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Influence of Zinc Fertilizer, Poultry Manure and Application Levels on the Performance of Sweet Corn

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Abstract: This study evaluated the effect of chicken manure, CM (0.02% Zn, 2.30% N, 0.55% P and 0.47% k), zinc sulphate, $ZnSO_4$ (23% Zn) and their organo-mineral combination (CM+$ZnSO_4$) on the performance of sweet corn (*Zea mays,* L. Saccharum). Two soils medium acid sandy clay Alfisol from the Southern Guinea Savanna agro-ecological zone of Nigeria and a weakly acid sand Alfisol from the Rainforest zone were used. The fertilizer materials were applied at 0, 20 and 40 mg Zn/kg soil to give nine treatment combinations replicated three times in a Completely Randomized Design (CRD) for each soil. Plant height, stem girth and leaf area) were measured after 7, 14, 21 and 28 days of growth while shoot weight as well as P and Zn concentration and uptake by the crop were determined after 28 days. With application of 40 mg Zn/kg soil on the medium acid Alfisol, CM+$ZnSO_4$ produced the highest plant shoot biomass (7.7 g/pot) while CM gave the highest (11.0 g/pot) on the weakly acid Alfisol. The application of CM also led to the highest Zn uptake.

Key word: Chicken manure, organomineral, alfisol, sweetcorn, fertilizer

INTRODUCTION

Concerns over the effects of low levels of micronutrients (Zn in particular) in human food have been overwhelming as it causes growth retardation coupled with delay in skeletal maturation. Improving human Zn nutrition would involve enhancing Zn concentrations in plant foods[1] and applications of Zn fertilizers could effectively increase Zn concentrations in edible portions of crops[2]. Zinc deficiency increases with time on a wide variety of tropical soils[3,4] through the use of purified, highly concentrated fertilizers[5] and high yielding, more nutrient demanding improved crop cultivars[6]. Maize is more sensitive to Zn supply than most other crops[7,8]. Affected plants have stunted growth arising from overall reduction in photosynthetic efficiency and disrupted metabolism[9]. Corrale *et al*.[10] Noted the yield advantages accruing from the application of inorganic fertilizers but cautioned on the negative influence of their cost and availability resulting in the popularity of organic materials (including chicken manure) as means of supplementing native soil fertility in tropical areas. Chicken manure improves soil structure, water holding capacity, aeration and drainage[11] besides containing high levels of Fe, Mn and Zn[12,13]. Nevertheless,[14] observed that combined use of organic and inorganic fertilizers is the best means of augmenting available nutrient contents of tropical soils. Organo-minerals reduce the acidification and increased removal of nutrients other than the one being supplied[15].

Marschner and Li *et al*.[16,17] reported significant negative interactions between P and Zn. Organic materials applied to supplement soil Zn may supply P that can induce Zn deficiency in plants by altering both the physico-chemical and biological factors in soil/plant systems. Reduction in the bioavailability of Zn in grains and plant tissue concentrations can also occur[18]. The work reported here sought to compare the effectiveness of Chicken Manure (CM), $ZnSO_4$ and their combination (CM+$ZnSO_4$) as Zn fertilizer sources for the growth as well as P and Zn nutrition of sweet corn grown on two Nigerian alfisols (an Oxic Paleustalf and a Typic Paleudalf).

MATERIALS AND METHODS

Soil preparation: Surface (0-15 cm) samples of medium acid (pH 5.9) sandy clay Alfisol (Oxic Paleustalf), A from Zaria (Southern Guinea Savannah) and weakly acid (pH 6.6) sand Alfisol (Typic Paleudalf), B from Epe (Rainforest zone) were used. The samples were air-dried, crushed and passed through a 2 mm sieve. Some characteristics of the soils as determined by standard laboratory methods[19] are:
Zaria location soil-Organic C (4.3g kg^{-1}), total N (1.52 g kg^{-1}), available P (1.50 mg kg^{-1}) and

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extractable Zn (0.013 cmol kg^{-1} soil) and K (0.19 cmol kg^{-1}).
Epe location soil-Organic C (8.30 g kg^{-1}), total N (0.8 g kg^{-1}), available P (8.77 mg kg^{-1}) and extractable Zn (0.092 cmol kg^{-1}) and K (0.21 cmol kg^{-1}).

The total N values were marginal in Zaria location soil and less than the critical level of 1.5 g kg^{-1}[20] in Epe location soil. The available P values were less than the critical level of 10-16 mg kg^{-1} in the two location soils[21]. However, exchangeable K values were above the critical level of 0.18 - 0.20 cmol kg^{-1}[22]. The Zn values were above the critical level of 0.003 cmol kg^{-1}[23].

Experimental design and treatment combination: The experiments involved the split-split plot arrangement in completely randomized design with three replicates. The two soil types formed the main treatment; the Zn fertilizer sources ($ZnSO_4$, CM and $ZnSO_4$+CM) formed the sub-treatment while the Zn levels (0, 20 and 40 mg Zn kg) formed the sub-sub treatment.

Greenhouse experiment: The Zn fertilizer materials were thoroughly mixed with one-kilogram samples of the soils, moistened to 60% Field Capacity (FC) and allowed to equilibrate for four days prior to planting of 5 pre-germinated sweet corn (var. TZEEY-SR EC5) seeds. Nitrogen and Potassium were applied uniformly to all pots at the rate of 60 kg N/ha (using urea) and 30 kg K/ha (using muriate of potash, KCl). Weekly measurement on each of three growth parameters (plant height, stem girth and leaf area) was done as from 1 Week After Planting (WAP). At the end of 28 days after planting, harvesting and processing of the above ground plant portions were conducted and shoot weights (fresh and dry) determined. Subsequently, Zn and P contents in plant tissue and the uptake of each of the two nutrient elements by the test crop were determined after grinding the dried plant samples and wet digesting with a mixture of 25 mL of HNO_3, 5 mL of H_2SO_4 and 5 mL of $HClO_4$. Phosphorus was determined by absorption spectrometry while Zn was read using atomic absorption spectrophotometer.

All statistical analyses were performed using the Statistical Analysis System[24].

RESULTS

The effects of the experimental factors (soil type, Zn fertilizer sources and levels) on maize growth (height and stem girth) are indicated in Fig. 1. Expectedly, the values of the two parameters increased with time almost reaching the peaks after 21 days of growth. The differences between the plants grown in the two soil types also became more appreciable with time such that they were smallest at 7 Days After Planting (DAP) and highest at 28 DAP. The plants were significantly ($p<0.05$) more vigorous in height and stem girth when grown on the slightly acid Alfisol than when grown on the medium acid Alfisol. After 28 days of growth, mean height and stem girth on the medium acid Alfisol (Oxic Paleustalf) were 40.00 cm and 1.3 cm, respectively compared with 53.00 cm and 2.0cm, respectively on the slightly acid Alfisol (Typic Paleudalf). Fig. 1 also shows that both the Zn fertilizer sources and levels significantly influenced the growth parameters. The tendency was such that the inorganic Zn fertilizer source ($ZnSO_4$) reduced plant growth while plants treated with either the organic (chicken) manure or a mixture of CM + $ZnSO_4$ had almost the same values at the successive growth periods. The untreated plants consistently had the least growth in height and stem girth, particularly with maturity while 20 and 40 mg Zn/kg soil application rates produced plants with similar height and stem girth at most of the growth periods.

Leaf area increased with time (Fig. 2). After 28 DAP, leaf area, fresh and dry shoot weights on the slightly acid Alfisol (Typic Paleudalf) were higher (95.0cm^2, 66.0g/pot and 7.7g/pot, respectively) compared with 62.0cm^2, 30.0 g/pot and 3.6 g/pot, respectively for the medium acid Alfisol (Oxic Paleustalf). Figure. 2 also shows the effects of the fertilizer sources and application levels on leaf area and fresh and dry shoot weights of maize plants. Between 7 and 21 DAP, the three fertilizer types produced no significant difference ($p<0.05$) in leaf area but at 28DAP, CM produced maize plants with significantly higher leaf area, fresh and dry shoot weights (84 cm^2, 59.5 g/pot and 6.5 g/pot, respectively) than $ZnSO_4$ (69.5 cm^2, 31.0 g/pot and 4.1 g/pot, respectively). Leaf area differences caused by the application levels were not significant until 21 DAP. At 28 DAP, the untreated maize plants recorded the least leaf area, fresh shoot weight and dry shoot weight values of 62 cm^2, 32 g/pot and 4 g/pot, respectively while those treated with 40mg/kg soil had the highest values of 89.5 cm^2, 62 g/pot and 7.0 g/pot, respectively. The application rates of 20 and 40 mg kg^{-1} soil produced plants with similar leaf area.

The soil type and fertilizer treatment (sources and application levels) had no appreciable effect on tissue Zn content of maize plants (Fig. 3). The fertilizer sources also failed to influence Zn-uptake by the crop. However, the soil types and application levels caused notable differences on Zn uptake such that maize plants grown on the slightly acid Alfisol (Typic Paleudalf) averagely took up to 1.10 mg Zn/pot compared with 0.42 mg Zn/pot for those grown on the medium-acid Alfisol (Oxic Paleustalf) at 28DAP. Treatment with 40 mg Zn/kg soil also led to

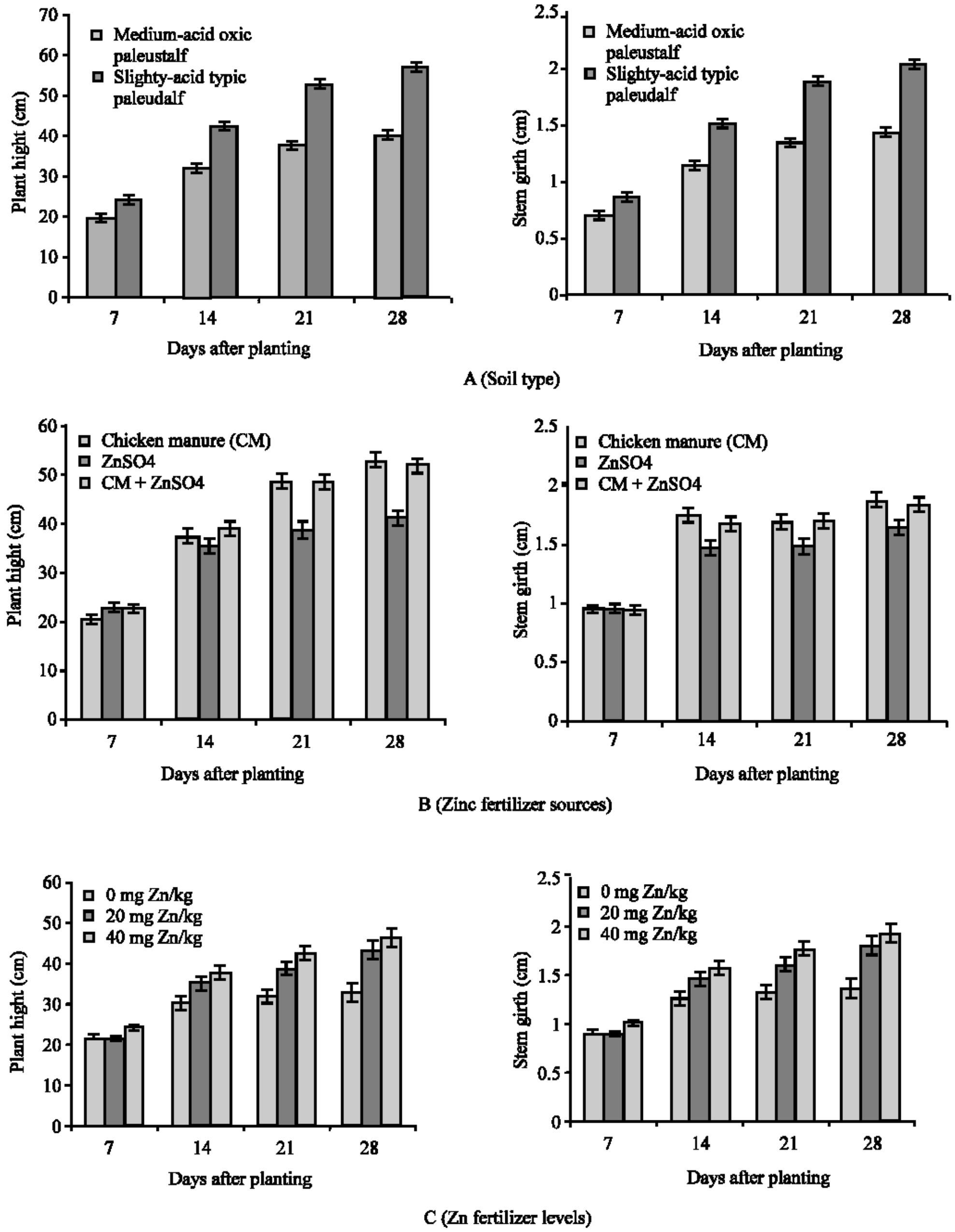

Fig. 1: The influence of (A) soil type, (B) zinc fertilizer sources and (C) zinc fertilizer levels on the growth (plant height and stem girth) of sweet corn

greater amount of Zn uptake (1.07 mg Zn/kg) as against 0.42 mg Zn/kg for the untreated maize plants while 0.80 mg Zn/pot for the plants treated with 20 mg Zn/kg soil was not significantly different from either of the other two.

The content and uptake of P as affected by the experimental factors were at variance with those of Zn. Except for the fertilizers sources, significant differences in P content of maize plant tissues were evident (Fig. 4). On the average, maize plants grown on the slightly acid Alfisol (Typic Paleudalf) recorded 0.58% tissue P content as against 0.24% for those grown on the medium acid Alfisol (Oxic Paleustalf). The control plants had a mean of 0.34% tissue P content compared with the significantly higher average of 0.45% for the treated ones. Phosphorus uptake by maize plants was affected by soil type in a

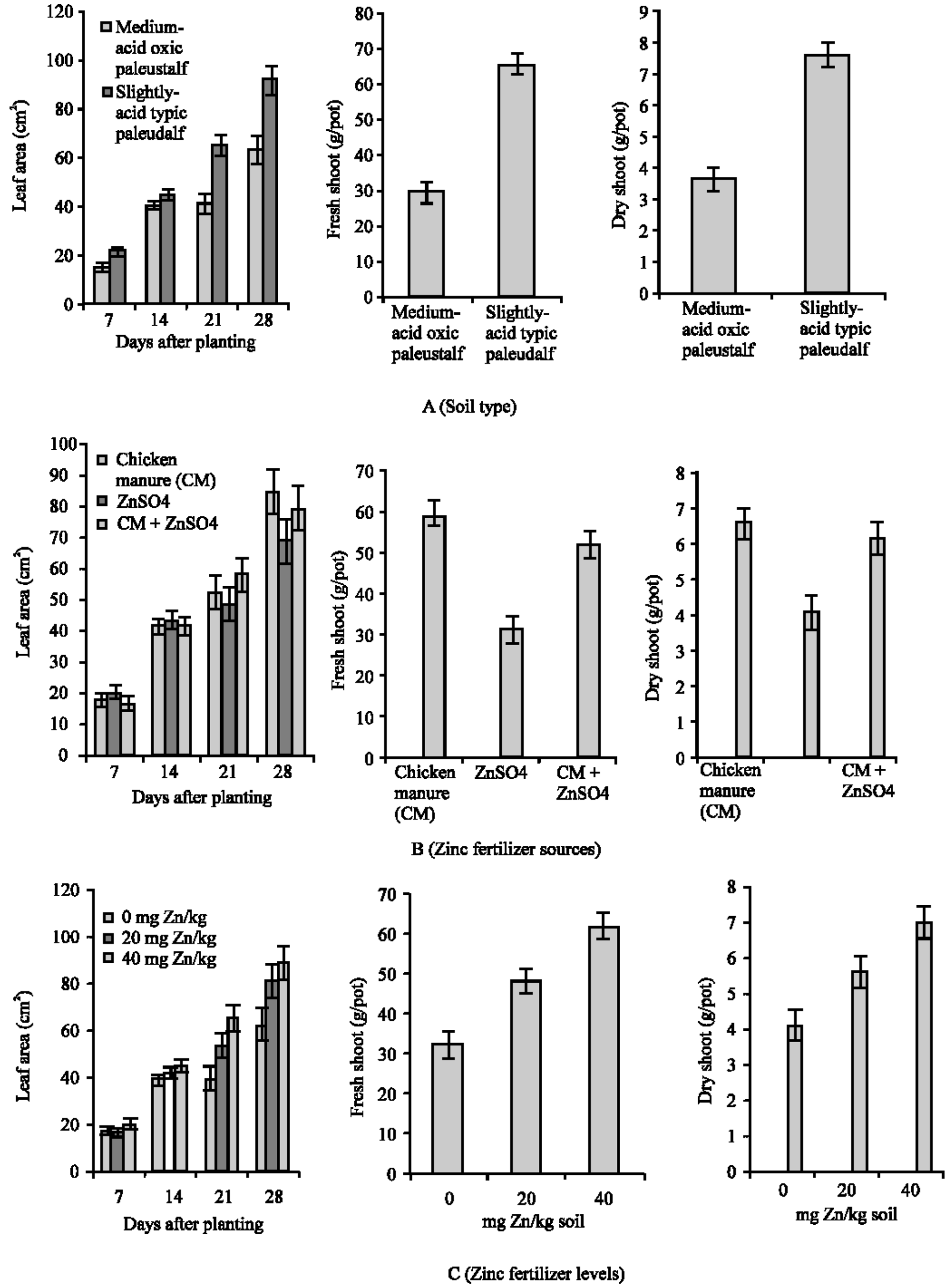

Fig. 2: The influence of (A) soil type, (B) zinc fertilizer sources and (C) zinc fertilizer levels on leaf area, fresh and dry shoot of maize

similar way to that of the tissue P-content as the slightly acid Alfisol (Typic Paleudalf) favored the uptake of more P (44 mg P/pot) than the medium acid Alfisol (Oxic Paleustalf) (10 mg/pot). Chicken Manure (CM) enhanced plant uptake of P than $ZnS0_4$ but had similar effect as CM + $ZnSO_4$ (Fig. 4). The values of P-uptake by maize plants treated with 20 and 40 mg Zn/kg soil were essentially similar (28 and 34 mg/pot) but different from those of the untreated ones (17.5 mg/pot).

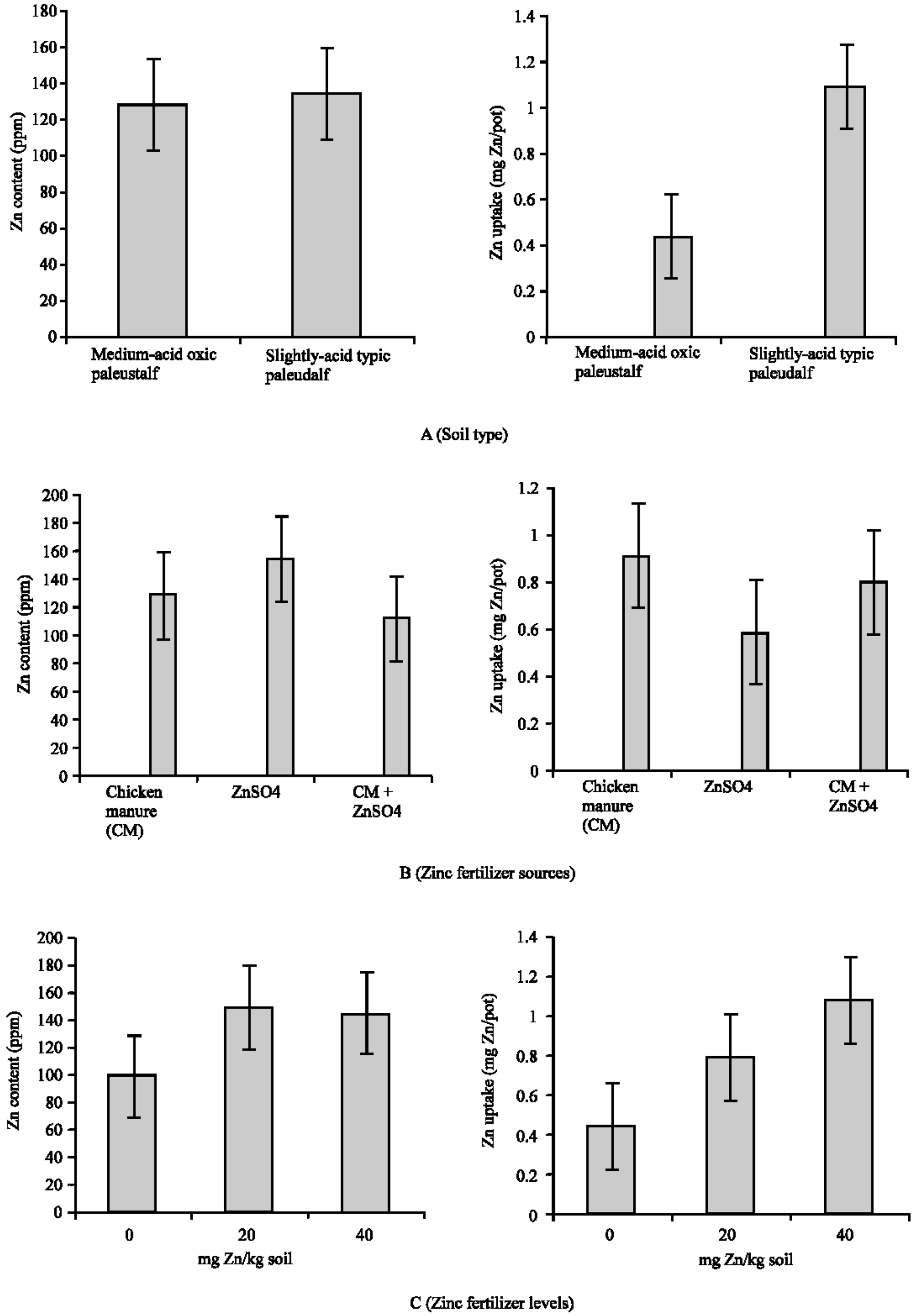

Fig. 3: The influence of (A) soil type, (B) zinc fertilizer sources and (C) zinc fertilizer levels on tissue zinc content and uptake by sweet corn

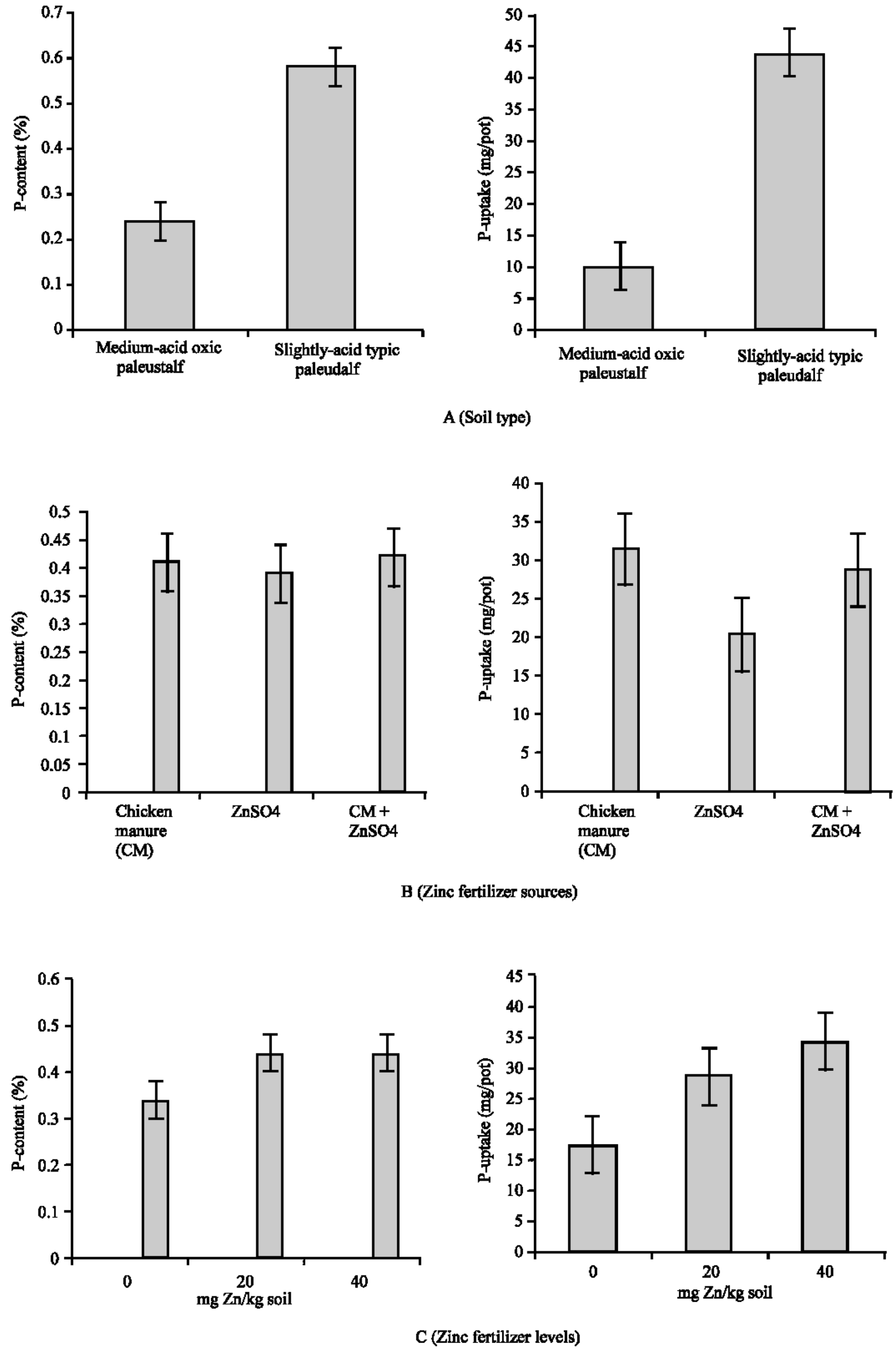

Fig. 4: The influence of (A) soil type, (B) zinc fertilizer sources and (C) zinc fertilizer levels on tissue phosphorus content and uptake by sweet corn

DISCUSSION

The remarkable differences in vigor and biomass production of the test crop grown on the two soil types are attributable to the differences in the physico-chemical properties of the soils. The slightly acid Typic Paleudalf (Soil B) was more fertile, having almost neutral pH compared with the medium acid Oxic Paleustalf (Soil A). This condition could probably have facilitated the release of nutrients for plant growth on soil B.

Soil fertility can be maintained with the use of organic manures alone[25] or in combination with inorganic fertilizers[26;14;27]. The use of organic manure in combination with inorganic fertilizers serves to reduce the negative effects of inorganic fertilizers, particularly in respect of acidification and increased removal of nutrients other than the one supplied by the fertilizer[15]. Thus, the fortification of CM with $ZnSO_4$, in this study, could have directly reduced the negative effects of and improved the efficiency of $ZnSO_4$ but had no negative effect on the efficiency of CM. This was evidenced by improved vigor and higher dry shoot yield of the test crop. The significant reduction of the effects of sources of Zn fertilizers on the vigor and shoot weight of maize should have been due to the toxicity effects of high concentrations of Zn in the soil, particularly, soil B.

Li *et al.*[17] Similarly attributed the reduction in plant biomass as Zn addition was made under low P conditions to Zn toxicity. They further reported the resumption of plant biomass increases when high P addition was made. In this study, it seems obvious that CM-fortified $ZnZO_4$ ameliorated the condition of Zn toxicity shown by $ZnSO_4$ in line with the view of[15]. CM acted as a reservoir of nutrients[13]. It was also reported that application of urea-fortified organic materials significantly increased dry matter accumulation of maize Stover in Zaria (Guinea Savanna zone), Nigeria[28].

The fact that maize plants performed best at 40 mg Zn/kg is indicative of possible positive interactive effect of Zn and P at that rate of Zn fertilizer application. This was evidenced by both the content and uptake of the nutrient elements by maize plants after 28 DAP. Apart from containing 0.02% Zn, the organic (chicken) manure had 0.55% P and reasonably high proportions of other nutrient elements (2.30% N and 0.47% K). This is an indication that for every gram addition of Zn through CM, about 27.5g of P is also added. These observations were also supported by Li *et al.*[17] who demonstrated that nutrient deficiency is a relative measure of soil fertility dependent on the balance of the limiting nutrients. These workers observed deleterious effects of Zn-P imbalance on barley only at a high Zn concentration of 150 mg Zn/kg. Besides, the significantly reduced uptake and content of P in the untreated maize plants was attributable to P toxicity as induced by Zn deficiency. This is in support of the findings of[29] who found that Zn deficiency causes an increase in the expression of P transporter genes both in P-deficient and P-sufficient barley roots and this condition may induce P toxicity in plants.

Nevertheless, a fertile soil may still require further addition of Zn for maximum plant growth if high levels of P fertilizer are applied[17].

Reductions in uptake and content of tissue P and uptake of tissue Zn of the test crop grown on soil A are further reflections of the low fertility status. The organic manure (CM) being a reservoir of nutrients[13] and with ameliorative capacity[15] in CM + $ZnSO_4$ fertilizer mixture remarkably increased the uptake of P and Zn in maize plants.

CONCLUSION

In conclusion therefore, combined use of organic and mineral fertilizers such as $ZnSO_4$ fortified CM is a good antidote for the antagonistic interaction between P and Zn that may result in Zn deficiency or toxicity in crop plants.

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