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Determination of zinc requirements for optimum yield performance of mungbean (*Vigna radiata* L.) in shale derived soils of humid tropical rainforest, Nigeria

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Abstract
Zinc deficiency is a global nutritional problem especially in shale soils of tropical region of south-eastern Nigeria. In view of this, the present study was carried out to evaluate the critical limits of Zn for mungbean producing areas and to establish the optimum rates of Zn fertilizer required to achieve maximum Zn uptake and yield performance of Mungbean. Hydrated Zn sulphate fertilizer was applied to the soils at five levels (0, 5, 15, and 20 kg ha^{-1}) for the greenhouse and at seven levels (0, 3, 6, 9, 12, 15 and 18 kg ha^{-1}) for the field studies. Results shows that, the shale soils were sandy loam (SL), very strongly acidic (4.73), low in OC (1.08 gkg^{-1}), ECEC (4.38 cmol kg^{-1}) and in EDTA-extracTable Zn (0.52 $mgkg^{-1}$). The critical limits of Zn for mungbean production soils, were established. Results of the greenhouse and field studies shows that levels of Zn significantly ($P<0.05$) increased Zn budget, Zn uptake and grain yields of mungbean. Maximum uptake (1.27 $mgplant^{-1}$) and grain yields (9.93$kgha^{-1}$) of mungbean were established at an estimated optimum rates of 13.01 kg Zn ha^{-1} and 12.53 kg Zn ha^{-1} for greenhouse and field studies, respectively. The current study showed that though the soils had a severe Zn deficiency, the mungbean production could be increased considerably by applying Zn sulphate at 12.5 kg Zn ha^{-1} in the soils and other similar soils of the same agroecological zone within a shale derived soil.

Keywords: Critical limit, humid tropical, mungbean, optimum yield, shale, Zn budget, Zn uptake

1. Introduction

Mungbean [*Vigna radiata* (L.) R. Wilczek] belongs to the family of Leguminosae and is one of the most important short duration, drought tolerant pulse crops commonly used for protein supplement (Kumar *et al.*, 2014; Roy, 2014) [23, 31]. It is cultivated in the tropical zones of the world, but recently introduced into Nigerian diet (Agugo, 2003) [1]. It is becoming an important crop, as it is the best alternative to meet the food needs of the large population of developing countries due to its nutritional superiority diet (Agugo, 2003) [1] and nitrogen fixing characters (Yakadri 2002; Jamal *et al.*, 2018) [41, 21]. Nutritionally, *Vigna radiata* contains 1-3% fat, 50.4% carbohydrates, 3.5-4.5% fibers and 4.5-5.5% ash, while, calcium and phosphorus are 132 and 367 mg per 100 grams of seed, respectively (Hossain, 2008; Kumar, 2014) [19, 23]. It also contains vitamin A (94 mg), iron (7.3 mg), calcium (124 mg), zinc (3mg) and folate (549mg) per 100 grams dry seeds (Roy 2014; Jamal *et al.*, 2018) [31, 21].
Mungbean requires a good mineral nutrition for optimum growth and sustainable production (Marschner, 1995) [25]. Zinc is a micronutrient element with known essential functions for plants which, is readily absorbed by plant roots and translocate to the above-ground plant parts (Marschner, 1995) [25]. However, the low grain yield performance of mungbesan in the farmer's fields could be an indication of possible deficiencies of Zn nutrient in the soil (Sillanpaa, 1990; Kabata-Pendias, 2010) [33, 22]. Zinc is crucial for the enzyme functioning in plants and it is very important for plant growth and development (Ahmad, 2012) [2].
Zn deficiency in plants is one of the major concerns globally (Jamal *et al.*, 2018) [21]. The deficiency in soils generally do not support optimum crop yields because, plant growth becomes retarded by the deficiency leading to low yields (Sillanpaa, 1990; Chude *et al* 2004) [8, 33].

The yield production could be increased by the supplying of sufficient amount of appropriate plant nutrient elements (Asaduzzaman *et al*., 2008) [4]. The uptake of these nutrient elements by plant could increase proportionally to increasing soil micronutrients cations when, the soil contains substantial concentration in soil solution though, can be affected by the presence of major nutrients due to either negative (antagonistic) or positive (synergistic) interactions (Sillanpaa, 1990; Marschner, 1995; Kabata-Pendias, 2010) [33, 25, 22]. Since the plant can absorb the micronutrient element from the soil, one can make a relationship between soil nutrient levels and plant response (Cate and Nelson, 1965) [7]. In crop production a useful concept which is widely used to relate the soil-plant nutrient and crop yield is the optimum concentration level (Tariq *et al.*, 2014) [36]. Thus, suiTable fertilizer recommendation can be presented by calibration experiments with crop response results for each crop (Enwezor, *et al*., 1981, 1989 and 1990) [9-11]. Mineral nutrient constraint therefore, is one of the many factors which, might be contributing to the large gap between farmers' (downstream) seed production and those of possible under experimental (upstream) research conditions (Enwezor, *et al*., 1989 and 1990) [10-11]. Comparatively, very little is known about the Zn requirements of mungbeans, and rather more is known about their requirements for NPK than for micronutrients (Kumar *et al*, 2014) [23]. Previous studies have attributed the paucity of information about Zn requirements of mungbean to their relatively low yield potential and hence to their low demand for micronutrients for grain yields. The purpose of this study was therefore, to determine Zn requirements for optimum yield performances of mungbean in shale derived soils of South-eastern Nigeria.

2. Materials and Methods

2.1 Study description: The experiment was conducted at, Ishiagu during the 2020/2021 cropping season. Ishiagu is located at the longitude 07^{0}46E and latitude 05^{0}05 45N with a mean annual temperature of 29^{0}C and mean annual rainfall of 1350mm. The area lies within the derived savannah vegetative zone of eastern Nigeria, with grassland and shrub tree combined together. There are two reported distinct seasons, the wet season which spans April to October and dry season; November to March (Ojanuga, 2006) [29]. The soil has been classified as a Typic Paleudult according to USDA system of classification (USDA, 2006) [38]. The soils have has a high potential for dual seasons arable crop production was selected to represent shale derived soil of, Ebonyi State, Nigeria. The soil is currently being used intensively and extensively for the cultivation of okra, yam, and sweet potato as well as, some new upland/swamp rice and cassava varieties.

Table 1: Mean annual and monthly precipitation (P), potential evapotranspiration (PET) and water balance of the study area

Station	Parameter	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
FCA Ishiagu	P	40	71	161	222	306	419	449	411	421	325	188	50	3063
	PET	80	85	91	85	79	64	53	51	58	69	76	83	887
	P-PET	-40	-14	70	137	227	355	396	360	363	256	112	-33	2176

2.2 Soil sampling and sample collection: Thirty (30) surface (0-20 cm) shale derived soil samples were collected from six different locations of Ebonyi State, Nigeria namely; Abakalike, Amasiri, Ikwo, Ishiagu, Ohaozara and Uwana in areas where the farmers have never applied micronutrient fertilizers. In each of the locations, 10 kg soil samples from three sampling points (replicates) at different distances of more than twenty (20) kilometers apart were, randomly collected. The 30 composite soil samples collected were air-dried and passed through 2.0 mm sieve. A portion of the sieved soil samples were bagged in plastic bags and used for the greenhouse experiment.

2.3 Laboratory study: The laboratory study was conducted to determine some physical and chemical properties, status of available Zn and the critical Zn range (CNR) of the soils collected from the six different locations of the study area having been informed that Zn nutrient was a limiting micronutrients (Enwezor *et al*., 1990) [11]. 100 g of each of the samples were subjected to some physical and chemical properties and to determine the total and available forms of zinc by Aqua Regia Digestion method of extraction.

The sample was analyzed for pH (H_2O) as described by Thomas (1996) [37], organic carbon was determined by wet oxidation (Nelson and Sommer, 1996) [27], available P was determined by Bray I method (Kuo, 1996) [24], and total N was determined by Kjeldahl procedure of Bremner (1996) [5-6]. Effective cation exchange capacity and exchangeable cations were determined by the method described by Sumner and Miller (1996) [35]. Zinc was extracted with EDTA as described by Eteng *et al* (2014) [12] and the concentration of the Zn was determined with atomic adsorption spectrophotosmeter (Unicam Solaar 32: Cu Astm D1688; Zn Astm D1691).

2.4 Greenhouse Study: The Greenhouse experiment was conducted on soils collected from the six (6) distinct locations to evaluate the optimum rate of Zn required to maximize DMY, Zn concentration and Zn uptake in mungbean shoots. Mungbean (*Vigna radiata* (L.) was used as the test crop. The treatments consists of five levels of zinc sulphate at 0, 5, 10, 15 and 20 kg ha^{-1} converted to mg kg^{-1} and applied as $ZnSO_4.7H_2O$. Five (5) kilogrammes of the soil samples from each the six (6) locations were collected and weighed into plastic containers of 7 L capacity placed on flat plastic receiver. The greenhouse study weas arranged in completely randomized design (CRD), replicated four times to give a total of 120 (6 locations x 5 rates x 4 reps.) containers.

Before planting, the soils were moistened with distilled water to field capacity. Five seeds of mungbean were sown in each container and thinned to three plants per container. Seven days after sowing (7DAS) after thinning, the zinc sulphate in solution form was applied to the containers as soil application according to the experimental design. A recommended basal dosages of N, P_2O_5 and K_2O at rates of 120, 60, 60 kgha^{-1} were applied as urea, single super phosphate and potassium sulphate in solution form, respectively.

Six weeks (6WAP) *i.e*., 42 days after emergence (DAE), the mungbean plants (shoots and roots) were uprooted from each pot, rinsed in distilled water, pre-dried under shade to remove excess water and later placed in large envelopes and oven-dried at 70ºC for 72 hrs. The oven-dried plants parts were weighed and recorded for dry-matter yield. The dried plant samples of each container were separately ground into powder in a stainless steel grinder to pass through a 0.5 mm. The dry powdered plant samples were digested in a tri-acid mixture of 10:2:1 of HNO_3: $HClO_4$: H_2SO_4 on a hot plate and filtered through Whatman No.42 for estimation of Zn. Atomic Absorption Spectrophotometer (AAS) (Unicam Solaar 32: Zn ASTM D1688) was used to measure the concentration of Zn in the digest.

2.5 Field Study: After the greenhouse study in 2010, a field study was conducted in 2011 at the Federal College of Agriculture, Ishiagu, Ebonyi State Nigeria, to determine the optimum Zn levels on yield of mungbean. The field had been under continuous and intensive cultivation of many arable crops. The soil was classified as Paleudult according to USDA and FAO soil classification systems, respectively (USDA, 2006). The field experiments were laid out in a randomized completely blocks design (RCBD) with four replications to give 28 (7 treatments x 4 Reps.) sub-plots. Each block had seven plots, with plot sizes of 5.0 x 4.0 m (20.0 m^2). Three seeds of mungbean were sown manually per hole at a spacing of 75 cm by 25 cm. 14 days after emergence, thinning was performed to two per hole in order to maintain uniform number of plants in all the plots. Zn fertilizer was applied at seven rates: 0, 3, 6, 9, 12, 15 and 18 kg Zn ha^{-1} as $ZnSO_4.7H_2O$. Recommended doses of 120 kg N, 30 kg P and 60 kg K fertilizers per hectare were soil applied uniformly as urea, single super phosphate, and muriate of potash, respectively to all the plots at sowing. The fertilizer application was carried out by mixing the recommended Zn dose with the NPK fertilizers and applied by band placement a week after emergence. All the recommended cultural practices were followed uniformly throughout the planting season. However, after twelve weeks of planting, the matured mungbean seeds was harvested, weighed and recorded. The Yield components of mungbean determined were: No of pods/plant, No of seeds/plant, Pod weight (g), and grain yield ($kgha^{-1}$).

2.6 Statistical Analysis: The data collected from the greenhouse and field studies were subjected to analysis of variance (ANOVA) procedure, using general linear model of GenStat and PASW Statistics 18 for Window 7.0. Significant means were separated using Fisher's Least Significant Different where appropriate at $P<0.05$. Also correlation and regression analysis was carried out to establish the relationship between soil Zn content and yield parameters. Zn uptake in plant shoots (mg $plant^{-1}$) were calculated by multiplying the dry matter accumulation ($gplant^{-1}$) by the concentration (mg kg^{-1}) in plant materials.

3. Results and Discussion

3.1 Laboratory Study

3.1.1 Soil characteristics of the study: The soil samples used in this study varied remarkably in their soil characteristics (Table 2). The mean pH of all the 5 locations were very strongly acidic (4.78) in reaction and ranged from 4.30 to 5.08. Based on the soil test data, all the soil samples were found to be low in organic carbon which, fluctuated between 0.91 and 1.24 gkg^{-1} with an average of 1.06 gkg^{-1}. In addition to the above properties, ECEC in the surface (0-20 cm) soils ranged from 2.91 to 6.14 cmol kg^{-1} with an average of 4.03 cmol kg^{-1}. The mean soil samples determined was sandy loam (SL). The mean values of the soil nutrients; N, P, K, Ca, Mg, Na, and extracTable Zn determined are, 0.79 gkg^{-1}, 12.77 $mg.kg^{-1}$, 0.09 $cmol.kg^{-1}$, 1.52 $cmol.kg^{-1}$, 1.37 $cmol.kg^{-1}$, 0.09 $cmol.kg^{-1}$ and 0.63 $mg.kg^{-1}$, respectively. These were relatively low in the soils (Table 2). The soil characteristics presented here are similar to the physiochemical properties of soils reported in soils of Southeastern Nigeria (Chude *et al*., 2004; Enwezor *et al.* 1981; Eteng *et al*., 2017) [8, 9, 13].

Table 2: Characterization of physical and chemical properties of the soils used for the Greenhouse study (N=30)

Sample location	Sand	Silt	Clay	Soil textural class	pH (H_2O)	Org carbon	Total Exch. Base	Total Exch. Acidity	ECEC	BS
	g/kg					g/kg	Cmol.kg^{-1}			%
Abakaliki	710.11	109.55	180.34	Sandy loam	5.04	1.19	2.86	1.12	3.98	71.86
Amasiri	656.04	123.61	220.35	Sandy clay loam	4.60	0.91	3.91	2.23	6.14	63.68
Ikwo	720.23	104.21	175.56	Sandy loam	4.90	0.83	2.28	2.06	4.34	52.53
Ishiagu	535.16	340.62	124.22	Loam	4.30	1.12	1.73	1.18	2.91	59.45
Ohoazara	655.44	104.44	240.12	Sandy clay loam	4.45	1.21	3.16	1.44	4.60	68.70
Uwana	707.22	83.59	209.19	Sandy clay loam	5.08	1.24	2.68	1.64	4.32	62.04
Mean	664.03	144.34	191.63	Sandy loam	4.73	1.08	2.77	1.61	4.38	63.04

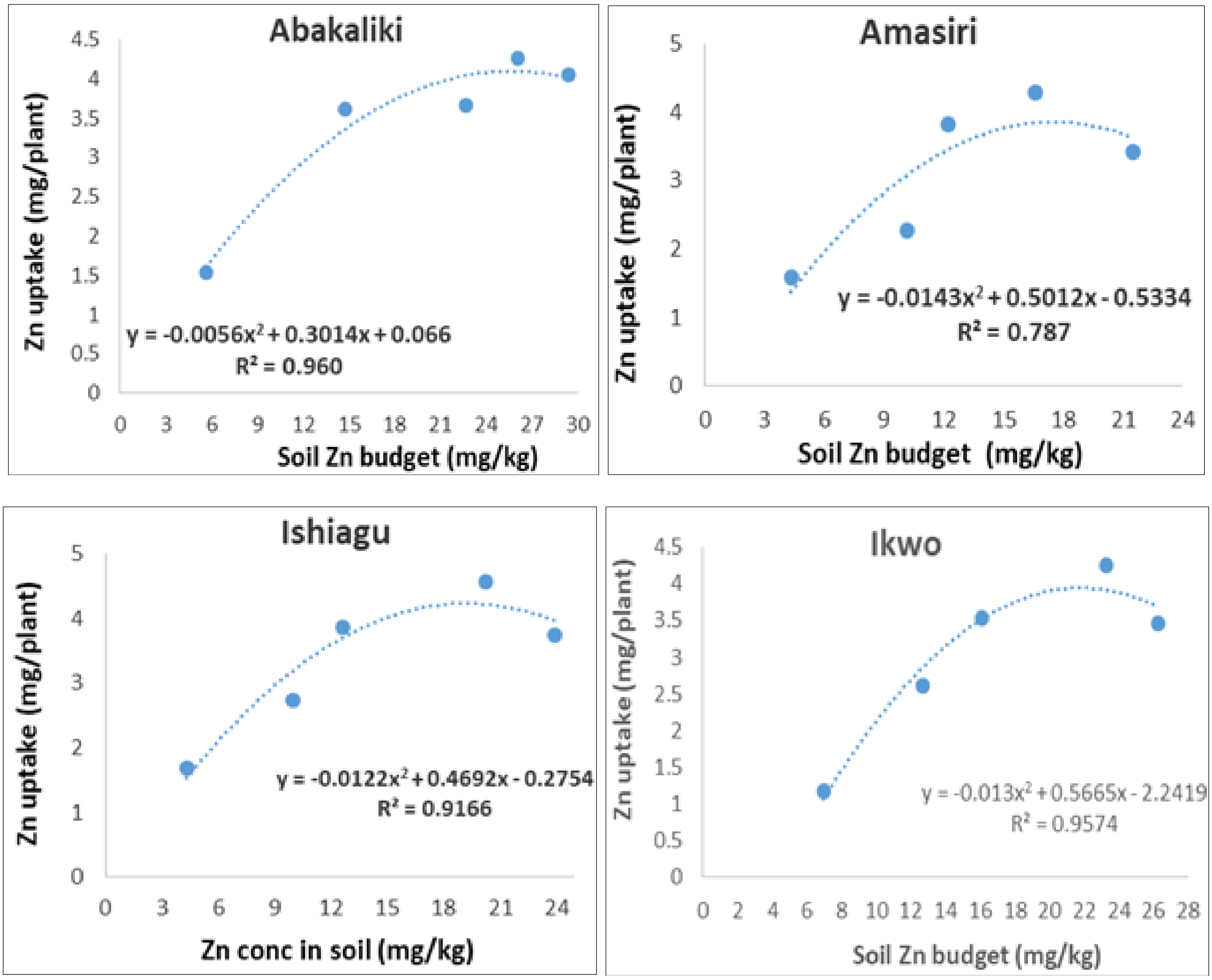
Table 3: Nutrient properties of the soils used for the Greenhouse study (N=30)

Sample location	Total Nitrogen (N)	Avail. Phosphorus (P)	Calcium (Ca^{+2})	Magnesium (Mg^{+2})	Sodium (Na^{+})	Potassium (K^{+})	Ext. Zinc (Zn^{+2})
	gkg^{-1}	**$mg.kg^{-1}$**	**$cmol.kg^{-1}$**				**$mg.kg^{-1}$**
Abakaliki	0.12	24.50	3.00	1.50	0.15	0.16	1.25
Amasiri	1.12	7.46	1.60	1.30	0.24	0.27	0.15
Ikwo	0.80	10.40	1.00	0.97	0.09	0.12	0.15
Ishiagu	0.90	12.60	0.90	0.76	0.03	0.04	0.30
Ohoazara	1.31	26.06	2.12	1.15	0.44	0.21	0.09
Uwana	1.00	8.90	1.10	1.43	0.05	0.06	1.15
Mean	0.91	15.00	1.61	1.19	0.17	0.14	0.52

3.2 Greenhouse study

3.2.1 Determination of optimum Zn uptake in shale soils of different locations as influenced by Zn levels on mungbean: Zinc application increased Zn uptake in mungbean shoots significantly ($P<0.05$), compared with the control, which, indicates that Zn may be attributed to one of the limiting nutrients in the soils (Fig 1). Zn uptake has often been used to assess the functioning of Zn nutrition in mungbean production. The application of various levels of $ZnSO_4$ as fertilizer on shale soils of different locations, showed a differential yield response curve which produced the optimum Zn level requires to produce maximum Zn uptake in mungbean shoots grown at 6 WAP.

Accordingly, the polynomial regression analysis with the corresponding R^2 values are presented in Fig. 1. The results shows that, the optimum levels for Zn uptake in mungbean shoots as influenced by Zn levels and determined by, the quadratic regression method are; 26.91, 17.52, 21.79, 19.23, 21.70 and 20.72 kg Zn ha^{-1} (soil application) with maximum accumulation of Zn uptakes of, 4.12, 3.86, 4.04, 3.93, 4.18 and 4.20 mg plant^{-1} in mungbean plant shoots for, shale derived soils of Abakaliki, Amasiri, Ikwo, Ishiagu, Ohaozara and Uwana, respectively. The Zn values presented by the quadratic regression curves, indicated the optimum points in kgha^{-1} with corresponding R^2 values which are presented in Table 4. These graph confirmed that mungbean yields will keep on improving with additional increments of Zn until the turning points which are slightly higher than the optimum level reached (Feiziasl *et al.*, 2009 [15]. These results is in agreement with findings of Hussain *et al.*, (2021) who found that the plant Zn content and uptake increased with soil Zn. In a similar studies, Srinivasan, *et al*., (2009) [34] reported similar critical limits of Zn in soil and plant for increase productivity of Ginger.



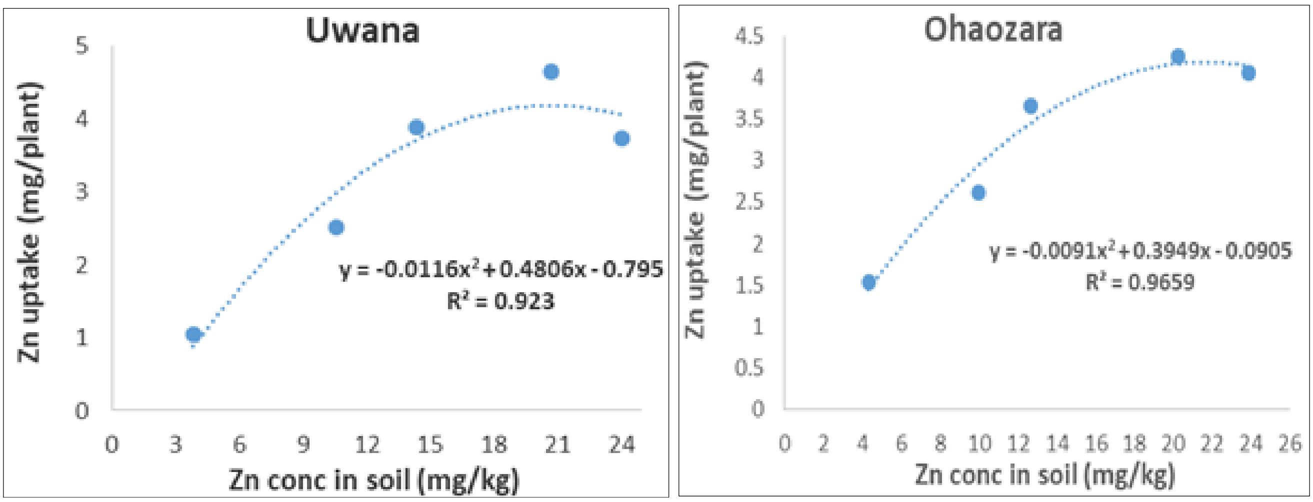


Fig 1: Scatter diagrams showing the relationship between extractable Zn and Zn uptake to determine the critical level of Zn in the different shale soil locations

Table 4: Coefficients of determination (R^2) between extractable Zn in different Shale soils and Zn uptake by mungbean plants (N=120)

S/No.	Sample location	Zn Coefficients of determination (R^2)
1.	Abakaliki	0.960**
2.	Amasiri	0.787*
3.	Ikwo	0.966**
4.	Ishiagu	0.917**
5.	Ohaozara	0.966**
6.	Uwana	0.923**

3.2.2 Critical limits of soil Zn in shale derived soils of different locations as influenced by Zn levels on mungbean: The critical limits of EDTA-extractable Zn estimated for mungbean production at different locations, were found to be 11.95-26.91, 11.45-17.52, 14.00-21.80, 11.15-19.23, 11.35-21.70 and 12.65-20.72 mg Zn kg^{-1} for, shale derived soils of Abakaliki, Amasiri, Ikwo, Ishiagu, Ohaozara and Uwana, respectively. These limits were determined by Cate-Nelson graphical method (Fig.1). Comparing these research results with the current study showed that reported critical levels of maize by different extract ants are nearly similar to the results obtained in this study (Table 5). Similar results on Zn were reported by Eteng and Asawalam (2017) [13]. Based on the significant response and non-response of mungbean crop to Zn application, its amount was ordered by plant response column order procedure. The results suggest that mungbean uptake/yield was significant ($P \leq 0.5\%$) and compared with results reported by Hafeez *et al*., (2013) [17], and Gahlot *et al*., (2020) [16]. The study suggests that all the soils within the area with values of available Zn below the corresponded critical value rated low were deficient (responsive) in levels of uptake of mungbean, while, those soils with values above the critical levels rated high were sufficient (non-responsive) or toxicity symptoms may appear.

Table 5: Critical limits of Zn in shale derived soils from the different locations (N=120)

S/No.	Sample Location	Rating of critical limits of Zn ($mgkg^{-1}$)		
		Low	Moderate	High
1.	Abakaliki	≤11.95	11.95-26.91	≥26.91
2.	Amasiri	≤11.45	11.45-17.52	≥17.52
3.	Ikwo	≤14.00	14.00-21.79	≥21.79
4.	Ishiagu	≤11.15	11.15-19.23	≥19.23
5.	Ohaozara	≤11.35	11.35 - 21.70	≥21.70
6.	Uwana	≤12.65	12.65 - 20.72	≥20.72

3.2.3 Estimation of optimum Zn levels for DMY, Zn content and Zn uptake in mungbean plant: The analysis of variance (ANOVA) conducted for yield attributes of mungbean in the greenhouse showed that, there were significant differences in DMY, Zn content and Zn uptake in mungbean (Figure 2). One attribute that is being used to evaluate the performance of Zn nutrition in mungbean production after grain yield are; dry matter yield, Zn uptake and Zn concentration in the plant tissues as well as Zn budgeted in soil. Figure 2 shows a differential growth response curve of dry matter yield, Zn uptake and Zn concentration at various levels of Zn application which produced the optimum Zn level require to produce maximum mungbean shoots grown at 6 WAP. From the result obtained, significant ($P<0.05$) higher dry matter yield (5.29 g $plant^{-1}$), Zn uptake (1.27 mg $plant^{-1}$), and Zn concentration (31.83 mg kg^{-1}) in mungbean shoots were produced from the application of 15 kg Zn ha^{-1}. Equally, the application of 15 kg Zn ha^{-1} budgeted higher Zn concentration of 44.54 $mgkg^{-1}$ in soil.

However, the optimum values for Zn, determined with the quadratic regression curves in Figure 2 and Table 6, indicates the optimum point of ZnSO4 at 14.23 $kgha^{-1}$ (R^2 = 0.990), 13.01 $kgha^{-1}$ (R^2 = 0.935), 14.49 $kgha^{-1}$ (R^2 = 0.993) as well as 15.49 $kgha^{-1}$ (R^2 = 0.975) for maximum accumulation of DMY, Zn uptake, Zn in plant and Zn budget in soil, respectively. These graph confirmed that mungbean yields will keep on improving with additional increments of Zn until the turning points which are slightly higher than the optimum level reached. These results is in agreement with findings of Furlani *et al.* (2005) who found that the plant Zn content and uptake increased with soil Zn. The variations in DMY, Zn content and uptake of mungbean shoot in different soils could be due to differences in ability of the soils to supply Zn to the plants. This inconsistency in the responses for DMY, Zn content and uptake in mungbean plants by the application of Zn fertilizers could be related to the variation in soil and environmental factors. This may also be due to the dilution effect as a result of the increase in DMY. The finding is at par with previous studies Potarzycki and Grzebisz (2009) on maize production as well as Srinivasan *et al*., (2009) [34] who worked on critical limits of Zn in soil of ginger.

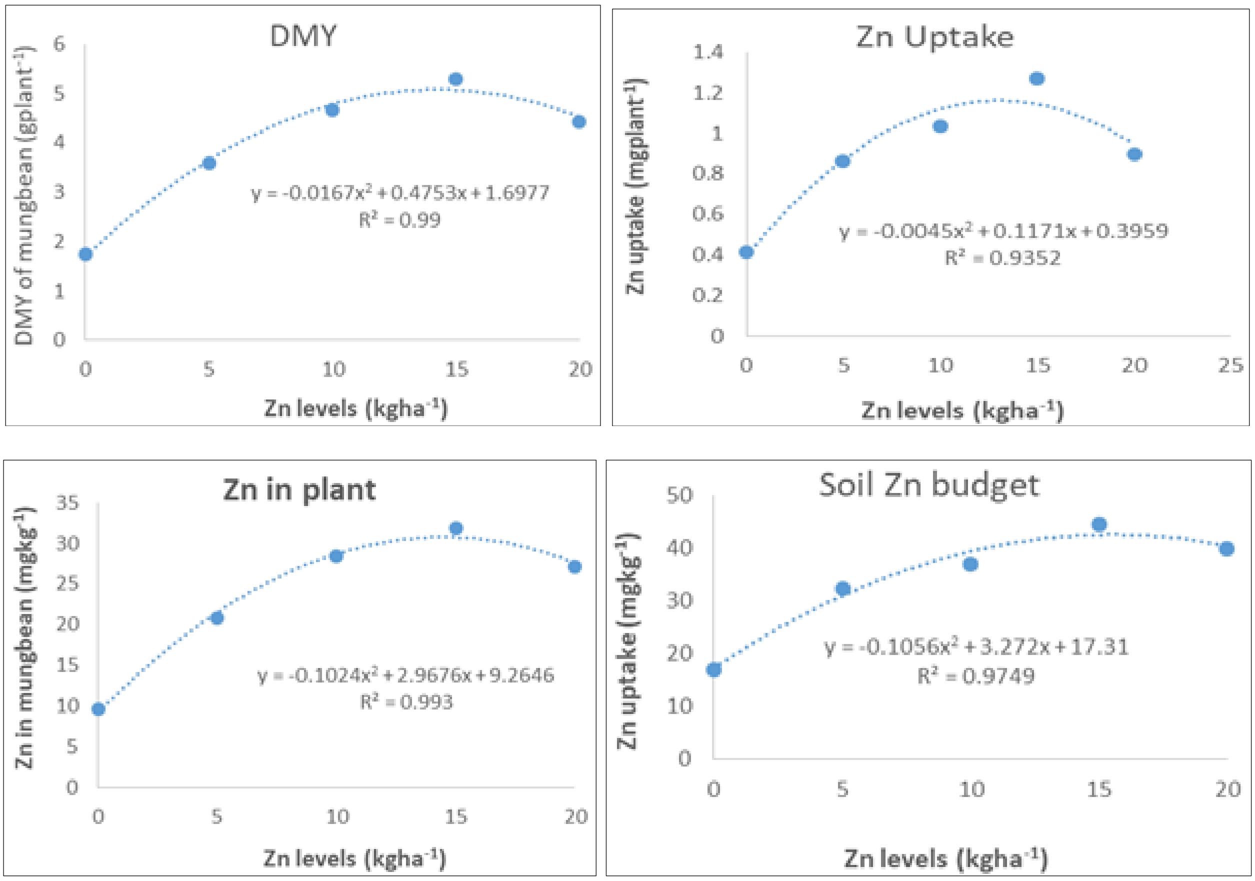


Fig 2: Polynomial graph showing optimum Zn levels for mungbean DMY (gplant^{-1}), Zn uptake (mgplant^{-1}), Zn in plant (mgkg^{-1}) and Soil Zn budget (mgkg^{-1}) of the greenhouse study.

3.3 Field calibration study

3.3.1 Effect of Zn levels on yield contributing characters of mungbean: The results presented in Fig. 3 showed that, ZnSO4 application significantly (P<0.05) increased the yield components of mungbean over control. Application of Zn fertilizer yielded maximum number of pods/plant, number seeds/pod, pod weight/plant and grain yield with values of 16.87, 228.35, 12.27 g and 9.93 kg ha^{-1} which were, obtained from the application of 14.05, 12.75, 13.97 and 12.53 kg Zn ha^{-1} (Fig. 3) with their corresponded R^2 of 0.98 (98%), 0.99 (99%), 0.96 (96%) and 0.98 (98%) predictability (Table 7), respectively. The findings presented in figures 3 shows that, increment in Zn levels caused decrease in yields, presumably due to toxicity level of applied Zn in soil (Rashid and Fox, 1992) [30]. However, the minimum mungbean yield components were consistently obtained in control, indicating that the low yields could be attributed to Zn deficiency in the shale soil. These findings are also in line with those of Roy, (2014) [31]; Jamal *et al*., (2018) [21] and Husain *et al*., (2021) [20] who reported that maximum seed yields, and yield attributes of mungbean were produced between 12 and 20 kg Zn ha^{-1}. Hussain *et al*., (2018) [18] also reported an increase in yield and grain zinc concentration of mung bean with increased Zn fertilizer levels. In similar studies, Farhan *et al*. (2019) [14] observed that application of P and Zn significantly increased the dry matter accumulation, number of pods per plant, number of seeds per pod, test weight and seed yield of Mung Bean. These authors, equally observed that, application Zn (20 kg/ha) and P (60 kg/ha) resulted in significant differences in leaf area ratios indicating better dry matter partitioning, increased number of pods and seed yield.

According to Husain *et al*., (2021) [20], Gahlot *et al*., (2020) [16] and Van Biljon *et al*., (2010) [39], the significant response of the mmungbean yield attributes to ZnSO4 application was as a result of low zinc concentration in the shale soil (Table 3). However, the improved budgeted soil Zn from the Zn application might have resulted to the availability in soil (Ahmad, 2012, Husain *et al*., 2021) [20, 21] which, led to the increase in Zn uptake and efficient utilization of the applied Zn fertilizer for grain yield. The significant increase in the grain yield and the fairly sTable yield in spite of the fluctuation in rainfall in the study area (Table 1), may be due to the capacity of Zn to contribute to the crop and this might results to a significant residual effect in the subsequent cropping on mungbean cultivation since, there has been no history of micronutrients application in the soils. It was observed from the study that, the application of Zn fertilizer to mungbean in the greenhouse and field experiments, not only enhances its production in the soils, but also increases tissue content and this could cure the micronutrients deficiency problem in human nutrition (Ahmad, 2012, Eteng *et al*, 2014) [2, 12]. Moreover, the response of mungbean yield components as influenced by levels of the Zn fertilizers in the field experiments confirmed the results of Zn uptake obtained from the greenhouse experiments in different shale soils (Eteng *et al*, 2014) [12].

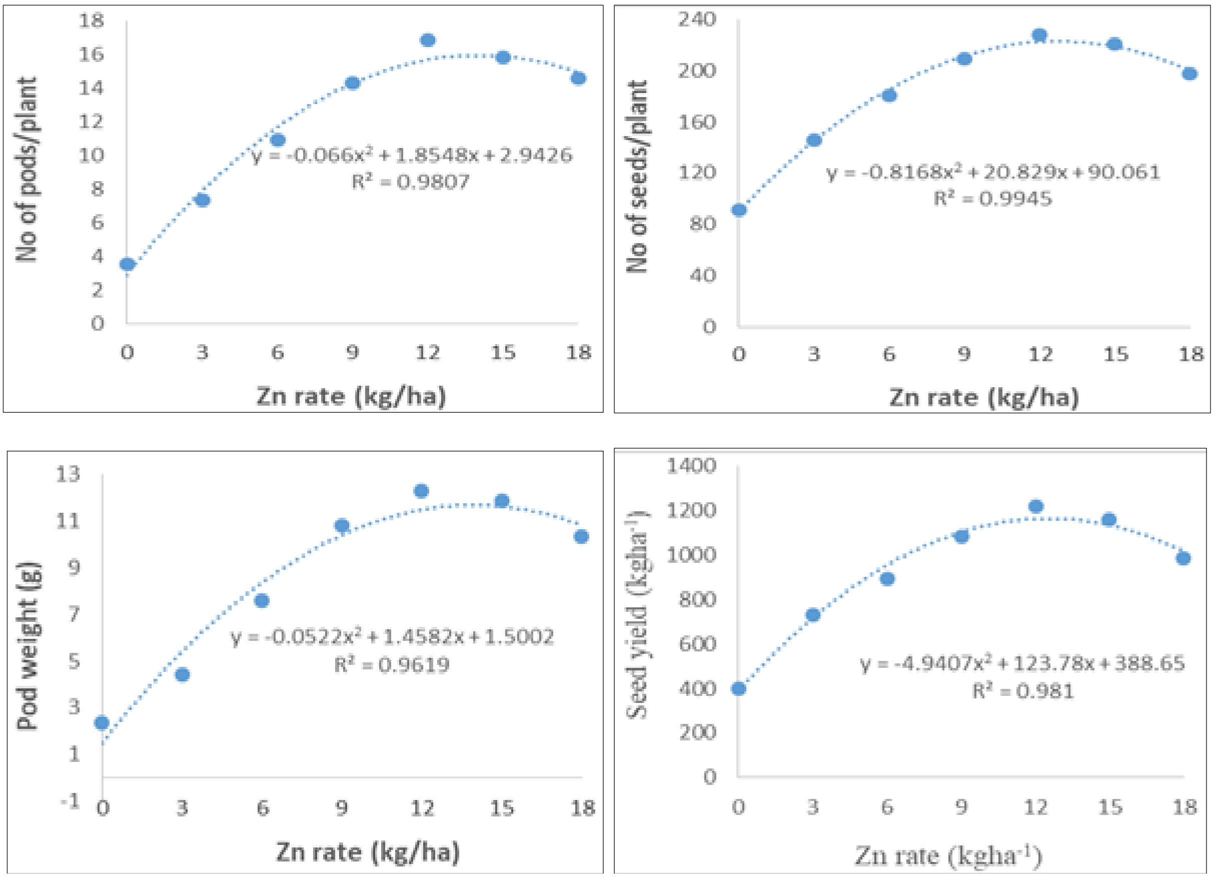


Fig 3: Polynomial graph showing the field optimum Zn levels on yield components of mungbean.

Table 6: Optimum Zn levels for mungbean yield parameters in the study soils (N=28)

Yield components of mungbean	Optimum Zn levels ($kgha^{-1}$)	Prediction value (R^2)
No of pods/plant	14.05	0.981
No of seeds/plant	12.75	0.995
Pod weight	13.97	0.962
Grain yield	12.53	0.981

4. Conclusion

The study showed that, the shale derived soil had severe Zn deficiency due to strongly acid soils with low OC, ECEC as well as available Zn status. The possible impacts of Zn fertilizers to improve on mungbean yield performance in the soils was established. The critical limits of EDTA-extractable Zn estimated for mungbean production at different locations, were established; 11.95-26.91, 11.45-17.52, 14.00-21.80, 11.15-19.23, 11.35-21.70 and 12.65-20.72 mg Zn kg^{-1} for, shale derived soils of Abakaliki, Amasiri, Ikwo, Ishiagu, Ohaozara and Uwana, respectively. Different levels of Zn application showed significant ($P<0.05$) variation in respect of number of pods $plant^{-1}$, number of seeds pod^{-1}, pod weight, grain yield Zn uptake of mungbean, as well as soil nutrient budget content. Maximum Zn uptake (1.27 $mgplant^{-1}$) and grain yields (9.93$kgha^{-1}$) of mungbean were established at an optimum rates of 13.01 kg Zn ha^{-1} and 12.53 kg Zn ha^{-1} for greenhouse and field studies, respectively. Due to the severe Zn deficiency, the application of Zn sulphate at 12.5 kg Zn ha^{-1} is recommended for the soils. Also the potentials of this nutrient mineral with other crops like roots and tubers, and vegetable crops in similar soils of the same agro ecological zone within a shale derived soil could be investigated as well.

5. References

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