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Evaluation the effect of paclobutrazol on bolting, qualitative and quantitative performance in autumn sown-sugar beet genotypes in Moghan region

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Abstract

The response of sugar beet genotypes to different levels of paclobutrazol was studied during 2013-2014 as a split plot based on randomized complete block design with three replications. Treatments were paclobutrazol application at three levels (0, 150 ppm and 300 ppm) as main plots and sugar beet genotypes at six levels (Eudora, Giada, Jawaher, Levante, Vico and (FC607*474)*Pool-PC.F2-HSF60-P.3) as subplots. Bolting percentage, root yield, sugar content, root K and Na contents, amino nitrogen, molasses sugar percentage, gross sugar yield, extractable sugar yield, alkalinity factor, white sugar yield and extraction coefficient were estimated. Results indicated that bolting percentage, bolting height, sugar content, Na content, alkalinity factor, molasses sugar percentage, extractable sugar, white sugar yield and extraction coefficient were affected by the paclobutrazol levels. Overall, results highlighted the positive effects of paclobutrazol on bolting percentage reduction, content sugar and root quality improvement. A significant difference was found sugar beet genotypes in bolting percentage, root yield and sugar content.

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Introduction

Paclobutrazol is a plant growth regulator from triazols inhibiting gibberlic acid production and has a lot of applications in agriculture (Davis and Curry, 1991). Paclobutrazol has been traced and detected in phloem and xylem saps from bean (Witchard, 1997), pear (Browning *et al.*, 1992) and pea (Hamid and Williams, 1997). Paclobutrazol can be transferred acripettally and basipetally in the plant. However, no data is found on the fate of paclobutrazol used which has high chemical stability (Jung *et al.*, 1986).

Paclobutrazol by preventing the oxidation of ent-kaurene to ent-kaurene acid due to inactivation of cytochrome P-450 oxygenase inhibits the biosynthesis of gibberellic acid (Izumi *et al.*, 1985; Graebe, 1987). Although biosynthesis by malonic acid to kaurene and kaurene acid to GA12 aldehyde is not affected (Izumi *et al.*, 1985).

Inhibitory effect of paclobutrazol on gibberellic acid biosynthesis is supported by lower concentrations of gibberellic acid in plants treated with paclobutrazol (Steffens *et al.*, 1992). Tsegaw (2006) found that paclobutrazol inhibited the biosynthesis of gibberellic acid and limited the rate of gibberellic acid in plants treated.

Paclobutrazol change the minerals uptake by the effect on shoot and root. Yelenosky *et al.* (1995) found that the leaves treated by paclobutrazol uptaked higher rates of N, Ca, B and Fe.

Autumn sown sugar beet has many advantages than spring planting; however, autumn sowing of sugar beet is threatened with risk of bolting and flowering in many areas. In bolting phenomenon, vernalisation and day length stimulates the biosynthesis of gibberellic acid and gibberellin by the expression B gene lead to bolting in autumn sown sugar beet. Thereby, by preventing the biosynthesis of gibberellic acid and also selecting the resistant genotypes to bolt, sugar beet can be sown broadly in autumn with decreasing the risk of bolting. Since autumn sowing of sugar beet is threatened with risk of bolting and in many areas and this phenomenon is influenced by genetic, environmental and physiological factors (Sadeghian, 1993), development of autumn planting in areas with longer winter (southern Spain) and new areas of Iran (Gorgan and Ilam) which are expected to be suitable for sowing of sugar beet requires completely resistant varieties to bolting (Sadeghian, 2002). Many studies have been conducted on sugar beet sowing. Carter and Traveller, (1981) implemented multiple field trials in regions with autumn sown sugar beet, who found dry matter accumulation and yield of sugar beet were influenced by date of sowing, genotype, nitrogen fertilizer and harvest date. According to Pfeiffer *et al.* (2013) variety played critical role in bolting of autumn sugar beet and suitable genotype could greatly prevent bolting. The objective of this study was to identify bolting-ressitant genotypes of sugar beet and to study the response of different genotypes of sugar beet to paclobutrazol levels and to evaluate of autumn sowing of sugar beet is possible or impossible in Moghan region.

Materials and methods

Geographical location and treatments

In order to investigate the feasibility of autumn sown sugar beet in Moghan region and to study the response of different genotypes of sugar beet to different levels of paclobutrazol, , a field trial was conducted during 2012-2013 at Research Farm of agricultural research center of Moghan, Iran (39°39' N, 47°55' E, and 32 m above sea level). The experiment was laid out as a split plot based on a complete randomized block design with three replications. Treatments were foliar application of paclobutrazol at three levels (0, 150 ppm and 300 ppm) as main plots and varieties at six levels (Eudora, Giada, Jawaher, Levante, Vico and (FC607*474)*Pool-PC.F2-HSF60-P.3) as subplots. Spraying was continued until the solution drops on plant surface. paclobutrazol spraying was performed after at three stages after cold and three stages (late March, early May and early June). The sugar beet was planted in 27 November 2012 at a density of 100000 plant ha^{-1}, 0.5 m row spacing and 20 cm distance between seeds within rows. Each plot involved three 6m rows. The soil fertility was improved by applying triple superphosphate (18-46-0 N-P-K) and urea at the rate of 100 and 150 kg ha1, respectively, before planting. The numbers of plants were recorded before and after the occurrence of cold in each plot. Plants were harvested in 31 July 2013 and transferred immediately to the laboratory.

Traits of study and data collection

Percentage of flowering stem, root yield, sugar content, root K and Na contents, amino nitrogen, molasses sugar percentage, gross sugar yield, extractable sugar yield, alkalinity factor, white sugar yield and extraction coefficient were estimated.

The sugar content was measured according to polarimetry method using Sakaromat which is based on the rotation of polarized light. In order to the qualitative analysis, each sample was kept at 20 °C then from each sample, 26 gram pulp with 177 ml of lead acetate basic was poured in a mixer and the content was mixed for 3 minutes. The clear liquid was obtained when the mixture was transferred to the funnel filter. The sugar content in the syrup obtained was measured by the polarimetry method using saccharimeter in term of grams of sugar per hundred grams of sugar beet (Clover *et al.*, 1998).

The contents of sodium and potassium were measured by flame photometry method and comparing lithium broad emission spectra. Amino nitrogen content was estimated by blue number method using betalaser. This procedure is based on the cooper reagent discoloration than nitrogen and compare with the existing standards. These values were determined using extracts prepared from the transparent mixture of roots pulp and lead acetate basic meq per 100 g sugar beet pulp (Clover *et al.*, 1998).

Alkalinity is the ratio of K + NA / N and these three elements (potassium, sodium and nitrogen) are as alkaline factors of environment which the purity of the crude sap is reduced with increasing their amounts (Cooke and Scott, 1993).

The last product of sugar is extracted from molasses which include 50% of sacarose and reducing sugars and raffinose. The product has better quality and more sugar if the sugar content of molasses is low (Cooke and Scott, 1993). Sugar cintent in molasses was obtained according to the follow equation (Reinfeld *et al.*, 1974):

$MS=0.0343(K^+ + Na^+) +0.094(\text{alpha-amino-N})-0.31$

The recoverable sugar percent was calculated using the follow equation (Reinfeld *et al.*, 1974):

$WSC=SC-(MS+0.6)$.

White sugar yield was obtained by multiplying the roots yield by recoverable sugar percent. This component is one of the most important qualitative and quantitative factors and is overall outcome of root crop, sugar content and impurities (Cooke and Scott, 1993), which is presented in term of t ha^{-1}.

Sugar extraction effeciency is the amount of recoverable white sugar from sucrose in sugar beet and it was estimated using the following formula:

$ECS= (WSY/SC) \times 100$

Statistical analysis

All data were subjected to ANOVA using the GLM procedure of SAS (SAS Institute, 2002). Treatment means were separated using Duncan test at $P < 0.05$. Excel software was used for creating the graphs.

Results and discussion

Percentage of bolting

Bolting percentage was affected by different levels of paclobutrazol (Table 1). paclobutrazol decreased percentage of flowering stems in sugar beet compared to control untreated, so that paclobutrazol application at the rates of 150 ppm and 300 ppm decreased bolting percentage by 42% and 41% than control, respectively (Table 2). Regarding the effect of vernalization and day length on bolting is by gibberellic acid production inducion and on the other hand, since paclobutrazol prevents the gibberellic acid biosynthesis through inhibition the kauren and kaurenoic acid oxidation Kaoronn (Lever, 1986; Davis and Zalman, 2002), its application decreased gibberellic acid synthesis and consequently bolting percentage. Inhibitory effect of paclobutrazol on gibberellic acid biosynthesis is supported by lower concentrations of gibberellic acid in plants treated with paclobutrazol (Steffens *et al.*, 1992). Tsegaw (2006) found that paclobutrazol inhibited the biosynthesis of gibberellic acid and limited the rate of gibberellic acid in plants treated. CaiFeng (2003) also found paclobutrazol reduced bolting percentage in sugar beet.

Table 1. Results of analysis of variance for qualitative and quantitative traits in sugar beet.

		Mean Square(MS)											
S.O.V.	df	bolting	Root yield (RY)	sugar content(SC)	Sodium (Na)	Potassium (K)	Amino-nitrogen(α-N)	Alkalinity coefficient (Alc)	Molasses sugar (MS)	Sugar yield (SY)	White sugar content (WSC)	White sugar yield (WSY)	ECS
Replication	3	88.02ns	461.14*	15.39**	3.18ns	15.19**	0.08ns	1.40**	3.47**	2.36ns	13.14**	1.61ns	64.66*
	2	519.13**	30.63ns	25.23**	44.09**	1.70**	1.24ns	5.23**	6.99**	12.03ns	58.67**	23.74*	761.17**
Rep×PBZ	6	32.56ns	83.59ns	0.57ns	1.00ns	0.11ns	0.42ns	0.08ns	0.21ns	3.54ns	1.22ns	3.06ns	14.49ns
Cultivar	5	1356.27**	1044.51**	18.74**	35.08**	2.24*	1.84*	0.65**	4.88**	48.40**	39.56**	43.46**	493.77**
Cul×PBZ	10	75.59**	113.62ns	1.88ns	3.15ns	0.39ns	0.57ns	0.17ns	0.59ns	4.79ns	3.65ns	3.66ns	69.32ns
Error	45	31.73	146.27	3.34	5.59	0.77	0.91	0.15	1.09	5.28	7.21	5.11	91.61
C.V.(%)	–	24.73	19.27	10.79	24.45	13.85	20.82	15.42	25.41	21.64	21.98	25.40	13.53

ns, * ,**: Non significant on 1 and 5 % levels of probability, respectively.

Different genotypes of sugar beet were found to be different in bolting percentage (Table 1). The maximum and minimum bolting percentage was related to (FC607*474)*Pool-PC.F2-HSF60-P.3 and Eudora, respectively (31.05 vs. 2.72%) (Table 2). According to Rabert *et al.* (1984) different genotypes were different in gibberellic acid content. Different genotypes showed critical role in bolting of autumn sugar beet and suitable genotype could greatly prevent bolting (Pfeiffer *et al.*, 2013). Bolting adverse phenomenon limiting the autumn sowing of sugar beet has been extensively studied and bolt resistant varieti*es* have prepared and even the breeding of more resistant cultivars has also been possible (Longden and Thomas, 1989; Sadeghian and Sharifi, 1999). Taleghani *et al.* (2011) found that bolting percentage was 12.23% and 89.75% in resistant and susceptible sugar beet cultivars.

Bolting percentage was also affected by genotypes×paclobutrazol effects (Table 1). The highest bolting percentage was detected under non-paclobutrazol treatment, followed by 300 ppm and 150 ppm treatments.

Root yield

Root yield of sugar beet was not affected by different levels of paclobutrazol (table 1). Paclobutrazol increased the root -shoot ratio (Pinhero and Fletcher, 1994; Yim *et al.*, 1997), improved assimilates production in bulbous plants (Le Guen-Le Saos *et al.*,2002; De Resende and De Souza, 2002) and tuber-bearing plants (Blamani and Poovaiah, 1985; Pelacho *et al.*, 1994; Simko, 1994). These findings are not consistent with those of Shahin *et al.* (2004) who found paclobutrazol reduced sugar beet root yield. Tsegaw (2006) found that potato shoot weight increased by paclobutrazol application. The sugar beet genotypes showed different response to paclobutrazol application, so that Eudora, Giada, Jawahar, Levante and Vico had the best performance in root yield (64.95, 65.31, 61.84, 66.71 and 72.54 t ha^{-1}, respectively). (FC607*474)*Pool-PC.F2-HSF60-P.3 was found to be the poorest in root yield (45.10 t ha^{-1}) (Table 2). These results agree with the findings of other studies (Taleghani *et al.*, 2011; Farahmand *et al.*, 2013).

Sugar content

Paclobutrazol levels had significant effects on sugar content (Table 1). The highest and lowest sugar content was related to 300 ppm application (17.32%)

and non paclobutrazol (15.81%), respectively (Table 2). According to Yim *et al.* (1997), greater levels of gibberellic acid increased assimilates allocation to shoots and lower levels of gibberellic acid increased assimilates allocation to roots. Increasing assimilate in roots can be attributed to increasing assimilates allocation to roots due to reducing demand in shoots (Symons *et al.*, 1990).

Table 2. Comparisons of means for qualitative and quantitative traits in sugar beet.

Treatment	bolting (%)	Root yield (ton.ha-1)	sugar content (SC) (%)	Sodium (Na) ………	Potassium (K) (Meq.100g beet-1)	Amino-nitrogen (α-N) ………	Alkalinity coefficient (Alc)	Molasses sugar (MS) (%)	Sugar yield (SY) (t.ha-1)	White sugar content) (WSC) (% in beet)	White sugar yield (WSY) (ton.ha-1)	ECS (% in sugar)
PBZ												
0	24.97a	62.01a	15.81c	6.85a	6.65a	4.37a	3.10a	4.37a	9.80a	10.48c	6.55b	64.31b
150ppm	16.97b	64.04a	17.16b	4.83b	6.20b	4.83a	2.32b	3.93b	11.00a	12.63b	8.15a	72.76a
300ppm	16.86b	62.17a	17.32a	4.27b	6.18b	4.58a	2.27b	3.70b	11.04a	13.52a	8.37a	74.99a
Cultivar												
Eudora	2.72d	64.95a	17.77ab	3.18c	6.32b	4.27ab	2.29b	3.35c	11.53ab	13.81ab	8.94a	77.34a
Giada	11.66c	65.31a	15.28c	8.11a	6.21b	4.98a	2.91a	5.07a	10.09b	9.61c	6.49b	60.64c
Jawaher	28.16a	61.84a	15.69c	5.92b	6.02b	4.69ab	2.59ab	4.23abc	9.36b	10.86c	6.60b	67.75bc
Levante	22.77b	66.71a	17.61ab	4.70bc	5.97b	4.70ab	2.32b	3.79bc	11.62ab	13.22ab	8.72a	74.80ab
Vico	21.22b	72.54a	18.47a	4.19bc	6.35b	3.99b	2.61ab	3.68bc	13.32a	14.19a	10.22a	75.82ab
(FC607*474)* Pool-PC.F2-HSF60-P.3	31.05a	45.10b	16.77bc	5.80b	7.17a	4.94a	2.68a	4.60ab	7.49c	11.57bc	5.15b	67.78bc

Treatment with the same letters don,t show significant differences.

Sugar content was influenced by sugar beet genotypes (Table 1), here, Vico (18.47%) and Giada (15.28%) were found to be the highest and lowest in sugar content, respectively (Table 2). Sadeghian *et al.* (1993) concluded that sugar content decreased by increasing bolting percentage. With regard to (FC607*474)*Pool-PC.F2-HSF60-P.3 had the most bolting percentage and least sugar content, Our results differ from the findings of Sadeghian *et al.* (1993).

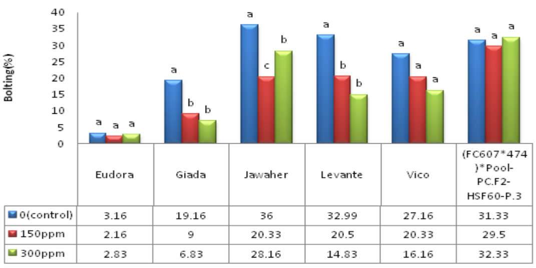

Fig. 1. Intraction effect of variety×paclobutrazol on bolting

Root Na content

Sodium is one of the soluble mineral salts in sugar beet roots disrupting sugar extraction process by preventing the crystallization of sucrose. It increases the sugar losses and decreases the extractable sugar content with increasing sugar content of molasses. Paclobutrazol levels had significant effects on root Na (Table 1). The maximum root Na (6.85 meq per 100 g sugar beet pulp) was found in control untreated (Table 2). By affecting the root and shoot, paclobutrazol changed the mineral absorption so that different plant species showed different response to this phenomenon (Yelenosky *et al.*, 1995).

Analysis of variance showed that root Na was affected by different genotypes (Table 1). Giada (8.11 meq per 100 g sugar beet pulp) and Eudora (3.18 meq per 100 g sugar beet pulp) were detected to be the highest and lowest in root Na, respectively. These results are consistent with those of Taleghani *et al.* (2012).

Root K content

Root K content was affected by paclobutrazol levels (Table 1), so that the highest (6.65 meq per 100 g root pulp) and lowest (6.18 meq per 100 g root pulp) K content was observed in control and 300 ppm treatments, respectively (Table 2). These results differ from the findings of Monge *et al. (*1994), who reported paclobutrazol increased K uptake.

According to the results, sugar beet varieties were different in the content of root K (Table 1). (FC607*474)*Pool-PC.F2-HSF60-P.3 (7.17 meq per 100 g root pulp) and Levante (5.97 meq per 100 g root pulp) had the highest and lowest K content, respectively (Table 2). Taleghani *et al.* (2011) and Farahmand *et al.* (2013) reported that autumn-sown sugar beet varieties under Moghan region showed significant differences in K content.

Amino nitrogen

An increase in amino nitrogen results in remaining the part of sucrose cotent in molasses. The content of amino nitrogen in sugar beet root was affected by paclobutrazol levels (Table 1). These findings differ from the findings of Yelenosky *et al.* (1995), who reported paclobutrazol increased amino nitrogen, but they are consistent with those of Wieland and Wample, (1985) and Yeshitela *et al.* (2004).

Amino nitrogen was influenced by sugar beet genotypes (Table 1), so that the maximum and minimum amino nitrogen was related to Giada and Vico, respectively. Taleghani *et al.* (2011) and Farahmand *et al.* (2013) found that autumn-sown sugar beet varieties were different in amino nitrogen content.

Alkalinity factor

A significant difference was found in alkalinity factor under paclobutrazol levels (Table 1). The maximum (3. 10) and minimum (2. 27) alkalinity factor was related to control and 150 ppm treatments, respectively (Table 2). Considering this factor is the ratio of total sodium and potassium to amino nitrogen in sugar beet roots, so alkalinity factor reduces with increasing amino nitrogen or decreasing sodium and potassium contents (Draycott, 2006).

As shown in Table 1, sugar beet varieties were different in alkalinity factor. Giada (2.91) and (FC607*474)*Pool-PC.F2-HSF60-P.3 (2.68) had the highest alkalinity factor, while Eudora (2.29) and Levante (2.32) had the lowest alkalinity factor, respectively (Table 2). Alkalinity factor indicates residue in syrup after filtration and its large amount disturbs sugar extraction (Ober, 2001). Given the amount of impurities reported from this test, this findings would be expected.

The content of sugar in molasses

The effect of paclobutrazol levels on the content of sugar in molasses was significant (Table 1). A greater molasses sugar was found in control treatment compared to paclobutrazol application at the rates of 150 ppm and 300 ppm. Considering molasses sugar is a function of impurities levels of root, on the other hand, a higher content of sodium and potassium in root was found in control untreated, an increase in molasses sugar in control plots was expected.

Sugar beet genotypes showed difference performance in molasses sugar (Table 1). Giada (5.07%) and Eudora (3.35%) were found to be the highest and lowest in molasses sugar content, respectively (Table 2). Given Giada genotype was the highest in sodium and amino nitrogen impurities, the content of sugar in molasses was the highest. The same trend was found in Eudora but Conversely Giada. Taleghani *et al.* (2011); Farahmand *et al.* (2013); Rinaldi and Vonella, (2006) found that autumn-sown sugar beet varieties showed significant differences in molasses sugar.

Gross sugar yield

Gross sugar yield was not affected by different levels of paclobutrazol (Table 1). Zheng *et al.* (2012) found that paclobutrazol increased root sugar content and decreased shoot sugar content. A similar result was found in the present study but since there was no difference between root yield in paclobutrazol levels, so it was overlapped with the difference in sugar content and as a result there was no difference in gross sugar yield between control and different levels of paclobutrazol.

The sugar beet genotypes showed significant difference in gross sugar yield (Table 1). The highest and lowest gross sugar yield content was related to Vico (13.32 t ha^{-1}) and (FC607*474)*Pool-PC.F2-HSF60-P.3 (7.49 t ha^{-1}) cultivars, respectively (Table 2). Since sugar yield is dependent on root yield and sugar content, increasing these factors result in an increase in sugar yield (Firoozabadi *et al.*, 2003). Regarding Vico cultivar had the maximum root yield and sugar content, it was found to be the highest in gross sugar yield, in contrast (FC607*474)*Pool-PC.F2-HSF60-P.3 cultivar which had lower performance in root yield and sugar content, it was found to be the lowest in gross sugar yield as well.

Extractable sugar percentage

Different concentrations of paclobutrazol had significant effects on extractable sugar percentage (Table 1), so that application of paclobutrazol at the rate to 300 ppm increased extractable sugar by 23% than control (Table 2). Extractable sugar is high under high content of sugar and less sugar of molasses. According to the results of the effect of paclobutrazol on sugar content and molasses sugar this result was predictable.

Extractable sugar yield were also affected by sugar beet genotypes (Table 1), so that Vico (14.19%) and Giada (9.61%) were found to be the highest and lowest in extractable sugar (Table 2). Taleghani *et al.* (2011); Farahmand *et al.* (2013); Rinaldi and Vonella, (2006) reported that autumn-sown sugar beet varieties showed significant differences in extractable sugar yield.

White sugar yield

Na significant difference was found between different concentrations of paclobutrazol in white sugar yield (Table 1). White sugar yield was increased by paclobutrazol treatment, so that application of 150 ppm and 300 ppm increased white sugar yield 20% and 22% compared to control untried (Table 2). White sugar yield depends on the amount of recoverable sugar and root yield and this result was predictable regarding extractable sugar content and root yield. These results are consistent with those of Zhang *et al.* (2012), but they differ from the findings of Stevens (1985).

Sugar beet gentotypes showed significant difference in white sugar yield (Table 1). the maximum white sugar yield was found to be in Vico, Eudora and Levante (10.22, 8.94 and 8.72 t ha^{-1}, respectively), the minimum white sugar yield was related to (FC607*474)*Pool-PC.F2-HSF60-P.3 (Table 4-3 and 4-4). Differences in qualitative and quantitative traits between genotypes have been reported in previous researches (Draycott, 2006; Cooke and Scott, 1993).

Extraction coefficient

Different levels of paclobutrazol had significant effects on extraction coefficient at the level of 1% (Table 1). Application of paclobutrazol 150 ppm and 300 ppm with 72.76 and 74.99, respectively, were paced in the same group, indicated significant difference with control treatment (Table 2). Extraction coefficient depends on extractable sugar and sugar content, thus considering higher levels of extractable sugar under paclobutrazol application, the extraction coefficient was also increased, while the impact of sugar content due to the proximity of the values was lower. Sugar beet genotypes showed significant difference in extraction coefficient (Table 1). Eudora (77.34%) Giada (60.64%) were detected to be the highest and lowest in extraction coefficient, respectively (Table 2). Extraction coefficient in Vico was low because it had high extractable sugar and sugar content. Eudora was found to be high in extraction coefficient due to more appropriate balance between these two features.

References

Browning G, Kuden A, Blake P. 1992. Site of (2RS, 3RS)-paclobutrazol promotion of axillary flower initiation in rear cv. Doyenne du Commice. Journal of Horticulture Science.67, 121-128.

CaiFeng L. 2003. Researches on regulation and its mechanism of plant growth regulating substances on bolting in sugar beet. PhD. Thesis. Northeast

Agriculture University. 127 p.

Carter JN, DJ Traveller. 1981. Effect of time and amonut of nitrigen uptake on sugarbeet growth and yield. Agronomy Journal. **73,** 665-671.

Clover G, Smith H, jaggard K. 1998. the crop under stress. British sugar beet review **66(3),** 17-19.

Cooke D, Scott R. 1993. The sugar beet crop:Science Into Practice Chapman and Hill, New York. 195 p.

Davis TD, Curry EA. 1991. Chemical regulation of vegetative growth. Crit. Review of Plant Science. **10,** 151-188.
http://dx.doi.org/10.1080/07352689109382310

De Resende GM, De Souza RJ. 2002. Effects of paclobutrazol doses on garlic crop. Pesquisa Agropecuaria Brasileira, **37(5),** 637-641.

Draycott PH. 2006. Sugar beet. Blackwell Publishing Ltd. 514 p.
http://dx.doi.org/10.1002/9780470751114

Farahmand KHM, Faramarzi A, Moharramzadeh M. 2013. Possibility of autumn beet planting in Moghan region. Journal of Agronomy and Plant Breeding. **9(3),** 45-55.

Firoozabadi M, Abdollahian-Noghabi M, Rahimzadeh F, Moghadam M, Parsaeyan M 2003. Effects of different levels of continuous water stress on the yield quality of three sugar beet lines. Journal of Sugar beet. No2. **19,** 133-142.

Graebe JE. 1987. Gibberellin biosynthesis and control. Annu. Rev. Plant Physiology. **38,** 419-465.
http://dx.doi.org/10.1146/annurev.pp.38.060187.002223

Hamid MM, Williams RR. 1997. Translocation of paclobutrazol and gibberellic acid in Stuart's desert pea (Swainsosa Formosa). Plant Growth Regulation. **23,** 167-171.
http://dx.doi.org/10.1023/A:1005982002914

Izumi K, Kamiya Y, Sakurai A, Oshio H, Takahashi N. 1985. Studies the site of action of new plant growth retardant (E)-1-(4-chlorophenyl)-4, 4-dimethy1-2-(1,2,4-trazoles-1-penten-3-o 1) (SS-3307) and comparative effects of its sterioisomers in a cell free system from Curcurbita maxima. Plant Cell Physiology **26,** 821-827.

Jung J, Rentzea C, Rademacher W. 1986. Plant growth regulation with triazoles of the dioxanyl type. Journal of Plant Growth Regulation **4,** 181-188.
http://dx.doi.org/10.1007/BF02266956

Le Guen-le Saos F, Hourmant A, Esnault F, Chauvin JE. 2002. In vitro bulb development in shallot (Allium cepa L. Aggregatum Group): effects of anti-gibberellins, sucrose and light. Annals of Botany. **89,** 419-425.
http://dx.doi.org/10.1093/aob/mcf063

Lever BG. 1986. Cultar-A technical overview. Acta Horticulturae. **179,** 459-467.

Longden PC, TH Thomas. 1989. Why not autumn sowing sugar beet. British Sugar Beet.

Monge E, Aguirre R, Blanco EE. 1994. Application of paclobutrazol and GA3 to adult peach trees: effects of nutritional status and photosynthetic pigments. Campo experimental Bajio.
http://dx.doi.org/10.1007%2FBF00210702

Ober E. 2001. The search for drought tolerance in sugar beet. British sugar beet review **69(1),** 40-43.

Pelacho AM, Martin-Closas L, Campabadal C, Torres A, Farran I, Mingo-Castel AM. 1994. In vitro tuberization of potato: Effect of several morphogenic regulators in light and darkness. Journal Plant Physiology **144,** 705-709.
http://dx.doi.org/10.1016/S0176-1617(11)80665-6

Pfeiffer N, Moller A, Jung CH, Kopisch F. 2013. Genetic and Phenotypic Characterization of bolting failure in sugar beet. Plant and animal genome Conference, San Drege CA.

Pinhero RG, Fletcher RA. 1994. Paclobutrazol and ancymidol protects corn seedlings from high and low temperatures stresses. Journal Plant Growth Regulation. **15,** 47-53. http://dx.doi.org/10.1007/FBF00024676

Reinfeld E, Emmerich A, Winner C. 1974. Zur vuraussage des melassezukers aus rubenanalysen. Zucker **27,** 2-15.

Rinaldi M, Vonella AV. 2006. The response of autumn ans spring sown sugar beet to irrigation in Southern Italy: Water and radiation use efficiency. Journal of Field Crop Research. **95(2-3),** 103-114. http://dx.doi.org/10.1016/j.fcr.2004.12.004

Roberts AV, Mathews D. 1995. The preparation in vitro of chrysanthemum for transplantation to soil. 5. The 2s, 3s enantiomwrs of paclobutrazol improves resistance to desiccation. Plant Cell, Tiss. Org. Cult. **40,** 191-193. http://dx.doi.org/10.1007/BF00037675

Sadeghian SY, Sharifi H. 1999. Improvement of sugar beet for combined resistance tobolting and cercopora leaf spot. 62th IIRB cong. Sevilla. Spain.

Sadeghian SY. 1993. Bolting in sugar beet, genetics and physiological aspects. The Swedish Univ.

Sadeghian SY. 2002. Advantages of winter beet as compared with summer beet. IIRB, Mediterranean Section Meeting, 24-26 Oct. 2002.

Shahin AH, El-Desouky SA, Saif LMA, Osman AMH. 2004. Effect of foliar nutrition and paclobutrazol on sugar beet and quality yield components and juice quality. Egyptian Journal of Agriculture Research. **82,** 3.

Simko I. 1994. Effects of paclobutrazol on in vitro formation of potato micro-tubers and their sprouting after storage. Biological Plant. **36(1),** 15-20. http://dx.doi.org/10.1007/BF02921262

Steffens GL, Lin JT, Stafford AE, Metzger JD, Hazebroek JP. 1992. Gibberellin content of immature apple seeds from paclobutrazol treated trees over three seasons. Journal of Plant Growth Regulation **11,** 165-170. http://dx.doi.org/10.1007%2FBF00194366

Stevens DR. 1985. The manipulation of sugar beet growth and development by paclobutrazol and mefluidide. Master of applied science University of Canterbury. 121 p.

Symons PRR, Hofman PJ, Wolstenholme BN. 1990. Responses to paclobutrazol of potted "Hass" avocado trees. Acta Horticulturae **275,** 193-198.

Taleghani D. 2001. Evaluation of autumn sugar beet in Golestan. Report of SBSI. 35-40.

Taleghani D. 2012. Determining suitable sowing date and harvesting time of winter beet in Moghan, Fars and Golestan regions. Final report. Agricultural Research, Education and Extension Organization (AREEO). Sugar Beet Seed Institute (SBSI).101 p.

Taleghani D, Moharamzadeh M, Sadeghzadeh Hemayati S, Mohammadian R, Farahmand KH. 2011. Effect of swing date and harvesting date on yield of autumn sugar beet in Moghan. Seed and Plant Production Journal. **27-2(3),** 355-371.

Tsegaw T. 2006. Response of potato to paclobutrazol and manipulation of reproductive growth under tropical conditions. Thesis of doctora degree. University of Pretoria etd. 203p.

Wieland WF, Wample RL. 1985. Root growth, water relation and mineral uptake of young 'Delicious' apple trees treated with soil and stem applied paclobutrazol. Science Horticulturae. **26,**

129-137.

Witchard M. 1997. Paclobutrazol is phloem mobile in castor oil plants (Ricinus communis L.). Journal of Plant Growth Regulation. **16,** 215-217.
http://dx.doi.org/10.1007%2FPL00006999

Yelenosky G, VUV, Wutscher HK. 1995. Influence of paclobutrazol in the soil on growth, nutrient elements in the leaves, and flood/freeze tolerance of citrus rootstock seedlings. Journal of Plant Growth Regulation **14,** 129-134.
http://dx.doi.org/10.1007%2FBF00210914

Yeshitela T, Robbertse PJ Stassen PJC. 2004. Paclobutrazol suppressed vegetative growth and improved yield as well as fruit quality of 'Tommy Atkins' mango (Mangifera indica) in Ethiopia. New Zealand Journal of Crop Horticultural Science **32,** 281-293.

Yim KO, Kwon YW, Bayer DE. 1997. Growth responses and allocation of assimilates of rice seedlings by paclobutrazol and gibberellin treatment. Journal Plant Growth Regulation **16,** 35-41.
http://dx.doi.org/10.1007%2FPL00006972

Zheng R, Wu Y, Xia Y. 2012. Cholorocholine chloride and paclobutrazol treatments promote carbohydrate accumulation in bulbs of Liliium Oriental hybrids Sorbonne. Journal of Zhejiang University Science.**13(2),** 136-144.
http://dx.doi.org/10.1631/jzus.B1000425