\dagger=}$Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using Duncan Multiple Range Test.

Table 6: Level of change in nutrients status at post harvest of sesame crop

Treatment	Soil N (%)	Soil P (mg kg^{-1})	Soil K (Cmol kg^{-1})	Soil Mn (mg kg^{-1})	Soil Zn (mg kg^{-1})
0-0-0	-0.10	-0.62	-0.14	+2.04	-0.04
NPK	-0.05	+0.26	+0.02	+13.87	+0.07
NPK + 0.5Mn	-0.05	+0.59	+0.01	+14.20	+0.13
NPK + 0.5Zn	+0.17	+0.65	+0.02	+11.47	+4.70
NPK + 1Mn	+0.01	+1.35	-0.02	+20.14	+1.46
NPK + 1Zn	+0.07	+2.35	-0.04	+14.34	+4.89
NPK + 0.5Mn + 0.5Zn	-0.06	+0.52	+0.05	+10.02	+1.60
NPK + 1Mn+ 1Zn	-0.05	+1.60	-0.03	+6.32	+3.45

Application of Mn and Zn fertilizer did not indicate any significant influence on soil residual Zn in 2005, 2006 and also in the combined analysis. However, NPK + 1 kg Zn ha^{-1} recorded the highest residual soil Zn in the two years and in the combined analysis which gave a corresponding highest residual soil Zn after cropping of 4.89 mg kg^{-1}.

Table 7: Correlation coefficient among uptake and residual soil N, P, K, Mn and Zn

	N uptake	P uptake	K uptake	Mn Uptake	Zn uptake	Soil N	Soil P	Soil K	Soil Mn	Soil Zn
N uptake	1.000									
P uptake	0.213	1.000								
K uptake	0.542*	0.424*	1.000							
Mn uptake	0.162	0.675*	0.491*	1.000						
Zn uptake	0.119	0.449*	0.251	0.402*	1.000					
Soil N	0.200	0.394*	-0.029	0.324*	0.183	1.000				
Soil P	0.088	0.339*	-0.007	0.240	0.032	0.278	1.000			
Soil K	0.242	0.070	0.521*	0.178	0.143	-0.355*	-0.292*	1.000		
Soil Mn	0.331*	-0.034	0.320*	0.013	-0.030	-0.194	0.023	0.401*	1.000	
Soil Zn	0.327*	0.049	0.195	0.223	0.042	0.181	-0.074	0.059	0.042	1.000

*= Significant at 5% level of probability

Correlation coefficients

The correlation that existed among uptake and residual soil N, P, K, Mn and Zn is shown in Table 7. N uptake is positively related to K uptake (r=0.545), soil Mn (r=0.331) and soil Zn (r=0.327). P uptake is positively associated with K, Mn and Zn uptake and soil N and P with corresponding r=0.424, 0.675, 0.449. 0.394 and 0.339, respectively. K uptake is positively 0.521 and 0.320, respectively). Mn uptake is positively related to Mn uptake, soil k and soil Mn (r=0.491, associated to Zn uptake (r=0.402) and soil N (r=0.324). Soil N is negatively related to soil K (r=-0.355) and soil P and soil K are negatively associated (r=-0.292) while soil K is positively related to soil Mn (r=0.401). However, a strong relationship existed between P uptake and Mn uptake greater than all other relationships with r^2=0.401.

4. Discussion

The increase in N uptake by sesame recorded in this study was also observed by Singaravel *et al.* (2002) where 25 kg $ZnSO_4$ ha^{-1} added to recommended NPK increased N uptake by 49% in Vertisols. The non significant response in N uptake from additions of Mn and Zn in this experiment differs with the findings of Singaravel *et al.* (2002) where significant increase (85%) in uptake by sesame was obtained with 2 kg $ZnSO_4$ + 5 kg $MnSO_4$ ha^{-1}.

There was no marked increase in the uptake of P with Zn and Mn fertilization. This did not agree with the findings of Tiwari *et al.* (1995) who reported increase in P uptake by 122% at 5 kg $MnSO_4$ ha^{-1} added to NPK. The non significant increase in P uptake concurs with Singaravel *et al.* (2002) who reported non significant increase in P uptake both at low and high $MnSO_4$ additions. Similar findings was also reported by Murphy *et al.* (1981) from a comparison of root and shoot concentration for both Zn and P in two varieties of dry bean. They found that Zn concentration did not have effect on P in the shoot, even when P was at high concentration. They also noted high levels of available P in the roots at high Zn concentrations.

Combination of Mn and Zn at 0.5 kg ha^{-1} each and also 1 kg ha^{-1} each depressed K uptake by 54.9 and 51.5% respectively over NPK. This result is at variance with the findings of Singaravel *et al.* (2002) who recorded significant increase in K uptake from additions of Mn and Zn to NPK on Vertisols.

Manganese applied at 1 kg ha^{-1} increased Mn uptake by 56.7% while 10% increase was recorded when 0.5 kg Mn and Zn ha^{-1} and 1 kg Mn and Zn ha^{-1} were added to NPK. Increase in Mn uptake from Mn application and Mn and Zn interaction on uptake of Mn was observed by Singh and Steengberg (1974). Manganese uptake in sesame was reduced by 16.7% at 1 kg Zn ha^{-1} application compared to NPK. Similar findings was also reported by El-Fouly *et al.* (1992) where total Mn uptake was reduced by increasing Zn rate in an experiment with sunflower under green house condition. Increase in Mn uptake from Mn application was also observed by El-Fouly *et al.* (2001) where 189% increase was recorded. Manganese in its chemical behaviour shows properties of both the alkali earth cations such as Mg^{2+} and heavy metals (Zn^{2+}). It is therefore not surprising that these ion species can affect uptake and translocation of Mn in the plant. This has been reported by Fox and Guerinot (1998) that Mn has a depressive effect on Fe uptake. Also, addition of Zn separately at lower rates favoured Mn uptake in sesame. El-Fouly *et al.* (2001) reported higher Mn uptake at low Zn rates.

Application of Mn and Zn at 0.5 kg each recorded the highest Zn uptake by 61.5% over NPK. Manganese application both at 0.5 and 1 kg ha^{-1} did not significantly change the uptake of Zn. This concurs with results of Singh and Steegberg (1974) which showed that total Zn uptake and percentage distribution among roots and shoots of maize and barley were not affected by Mn application. Zinc uptake increased by 13.3 and 17.7% from application of 0.5 and 1 kg Zn ha^{-1} rates respectively. This response also agrees with the studies of Singh and Steegberg (1974) who observed significant increase in Zn uptake by roots and shoots of maize and barley plants from Zn application. In a similar work by Schenkano and Berber (1979), it was found that nutrient absorption from the soil by the roots depends on the nutrient concentration in soil solution. Similar results were observed by Brown (1979).

Zinc at 0.5 kg Zn ha^{-1} increased residual soil N by 220% and 120% at 1 kg ha^{-1}. At 1 kg Zn ha^{-1}, it is expected that uptake of N increased more, than at 0.5 kg Zn ha^{-1}. With this higher uptake, the amount of N removed from the soil will be higher, leaving low amount of N in the soil. This is indicated in the higher uptake at 1 kg Zn ha^{-1}.

Zinc application at 1 kg Zn ha^{-1} increased residual soil P by 62.2%. This shows that Zn reduced the uptake of P, leaving in the soil more P to form complexes or precipitates. This result concurs with the findings of Mandal and Mandal (1990) which indicated that interaction between P and Zn occur at the plant metabolic level. Interaction between Mn and P was observed as Mn at 1 kg ha^{-1} increased residual soil P by 32.4%. This implies that Mn suppressed P uptake. This result agrees with the studies of Giordano and Mortvedt (1969) who examined P availability for corn when Mn was granulated with ortho and polyphosphate fertilizers. Large concentrations (10%) of Mn as $MnSO_4$ in ammonium phosphate fertilizers significantly reduced corn forage yield and P uptake relative to treatments where P and Mn were applied separately. This may be as a result of complexes formed by Mn with P, thus reducing the uptake in the soil. Similar reports were obtained by Smilde (1973) who observed antagonistic interaction between P and Mn. This result also shows that Zn has greater effect on P absorption than Mn. Their combined effect increased residual soil P by 1.34 mg kg^{-1} at added 1 kg ha^{-1} of each.

The combined field experiment shows that there was no significant response in K uptake from the applications of Mn and Zn at all rates, both in combination and separate additions. This result did not concur with the report of Fageria (2001) that increasing Mn concentration in nutrient solution triggered a general antagonistic effect on K. Manganese and Zn rates applied in this experiment may not be high enough to trigger antagonistic effect on K since K plant content did show any significant difference. The highest residual soil K (0.38 cmol kg^{-1}) at NPK + 0.5 Mn + 0.5 Zn corresponds with the uptake of K at same rate. This indicates that combined Mn and Zn reduced K uptake leaving in soil more K than other treatment rates though not significant. This effect is both in plant and soil. K reduced Mn absorption and it has been used to alleviate Mn toxicity in acid soils. Therefore at low and moderate Mn rates, residual K may not be significantly affected. Similar findings were reported by Hennan and Campbell (1981) and Alam *et al.* (2002). Application of 1 kg Zn ha^{-1} reduced residual soil K by 0.06 cmol kg^{-1} compared to NPK though not significantly different from other treatment rates.

Application of Mn at 0.5 and 1 kg Mn increased soil residual Mn by 0.6 and 12%, respectively. The increase in residual soil Mn concurred with the report of Weil *et al.* (1997) that addition of Mn to soils increased Mn concentration and directly availability of plant Mn. The level of Mn begins to fall when the soil becomes well aerated as the Mn is being absorbed by plants. Webb *et al.* (1993) elucidated that high level of Mn decreases with time under field capacity and optimum pH of 7. The soil condition in this experiment is a favourable one (sandy loam and pH 6.2) with good aeration. Soils in the area of study have been classified as low in Mn (FAO, 2004). Addition of Mn fertilizer will raise the soil Mn concentration but will be depleted as the plant absorbs it. However the absorption of Mn in this case is low since 57.97 mg kg^{-1} was left in the soil after cropping. Application of Zn did not influence soil Mn. Both Mn and Zn absorption and translocation are favoured by acid soil condition. In a similar work by Mengel and Kirby (2006), it was observed that the concentration of Mn in soil solution are considerably higher than Zn and complexed Mn in soil solution can easily be replaced by Zn^{2+}.

Application of Zn at 0.5 and 1 kg Zn ha^{-1} increased residual soil Zn by 198 and 207% respectively. The non significant influence on residual soil Zn coincides with non significant response to Zn uptake from Mn and Zn applications. Zinc uptake by plant which is supposed to deplete soil Zn was not significant. The presence of P though not in high concentration might have reduced Zn uptake and thus increased residual soil Zn. Attempts have been made to explain P antagonism on Zn nutrition on the basis of chemical reaction between P and Zn in growth medium, making Zn unavailable to the plant. Veits (1966) further explained that precipitation of $Zn_3(PO_4)_2$ having a low Zn availability, have been reported. However, Khan and Zende, (1977) added that, evidence exists for P inhibition of Zn absorption into the root or interferences with translocation of Zn from roots to metabolic use sites in the shoot.

5. Conclusion

Soil N, P, Mn and Zn balance increased at higher Mn and Zn rates while soil K build up increased when both Mn and Zn are applied together at 0.5 kg ha^{-1} each. Agronomic efficiencies, as high as 25 and 61 for Mn and Zn were obtained at 0.5 kg Mn ha^{-1} and 0.5 kg Zn ha^{-1}. A strong relationship existed between P uptake and Mn uptake.

References

1. Adebayo, A. A. (2004). Mubi region a geographical synthesis. Paraclete Publishers, Yola, Nigeria. pp 22-31.
2. Alam, S., Rahman, M. H., Kamei, S. and Kawai, S. (2002). Alleviation of manganese toxicity and manganese induced iron deficiency in barley by additional potassium supply in nutrient solution. *Soil Science and Plant Nutrition* 48:387-392.
3. Bouyoucos, G. J. (1962). Hydrometer method improved for making particle size analysis of soil. Agronomy Journal 54: 564-565.
4. Bray, R. H and Kurtz, L. T. (1945). Determination of total, organic and available forms of P in soils. *Soil Science* 59:39-45.
5. Bremner, J. M. (1982). Inorganic nitrogen *In*: Page, A. L. Miller, R. H and Keeney, D. R. (1982) Methods of soil analysis Part 2. Chemical and mineralogical properties. Agronomy monograph No. 9 ASA-SSSA Madison.
6. Brown, J. C. (1979). Effects of Zn stress on factors affecting iron uptake in navy bean. *Journal Plant Nutrition* 1:171-183.
7. Cakmak, D., Sajnikov, E., Perovic, V., Jaramaz, D. and Mrvic, V. (2010). *Proceedings of the 19th World Congress of Soil Science, Soil Solutions for a Changing World, 1-6 August, 2010, Brisbane, Australia.*
8. Crasswel, E.T. and Godwin, D. C. (1984). The efficiency of nitrogen fertilizer applied to cereals in different climates. *Advance Plant Nutrition* 1:1-55.
9. Daulay, H. S. and Singh, K. C. (1982). Effects of and P rates and Plant Density on the yield of rainfed sesame. *Indian Journal of Agricultural Science*, 52: 166-169.
10. El-Fouly, M. M., Amberger, A. and Fwazi, A. F. A. (1992). Balanced fertilizer use with micronutrients under Egyptain conditions (The Micronutrient Project). *African Journal of Agricultural Science* 19:41-61.
11. El-fouly, M. M., Notal, O. A. and Mobarak, Z. M. (2001). Effects of Soil treatment with Iron, Manganese and Zinc on growth and Micro Nutrient Uptake of Sunflower Plants grown in High – pH soil. *Journal of Agronomy and Crop science* 186: 245 – 257.
12. Fageria, N. K. 2001. Nutrient interactions in crop plants. *Journal of Plant Nutrition* 24 (8):1269-1290.
13. Fox, T. C. and Guerinot, M. L. (1998). Molecular biology of cation transport in plants. Annual Review Plant Physiology. *Plant Molecular Biology* 49:669-696.
14. Giordano, P. M., and Mortvedt, J. J (1969) Phosphorus Availability to Corn as Affected by Granulating Manganese with ortho and Pyrophosphate Fertilizer *Soil Science Society American Proceeding* 33:460 – 463.
15. Hennan, D. P and Campbell, L. C (1981). Influence of Potassium and Manganese on Growth and Uptake of Magnesium by soybean (*Glycine max* L.). *Soil Plant* 61:447 – 456.
16. Kalaiselvan, P., Subramaniyan, K. and Balasubramanian, T. N. (2002). Effect of application of N and K on the growth, yield attributes and yields of sesame. *Sesame and Safflower Newsletter* 17: 62-65.
17. Khan, A. A. and Zende, G. K. (1977). The Site for Zn – P Interactions in Plants. *Plant Soil* 46-259 – 262.
18. Lindsay, W.L., and Norvell, W.A. (1978). Development of DTPA soil test for zinc, iron, manganese and copper. *Journal of Soil Science. 42: 421-428.*
19. Malik, M. A., Saleen, M. F., Cheeme, M. A. and Ahmed, S. (2003). Influence of Different N levels on productivity of sesame (*Sesamum indicum* L.) under varying planting patterns. *International Journal of Agriculture and Biology*, 5(4):490-492.
20. Mandal, B. and Mandal, L. N. (1990). Effects of phosphorus application and transformation of Zn fraction in soil and on the Zn nutrition of lowland rice. *Plant Soil* 121:115-123.
21. Mengel, K. and Kirby, C. A. (2006). Principles of Plant Nutrition. 5th edition. Springer publishers India. 849pp.
22. Murphy, L. S., Ellis Jr., R. and Adriano, D. C., (1981). Phosphorus Micro Nutrient Interaction Effects on Crop Production. *Journal Plant Nutrition* 3(1):593-613.
23. Mclean, E. O. (1965). Aluminium. *In*: C.A. Black (ed), methods of soil analysis. Methods of soil analysis Part 2. Chemical and mineralogical properties. Agronomy monograph No. 9 part 2, pp 686-994.
24. McVickar, M.H. and W.M. Walker, 1978. Using commercial fertilizer. The interstate printers and publishers. pp: 363. Padwick, (1983).
25. Padwick, G.W., 1983. Fifty years of experiment II. The maintenance of soil fertility in tropical

Africa: A review. Experimental Agriculture, 19: 293-310.

26. Page, A. L. Miller, R. H and Keeney, D. R. (1982). Methods of soil analysis Part 2. Chemical and mineralogical properties. Agronomy monograph No. 9 ASA-SSSA Madison.
27. Rhodes, J. A. (1982). Methods of soil analysis Part 2. Chemical and mineralogical properties. Agronomy monograph No. 9 ASA-SSSA Madison.
28. SAS (2010). Proprietary Software Release 9.1.3 (TS1M0) SAS Institute Inc., North Carolina State University-Campuswide-T/R, Site 0027585003. Cary, NC, USA.
29. Schenkano, M. K. and Barber, S. A. (1979) Root Characteristics of Corn Genotypes as Related to P Uptake. *Agronomy Journal* 71:921.
30. Singaravel, R. Imayavaramban, V. Thanunathan, K and Shanmughapriya, V. (2002). Effect of micronutrients on yield and nutrient uptake of sesame (*Sesamum indicum* L.) in a Vertisol soil. *Sesame and safflower Newsletter* 17:46-48.
31. Singh, B. R. and Steenberg, K., (1974). Plant Response to Micronutrients – III. Interaction between Mn and Zn in Maize and barley Plants. *Plants Soil* 40: 655 – 667.
32. Smilde, K. W. (1973). Potassium and micronutrient metal uptake by some tree species as affected by phosphate and lime applied to an acid sandy soil. *Plant Soil* 39:131-149.
33. Shehu H. E. (2014) Uptake and agronomic efficiencies of nitrogen, phosphorus and potassium in Sesamum indicum L. American Journal of plant nutrition and fertilizer technology 4(2):41-56.
34. Soil Survey Staff, (1975). Soil taxanomy: Abasic system of Soil Classification for making and interpreting soil surveys. Washington, DC: US. Department of Agriculture, Soil conservation Services, In: Brady, N. C. (1984). The nature and properties of soils, 9th Ed. Macmillan Publishing Co. Inc. 750pp.
35. Tiwari, K. P., Namdeo, K. N., Tomar, R. K. S and Raghu, J. S.,(1995) Effect of Macro and Micronutrients in Combination with Organic Manures on the Production of sesame (*Sesamum indicum* L.). *Indian Journal of Agronomy* 40(1):134-136.
36. Veits, F. G., Jr. (1966) Zn Deficiency in the Soil Plant system, *In:* Zinc Metabolism, Prasad, A. S. (Ed.), Thomas, C. C. Spring field publisher III.
37. Walkley, A., and Black, C. A. (1934). An examination of Detjaraff method of determining soil organic matter and proposed modification of the chromic acid/titration method. Soil Science 37:29-38.
38. Webb, M. J., Dinkelaker, B. E and Graham, R. D. (1993). The Dynamic Nature of Mn Availability During storage of Calcareous Soil: Its Importance in plant growth experiments. *Biology Fertility Soils* 15:9 -15.
39. Weil, R. R., Foy, C. D. and Coradetti, C. A. (1997). Influence of Soil Moisture Regimes on Subsequent Soil N Availability and toxicity in two Cotton Genotypes. *Agronomy Journal* 89:1 – 8.

1/1/2017