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Research Article

Zinc Sulphate and Boron-Based Foliar Fertilizer Effect on Growth, Yield, Minerals, and Heavy Metal Composition of Groundnut (*Arachis hypogaea* L) Grown on an Alfisol

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Field experiments were conducted during 2016 and 2017 cropping seasons in the derived agro-ecological zone of Nigeria to study the combined and sole effect of zinc and boron fertilizers on the growth, seed yield, and quality of groundnut (*Arachis hypogaea* L). The experiment was laid out in randomized complete block design (RCBD), replicated four times. Three levels of zinc (0, 4, and 8 $kg\cdot ha^{-1}$) and four levels of boron (0, 300, 600, and 900 $ml\cdot ha^{-1}$) were combined and evaluated. Groundnut seeds were analyzed at the end of the experiments to determine nutrient elements and some heavy metal contents. Data collected were subjected to Statistical Analysis of Variance using SAS 2000. Treatment means were compared using the Duncan multiple range test at 0.05 level of probability. The effect of zinc was not significant on the vegetative parameters, while application 8 kg $Zn\cdot ha^{-1}$ significantly increased number of seeds, weight of seeds, seed yield per hectare, and seed quality though the values were similar to the application of 4 kg $Zn\cdot ha^{-1}$ only on the seed yield and its parameters. Application of 600 and 900 ml $B\cdot ha^{-1}$ gave higher and statistically similar values for vegetative parameters, yield, and yield parameters, while 600 ml $B\cdot ha^{-1}$ significantly improved the seed quality. It can therefore be recommended that for optimum yield and seed quality, application of 8 kg $Zn\cdot ha^{-1}$ combined 600 ml $B\cdot ha^{-1}$ is sufficient in the study area without increasing the heavy metal concentration of groundnut seed.

1. Introduction

Groundnut (*Arachis hypogaea* L.) is a species of the legume or "bean" family (Fabaceae). It is an annual herbaceous plant that grows within 30–50 cm in height [1].

The worldwide groundnut is grown in 26.4 million hectares with a total production of 37.1 million metric tonnes and an average productivity of 1.4 metric $t\cdot ha^{-1}$. Global production (2011) totaled 38.6 million tons, 95 percent of which occurred in developing countries, and major producers include China, India, Nigeria, USA, and Myanmar [2]. Rich in protein and oil fit for human consumption, groundnut (*Arachis hypogaea*) is principal to the financial and nutritional well-being of hundreds of millions of farmers and consumers across the semi-arid tropics.

Mineral nutrition of plants is important for controlling physiological and biochemical processes of plants [3]. Micronutrients are essential elements for life [4], as they play key roles in the release of carbon dioxide and in optimizing the function of vitamin A and the immune system [5]. The amount of trace elements found in soil is sometimes so small that they are barely detectable, but without them, plants fail to thrive [6]. Micronutrient deficiency can greatly affect plant yield and quality and the health of domestic animals and humans negatively [7]. Application of micronutrients through foliage can be from 10 to 20 times as efficient as soil application [8].

Boron (B) plays an important role in the physiological process of plants, such as cell elongation, cell maturation, meristematic tissue development, and protein synthesis [9]. The need for B application in groundnut is therefore, to increase the growth, development, and at the same time to increase the yield of crops. The application of B also promotes the absorption of N by groundnut and increases the plant height, plant dry weight, and the total number of pods [10].

Globally, zinc (Zn) is now recognized as the 5th major nutrient deficiency in human beings mainly due to its deficiency in the soil. Zn has specific and essential physiological functions in plant metabolism, influencing yield and quality [11].

In determining the yield and quality of groundnut, the role of Zn and B is much pronounced. Restricted availability of these nutrients in sandy soil greatly impairs the yield of groundnut [12].

Legumes are considered the most important source of food after cereals in the world, as they are main sources of protein and energy for humans. Due to its nutritional values and economic importance, it is necessary to develop new methods for increasing the crop production [13]. Nutrient deficiency in soil is one of the important factors for poor productivity of pulses, while nutrient management is one of the key agronomic factor affecting crop yields.

The continuous and imbalanced use of selected inorganic fertilizers (NPK) has resulted in deterioration of soil health, higher cost of production, and decline in factor productivity [14]. The objective of the study was to evaluate the response of *Arachis hypogaea* L. to micronutrient fertilizer application with a view to determining the requirements for nut quality and possible heavy metal accumulation on an alfisol of derived guinea savanna.

2. Materials and Methods

The experiment was carried out at the Teaching and Research farm, Landmark University, Omu-Aran, Kwara State (latitude 8.9°N and longitude 50°61°E.), located at the derived agro-ecological zone of Nigeria. It has an annual rainfall pattern which extends between the months of April and October with average annual rainfall of between 600 mm and 1500 mm. The peak rainfall is in May-June and September-October while the dry season is between November and March. Precropping soil samples (0–30 cm depth) were collected from each plot during the cropping seasons and bulk to determine the physicochemical properties of the soil.

The land was ploughed once and harrowed twice to give a well-pulverized soil after which it was ridged. Thereafter, the field layout was carried out to mark out the appropriate number of treatment plots. The size of each plot in the experiment was $4.2\,m \times 8\,m = 33.60\,m^2$ and there were 12 plots per replicate ($33.60\,m \times 12\,m = 403.20\,m^2$) which was replicated four times. The size of the whole experimental plot was $430.20\,m^2 \times 4\,m = 1{,}612.80\,m^2$. Phosphorus fertilizer (18% single superphosphate) was applied at planting at the rate of $54\,kg\ P_2O_5{\cdot}ha^{-1}$ to all the plots as basal dose.

Treatments consisted of zinc in the form of $ZnSO_4$ (zinc sulphate) and boron in the form of $C_2H_{10}BNO_4$ (boron ethanolamine) which were applied by side placement and foliar application, respectively. Three levels of zinc (0, 4, and $8\,kg{\cdot}ha^{-1}$) and four levels of boron (0, 300, 600, and $900\,ml{\cdot}ha^{-1}$) were combined and evaluated as follows: —B_0Z_0 (T_1), $B_{300}Z_0$ (T_2), $B_{600}Z_0$ (T_3), $B_{900}Z_0$ (T_4), B_0Z_4 (T_5), $B_{300}Z_4$ (T_6), $B_{600}Z_4$ (T_7), $B_{900}Z_4$ (T_8), B_0Z_8 (T_9), $B_{300}Z_8$ (T_{10}), $B_{600}Z_8$ (T_{11}), and $B_{900}Z_8$ (T_{12}). The experiment was laid out in randomized complete block design (RCBD) with split-plot arrangement replicated four times.

Four groundnut seeds commonly grown in the derived savanna of Nigeria were manually sown per hole at inter- and intrarow spacing of $0.70\,m \times 0.2\,m$ and at a depth of about 5 cm on a well-prepared ridge. Plants were thinned to two plants per stand two weeks after sowing. At two weeks after sowing, zinc fertilizer was manually applied by side placement 5–8 cm away from the base of the plant, while boron-based foliar fertilizer was applied at 2, 4, and 6 WAS based on the experimental layout.

Soon after sowing, metolachlor which is a pre-emergence herbicide suitable for groundnut was applied at the rate of $1.5\,kg\ a.i{\cdot}ha^{-1}$ using a knapsack sprayer, and thereafter, it was supplemented with manual weeding at four weeks after sowing.

The following parameters were collected during the experiments: plant height (cm), plant spread (cm), average number of pod and seed per plot, average weight of pod and seed, and average pod and seed yield per plot ($kg{\cdot}ha^{-1}$).

2.1. Laboratory Analysis of Mineral Elements of Groundnut Seeds. Representative seed samples were taken per plot and per replicate to analyze for the levels of mineral elements contained in the seed at the crop and soil laboratory of Landmark University, Omu-Aran, Nigeria. Mature fresh seeds of groundnut were collected, oven-dried for 24 h at 80°C, and ground in a Willey mill. Mineral elements were determined according to the methods recommended by the Association of Official Analytical Chemists [15]. One gram of each sample was digested using $12\,cm^{-3}$ of the mix of HNO_3, H_2SO_4, and $HClO_4$ (7 : 2 : 1 v/v/v). Contents of P, K, Ca, and Mg were determined by an atomic absorption spectrophotometer.

2.2. Dry Ashing Procedure and Heavy Metal Determination of Groundnut Seeds. Dry ashing of the seed samples collected was carried out by the procedure as described in [16]. One gram of the portion of each fruit sample was weighed into a 50 ml porcelain crucible and gently placed into the muffle furnace and the temperature was gradually increased to 550°C for about 5 hours during which the muffle furnace was shut, and after 5 hours, the furnace was gently opened to allow for rapid cooling before carefully taking out the porcelain crucibles.

The cooled ash was dissolved in a 5 ml portion of 2 N hydrochloric acid (HCl) and mixed thoroughly with a plastic rod for 15 minutes. Then, it was mixed with 50 ml of distilled water and allowed to stand for 30 minutes before using the supernatant (or filter through Whatman No. 42 filter paper); discarding the first portions of filtrates, the aliquots were used to analyze for the heavy metals (Zn, Cu, Cd, Fe, Cr, and Mn) using the atomic absorption spectrometry (AAS) as described in the methods of the Association of Official Analytical Chemists [15]. Heavy metals (Zn, Cu, Cd, Fe, Cr, and Mn) were calculated using the following equation:

$$\text{heavy metals (mg/kg)} = \frac{\text{titre value from machine} \times \text{volume used}}{\text{molar mass}}. \quad (1)$$

Data collected were subjected to Statistical Analysis of Variance using [17]. Significant treatment means were compared using the Duncan multiple range test at 0.05 level of probability.

3. Results

3.1. Soil Physical and Chemical Properties prior to Planting (0–15 cm). The preplanting soil analysis is as shown in Table 1. The pH of the soil was strongly acidic, the nitrogen content of the soil was very low, the available phosphorus was high, and the exchangeable K was at moderate, while the exchangeable Na, Ca, and Mg were all suitable. The organic carbon and organic matter are adequate. The soil is high in sand with relatively low values in both silt and clay; hence, the textural class is sandy loam.

3.2. Chemical Properties of Boron-Based Liquid Fertilizer. Chemical analysis of the boron-based liquid fertilizer as shown in Table 2 indicated that it contained mineral elements required for plant growth and some heavy metals as essential elements.

3.3. The Effect of Zinc and Boron Fertilizers on Plant Height and Spread of Groundnut. The effect of zinc and boron on plant height and spread of groundnut is shown in Table 3. At all sampling periods, increasing rates of Zn fertilizer from 0–8 kg Zn·ha^{-1} increased plant height of groundnut though the effect was not significant. At all weeks after sampling, varying rates from 0–600 ml B·ha^{-1} significantly increased plant height except at 8 weeks after sowing (WAS) where application of 300 ml B·ha^{-1} was significantly similar to the application of 600 ml B·ha^{-1} and 900 ml B·ha^{-1}. Relative to the control which gave the least value for plant spread, application of 600 ml B·ha^{-1} significantly increased plant spread, values of which were statistically similar with the application of 900 ml B·ha^{-1}. There was no significant interaction between the application of zinc and boron fertilizers on plant spread.

3.4. The Effect of Zinc and Boron Fertilizers on Number, Weight, and Yield of Groundnut Pod. Number of pods, weight of pods, and yield of pods ha^{1} as affected by application of zinc and boron fertilizers is shown in Table 4. Higher value for number of pods, weight of pods, and pod yield ha^{-1} was observed at the application of 8 kg Zn·ha^{-1} which was significantly different from the value obtained when 4 kg Zn·ha^{-1} was applied. The control Zn gave the least value for the parameters measured.

As the rates of boron fertilizer increases from 0–600 ml B·ha^{-1}, the value for the parameters also increases significantly. Further increase from 600 ml B·ha^{-1} to 900 ml B·ha^{-1} increases the values for the parameters though the difference was not significant. There was a significant interaction between Zn and B on number of pods, weight of pods, and pod yield ha^{-1}.

3.5. The Effect of Zinc and Boron Fertilizers on Number, Weight, and Yield of Groundnut Seed. Data shown in Table 4 indicated that application of 8 kg Zn·ha^{-1} significantly increased number of seeds, weight of seeds, and seed yield ha^{-1} though the values were statistically similar with the values obtained at the application of 4 kg Zn·ha^{-1}. The control gave a significantly lower value for all the parameters.

Increase in the application of boron fertilizer from the control to 600 ml B·ha^{-1} significantly increased number of seeds, weight of seeds, and seed yield ha^{-1}. Further increase in boron fertilizer application from 600 to 900 ml B·ha^{-1} increased values for the parameters though not statistically different with the application of 600 ml B·ha^{-1}. Interaction between Zn and B was significant on the parameters.

3.6. The Effect of Zinc and Boron Fertilizers on Nutrient Content of Groundnut Seed. The effects of Zn and B on the nutrient contents of groundnut seeds are shown in Table 5. When compared with the control which gave the least but statistically similar values for N, P, and K when 4 kg Zn·ha^{-1} was applied, application of 8 kg Zn·ha^{-1} significantly increased values for N, P, K. and Mg. Increasing application of Zn significantly reduced values for Ca though values obtained when 4 kg Zn·ha^{-1} and 8 kg Zn·ha^{-1} were applied were statistically similar. In a similar vein, application of 900 ml B·ha^{-1} significantly increased values for all the parameters tested though statistically similar with the application of 600 ml B·ha^{-1}.

3.7. The Effect of Zinc and Boron Fertilizers on Heavy Metal Contents of Groundnut Seed. The effects of Zn and B on some heavy metal (zinc, copper, cadmium, iron, chromium, and manganese) contents in groundnut seeds are shown in Table 6. Application of zinc fertilizer from 0 to 8 kg·ha^{-1} significantly increased the contents of zinc, copper, and manganese in groundnut seeds, while the contents of iron, cadmium, and chromium were reduced.

900 ml B·ha^{-1} had significantly higher values for all the heavy metal values of which was statistically similar with cadmium, iron, chromium, and manganese content in groundnut seeds when 600 ml B·ha^{-1} was applied There was a significant interaction between the two fertilizers.

Table 1: Soil physical and chemical properties prior to planting (0–15 cm).

Parameter	Values	
	2016	2017
Sand (%)	76.12	75.00
Silt (%)	12.00	12.85
Clay (%)	11.88	12.15
Textural class	Sandy loam	Sandy loam
pH (H_2O) 1 : 1	5.25	6.39
Total N	0.16	0.13
O.M	1.88	1.58
O.C	3.24	3.05
Exchangeable bases		
K (cmol/kg)	0.23	0.33
Na (cmol/kg)	0.66	0.43
Ca (cmol/kg)	3.97	3.70
Mg (cmol/kg)	1.32	1.41
ECEC (cmol/kg)	6.18	5.87
Available phosphorus (mg/kg)	21.12	20.55
Zn (mg/kg)	0.45	0.45

4. Discussion

The productivity of groundnut depends on proper selection of variety, fertilizer management, and other management practices [18]. Zn and B are recognized as key elements in promoting growth, yield, and quality of groundnut. Boron (B) plays an important role in the physiological process of plants, such as cell elongation, cell maturation, meristematic tissue development, and protein synthesis [9].

Foliar application of micronutrients to plants is the most effective and safest way [19]. The need for B application in groundnut is to increase the growth, development, and at the same time to increase the yield of crops. The application of B also promotes the absorption of N by groundnut and increases the plant height, plant dry weight, and the total number of pods [10]. Application of boron-based fertilizer significantly increased the vegetative parameters of groundnut. Increased in vegetative parameters might be due the presence of nitrogen in boron ethanolamine ($C_2H_{10}BNO_4$) fertilizer and the effect of B in promoting the absorption of nitrogen in the soil which assisted in improved growth. Boron's application promoted the absorption of N by groundnut and thus, helped in increasing plant growth and development [10].

B plays an important role in retaining flowering and fruit setting in pulses [20]. The results also showed that yield and all the yield parameters measured during this study increased with increasing levels of B-based fertilizer. Increase in yield could be as a result of filled pods with the application of B fertilizer compared with the least number of unfilled pods when boron fertilizer was not applied. Chitdeshwari and Poongothai [21] observed that the positive role of B in quality improvement through its involvement in the synthesis of protein and amino acids further increased the pod yield of groundnut.

Zn fertilization of crops has received further attention due to widespread Zn malnutrition, especially in developing countries [22]. Zn is essential for normal plant growth and development as carbohydrates, protein metabolism, and sexual fertilization depend on Zn [23]. However, the Zn deficiency in agricultural soil caused by removal of Zn by crops is not fully replenished by fertilizer applications [24]. Zn deficiency is a common feature in many climatic regions, particularly in sandy soil, and it causes severe decreases in yield and quality of groundnut.

Zn functions in plants are largely associated with activity [25]. The result of this study revealed that increasing levels of Zn fertilizer from the control to 8 kg Zn·ha^{-1} did not significantly increase the vegetative parameters of groundnut. This could be due to the fact that the soil is highly deficient in available Zn and the limit of the applied Zn has not been met by the test crop in the study area.

Zn plays as an activator of several enzymes in plants, and it is directly involved in the biosynthesis of growth substances such as auxin which produces more plant cells and more dry matter that in turn will be stored in seeds as a sink. Thus, the increase in seed yield is more expected [25]. Yield and yield parameters increased significantly with increasing application of zinc fertilizer up to 8 kg $ZnSO_4$·ha^{-1}. This might be due to the significant improvement in plant height and spread, leading to improved nodulation through activation of various enzymes and the basic metabolic rate in plants, which in turn enhanced the pod yield due to greater availability of nutrients and photosynthates. It could also be as a result of increased photosynthesis by facilitating nitrogen in leguminous plants. Ved et al.[26] stated that foliar-applied Zn enhances photosynthesis at early growth of plants and improves nitrogen fixation, grain protein, and yields of mungbean plants.

The study also showed that sole and combined application of Zn and B fertilizer increased the nitrogen and phosphorus content of the seeds. These results may be due to the beneficial effect of B and Zn on metabolic processes and growth which in turn reflected positively on the chemical content of groundnut seeds. Darwish et al.[27] found that application of 48 kg K_2O/fad combined with spraying zinc (1000 ppm zinc sulphate) gave the highest seed and oil yields per fad and protein.

Major elements in the human body include oxygen, carbon, hydrogen, nitrogen, carbon, phosphorus, potassium, calcium, and magnesium. Helmenstine [28] identified the following about the elements in the human body: N is a component of proteins, nucleic acids, and other organic compounds; Ca is also found in the nervous system, muscles, and the blood where it is integral in proper membrane function, conducting nerve impulses, regulating muscle contractions, and blood clotting; and phosphorus is part of nucleic acids, energy compounds, and phosphate buffers. The element is incorporated into the bones and combines with other elements including iron, potassium, sodium, magnesium, and calcium. It is necessary for sexual function and reproduction, muscle growth, and to supply nutrients to the nerves; that P is important for membrane function, nerve impulses, and muscle contractions; that K is important for membrane function, nerve impulses, and muscle contractions; and that Mg is needed for strong teeth and bones.

The results of the study indicated that application of Zn and B fertilizers increased values for all the elements (N, P,

Table 2: Chemical properties of boron-based liquid fertilizer.

	% w/v					mg/L					mg/L		
Nutrients	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B	Cd	Pb	Cr
Concentration	3.01	0.15	0.04	0.08	0.10	0.005	28.0	1.40	17.0	12.60	2.40	5.80	0.10

Table 3: Effect of application of zinc and boron fertilizers on vegetative parameters of groundnut (pooled data of 2016 and 2017 cropping seasons).

Treatments	Plant height			Plant spread		
	4 WAS	6 WAS	8 WAS	4 WAS	6 WAS	8 WAS
$ZnSO_4$ kg·ha^{-1}						
0	21.97a	25.84a	26.57a	36.38a	39.72a	43.14a
4	22.86a	26.24a	28.46a	36.83a	41.08a	45.14a
8	22.91a	26.60a	28.89a	36.85a	41.25a	45.22a
Boron (ml·ha^{-1})						
0	18.58c	22.40c	23.78b	28.93c	32.18c	35.71c
300	22.38b	25.50b	26.85ab	35.85b	41.85b	44.26b
600	25.09a	28.72a	30.70a	41.69a	45.22a	50.85a
900	24.26a	26.26a	30.55a	40.26ab	43.48ab	47.51ab
Interaction						
Zn	ns	ns	ns	ns	ns	ns
B	*	*	*	*	*	*
Zn*B	ns	ns	ns	ns	ns	ns

Means in a column under any given treatment followed by the same letters do not differ significantly at 0.05 level of probability using the Duncan multiple range test (DMRT). ns = not significant. *Significant at 0.05 level of probability. WAS = weeks after sowing.

Table 4: Effects of zinc and boron fertilizers on pod and seed yield of groundnut (pooled data of 2016 and 2017 cropping seasons).

Treatments	Number of pods/ plant	Pod weight/plant (g)	Pod yield (kg/ ha)	Number of seeds/ plot	Seed weight/plot (g)	Seed yield (kg ha^{-1})
$ZnSO_4$ kg·ha^{-1}						
0	26.10c	37.73c	3018.4c	40.18b	28.47b	2357.6b
4	27.87b	42.31b	3384.8b	43.35a	31.10a	2508.2b
8	29.40a	44.91a	3592.8a	45.46a	33.16a	2672.8a
Boron (ml·ha^{-1})						
0	22.39c	36.24c	2899.2c	35.11c	26.46c	2116.8c
300	26.63b	40.02b	3201.6b	40.99b	28.44b	2275.2b
600	30.09a	44.22a	3537.6a	47.40a	33.12a	2669.6a
900	32.05a	46.11a	3688.0a	48.16a	35.29a	2823.7a
Interaction						
Zn	*	*	*	*	*	*
B	*	*	*	*	*	*
Zn*B	*	*	*	*	*	*

Means in a column under any given treatment followed by the same letters do not differ significantly at 0.05 level of probability using the Duncan multiple range test (DMRT). *Significant at 0.05 level of probability.

K, and Mg) except Ca where the value reduced with the application of Zn. Increase in N, P, K, and Mg could be as a result of the stimulating effect of Zn X N on wheat [29], Zn X P on St. Augustine grass [30], Zn X K on wheat [31], and Zn X Mg on tung trees [32]. The reduction in Ca content of groundnut seeds could be attributed to the antagonistic effect of the two elements which makes Ca not to be available to plants. Kalyanasundaram and Mehta [33] reported reduced availability of Ca under high Zn applications. Schroeder and Balassa [34] were the first to identify that fertilizers were implicated in raising some heavy metal concentrations in food crops, and since then researchers have been urged to investigate the impact of impurities in fertilizers on crop uptake of potentially toxic elements. Studies of heavy metal uptake by plants have often revealed their accumulation at a level toxic to human health.

The result indicated that progressive increase in the values of heavy metals as a result of increase in the application of B fertilizer could be as a result of the presence of those heavy metals in the applied boron fertilizer or as a result of application of basal phosphorus fertilizer. Several studies have shown that the main source of fertilizer-derived heavy metals in soils is phosphatic fertilizers, manufactured from phosphate rocks that contain various metals as minor constituents in the ores [35]. Ebong et al. [36] found that these heavy metals in phosphatic fertilizers can subsequently accumulate in soil and become readily available to plants.

Table 5: Effects of Zn and B fertilizers on the nutrient content ($mg \cdot kg^{-1}$) of groundnut seeds (pooled data of 2016 and 2017 cropping seasons).

Treatments	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
$ZnSO_4$ $kg \cdot ha^{-1}$					
0	0.37b	0.82b	0.75b	2.56a	4.86c
4	0.38b	0.84b	0.77b	2.50b	5.59b
8	0.40a	0.90a	0.83a	2.49b	5.86a
Boron ($ml \cdot ha^{-1}$)					
0	0.30c	0.73c	0.71c	2.64b	3.86c
300	0.35b	0.87b	0.76b	2.70a	4.63b
600	0.39a	1.03a	0.81a	2.71a	5.06a
900	0.40a	0.98a	0.84a	2.71a	5.04a
Interaction					
Zn	*	*	*	*	*
B	*	*	*	*	*
Zn*B	*	*	*	*	*

Means in a column under any given treatment followed by the same letters do not differ significantly at 0.05 level of probability using the Duncan multiple range test (DMRT). *Significant at 0.05 level of probability.

Table 6: Effect of zinc and boron fertilizers on some heavy metal concentrations ($mg \cdot kg^{-1}$) in groundnut seeds (Pooled data of 2016 and 2017 cropping seasons).

Treatment	Zinc	Copper	Cadmium	Iron	Chromium	Manganese
$ZnSO_4$ $kg \cdot ha^{-1}$						
0	0.0227c	0.0355c	0.1763a	0.2340a	0.0225a	0.1110c
4	0.0440b	0.0370b	0.1755b	0.2330b	0.0210b	0.1120b
8	0.0450a	0.0385a	0.1750b	0.2325b	0.0205b	0.1128a
Boron ($ml \cdot ha^{-1}$)						
0	0.0430c	0.0307c	0.1637c	0.2283b	0.0210b	0.0927c
300	0.0480b	0.0307c	0.1827b	0.2493b	0.0223b	0.1177b
600	0.0485b	0.0470b	0.2000a	0.2983a	0.0347a	0.1340a
900	0.0572a	0.0563a	0.2012a	0.2997a	0.0350a	0.1415a
Interaction						
Zn	*	*	*	*	*	*
B	*	*	*	*	*	*
Zn*B	*	*	*	*	*	*
*FAO/WHO	99.4	10	0.2	0.3	1.30	0.5

Means in a column under any given treatment followed by the same letters do not differ significantly at 0.05 level of probability using the Duncan multiple range test (DMRT). *Significant at 0.05 level of probability. *FAO/WHO (2010) recommended limit.

It was observed from this research work that application of Zn and B fertilizers at all rates did not increase the concentration of all the heavy metals in groundnut seeds above the safe limit as recommended by the Joint FAO/WHO Expert Committee on food additives to ensure the safety of the consumers [37].

5. Conclusion

The effect of zinc was not significant on the vegetative parameters, but application of 8 kg $Zn \cdot ha^{-1}$ significantly increased number of seeds, weight of seeds, seed yield per hectare, and seed quality. Application of 600 and 900 ml $B \cdot ha^{-1}$ gave higher but statistically similar values for vegetative parameters, yield, and yield parameters, while 600 ml $B \cdot ha^{-1}$ significantly improved the seed quality. Results also indicated that application of Zn and B did not increase the concentration of heavy metals in groundnut seeds beyond the safe limit as recommended by the Joint FAO/WHO Expert Committee on food additives to ensure the safety of the consumers.

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Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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