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Research Paper

Productivity of fodder beet (*Beta vulgaris* var. *Crassa*) cultivars as affected by plants spacing in Al Ghab, Syria

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Abstract. Field experiment was conducted at the General Commission for Scientific Agriculture Research (GCSAR), Al Ghab Research Station from 2009 to 2011, to investigate the effect of plant density (25 × 50, 30 × 50, 25 × 60 and 30 × 60 cm) on production traits of four monogerm fodder beet varieties (Jamon, Splendids, Starmon and Vermon). Split plot design was used with three replications. The statistical analysis exhibited a significant effect of the varieties (V) and plant spacing (D) for most of the production traits (biology, root and shoot yields (ton/ha), root and shoot weight per plant (g), and sucrose content (%). The variety Splendids showed the superiority for most of the production traits as compared with the other varieties. The results also clarified the superiority of 25 × 50 plant density with the highest production traits, but to get a higher sucrose % it is recommended to grow the beet roots at spacing 30 × 60 cm.

Keywords: Fodder beet, plant density, production traits, monogerm varieties.

INTRODUCTION

Production of forage crops is very important for livestock production in Syria, and contributes largely to the national income. Fodder beet can fulfill this aim through its high content of carbohydrate up to 72% of dry matter (Acar and Mulayim, 2000; Türk, 2010; Kassab *et al.*, 2012) and its higher yield (up to 24 ton dry matter/ha) in some new regions (Farmfact 1-77, 2013). This crop is considered as a source of renewable energy, as it provides more energy than cereals and fodder crops (Urban *et al.*, 2005; Hnilička *et al.*, 2005; Martínez-Pérez *et al.*, 2007). It was also reported that the plant is suitable to make silage (Özköse, 2013); besides the traditional use of fodder beet. It is also used in bioenergetics, such as production of bioethanol (Chochola, 2007; Pulkrábek *et al.*, 2007; Mähnert and Linke, 2009) and biogas (Klocke *et al.*, 2007; Scherer, *et al.*, 2009). At present, there is a new application of fodder beet in organic farming, which is among the good fore crop (Hansova, 2010).

The feeding of low-quality forages, such as crop residues (wheat, barley, straw) and low quality hays, are a common practice in Syria (Kassab *et al*., 2012; Bagdadi, 2013). Fodder beet is used as a valuable source of fodder for cattle (Özköse, 2013; Al- Jbawi *et al.*, 2014).

Many studies have demonstrated that yield of fodder beet is determined by genetic dispositions of varieties, the canopy density and weather conditions (Khogali *et al.*, 2011; Kassab, *et al.*, 2012; El Sarage, 2013; Al-Jbawi *et al.*, 2015). Hansova (2010) tested six fodder beet varieties (Lenka, Hako, Kostelecká Barres, Jamon, Monro, and Starmon), and reported that the most yielding cultivar was Hako, while Lenka, Kostelecká Barres and Hako were the highest weight of one root.

Al-Jbawi *et al.* (2015) also confirmed no significant differences between varieties in respect of shoot weight/plant, shoot yield, and number of plant/ha.

Table 1. Temperatures and rainfall distribution during 2009/2010 to 2010/2011 seasons.

Season / Month	2009/2010			2010/2011		
	Max. temp. (°C)	Min. temp. (°C)	Rainfall (mm)	Max. temp. (°C)	Min. temp. (°C)	Rainfall (mm)
October	24	17	25.0	20	12	20
November	21	13	60	17	9	50
December	16	8	30	10	5	60
January	10	6	120	7	-1	180
February	17	7	100	12	5	150
March	21	11	120	15	6	130
April	24	14	40	18	10	100
May	30	19	-	25	14	-
June	32	22	-	27	18	-
July	34	24	-	32	22	-

Source: Meteorology Station in Al Ghab Agricultural Research Center.

Khogali *et al.* (2011) studied the effect of plant spacing (15, 20 and 25 cm between holes) of three fodder beet cultivars (Voroshenger, Anisa and Polyproductiva) on yields and yield components. They reported that spacing had no significant effects on root fresh weight, shoot fresh weight, and shoot dry weight. Similarly, Polyproductiva cultivar sown at 25 cm apart attained significantly greater root dry weight.

This research aims to study the effect of planting density on the production traits of four fodder beet varieties in the middle region of Syria.

MATERIALS AND METHODS

The research was conducted at Al Ghab (latitude 35° 9′ N and longitude 36° 52′ E) located in the middle region of Syria during 2009/2010 and 2010/2011 autumn growing seasons. The major soil characteristics, based on the method described by Rowell (1996) were sandy clay, with low organic matters, high nitrogen and phosphorous and good content of potassium. Therefore, there was no need to apply additional nitrogen, potassium, and phosphorous fertilizers in the soil. The previous crop was grown in the experimental field was wheat. Climate data for the research area are given in Table 1. Fodder beet (*Beta vulgaris* var. crassa Mansf.) cultivars viz., Jamon, Splendids, Starmon and Vermon that were introduced by French Desprez company were used for fodder evaluation. Four varieties and four plants densities (25 × 50, 30 × 50, 25 × 60 and 30 × 60) were evaluated in a randomized complete block design as split plot arrangements with three replications. The main plots were allotted to plant densities and the sub-plots were allotted to varieties.

Individual plot size was 8 m × 5 m = 40 m^2, consisting of eight ridges of 8 m length. Sowing was done by hand on 15th November. Hand thinning to one plant per hole and re-sowing the removed seedlings were done simultaneously after 5 to 6 weeks from planting. Manual hoeing was done after 5 weeks from planting. Crop was irrigated 8 times throughout the growing period.

The land was disc-ploughed, harrowed twice, leveled and ridged 50, and 60 cm apart, and 25, and 30 cm the space between holes. Plots were harvested at 240 days after sowing on 15th June. A sample of random five plants of each variety was taken per plot from the inner ridges by hand-pulled to determine: sucrose content according to McGinnis (1982), root weight/plant (g) and shoot weight/plan (g). Three inner rows were harvested to determine number of plants/ha (plant density), biological, root and shoot yield/ha.

Data were analyzed by using the standard analysis of variance (ANOVA) technique for each year. A combined analysis for two years was done according to Gomez and Gomez (1984). Treatment means were compared by using L.S.D at 5% level of probability according to Waller and Duncan (1969), using Gene Stat Computer Program v.12. Bartelett test of homogeneity (Sokal and Rohlf, 1969) was used to compare error variance within the experiment.

RESULTS AND DISCUSSION

Root and shoot weight/plant (g)

The combined analysis (Table 2) reveals that the effect of plant spacing on root weight/plant was non-significant ($P \geq 0.05$). But for shoot weight/plant, the plant spacing 25 × 60 cm attained significantly the lowest value (137.9 g).

In terms of root weight/plant the differences between varieties were significant, where Vermon surpassed significantly than other varieties with a value of (1293 g). But the differences were not significant for shoot weight/plant. The interaction effect between spacing and varieties on root and shoot weight per plant (Table 3) showed the superiority of 25 × 50 cm for Vermon variety

Table 2. Combined analysis of variance (ANOVA) of root and shoot weight/plant (g).

Source of variance \ Trait	DF	Root weight/plant (g)			Shoot weight/plant (g)		
		MS	Variance (%)	P	MS	Variance (%)	P
Replications	2	97946.	3.26	-	2536.8	2.45	-
Year (Y)	1	3536892.	54.80	<.001	1111.0	1.76	0.222
Plant Spacing (D)	3	52328.	1.74	0.257	2849.9	2.75	0.050
D*Y	3	149647.	2.32	0.152	3061.5	4.84	0.033
Error A	6	30024.	0.47	-	1034.8	1.64	-
Varieties (V)	3	183736.	6.31	0.001	629.8	0.85	0.473
D*V	9	62130.	2.13	0.045	1395.3	1.89	0.047
Y*V	3	48653.	1.67	0.186	1519.2	2.05	0.119
D*Y*V	9	74634.	2.56	0.017	2128.9	2.88	0.008
Error B	8	64537.	2.22	-	632.3	0.85	-
Pooled Error	48	29127.	-	-	739.8	-	-

DF: Degree of Freedom, MS: Mean Square, P: Probability 0.05.

Table 3. Response of fodder beet varieties to plant spacing on root and shoot weight/plant (g).

Season	Trait / Variety (V) / Plant spacing (D)	Root weight/plant (g)					Shoot weight/plant (g)				
		Jamon	Splendids	Starmon	Vermon	Mean	Jamon	Splendids	Starmon	Vermon	Mean
2009/2010	50 × 25	896	960	877	1019	938^{b}	139.2	145.3	164.9	132.8	145.6^{a}
	50 × 30	1007	989	900	1032	982^{ab}	169.4	150.7	169.3	114.4	151.0^{a}
	60 × 25	948	908	843	1001	925^{b}	140.8	153.6	153.5	134.1	145.5^{a}
	60 × 30	1070	1045	950	1162	1057^{a}	136.8	163.7	148.4	178.3	156.8^{a}
Mean		980^{ab}	976^{ab}	893^{b}	1054^{a}	975	146.6^{a}	153.3^{a}	25.3^{a}	23.7^{a}	149.7
$L.S.D_{0.05}$		V = 105.4, D = 104.1, V*D =199.0					V = 23.7, D = 25.3, V*D = 47.7				
CV%		20.0					20.1				
2010/2011	50 × 25	1565	1268	1433	1782	1512^{a}	172.5	212.5	154.3	185.3	181.2^{a}
	50 × 30	1295	1021	1049	1618	1246^{a}	163.5	140.9	143.7	209.0	164.3^{ab}
	60 × 25	1525	1444	1308	1237	1379^{a}	148.2	168.4	119.7	85.1	130.4^{b}
	60 × 30	999	1240	1478	1489	1302^{a}	139.7	150.6	153.3	157.6	150.3^{ab}
Mean		1346^{b}	1243^{b}	1317^{b}	1532 ^{a}	1359	156.0^{ab}	168.1^{a}	142.8^{b}	159.3^{ab}	156.5
$L.S.D_{0.05}$		V = 293.3, D = 174.7, V*D =390.9					V = 33.5, D = 20.2, V*D =45.0				
CV%		15.3					15.3				

Table 3. Contd.

Pooled mean	50 × 25	1231	1114	1155	1401	1225[a]	155.9	178.9	159.6	159.1	163.4[a]
	50 × 30	1151	1005	975	1325	1114[a]	166.5	145.8	156.5	161.7	157.6[ab]
	60 × 25	1237	1176	1076	1119	1152[a]	144.5	161.0	136.6	109.6	137.9[b]
	60 × 30	1035	1143	1214	1326	1179[a]	138.3	157.2	150.9	168.0	153.6[ab]
Mean		1163[b]	1109[b]	1105[b]	1293[a]	1167	151.3[a]	160.7[a]	150.9[a]	149.6[a]	153.1
$L.S.D_{0.05}$		Y = 119.6, D = 122.4, V = 99.1, D*V=199.3					Y = 11.8, D = 22.7, V = 7.8, D*V = 15.8				
CV%		14.6					17.8				

Table 4. Combined analysis of variance (ANOVA) of root, shoot, and biological yield (ton/ha).

Trait / Source of variance	DF	Root yield (ton/ha)			Shoot yield (ton/ha)			Biological yield (ton/ha)		
		MS	Variance (%)	P	MS	Variance (%)	P	MS	Variance (%)	P
Replications	2	243.7	1.55	-	5.356	4.49	-	320.5	2.16	-
Year (Y)	1	39679.2	141.02	<.001	100.643	32.92	<.001	43776.6	146.34	<.001
Plant Spacing (D)	3	1660.7	10.54	0.008	14.398	12.07	0.006	1902.5	12.83	0.005
D*Y	3	504.3	1.79	0.226	7.218	2.36	0.147	510.0	1.70	0.243
Error A	6	157.6	0.56	-	1.193	0.39	-	148.3	0.50	-
Varieties (V)	3	183.8	1.06	0.377	15.940	8.50	<.001	208.1	1.09	0.361
D*V	9	280.8	1.61	0.139	5.333	2.84	0.009	338.5	1.78	0.098
Y*V	3	314.1	1.80	.159	4.751	2.53	0.068	310.4	1.63	0.195
D*Y*V	9	411.6	2.36	0.027	2.792	1.49	0.179	446.8	2.34	0.028
Error B	8	281.4	1.62	-	3.057	1.63	-	299.2	1.57	-
Pooled Error	48	174.2	-	-	1.874	-	-	190.5	-	-

DF: Degree of Freedom, MS: Mean Square, P: Probability 0.05.

(1401 g) and Splendids (178.9 g), respectively. Therefore, the significant highest root and shoot weight per plant was achieved by sowing at spacing of 25 × 50 cm.

The results in Table 3 show that increase in plant spacing (30 × 60 cm) of beet roots in the fields increased root and shoot weight/plant of the varieties. This may due to the increment in biomass as a result of net assimilation efficiency in shoots which was transported to roots. This result is in agreement with Al- Jbawi *et al*. (2015) who stated a significant difference between fodder beet varieties for root and shoot weight per plant. While Khogali *et al.* (2011) confirmed that fresh weight of root was not significantly affected by cultivars. Kassab *et al.* (2012) also stated a significant effect on root weight/plant.

Root, shoot and biological yield (ton/ha)

Plant spacing shows significant differences in respect of root, shoot, and biological yield (ton/ha) (Tables 4, 5 and 6).

Table 5. Response of fodder beet varieties to plant spacing on root and shoot yield (ton/ha).

Season	Trait / Variety (V) / Plant spacing (D)	Root yield (ton/ha)					Shoot yield (ton/ha)				
		Jamon	Splendids	Starmon	Vermon	Mean	Jamon	Splendids	Starmon	Vermon	Mean
2009/2010	50 × 25	58.0	68.9	53.6	64.4	61.2[a]	7.50	8.61	8.33	6.94	7.85[a]
	50 × 30	49.7	58.9	52.8	50.8	53.1[a]	6.94	7.22	8.33	4.72	6.80[a]
	60 × 25	65.0	61.1	54.7	56.6	59.4[a]	8.05	8.61	8.33	6.11	7.78[a]
	60 × 30	57.8	57.5	49.4	56.4	55.3[a]	6.11	7.50	6.39	7.22	6.81[a]
Mean		57.6ab	61.6a	52.6b	57.1ab	57.2	7.15[ab]	7.99[a]	7.85[a]	6.25[b]	7.31
L.S.D0.05		V = 11.2, D = 6.6, V*D =14.9					V = 1.12, D = 1.08, V*D =2.07				
CV%		13.8					17.5				
2010/2011	50 × 25	133.6	95.2	109.4	105.8	111.0[a]	12.22	13.33	9.72	9.16	11.11[a]
	50 × 30	97.2	71.9	78.0	85.5	83.2[b]	10.27	8.33	8.89	9.16	9.16[b]
	60 × 25	119.4	110.8	98.0	96.1	106.1[a]	9.72	10.83	7.50	5.55	8.40[b]
	60 × 30	69.1	90.2	100.5	105.2	91.3[b]	8.05	9.16	8.61	9.16	8.75[b]
Mean		104.8[a]	92.0[a]	96.5[a]	98.2[a]	97.9	10.07[a]	10.41[a]	8.68[b]	8.26[b]	9.35
L.S.D0.05		V = 13.2, D = 14.3, V*D = 26.8					V = 1.81, D = 1.22, V*D = 2.60				
CV%		17.3					15.5				
Pooled mean	50 × 25	95.8	82.1	81.5	85.1	86.1[a]	9.86	10.97	9.03	8.05	9.48[a]
	50 × 30	73.5	65.4	65.4	68.2	68.1[b]	8.61	7.78	8.61	6.94	7.98[b]
	60 × 25	92.2	86.0	76.4	76.4	82.7[a]	8.89	9.72	7.92	5.83	8.09[b]
	60 × 30	63.5	73.9	75.0	80.8	73.3[b]	7.08	8.33	7.50	8.19	7.78[b]
Mean		81.2[a]	76.8[a]	74.6[a]	77.6[a]	77.5	8.61[ab]	9.20[a]	8.26[b]	7.25[c]	8.33
L.S.D0.05		Y = 7.9, D = 8.9, V = 7.8, D*V = 15.1					Y = 0.77, D = 0.82, V = 0.80, D*V = 1.29				
CV%		17.0					16.4				

This contravene the work of Al- Jbawi *et al*. (2015), who reported that fodder beet cultivars differed significantly in their shoot yield. This corroborated with Khogali *et al.* (2011) who stated that green fodder yields were not significantly affected by cultivars.

The combined analysis shows that the differences between varieties were comparable in respect of root and biological yield (ton/ha) (Table 4). Shoot yield of the varieties Jamon and Splendids attained the highest values (8.61 and 9.20 ton/ha), respectively. Interaction between spacing and varieties was significant, for shoot and biological yield. Therefore, the significant highest shoot and biological yield was achieved by sowing at spacing of 25 × 50 cm with Splendids and Jamon (10.97 and 105.7 ton/ha), respectively. In general yield traits were increased when sown at narrow spacing of 25 × 50 cm (Tables 5 and 6).

Sucrose (%) and plant number (thousand/ha)

Combined analysis of variance shows a significant effect of varieties in terms of sucrose % and plant number ($P \leq 0.05$) (Table 7). Splendids achieved

Table 6. Response of fodder beet varieties to plant spacing on biological yield (ton/ha).

Season	Variety (V) / Plant spacing (D)	Jamon	Splendids	Starmon	Vermon	Mean
2009/2010	50 × 25	65.5	77.5	61.9	71.4	69.1[a]
	50 × 30	56.6	66.1	61.1	55.5	59.8[a]
	60 × 25	73.0	69.7	63.0	62.8	67.1[a]
	60 × 30	63.9	65.0	55.8	63.6	62.1[a]
Mean		64.8[ab]	69.6 [a]	60.5[b]	63.3[ab]	64.5
$L.S.D_{0.05}$		V = 11.3, D = 7.1, V*D = 15.6				
CV%		13.1				
2010/2011	50 × 25	145.8	108.6	119.1	115.0	122.1[a]
	50 × 30	107.5	80.2	86.9	94.7	92.3[b]
	60 × 25	129.1	121.6	105.5	101.6	114.5[a]
	60 × 30	77.2	99.4	109.1	114.4	100.0[b]
Mean		114.9[a]	102.5[a]	105.2[a]	106.4[a]	107.2
$L.S.D_{0.05}$		V = 12.8, D = 14.8, V*D = 27.6				
CV%		16.4				
Pooled mean	50 × 25	105.7	93.1	90.5	93.2	95.6[a]
	50 × 30	82.1	73.2	74.0	75.1	76.1[b]
	60 × 25	101.1	95.7	84.3	82.2	90.8[a]
	60 × 30	70.6	82.2	82.5	89.0	81.1[b]
Mean		89.8[a]	86.0[a]	82.8[a]	84.9[a]	85.9
$L.S.D_{0.05}$		Y =8.1, D = 8.6, V = 8.0, D*V = 15.6				
CV%		16.1				

higher sucrose % and plant number (6.6%, and 102.8 thousand/ha), respectively compared with all other varieties. Sucrose % and number of plants per hectare were significantly affected by plant spacing. Al- Jbawi *et al.* (2015) confirmed that sucrose % and number of plant per hectare had a significant difference between fodder beet varieties.

Interaction between plant spacing and varieties was significant, for sucrose and plant number (Table 7). Sucrose % was increased when sown at wider spacing of 30 × 60 cm (9.74%) (Table 8); this may due to small root size, because there is a negative correlation between root size and sucrose % (Sabsabi *et al.*, 2012). Also plant number per hectare was increased when sown at wider spacing of 30 × 60 cm (109.3 thousand/ha). This is because of less competition between

Table 7. Combined analysis of variance (ANOVA) of sucrose (%), and plant number (thousand/ha).

Trait / Source of variance	DF	Sucrose (%)			Plant number (thousand/ha)		
		MS	Variance (%)	P	MS	Variance (%)	P
Replications	2	1.2134	4.89	-	22.28	0.90	-
Year (Y)	1	4.4980	7.03	0.029	2087.21	38.09	<.001
Plant Spacing (D)	3	3.0275	12.20	0.006	325.00	13.19	0.005
D*Y	3	2.7961	4.37	0.042	43.04	0.79	0.535
Error	6	0.2481	0.39	-	24.64	0.45	-
Varieties (V)	3	6.6740	7.79	<.001	194.36	9.66	<.001
D*V	9	1.0484	1.22	0.303	31.38	1.56	0.155
Y*V	3	0.8953	1.05	0.381	30.21	1.50	0.226
D*Y*V	9	0.9074	1.06	0.409	50.41	2.50	0.019
Error B	8	0.6397	0.75	-	54.80	2.72	-
Pooled Error	48	0.8564	-	-	20.13	-	-

Table 8. Response of fodder beet varieties and plant spacing on sucrose (%), and plant number (thousand/ha).

Season	Trait / Variety (V) / Plant spacing (D)	Sucrose (%)					Plant number (thousand/ha)				
		Jamon	Splendids	Starmon	Vermon	Mean	Jamon	Splendids	Starmon	Vermon	Mean
2009/2010	50 × 25	10.16	9.07	9.75	10.09	9.77^{a}	81.7	89.2	76.2	79.2	81.6^{b}
	50 × 30	8.91	9.81	8.19	9.76	9.17^{ab}	74.0	88.9	87.9	73.5	81.1^{b}
	60 × 25	7.90	9.81	7.37	9.34	8.61^{b}	103.3	101.3	97.3	84.4	96.6^{a}
	60 × 30	8.95	10.09	7.99	10.01	9.26^{ab}	96.1	97.9	92.6	86.0	93.2^{ab}
Mean		8.98^{ab}	9.70^{a}	8.33^{b}	9.80^{a}	9.20	88.8^{a}	94.3^{a}	88.5^{a}	80.8^{b}	88.1
L.S.D$_{0.05}$		V = 0.81, D = 0.81, V*D =1.56					V = 13.3, D = 7.54, V*D =17.25				
CV%		10.5					10.2				
2010/2011	50 × 25	8.49	9.67	9.41	9.23	9.20^{b}	106.2	94.2	95.4	74.2	92.5 ^{b}
	50 × 30	9.44	10.80	9.61	9.69	9.89^{a}	112.2	105.3	110.8	78.5	101.7^{b}
	60 × 25	9.60	9.67	8.21	9.40	9.22^{b}	116.7	115.7	114.2	117.2	116.0^{a}
	60 × 30	9.97	10.36	9.76	10.80	10.22^{a}	124.6	129.9	120.4	127.0	125.5^{a}
Mean		9.38^{ab}	10.13 ^{a}	9.25 ^{b}	9.78^{ab}	9.63	114.9^{a}	111.3 ^{a}	110.2 ^{a}	99.2 ^{b}	108.9
L.S.D$_{0.05}$		V = 0.61, D = 0.74, V*D =1.38					V = 12.65, D = 9.02, V*D =18.79				

Table 8. Contd

CV%		9.2					9.8				
	50 × 25	9.33	9.37	9.58	9.66	9.48[a]	94.0	91.7	85.8	76.7	87.0[b]
Pooled	50 × 30	9.18	10.31	8.90	9.73	9.53[a]	93.1	97.1	99.4	76.0	91.4[b]
mean	60 × 25	8.75	9.74	7.79	9.37	8.91[b]	110.0	108.5	105.8	100.8	106.3[a]
	60 × 30	9.46	10.23	8.88	10.41	9.74[a]	110.4	113.9	106.5	106.5	109.3[a]
Mean		9.18[b]	9.91[a]	8.79[b]	9.79[a]	9.42	101.9[a]	102.8[a]	99.4[a]	90.0[b]	98.5
$L.S.D_{0.05}$		Y = 0.38, D = 0.35, V = 0.54, D*V = 0.97					Y = 7.2, D = 7.6, V = 5.7, D*V = 11.9				
CV%		9.8					10.0				

plants for light, water and nutrients.

CONCLUSIONS

The statistical analysis exhibited a significant effect of the varieties (V) and plant densities (D) for most of the production traits (biology, root and shoot yields (ton/ha), root and shoot weight per plant (g), and sucrose content (%). The least significant difference test ($LDS_{0.05}$) showed the superiority of monogerm variety Splendids in most of the production traits as compared with the other varieties with plant spacing 30 × 60 cm.

The percentage of variance confirmed that the most variations for the all studied traits were between plant spacing, followed by the varieties. Hence it is very important to focus on this factor to achieve the required production of fodder beet.

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