Journal of Sugar Beet
http://jsb.areeo.ac.ir/
Journal of Sugar Beet 2015, 30(2)

Effects of sprinkler and furrow irrigation systems on powdery mildew disease severity in sugar beet

J. Basati[(1)*], M. Sheikholeslami[(2)], A. Jalilian[(2)], M.R. Jahadakbar[(3)] and F. Hamdi[(4)]

[(1)] *Instructor of Agricultural and Natural Resources Research Center Kermanshah - Kermanshah, Iran.*
[(2)] *Assistant professor of Agricultural and Natural Resources Research Center Kermanshah - Kermanshah, Iran.*
[(3)] *Instructor of Agricultural and Natural Resources Research Center Isfahan- Isfahan, Iran.*
[(4)] *Master expert of Sugar Beet Seed Institute (SBSI)- Karaj, Iran.*

Basati J, Sheikholeslami M, Jalilian A, Jahadakbar MR, Hamdi F. Effects of sprinkler and furrow irrigation systems on powdery mildew disease severity in sugar beet. J. Sugar Beet. 2015; 30(2): 73-79.

Received May 20, 2014; Accepted October 4, 2014

ABSTRACT

Powdery mildew is a fungal disease which causes a serious reduction in both root yield and sugar yield in sugar beet fields. This study aimed to determine the effect of different irrigation methods on powdery mildew's infection severity in sugar beet fields. Eight sugar beet commercial cultivars with different susceptibility and resistance to powdery mildew were evaluated under sprinkler and furrow irrigation systems in randomized complete block design with four replications at Mahidasht Research Station, Kermanshah, Iran in 2011-12. Combined analysis of variance showed that the disease severity under furrow and sprinkler irrigation was about 49.1 and 5.9%, respectively. Therefore, sprinkler irrigation is more effective on the control of sugar beet powdery mildew than furrow irrigation. A wide range of infection was observed among cultivars. The highest (36.6%) and lowest (10.62%) rate of infection was observed in SBSI004 and Brigitta, respectively. Although not statistically significant, root yield was 0.7 t ha^{-1} higher in furrow than sprinkler irrigation. The highest root yield (65.13 t ha^{-1}) along with the lowest infection percentage was observed in Brigitta cultivar. Irrigation method had significant effect ($P < 0.05$) on sugar content, so that furrow irrigation yielded higher sugar content (15.04%) than sprinkler irrigation (13.59%). As a result, furrow irrigation resulted in 1.45% higher sugar content and less amino-N and Na accumulation in the root.

Keywords: disease severity, *Erysiphe betae*, furrow and sprinkler irrigation, sugar beet

INTRODUCTION

Powdery mildew is one of the sugar beet diseases which causes reduction in root yield and sugar content. The disease is almost widespread in all sugar beet production areas in Iran (Basati 2008; Basati et al. 2003). The causal agent of powdery mildew is *Erysiphe betae* fungus (Weltezien 1963) and it acts at the time when sugar beet is synthesizing sugar and accumulating it. The disease damage varies in different regions. The disease spread and severity is largely dependent on weather condition in last winter and the summer of planting year so that moderate winter following dry and warm summer results in the quick beginning and spread of the disease (Whiteny 1987; Asher and Dewar 2001; Asher 1987; Asher and williams 1991,1992). In recent years, an average of 150000 hectares of arable lands were allocated to sugar beet planting in Iran. Different irrigation methods are used by farmers and most fields are irrigated by furrow or surface irrigation method. However, sprinkler irrigation is also used in some areas. Sprinkler irrigation not only reduces water consumption per hectare, but also prevents some diseases widespread (Alimoradi et al. 1998). All irrigation methods such as furrow, basin, and sprinkler are used in sugar beet planting in Iran (Alimoradi et al. 1998). Most studies showed that irrigation methods have remarkable impact on disease control. Miller and Arastad

*Corresponding author's email: basatij@yahoo.com

(1976) showed that high water consumption leaches out nutrients from plants reach and increases pest and plant disease problems which ultimately reduce performance.

Improper water management increases insects and weed population and also disease widespread which consequently prevents steady growth of sugar beet (Dainello and Hall 1996). In a study by Malekzadeh et al. (2009), the armyworm population was significantly lower under sprinkler irrigation than furrow irrigation. Sprinkler irrigation can have significant effect on the reduction of sucking pest damages and is more effective than furrow irrigation (Yosupov et al. 1975). Christman (1976) suggested that this type of irrigation results in reduction of the disease widespread and population of some sugar beet insects including agrotis (*Agrotis segetum*), sugar beet aphids, and flea (*Chaetocnema tibialis* I.). Another study showed that sprinkler irrigation controls root aphid more effectively than furrow irrigation and aphid population in furrow irrigation was more than sprinkler irrigation (Parihar and Name Singh 1999).

The relationship between irrigation method and sugar beet powdery mildew has been studied before. Research conducted in the USA showed that the semi-arid and hot conditions are suitable for the outbreak of the disease. Micro-climate conditions developed under sprinkler irrigation increase humidity and slow outbreak of the disease. In general, the widespread of powdery mildew disease under sprinkler irrigation is slower than furrow irrigation (Gallian 2001). In another experiment, Gallian (2012) showed that powdery mildew has more widespread in furrow than sprinkler irrigation because sprinkler irrigation rinses the causative agent of the disease from leaf surface and prevents the disease stability. In another study, Gallian (2002) illustrated that sprinkler dramatically reduced powdery mildew widespread. Sprinkler irrigation rinses fungal hyphae with less infection since this fungus needs warm and dry condition for distribution. Therefore, sprinkler irrigation decreases infection (O'Connell, 2013).

Because under microclimate condition resulted from sprinkler irrigation, the humidity is more than fungi need, the disease development is slow. Therefore, sprinkler irrigation limits the disease development (Gallian, 2001). Other studies in the United States showed that the fungi conidia are able to grow under any humidity condition, so the fungus can develop and cause infection throughout the season. Only under rainy circumstances, the disease widespread is limited (Hill et al 1975; Hill et al 1980). Powdery mildew disease infects sugar beet fields in Idaho, Oregon, and Washington states every year. Other agronomic factors have little impact on the powdery mildew widespread, but sprinkler irrigation significantly reduces the powdery mildew (Gallian 2002).

Irrigation method has significant effect on root yield, qualitative traits, and the development or nondevelopment of some diseases. Study of the effects of furrow and sprinkler irrigation on the quantitative and qualitative characteristics of sugar beet showed that under furrow irrigation, sugar beet root yield and sugar yield per hectare was higher than sprinkler irrigation (Eckoff et al. 2001). In another study, three irrigation methods including sprinkler, drip, and furrow were studied and results showed that in sprinkler irrigation, the sugar beet root yield was higher than the other irrigation methods (Butrus and Nimal 1981).

It was shown that the water consumption under sprinkler irrigation was on average 22.2% lower than furrow irrigation. Root yield under sprinkler irrigation was higher than furrow and drip irrigation methods, but sugar content was not significantly different. Moreover, sprinkler irrigation caused higher extractable sugar per hectare than the other two methods (Rezvani et al. 2008). Therefore, the type of irrigation method not only influenced the disease severity but also influenced quantitative characteristics such as root yield and qualitative traits such as nitrogen and sodium. Under furrow irrigation, the root yield was higher than sprinkler irrigation but the amount of some impurities such as nitrogen and sodium decreased (Davidoff and Hanks 1989; Hosainpor 2006; Safarian et al. 2006; Malekzadeh et al. 2009; Basati et al. 2011).

MATERIALS AND METHODS

In this study, eight foreign commercial sugar beet cultivars were evaluated under two irrigation (sprinkler and furrow) methods in randomized complete block design with four replications at Mahidasht Research Station, Kermanshah, Iran in 2011-12 (Table 1). In the first year of the study, the infection was created artificially but following experiment showed that the infection was as high as can be used for treatments differentiation. Therefore, in this station, the powdery mildew natural infection is sufficient for treatment differentiation. The irrigation frequency was 16 times.

Soil samples were taken from 0-30 cm depth

Table 1. Genotypes tested at Mahidasht Research Station in 2011-12

No.	Cultivar	Characteristics
1	SBSI004	Susceptible to powdery mildew, domestic cultivar, diploid
2	SBSI005 (Pars)	Susceptible to powdery mildew, domestic cultivar, diploid
3	SBSI006 (Torbat)	Susceptible to powdery mildew, domestic cultivar, diploid
4	SHIRIN	Susceptible to powdery mildew, domestic cultivar, diploid and Z type
5	BRIGITA	Resistant to powdery mildew, foreign cultivar, diploid
6	ISELLA	Susceptible to powdery mildew, foreign cultivar, diploid
7	14442	Resistant to powdery mildew, resistant bulk, diploid
8	Rasol	Susceptible to powdery mildew, domestic cultivar, triploid, N type

Table 2. Analysis of variance for root yield, sugar content, sugar yield, N, Na, K and infestation rate

S.O.V.	df	Root yield	Sugar content	Sugar yield	N	Na	K	Infestation rate
Year[a]	1	21.9	11.33	3.48	2.83*	1.37	4*	250.5**
Error 1	6	27.8	3.04	2.16	0.28	0.54	0.52	14.59
Irrigation	1	15.65	66.8*	51.3	6.18	3.21*	7.22	58887.4*
Irrigation × year	1	42.4	0.35	3.83	0.11	0.001	0.52	361.4**
Error 2	6	9.72	1.73	0.68	0.30	0.12	0.19	5.11
Cultivar	7	1227.02**	44.7**	51.88**	7.13*	0.63	1.79	1071.5*
Cultivar×year	7	50.43*	5.8*	4.5*	1.17*	0.66*	1.08*	237.1**
Cultivar×irrigation	7	4.51	3.53	1.57	1.9	0.22	0.34	1030.8*
Cultivar×irrigation×year	7	88.3**	9.28**	14.32**	2.09**	1.64**	1.1*	162.3**
Error 3	90	19.7	1.62	1.32	0.33	0.19	0.39	6.3
CV	-	7.92	8.89	10.16	19.85	16.69	13.09	9.06

[a]Year was considered as random.
* and **, significant at 5 and 1%, respectively

and fertilizer recommendation was performed based on soil analysis. Seedbed was prepared in March following wheat - fallow - sugar beet rotation. Each entry was represented by a 3-row plot with 60 cm apart and 8 m length. Plant to plant distance was 20 cm. At harvest, 3 m from the beginning and end of the row was discarded as border. When the severity of the disease reached its maximum, recording was conducted to determine the extent of infestation. For determination of infestation percentage and selection of healthy plants, the index suggested by Paulus et al. (2001) was used which is the latest index used for powdery mildew damage. In this method, the infestation score of 0-5 was attributed to the leaves based on 10, 35, 65, 90 and 100% infestation. For each treatment in eacg replication, 100 leaves were recorded and infestation score was attributed. Using the given score, K (rate of infestation) was estimated for each replication as follows:

$$K \quad \frac{\Sigma \text{ (Given Score x leaf number with given score)}}{\text{Total leaves}}$$

$$R= K1+ K2+K3+\ldots+Kn /n$$

where R is the sum of replications. Using Paulus et al (2001) index, infestation percentage was calculated using the following formula:

$$\text{Percentage MLAD} = 100\ [\sin(R*18)]^2$$

where MLAD is a mature leaf area disease and 18 is a static factor. Root numbers were counted and weighed for each plot and 25 roots were sent to Sugar Technology laboratory of Sugar Beet Seed Institute for quality analysis. Infestation scores were transformed using the arcsin√Y; however original data were used since no difference was observed between transformed and original data (Yazdisamadi 1997). Data were analyzed using SAS software.

RESULTS AND DISCUSSION

Powdery mildew status under sprinkler irrigation

Year treatment had significant effect ($P < 0.01$) on infestation rate (Table 2). The average infestation rate in the first and second years was 28.93 and 16.13%, respectively (Tables 2 and 3). Significant difference was also observed among irrigation methods. Under sprinkler and furrow irrigation, the infestation rate was 5.9 and 49.1%, respectively. Significant difference ($P < 0.05$) was also observed among cultivars for infestation score. The highest (36.5) and lowest (10.62%) infestation rate was observed in SBSI004 and Brigitta, respectively. The population 14442 showed 21.62% infestation (Table 2, 3). Cultivar ×

Table 3. Mean classification of root yield, sugar content, sugar per hectare, N, Na, K, and infestation percentage

Year	Irrigation method	Cultivar	Root yield (t ha^{-1})	Sugar content	Sugar yield (t ha^{-1})	N	Na	K	Infestation (%)
						meq/100 g root			
1			55.56a	14.02a	11.15a	3.07a	2.54a	4.59b	28.93a
2			54.74a	14.61a	11.48a	2.77b	2.74a	4.95a	16.13b
	Furrow		55.5a	15.04a	11.94a	2.7a	2.48b	5.01a	49.1a
	Sprinkler		54.8a	13.59b	10.68a	3.14a	2.8a	4.53a	5.9b
		SBSI004	55.36cd	13.31cde	10.65c	3.34ab	2.61a	4.56ab	36.5a
		SBSI005	59.17b	12.46ed	10.84c	3.5ab	2.77a	4.8ab	31.25ab
		SBSI006	63.75a	11.73e	10.79c	3.27abc	2.78a	4.66ab	30.5ab
		SHIRIN	51.96d	14.18bcd	10.58c	2.9bcd	2.68a	4.65ab	33.8ab
		BRIGITA	65.13a	15.61ab	14.66a	1.95e	2.24a	4.4b	10.62c
		ISELLA	58.03bc	15.25abc	12.71b	2.23de	2.86a	4.55ab	26.36ab
		14442	37.76e	15.65ab	8.51d	2.38cde	2.48a	5.4a	21.62bc
		Rasol	50.05d	16.34a	11.75bc	3.8a	2.7a	5.14ab	29.62ab

Means with similar letters in each column are not significantly different.

irrigation interaction was also significant ($P < 0.05$). All treatments showed lower infestation under sprinkler irrigation.

Powdery mildew outbreaks occur under certain circumstances such as air moisture and microclimate of the field. If the moisture content is higher than the pathogen's optimum level, its activity decreases and consequently the damage reduces. Sprinkler irrigation causes unfavorable condition for the disease since it increases microclimate moisture, rinses the fungi from leaf surface, and prevents conidial growth. Results showed that under sprinkler irrigation, the infestation level was low because of unfavorable condition for the disease widespread. Results of this study are in accordance with other studies which showed that sprinkler irrigation decreases the disease widespread but furrow irrigation contributes to the leaf and root disease widespread as well as pest population increase (Yosupov et al. 1975; Christman 1976; Miller and Arastad 1976; Dainello and Hall 1996; Gallian 2001 and 2012; Parihar and Nam Singh 1999). In this study, sprinkler irrigation application controlled the infestation rate up to 5.9%; however, results of Kermanshah showed that four times insecticide application decreased infestation rate to 20%. Thus, it seems that sprinkler irrigation was more effective in powdery mildew control than furrow irrigation.

The disease infestation had a fluctuation in different years so that the infestation rate under furrow irrigation in the first and second years was 52.24 and 46.08%, respectively with an average of 49.1%, and for sprinkler irrigation it was 6.12 and 5.62%, respectively with an average of 5.9%, although the effect of sprinkler irrigation on the disease control was confirmed in the both years. In this study, both susceptible and resistant cultivars were used. Resistant cultivars showed low infestation under furrow irrigation albeit the rate was lower than susceptible cultivars. However, under sprinkler irrigation, both susceptible and resistant cultivars did not show much difference in infestation rate since sprinkler irrigation prevented the disease widespread. The disease infestation never reaches zero percentage since some leaves especially the old ones remain away from direct contact with water and thus a low infestation rate can be seen on them. In this study, about 6% infestation was recorded under sprinkler irrigation. Therefore, resistant cultivars also showed low infestation rate of 5-6% which illustrates that under sprinkler irrigation, the infestation rate was limited to 5-6%.

Brigitta, Isella and 14442 had lower rate of infestation compared with the other cultivars accompanied by lower N content in root. However, cultivars with higher rate of infestation accumulated more nitrogen in root. A correlation was found between infestation rate and N content but it is not still clear whether infestation results in high N accumulation or N increase in the root causes more infestation widespread in the leaves. It seems that cultivars with more ability to absorb N provide better opportunity for higher infestation since leaves become more succulent and fresh and this condition makes fungal hyphae establishment easier. Another assumption is that cultivars with high level of infestation force the plants to absorb more N due to high density of fungal hyphae establishment on leaves and feeding of the leaves. This was confirmed by Basati (2000) in Kermanshah. Genotypes with more nitrogen in the roots showed higher infestation rate.

Table 4. Classification of irrigation × cultivar interaction for root yield, sugar content, sugar yield, N, Na, K, and infestation rate

Cultivar	Irrigation method	Root yield (t ha^{-1})	Sugar content	Sugar yield (t ha^{-1})	N	Na	K	Infestation (%)
					meq/100 g root			
1	1	56.3a	13.90ab	11.36ab	3.10a	2.29a	4.63a	66a
1	2	54.3ab	12.72ab	9.94ab	3.59a	2.93a	4.49a	7c
2	1	59.9a	14.05ab	12.07ab	3.12a	2.44a	4.96a	57ab
2	2	58.4a	10.88b	9.62ab	3.89a	3.10a	4.64a	5.5c
3	1	63.6a	12.63ab	11.60ab	2.93a	2.70a	4.69a	55ab
3	2	63.8a	1083b	9.99ab	3.61a	2.87a	4.63a	6c
4	1	52.6ab	14.14ab	10.70ab	2.09a	2.52a	4.84a	62a
4	2	51.3ab	14.22ab	10.47ab	3.70a	2.84a	4.45ab	5.5c
5	1	65.7a	16.05ab	15.25a	1.61a	2.19a	4.77a	15c
5	2	64.6a	15.17ab	14.08ab	2.30a	2.29a	4.04a	5.5c
6	1	58.5a	15.85ab	13.30ab	2.16a	2.68a	4.86a	46ab
6	2	57.5a	1465ab	12.12ab	2.30a	3.05a	4.25a	6c
7	1	37.9b	16.65a	9.09ab	2.47a	2.35a	4.85a	37b
7	2	37.4b	14.65ab	7.93b	2.30a	2.62a	4.95a	6.25c
8	1	49.4ab	17.05a	12.21ab	4.15a	2.70a	5.46a	53ab
8	2	50.7ab	15.64ab	11.30ab	3.46a	2.70a	4.82a	5.5c

Means with similar letters are not significantly different.

Root yield

The effect of year on root yield and sugar content was not significant. Year had significant effect on N and K and the amount of these impurities was different within the two-year experiments. Year had also significant effect on infestation rate so that the infestation rate was significantly higher in the first year compared with the second year (Table 2). Irrigation method had no significant effect on root yield. Under furrow irrigation, root yield was 0.7 t ha^{-1} higher than sprinkler irrigation (Table 2, 3, Davidoff and Hanks 1989; Hoseinpor 2006; Malekzadeh et al. 2009). Contrary to these results, other studies showed that sprinkler irrigation yielded higher root yield than furrow irrigation (Butrus and Nimal 1981; Eckoff et al. 2001; Rezvani et al. 2008; Jahedi et al 2012). Thus, we see that irrigation alone will not increase or decrease root yield. Although there may be some difference in root yield in each of irrigation methods but the difference is not significant and it cannot be concluded that irrigation method influences root yield. Under furrow irrigation, more water is available to plant (Rezvani et al. 2008) and as a result, it is expected that obtained root yield must be higher than sprinkler irrigation. Sprinkler irrigation can be considered as a kind of stress compared with furrow irrigation since less water is available to plant. Studies showed that under both irrigation methods, root yield and other characteristics such as sugar content, N, Na and K varied under stress. Under normal furrow irrigation, root yield was higher than other treatments, whereas under stress condition, the obtained root yield was lower than normal irrigation (Carter et al. 1980; Fotohi et al. 2008; Abaspor 2003; Ebrahimipak 2010; Jehadakbar 2003; Noorjo and Bagaee 2004). Owing to the fact that under normal irrigation, more water is available to the plant and in furrow irrigation more water was available compared with sprinkler irrigation (Rezvani et al. 2008), higher root yield is expected and likewise, in this study furrow irrigation yielded a bit higher root yield than sprinkler irrigation.

Sugar content

Irrigation method had significant effect on sugar content ($P < 0.05$). Results showed that sugar content under furrow irrigation (15.04%) was higher than sprinkler irrigation (13.59%, Table 2). Similarly, Davidoff and Hanks (1989) reported that by increasing the amount of water, sugar content increased in root. In most studies, water stress resulted in sugar content increase in plant (Carter et al. 1980; Fotohi et al. 2008; Abaspor 2003; Ebrahimipak 2010; Jehadakbar 2003; Noorjo and Bagaee 2004). Water stress condition is similar to sprinkler irrigation since less water is provided to plant compared with furrow irrigation. Results of this study are in accordance with Davidoff and Hanks (1989).

Sugar yield

Irrigation method had no significant effect on sugar yield. Under furrow and sprinkler irrigation methods, 11.94 and 10.68 t ha^{-1} white sugar yield was obtained, respectively (Tables 2 and 3). Furrow irrigation produced 1.26 t ha^{-1} higher sugar yield than sprinkler irrigation. Under furrow irrigation, plants receive 22.2% more water than sprinkler irrigation (Rezvani et al. 2008) and this results in more root growth and sugar content and finally sugar yield. Under furrow irrigation, the disease rate was high which imposed damage to root yield and sugar content. Under sprinkler irrigation, owing to the disease control, the disease severity almost wiped out and the performance achieved approximately the same as furrow irrigation. Hassanpour (2006) showed that furrow irrigation produced about 6% more root yield than sprinkler irrigation; however, in this study, furrow irrigation resulted in 0.7 t ha^{-1} higher root yield than sprinkler irrigation and this small difference was achieved through the disease control. Therefore, sprinkler irrigation not only consumed less water but also controlled the disease in desirable level. Basati (2008) showed that chemical control decreased the infestation rate to about 20% but sprinkler irrigation controlled leaf infestation up to 5%. Sprinkler irrigation has the advantage of producing sugar yield and sugar content similar to furrow irrigation while consuming less water and makes insecticide usage unnecessary.

Quality traits

Sugar beet quality traits such as N, Na, and K were also influenced by irrigation method. Irrigation method had significant ($P < 0.05$) effect on Na content only. Under furrow and sprinkler irrigations, N contente were 2.7 and 3.14 meq/100g root and Na contents were 2.48 and 2.8 meq/100g root, respectively. Therefore, N and Na content under furrow irrigation was lower than sprinkler irrigation but K content under furrow irrigation was higher than sprinkler irrigation (Tables 2 and 3). Different studies showed that plants accumulate more N and Na under stress and the impurities decrease under normal irrigation (Carter et al. 1980; Fotohi et al. 2008; Abaspor 2003; Ebrahimipak 2010; Jehadakbar 2003; Noorjo and Bagaee 2004). In this study, the N as well as Na accumulation was lower under furrow irrigation than sprinkler irrigation.

Significant difference was observed among the cultivars for root yield (Table 2). Brigitta, Torbat, and Pars with 65.13, 63.75, and 59.17 t ha^{-1} root yield were superior to the other cultivars. Among the cultivars, Torbat with high root yield and medium infestation is recommended for regions with powdery mildew disease.

REFERENCES

Abbaspoor F. Sugar Beet: Guide of Farmers. Research and Service Sugar Beet Agricultural Co. Khorasan. 2003. (in Persian)

Alimoradi A, Dehganshoar M, Sadegian SY, Hashemi P, Yavari N, Goharim J, Galebi S, Arjmand M, Gadiri V, Sheikholeslami R. Sugar beet from scientific to Practice (translation), Olom-e-Keshavarzi Press.Tehran, Iran.731pp. 1998. (in Persian, abstract in English).

Asher M. Powdery mildew a problem of the south-east of England. British Sugar Beet Review, 1987. 55: 37-39. Asher M, Dewar A. Pests and diseases in sugar beet in 2000. British Sugar Beet Review .2001 69: 21-26

Asher M, Williams G. Forecasting the national incidence of sugar beet powdery mildew from weather data in Britain. British Sugar Beet Review, 1991. 40: 100-107.

Asher M, Williams G. Controlling leaf disease: powdery mildew. British Sugar Beet Review,1992. 60: 35-37.

Basati J, Mesbah M, shikholeslami M. Effect of powdery mildew on quality and quantity of sugar beet genotype in Kermanshah. Journal of Sugar Beet. 2000.16(2): 25-39. (in Persian, abstract in English)

Basati J, Mesbah M, Shikholeslami M. Effect powdery mildew on quality and quantity of sugar beet genotype in kermanshah. Journal of Sugar Beet .2008 .16(2):44-61. (in Persian, abstract in English)

Basati J, Zebarjadi A, Jalilian A, Abdolahian M, Abdi F. Effect of Time of irrigation cutoff in the end season of growth and silage in sugar beet. Journal of Sugar Beet. 2011. 26(2):157-167. (in Persian, abstract in English)

Basati J, M Zarabi, Fazli H. Investigation of comercial variety for powdery mildew tolerance. Journal of Sugar Beet. 2003. 19(2):97-107. (in Persian, abstract in English).

Basati J. Evaluation of commercial variety for powdery mildew resistance report. Kermanshah Agricultural Research Center (Iran); 2008 . 19-27 p. report. (in Persian, abstract in English).

Butrus LE, Nimal MN. potato and sugar beet yield and water use efficiency under different irrigation system and water stress. Agronomy Abstract.73rd. Annual Meeting American Society of Agronomy. P:209. .1981.

Carter GN, Jensen ME, Traveller DI. Effect of mid-and late season water stress on sugar beet growth and yield. Agronomy Journal. 1980. 72(5):806-815

Christman J. Interrelation between irrigation and pests and disease of sugar beet. Compt Rendu Congress. 1976. 39: 149-160.

Dainello FJ, Hall CR. General management practices to improve efficiency of pest control. Vegetable Production and Marketing. 1996. 6(9).

Davidoff B, Hanks RJ. Sugar beet production an influenced by limited irrigation. Journal of Irrigation Science. 1989.10: 1-17.

Ebrahimipak NA. Reaction of sugar beet yield to low irrigation in different step of sugar beet growth. Journal of Sugar Beet.2010.26(1):67-79.

Eckoff JLA, Bergman JW. Sugar beet (*Beta vulgaris*) production under sprinkler and flood irrigation. Montana State

University. Strength Agricultural Research Center. Available on: http//www.sidny.ars. usda.gov/state/publications/sbflood and sprinkler.htm. 2001.

Fotohi K, Ahmadasi J, Noorjo A, Pedram A, Khorshid A. Irrigation of management based on humidity of soil in different step of growth in sugar beet in Miandoab. Journal of Sugar Beet.2008.24(1):43-60. (in Persian, abstract in English)

Galian JJ. Sugar beet powdery mildew: Biology, economic importance and disease management. Snake River Sugar Beet Conference. Twin fall Idaho, January 11-12, 2001.

Galian JJ. Powdery mildew spread in sugar beet fields. Capitalpress.com/Idaho. The west's Ag website. .2012.

Galian JJ, Vargas D, Foote P. Fungicide for control of sugar beet powdery mildew. University Idaho. www.uiweb. uidaho.edu. 2002.

Hills FJ, Chiarappa L, Geng S. Powdery mildew of sugar beet.: Disease and crop loss assessment. Phytopathology 1980. 70: 680- 682.

Hills FJ, Hall DH, Kontaxis DG. Effect of powdery mildew on sugar beet production. Plant Dis. Rep 1975. 59:513- 515

Hoseinpor M, Soroshzadeh A, Alikhani M, Khoramian M, Taleghani D. Effect of two irrigation method (furrow and Drop) on quantity and quality of sugar beet in Khozestan. Journal of Sugar Beet. 2006. 22(1):39-57. (in Persian, abstract in English)

Jahedi A, Norozi A, Hamdi F. Effect of irrigation different method and nitrogen on quantity and quality of sugar beet. Journal of Sugar Beet. 2012.28(1):43-53.

Jehadakbar M, Ebrahimian H. Torabi M, Gohari J. Effect of low irrigation on quantity and quality of sugar beet in Esfahan. Journal of Sugar Beet. 2003. 19(1):81-93. (in Persian, abstract in English)

Malekzadeh M. Orazizadeh M, Moaieri M, Arbabtafti R. Effect of different system of irrigation on Agrotis Larva Karaderina and Proderina infected. Journal of Sugar Beet. 2009. 25(2):163-174. (in Persian, abstract in English)

Miller DE, Arastad JS. Yield and sugar content of sugar beet as affected by deficit high frequency irrigation. Agronomy Journal .1976.68(23) :231-234.

Noorjo A, Abasi F, Bagaeekia M, Jalali A. Effect of irrigation on quantity and quality of sugar beet in Miandoab. Journal of Sugar Beet. 2006. 22(2):53-66. (in Persian, abstract in English)

Noorjo A, Bagaeekia M. Effect of cut irrigation in different step of sugar beet growth on quantity and quality of sugar beet. Journal of Sugar Beet. 2004.20(1):27-38. (in Persian, abstract in English)

O´Connell J. Powdery Mildew Spread in Sugar Beet Field. Capital Press. The West's Ag Website. 2013.

Parihar SB, Nam Singh S. Influence of irrigation methods of the aphid, *Myzus persica* (sulzer). Insect Environment. 1999.5(1): 25-26.

Paulus AO, Harvey OA, Nelson J, Meek V. Fungicides and timing for control of sugar beet powdery mildew. Plant Disease Reporter.2001; 59: 516-517.

Rezvani SM, Norozi A, Azari K. Effect of different irrigation method and rate nitrogen upon root yield and water use efficiency in sugar beet. Journal of Sugar Beet. 2008.24(2):57-72. (in Persian, abstract in English)

Safariantosi MJ, Talegani D, Khodadadi S, Beigpanah H, Dehganshoar M. Effect of later irrigation on quantity and quality of two varieties of sugar beet in Mashhad. Journal of Sugar Beet. 2006. 22(1):13-23. (in Persian, abstract in English)

Yazdi Samadi B, Rezaee B, Aand Valizadeh M. Statistical Designs in Agricultural Research. Tehran University Press. 764 pp. .1997. (in Persian)

Yusupov TYU, Markov FI, Polvoi VV. Irrigation- also a method of control. Zashchita-Rastenii. 1975.3: 20-21.

Weltzien HC. *Erysiphe betae* (Vanha), the powdery mildew of beet. Phytopathology. 1963. 47: 123-123.

Whitney ED. High level of resistance to powdery mildew in *Beta maritima*. Phytopathology. 1987. 77: 1723.