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Research Article

EFFECTS OF INTERCROPPING AND CULTIVAR ON SUGAR BEET (*Beta vulgaris* L.) ROOT AND SUGAR YIELD

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ABSTRACT. In order to study the effect of the intercropping of different sugar beet cultivars with soybean, Moldavian balm and proso millet on sugar beet yield a factorial experiment was conducted based on randomized complete block design with four replications in 2016 and 2017 in West Azarbayjan, Iran. The results indicated that among the intercropping patterns the highest and lowest LAI were observed in sugar beet–Moldavian balm (4.8) and sugar beet–proso millet (4.2) intercropping patterns, respectively. The highest and lowest root yield was obtained in sugar beet–Moldavian balm (50.21 ton ha^{-1}) and sugar beet–soybean (23.70 ton ha^{-1}) intercropping patterns, respectively. The highest sugar content was observed in cv. Ghazira and cropping pattern of sugar beet–Moldavian balm (16.12%) that was not significantly different with them in the sugar beet monocropping (16.11%) and sugar beet–proso millet (15.90%). Among the intercropping patterns the sugar beet–Moldavian balm and sugar beet–soybean patterns had the greatest (7.90 ton ha^{-1}) and lowest (3.66 ton ha^{-1}) gross sugar yield, respectively. The cv. Ghazira had the highest gross and pure sugar yield (12.45 and 10.59 ton ha^{-1}, respectively) among the cultivars. We can conclude that the sugar beet–Moldavian balm intercropping pattern could be introduced as sustainable production systems with high productivity and profitability.

Keywords: *Leaf area index (LAI), sustainable production, sugar content, sugar yield, tuber yield*

INTRODUCTION

Sugar beet (*Beta vulgaris*, L.), a warm season crop, is the second important sugar crop after sugarcane (*Saccharum officinarum* L.), 40% of the sugar is produced from sugar beet [1]. The sugar beet cultivated area in Iran in 2016 was about 110,000 hectares with a production of about 6 million tons [2]. Given the increasing population and the need for sugar, sugar beet is one of the industrial crops that have a major role in production of sugar in Iran. In these conditions the sugar beet growers have focused on the strategies such as development of new cultivars with tolerance to biotic and abiotic factors and high yield potential, modifying the crop row distance and planting arrangement, application of organic fertilizers and also intercropping with other crops to increase the sugar beet root yield and quality [3]. Intercropping is as an example of sustainable systems in agriculture with more resource utilization, quantitative and qualitative increase in yield, reduction of pest damage, diseases and weeds, and reduction in farmers dependence on pesticides, while maintaining product quality and marketability [4], [5]. When two crops with different plant height, vegetation and different growth patterns are cultivated at the same time in intercropping**,** they create the least competition and this increases the yield of intercropping compared with monocropping [6].

It has been reported that intercropping of proso millet (*Panicum miliaceum* L.) stylo (*Stylosanthes guianensis* L.) maximizes labor efficiency and minimizes the risk in adverse weather conditions [7]. Usmanikhail et al. [8] evaluated the intercropping of three sugar beet varieties with barley (*Hordeum vulgare* L.), wheat (*Triticum aestivum* L.), mustard (*Brassica alba* L.), lentil (*Lens culinaris* L.) and canola (*Brassica napus* L.) concluded that sugar beet yields and economic advantage were the maximum in lentil intercropping compared to other intercropping paterns. El-Fakharany et al. [9] observed that the sugar beet plants intercropped with faba bean (*Vicia faba* L.) had the highest root yield comparing with intercropping with maize (*Zea mays* L.) and cabbage (*Brassica oleracea* var. *capitata* Linneu). These results could be attributed to the least population density of pests infesting sugar beet plants in intercropping of sugar beet with faba bean.

Cultivar (genotype) selection is one of the management solutions to improve crop yield and quality in mono-and intercropping [10]. Refay [11] observed that quality parameters such as sugar content (19.9%), white sugar content (17.3%) and sugar yield (19.2 tha^{-1}) as well as chemical composition of roots were greater for Samo-2 as compared to those of other two varieties including Univers and Samo-1. Milford et al. [12] reported that leaf area and growth rate in sugar beet varieties differ mainly and selection of suitable cultivar is one of the main factors conferring sugar beet yield and quality traits. In intercropping patterns sugar beet cultivars Cauvery and Shubhra in 1:3 and 1:2 ratios indicated higher tuber and sugar yield than 1:1 ratio [10]. Usmanikhail et al. [8] studied the intercropping of three sugar beet varieties including Kaweterma, Aura and Pamela with different crops and found that among the sugar beet varieties; Kaweterma had the highest performance for growth, tuber yield and quality parameters as intercropped with lentil.

In Iran sugar beet mainly is cultivated as monocropping but in this study our objective is evaluating the 1) effect of intercropping of different sugar beet cultivars with millet, soybean (*Glycine max* L. Merr.) and Moldavian balm (*Dracocephalum moldavica* L.) on sugar beet growth, root and sugar yield.

MATERIALS AND METHODS

Site description

This experiment was conducted in 2016 and 2017 in the Khoy, West Azerbaijan, Iran (38° 29′ N, 44° 51′ E, 1247 m a.s.l.). This region has a hot and dry Mediterranean climate with cold and wet winter and hot and dry summer with 240 mm mean annual precipitation. The mean temperature and total monthly precipitation during the growing season for 2016 and 2017 in Khoy, West Azerbayjan is presented in Table 1. The detail of soil analysis for experimental site is presented in Table 2.

Table 1. *The mean temperature (˚C) and total monthly precipitation (mm) during the growing season for 2016 and 2017 in Khoy, West Azarbayjan, Iran*

Months	2016		2017	
	Temperature (˚C)	Precipitation (mm)	Temperature (˚C)	Precipitation (mm)
January	-0.2	19.7	-7.4	19.0
February	-0.2	21.7	-7.4	10.1
March	8.7	13.1	7.6	17.2
April	13.4	38.3	12.9	52.1
May	19.1	12.8	18.1	49.1
June	21.8	66.7	24.1	5.1
July	25.7	12.8	27.8	1.6
August	27.0	2.5	27.7	1.5
September	20.9	7.2	23.1	0.0
October	13.2	29.7	13.7	19.6
November	5.4	1.5	8.0	39.5
December	-1.8	16.3	4.0	3.8

Table 2. *The physical and chemical properties of the soil at experimental site*

Texture	Sand (%)	Silt (%)	Clay (%)	K (mg/kg)	P (mg/kg)	N (%)	OC[1] (%)	pH	EC (dS/m)
Loam	31.4	48.0	20.6	222	9.3	0.09	0.85	8.04	0.81

[1]OC: Organic carbon

Experimental design and field practice

The experiment was conducted as factorial based on randomized complete block design with 15 treatments and four replications. The first factor was sugar beet cultivar in three levels; Kevin (Strube co., Germany), Ghazira (Kuhn & co. International B.V., Netherlands) and Vaclav (Strube co., Germany), and the second factor was cropping patterns at four levels; monocropping of sugar beet, intercropping of sugar beet and soybean (50:50 ratio), intercropping of sugar beet and Moldavian balm (50:50 ratio) and intercropping of sugar beet and proso millet (*Panicum miliaceum* L.) (50:50 ratio). The intercropping treatments were planted based on replacement design and 50:50 ratios. Also the monocropping of soybean, Moldavian balm and proso millet were considered in the experiment.

During both years of study, field practices consisted of fall mold–board plowing followed by disking and cultivation in spring. The experiment was conducted in the field that was under organic production system in previous eight years as no chemical fertilizers, pesticides and herbicides were used in production systems. Sugar beet was planted on 30 March 2016 and 29 March 2017. Soybean, Moldavian balm and proso millet were planted on 18 April 2016 and 16 April 2017. At all treatments, the area of each plot was 16 (4×4) m^2, with 8 rows and 4 m length, and 50 cm row space. Planting densities for sugar beet, soybean, Moldavian balm and proso millet was 10, 40, 30 and 30 plants m^{-2}, respectively. The sowing depths for sugar beet, soybean, Moldavian balm and proso millet were 3–4, 3–5, 1–2 and 2–3 cm, respectively.

Data collection

The leaf area index (LAI) of canopy was measured by Accu PAR device (LP–80, Decagon Device INC., USA) at 92 DAP of sugar beet (in 2016) and 91 DAP (in 2017). At maturity stage, the final harvest of sugar beet root was done on 27 October 2016 and 25 October 2017 from central rows of plots (a total area of 6 m^2 from each plot) and the root yield per unit area was determined for different cultivars and cropping systems. Sugar beet root samples were transferred to the Khoy Sugar Beet Laboratory for quality analysis. The sugar content (%), gross and pure sugar yield ha^{-1}, were determined.

Statistical analysis

The SAS Version 9.0.3 was used for ANOVA. The data that were used in ANOVA met the assumptions of homogeneity of variance and normality and did not need transformation. The Duncan´s multiple range test was used for mean comparison at 5% probability level.

RESULTS AND DISCUSSION

Leaf area index (LAI)

The effect of year and sugar beet cultivar was not significant on LAI. The sugar beet LAI was significantly ($p \leq 0.05$) affected by the cropping pattern. The highest leaf area index (5.492) was belonged to the monocropping of sugar beet (Table 3). Among the intercropping patterns the highest and lowest LAI were observed in sugar beet–Moldavian balm (4.792) and sugar beet–proso millet (4.183) intercropping patterns, respectively (Table 3).

Table 3. *The mean comparison of sugar beet LAI and root yield affected by the cropping pattern (The means with the same letter in each column are not significantly different at p≤0.05)*

Cropping pattern	LAI	Root yield (ton ha^{-1})
sugar beet monocropping	5.492^{a}	98.47^{a}
sugar beet–soybean	4.341^{c}	23.70^{d}
sugar beet–Moldavian balm	4.792^{b}	50.21^{b}
sugar beet–Proso millet	4.183^{c}	28.61^{c}

The decrease in sugar beet LAI in intercropping patterns can be attributed to the reduction of light with lower canopy layer, especially in soybean and proso millet intercropping with sugar beet. Manjunath and Salakinkop [13] reported that in soybean and Proso millets intercropping the LAIs of both crops in monocropping was higher than those in intercropping. Also, Arshad and Ranamukhaarachchi [14] in intercropping of sweet sorghum (*Sorghum bicolor* L.) and mung bean (*Vigna radiata* L.) reported that the LAIs of both crops were higher in monocropping than those of intercropping.

Root yield

The effect of year and sugar beet cultivar was not significant on root yield. The sugar beet root yield was significantly ($p \leq 0.05$) affected by the cropping pattern. The highest root yield (98.47 ton ha^{-1}) was obtained in monocropping of sugar beet (Table 3). Among the intercropping patterns the highest and lowest root yield were obtained in sugar beet–

Moldavian balm (50.21 ton ha^{-1}) and sugar beet–soybean (23.70 ton ha^{-1}) intercropping patterns, respectively (Table 3).

Among the intercropping pattern the greatest root yield was obtained in sugar beet–Moldavian balm pattern. The reason of decrease in root yield in sugar beet–soybean and sugar beet–proso millet patterns could be attributed to the shadowing of soybean and proso millet on sugar beet canopy and consequently decrease in sugar beet IPAR and root yield. Abou Khadra et al. [15] observed that in the intercropping of sugar beet and wheat (*Triticum aestivum* L.), the highest root yield was related to the monocropping of sugar beet. Similar result was observed by Heba et al. [16] when sugar beet was intercropped with faba bean (*Vicia faba* L.). The effect of intercropping on the root yield of sugar beet mainly depends on the nature and growth habit of the companion crop. Abdel Motagally and Metwally [17] reported that the highest root yield of sugar beet was achieved for monocropping, when sugar beet was intercropped with faba bean [17].

Sugar content (%) and sugar yield

The interaction effect of year × sugar beet cultivar was significant ($p \leq 0.01$) on sugar content. In 2016 the sugar content of cv. Ghazira (15.89%) was greater than those of cv. Kevin and Vaclav (Table 4). In 2017 the sugar content of cultivars was not significantly different. The sugar contents of cv. Kevin and Vaclav in 2017 were greater than those in 2016. The sugar content of cv. Ghazira was not significantly different in 2016 and 2017 (Table 4). The interaction effect of year × cropping pattern was significant ($p \leq 0.05$) on sugar content (Table 5). In 2016 the sugar content was the greatest in sugar beet–Moldavian balm (15.66%) that was not significantly different with sugar beet monocropping and sugar beet–proso millet patterns. The lowest sugar content (14.89 %) was obtained in sugar beet–soybean intercropping and was not significantly different with sugar beet–proso millet intercropping. In 2017 the sugar content in sugar beet–soybean intercropping (16.03%) was the greatest and was not significantly different with sugar beet monocropping and sugar beet–Moldavian balm intercropping. In 2017 the lowest sugar content (15.48%) was obtained in sugar beet–proso millet intercropping that was not significantly different with sugar beet monocropping. The sugar content of sugar beet–soybean intercropping in 2017 (16.03%) was significantly greater than that of 2016 (14.89%).

The interaction effect of cultivar × cropping pattern was significant ($p \leq 0.05$) on sugar content (Table 5). The highest sugar content was observed in cv. Ghazira and cropping pattern of sugar beet–Moldavian balm (16.12%) that was not significantly different with them in the sugar beet monocropping (16.11%) and sugar beet–proso millet (15.90%). In cv. Kevin the sugar contents were not significantly different among the intercropping patterns. In cv. Vaclav, among the cropping patterns the sugar beet–proso millet intercropping had the lowest sugar content (14.87 %) that was not significantly different with that in the sugar beet mono–cropping (15.28%).

Table 4. *The means comparison for interaction effect of cultivar × year on sugar content of sugar beet (The means with the same letter in each column are not significantly different at p≤ 0.05)*

Sugar content (%)		
Cultivar	**2016**	**2017**
Kevin	15.00^{b}	15.83^{a}
Ghazira	15.89^{a}	15.89^{a}
Vaclav	15.06^{b}	15.78^{a}

Table 5. *The means comparison for interaction effect of cropping pattern × year and cropping pattern × cultivar on sugar content of sugar beet (The means with the same letter in each column are not significantly different at p≤ 0.05)*

	Sugar content (%)				
	Year		Sugar beet cultivar		
Cropping pattern	2016	2017	Kevin	Ghazira	Vaclav
sugar beet monocropping	15.45^{bc}	15.84^{ab}	15.56^{abc}	16.11^{a}	15.28^{cd}
sugar beet–soybean	14.89^{d}	16.03^{a}	15.19^{cd}	15.44^{bc}	15.75^{abc}
sugar beet–Moldavian balm	15.66^{abc}	15.98^{a}	15.57^{abc}	16.12^{a}	15.77^{abc}
sugar beet–Proso millet	15.26^{cd}	15.48^{bc}	15.34^{cd}	15.90^{ab}	14.87^{d}

Gross and pure sugar yield was significantly affected by cropping pattern (p≤0.05). The greatest gross sugar yield (15.41 ton ha-1) was observed in sugar beet monocropping (Figure 1). Among the intercropping patterns the sugar beet–Moldavian balm and sugar beet–soybean patterns had the greatest (7.90 ton ha-1) and lowest (3.66 ton ha-1) gross sugar yield, respectively. The results for pure sugar yield were similar to the gross sugar yield, and only the values of pure sugar yields were lower than those of gross sugar yield (Figure 1).

The effect of sugar beet cultivar was significant on gross sugar yield (p≤ 0.05) and pure sugar yield (p≤ 0.01). The cv. Ghazira had the highest gross and pure sugar yield (12.45 and 10.59 ton ha-1, respectively) among the cultivars (Figure 2). The gross and pure sugar yield in cv.s Kevin and Vaclav were not significantly different.

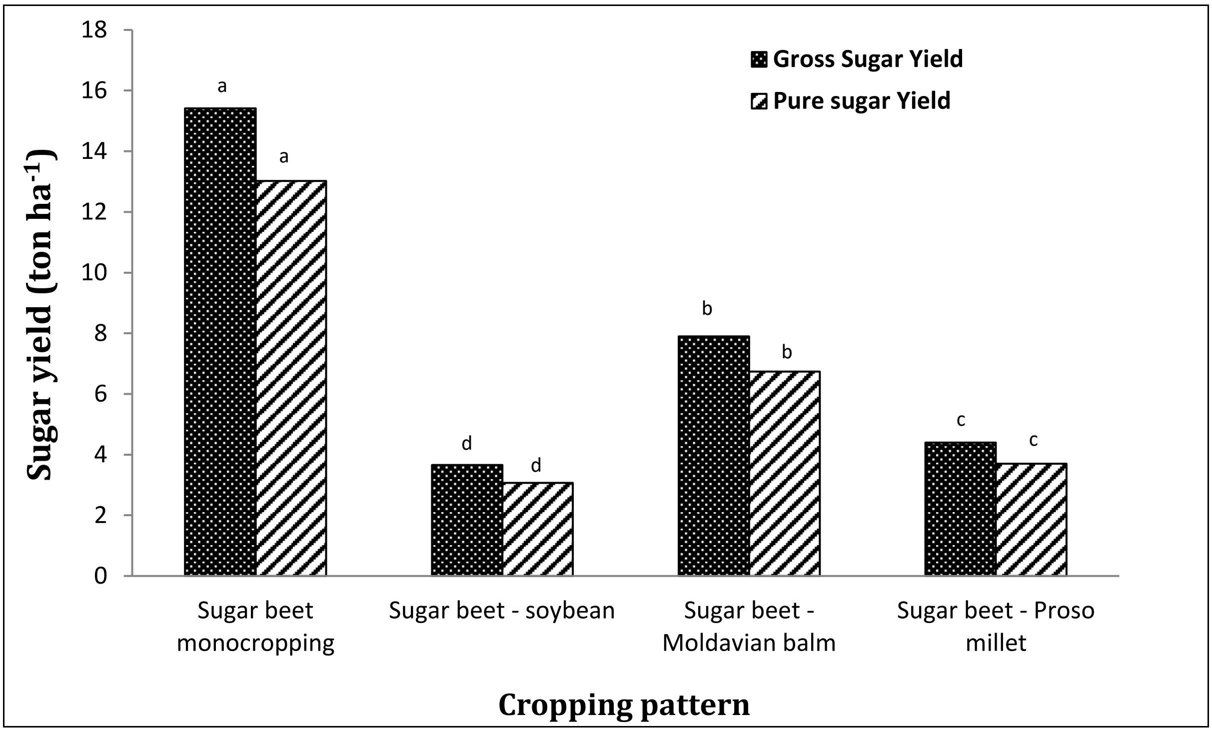

Figure 1. *The mean comparison for effect of cropping pattern on pure and gross sugar yield (The means with the same letter are not significantly different at p≤ 0.05)*

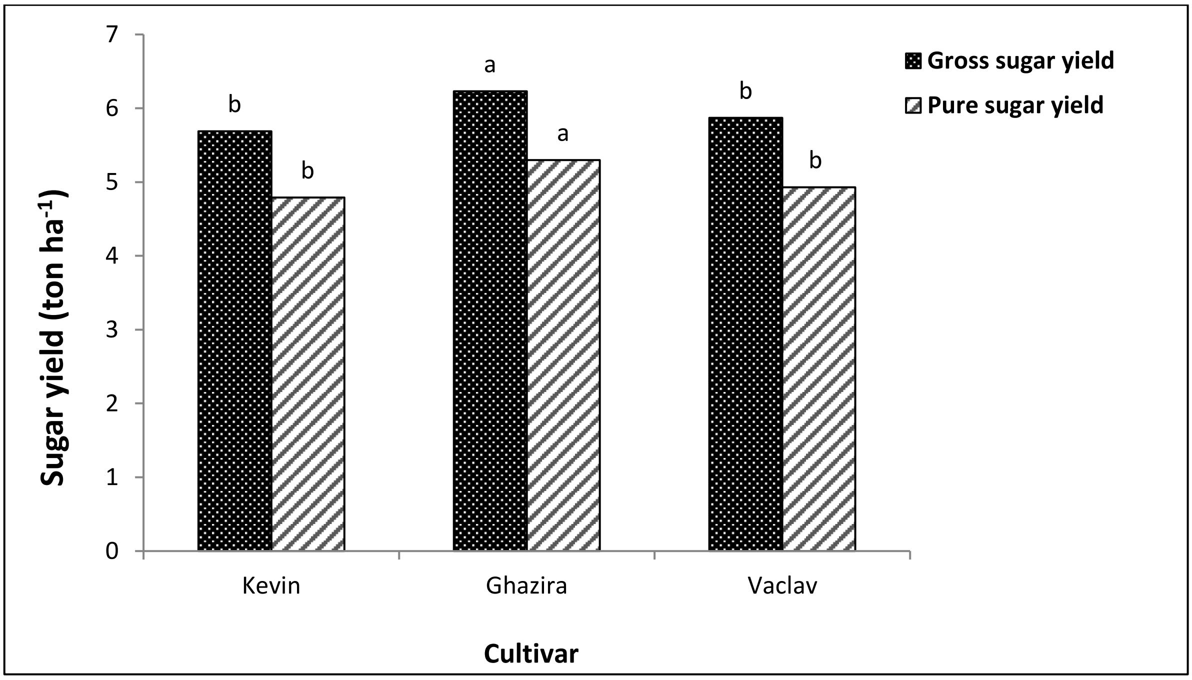

Figure 2.*The mean comparison of gross sugar yield and pure sugar yield affected by the cultivar (The means with the same letter in each column are not significantly different at p≤0.05)*

The sugar content was affected by interaction effects of year, sugar beet cultivar and cropping pattern. In 2017 the sugar contents of cv.s Kevin and Vaclav were greater than those in 2016. This may be attributed to the lower precipitation in April-September for 2017 than 2016 (Table 2). The different response in term of sugar content could be due to various environmental factors such as temperature and precipitation in two years of the study [18], [19]. Mahrokh and Khajehpour [20] also reported that in drought stress condition the sugar content of sugar beet increased. Generally the sugar beet–Moldavian balm intercropping had the greatest sugar content in both years and all sugar beet cultivars. It could be concluded that cv. Ghazira is the best cultivar for sugar beet intercropping specially with higher crops. Previous studies [11], [12] also confirmed that the sugar beet cultivars are different in sugar content. According to reports, all three cv.s Kevin, Ghazira and Vaclav, have high sugar content and low sugar impurities [21].

CONCLUSIONS

We observed that in sustainable production system of sugar beet the intercropping with other crops could increase the productivity of cropping system. The differences in tuber and sugar yield for intercropping patterns between two years could be explained by differences in average temperature and precipitations in growth season. The sugar beet–soybean and sugar beet–Moldavian balm intercropping patterns could be recommended in sustainable production systems in order to increase crop production per unit area without chemical fertilizer and pesticide application that is consistent with environmentally-friendly agriculture.

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