EFFECT OF BORON AND IRON APPLICATION ON THE YIELD AND YIELD PROPERTIES OF COWPEA (*Vigna unguiculata* L.) PLANTED AT DIFFERENT SOWING TIMES

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Abstract. Cowpea (*Vigna unguiculata* L.) is an important grain legume which is grown for food and feed. It has been employed as both a nutritious animal feed and a human nutritional component. Unavailability of essential micronutrients is a major constraint for cowpea growth, nodulation, and pod yield. In this context a two-year experiment was conducted to assess the effects of iron (Fe) (control-1-2-4 kg da^{-1}) and boron (B) (control-150-300-600 g da^{-1}) on the yield and yield properties of the cowpea (*Vigna unguiculata* L.) planted at different sowing times (15 May-30 May) in Ordu, Turkey region. The experiment design was split-split plot in randomized complete block design with 3 replications. The result revealed that combined use of seed treatment with Fe, B and sowing time significantly ($P \leq 0.01$) enhanced the yield and yield attributes of cowpea. Although all the properties examined showed positive increases with Fe and B applications, decreases occurred at 600 doses of boron. Even lower results were obtained for some properties than the control. In FexB interactions, results are higher than the effects of the applications alone, but the 600 dose of boron prevents the positive effect of iron alone. When the results obtained were examined, it was seen that the best results were obtained from the interactions of 2 kg da^{-1} Fe dose, 300 g da^{-1} B dose and May 15 sowing time.
Keywords: *micronutrient, legume, production constraints, fertilization, interactions, crop*

Introduction

Cowpea is an important legume plant that can be used for both human and animal nutrition (Debnath et al., 2018). Edible grain legumes play a momentous role in Turkish field crop cultination and production (Yılmaz et al., 2014). Cowpea is a legume plant with a consumption pattern like beans, and it is an easy plant for the consumer to get used to the plant in regions where preferably beans are grown fondly (Özkorkmaz and Yılmaz, 2017).

Cowpea originates from South Asia, India and Africa (Ünlü and Padem, 2005). Although the protein in cowpea seeds is deficient in methionine and cystine compared to animal proteins, it is richer in lysine and tryptophan than cereal seeds. As it is a legume plant, it enriches the soil with nitrogen by binding the free nitrogen in the air to the soil through rhizobium bacteria in its roots (Özkorkmaz Atıcı et al., 2014).

Heat is a major requirement for cowpeas, which have tropical origins. For this reason, it is very important to determine suitable varieties and sowing times according to ecological regions. In efficient plant cultivation, the priority is the selection of the plant that is suitable for the ecology of the region and the purpose of cultivation.

Timely and correct application of cultural practices in plants is very important for the success of plant production. Fertilization is important cultural practice (Özkorkmaz and Yılmaz, 2022). While the excess or deficiency of nutrients prevents the uptake of other nutrients by plants, it also affects yield and quality negatively (Çimrin and Boysan, 2006). Micronutrient deficiencies can reduce the yield and quality of crop. Soil nutrient content

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must be known and macro and micronutrients must be applied for obtaining higher yield (Öktem, 2022). The micronutrient requirements of plants restrict optimum production.

Boron (B) is one of the most deficient micronutrients in this requirement (Gupta, 1993). B is important micronutrient involved in plant growth and development. Therefore, B is one of the important micronutrients that should be emphasized. B plays very important role in metabolism of nucleic acid, hormone production photosynthesis and protein synthesis (Day and Aasim, 2020). Especially, nitrogen fixation and nodule formation are negatively affected by B deficiency. The amount of B required by plants is quite low. However, the excess of B, which is needed very little, has a negative effect on the development of plants, as in boron deficiency (Gezgin and Hamurcu, 2006). Adverse effect on the yield can occur even though B deficiency symptoms are not evident on the foliage, and it is known as hidden hunger (Satya et al., 2009). B toxicity is an important factor limiting plant growth, especially in arid and semi-arid regions. Although B deficiency is relatively easy to manage using B rich fertilizers, B toxicity is more difficult to manage (Tahghighi et al., 2019). B deficiency is most common in Turkey in acidic soil conditions such as the Black Sea Region (Gülümser et al., 2005).

Iron (Fe), another micronutrient, is an element that plays an important role in the development and growth of plants, although it is used in small amounts in physiological events in the plant. Fe has a very important role in the formation of leghemoglobin, which takes part in nitrogen fixation (Elkoca and Kantar, 2001). If the required amount of Fe cannot be taken, it has been observed that chlorophyll does not form in plants (Uysal and Akay, 2007). In Fe deficiency, there is a decrease in the number of nodules in legume plants (O'hara et al., 1988). Fe is found in nitrogenase and ferredoxin, and excess Fe is used when the bacteria fix nitrogen. Some researchers have reported that B and Fe fertilization in cowpea had increasing effects on yield and yield components.

Quddus et al. (2011) have reported that the applied B doses (0, 0.50, 1, 2 kg ha^{-1}) increased in cowpea plant height, number of pods per plant, number of grains per pod, 100-seed weight and yield values increased with increasing B doses. Debnath et al. (2018) have reported that B applications (0, 1, 1.5, 2 kg da^{-1}) in cowpea had a significant effect on the yield characteristics studied and the values increased as the doses increased. Al-Hayani and Al-Jumaili (2019) have reported that B doses (0-25-50-75 ml L) increased yield elements up to 75 ml in cowpea, a decrease occurred at the highest dose, and the toxic effect of B began to be seen. Marquez-Quiroz et al. (2015) reported that Fe fertilization in cowpea increased plant height, number of pods per plant, yield, and protein ratio values with increasing Fe doses.

In some cases, the intake of one nutrient can be prevented in the presence of another nutrient, or vice versa, its intake can be facilitated. In plant nutrition, to know the different interactions between nutrients, the factors affecting these interactions and their reasons are very important for balanced nutrition of plants and obtaining high quality products (Gezgin and Hamurcu, 2006). Keeping this view in mind the present study was to formulated to access the most suitable combination of Fe and B for maximization of yield and yield properties of cowpea in different sowing times.

Material and Methods

The study was carried out in Ordu, Turkey conditions in the 2016-2017 summer season. The research area is located at an altitude of 6 m above sea level. The meteorological data for the vegetation and long-term period of the experimental area

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where cowpea is grown are presented in *Table 1 and Table 2*. Total rainfall (624 mm) in 2016, the first year of the experiment, is considerably higher than in 2017 (291.5 mm). Average temperature and average humidity values are close to each other in both years (*Table 1*). In 2016, the first year of the experiment, the total rainfall was considerably higher than the long-term average. The total rainfall values for 2017 were below the long-term average. In the long-term average, the rainfall was 477.7 mm, the average temperature was 19.9 ^{0}C, and the average humidity was 73.58% (*Table 2*). In 2016, the first year of the experiment, the total rainfall was considerably higher than the average for long-term average. The total rainfall in 2017 were below the average for long-term. While the temperature values for two years were above the long-term average, the humidity values remained below the long-term average (*Table 1, Table 2*).

Table 1. *Meteorological parameters of experimental area for 2016 and 2017*

Months	2016					2017				
	Temperatures (^{0}C)			Total Rainfall (mm)	Avg. Humidity (%)	Temperatures (^{0}C)			Total Rainfall (mm)	Avg. Humidity (%)
	Max.	Min.	Avg.			Max.	Min.	Ort.		
May	29.5	8.9	16.7	115.1	75.1	27.9	9.5	15.4	72.6	77.7
June	34.2	14.3	22.1	55.1	70.3	27.2	14.2	20.8	54.7	72.8
July	30.1	18.3	24.1	138.8	69.2	30.6	17.1	24	10.8	69.5
August	32.3	18.3	25.7	57.0	71.6	31.5	17.8	25.3	38.8	74.2
September	35.8	12.9	20.9	158.6	66.2	35.1	14.4	22.3	29.6	69.5
October	26.2	8.8	16.2	99.4	73.6	30.9	9.9	16.4	85.0	67.9
Total/ Average	31.35	13.58	22.46	624	71	30.53	13.81	22.17	291.5	71.93

Table 2. *Meteorological parameters of experimental area for long-term (1973-2015)*

Months	Long-term (1973-2015)				
	Temperatures (^{0}C)			Total Rainfall (mm)	Avg. Humidity (%)
	Max.	Min.	Avg.		
May	35.6	3.4	15.6	56.1	76.3
June	37.3	9.6	20.3	75.6	72.5
July	37.1	13.3	23.2	59.5	72.3
August	36.3	13.0	23.6	68.6	72.4
September	36.4	9.2	20.3	80.7	73.2
October	34.2	2.5	16.4	137.6	74.8
Total/ Average	36.15	8.5	19.9	477.7	73.58

In terms of microelement content, the soil is deficient in Fe (2.11-2.32 ppm) and B (0.30-0.36 ppm) (*Table 3*). The critical limit values for low, adequate, and high B in soil are generally accepted to be 0.5, 0.5-5.0, and > 5.0 ppm, respectively (Uysal et al., 2007). If the amount of extractable Fe in the soil is less than 2.5 ppm, it is considered low, between 2.5 and 4.5 ppm is moderate, and if it is more than 4.5 ppm, it is generally considered as high and toxic (Lindsay and Norwell, 1978).

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Table 3. *Some soil characteristics of the experimental area*

Characteristics	2016	2017
Texture	Clayey	Clayey
pH	6.88	6.55
%Lime ($CaCO_3$)	5.3	5.1
Total salt (mS)	0.69	0.71
Organic matter (%)	2.08	2.34
P(ppm)	8.19	9.40
K (ppm)	95	102
Fe (ppm)	2.11	2.32
B (ppm)	0.30	0.36

The plant material used in the study was the Amazon cowpea variety (*Vigna unguiculata* L.). The experiment design was split-split plot in randomized complete block design with three replications. Sowing times were applied for the main plots (15-30 May), Fe doses were applied for the sub-plots (control-1-2-4 kg da^{-1}), and B doses were applied for sub-sub-plots (control-150-300-600 g da^{-1}). Ferrous sulfate ($FeSO_4$) was used as the Fe source, and boron oxide (B_2O_3) was used as the B source.

The plots consisted of 5 plant rows. The distance between the rows was 50 cm, intrarow spacing was 15 cm, plot length was 3 m, and each plot was 7.5 m^2. Considering the amount of nitrogen and phosphorus in the soil, the fertilization amount was completed to 60 kg ha^{-1} N and 60 kg ha^{-1} P_2O_5 (Arslan and Öktem, 2004; Öktem et al., 2011). Banded nitrogen and phosphorous fertilizers were applied with sowing.

Sowing was done by hand at a depth of 4-5 cm. Fe and B applications were made by dissolving in water and adding to the soil after sowing before emergence. The crop was raised adopting standard cultural practices. The observations were recorded on ten randomly selected plants from each plot. In the experiment, plant height, number of pods per plant, number of grains per pod, 1000-seed weight, and grain yield per decare were examined.

Two-year data were collected and subjected to statistical analysis. The data for individual year were computed and pooled mean was worked out. The ANOVA of the obtained data was performed in the JUMP 13.0 package program. The treatment means were compared using least significant difference (LSD) test at 0.05 level of significance (Panse and Sukhatme, 2000).

Result and Discussion

Plant height (cm)

Sowing times, Fe, B applications and all combine treatments had significant effect ($P \leq 0.01$) on plant height for cowpea (*Table 4*).

The results revealed that the B applications, an increase occurred up to the highest dose of 600 g da^{-1}, while lower values were obtained at 600 g/da B dose (126.22 cm) than the control (127.43 cm). It can be said that the 600 g/da dose of B started to show toxic effects in cowpea (*Table 5*). In parallel with increased Fe doses, plant height increased. Considering the values in the Fe and B combined treatment, the highest plant height (133.91 cm) was obtained from 2 kg da^{-1} of Fe and 300 g da^{-1} of B doses. The values obtained from 4 kg da^{-1} Fe and 150 g da^{-1} B (132.50 cm) and 4 kg da^{-1} Fe 300 g da^{-1} B (133.50 cm) doses were in the same group with the highest plant height.

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Table 4. *Analysis of variance (ANOVA) for the parameters*

Variables	Combined years				
	Mean Square				
	Plant height (cm)	**Number of pods per plant (pods/plant)**	**Number of grains per pod (grains/pod)**	**1000-seed weight (g)**	**Grain yield per decare (kg da^{-1})**
ST	59,63*	12*	27*	59.63^{ns}	391.02*
Fe	118.01**	308.81**	2.67*	695.93**	4344**
B	53.67*	48.74**	0.28^{ns}	2546**	4748**
FexST	105.93**	3.43*	0.34^{ns}	295.22**	924.22**
BxST	47.81*	9.41**	1.70*	162.11**	122.28**
BxFe	162.57**	11.03**	3.34**	385.07**	316.37**
BxFexST	57.54**	4.58**	3.35**	177.32**	175.03**

ns: not significant, * (P≤0.01) and ** (P≤0.05) respectively represent significance at probability level. ST: Sowing time, Fe: Iron, B: Boron

Table 5. *Means of plant height (cm) and statistical groups*

Combined years							
		Iron doses (kg da^{-1}) (Fe)					
Sowing times (ST)	**Boron Doses (g da^{-1}) (B)**	**0**	**1**	**2**	**4**	**STxB (Avg.)**	**ST. (Avg.)**
15 May	**0**	118.50 q	125.33 klm	125.33 klm	129.16 hıj	125.74 G	**127.35 B**
	150	123.16 mno	128.50 h-k	127.83 ıjk	131.66 c-f	128.45 E	
	300	128.50 hıj	130.50 fgh	131.16 d-g	132.33 cde	130.60 C	
	600	119.33 opq	121.33 nop	127.50 i-l	130.33 f-ı	124.62 H	
	STxFe (Ort.)	**122.30 F**	**126.41 E**	**129.62 C**	**131.11 B**		
30 May	**0**	127.66 ıjk	128.83 g-j	128.83 g-j	131.16 d-g	129.12 D	**130.60 A**
	150	129.50 hı	130.00 ghı	133.83 abc	133.33 a-d	131.66 B	
	300	130.50 fgh	133.33 bcd	136.66 a	134.66 ab	133.78 A	
	600	124.50 lmn	127.16 jkl	128.83 g-j	131.33 def	127.82 F	
	STxFe (Ort.)	**127.91 D**	**129.83 C**	**131.70 B**	**132.62 A**		

FexB (Avg.)						
		Iron doses (kg da^{-1}) (Fe)				
		0	**1**	**2**	**4**	**B (Avg.)**
Boron Doses (g da^{-1}) (B)	**0**	123.08 ıj	127.08 fg	127.08 fg	130.16 cde	**127.43 C**
	150	126.33 gh	129.25 def	130.83 cd	132.50 abc	**130.05 B**
	300	129.50 de	131.91 bc	133.91 a	133.50 ab	**132.19 A**
	600	121.91 k	124.24 hı	128.16 ef	130.83 cd	**126.22 D**
	Fe (Avg.)	**125.10 D**	**128.12 C**	**130.66 B**	**131.86 A**	

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While Fe doses alone increased plant height, low values were obtained in interactions with 600 g da^{-1} B dose. It is seen that 600 g da^{-1} dose of B inhibits the plant height increasing effect of Fe. The plant height is higher at late sowing time 30 May (130.60 cm) than early sowing dates (15 May). In Fe, B and sowing time interaction, the highest plant height was 136.66 cm, and it was obtained from 2 kg da^{-1} Fe and 300 g da^{-1} B dose at the sowing time of May 30. The shortest plant height, 118.50 cm, was obtained from the plots where Fe and B were not applied at the sowing time of May 15 (*Table 5*).

Çulha and Bozoğlu (2016) have reported that cowpea plant height was higher in late sowings. İdikut (2019) reported the plant height of cowpea as 99.65 cm, 82.75 cm, 104.90 cm and 100.90 cm, respectively, according to the sowing time (20 April, 5 May, 20 May, 5 June).

Quddus et al. (2011) reported that plant height increased with increasing B doses. Patra and Bhattacharya (2009) reported that B applications in cowpea increased plant height, and plant height began to decrease at the highest B dose. Anitha et al. (2005) reported that plant height (Fe_1: 42.30, Fe_2: 47.26, control: 40.16 cm) increased in cowpea as the applied Fe doses increased. In this study, as the Fe and B doses increased, the plant height increased, but a decrease was observed at the highest dose of B.

Number of pods per plant (pods/plant)

The effect of sowing time, Fe and B applications and their interactions on the number of pods per plant was found to be significant ($P \leq 0.01$) statistically (*Table 4*). Considering the effect of sowing times, is seen that the number of pods in the plant obtained at the sowing time of May 15 (21.96 pods/plant) is higher than the sowing time of May 30 (19.20 pods/plant). As the Fe doses increased, the number of pods in the plant increased proportionally to the doses up to the highest Fe dose. In the 4 kg da^{-1} Fe dose (21.07 pods/plant) higher values were obtained than the control (18.19 pods/plant) and 1 kg da^{-1} (20.45 pods/plant) Fe doses, but lower than the 2 kg da^{-1} Fe dose (22.61 pods/plant). In B applications, an increase occurred up to 600 g da^{-1} dose, and values were obtained in the same group as the control (19.32 pods/plant) at 600 g da^{-1} B dose (19.83 pods/plant).

In the Fe and B interactions, the highest number of pods in the plant was obtained from the interactions of 2 kg da^{-1} dose of Fe and 150 g da^{-1} dose of B (24.24 pods/plant) and 2 kg da^{-1} dose of Fe and 300 g da^{-1} dose of B (24.16 pods/plant) and they were included in the same group. The lowest number of pods in the plant (16.41 pods/plant) was obtained from control of Fe and 600 g da^{-1} dose of B. The number of pods in the plant obtained from the plots where Fe and B were not applied (17.49 pods/plant) was in the same group with the lowest number of pods in the plant.

In the sowing time, Fe and B interactions, the highest number of pods per plant (25.66 pods/plant) was obtained from 2 kg da^{-1} Fe dose and 150 and 300 g da^{-1} B doses applications at the sowing time of May 15. The lowest number of pods in the plant (15.00 pods/plant) was obtained from control group of Fe and 600 g da^{-1} dose of B at the sowing time of May 30, and the value obtained from the plots where Fe and B were not applied at the sowing time of May 30 (15.83 pods/plant) was in the same group with the lowest value (*Table 6*).

Çulha and Bozoğlu (2016) reported that the number of pods (21.8 pods/plant) per plant obtained from early sowing in late April was higher than the number of pods (16.7 pods/plant) obtained from late sowing one month later. Patra and Bhattacharya (2009) reported that at increasing B doses in cowpea, the number of pods per plant was

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9.4-10.1-11.7-11.6 pods/plant. In this study, an increase was observed in the B doses applied up to 600 g da^{-1}, and a decrease was observed in the 600 g da^{-1} B dose.

Table 6. *Means of number of pods per plant (pods/plant) and statistical groups*

Combined years							
Iron doses (kg da^{-1}) (Fe)							
Sowing times (ST)	**Boron Doses (g da^{-1}) (B)**	**0**	**1**	**2**	**4**	**STxB (Avg.)**	**ST. (Avg.)**
15 May	0	19.16 lmn	20.16 hıj	23.00 b-e	21.16 f-ı	20.86 D	21.96 A
	150	20.00 ıjk	22.16 ef	25.66 a	23.16 bcd	22.74 B	
	300	21.66 fg	24.16 b	25.66 a	23.33 bc	23.70 A	
	600	17.83 opq	21.33 fgh	23.66 b	22.50 def	21.32 C	
	STxFe (Avg.)	19.65 D	21.95 C	23.74 A	22.53 B		
30 May	0	15.83 t	17.50 pqr	20.00 ıjk	17.83 opq	17.78 G	19.20 B
	150	17.48 p-s	19.33 klm	22.83 cde	20.00 ıjk	19.91 E	
	300	18.66 mno	21.00 hı	22.66 c-f	20.83 ghı	20.77 D	
	600	15.00 t	18.00 nop	20.50 ghı	19.83 jkl	18.32 F	
	STxFe (Avg.)	16.74 F	18.95 E	21.49 C	19.62 D		
FexB (Avg.)							
Iron doses (kg da^{-1}) (Fe)							
		0	1	2	4	B (Avg.)	
Boron Doses (g da^{-1}) (B)	0	17.49 ı	18.83 h	21.50 d	19.50 gh	19.32 C	
	150	18.74 h	20.75 ef	24.24 a	21.55 d	21.32 B	
	300	20.14 fg	22.58 b	24.16 a	22.07 bc	22.23 A	
	600	16.41 ı	19.66 gh	22.08 bc	21.16 de	19.82 C	
	Fe (Avg.)	18.19 D	20.45 C	22.61 A	21.07 B		

Meena et al. (2013) reported that as a result of Fe applications in cowpea, the number of pods in the plant was 12.80, 12.25, control: 11.71, while the highest Fe dose increased the number of pods in the plant compared to the control, other doses decreased the number of pods in the plant. Similarly, in this study, while the number of pods in the plant increased up to the highest dose, with the increase of Fe doses, a decrease was observed at the highest dose.

Number of grains per pod (grains/pod)

As a result of the statistical analysis, the effect of sowing time, Fe, and interactions on the number of grains per pod was significant (P≤0.01), the effect of B, however, was insignificant (*Table 4*). As the sowing times were delayed, the number of grains per pod decreased. Considering the effect of Fe doses, an increase occurred in parallel with increasing doses up to 4 kg da^{-1}, and the values obtained from 1 kg da^{-1} (11.39 grains/pod) and 2 kg da^{-1} (11.41 grains/pod) doses were in the same group.

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In the Fe and B interactions, the highest number of grains per pod (12.08 grains/pod) was obtained from plots 2 kg da^{-1} dose of Fe and B was not applied. The values obtained from 1 kg da^{-1} dose of Fe and 300 g da^{-1} B dose (12.00 grains/pod) and 2 kg da^{-1} dose of Fe and 600 g da^{-1} B dose (11.91 grains/pod) are in the same group with the highest number of grains in the pod. The lowest number of grains per pod was determined in the plots where Fe was not applied and at control, 150 and 300 g da^{-1} doses of B and at 1 kg da^{-1} Fe dose and 600 g da^{-1} B dose.

In the sowing time, Fe and B interactions, the highest number of grains per pod (12.50 grains/pod) was obtained from 1 kg da^{-1} Fe and 300 g da^{-1} B doses at the sowing time of May 15. At the sowing time of May 15, values in the same group with the highest grains per pod were determined at 2 kg da^{-1} Fe dose and control, 300 and 600 g da^{-1} B doses and 1 kg da^{-1} Fe dose and control B dose. The lowest number of grains per pod was obtained from control group of Fe and 150 g da^{-1} B dose at the sowing time of May 30 (9.50 grains/pod) and from the plots where Fe and B were not applied at the same sowing time (10.33 grains/pod) (*Table 7*).

Table 7. *Means of number of grains per pod (grains/pod) and statistical groups*

Combined years							
		Iron doses (kg da^{-1}) (Fe)					
Sowing times (ST)	**Boron Doses (g da^{-1}) (B)**	**0**	**1**	**2**	**4**	**STxB (Avg.)**	**ST. (Avg.)**
15 May	**0**	10.66 g-k	12.16 abc	12.33 ab	11.66 de	11.70 A	**11.53 A**
	150	11.33 d-g	11.16 fgh	11.66 de	11.00 f-ı	11.28 B	
	300	10.33 ı-l	12.50 a	12.16 abc	11.33 d-g	11.58 AB	
	600	11.50 cde	10.83ghı	12.00 a-d	11.83 cde	11.54 AB	
	STxFe (Avg.)	**10.95**	**11.66**	**12.04**	**11.45**		
30 May	**0**	10.33 ı-l	10.33 ı-l	11.83 cde	10.00 kl	10.62 C	**10.78 B**
	150	9.50 l	11.33 d-g	10.50 ıjk	11.50 cde	10.70 C	
	300	11.16 fgh	11.50 def	10.33 ı-l	10.83 ghı	10.95 C	
	600	10.66 g-k	10.50 ıjk	11.83 cde	10.33 ghı	10.83 C	
	STxFe (Avg.)	**10.41**	**11.12**	**10.79**	**10.83**		
		FexB (Avg.)					
		Iron doses (kg da^{-1}) (Fe)					
		0	**1**	**2**	**4**	**B (Avg.)**	
Boron Doses (g da^{-1}) (B)	**0**	10.50 ef	11.24 bcd	12.08 a	10.83 ef	**11.16**	
	150	10.41 f	11.24 bcd	11.08 b-e	11.25 bcd	**11.00**	
	300	10.74 ef	12.00 a	11.24 bcd	11.08 b-e	**11.26**	
	600	11.08 b-e	10.66 ef	11.91 a	11.08 b-e	**11.18**	
	Fe (Avg.)	**10.68 C**	**11.39 A**	**11.41 A**	**11.14 B**		

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Ünlü and Padem (2005) reported that as the sowing times of cowpea were delayed, the number of grains per pod decreased. Patra and Bhattacharya (2009) reported that the number grains per pod increased with increasing B doses. Rahman (2015) found the number of grains per pod to be 8, 8.90 and 9 grains/pod at increasing B doses (B_1:0, B_2:1, B_3:2 kg da^{-1}) and reported the effect of B as insignificant. In this study, the effect of B on the number of grains per pod was found to be insignificant. Anitha et al. (2005) reported that increasing Fe doses increased the number of grains per pod.

Similarly, in this study, the increase in Fe doses increased the number of grains per pod, and the highest number of grains per pod was obtained from the dose of 2 kg da^{-1}. Although the effect of B alone was insignificant, the interaction with Fe doses resulted in a high grain number, especially at the dose of 300 g da^{-1}.

1000-seed weight (g)

While the effect of Fe, B and all interactions on 1000-seed weight was found to be significant ($P \leq 0.01$), the effect of sowing time was found to be insignificant (*Table 4*). As the sowing times were delayed, there was an increase in 1000-seed weight, but it was statistically insignificant. As the Fe doses increased, the 1000-seed weight increased in parallel with the increasing doses. While an increase was observed in B doses up to 600 g da^{-1}, a lower value was obtained from 600 g da^{-1} B dose than the control.

In the Fe and B interaction, the highest 1000-seed weight (243.66 g) was obtained from 4 kg da^{-1} of Fe and 300 g da^{-1} of B doses. The lowest value (218.41 g) was obtained from 1 kg da^{-1} of Fe and 600 g da^{-1} of B doses. The 1000-seed weight obtained from control group of Fe and 600 g da^{-1} dose of B is in the same group with the lowest value. It is seen that the toxic effects of B begin to be seen in cowpea at a dose of 600 g da^{-1}, and it negatively affects the increasing effect of Fe on 1000-seed weight. The excess of B required has a negative effect on the development of the plant as in B deficiency.

In the sowing time, Fe and B interaction, the highest 1000-seed weight (249.50 g) was obtained from 4 kg da^{-1} Fe and 300 g da^{-1} B doses at the sowing time of May 30. At the same sowing time, the value obtained from 4 kg da^{-1} Fe dose and 150 g da^{-1} B dose was in the same group with the highest value.

The lowest 1000-seed weight (216.16 g) was obtained from control group of Fe and 600 g da^{-1} of B doses at the sowing time of May 30. At the same sowing time, the value obtained from 1 kg da^{-1} of Fe and 600 g da^{-1} of B doses was in the same group with the lowest value (*Table 8*).

Toğay and Toğay (2010) in their study with three different sowing times (April 15, April 30, May 15), reported that the weight of a thousand grains in cowpea varies between 148-158 g and the weight of a thousand grains increases as the sowing time passes.

Rawashdeh and Sala (2016) determined that the 1000-grain weight was higher than the control in B and Fe applications, and the effect of Fe and B interaction on the 1000-grain weight was higher than B application and lower than Fe application.

In their study, Marquez-Quiroz et al. (2015) reported that Fe doses reduced the 1000-grain weight of cowpea with increasing doses. Atalay (2009) in his study with Fe applications, determined that increasing Fe doses did not have a significant effect on 1000-grain weight.

Grain yield per decare (kg da^{-1})

According to the ANOVA analysis, the grain yield per decare was significantly ($P \leq 0.01$) affected by sowing time, Fe, B, and all interactions (*Table 4*). As the sowing

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times were delayed, the grain yield per decare decreased. As the Fe doses increased, the grain yield per decare increased. The highest values were recorded at 2 kg da^{-1} and a decrease was recorded at 4 kg da^{-1}, indicating that a plateau effect was reached. Fe doses increased the grain yield per decare by 13.60%, 23% and 18%, respectively, compared to the control. While an increase was observed in B doses up to 600 g da^{-1}, a lower grain yield per decare was obtained at 600 g da^{-1} B dose. While 150 and 300 g/da^{-1} B doses increased the grain yield per decare by 12% and 15%, respectively, compared to the control, the 600 g da^{-1} dose decreased the grain yield per decare by 2.2% compared to the control.

Table 8. *Means of 1000-seed weight (g) and statistical groups*

Combined years							
		Iron doses (kg da^{-1}) (Fe)					
Sowing times (ST)	**Boron Doses (g da^{-1}) (B)**	**0**	**1**	**2**	**4**	**STxB (Avg.)**	**ST. (Avg.)**
15 May	**0**	226.66 jk	223.00 k-n	241.00 cd	235.00 e-h	**227.54 D**	**229.44**
	150	232.66 gh	235.50 e-h	221.83 mno	235.50 e-h	**233.16 C**	
	300	232.00 hı	230.16 hı	236.16 efg	237.83 de	**235.41 B**	
	600	220.16 no	220.66 no	225.50 j-m	222.16 lmn	**222.12 F**	
	STxFe (Avg.)	**225.91 F**	**228.95 CD**	**228.82 D**	**237.49 B**		
30 May	**0**	222.66 lmn	226.66 jk	224.50 klm	237.16 ef	**231.66 CD**	**233.14**
	150	220.83 no	232.00 hı	228.83 ıj	247.50 a	**232.29 C**	
	300	240.16 d	233.50 fgh	242.83 bc	249.50 a	**243.33 A**	
	600	216.16 p	218.16 op	235.83 efg	225.83 jkl	**224.00 E**	
	STxFe (Avg.)	**226.79 E**	**229.45 C**	**237.53 B**	**240.53 A**		

FexB (Avg.)						
		Iron doses (kg da^{-1}) (Fe)				
		0	**1**	**2**	**4**	**B (Avg.)**
Boron Doses (g da^{-1}) (B)	**0**	226.66 gh	222.83 ı	232.83 e	236.03 d	**229.06 C**
	150	232.33 e	228.16 fg	225.33 hı	241.50 b	**233.30 B**
	300	232.75 e	231.83 ef	239.50 c	243.66 a	**240.68 A**
	600	219.16 j	218.41 j	230.66 f	224.00 ı	**223.06 D**
	Fe (Avg.)	**226.62 D**	**229.20 C**	**233.17 B**	**239.01 A**	

In the Fe and B interactions, the highest grain yield per decare (161.91 kg da^{-1}) was obtained from 2 kg da^{-1} Fe dose and 300 g da^{-1} B dose. The lowest value (106.16 kg da^{-1}) was obtained from the plots where iron and boron were not applied.

In the sowing time x iron x boron interactions, the highest grain yield per decare (163.66 kg da^{-1}) was obtained from 2 kg/da^{-1} Fe dose and 300 g da^{-1} B dose at the sowing time of May 30. The lowest grain yield per decare (102.83 kg da^{-1}) was obtained from the plots where Fe and B were not applied at the sowing time of May 30 (*Table 9*).

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Table 9. *Means of grain yield per decare (kg da^{-1}) and statistical groups*

Combined years							
		Iron doses (kg da^{-1}) (Fe)					
Sowing times (ST)	**Boron Doses (g da^{-1}) (B)**	**0**	**1**	**2**	**4**	**STxB (Avg.)**	**ST. (Avg.)**
15 May	**0**	109.49 m	130.99 ıj	141.33 fg	138.16 gh	**129.99 E**	
	150	125.83 jk	146.83 de	150.99 bc	149.99 bc	**143.41 C**	
	300	132.66 ıj	142.66 fg	160.16 b	146.16 ef	**146.99 A**	
	600	112.50 l	126.33j	126.66 j	124.66 j	**122.53 G**	
	STxFe (Avg.)	**120.11 E**	**136.70 C**	**144.78 A**	**141.32 B**		**135.71 A**
30 May	**0**	102.83 n	127.33 ıj	136.33 h	136.66 h	**121.41 F**	
	150	123.00 k	135.33 ı	148.99 bcd	137.83gh	**136.29 D**	
	300	130.83 ıj	139.16 gh	163.66 a	147.66 cd	**145.33 B**	
	600	108.83 m	130.99	129.16 ıj	123.00 k	**121.20 F**	
	STxFe (Avg.)	**115.12 F**	**130.53 D**	**144.53 A**	**136.28 C**		**131.61 B**

FexB (Avg.)						
		Iron doses (kg da^{-1}) (Fe)				
		0	**1**	**2**	**4**	**B (Avg.)**
Boron Doses (g da^{-1}) (B)	**0**	106.16 j	129.16 f	138.83d	137.41 e	**124.81 C**
	150	123.41 h	141.08 cd	149.99 b	143.91 c	**139.87 B**
	300	131.74 e	140.91d	161.91 a	146.91 b	**143.64 A**
	600	110.66 ı	128.66 fg	127.91 fgh	123.83 gh	**121.99 D**
	Fe (Avg.)	**117.61 D**	**133.61 C**	**144.65 A**	**138.80 B**	

İdikut et al. (2018) reported grain yields per decare of cowpea as 219.71, 141.70, 168.91 and 132.68 kg da^{-1} at different sowing times (5 May, 20 May, 5 June, 20 June). High values were obtained at early planting times in the studies mentioned. In this study, grain yields per decare were higher in early sowing.

Meena et al. (2013) obtained grain yields per decare as 105.8, 103.7, control: 99 kg da^{-1} at increasing Fe doses. Marquez-Quiroz et al. (2015) reported that Fe applications increase the seed yield in cowpea up to a certain dose, but these values decrease at high doses. The findings of this study are consistent with those of the other studies mentioned.

Khurana and Arora (2012) reported that 0.75 kg ha^{-1} B increased the yield by 21.4-23.3% compared to the control group. Patra and Bhattacharya (2009) in their study the effect of B on yield values of cowpea, reported the grain yields per decare of 4 boron doses (B_1:%0, B_2:0.1%, B_3:0.2%, B_4:0.3%) as 407.3, 456.7, 707.3, 506 kg ha^{-1} respectively, at increasing B doses. At the highest B dose, the values decreased.

According to the results we obtained in our study, while an increase in grain yield per decare was observed at B doses up to 300 g da^{-1} B dose, lower values were obtained at 600 g da^{-1} B dose, the highest dose. It has been stated that the application of B to plants in soils deficient in boron will increase the yield, but high doses of boron may cause negative results (Ceyhan et al., 2006; Ross et al., 2006). The soil of our experimental area is insufficient in terms of B (*Table 2*) and it is seen that 600 g da^{-1} B dose is not suitable for cowpea cultivation. Sankaranarayanan et al. (2010) reported that the use of B increased the yield by 15% compared to the control. Gurmus (2005) reported that the use of B increased the yield.

Many researchers reported that the yield values in wheat increased as the B and iron Fe increased, and the results obtained from the FexB interactions were higher than the single applications of B and Fe (Mirshekari, 2012; Rawashdeh and Sala, 2016; Kumarl et al., 2022). Nahardani et al. (2013) reported that early sowing increases the yied of cowpea and the yield is higher in sowing time x B interactions.

Conclusion

As a result of the 2-year field research, either alone or interactions with each other, the effects of planting time, Fe and B applications on properties of cowpea studied were found to be statistically significant. The values obtained for most of the characteristics examined increased with increasing Fe doses. An increase was obtained in B doses up to 600 g da-^{1}. Results of 600 g/da^{-1} were even lower than those of the control in some characteristics. Highest values were recorded at 300 g da^{-1} and decreased thereafter.

It is thought that one of the reasons for the response to different sowing times could be genotype dependent. Different sowing times could act via growth degree units' accumulation. It is thought that the reason for this is the amount of heat accumulated until the harvest time as a result of different sowing time applications. Fe and B interactions were found to be significant in all the characteristics examined. This shows us that Fe and B act interdependently. Except for the 600 g da^{-1} B dose, positive results were obtained in most of the characteristics examined in the interactions of the other doses. However, 600 g da^{-1} B dose inhibited some positive effects of Fe on single effects.

Legume crops like cowpea required more amount of boron compared to most field crops as boron plays vital role in proper development of reproductive organs. Iron is a very important and necessary microelement for nitrogen fixation, and it is recommended for cowpea. We found that the soil of our experiment area was clayey, slightly alkaline, and deficient in B and Fe. Considering these conditions and the information obtained, the highest yield per decare was obtained from a dose of 2 kg da^{-1} Fe and a dose of 300 g da^{-1} B interaction. The 600 g da^{-1} dose of B was determined as the dose at which the toxic effect started to be seen, and it is not recommended for cowpea cultivation.

Our soil is insufficient in terms of boron and iron. Considering the boron and iron requirement of cowpea, 300 g da^{-1} of boron and 2 kg da^{-1} of iron can be recommended for cowpea cultivation according to the results we obtained.

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