ACTA BOTANICA PLANTAE

www.actabotanica.org

Original Research Article
ISSN: 2583-7400

Growth and Yield Responses of Iron (Fe) and Boron on Groundnut in Ghana

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Citation: Charles Afriyie-Debrah, James Yaw Asibuo, Kwabena AsareBediako, Franklin Bosompem, Maxwell Lamptey and Afua Gyaama Gyimah (2026). Growth and Yield Responses of Iron (Fe) and Boron on Groundnut in Ghana. *Acta Botanica Plantae.* **https://doi.org/10.51470/ABP.2026.05.01.44**

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Received 10 December 2025 | Revised 08 January 2026 | Accepted 05 February 2026 | Available Online 02 March 2026

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ABSTRACT

Groundnut is a vital food and cash crop in Ghana, contributing to protein supply and livestock fodder. However, yields lag behind potential due to soil fertility limitations. Iron (Fe) and boron (B) are essential micronutrients involved in chlorophyll formation, reproductive development, and seed set in legumes, and their foliar application can influence growth and yield. This study aimed to evaluate the interactive effects of foliar Fe and B on growth performance, yield, and nutrient uptake of two groundnut genotypes grown at two Ghanaian locations, with the goal of identifying nutrient management strategies to enhance productivity under local agro-ecologies.The experiment followed a factorial arrangement (Fe × B × genotype × location) in a completely randomized design with three replications. Treatments comprised Fe at 0, 0.6, and 0.9% and B at 0, 0.3, and 0.45%, applied as foliar sprays. The two groundnut genotypes tested were Yenyawoso and Dehye, and trials were conducted at Fumesua and Akomadan research stations. Growth and yield parameters measured included plant height, number of leaves, number of branches, pods per plant, chlorophyll content (SPAD), leaf area index, biomass yield, and grain yield. Nutrient uptake was assessed to gauge micronutrient status in tissues. Data were analyzed for main effects and interactions (genotype × location × Fe × B) at $P \leq 0.05$. The results showed significant effects of genotype, location, and their interaction on plant height, number of leaves, pods per plant, and grain yield, indicating that genotypic and environmental contexts modulate response to micronutrient sprays. Across genotypes and locations, the highest yields and favorable growth were generally associated with the Fe0.9% × B0.45% combination, though performance was trait- and site-dependent. Chlorophyll content, leaf area index, and total biomass were significantly influenced by Fe and B treatments. Overall, Yenyawoso tended to outperform Dehye for several traits under the combined micronutrient regimes, but the magnitude of response varied by location. Drought stress encountered during the trial period likely constrained maximal responses and may have amplified genotype- and site-specific differences. Microscale foliar applications of Fe and B can enhance growth and yield attributes of groundnut in Ghanaian agro-ecologies, with genotype and location shaping the magnitude of response. The findings support the potential of integrating Fe and B foliar nutrition into Ghana's groundnut production systems, but further multi-location trials under different moisture regimes are recommended to confirm stability and to optimize dosage and timing.

Keywords: *groundnut, Arachishypogaea, foliar micronutrients, iron, boron, grain yield, chlorophyll, genotype × environment, Ghana, drought stress.*

Introduction

Groundnut (Arachishypogaea L.) is one of the most important legume crops grown by farmers in Ghana. Groundnut kernels contain about 50% edible oil, 25–28% protein, and around 20% carbohydrate [1] and [2], and it is considered important for its nutritional, economic, and ecological value. In Ghana, groundnuts produce food for direct consumption in diverse ways like weaning foods, soups, stew, roasted food, and highly nutritious and quality oil for cooking. The haulms of groundnut have been used as livestock feeds, especially during the dry season [3] and [4]. The estimated per capita annual consumption of groundnuts in Ghana is 12 kg and is increasing with growing incomes and urbanization [5].

Production of groundnut in Ghana, especially the northern region, is dominated by smallholder farmers under rainfed production conditions [6].

Though groundnut ranks among the most important field legumes grown by smallholder farmers in northern Ghana, production levels are low compared to its potential due to various production constraints such as poor soils, low use of improved seed, and poor crop management practices [7] and [8]. Micronutrient deficiency is one of the major constraints facing crop productivity. Organic amendments alone cannot sufficiently meet the nutrient demand of crops [9]. Balanced fertilizer approach needs to be considered in the management of crops.

Iron (Fe) plays a crucial role in chlorophyll synthesis and function, and it is required for respiration and as a cofactor in many different enzymes involved in oxidation–reduction reactions within plant cells [10]. Availability of Fe therefore has a direct effect on photosynthetic capacity and hence biomass production [11].

Fe deficiency symptoms include chlorosis, poor vegetative growth, and yield. Boron (B) is required for pollen formation, pollen germination, tube growth, fertilization, pod development and growth, and seed filling processes [12] and [13]. Boron is essential for reproductive growth and development. Application of B increases flowering, pod set and fruit set, and seed quality in legumes [14] and [15]. Recently, evidence suggested that foliar application of micronutrients showed better uptake and improvement in growth and yield of crops than soil application under deficient soils [16] and [17]. Many studies have been carried out on nutrient management of groundnut but still lack information on micronutrient management under contrasting agro-ecologies.

Therefore, this study was conducted to assess the effect of foliar-applied Fe and B on growth, yield, and nutrient uptake of two varieties of groundnut under two contrasting agro-ecologies in Ghana.

Materials and Methods

Study Sites

The experiments were conducted at Fumesua (Lat. 7.54°N Long. –1.95°W) and Akomadan research fields (Lat. 7.3912° N, Long. 1.9545° W) of CSIR-Crops Research Institute (CSIR-CRI), Ghana during the growing seasons. Fumesua is situated in the Forest agro-ecological zone while Akomadan is located in the Transitional agro-ecological zone. These sites were chosen because of their contrasting soil types and climate where groundnut is produced.

Experimental Materials

Improved varieties of groundnut (Arachishypogaea L.), namely, Dehye and Yenyawoso were used in the study. They are the predominant varieties grown by farmers in Ghana due to their superior yield potential and wide adaptability. The seeds were sourced from the seed unit of CSIR-CRI.

Experimental Design and Treatments

The experiment followed a 2 × 3 × 3 factorial arrangement of treatments in a Randomized Complete Block Design (RCBD) with three replications. The treatment factors included:

Concentration of Iron (Fe): 0%, 0.6% and 0.9% foliar spray

Concentration of Boron (B): 0%, 0.3% and 0.45% foliar spray

Varieties: Dehye (D) and Yenyawoso (Y)

Plot size was spaced [insert here if given]. Seeds were sown using a spacing of 10 cm × 30 cm between plants and rows, respectively. Agronomic practices such as weeding and pest control were applied to all the plots as needed. Foliar application of Fe and B were sprayed at the early vegetative stage and flowering stage using a knapsack sprayer. The sprayer was calibrated to produce uniform sprays. Growth, reproduction, and yield parameters were measured and recorded as described below:

Data Collection

Growth parameters: plant height (cm), number of leaves per plant, number of branches per plant, leaf area (cm^2), chlorophyll content index (CCI).

Reproductive traits: Days to 50% flowering, days to physiological maturity, number of pods per plant, and pod length (cm).

Yield traits: Plant biomass (g/plant) and grain yield (kg/ha).

Data Analysis

Analysis of variance (ANOVA) was performed on the data using STAR version 6 (IRRI, 2014) [18] statistical software package. Means were separated using the Least Significant Difference (LSD) test at $p \leq 0.05$ whenever there were significant treatment effects.

Plate 1: Land Preparation

Plate 2: Planted Land

Plate 3: Application of micro nutrients

Plate 4: Chlorophyll data collection

Plate 4: Other agronomic data collection

Plate 4: vegetative stage before harvest

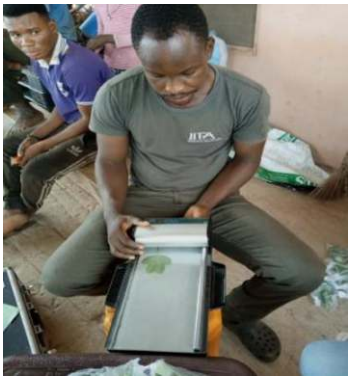

Plate 4: Leaf area data collection

Results and Discussion

Plant Growth

Plant Height

Statistically, no significant difference was observed among varieties for plant height at Akomadan site but varied significantly at Fumesua site (Table 2). Mean plant height at Fumesua was higher (31.06 cm) than Akomadan (30.96 cm).

Plant height ranged from 24.3–36.5 cm at experimental sites (Table 1). The difference could be due to variation in soil fertility levels and micro-climatic conditions prevailing in the sites. Earlier research has established groundnut height to be influenced by nutrients availability and environmental conditions of a particular location, especially rainfall and temperature regime [19] and [20]Obisesan et al., 2019.

Number of Leaves

Varieties differed significantly at Akomadan site for leaf number but not at Fumesua site (Table 2). Mean leaf number was higher at Fumesua (50.23) compared to Akomadan (44.69). Provision of nutrients and favourable soil conditions hastens leaf production by plants and micronutrients like Fe are known to be required in chlorophyll production and vegetative growth and development in plants (table 1) [10] and [11]. Reported earlier also observed higher leaf numbers in legumes supplemented with Fe.

Number of Branches

Varietal differences for branching was significant at Fumesua site but not at Akomadan site. Number of branches ranged from 5–9 at both sites and mean branch number was higher at Fumesua (6.36) than Akomadan (5.54) (Table 1 and Table 2 respectively). Branching determine number of pod-bearing sites on the groundnut plant. Earlier studies have reported groundnut plants supplied with adequate B nutrition showed increased branching habits leading to reproductive growth.

Phenology

Days to 50% Flowering

Varietal differences for days to 50% flowering were significant at both sites (Table 2). Mean days to 50% flowering at Akomadan (57 days) was earlier than Fumesua (60 days) (Table 1). The differences recorded in days to 50% flowering can be explained by environmental factors such temperature and fertility status of the sites. Earlier flowering was recorded at Akomadan which could be attributed to higher day temperatures that advance phenological development at that site. Previous study also reported this phenomenon.

Days to Maturity

Varieties differed significantly at both sites for days to maturity. Mean maturity duration was longer at Fumesua site (98 days) than Akomadan (97 days). Variation in maturity duration ranged from 85–110 days across treatment combinations (Table 1 and Table 2 respectively). Reports have indicated that the maturity duration of groundnut is influenced by agro-ecological conditions where the experiment is being conducted as well as varietal differences.

Yield Components

Number of Pods per Plant

Significant differences were not observed among varieties at both sites for number of pods per plant (Table 2). Mean pod number per plant was higher at Fumesua (71) than Akomadan (38). Wide variation observed in pod number across sites was due to range of 12–111 pods per plant. Similar differences were reported by previous research where application of B had a positive effect on pod formation and retention in legumes [13] and [21].

Pod Length

Varietal differences for pod length were significant at both sites. Mean pod length recorded was higher at Akomadan (21.83 cm) than Fumesua (20.18 cm) (Table 1 and Table 2 respectively). Pod length determine yield class of groundnut and its variation may be a result of genotypic difference as well site variation. Similar studies reported site dependent effect on pod length.

Total Plant Yield

Statistically no significant difference was observed among varieties for total plant yield at both sites. Mean yield was higher at Fumesua site (0.45 t/ha) than Akomadan (0.39 t/ha). Variation in total plant yield ranged from 0.022–1.03 t/ha across sites. This follows what was reported earlier that groundnut yield is sensitive to climatic variables such as rainfall distribution as well as soil fertility conditions of the field [22] and [23].

Physiological Traits

Leaf Area

Varietal differences were significant for leaf area at Akomadan site but not at Fumesua site (Table 1). Mean leaf area value recorded was almost the same at both sites (Akomadan = 193.14 cm^2; Fumesua = 192.88 cm^2) (Table 2). Leaf area has been reported to be related to photosynthetic rate of the leaf and responds to Fe application due to involvement of micronutrient in chlorophyll biosynthesis [10].

Chlorophyll Content Index (CCI)

Varietal differences for chlorophyll content index (CCI) were significant at both sites (Table 2). Mean CCI recorded was higher at Akomadan (31.33) than Fumesua site (29.97) (Table 1). Findings agrees with what reported earlier that Fe application improved chlorophyll synthesis resulting in higher CCI value.

Total Plant Biomass

Total plant biomass showed no significant difference among varieties at both sites (Table 2). Mean biomass recorded was higher at Fumesua site (129.21 g) than Akomadan (94.14 g) (Table 1). Biomass accumulation was dependent on crop vigour and could be influenced by both genotypic difference and environment. Earlier reported that foliar application of Fe and B increased dry matter accumulation in bean and cowpea due to increase efficiency in nutrients uptake.

Discussion

Results from this study revealed that varieties responded differently to Fe and B applied to soil. Location also had profound effect on growth, physiological and yield parameters assessed in the study. Generally speaking, higher plant height, leaf number, chlorophyll content index (CCI) and total plant yield were recorded at Fumesua site while higher pod length was recorded at Akomadan site. Site differences observed in growth, physiological and yield parameters could be credited to differences in soil fertility levels available to plants. Above observations agree with reports that micronutrients are essential for good crop growth, reproduction and yield production in legumes [24], [21] and [23].

Table 4. Descriptive means of growth parameters at two research sites

Trtments		AkPlt Ht	Fu PltHt	AkNoL	Fu NoL	AkNoB	Fu NoB	Ak 50%DoF	Fu 50%DoF	Ak Mat.	Fu Mat	AkNoPP	Fu NoPP	Ak Pod Le	Fu Pod Le	AkTPY	Fu TPY	Ak LA	Fu LA	Ak CCI	Fu CCI	Ak TPB	Fu TPB
F1B1V1	F0B0VY	31.63	30.47 abc	40 a	47	5	6 ab	60 ab	56 ab	89 d	89 d	38	77	24.13 a	21.8 a	399.47	288.03	204.87 a	199.9	30.97 ab	30.03 a	75.17	123.7
F1B1V2	F0B0VD	34.53	33.00 abc	48 a	49	5	6 b	59 ab	58 ab	109 a	108 ab	56	62	20.03 a	18.07 a	429.67	315.13	190.37 abc	195	27.87 b	31.5 a	94.73	127
F1B2V1	F0B15VY	29.4	31.83 abc	42 a	53	6	7 ab	59 ab	56 ab	88 def	89 d	42	92	24.3 a	18.3 a	514.57	735.43	196.33 abc	195.9	31.83 ab	28.5 a	88.17	119.37
F1B2V2	F0B15VD	31.37	32.70 abc	47 a	49	6	6 b	61 a	58 ab	109 a	108 ab	38	74	20.23 a	20.93 a	258.33	434.9	195.33 abc	191.6	34.1 ab	25.2 a	118.07	141.4
F1B3V1	F0B22.5VY	30.2	31.17 abc	41 a	45	5	6 b	59 ab	58 ab	89 de	88.33 d	20	69	23.6 a	24.2 a	180.73	476.07	189.07 abc	190.93	36.2 ab	35.43 a	69.33	105.1
F1B3V2	F0B22.5VD	32.57	33.57 ab	50 a	54	5	6 ab	60 ab	59 a	109 ab	108 ab	33	55	20.07 a	18.63 a	345.3	333.83	187.97 bc	195.3	30.7 ab	29.73 a	112.27	180.67
F2B1V1	F60B0VY	30.43	27.57 bc	43 a	57	5	8a	58 b	56 ab	88 def	88.67 d	44	80	23.63 a	22.77 a	406.27	562.5	186.33 bc	183.67	28.67 ab	29.1 a	74.07	152.93
F2B1V2	F60B0VD	32.43	31.33 abc	49 a	49	6	6 ab	61 ab	58 ab	109 a	109 a	44	79	19.1 a	18.5 a	380.2	344.8	190.27 abc	191.93	29.83 ab	27.23 a	95.33	185.63
F2B2V1	F60B15VY	27.63	28.47 abc	41 a	44	5	6 ab	59 ab	56 ab	89 de	89 d	32	76	22.73 a	24.07 a	286.97	401.03	183.7 c	186.27	37.27 a	34.4 a	68.33	111.57
F2B2V2	F60B15VD	33.83	32.60 abc	43 a	52	6	7 ab	61 ab	57 ab	109 de	109 a	46	56	21.43 a	17.83 a	410.93	496.9	190.9 abc	196.1	32.17 ab	30.37 a	90.27	133.93
F2B3V1	F60B22.5VY	31	31.07 abc	41 a	46	5	6 ab	59 ab	56 ab	88 def	88 d	45	85	23.3 a	21 a	455.73	820.83	192.57 abc	197.83	29.17 ab	34.77 a	76.87	106.93
F2B3V2	F60B22.5VD	32.4	29.10 abc	44 a	46	5	6 ab	61 ab	59 a	107 abc	108 ab	35	72	19.63 a	18.5 a	353.13	333.87	189.13 abc	189.2	28.37 b	27.73 a	120.03	144.87
F3B1V1	F90B0VY	28.07	29.3 abc	46 a	46	7	6 ab	59 ab	56 ab	87 def	87 de	39	73	23.4 a	21.07 a	574.5	516.13	192.07 abc	184.23	30.6 ab	28.77 a	77.53	139.87
F3B1V2	F90B0VD	32.2	32.63 abc	46 a	48	6	7 ab	61 ab	58 ab	106 bc	107 abc	41	48	20.77 a	18.3 a	572.9	291.7	198.47 abc	193	36.23 ab	25.9 a	110.93	98.37
F3B2V1	F90B15VY	29.77	27.03 c	48 a	54	5	7 ab	58 ab	55 b	86 ef	87 bc	37	72	21.67 a	20.77 a	484.4	503.67	199.87 abc	193.1	30.37 ab	36.2 a	82.37	122.83
F3B2V2	F90B15VD	30.6	31.67 abc	51 a	55	5	6 ab	61 ab	58 ab	105 c	106 bc	30	85	20.77 a	17.73 a	250.53	332.27	192.8 abc	193	31.37 ab	24.53 a	138.47	93.93
F3B3V1	F90B22.5VY	29.47	31.1 abc	39 a	54	6	7 ab	61 ab	56 ab	85 f	85 e	28	74	24.13 a	21.13 a	584.4	417.73	195.07 abc	197.63	30.77 ab	34.57 a	70.8	106.7
F3B3V2	F90B22.5VD	29.83	34.47 a	45 a	55	5	6 ab	60 ab	57 ab	104 c	105 c	31	47	20.03 a	19.67 a	159.93	407.83	201.4 ab	197.27	27.4 b	25.47 a	131.77	131.07
Min		24.3	24.8	34	40	5	5	56	55	85	85	12	17	14.8	15.4	31.3	21.9	182.3	176.8	25.1	21.3	53.2	22.5
Max		35.6	36.5	54	66.3	8	8.7	63	59	110	110	68	111	27.2	27.3	889.1	1025	212.5	209	44.6	43.8	184	265.9
Mean		30.96	31.06	44.69	50.23	5.54	6.36	59.89	57.04	97.46	97.83	37.7	70.93	21.83	20.18	391.55	445.15	193.14	192.88	31.33	29.97	94.14	129.21
StdDev		2.8	2.87	4.91	5.94	0.6926	0.7253	1.81	1.36	10.07	10.1	13.75	19.87	2.5	2.8	225.02	218.06	7.07	7.1	3.79	5.43	33.31	41.27
CV (%)		8.56	6.6	9.05	10.91	11.76	10.03	1.77	1.76	1.01	0.8687	32.41	23.75	9.7	11.69	56.71	44.19	2.76	3.25	9.2	15.63	32.08	27.55

Means with the same letter are not significantly different
VY-Variety Yenyawoso, VD-Variety Dehye, Ak-Akomadan, Fu-Fumesua, Plt_Ht-Plant height, NoL-Number of leaves, NoB-Number of branches, 50% DoF-50% days of flowering, Mat-Maturity period, NoPP-Number of pod per plant, Pod Le- Pod length, TPY-Total plant yield, LA-leaf area, CCI-Chlorophyll content index, TPB-Total plant biomass

Table 5. ANOVA for separation of means at two research sites

Response		AkPlt Ht	Fu PltHt	AkNoL	Fu NoL	AknoB	Fu NoB	Ak 50%DoF	Fu 50%DoF	Ak Mat.	Fu Mat	AkNoPP	Fu NoPP	Ak Pod Le	Fu Pod Le	AkTPY	Fu TPY	Ak LA	Fu LA	Ak CCl	Fu CCl	Ak TPB	Fu TPB
Source	DF	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
Rep	2	4.28	75.88**	17.82	3.23	0.26	0.12	80.33**	1.15	4.48	1.44	1621.15**	3131.70**	11.96	0.38	155526.23	100278.66	139.46	226.55	92.84	92.84	2038.5	13591.73**
Treatments	17	173.36	218.03**	701.65	845.24	10.76	13.91*	54.67**	62.59**	5334.09**	538 3.5	3320.59	8155.04	166.13*	225.57*	851804.83	110457 2.17	1546.50**	1106.47	722.98**	722.98**	25765.26	33573.92
Error	34	238.9	142.8	556.19	1022.11	14.41	13.86	38.33	34.19	32.85	24.56	5077.52	9644.96	152.51	189.15	167617 6.59	131538 7.57	962.81	1336.9	745.74	745.74	31017.45	43091.51
Total	53	416.54	436.71	1275.65	1870.58	25.43	27.88	173.33	97.93	5371.43	540 9.5	10019.26	20931.7	330.6	415.1	268350 7.65	252023 8.4	2648.77	2669.92	1561.56	1561.56	58821.21	90257.17

*(**p < 0.01 signifiance at 1%, *p < 0.05 signifiance at 5%)*
Means with the same letter are not significantly different
Ak-Akomadan, Fu-Fumesua, Plt_Ht-Plant height, NoL-Number of leaves, NoB-Number of branches, 50% DoF-50% days of flowering, Mat-Maturity period, NoPP-Number of pod per plant, Pod Le- Pod length, TPY-Total plant yield, LA-leaf area, CCl-Chlorophyll content index, TPB-Total plant biomass

Conclusion

The groundnut varieties responded differently to Fe and B application treatments in both locations. Yenyawoso gave the best response in Fumesua to treatment T9 (0.6% Fe + 0.45%B). While at Akomadan location, it gave the best response to treatment T10 (0.9% Fe + 0.45%B). The variety Dehye responded best to treatment T8 (0.6% Fe + 0.3%B) and treatment T7 (0.9% Fe without B) at Fumesua location. Fe and B applications increased leaf area index, chlorophyll content and biomass production. These attributes are important factors that influence crop productivity positively. Therefore, adequate application of Fe and B is very essential to achieve optimum groundnut production. But because there was severe drought towards the middle of the trial period, the treatments could not express themselves. I therefore recommend that the trial be conducted in a season where there will be no drought or less occurrence of drought in the study area.

Recommendation

1. Conduct the trial in seasons where there will be no drought or least occurrence of drought in the study area to validate the study.
2. Promote site-specific fertilizer management since varieties performed differently in location.
3. Add iron and boron to fertilizer packages where they are known to be deficient.
4. Educate small holder farmers on the importance of micronutrients such as Fe and B and how to correctly apply them as foliar sprays.
5. Conduct long term trial on how Fe and B interact with other macro and micro nutrients, level of soil fertility and water management.

Acknowledgements

Authors would like to acknowledge their thanks for the support and guidance from the staff members of Legume and Oil Section of the CSIR-Crops Research Institute for the successful completion of writing the manuscript. I would like to express my heartfelt gratitude to Dr James Yaw Asibuo for their unwavering support, encouragement, and guidance throughout this work.

Authors' contributions

Writing of original draft and conceptualization were done by CAD. JYA, KAB, FB, ML and AGG done the revision of draft, proof reading, formatting and supervision.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing; None

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