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Growth and Zinc Uptake of Sorghum and Cowpea in Response to Phosphorus and Zinc Fertilization

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Abstract: A 2-year field experiments were conducted in the Guinea savanna agro-ecological zone of Nigeria in 2005 and 2006 growing seasons to determine the response of sorghum [*Sorghum bicolor* (L.) Moench] and cowpea [*Vigna unguiculata* (L.) Walp] to different levels of phosphorus and zinc fertilization on low P soil. The experiment was laid out in a 4x3 factorial arrangement in a randomized complete block design and replicated three times. The treatments consisted of 4 levels of fertilizer P (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) applied as single super phosphate (SSP) and 3 levels of Zn (0, 2.5 and 5.0 kg Zn ha^{-1}) applied as zinc sulphate. The grain and straw yields of sorghum and the haulm yield of cowpea were significantly affected (P=0.05) by P, Zn and their interactions in both growing seasons years. Zinc uptake was decreased in both sorghum and cowpea with increasing P application up to 60 kg ha^{-1}. A significant but negative correlation of (r = -0.564*) and (r = -0.594*) were obtained between zinc uptake and P application for sorghum and cowpea, respectively. However, application of 20 - 40 kg ha^{-1} P without Zn and 40 kg ha^{-1} P with 2.5kg ha^{-1} Zn to cowpea and sorghum respectively, in the Guinea savanna agro ecology will substantially improve the productivity and Zn nutrition of these crops.

Key words: Cowpea · Dry matter yield · Phosphorus · Savanna · Sorghum · Zinc uptake

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp) is an important grain legume in Nigeria which is usually grown as an intercrop with major cereals such as maize, sorghum and millet by traditional farmers in the Nigerian savanna [1]. Sorghum constitutes the staple food for the bulk of the Nigerian population in the Sudan and Guinea savanna ecological zones [2]. The soils of the Nigerian savanna are inherently low in fertility and phosphorus deficiency is regarded as the most limiting soil fertility factor for cowpea production and its application is therefore a major nutritional constraint to Zn uptake of cowpea in the savanna zone of Nigeria. Crop yields from fertilizer trials in the Nigerian savanna are most often not satisfactorily high and the maximum fertilizer P required for high yield rarely exceed 30kg P $ha^{1,}$ with most savanna soils being low to medium in available P [3]. Legumes have been reported to have a high P requirement and have been reported to stimulate root and plant growth, initiate nodule formation as well as the efficiency of the rhizobium-legume symbiosis [4]. Khan and Zende, [5] reported that application of P resulted in significant decrease of Zn concentration in cowpea grains and this can affect the nutritional quality of cowpea [6]. Similarly, Farah and Solimon [7] reported that increase in the application of fertilizer P for higher crop yields are likely to be hindered by reducing availability of Zinc owing to the highest doses of P in such soils. Results have shown that when both P and Zn are marginal or limiting in soil, P fertilizer application can promote plant growth and cause dilution in tissue Zn which may further complicate Zn deficiency [8]. The importance of Zn for cowpea production and the current void of knowledge on the P and Zn interactions on sorghum and cowpea production in the savanna prompted this study. Therefore, the objective of the present study is to determine the response of cowpea and sorghum to fertilizer P and Zn and formulate recommendations for their production on savanna soil low in available P.

MATERIALS AND METHODS

Field experiments were conducted during the growing seasons (June – October) of 2005 and 2006 to study the response of cowpea and sorghum to P and Zn fertilization

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at the Teaching and Research farm of Abubakar Tafawa Balewa University, Bauchi in the Northern Guinea savanna agro ecological zone of Nigeria. The physico-chemical analysis of the top soil (0-25 cm) was carried out before the commencement of the study following the methods described by A.O.A.C. [9] and revealed the following composition:- Sand 82.8 %; Silt 6.3%; clay 10.9% Total Nitrogen 0.085 % ; Organic Carbon 0.48 % Available P (Bray 1) 11.5 mg kg^{-1}; pH (water) 6.3; C.E.C. 2.46 meq/100g soil; Exchangeable bases (meq/100g soil); Ca 0.49; Mg 0.31; K 0.05; Mn 0.08 and Zn 0.61 mg kg^{-1}. The experimental design was a randomized complete block consisting of 3 blocks (replications). The treatment factorials consisted of 4 rates of fertilizer P (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) applied as SSP and 3 rates of fertilizer Zn (0, 2.5 and5.0 kg Zn ha^{-1}) applied as zinc sulphate. Cowpea TXV-3236 and sorghum KSV4 were planted in two separate experiments at 75x20cm (66667 plants ha^{-1}) and 75x25cm (53333plants ha^{-1}), respectively, in six row-plots of 5m length. The plantings were done in the 3rd week of July and 1st week of August for sorghum and cowpea, respectively, in both seasons. All doses of P and Zn treatments and a uniform dose of 40 kg K ha^{-1} were applied as basal dose at planting. Sorghum also received 60 kg N ha^{-1} Calcium ammonium nitrate (CAN) in 2 equal splits (at planting and 6 weeks after sowing) while cowpea received 20 kg N ha^{-1} CAN at 2 weeks after sowing. The crops were weeded twice at 30 and 65 days after planting. At maturity, all plants of the 4 central rows of 4 m long (9 m^2) were harvested for grain yield determination in both crops. Harvesting was done by cutting the stem immediately above ground when the plants were partially dried in the field. The crops matured at different times and harvesting days for cowpea and sorghum were 65 and 110 days, respectively after planting. Dry grain yield was determined by hand shelling the cowpea pods and sorghum heads of each harvested plant after drying the seeds to about 13% moisture content. For Zn uptake, 5 plant samples of both crops were partitioned into grains and vegetative parts, oven dried at 70°C to a constant weight and Zn was determined using Perkins model 403 atomic absorption spectrophotometer after digestion. Total Zn uptakes by grain and straw or haulm were computed by multiplying Zn content and their respective dry weights ha^{-1}. Data for the 2 years of each crop were averaged and subjected to ANOVA and LSD calculated to delineate the differences among treatment means where the 'F' test was significant according to Steel and Torrie [10].

RESULTS AND DISCUSSION

Growth and Dry matter Yield: The straw yields of sorghum but not the grain were was significantly affected by P, Zn and P x Zn interactions, but the grain yield insignificantly affected as shown in Table 1. Averaged over Zn rates, the overall effect of P fertilizer did not have any significant and consistent effect on sorghum grain and straw yields as shown in Fig. 1. There was no significant difference (P=0.05) in sorghum grain yield with increasing P application up to 60kg ha^{-1}, however, straw yield increased significantly but not consistently with increasing P application. The highest sorghum grain yield was obtained in the control treatment, while that of straw occurred with 40 kg P ha^{-1}. However, averaged over P rates, Zn application significantly increased sorghum straw yield (P=0.05), but the grain yield was insignificantly affected (Fig. 2). Table 2 shows that the grain and haulm yields of cowpea were not significantly (P=0.05) affected by P, Zn and their interactions. The highest grain yield was obtained with 20 kg P ha^{-1} and 5.0 kg Zn ha^{-1}, while that of haulm occurred at 60 kg P ha^{-1} and 2.5 kg Zn ha^{-1}. However, averaged over Zn levels, application of P enhanced grain and haulm yields (Fig. 3) of cowpea up to 20 kg P ha^{-1} and 40 kg P ha-1, respectively. Higher yields of grain and haulm in cowpea was obtained at 0 kg Zn ha^{-1}(control)

Table 1: Treatment means of P x Zn interactions on sorghum yields

	Zn rate (kg ha^{-1})					
	0	2.5			2.5	5.0
P rate (kg ha^{-1})	Grain (t ha^{-1})		5.0	0	Stover (t ha^{-1})	
0	1.29	1.32	0.99	2.96	4.81	1.65
20	1.13	1.07	1.10	2.35	2.76	3.81
40	1.23	0.74	0.98	2.69	3.74	3.38
60	1.14	1.08	1.06	3.24	2.96	2.69

LSD (P=0.05) PxZn = 0.41 PxZn = 0.67

Table 2: Treatment means of P x Zn interactions on cowpea yields

	Zn rate (kg ha^{-1})					
	0	2.5			2.5	5.0
P rate (kg ha^{-1})	Grain (t ha^{-1})		5.0	0	Haulm (t ha^{-1})	
0	0.49	0.38	0.31	1.04	0.52	0.48
20	0.57	0.49	0.60	0.89	0.61	0.76
40	0.54	0.47	0.40	0.94	1.05	0.17
60	0.42	0.47	0.40	0.67	1.07	0.74

LSD (P=0.05) P*Zn = 0.34 P*Zn = 1.23

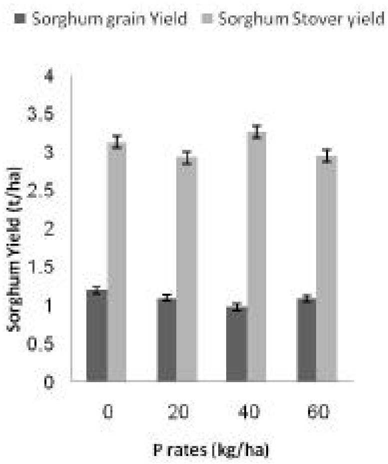

Fig. 1: Effect of P fertilizer on grain and stover yield of sorghum

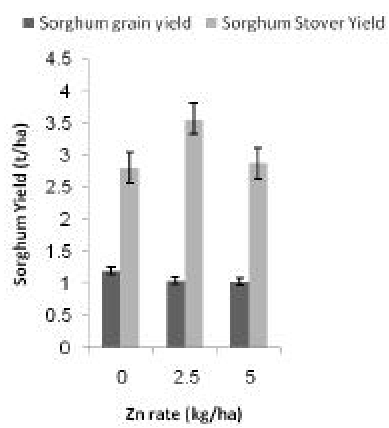

Fig. 2: Effect of Zn fertilizer on gram and stover yield of sorghum

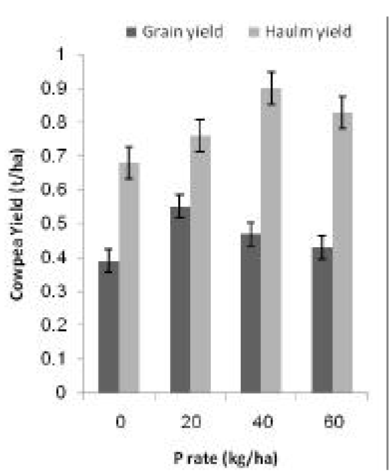

Fig. 3: Effect of P on gram and haulm yield of cowpea

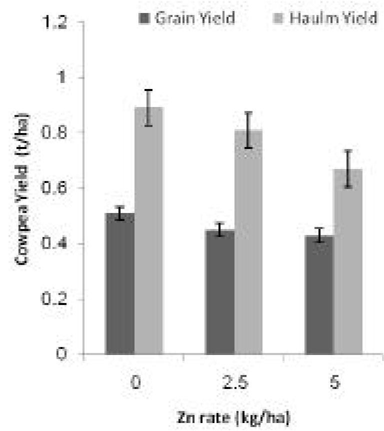

Fig. 4: Effect of Zn fertilizer on grain and haulm yield of cowpea

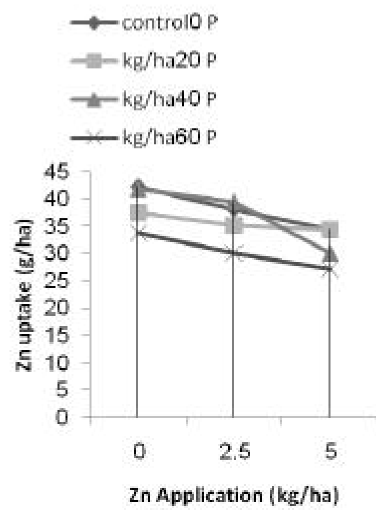

Fig. 5: Effect of P and Zn on grain Zn uptake of sorghum

when averaged over P rates (Fig. 4). Generally, cowpea yield was decreased with increasing Zn application. The Zn x P interactions showed grain yields to be slightly lower in both sorghum and cowpea with P application in combination with Zn than those without applied Zn. Similarly, Zn application alone was more suppressive on sorghum than P and its combination with P probably counteracted the toxic effects of Zn which varied with the rate of application. The observed effects could be attributed to the fact that P application reduced the Zn requirements for optimum plant growth. Results similar to this had earlier been reported by Farah and Solimon [7] and Krishnasamy [11]. Similarly, Sahu *et al.* [12] attributed this observation to the presence of high concentration of $P0_4^-$ ions in the soil leading to the formation of soluble Zn-$P0_4$complex.

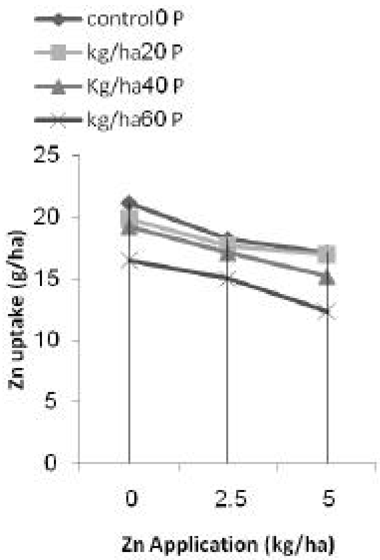

Fig. 6: Effect of P and Zn on straw Zn uptake of sorghum

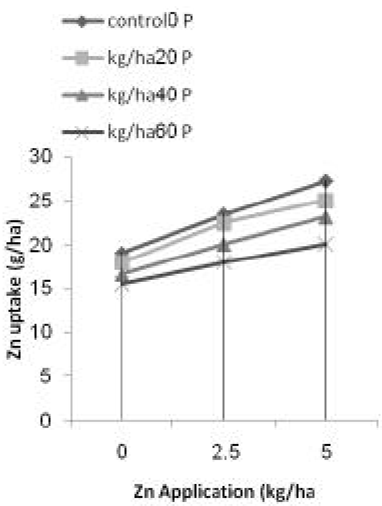

Fig. 7: Effect of P and Zn on gram Zn uptake of cowpea

Zinc Uptake: The main effects of P, Zn and P x Zn interactions were significant in affecting the Zn uptake in both sorghum and cowpea. Zn uptake in both sorghum grain (Fig. 5) and sorghum straw (Fig. 6) was decreased with increasing Zn application up to 5kg ha^{-1}. However, in cowpea, the Zn uptake of both grain (Fig. 7) and haulm (Fig. 8) was increased with increasing Zn application. The Zn x P interactions in cowpea showed that Zn uptake was always higher with Zn application in combination with P than those without Zn, while in sorghum, the Zn x P interactions showed decreased Zn uptake with Zn application in combination with P than those without Zn. This findings confirmed results obtained by Goh *et al*. [8]. Neue and Marmaril [13]

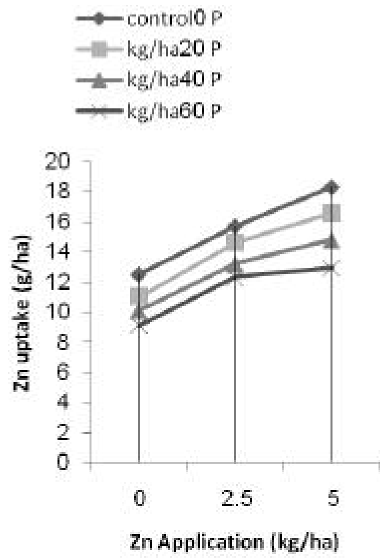

Fig. 7: Effect of P and Zn on haulm Zn uptake of cowpea

reported that P application depressed the availability of Zn, presumably due to the formation of organic-metal-phosphate complexes. Also, Loneragan and Webb [14] reported that under high conditions of high Zn supply, P may immobilize Zn in roots through the formation of Zn-phytate. The treatments receiving no P application (control) had the highest Zn uptake in both crops whilst P application tended to reducing Zn uptake. This result corroborated the earlier findings of Farah and Solimon [7], Olsen [15] and Prabhakarannair and Babu [16]. The decrease Zn uptake due to P application at the highest level of application of 60 kg ha^{-1} may probably be due to the formation of soluble Zn-$P0_4$ compounds in the soil as reported by Krishnasamy [11] and Sahu *et al.* [12]. Similarly, Harrel [17] reported that P x Zn interactions in corn decreased PO_4^{3-} and increased Zn availability, thereby suggesting that Zn and P fertilizers should be applied separately. A negative and highly significant correlation of (r = -0.594**) for cowpea and (r = -0.564*) for sorghum were obtained between Zn uptake and P fertilizer application, thus lending support to the claim made by Krishnasamy [11]. Agboola and Corey [18] also observed that most of the negative Zn - P relationships involved higher application rate of P fertilizer and not necessarily the relatively low soil P levels. This study confirms the role of phosphorus and zinc in increasing growth and grain yield of both Sorghum and cowpea, in conclusion therefore, application of 20 – 40 kg ha^{-1} P without Zn and 40 kg ha^{-1}P with 2.5kg ha^{-1} Zn to cowpea and sorghum, respectively in the Guinea savanna agro ecology will substantially improve the productivity and Zn nutrition of these crops.

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