# Manganese and Zinc nutrition of Sesame (*Sesamum indicum*) in Mubi, Northern Guinea Savannah Zone of Nigeria.

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**Abstract:** Studies were conducted 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 to assess the effects of Mn and Zn on the growth and yield characters of sesame (*Sesamum indicum* L.) in Mubi, Northern Guinea savannah zone of Nigeria. The experiment consisted of optimum rates of N, P, and K (75 kg N, 45 kg $P_2O_5$ and 22.5 kg $K_2O$) combined with two rates of Zn (0.5 and 1 kg $ha^{-1}$) and two rates of Mn (0.5 and 1 kg $ha^{-1}$) which gave 8 treatments combinations replicated 3 times giving a total of 24 plots. The treatment combinations were 0, NPK, NPK + 0.5 kg Zn $ha^{-1}$, NPK + 1 kg Zn $ha^{-1}$, NPK + 0.5 kg Mn $ha^{-1}$, NPK + 1 kg Mn $ha^{-1}$, NPK + 0.5 kg Zn $ha^{-1}$ + 0.5 kg Mn $ha^{-1}$, NPK + 1 kg Zn $ha^{-1}$ + 1 kg Mn $ha^{-1}$. These were laid out in randomized complete block design. Results shows that there were no significant (P=0.05) effect of Mn and Zn on stem height, number of leaves, number of branches and capsules. The different grain yield responses were associated to their differences in Mn and Zn concentrations. Sesame seed yield increased by 2 and 5% from the application of 0.5 kg Mn $ha^{-1}$ and 0.5 kg Zn $ha^{-1}$, respectively. Dry matter increased by 13.2 and 2% from 1 kg Mn $ha^{-1}$ and 0.5 kg Zn $ha^{-1}$ rates, respectively. Mn uptake was associated to Zn uptake (r=0.403).

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## 1. Introduction

Manganese exists in soils as insoluble oxides of trivalent and tetravalent Mn, exchangeable and water soluble divalent Mn, all in a state of equilibrium (Havlin, 2005). Total content in surface soils ranged from 37-11,500 mg $kg^{-1}$ (Deb and Sakal, 2002). Mn content of 0.1 HCl extractable of 8-29 mg $kg^{-1}$ was reported by Yaro *et al*. (2006) in some soils of Samaru, Zaria. Sadiq *et al*. (2008) reported an average range of 27.27 mg $kg^{-1}$ in Adamawa State.

Zinc content in the lithosphere is about 80 mg $kg^{-1}$ and ranged from 10-300 mg $kg^{-1}$ in soils with an average of 50 mg $kg^{-1}$ (Havlin, 2005). Yaro, *et al.* (2006) reported 0.1 HCl extractible Zn to be 1.0 to 9.5 mg $kg^{-1}$ for soils of the Northern Guinea savanna region of Nigeria as Deb and Sakal (2002) recorded a critical range of 1-5 mg $kg^{-1}$ 0.1N HCl extractible Zn. In some soils of Adamawa state, Sadiq *et al*. (2008) reported Zn range of 1.44- 3.68 with mean of 2.83 mg $kg^{-1}$.

It is quite likely that sesame productivity is also limited by one or more micronutrients (Balamurugan and Venkatesan, 1983; Muthuvel *et al.,* 1985). The beneficial effect of micronutrients like Zn and Mn might be due to the activation of enzymes and the efficient utilization of applied nutrients resulting in increased yield components as reported by Tiwari *et al*. (1995) and Shanker *et al*. (1999). Singaravel *et al.* (2002) reported that the combined application of Zn and Mn in soil produced the highest number of capsules $plant^{-1}$ by 59% and number of seeds $capsules^{-1}$ by 57% over control. They also reported that application of Zn alone as foliar and soil increased the yield from 592 to 611 kg $ha^{-1}$. Vadivel (1980) and Balamurugan (1982) who worked on the uptake of Zn and Mn observed increased growth and yield components as well as an increased availability and better uptake of these nutrients which agreed with the findings of Singaravel *et al.* (2002). Singaravel *et al*. (2002) went further to observe and state that combined application of Zn and Mn in soil registered the highest NPK uptake in seed and shoot. Therefore, this study was initiated with the objectives of assessing the effects of Mn and Zn fertilizers on the growth and yield parameters of sesame for optimum yield of the crop.

## 2. Materials and Methods

Two years field study were conducted during the 2005 and 2006 rainy seasons at the Food and Agricultural Organisation of the United nations/Tree Crop Programme (FAO/TCP) Teaching and Research farm of the Adamawa State University, Mubi (10° 11' N: 13° 19' E, altitude 594 m above sea level) Northern Guinea savanna of Nigeria. The climate of the area is characterized by alternate wet and dry seasons. The rains last from April to October with a mean annual rainfall ranging from 700 mm to 1,050 mm. The rainfall is unimodal, reaching its peak in the month of July and August. The coldest months of the year are November to February whereas the hottest months are March and April (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 samples were collected at 0-15 cm depths, 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 N by a modified Kjeldahl method (Bremner and Mulvaney 1982); Available P 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 Mg 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 Lindsay and Norvell (1978).

Data measured were stem height, number of leaves, number of branches, number of capsules, number of seed in capsule, seed and dry matter yields. Data collected were subjected to analysis of variance (ANOVA). Duncan's Multiple Range Test (DMRT) was used for mean separation where differences were significant, at 5% level of probability and correlation analysis was also carried out using SAS (2000).

**3. Results**

Experimental soil was sandy loam in texture and slightly acidic in reaction. The soil was also characterized by low organic carbon (<1%), total N (<0.1%), available P (<7 mg $ka^{-1}$), potassium (<0.3 cmol $kg^{-1}$), Zinc (<2.26 mg $ka^{-1}$) and Mn (37.83 mg $kg^{-1}$) as presented in Table 1.

The effect of Mn and Zn on stem height, and number of branches and number of leaves of sesame is presented in Table 2. Stem height and number of branches did not yield any significant response. The other treatment rates did not show any significant difference in their effects on the number of leaves. Addition of 0.5 and 1 kg Mn $ha^{-1}$ reduced the number of capsules by 5.1 and 15.9%, respectively as 0.5 and 1 kg Zn $ha^{-1}$ reduced number of capsules by 35.1 and 22.9%, respectively. Combination of 0.5 kg Mn and 0.5 kg Zn $ha^{-1}$ reduced number of capsules by 9.9% as 1 kg Mn and 1 kg Zn $ha^{-1}$ combination reduced number of capsules by 13.3%.

Thus, addition of Mn and Zn depressed the number of capsules of sesame. Except for the 0 kg $ha^{-1}$ treatment, all others recorded no significant difference. However, highest number of capsules was produced when NPK was applied alone with corresponding number of capsules of 207.67.

Table 1: Texture and Some selected Chemical Characteristics of Soil of the Experimental Site

| **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 |

The effect of Mn and Zn on the number of seeds in capsule is presented in Table 2. The lowest number of seed in capsules was produced from treatments that did not receive any fertilizer. The highest number of seeds in capsule (86.00) was produced by NPK + 1 kg Zn $ha^{-1}$ application, an increase of 1.2% over NPK alone.

The effect of Mn and Zn on seed yield of sesame is presented in Table 3. Application of NPK + 0.5 kg Zn $ha^{-1}$ produced the highest seed yield of 591.32 kg $ha^{-1}$. However this is at par with yields recorded from the application of NPK, NPK + 0.5 kg Mn $ha^{-1}$, NPK +1 kg Mn $ha^{-1}$ and NPK +1 kg Zn $ha^{-1}$ (560.5, 573.17, 479.81 and 552.5 kg $ha^{-1}$, respectively).

Seed yields recorded from the application of NPK + 0.5 Mn + 0.5 Zn and NPK + 1 Mn + 1 Zn were not significantly different from each other. Application of NPK + 1 kg Mn $ha^{-1}$ gave the highest dry matter yields of 2003 kg $ha^{-1}$. This value was not significantly different from the yields produced from the application of NPK (1769 kg $ha^{-1}$), NPK + 0.5 kg Mn (1803 kg $ha^{-1}$), NPK + 0.5 kg Zn (1767 kg $ha^{-1}$) and NPK + 1 kg Zn $ha^{-1}$ (1803 kg $ha^{-1}$). This show an increase of 13.2% dry matter yield from addition of 1kg Mn $ha^{-1}$ and 2% from 0.5 kg Zn $ha^{-1}$ addition.

The effect of Mn and Zn on shoot Mn content of sesame is shown in Table 3. Results indicated that the application of Mn and Zn fertilizers did not influence Mn content of sesame shoot significantly. Significant effects on shoot Zn content were recorded from the application of Mn and Zn (Table 3). Analysis revealed that 8.50 mg $kg^{-1}$ was the highest Zn accumulation obtained from the application of NPK + 0.5 kg Zn $ha^{-1}$ as accumulation of Zn in shoots were more in treatments that received NPK +0.5 kg Zn $ha^{-1}$ application and lower in the treatments without Zn application. Combination of Mn and Zn up to 1 kg $ha^{-1}$ each reduced shoot Zn content compared to NPK + 0.5 kg $ka^{-1}$.

Table 2: Variance analysis of effects of Mn and Zn on growth and yield characters of sesame

| | Stem height (cm) | Number of branches | Number of leaves | Number of capsules | Number of seeds in capsule |
|---|---|---|---|---|---|
| Year | 93.98** | 6.41* | 0.94ns | 31.89** | 1.82ns |
| Treatment | 0.93ns | 0.57ns | 0.20ns | 1.85ns | 4.16* |
| CV(%) | 10.39 | 42.56 | 36.16 | 33.27 | 6.41 |

* = Significant at 5% level of probability
** = Significant at 1% level of probability
ns = not significant

Table 3: Effect of Mn and Zn on yield, shoot content and uptake by sesame

| | Seed yield (kg $ha^{-1}$) | Dry matter yield (kg $ha^{-1}$) | Mn shoot content (mg $kg^{-1}$) | Zn shoot content (mg $kg^{-1}$) | Mn Uptake (kg $ha^{-1}$) | Zn Uptake (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|
| **Year** | | | | | | |
| 2005 | 472.83 | 1636.9 | $238.81^{a}$ | 8.071 | 0.392 | 0.015 |
| 2006 | 530.82 | 1841.7 | $185.24^{b}$ | 6.833 | 0.336 | 0.013 |
| SE(±) | 55.60 | 190.03 | 26.15 | 1.53 | 0.15 | 0.004 |
| Level of Significance | ns | ns | ** | ns | ns | ns |
| **Fertilizers** | | | | | | |
| 0-0-0 | $220.65^{d}$ | $682^{c}$ | 170.83 | $4.17^{b}$ | $0.12^{c}$ | $0.003^{c}$ |
| NPK | $560.50^{a}$ | $1769^{ab}$ | 172.50 | $7.50^{ab}$ | $0.30^{b}$ | $0.013^{ab}$ |
| NPK + 0.5Mn | $573.17^{a}$ | $1803^{ab}$ | 195.00 | $7.00^{ab}$ | $0.34^{ab}$ | $0.013^{ab}$ |
| NPK + 0.5Zn | $591.32^{a}$ | $1767^{ab}$ | 236.67 | $8.50^{a}$ | $0.42^{ab}$ | $0.016^{ab}$ |
| NPK + 1Mn | $479.81^{ab}$ | $2003^{a}$ | 235.00 | $5.83^{ab}$ | $0.47^{a}$ | $0.012^{a-c}$ |
| NPK + 1Zn | $552.50^{a}$ | $1803^{ab}$ | 205.00 | $8.83^{a}$ | $0.36^{ab}$ | $0.016^{ab}$ |
| NPK + 0.5Mn + 0.5Zn | $398.40^{bc}$ | $1526^{b}$ | 216.67 | $8.83^{a}$ | $0.33^{b}$ | $0.021^{a}$ |
| NPK + 1Mn+ 1Zn | $357.09^{c}$ | $1505^{b}$ | 223.33 | $5.67^{ab}$ | $0.33^{b}$ | $0.008^{bc}$ |
| SE(±) | 55.46 | 186.76 | 32.14 | 1.50 | 0.06 | 0.004 |
| Level of Significance | ** | *** | ns | * | * | * |

†=Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using Duncan Multiple Range Test.
* = Significant at 5% level of probability
** = Significant at 1% level of probability
*** = Significant at 0.1% level of probability
ns = not significant

The effect of Mn and Zn fertilizers on the uptake of Mn is presented in Table 3. 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. The lowest Mn uptake (0.12 kg $ha^{-1}$) from treatment that did not receive any fertilizer application. The two years of study revealed significant responses of Zn uptake to Mn and Zn fertilizer application. 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 kg Mn $ha^{-1}$ 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.

The relationship among yield and yield components of sesame is presented in Table 4. Stem height was positively correlated with number of branches, number of capsules (r = 0.510 and 0.620, respectively). Number of branches was positively associated with number of capsules (r = 0.485). Number of leaves was positively correlated with number of capsules, seed yield and dry matter (r = 0.301, 0.303 and 0.308, respectively). A positive relationship existed between number of capsules and seed yield, and dry matter (r = 0.418 and 0.420, respectively). A positive relationship existed between seed in capsule and seed yield (r = 0.349) and dry matter (r = 0.405). A high positive correlation existed between seed yield and dry matter with r = 0.751. Mn uptake was positively related to seed, dry matter and Zn uptake (r=0.498, 0.716 and 0.403, respectively.

Table 4: Correlation coefficients among growth and yield components of sesame

| | Height | Branches | Leaves | Capsules | Seed in capsule | Yield | Dry matter | Mn uptake | Zn uptake |
|---|---|---|---|---|---|---|---|---|---|
| Height | 1.000 | | | | | | | | |
| Branches | 0.510*** | 1.000 | | | | | | | |
| Leaves | 0.023 | 0.197 | 1.000 | | | | | | |
| Capsules | 0.610*** | 0.485*** | 0.301* | 1.000 | | | | | |
| Seed in capsule | 0.126 | 0.029 | 0.201 | 0.250 | 1.000 | | | | |
| Yield | 0.175 | 0.222 | 0.303* | 0.418** | 0.349* | 1.000 | | | |
| Dry matter | 0.261 | 0.172 | 0.308* | 0.420** | 0.405** | 0.751*** | 1.000 | | |
| Mn uptake | -0.109 | -0.191 | 0.127 | 0.061 | 0.236 | 0.498*** | 0.716*** | 1.000 | |
| Zn uptake | -0.014 | -0.009 | 0.116 | 0.073 | 0.225 | 0.338* | 0.465** | 0.403** | 1.000 |
| * = Significant at 5% level of probability | | | | | | | | | |
| ** = Significant at 1% level of probability | | | | | | | | | |
| *** = Significant at 0.1% level of probability | | | | | | | | | |

## 4. Discussion

The results from two year field experiment have shown that application of Mn and Zn at all rates did not increase stem height, number of branches and leaves. The addition of Mn and Zn to NPK did not significantly influence the number of capsules of sesame. Application of Zn at 1 kg Zn $ha^{-1}$ increased number of seeds in pod by 1.2 and 24% over NPK and control respectively. The lack of significant increase in seed yield from Mn application agrees with the findings of Draycott and Farley (1973). He compared soil application and foliar spray of Mn and reported that soil application of $MnSO_4$ salts did not prevent Mn deficiency. Also Mengel and Kirby (2006) observed that application of Mn salts to the soil in an experiment with barley was of no use. This was attributed to the rapid oxidation of Mn and less suitability of the the method of application compared to foliar spray.

It was observed in this result that application of Mn and Zn at 1 kg $ha^{-1}$ each to NPK yielded an increase of 61.8% in seed yield while the application of Zn alone at 0.5 kg Zn $ha^{-1}$ to NPK increased seed yield by 168% and 5.5% over control and NPK respectively. This concurs with the report of Cakmak *et al.* (1996) that application of Zn at 23 kg Zn $ha^{-1}$ increased seed yield of wheat by 43%. Increase in seed yield may be attributed to the high solubility of $ZnSO_4$ and thus its absorption by the plant.

Application of 1 kg Mn $ha^{-1}$ increased dry matter yield by 194 and 13.2% over control and NPK respectively. Similar result was reported by El-Fouly *et al.* (1992) where increased dry matter weight was observed at higher Mn rates. Application of Mn and Zn at 0.5 and 1 kg $ha^{-1}$ each decreased dry matter yield by 15.9 and 17.5% respectively. This differs from El-Fouly *et al.* (2001) where increase in dry matter was recorded at higher rate of Zn. The interaction of Mn and Zn at these rates might have suppressed the uptake of some secondary nutrients such as Ca and Mg thus altering their functions and subsequently depressing dry matter production.

Application of Mn at 0.5 and 1 kg $ha^{-1}$ increased shoot Mn by 13 and 36% respectively. Increased shoot Mn from increased Mn application was observed by Singh and Steenberg (1974) who reported increase in Mn content of maize and barley plants from Mn fertilizer application. Increase in Mn content was also observed at 0.5 kg Zn $ha^{-1}$. Increase from 0.5 to 1 kg Zn $ha^{-1}$ depressed Mn concentration by 15.4%. Reduced Mn content of sesame plant due to increased Zn application rate was reported by El-Fouly *et al.* (2001) and Singh and Steenberg (1974). This negative response could be attributed to cation competition during absorption, translocation and distribution into and within the shoot.

Combined NPK fertilization increased sesame shoot Zn content by 79.9% over control. Application of Mn at 0.5 and 1 kg $ha^{-1}$ reduced shoot Zn by 7.1

and 28.6% respectively. Similar result was observed by El-Fouly (2001) where application of 3.30 ppm Mn reduced sunflower Zn content by 74%. It was also observed from this study that increased Zn application rate from 0.5 to 1 kg $ha^{-1}$ increased shoot Zn by 17.7%. Increase in shoot Zn from Zn application was also reported by Paivoke (2003) who studied *Pisum sativum* at different Zn supply levels. Combined Zn and Mn at 0.5 kg $ha^{-1}$ also increased sesame shoot Zn content by 17.7%.

As regards Mn uptake, Mn 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).

## Conclusion

Based on the results of this experiment, optimum levels Manganese and Zn rates are 0.5 kg Mn and 0.5 kg Zn $ha^{-1}$ respectively. After cropping of sesame, Mn and Zn increased seed yield by 2.3 and 5.5%, respectively. Mn shoot content was linked to Zn concentration while Zn shoot content was not directly linked to varying Mn and Zn rates. Manganese contributes more to dry matter production of sesame while Zn in seed yields.

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