Growth, nodulation and nutrients content of cowpea (*Vigna unguiculata* (L.) Walp) following different Zinc fertilizer rates in the semi-deciduous forest zone of Ghana

ABSTRACT

Cowpea can fix atmospheric nitrogen through symbiotic association with indigenous rhizobia but unfortunately, the amount of N–fixed is usually not enough due to the presence of ineffective or low numbers of indigenous rhizobia in the soil. The effect of Zinc rates on growth, nodulation and nutrient content of cowpea was investigated at the Plantation Section of the Department of Crop and Soil Sciences, Faculty of Agriculture, KNUST/Kumasi (Ghana) during the major and minor cropping seasons (2016). Cowpea seed varieties (Asontem, Agyenkwa and Zamzam) were treated to three levels of Zinc fertilizer rates (0, 5 and 10 kg Zn/ha). The Zn fertilizer was applied as foliar application in both experiments. The split plot design was used for both studies. All recommended cultural practices were timely done. The results indicated that all yield components increased significantly following Zn fertilizer application. Application of Zn fertilizer improved the N and K contents of cowpea seeds. This implies the Zinc rates used can be applied to any of the varieties used. The application of the Zn fertilizer did not affect nodulation, and the nodule number was nearly successively decreased over time at all treatments and is not correlated with the Zinc fertilizer applied. Percentage nodule effectiveness and nodule dry weight were not significantly affected by Zinc rates at both sampling times. The amount of nodule dry biomass was drastically reduced with the mineral Zinc fertilizer, whereas the amount of nodule biomass was not affected in the control group, probably because the soil had satisfactory levels of available N and P. The results suggest that cowpea responds differently to Zinc sulphate application depending on its rates.

Keywords: N-fixed, Nodulation, Zinc fertilizer, NPK uptake and Yield

INTRODUCTION

Proper nutrition of plants with micronutrients depends on various factors, such as the rate of absorption of nutrients by the plants, distribution of nutrients to functional sites and nutrient mobility within the plant. Interactions occur between the micronutrients and some nutrients [1, 2, 3]. The amount of nitrogen fixed is usually high in soils with low mineral N but with sufficient water and enough of other nutrients capable of supporting plant growth [4]. Another factor is the differential response of plants to one nutrient in combination with varying levels of a second element applied simultaneously i.e. the two elements combine to produce an added effect not due to each of them acting alone [1, 2]. Such interactions may take place in the soil and within the plant [3]. However, the amount of nutrients uptake is strongly dependent on nutritional and environmental factors.

Cowpea is especially important for dry savannah of West Africa between latitudes 7 and 14°N [5] and second after groundnut as the most important legume of Ghana in terms of space under cultivation (156,000 ha) and quantity produced and consumed annually (143,000 Mg) making Ghana among the largest cowpea producer in Africa [6]. Cowpea is a protein-rich component of an otherwise protein-poor diet [7]. Many researchers have observed that Zn have a positive relationship with the nitrogen metabolism pathway of plants, its deficiency cause a reduction in protein synthesis into the plants. [8] identified the positive relationship between the flowering and fruiting process and Zn. As micronutrient, Zinc has received much recent attention [9] because it is present in all body tissues and fluids [10].

The native rhizobia are often low in numbers or ineffective and are therefore not able to fix enough nitrogen to meet the nitrogen demand of plants. The study was undertaken to examine the dynamics mineral contents in grain and haulm tissues and nutritional benefits following by zinc fertilizer application. The nodule parameter was also under investigation.

MATERIALS AND METHODS

The study was conducted at the Plantation Section of the Department of Crop and Soil Sciences, Faculty of Agriculture, KNUST, in the cropping seasons of 2016. The site is located at 06° 45’ N and 01° 31’ W in the rainforest belt of Ghana. The site was located at 06° 45’ N and 01° 31’ W in the rainforest belt of Ghana. The total nitrogen content was low with a mean value of 0.06%, available P content was low with value of 6.4 mg/kg, soil Zn content was moderately low, found to be 1.290 mg/kg. Three early maturing cowpea varieties (Asontem, Agyenkwa and Zamzam) were grown in both experiments and Zn fertilizer rates of 0, 5 and 10 kg/ha were applied into the varieties. The Zn fertilizer was applied as foliar application in both experiments. The split plot design, arranged in RCBD **(The Randomized Complete Block Design)** was used for both cropping seasons. All recommended cultural practices were done in schedule. Cowpea varieties were obtained from the Crops Research (CSIR) at Fumesua, Kumasi/Ghana. Zinc sulfate heptahydrate was applied at 3rd weeks (40%) and 5th weeks (60%) after sowing. The application was done early morning before 9:00 am, using a sprayer. The plots were demarcated three days after harrowing and seeds were sown by hand using manual labour. Seeds were sown at a spacing of 60 cm x 20 cm with a rate of two seeds per hill at the depth of 3-5 cm. Urea and triple superphosphate (TSP) fertilizers were applied as band placement by making a furrow of 5-7 cm deep and covering with 2 cm of soil. As starter nitrogen, Urea was applied at the rate of 20 kg N/ha uniformly to all plots at two weeks after sowing (WAS). Triple super phosphate (TSP) was also applied two weeks after??? (before) sowing (WBS) to the cowpea plant at the rate of 40 kg P_20_5/ha. Standard agronomic and plant protection treatments were used uniformly across the plots for the duration of the experiment. Grass hoppers *(Empoasca kerri Pruth),* Thrips *(Caliothrips indicus Bagnall)* and Aphids (*Aphis craccivora Koch*) were pests, respectively at vegetative stage and flowering to the end of pod filling. Lambda master 2.5 % E.C. [Active ingredients (Lambda-Cyhalothrin, 9.8 %)] was the pesticides used for pests' control.

A random sample of five plants from each plot and a random sample of five pods from each of the five plants were selected to measure. Plant height, stem girth and number of leaves were measured at 30, 45 and 60 days after sowing (DAS) and means for each plot were calculated. Nodules were sampled at 30 and 45 days after sowing. Plants samples were uprooted gently washed with water and the total nodules counted and the mean calculated for each plot. The ground was sufficiently soaked with water 48 hours before sampling to each uprooting of plants. To determine nodule effectiveness, nodules were cut open using a razor blade and hand lens. Nodules with pink or reddish colour were considered effective and fixing nitrogen, while those with green or colourless appearance were recorded as ineffective nodules. Nodules per plot were kept in labelled envelops and sent to the laboratory to oven-dry at 70°C for 48 hours. Average dry weight of nodules per plant was computed and expressed in grams. For mineral content analysis, random samples of five plants were uprooted gently from each plot at harvest and the root system was removed. The above ground parts were put in labelled envelops and oven dry at 70° C for 72 hours and milled and one hundred gram samples of each of the plant part (seeds and haulms) were taken to determine nitrogen, phosphorus and potassium content. The nitrogen content was determined using the Kjeldahl method [11]. The protein content of seed was determined on the basis of total nitrogen content [12]. N-fixed was obtained using the N-difference method. The total nitrogen content of the maize (reference crop) was subtracted from that of the cowpea [13]. In this study Omankwa maize variety was the reference crop. Phosphorus (P) content was measured on the Spectronic 20 spectrophotometer to give absorbance measurements at a wavelength of 420 nm. The observed absorbance was used to determine the P content from the standard curve [14, 15] and Potassium (K) was obtained using the flame photometer. From the standard curve, the concentration of K was calculated using the particular absorbance observed for the sample. NPK uptake were done by multiplying the grain and haulm yield in kilograms per hectare by each analysed parameters separately, nitrogen, phosphorus and potassium, in the grain and haulm then divided by 100 percent. Zn content was determined using Perkins model 403 atomic absorption spectrophotometer after digestion. The file for the type of analysis and hollow cathode lamps were selected with appropriate wavelengths of 213.9 nm [16]. The grain and straw yields were recorded separately. Total Zn uptakes by grain and tissue were computed by multiplying Zn content and their respective dry weights/ha. Data collected were subjected to analysis of variance (ANOVA) using GenStat statistical package version 15th. The LSD test was used to compare treatment means at 5% probability.

RESULTS

1. Effects of cowpea varieties on growth

Figure 1a should be prepared again.

Fig 1 illustrates the effect of different cowpea varieties on plant height, stem girth and number of leaves over the period of the experiment. The significant effect at 5% level of probability of cowpea varieties used was recorded over all sampling period of the study. The tallest plant was obtained by Asontem variety and the lowest by Zamzam. However, cowpea varieties did not show any significant (P > 0.05) effect on stem girth and number of leaves. Additionally, variety by Zinc rates was not significantly different on all days of sampling.

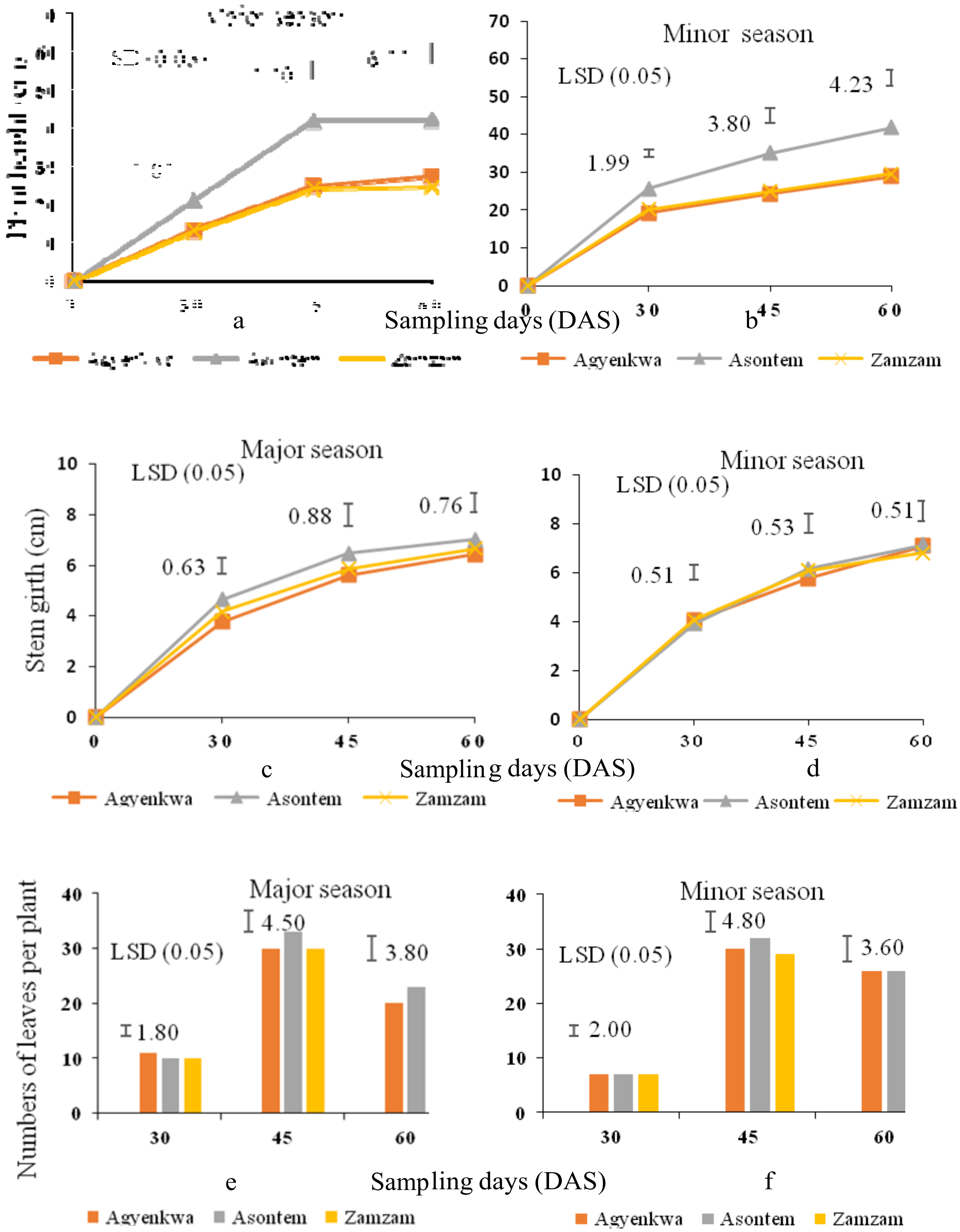
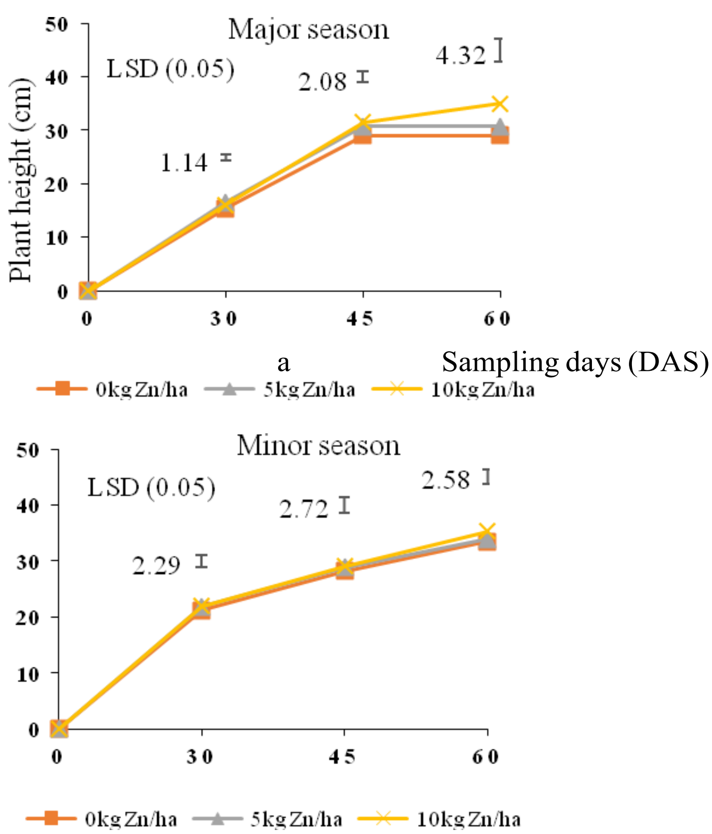


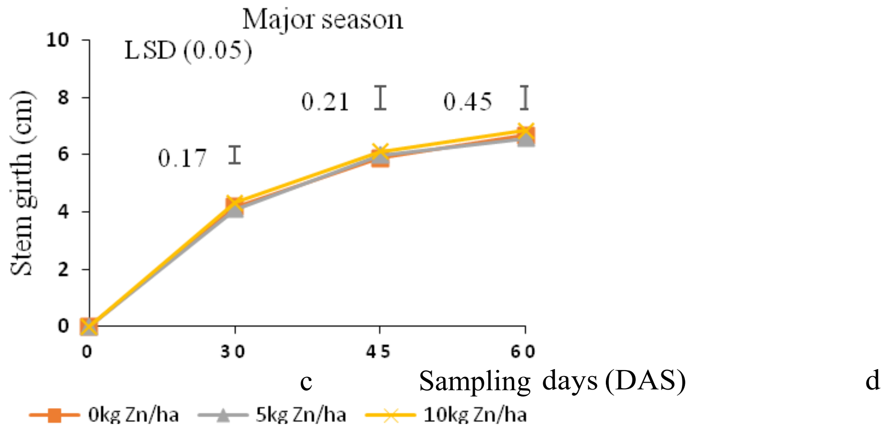
Figure 1. Effects of cowpea varieties on plant height (a and b), stem girth (c and d) and number of leaves (e and f) under Zinc foliar application in 2016 cropping seasons

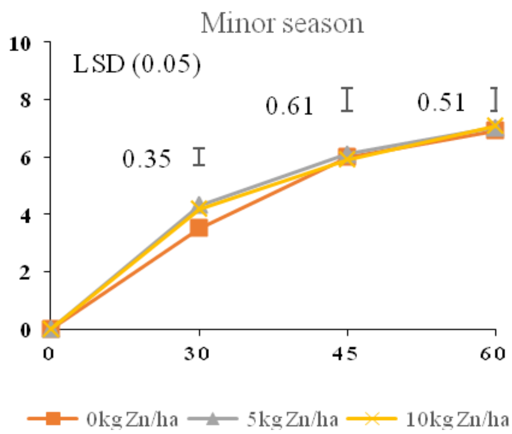
2. Effects of Zinc rates ongrowth

Fig 2 illustrates the effects of Zn fertilizer application on plant height, stem girth and number of leaves over the period of the experiment. Analysis of variance showed no significant effect of Zn fertilizer on plant height and leaf production. However, plots with Zn application had the tallest plants compare to the control. Branch production was significantly affected by Zn rates in both seasons. At 30 DAS, the 5 kg/ha treatment effect was significantly higher than other treatment effects. Treatment effect at 45 DAS was similar. At 60 DAS, the control treatment effect was significantly lower ($P < 0.05$) than all Zinc treatments. Variety by zinc rates interaction was not significant at 5% level of probability on all sampling days.



b


Major season
LSD (0.05)
0.17
0.21
0.45
Stem girth (cm)
10
8
6
4
2
0
0
30
45
60
c
Sampling days (DAS)
d
0kg Zn/ha
5kg Zn/ha
10kg Zn/ha


Minor season
LSD (0.05)
0.35
0.61
0.51
10
8
6
4
2
0
0
30
45
60
0kg Zn/ha
5kg Zn/ha
10kg Zn/ha

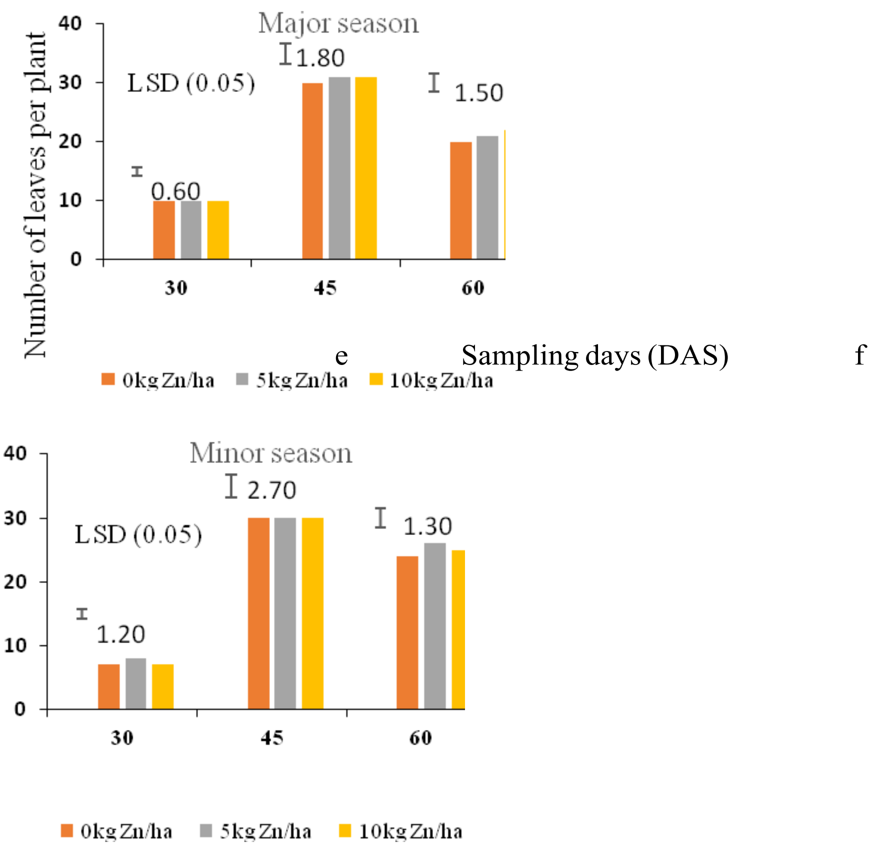


Figure 2. Effects of Zinc rates on plant height (a and b), stem girth (c and d) and number of leaves (e and f) in 2016 cropping seasons

3. Nodulation parameters

Results on number of nodules per plant, effective nodules per plant and nodule dry weight per plant as influenced by cowpea varieties and Zinc fertilizer application in the two sampling periods in both experiments are presented in Tables 1 and 2. Treatment differences for all parameters on all days at both seasons were not significant (P > 0.05). The interaction effect was also not significant at 5% probability. Nodule number was nearly successively decreased over time at all treatments and is not correlated with the Zinc fertilizer applied. No interaction effect was significant for all parameters at all sampling periods.

Table 1. Effect of cowpea varieties in changes of nodule number (nodules per plant), nodule dry weight (g per plant) and effective nodules (%)

	Time (Days after sowing)			
	Major season		Minor season	
	30	45	30	45
Varieties	**Nodule number (nodules per plant)**			
Agyenkwa	5	3	7	6
Asontem	8	5	10	6
Zamzam	5	4	8	6
LSD (0.05)	NS	NS	NS	NS
CV (%)	21.8	31.8	14.2	22.4
	Nodule dry weight (g per plant)			
Agyenkwa	0.06	0.09	0.22	0.16
Asontem	0.04	0.08	0.19	0.14
Zamzam	0.05	0.12	0.18	0.13
LSD (0.05)	NS	NS	NS	NS
CV (%)	18.8	21.0	10.5	20.3
	Effective nodules (%)			
Agyenkwa	82.54	37.82	84.48	47.55
Asontem	74.44	32.64	76.56	42.11
Zamzam	76.94	65.13	79.72	68.27
LSD (0.05)	NS	NS	NS	NS
CV (%)	4.9	5.5	2.4	13.3
Variety x Zn rate	NS	NS	NS	NS

Analysis of variance and LSD evaluations should be re-established. Because the mean values in the 'effective nodules (%)' section are very different (32.64% and 65.13%), but they are shown as NS.

Table 2. Changes in nodule number (nodules per plant), nodule dry weight (g per plant) and effective nodules (%) of cowpea growing under Zinc foliar application

	Time (Days after sowing)			
	Major season		Minor season	
	30	45	30	45
Rates	**Nodule number (nodules per plant)**			
0	6	4	8	6
5	5	4	8	5
10	7	4	9	6
LSD (0.05)	NS	NS	NS	NS
CV (%)	11.3	13.8	5.0	11.9

		Nodule dry weight (g per plant)		
0	0.05	0.11	0.18	0.15
5	0.05	0.09	0.20	0.15
10	0.06	0.08	0.21	0.14
LSD (0.05)	NS	NS	NS	NS
CV (%)	9.8	22.8	7.1	28.5
		Effective nodules (%)		
0	78.56	43.33	81,97	49.25
5	74.26	53.11	76,48	48.88
10	81.11	39.16	82,31	59.80
LSD (0.05)	NS	NS	NS	NS
CV (%)	3.6	8.8	4.4	8.4
Variety x Zn rate	NS	NS	NS	NS

4. Yield and harvest index

The cowpea grain yield was significant (P < 0.05) under Zinc fertilizer application in all the two seasons (Table 3). Cowpea grain yield recorded on the application of Zinc fertilizer at 5 kg/ha increased at 28 % for Agyenkwa > Zamzam (20 %) > Asontem (19%) compare to the control in major season and the minor season the results followed the same trend. The Zinc levels are increased the cowpea grain yield in the order: 5 kg Zn/ha > 10 kg Zn/ha > 0 kg Zn/ha during all cropping seasons (2016 major and minor seasons). The cowpea grain yield decline over increasing the Zinc rate beyond 5 kg/ha. There was about 6 % and 10 % yield reduction in the main season obtained with Agyenkwa and Asontem respectively. 100 seed weights were different at 5% level of probability. One hundred seeds weight was higher with Zamzam following by Agyenkwa and at the end Asontem with the lowest one. The shoot dry weight was significant (p < 0.05) affect by Zinc fertilizer application. Similarly, cowpea varieties did significant (P < 0.05) affect the cowpea biomass yield in all sampling periods and the interaction follows the same trend.

Table 3. Effects of Zn rates on harvest index, haulm and grain yield of cowpea

If there is a statistically significant difference between the averages, the averages should be grouped with the letters.

Treatments	Major season			Minor season		
	100 seeds weight	Haulm	Grain yield	100 seeds weight	Haulm	Grain yield

	g	Kg/ha		g	Kg/ha	
Varieties						
Agyenkwa	16.25 ab	1382.74	1142.23	16.20	1311.58	1620
Asontem	13.63 b	1596.68	1082.15	13.26	1650.58	1326
Zamzam	17.18 a	1470.64	1423.62	17.07	1630.33	1707
LSD (0.05)	1.29	342.94	268.69	1.25	317.90	125.2
CV (%)	4.7	13.40	12.80	4.7	6.40	6.1
Zn levels (kg.ha^{-1})						
0	15.34	1451.48	1087.45	14.93	1440.58	1493
5	15.58	1440.24	1283.94	15.61	1587.67	1600
10	16.14	1558.34	1276.60	16.00	1564.25	1560
LSD (0.05)	NS	225.13	120.87	0.79	218.492	79.4
CV (%)	5.5	17.20	16.00	4.7	10.40	4.7

5. N-fixed and crude protein

The results of cowpea N-fixed and crude protein at all sampling periods are presented in Table 4. In this study Zinc fertilizer application interacted to significantly ($p < 0.05$) affect cowpea N-fixed and crude protein. Zinc levels increased the cowpea N-fixed and crude protein in the order: 5 kg Zn/ha > 10 kg Zn/ha > 0 kg Zn/ha. N-fixed and crude protein interaction differed significantly ($p < 0.05$) among some the treatment interactions. Zamzam variety interacted markedly to produce the highest value of N-fixed in cowpea haulm and grain and Agyenkwa presented the lowest one. For the cowpea crude protein, the result is presented in the following order: Asontem > Agyenkwa > Zamzam.

Table 4. Effects of Zn rates on cowpea N-fixed and crude protein

Treatment	Major season			Minor season		
	Grain N-fixed	Tissue N-fixed	Crude protein	Grain N-fixed	Tissue N-fixed	Crude protein
	Kg.ha^{-1}		(%)	Kg.ha^{-1}		(%)
Varieties						
Agyenkwa	22.40	26.72	25.80	39.61	15.70	24.84
Asontem	26.40	27.64	29.44	32.23	16.59	26.86
Zamzam	31.80	30.82	24.87	39.14	20.95	23.44
LSD (0.05)	NS	12.32	0.91	4.81	NS	1.46
CV (%)	16.60	13.50	2.00	10.40	3.20	3.40
Zn levels (kg.ha^{-1})						

0	21.80	26.12	26.88	33.59	14.12	24.57
5	30.90	27.26	27.28	38.39	20.09	25.56
10	27.90	31.79	25.95	39.00	19.03	25.01
LSD (0.05)	5.26	7.11	0.59	4.81	5.58	1.15
CV (%)	17.30	14.30	1.40	4.00	2.30	4.50
Variety x Znrate	*	*	*	*	*	*

6. Effects of Zinc rates on NPK content

The results of grain nutrients analysis showed no significant varietal effects for content of nitrogen and Phosphorus (Table 5). Additionally, Potassium content in the haulms was not different among varieties. However, for Potassium content in seed, the Zn treatments effects were similar, but greater either effect was greater than the control treatment effect in both seasons.

Table 5. NPK content of cowpea as affected by varieties

	Nutrient uptakes (kg/ha)			
	Major season		Minor season	
	Haulm	Grain	Haulm	Grain
Rates		**N**		
Agyenkwa	40.92	47.21	29.90	64.41
Asontem	41.84	51.18	30.80	57.03
Zamzam	45.46	56.61	35.20	63.94

LSD (0.05)	NS	NS	NS	NS
CV (%)	8.4	6.9	9.40	6.2
		P		
Agyenkwa	3.23	5.46	3.53	12.19
Asontem	3.39	5.09	3.80	14.33
Zamzam	2.75	5.68	3.77	12.33
LSD (0.05)	NS	NS	NS	NS
CV (%)	7.5	6.5	7.1	7.70
		K		
Agyenkwa	14.32	12.01	13.95	20.92
Asontem	13.17	13.61	13.58	16.84
Zamzam	10.79	13.83	11.72	20.43
LSD (0.05)	NS	1.27	NS	2.89
CV (%)	12.1	7.20	7.70	4.30

For the Zn treatments, N content of grain was affected by Zn application in both seasons. Haulm N content was also significantly affected by Zn fertilizer application. In all these cases, treatments differences between the Zinc treatments were similar, but either effect was greater than the control treatment (Table 6). Haulm P content were significantly affected by Zn fertilizer application (Table 6), with the exception haulm Zinc content in the major season, where the control treatment effect was similar to the 5 kg/ha Zn treatment. In all cases, the Zn treatment effects were similar, and either effect was significantly higher than the control treatment effect. Haulm K content was not affected by Zn fertilizer in both seasons (Table 6). However, grain K content significantly affected by the Zn fertilizer in both seasons. In both seasons, grain K content in the control treatment was lower than the Zn treatment effects.

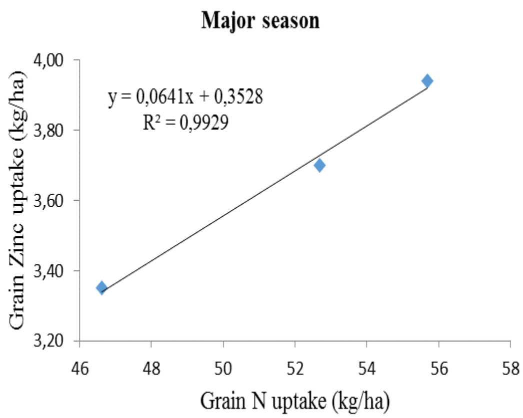
Table 6. NPK content of cowpea as affected by Zinc fertilizer

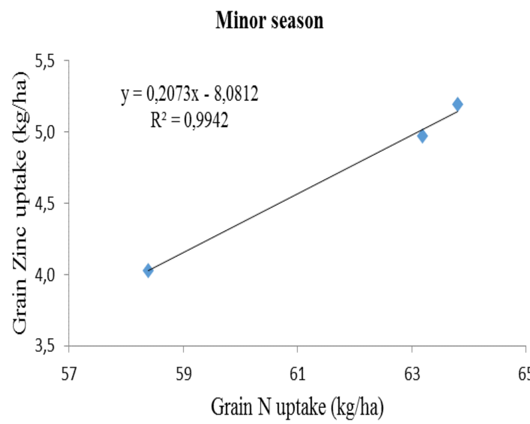
	Nutrient uptakes (kg/ha)			
	Major season		Minor season	
	Haulm	Grain	Haulm	Grain
Rates		**N**		
0	40.32	46.63	28.30	58.39

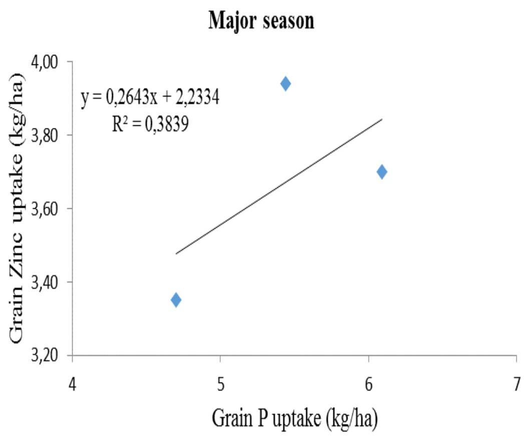
5	41.46	55.69	34.30	63.19
10	45.99	52.68	33.20	63.80
LSD (0.05)	NS	5.26	5.59	2.29
CV (%)	8.90	8.20	9.40	2.40
			P	
0	2.94	4.70	3.22	12.01
5	2.89	6.09	3.88	13.61
10	3.54	5.44	4.01	13.83
LSD (0.05)	0.55	0.70	0.65	1.27
CV (%)	9.20	13.50	9.60	7.20
			K	
0	12.45	12.01	12.42	17.84
5	13.38	13.61	14.38	20.27
10	12.45	13.83	12.45	20.08
LSD (0.05)	NS	1.27	NS	1.67
CV (%)	14.30	7.20	17.30	8.10

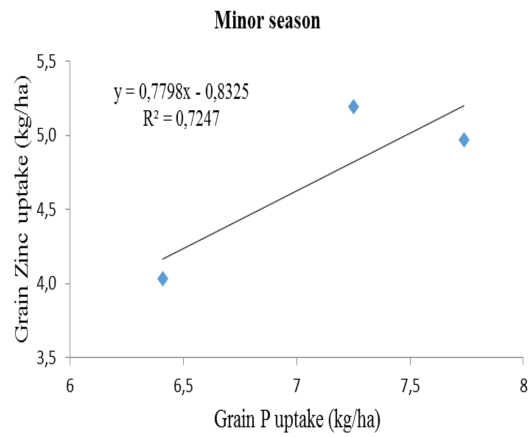
7. Interrelationship between Zinc and NPK uptake in plant grain

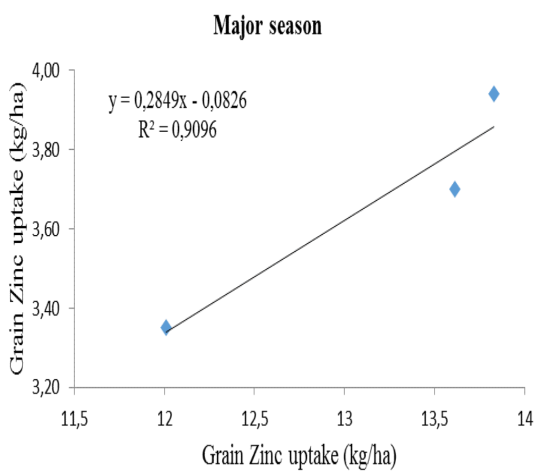
The linear regression showed the positive relationship between grain Zn uptake and NPK content for three sampling periods during the experiment in the major and minor seasons (Fig. 3). The argument on the enhanced NPK uptake y Zn content was ably supported by the significant positive relationship observed in the present study between NK and Zn uptake (0.9929*** with N and 0.9096** with K) in the major cropping season. The minor cropping season also follows the same trend with 0.9942** and 0.9389** with N and K respectively. And with P the relationship was weak but positive (0.3839 in major season and 0.7289 in minor season).


Major season
y = 0,0641x + 0,3528
R² = 0,9929
Grain Zinc uptake (kg/ha)
Grain N uptake (kg/ha)
4,00
3,80
3,60
3,40
3,20
46
48
50
52
54
56
58


Minor season
y = 0,2073x - 8,0812
R² = 0,9942
Grain Zinc uptake (kg/ha)
Grain N uptake (kg/ha)
5,5
5,0
4,5
4,0
3,5
57
59
61
63
65


Major season
y = 0,2643x + 2,2334
R² = 0,3839
Grain Zinc uptake (kg/ha)
Grain P uptake (kg/ha)
4,00
3,80
3,60
3,40
3,20
4
5
6
7


Minor season
y = 0,7798x - 0,8325
R² = 0,7247
Grain Zinc uptake (kg/ha)
Grain P uptake (kg/ha)
5,5
5,0
4,5
4,0
3,5
6
6,5
7
7,5
8


Major season
y = 0,2849x - 0,0826
R² = 0,9096
Grain Zinc uptake (kg/ha)
Grain Zinc uptake (kg/ha)
4,00
3,80
3,60
3,40
3,20
11,5
12
12,5
13
13,5
14

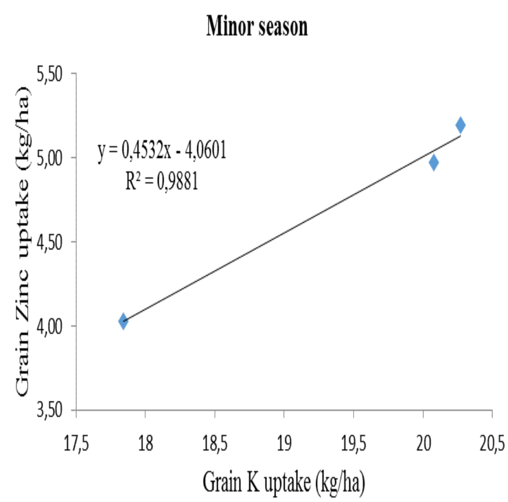

Minor season
y = 0,4532x - 4,0601
R² = 0,9881
Grain Zinc uptake (kg/ha)
Grain K uptake (kg/ha)
5,50
5,00
4,50
4,00
3,50
17,5
18
18,5
19
19,5
20
20,5

Figure 3. Relationship between Zn uptake and the macronutrients (NPK) in 2016 cropping seasons

DISCUSSION

Plant height was affected by both variety and Zn rates. Among the Zn treatments, plant height was greatest in the Zn plots applied in both cropping seasons. [17] reported that added Zn significantly increased plant height by increasing internodes distances. [18] stated that grain yield was positively correlated with leaf weight, stem weight, plant height and number of branching per plant. Zinc fertilizer application did not, however, have any significant effect on the number of leaves and stem girth in all the days examined. It was reported that application of zinc had positive effects on growth parameters [19]. Contrarily, foliar application of micronutrients increased the diameter of plant over the control treatment [20]. So, these findings conclude that the entire cowpea varieties gave equal stem diameter at all treatments of zinc application.

The application of the Zn fertilizer did not affect nodulation, indicating that some of inoculation factors were limiting such as soil pH, initial phosphorus and others micronutrients. And also, [21] reported that the nodule initiation may depend on the relative concentrations of plant-specific signals and host species appears to be a significant factor determining the maximum number of nodules generated. Effective nodule is essential for a functioning Legumes-Rhizobium symbiosis and Zinc, chloride and cobalt have no effect on nodulation but are required for the growth of the host legume [22]. Two hosts may have the same sensitivity to bacterial signal molecules, but might differ in their ability to elicit synthesis of required nodulation signals in the bacteria [23]. Cowpea root exudates have also been reported to contain substances that enhance nodule initiation [24, 25, 26]. However, lower efficiency of cowpea cannot be readily explained in terms of reduced numbers of bacteria in contact with the root [21]. Varieties most susceptible to infection and capable of producing effective nodules should have greater potential to fix more atmospheric N. However, this assumption often depends on other factors such as the environment and crop management [27]. Indeed [28] reported that the ability to form nodules is not enough to obtain an effective nitrogen fixation symbiosis. Nodule number was nearly successively decreased over time at all treatments and is not correlated with the Zinc fertilizer applied. The amount of nodule dry biomass was drastically reduced with the mineral Zinc fertilizer, whereas the amount of nodule biomass was not affected in the control group, probably because the soil had satisfactory levels of available N and P. Nodule number correlated negatively with nodule dry weight [29]. The interaction effect was also not significant at 5% probability.

The present results were supported by [30] who reported that foliar application of micronutrients help in improving yield. In both seasons, foliar spray of Zn fertilizer had effect on hundred grain weights. In all these parameters, the control treatment effect was lower than Zn treatments, whereas among the Zn treatments. [31] reported that following Zn fertilization increased hundred seed weight. Also, [32] reported that yield and its components in lentil are improved by foliar application of micronutrients. Crop yields and quality are reduced by Zn inadequate in soil; therefore, Zn utilization is essential to obtain high yield and quality in crops as showed the results (Table 3). These results are in close conformity with those of [33, 34, 35]. This was because of the fact that better and higher availability of Zinc, resulting better nutritional environment, higher dry matter accumulation and its associated effect on growth attributes increased haulm and grain yield. It is also evident from table 3 that all the Zinc treated plots increased the grain yield over the control, as there was a consistent increase in cowpea grain yield up to 10 kg Zn/ha. This suggests that, the application of Zn significantly affect cowpea yield. Similar results were reported as in [36] and [37]. In this connection, [38] reported that the foliar application of Zn affected yield and its components of soybean. Also, [39] reported that the highest yield of common bean was obtained by Zinc foliar application. [40] believe that more production of chlorophyll and IAA can cause delay in plant oldness and prolong the period of photosynthesis. This incident improves the production of carbohydrates and their transportation to the growing seeds.

The Zn deficiency symptoms can be prevented by the application of Zn fertilizers. The actual causal relationship and mechanisms are still not fully understood [3]. As shown in Tables 4 and 5 the mean percentage total nitrogen, phosphorus and potassium uptakes in the harvested leaves were quantitatively higher under zinc fertilizer application and increased with incremental zinc rates. These results corroborate the findings of [41] and [42] who reported that zinc is an essential micronutrient for plant growth and plays an important role in the catalytic part of several enzymes its deficiency will result in stunted growth and nutrient uptakes. And also, [43] reported that zinc exerts a great influence on basic plant life processes, such as (i) nitrogen metabolism – uptake of nitrogen and protein quality; (ii) photosynthesis - chlorophyll synthesis and carbon anhydrase activity. Also many researchers have observed that Zn is closely related to the nitrogen metabolism pathway of plants, thus causing a reduction in protein synthesis for Zn deficient plants. Zinc deficiency significantly affects the root system including root development [44].

CONCLUSION

Zn fertilizer significantly affected NPK content and grain yield of cowpea varieties used. The increment of Zn content in the grain had a positive relationship with NK, which will definitely enhance nutrition of both human and animals. At all sampling periods, nodule number per plant was not affected by Zinc rates and nodule number was nearly successively decreased over time at all treatments and is not correlated with the Zinc fertilizer applied. The Zinc fertilizer significantly enhanced N-Fixed and Crude protein in both cropping season's trial investigating effect of Zinc rates on growth, nodulation and mineral content of cowpea in the semi-deciduous forest zone of Ghana. This implies the Zn rates used can be applied to any of the varieties used.

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