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Fodder Beet (*Beta Vulgaris Var Crassa*) Yield and Quality Attributrs As Affected By Nitrogen Fertilization and Foliar Boron Application

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ABSTRACT

A field experiment was conducted during two seasons 2018/2019 and 2019/2020 at Homs Agriculture Research Center, General Commission for Scientific Agriculture Researches (GCSAR), Syria, to study the effect of nitrogen fertilization rates and foliar application of boron on root yield and quality and dry matter yield of fodder beet. Results showed that the effect of nitrogen fertilization was significant ($p \leq 0.001$) for all studied traits except brix%. The effects were significant positive on root, shoot and biological yields, sucrose percentage, root, shoot and total dry matter yields. On the other hand the effect of boron spraying was presented for each season separately, because the differences of boron treatments were significant for all parameters except brix% at each season, and HI at the two seasons, while the differences of years were significant for all parameters except for HI. the highest yield and yield components were achieved by adding 300 kg N/ha with the addition of boron under Homs governorate conditions.

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Introduction

Fodder beet (*Beta vulgaris var. Crassa*), is a member of the Chenopodiaceae family, and this forage crop is native to Mediterranean area and was grown as a root crop in Germany and Italy as early as the sixteenth century. It is world-wide in temperate zones up to 55o N [1].

There is renewed interest in fodder beet (*Beta vulgaris L.*) production in Syria, especially a strong interest toward use of fodder beet for autumn and winter feeding of dairy herds [2].

The production of forage crops is very important for livestock production in the world, which contributes largely to the national income [3]. Animal production in the Syria depends mainly on natural range which is affected by the seasonal rains and low quality grasses, this necessitates the introduction of irrigated forage crops in the irrigated schemes. There are many constrains facing forage production in Syria, like lack of information of fodder beet which considered as a new crop [4]. Suggested solutions for these problems are application of technological packages, integration of animal production with forage production and introduction of new forage species of high yield especially during periods of forage shortage like late winter and early summer [1,5].

Fodder beet offers a higher yield potential than any other arable fodder crop and when grown under suitable conditions can produce almost 20 t/ha^{-1} dry matter yield, and this makes it popular in many countries like New Zealand, Germany, America, Australia, Syria and Egypt [6,7]. It contains 10-15% dry matter and may yield more than 20 t/ha of dry matter in one harvest as compared to 13-15 t/ha from four cuts of grass [8].

Nitrogen is a vital element for plant growth as it is a component of protein and chlorophyll, it is often the most limiting factor in crop production. Hence, application of fertilizer nitrogen results in higher biomass yield [9].

Chakwizira et al., studied the effects of N supply on growth, N uptake and its influence on nutritive value of fodder beet, they found that both dry matter (DM) yield and N uptake increased with N supply, by 39% and 129%, respectively, when 200 kg N ha^{-1} was applied, compared with the control plots [10]. The results suggest 100 kg N ha^{-1} was adequate for optimum DM production, while Turk, found that the highest root yield and crude protein yields were obtained from 225 kg ha^{-1}N under Turkey conditions.

Amongst the dicot plant families, the Beta spp. are known for their high sensitivity to boron deficiency [11]. Al Numan et al., estimated the effect of boron fertilizer application method and level on the production and quality traits of two sugar beet varieties in a loamy silt soil, at Der Al Zur Agricultural Research Center in Syria, they found that ground boron application has no significant effects on the studied traits, and exhibited a significant effect of the spray boron on sugar and root yields [12].

Abd El-Hady, in Egypt found that after 180 days from sowing two sprays with boron (Borfam) treatment compare to one spray and control recorded the highest values of root and leaves fresh weight, root/leaves ratio, root diameter, effective root length and photosynthetic pigments, also at harvest this treatment showed superiority in all root parameters, i.e. root diameter (52.33 cm), root length (32.00 cm) and root weight (3755 g/plant) [13]. The aim of the present study is to investigate the effects of nitrogen fertilization rates and foliar boron application on root yield, quality and dry matter yield of fodder beet.

Materials and Methods

The experiment was carried out during two successive winter seasons of 2018/2019-2019/2020, at Homs Agricultural Research Center, General Commission for Scientific Agriculture Researches (GCSAR), Syria. The site has a latitude of 34.7324º N, and longitude of 36.7137º E. The soil of the experimental site is clay silty, characterized by low nitrogen content (5.4-6.5 ppm) and pH of (7.5-8.1), Ec (0.34-0.32 $dS.m^{-1}$), organic matter (1.38-1.41) and boron (0.44, 0.38 ppm) at the first and second seasons respectively.

Phosphorus as triple superphosphate (46% P_2O_5) at a rate of 160 kg/ha, and potassium as potash sulfate (50% K_2O) were added at a rate of 120 kg/ha before planting as agronomic practice. Nitrogen fertilization in the form of urea (46% N) was applied at four rates as follow, 100 (N1), 200 (N2), 300 (N3) and 400 (N4) kg N/ha. The total amount was divided into three doses (the first added at planting, the second added after thinning and the third after one month following the second dose according to the recommendations of Abbas et al., (2018). Boron was sprayed on fodder beet foliage after 110 and 140 days from sowing at a form of borax (10 % B). Climatic data is are given in Table (1).

Table 1: Temperatures and rainfall distribution during 2018/2019 and 2018/2020 seasons

Months	Total rainfall (mm)		Max. temperature (°C)		Min. temperature (°C)	
	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
January	131.3	115	11.43	11.7	3.97	4.45
February	121.7	69.7	13.67	12.34	5.26	4.66
March	51.5	59.2	16.52	18.10	7.82	8.52
April	27.5	47.3	19.68	21.31	9.38	11.14
May	0.0	11.3	30.51	27.29	15.94	14.64
June	0.1	0.0	32.32	30.82	20.67	18.52
July	0.0	0.0	32.62	31.86	21.97	20.58

At harvest (6 months from sowing), when plants showed signs of maturity which is indicated by leaf yellowing and partial drying of the lower leaves, a sample of 10 plants of each experimental plot was taken from the inner two ridges randomly hand-pulled to determine: Root yield ($ton.ha^{-1}$), shoot yield ($ton.ha^{-1}$), biological yield ($ton.ha^{-1}$), harvest index (HI), total soluble solids (brix%), sucrose percentage (%), root and shoot dry matter yield ($ton.ha^{-1}$) and total dry matter yield ($ton.ha^{-1}$),.

Statistical analyses

Analysis of variance (ANOVA) appropriate for the completely randomized design with two factors was applied. The treatment means were compared using least significant difference (LSD) procedures at 5% level using GeneStat Computer Program v.12.

Results and Discussion

The results of ANOVA for brix, sucrose percent, root yield, shoot yield, biological yield, harvest index, root dry matter, shoot dry matter, and total dry matter of fodder beet are summarized in Table (2).

Table 2: Analysis of variance of the traits studied

Source of variation	df	BX%	Suc%	RY	SY	BY	HI	RDM	SDM	TDM
2018/2019										
Nitrogen (N)	3	**	***	***	***	***	***	***	***	***
Boron (B)	1	ns	***	**	***	***	ns	***	***	***
N*B	3	ns	*	**	*	*	*	*	*	*
CV%	-	10.0	2.7	4.2	2.5	3.6	0.6	4.2	3.5	3.8
2019/2020										
Nitrogen (N)	3	**	***	***	***	***	***	***	***	***
Boron (B)	1	ns	***	***	***	***	ns	***	***	***
N*B	3	ns	*	*	*	*	ns	*	*	*
CV%	-	6.8	2.5	6.4	3.3	5.7	0.8	6.7	3.6	6.2
Combined 2018/2019-2019/2020										
Year (Y)	1	*	***	***	***	***	ns	***	***	***
Nitrogen (N)	3	***	***	***	***	***	***	***	***	***
Boron (B)	1	ns	***	***	***	***	*	***	***	***
Y*N	3	ns	***	ns	ns	*	ns	ns	*	ns

Y*B	1	ns	ns	ns	ns	ns	ns	ns	*	ns
N*B	3	ns	*	ns	***	*	ns	*	***	*
Y*N*B	3	ns	ns	ns	ns	*	ns	ns	ns	ns
CV%	-	8.5	2.7	5.4	3.0	4.8	0.8	5.5	3.6	5.1

df, degrees of freedom; CV, coefficient of variation; ns, not significant. *P < 0.05, **P < 0.01, ***P < 0.001.

The analysis of variance show that the effect of nitrogen fertilization was high significant ($p \leq 0.001$) except for bx%. The effect of boron spraying was shown separately, because differences of boron were significant for all parameters except bx% at the individual seasons and their average, and HI at the two seasons. the differences of years were significant for all parameters except HI.

Root yield (ton.ha^{-1}) and Shoot yield (ton.ha^{-1})

The effect of nitrogen fertilization and boron application is significant on root yield, which increased at both first and second seasons with increasing nitrogen dose up to N3 (300 kg N/ha), so the highest root yield (162.09, 142.89 ton.ha^{-1}) were obtained from the treatment N3B1 at the first and second season respectively, while the combined analysis for two seasons show that root yield also significantly increased from N0 to N3, then it decreased in N4 treatment (Table 3).

Table 3: Effect of nitrogen fertilization and boron on root yield (ton.ha^{-1}) and shoot yield (ton.ha^{-1})

Treatments	Root yield (ton.ha^{-1})			Shoot yield (ton.ha^{-1})		
	2018/19	2019/20	Mean	2018/19	2019/20	Mean
N1B0	80.69^{e}	69.62^{f}	75.15^{g}	12.40^{g}	10.90^{g}	11.65^{h}
N1B1	84.48^{e}	74.04^{e}	79.26^{g}	13.11^{g}	11.82^{f}	12.47^{g}
N2B0	111.74^{d}	93.22^{d}	102.48^{f}	15.40^{f}	13.33^{e}	14.36^{f}
N2B1	120.52^{c}	101.91^{cd}	111.22^{e}	16.66^{e}	14.96^{d}	15.81^{e}
N3B0	148.05^{b}	122.49^{b}	135.27^{b}	18.79^{d}	16.13^{c}	17.46^{d}
N3B1	162.09^{a}	142.89^{a}	152.49^{a}	20.53^{b}	18.54^{b}	19.54^{b}
N4B0	128.25^{c}	110.06^{c}	119.16^{d}	19.73^{c}	17.83^{b}	18.78^{c}
N4B1	128.77^{c}	123.88^{b}	126.33^{c}	22.07^{a}	20.98^{a}	21.52^{a}

At the same dose of nitrogen, the root yield increased significantly when boron sprayed compared with the addition of nitrogen alone, except the treatments N1 (B0, B1) and N4(B0, B1) at the first season, differences were not significant (Table 3).

There are a significant difference between the two years, where root yield value at the first season was 120.57 ton.ha^{-1} and decreased significantly to 104.67 ton.ha^{-1} at the second season. This may explained by the genotype-environment interaction and variation in weather conditions [3].

Shoot yield was influenced significantly with the addition of nitrogen fertilization and boron, at first and second seasons with increasing nitrogen dose up to N4 (400 kg N/ha), so the highest shoot yields (22.07, 20.98 ton.ha^{-1}) were obtained in the treatment N4B1 at the first and second seasons respectively. The combined analysis of the two seasons; root yield also significantly increased from N0 to N4, and boron affects this parameter positively (Table 3).

These results are consistent with those reported by Zaki, Abdel-Gwad et al., Abbas et al., Dewdar et al, and Abbas et al., [14-18]. The increase in root and shoot yields as a result of increasing nitrogen fertilizer levels may be due to the role of nitrogen in increasing vegetative growth, fresh root and shoot weight [9]. The positive effect of boron may be due to its role in cell elongation where, in case of boron deficiency, plant leaves will be smaller, stiff and thick [12].

Biological yield (ton.ha^{-1}) and harvest index (%)

The biological yield influenced significantly by nitrogen fertilization and boron spray, which increased at both first and second seasons with increasing nitrogen level up to N3 (300 kg N/ha), so the highest biological yields (182.62, 161.43 ton.ha^{-1}) were obtained from the treatment N3B1 at the first and second seasons respectively (Table 4).

Table 4: Effect of nitrogen fertilization and boron spray on biological yield (ton.ha-1) and harvest index

Treatments	Biological yield (ton.ha^{-1})			Harvest index (%)		
	2018/19	2019/20	Mean	2018/19	2019/20	Mean
N1B0	93.09^{f}	80.52^{f}	86.80^{f}	86.68^{b}	86.42^{cde}	86.55^{c}
N1B1	97.59^{f}	85.86^{f}	91.73^{f}	86.56^{b}	86.19^{de}	86.38^{c}
N2B0	127.14^{d}	106.54^{e}	116.84^{e}	87.88^{a}	87.47^{abc}	87.68^{b}
N2B1	137.18^{d}	116.87^{de}	127.03^{d}	87.84^{a}	87.19^{bcd}	87.52^{b}
N3B0	166.84^{b}	138.62^{bc}	152.73^{b}	88.73^{a}	88.36^{ab}	88.55^{a}
N3B1	182.62^{a}	161.43^{a}	172.02^{a}	88.76^{a}	88.50^{a}	88.63^{a}
N4B0	147.98^{c}	127.89^{cd}	137.93^{c}	86.63^{b}	86.06^{de}	86.34^{c}
N4B1	150.84^{c}	144.86^{b}	147.85^{b}	85.35^{c}	85.46^{e}	85.41^{d}
Mean	137.91^{a}	120.32^{b}	-	87.31^{ns}	86.96^{ns}	-

The combined analysis for the two seasons show significant increase in biological yield from N0 to N3, then it decreased in N4 treatment according to decreasing of root yield at this level, which contributes more than 80% of total beet biomass.

At the same level of nitrogen, the biological yield increased significantly when boron sprayed compared with the addition of nitrogen alone, according to the positive effect of boron on roots and shoots [12].

There are a significant effect between the two years, regarding biological yield, and its value at the first season was 150.84 ton.ha^{-1} which decreased significantly to 144.86 ton.ha^{-1} at the second season.
The combined effect of nitrogen fertilization and boron application was significant on harvest index. The highest HI values (88.76, 88.50%) were obtained from the treatment N3B1 at the first and second seasons respectively, while the lowest values were obtained from the treatments N1 and N4 (Table 4).

Brix% (Total soluble solids) and Sucrose %
The combined effect of nitrogen fertilization and boron spray was significant on brix percent, which increased at both first and second seasons with increasing nitrogen rate to N3 (300 kg N/ha), so the highest brix percent (17.40, 17.58%) were obtained from the treatment N3B1 at the first and second seasons respectively, while the combined analysis of the two seasons show that, brix percent significantly increased from N0 to N3, then it decreased in N4 treatment (Table 5).

Table 5: Effect of nitrogen fertilization and boron on brix% and sucrose %

Treatments	Brix%			Sucrose%		
	2018/19	2019/20	Mean	2018/19	2019/20	Mean
N1B0	12.79^{c}	14.46^{b}	13.63^{d}	7.23^{f}	11.13^{f}	9.18^{g}
N1B1	13.75^{c}	15.00^{b}	14.38^{cd}	8.23^{e}	11.77^{e}	10.00^{f}
N2B0	14.73^{bc}	15.93^{ab}	15.33^{c}	9.83^{d}	12.03^{d}	10.93^{e}
N2B1	15.25^{abc}	15.74^{ab}	15.49^{bc}	10.47^{c}	12.50^{c}	11.48^{d}
N3B0	16.67^{ab}	17.50^{a}	17.09^{a}	12.10^{a}	13.93^{b}	13.02^{b}
N3B1	17.40^{a}	17.58^{a}	17.49^{a}	12.90^{a}	15.00^{a}	13.95^{a}
N4B0	14.61^{bc}	15.63^{b}	15.12^{cd}	10.83^{c}	12.87^{c}	11.85^{c}
N4B1	15.50^{ab}	15.32^{b}	15.41^{c}	11.50^{b}	13.93^{b}	12.72^{b}
Mean	15.09^{b}	15.90^{a}	-	10.39^{b}	12.90^{a}	-

There are a significant difference between the two years, the value of brix% at the first season was 15.09%, which increased significantly to 15.90% at the second season. This could be explained that total rainfall and weather conditions varied between seasons.

The effect of nitrogen fertilization and boron application was significant on sucrose percent, which increased at both first and second seasons with increasing nitrogen rate to N3 (300 kg N/ha), so the highest sucrose percent (12.90, 15.00%) were obtained from the treatment N3B1 at the first and second seasons respectively, also the combined data of two seasons show that, sucrose percent significantly increased from N0 to N3, then it decreased in N4 treatment (Table 5).

At the same rate of nitrogen, the percent of sucrose increased when boron sprayed compared with the addition of nitrogen alone, except the treatments N3B0 and N3B1, where the differences were not significant (Table 5).

Also, there are a significant difference between the two years, and the mean value of sucrose % at the first season was 11.50% and increased significantly to 12.90% at the second season. This could explained that total rainfall and weather conditions varied between seasons.

Sucrose increased with increasing nitrogen rate, that may due to the importance of nitrogen as one of the macronutrient elements for plant nutrition and its role in increasing vegetative growth through enhancing leaf initiation, increment chlorophyll concentration in leaves which may reflected in improving photosynthesis process and increasing assimilated sugars. The results in this study are consistent with Gobarah Mirvat and Mekki, who indicated that sucrose percentage increased by boron addition which may be attributed to decrease Na and K uptake in root juice.

Dry matter yield (ton.ha^{-1})

Root dry matter yield was significantly increased as nitrogen rate increased to N3 (300 Kg N/ha). The greatest weight was obtained by adding 300 Kg N/ha + boron (23.22, 21.26 ton. ha^{-1}) at the first and second seasons respectively (Table 6).

Table 6: Effect of nitrogen fertilization and boron on root dry matter yield (ton.ha^{-1}), shoot dry matter yield (ton.ha^{-1}) and total dry matter yield (ton.ha^{-1})

Treatments	Root DM ton.ha^{-1}			Shoot DM ton.ha^{-1}			Total DM ton.ha^{-1}		
	2018/2019	2019/2020	Mean	2018/2019	2019/2020	mean	2018/2019	2019/2020	Mean
N1B0	12.35^{e}	10.65^{e}	11.50^{f}	1.33^{e}	1.16^{d}	1.25^{e}	13.68^{f}	11.82^{e}	12.75^{g}
N1B1	13.35^{e}	11.72^{e}	12.53^{f}	1.50^{d}	1.31^{c}	1.40^{d}	14.85^{f}	13.03^{e}	13.94^{f}
N2B0	16.50^{d}	13.78^{d}	15.14^{e}	1.60^{d}	1.38^{c}	1.49^{c}	18.10^{e}	15.16^{d}	16.63^{e}
N2B1	18.28^{c}	15.45^{cd}	16.86^{d}	1.94^{c}	1.59^{b}	1.76^{b}	20.22^{cd}	17.03^{c}	18.63^{c}
N3B0	20.58^{b}	17.47^{b}	19.02^{b}	1.90^{c}	1.64^{b}	1.77^{b}	22.48^{b}	19.11^{b}	20.79^{b}
N3B1	23.22^{a}	21.26^{a}	22.24^{a}	2.35^{a}	1.93^{a}	2.14^{a}	25.57^{a}	23.19^{a}	24.38^{a}
N4B0	17.18^{cd}	14.95^{d}	16.07^{de}	1.96^{c}	1.66^{b}	1.81^{b}	19.14^{de}	16.61^{cd}	17.87^{d}
N4B1	17.70^{cd}	17.08^{bc}	17.39^{c}	2.30^{b}	1.97^{a}	2.14^{a}	20.00^{cd}	19.05^{b}	19.53^{c}
Mean	17.40^{a}	15.30^{b}	-	1.86^{a}	1.58^{b}	-	19.25^{a}	16.87^{b}	-

Raising nitrogen fertilization levels from 100, 200 to 300 kg N/ha resulted in a significantly higher shoot dry weight, and the application of foliar boron spray enhanced shoot dry matter accumulation in all treatments (Table 6). Consequently the higher values of total dry matter yield (25.57, 23.19) ton.ha-1 were obtained from the treatment N3B1 at the first and second seasons respectively (Table 6).

This increase in total dry matter could be attributed to the role of nitrogen in enhancing plant growth and consequently accumulation of more assimilates, and to the increase in the amount of metabolites synthesized by plants due to the effect of nitrogen in enhancing photosynthesis and hence dry matter accumulation. These results are consistent with the findings of Nemeat Alla et al., Nafei and Khogali et al., [19-21].

Conclusion

Nitrogen fertilization improved yield and quality of fodder beet, and had significant positive effects on root, shoot and biological yields, sucrose percentage, root, shoot and total dry matter yields. The highest yield and yield components were associated with 300 kg N/ha with boron as foliar application. So, it can be recommended to be the optimum rate under Homs governorate conditions [22].

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