International Journal of Agriculture and Plant Science
Online ISSN: 2664-7664; Print ISSN: 2664-7656
Received: 04-11-2019; Accepted: 06-12-2019; Published: 11-01-2020
www.agriculturejournal.in
Volume 2; Issue 1; 2020; Page No. 15-22

Response of cowpea (*Vigna unguiculata L.* Walp) to zinc fertilizer application in the semi-deciduous forest zone of Ghana

ZP Chakirwa[1*], J Sarkodie-Addo[2], T Adjei-Gyapong[3], BJ Bashagaluke[4]
[1, 2, 3, 4] Department of crop and soil science, Kwame Nkrumah University of science and technology, Kumasi, Ashanti region, Ghana
[1] Centre Interdisciplinaire pour le Développement Permanent, Bukavu, Sud-Kivu, DR Congo
[1, 4] Université Catholique de Bukavu, Sud-Kivu, DR Congo

Abstract

Cowpea is a widely consumed pulse to address protein deficiency but its potential for Zinc bio-fortification is not widely studied in West Africa and optimal rates for different cowpea varieties are not known. In connection with this field and pot experiments were conducted in the major and minor seasons of 2016 to investigate the effect of Zn fertilizer on the growth, yield and nutritional benefits to cowpea. 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 them. 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 showed that Zn application improved leaf area index and shoot dry matter. Grain yield and harvest index were also enhanced following the Zn fertilizer application. Furthermore, Zn fertilizer application resulted in increase in the Zinc contents of cowpea haulms and grains. The results indicated that Zn fertilizer application can lead to better growth, yield and nutrient quality. This will not only improve cowpea nutrition, but cost use of Zn supplements in humans will be reduced.

Keywords: nutrient depletion, zinc content, zinc deficiency, yield, cowpea and Ghana

Introduction

Micronutrient-deficient soils are widespread; many parts on agricultural farmlands worldwide are deficient in one or more of micronutrient elements. Soils with low plant-available Zn are common in tropical climates, including the cropping areas of Ghana (Rengel, 2002) [19]. Zinc deficiency is widespread on arable land in many parts of Ghana and it constitutes a major limiting factor in the production of zinc-rich food and vegetables, therefore grains are frequently produced that have low Zn content (Rengel, 2002) [19]. This low Zn concentration may be due to the physiological imbalances within the plant (Olsen, 1972) [17], high or low pH, high or low organic matter, wetland, sandy soils and high phosphorus. According to Sillanpää (1982) [21], Copper, Zinc and Molybdenum deficiencies are common in many coarse textured, acid soils of several African countries including Ghana (Anynomous, 1985) [4]. This means Zn content of Ghana soils and plants are somewhat on the low side in the "international Zn fields". The lowest plant soil Zn values, almost without exception, were measured from samples which came from the Ashanti region (Sillanpää, 1982) [21]. The major constraint of Zinc deficiency in world food production not only retards growth and yield of plants by affecting the capacity for water uptake and transport in plants, but it also has effects on human beings (Alloway, 2008) [3], also known as 'Hidden hunger'. Cowpea is an important food crop with good soil fertility enhancement. Ability (Yirzagla *et al.*, 2016) [28]. In West Africa, cowpea is a protein-rich component of an otherwise protein-poor diet (Hall, 2004). The protein concentration in cowpea grain (20-25 %) is about twice the protein content of most cereals (Addo-Quaye *et al.*, 2011) [1] and 16-54 mg/kg of Zn content (Rengel, 2002) [19] according to integrated soil fertility management approach used. Use of nutrient-efficient crop species and genotypes within species is a very attractive strategy to reduce the cost of crop production. To improve the life and livelihoods of dryland farms in West Africa and increase the sustainability of the cropland upon which they depend through greater dependence upon and response of fertilizers applications; integrated soil fertility management must be the key for these achievements. Many approaches, including crop rotation, manure application, and the use of crop residues, have been used to restock micronutrients into the North Ghanaian soils; however, such methods and materials do not enhance crop yields due to the scarcity of micronutrients in these materials. Cowpea is a widely consumed pulse to address protein deficiency but its potential for Zinc bio-fortification is not widely studied in West Africa and optimal rates for different cowpea varieties are not known. Therefore, this study investigated the influence of Zinc fertilizer application on the growth, grain yield and seed content of zinc in cowpea varieties in the semi-deciduous forest zone of Ghana.

Materials and Methods

The experiment was conducted at the Plantation Section of the Department of Crop and Soil Sciences, Faculty of Agriculture, KNUST, in cropping seasons 2016. The site is located at 06° 45' N and 01° 31' W in the rainforest belt of Ghana. According to Hazelton and Murphy (2007), the soil was moderately acid with moderate organic carbon content (1.04%). The total soil nitrogen was low with a mean value of 0.06%, The soil Zn content was moderately, found to be 1.290 mg/kg (Eteng *et al.*, 2014) [6] and Kparmwang *et al.*, 2000) [12] and Veldkamp *et al.* (1991) [24] reported the zinc deficiency in the tropical soil is very severe, all showing values below the critical level of 0.8 mg Zn kg^{-1}. The experiment was a split-plot design, with the treatments arranged in RCBD design. The factors studied were cowpea varieties (main-plot factor) and Zn fertilizers spray (sub-plot factor). The treatment combinations were replicated four times. Cowpea varieties (Agyenkwa, Asontem, and Zamzam) were obtained from the Crops Research Institute at Fumesua, Kumasi/Ghana. Cowpea varieties used were selected according to their yield, maturity (62-70 days) and availability in the study area. Zinc sulfate heptahydrate was applied at a rate of 0, 5 and 10 kg Zn ha^{-1} as foliar application at 3 weeks (40%) and 5 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 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^{-1} uniformly to all plots at two weeks after planting (WAP). Triple super phosphate (TSP) was also applied two weeks after planting (WAP) to the cowpea plant at the rate of 40 kg P_20_5 ha^{-1}. Standard agronomic and plant protection treatments were done 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 %)] and sunpyrifos 48 % E.C. [Active ingredients (Chlorpyrifos-methyl)] were used for their control. Random samples of five plants from each plot were selected for data collection. Leaf area index (LAI) was obtained by leaf area of plant and plant ground area, using Adeoye *et al.* (2011) [2] formula. Dry shoot yield was determined by uprooting gently the plant and cutting of all roots. The above ground parts were put in labelled envelops and oven dried at 80°C for 48 hours. The average dry shoot weight was computed as dry matter yield per hectare. Haulm and grain yield were obtained by weighing the dry haulm and seeds harvested per each sub-plot with a top loading scale and converted to kg ha^{-1}. After shelling the pods from each plot, the seeds, chaff and the total biomass were oven dried at 80°C for 48 hours and dry weight determined. Harvest index was calculated by using the formula suggested by Donald (1963) [6] and expressed as a percentage. Zinc content was determined by oven dried at 70°C to a constant weight for 72 hours. 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 (Okalebo *et al.*, 1993) [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^{-1}. Data collected were subjected to analysis of variance (ANOVA) according to Steel and Torrie (1980) [22] using GenStat statistical package version 15th. Analysis of variance was done to test significance levels of the variables and the LSD test was be used to compare treatment means at 5% probability. Correlation analysis was done to determine relationship among parameters.

Results

1. Changes in leaf area index and shoot dry weight as influenced by cowpea varieties

Results of leaf area index and shoot dry matter yield as influenced by cowpea varieties at all sampling times are shown in Fig. 1. The leaf area index did not differ significantly among the cowpea varieties. Cowpea varietal differences for shoot dry weight were significant only 45 and 60 DAS in both seasons. The Asontem varietal effect was greater than other varieties at 45 and 60 DAS during the major season. The Zamzam varietal effect was greater than Agyenkwa at 60 DAS sampling only. In the minor season, the Asontem varietal effect was greater than both varieties at 45 DAS, but only the Agyenkwa varietal effect at 60 DAS. At 60 DAS, the Zamzam varietal effect was greater than that of Agyenkwa. Variety by Zn rate interaction effect was not significant.

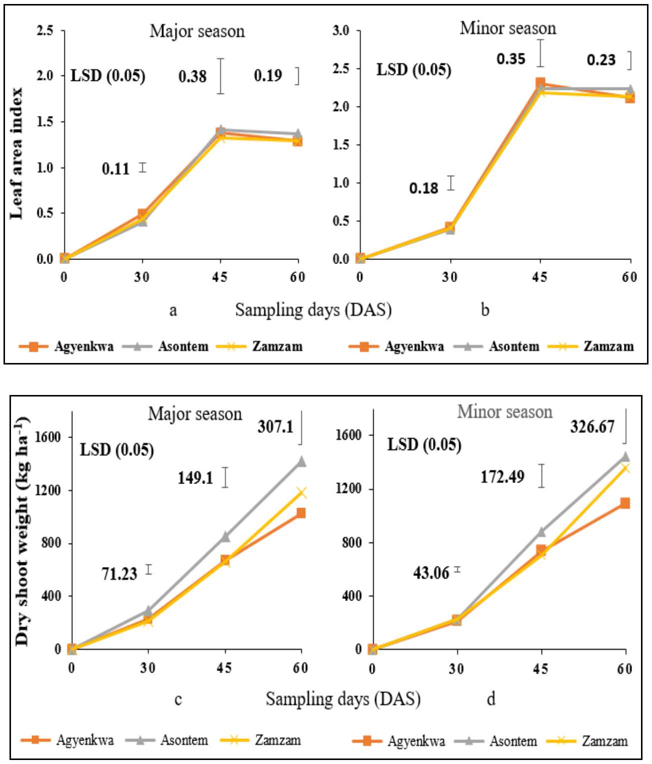


Fig 1: Effects of cowpea varieties on leaf area index and shoot dry matter yield in 2016 cropping season

2. Changes in leaf area index and shoot dry matter yield as influenced by Zn rates

Results of leaf area index and shoot dry matter yield as influenced by zinc rates at all sampling times are shown in Figure 2. The leaf area index Did not differ significantly among the Zn fertilizer rates in both seasons. Zn rates also did not significantly affect shoot dry matter yield in all sampling days, except at 60 DAS in the minor season when the control treatment effect was significantly lower than all Zn treatments.

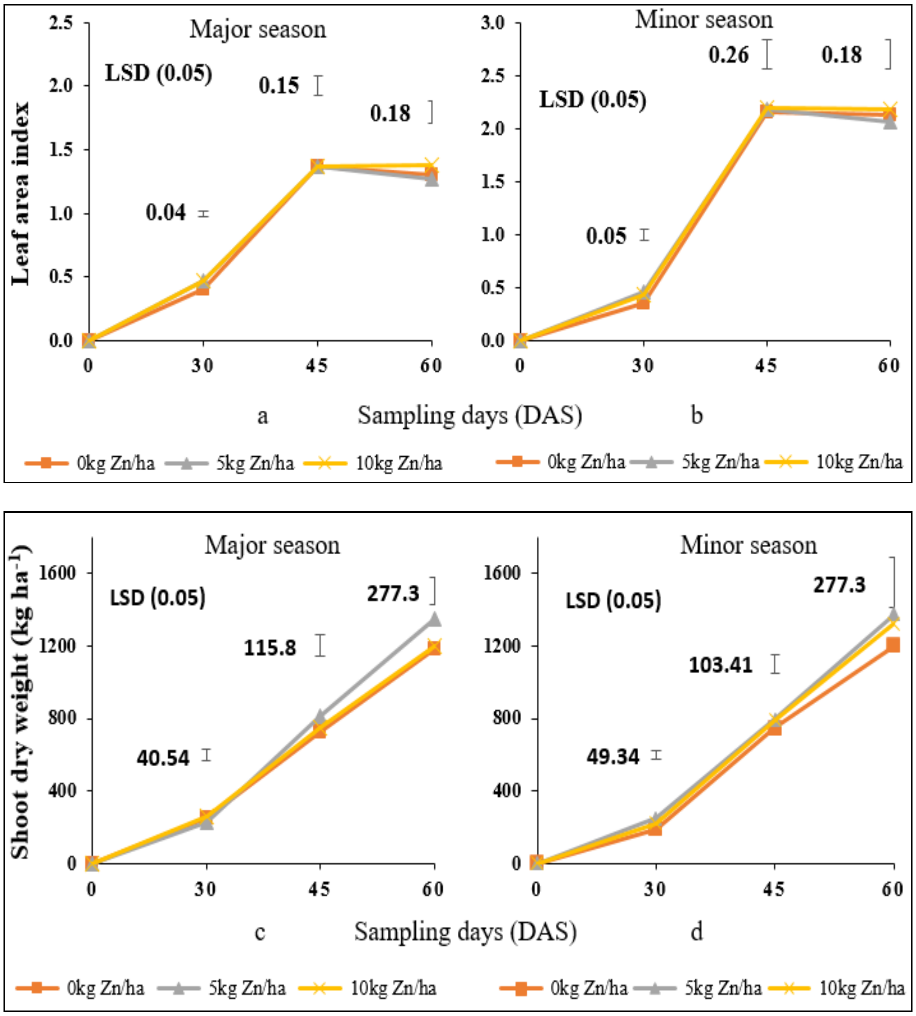


Fig 2: Effects of Zn rates on leaf area index and shoot dry matter yield of cowpea in 2016 cropping season

3. Harvest index, haulm and grain yield

Grain yield was significantly ($P < 0.05$) affected by Zinc fertilizer application and cowpea variety in all the two seasons (Table 1). Cowpea grain yield was greatest in Zamzam variety, whilst Asontem recorded the lowest yield in both seasons. Zn fertilizer application also significantly affected cowpea grain yield. In both seasons, the Zn treatments resulted in similar effects, which were greater than the control treatment effect. Harvest index in both seasons were affected by variety. In this case, the Asontem variety effect was significantly lower than those of Zamzam and Agyenkwa varieties. In the major season the 5 kg/ha treatment effect was significantly ($P < 0.05$) higher than the control treatment effect only. But in the minor season, Zn application did not affect harvest index. Haulm yield was not affected ($P > 0.05$) by Zn application in both seasons. Varietal differences were significantly only in the minor season, where Agyenkwa produced lower yield than the others varieties.

Table 1: Effects of Zn rates on harvest index, haulm and grain yield of cowpea

Treatments	Major season			Minor season		
	Harvest index	Haulm	Grain yield	Harvest index	Haulm	Grain yield
	%	Kg ha^{-1}		%	Kg ha^{-1}	
Varieties						
Agyenkwa	45.87	1382.74	1142.23	56.33	1311.58	1620
Asontem	40.28	1596.68	1082.15	44.50	1650.58	1326
Zamzam	49.59	1470.64	1423.62	51.75	1630.33	1707

LSD (0.05)	4.27	NS	268.69	6.57	317.90	125.2
CV (%)	5.50	13.40	12.80	7.50	6.40	6.1
Zn levels (kg ha^{-1})						
0	42.98	1451.48	1087.45	52.00	1440.58	1493
5	47.66	1440.24	1283.94	50.58	1587.67	1600
10	45.10	1558.34	1276.60	50.00	1564.25	1560
LSD (0.05)	4.20	NS	120.87	NS	NS	79.4
CV (%)	2.60	17.20	16.00	10.30	10.40	4.7
Variety x Zn rate	*	NS	*	*	*	*

‘’*’’Significant and ‘’NS’’ non-significant

4. Zinc content and zinc uptake

The zinc concentration was significantly influenced by various levels of zinc applied and cowpea variety (Fig. 3 and 4). Treatment differences for Zinc content in haulm and grain were significantly higher with 10 kg ha^{-1} Zn treatment in all cropping season. The control treatment produced significantly low concentration than the Zn treatments. The grain Zinc content was highest with the increment of Zinc rates. The Zn concentration in grain ranged from 16.45 to 30.83 ppm and that of haulm 19.72 to 32.22 ppm. Cowpea varietal differences were not significant in both seasons at 5% level of probability, but there was no clear consistent pattern. Haulm and grain Zn contents appeared to be different with the varieties and season (Fig.4).

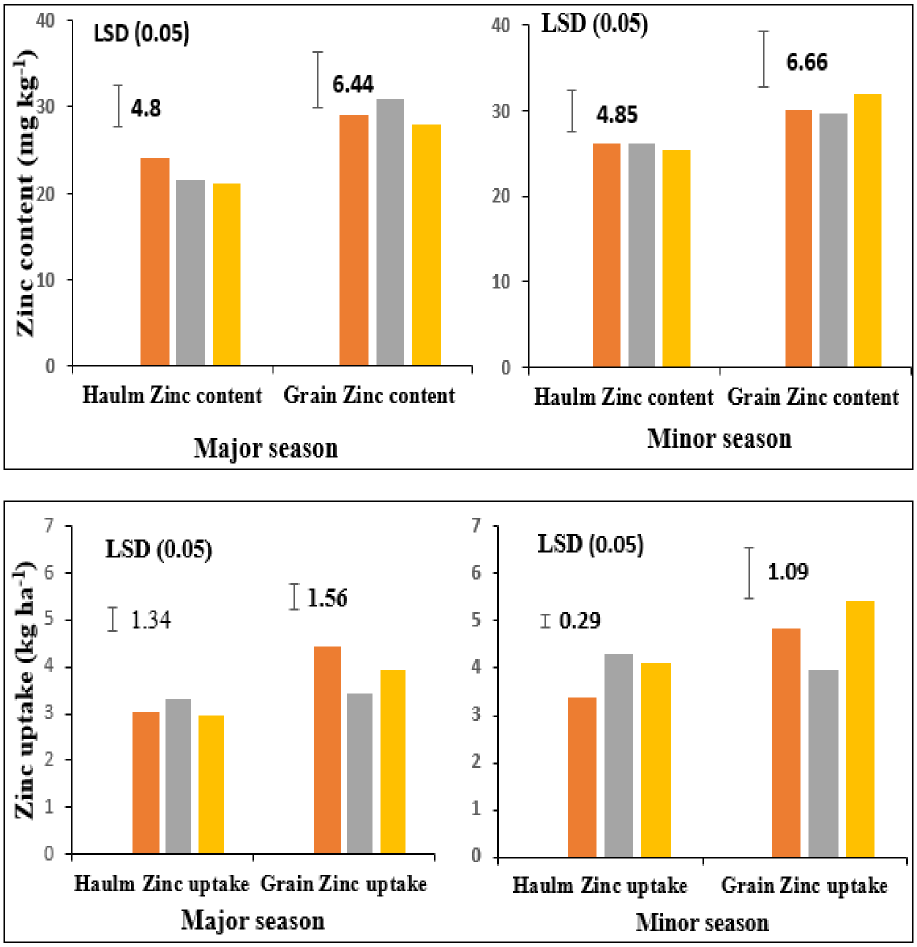


Fig 3: Effect of cowpea varieties on haulm and grain Zn content and uptake in both cropping seasons

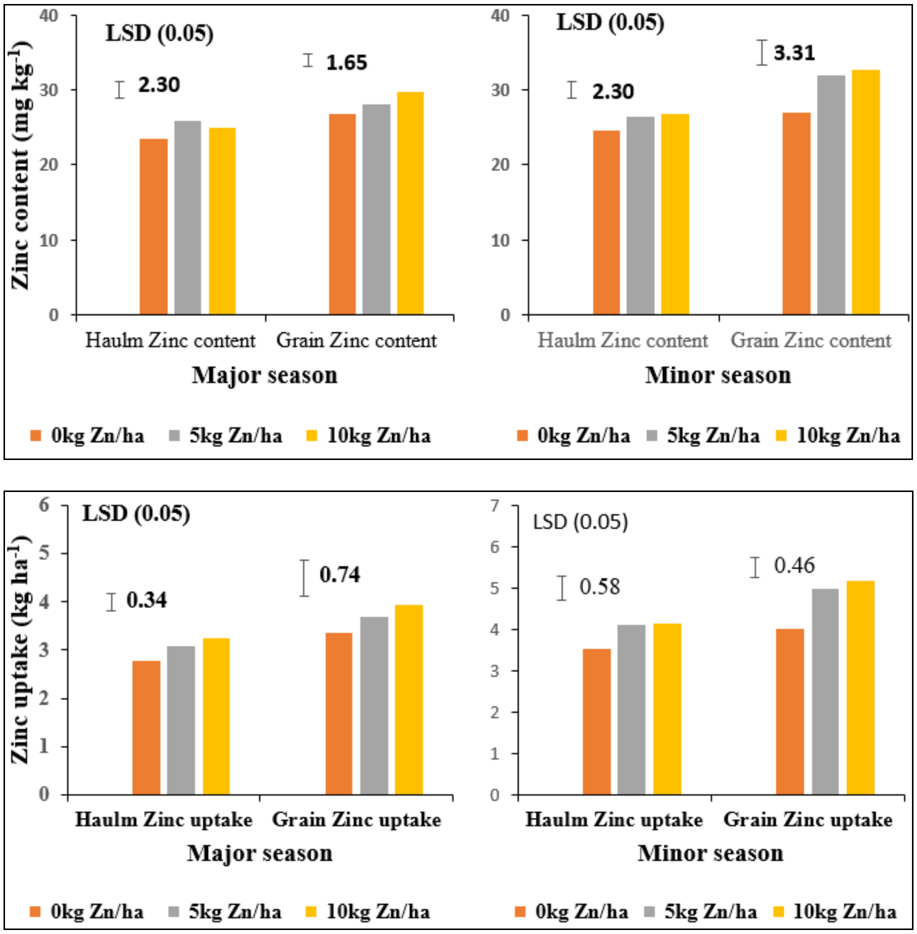
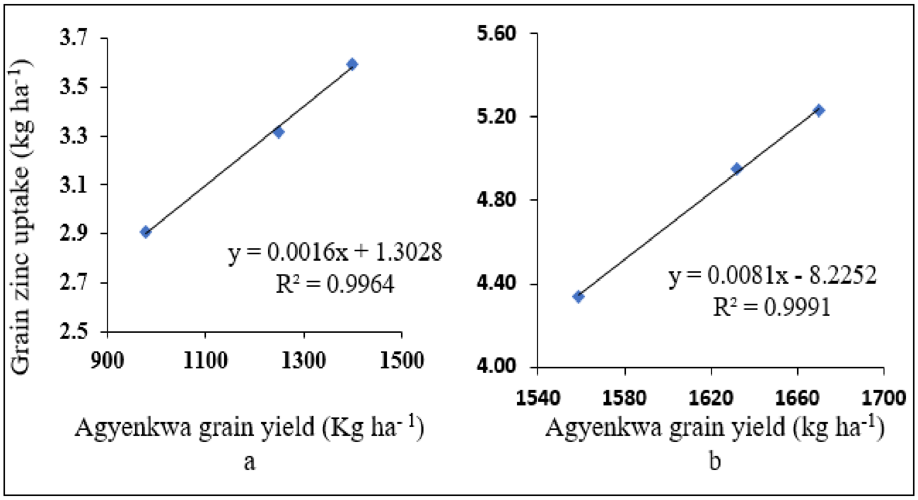


Fig 4: Effect of zinc rates on haulm and grain Zn content and uptake at all sampling periods

The linear regression showed the positive relationship between varieties and zinc fertilizer application for three sampling periods during the experiment in both seasons (Fig 5). The results showed enhanced cowpea yield by zinc addition by the significant positive relationship observed between grain yield and Zn rates (0.9964*** with Agyenkwa variety, 0.9803** with Asontem variety and 0.9706** with Zamzam variety) in the major cropping season, and 0.9991***, 0.9646** and 0.9034* with Agyenkwa, Asontem and Zamzam varieties respectivily.



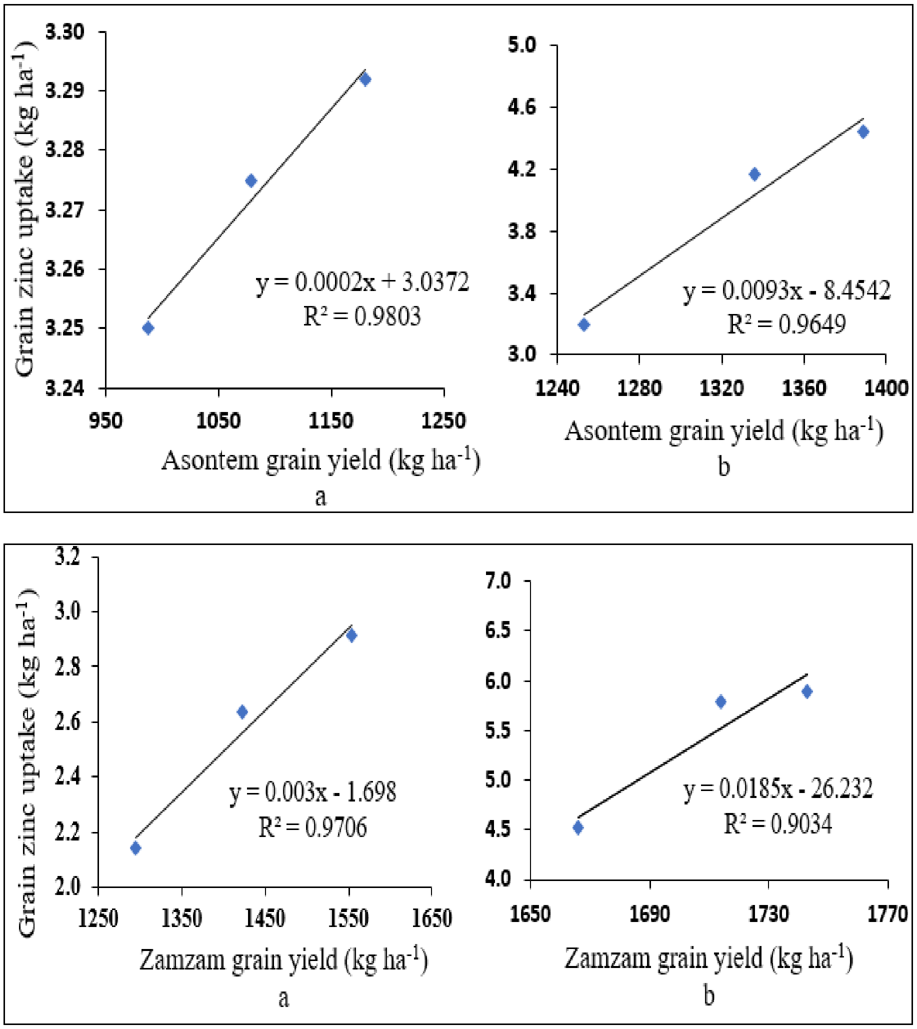


Fig 5: Interrelationship between cowpea grain yields and zinc uptake on 2016 major season (a) and minor season (b)

Discussion

All varieties recorded LAI between 0.4 and 2.18 during the period of sampling; greater values in major and minor seasons were recorded on Zinc plots applied. Sampling at 45 DAS were greater also than at 30 DAS in both cropping seasons. LAI, which describes the size of the assimilatory apparatus of the plant stand, is said to be the primary factor that determines the rate of dry matter production in a closed stand. It also reflects differences in productive efficiency between crop varieties (Kvet *et al*., 1971) [13]. IITA (1977) [11] reported that, for large yields of cowpea to be achieved, LAI between 1 and 2 were required for as long as possible after flowering. This, however, needed to be combined with efficient partitioning of dry matter into fruits. The dry matter yield increase in the Zn treatments over the control suggests that Zn was one of the limiting nutrients in the soils. In this study, the rate of 5 kg Zn ha^{-1} was the best in optimizing cowpea yields in the soils. Similarly, Zn levels increased dry matter yields from 970 kg ha^{-1} to 1522 kg ha^{-1} in the major season and from 991.25 kg ha^{-1} to 1563.75 kg ha^{-1} in the minor season. This indicates that, at this level, the soil Zn was further improved with better Zn nutrition leading to high dry matter production. Further addition of Zn as foliar application after 5 kg Zn ha^{-1} level, did not significantly improve dry matter yield of plant. This finding is in agreement with result reported in Moswatsi (2015) [15].

Crop yields and quality have been reported to be reduced by zinc inadequacy in soil; such reports have been made by some authors including Sharma and Jat (2003) [20], Yadav (2004) [26] and Tripathi *et al.* (2011) [23]. Haulm yield was also improved following zinc fertilizer application, which had been earlier reported by Moswatsi (2015) [15] and Oseni (2009) [18]. The possible explanation is that Zn application may not only correct the deficiency in the soil, but could made others nutrients available for crop uptake (Eteng *et al.*, 2014) [6]. Generally, the grain yield enhancement at 5 kg Zn/ha suggests that, this is the economical level required for optimum cowpea production. This rate is similar than the level obtained as reported in Moswatsi *et al.* (2013).

The results showed that zinc content of grains was significantly improved following zinc fertilizer application. Yilmaz *et al.* (1997) [27] reported that fertilizers can increase Zn concentration up to three- or fourfold. The amounts of Zn concentrations in cowpea grain ranged from 16-54 mg kg^{-1} of Zn content, these were far above the critical ranges reported by Rengel (2002) [19]. Moreover, Zn application increased Zn uptake significantly compared with the control, signifying that Zn was low in this soil (Eteng *et al.,* 2014 [6] and Kparmwang *et al.*, 2000) [12]. The increase in the zinc content in grain and haulm might be due to the presence of increased amount of Zn in soil solution by the application of zinc that facilitated greater absorption. Welch (1999) [25] emphasized the importance of Zn grain reserves on early wheat seedling performance, mainly under low external Zn conditions and that the benefits of Zn grain reserves conferring seedling vigour during germination cannot be substituted by Zn supply after germination. Greater Zn grain reserves resulted in greater seedling root and shoot growth in a Zn deficient soil and the differences between plants from high-Zn and low-Zn-grains were evident even after six weeks of growth (Welch, 1999) [25]. Improved Zn content in the seed will improve the nutrition benefits to cowpea consumers, especially in children. This will definitely reduce the amount of zinc supplements intake by consumers of cowpea grains.

Conclusion

The results showed that zinc fertilizer application significantly improved growth in the varieties. Leaf area index and shoot dry weights were enhanced following the zinc fertilizer application. Additionally, Harvest index and grain yield were greater in the Zinc treatments than in the control treatment. However, yield improvement was better in the 5 kg/ha rate than the 10 kg ha^{-1} rate. Finally, zinc uptake, haulm and seed contents of zinc were improved following zinc fertilizer application. This will be improved nutrition in both livestock and humans.

Acknowledgements

The authors wish to appreciate the support received from the intra-ACP academic mobility scheme and the field technicians for their support during the data collection.

References

1. Addo-Quaye AA, Darkwa AA, Ampiah MKP. 'Performance of three cowpea (Vigna unguiculata (L) Walp) varieties in two agro-ecological zones of the central region of Ghana I : Dry matter production and growth analysis', ARPN Journal of Agricultural and Biological Science. 2011; 6(2):1-9.
2. Adeoye PA, Adebayo SE, Musa JJ. 'Growth and yield response of cowpea (Vigna unguiculata L.) to poultry and cattle manures as amendments on sandy loam soil plot', Agriculture journal. 2011; 5:218-221.
3. Alloway BJ. Zinc in Soils and crop nutrition. Second edition, published by IZA and IFA in Brussels, Belgium and Paris, France. 2008; 14:139.
4. Anynomous. 'Micronutrients', Rocks for crops, 1985, 30-3.
5. Donald CM. 'Competition among crop and pasture plants', Advanced agronomy. 1963; 15:1-118.
6. Eteng EU, Asawalam DO, Ano AO. 'Effect of Cu AND Zn On Maize (Zea Mays L.) Yield and Nutrient Uptake in Coastal Plain Sand Derived Soils of Southeastern', journal of soil science. 2014; 4(25):235-45.
7. Hägnesten H. Zinc deficiency and iron toxicity in rice soils of Office du Niger, Mali, 2006.
8. Hall AE. 'Breeding for adaptation to drought and heat in cowpea', European Journal of Agronomy. 2004; 21(4):447-54.
9. Hazelton P, Brian M. Interpreting Soil test – What do all the numbers Mean? CSIRO Publishing, Collingwood/Australia, 2007.
10. Hofman G, Van Cleemput O. Soil and Plant Nitrogen Soil and Plant Nitrogen, 2004, 30.
11. IITA. Grain legume improvement program annual report, Ibadan, Nigeria, 1977.
12. Kparmwang T, Chude VO, Raji BA, Odunze AC. 'Extractable Micronutrients in Some Soils Developed on Sandstone and Shale in Benue Valley', Nigerian journal of Soil Science Research. 2000; 1:42-8.
13. Kvet J, Ondok JP, Necas J, Jarvis PG. Methods of Growth Analysis. In: Sestak, Z., Catsky, J. and Jarvis, P.G. (Eds.), Plant Photosynthetic Production: Manual of Methods. Dr W. Junk N.V., The Hague, 1971, 343-91.
14. Moswatsi MS, Kutu FR, Mafeo TP. 'Response of cowpea to variable rates and methods of zinc application under different field conditions', African Crop Science Conference Proceedings. 2004; 11:757-62.
15. Moswatsi MS. 'Response of cowpea to variable rates and methods of zinc'. Thesis, University of Limpopo, 2015, 77.
16. Okalebo JR, Gathua KW, Woomer PL. Laboratory methods of soil and plant analysis: A working manual, Tropical S., vol. 1, Soil Science Society of East Africa, Nairobi/Kenya, 1993.
17. Olsen SR. 'Micronutrient Interactions', In J.M Mortved, J.J. Goirdano, and W.L. Lindsay (eds). Micronutrients in Agriculture. Soil Science Society of America. 1972; 6:243-64.
18. Oseni T. 'Growth and Zinc Uptake of Sorghum and Cowpea in Response to Phosphorus and Zinc Fertilization', World Journal of Agricultural Sciences. 2009; 5(6):670-4.
19. Rengel Z. 'Agronomic approaches to increasing Zinc concentration in staple food crops', Soil science and plant nutrition, 2002, 1.
20. Sharma SK, Jat ML. 'Effect of sulphur on growth and yield of cowpea [Vigna unguiculata (L.) Walp]', Annals of Agriculture Research. New Series. 2003; 24(1):215-216.
21. Sillanpää. Micronutrients and the nutrient status of soils: a global study, FAO soils bulletin CN - S592.6.T7 S538 1982, Fao soils bulletin, Finland, 1982.
22. Steel RGD, Torrie JH. Principles and Procedures of Statistics, 2nd edition. McGraw-Hill, New York, USA, 1980, 20-90
23. Tripathi HC, Pathak RK, Kumar A, Dimsec S. 'Effect of sulphur and zinc on yield attributes, yield and nutrient uptake in chicpea', Annals of Plant and Soil Research. 2011; 13:134-6.
24. Veldkamp WJ, Traoré A, N'Uiaye K, Keita MK, Keita B, Bagayoko M, *et al*. Fertilité des sols du Mali, Mali-Sud/Office du Niger, Interpretation des données

analytiques des sols et des plantes. IER, Bamako/Mali, 1991.

25. Welch R M. 'Importance of seed mineral nutrient reserves in crop growth and development', In: RENGEL, Z. (Ed.) Mineral nutrition of crops: fundamental mechanisms and implications. Binghamton: Food Products Press, 1999, 05-26.
26. Yadav SS. 'Growth and yield of cowpea [Vigna unguiculata (L.) Walp] as influenced by phosphorus and sulphur fertilization', Haryana Journal of Agronomy. 2004; 20(1):10-12.
27. Yilmaz A, Ekiz H, Torun B, Gulekin I, Karanlink, S, Bagci SA. *et al*. 'Effect of different zinc application methods on grain yield and zinc concentration in wheat cultivars grown on zincdeficient calcareous soils', Journal of plant nutrition. 1997; 20:461-71.
28. Yirzagla J, Atokple IDK, Haruna M, Kusi F, Suguri I, Muntari A, *et al*. 'Scaling out Cowpea Production in Northern Ghana, Community Seed Production Scheme Cowpea Out-scaling Project. ', Pan-African Grain Legume and World cowpea conference, IITA, Livingstone, Zambia, 2016, 20.