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Effects of Steckling Weight and Planting Density on Sugar Beet (*Beta vulgaris* L.) Monogerm Seed Yield and Qualitative Traits

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Abstract: In order to determine the effects of steckling weight and planting density on sugar beet monogerm (Cv. 9597) seed quantitative and qualitative characteristics, this experiment was carried out in Ardabil Agricultural Research Station-Iran (38°30'N and 48°30'E) during 2 years (2002-2003). In the study, steckling weight (main-plot) in three levels including 100, 100-200 and 200-300 g and planting density (sub-plot) in three levels including 40, 50 and 60 cm were used in a split-plot experiment based on the RCBD (Randomized Complete Blocks Design) with 5 replications. The measured characteristics were morphological and qualitative (velocity and uniformity of germination) characters, seed size distribution and monogerm seed percentage. According to the results of the experiment, the effect of planting density on the auxiliary branches No. and seed yield was significant at the probability levels of 1 and 5%, respectively. Seed yield increased by 43% as planting density was increased from 65×40 to 65×60 cm. The increase in steckling weight led to the increase in standard seed portion (with 3.5-4.5 mm in diameter), germinable standard seed yield (11%) and decrease in germination velocity and germination uniformity; and increase in planting density was accompanied by increase in >4.5 mm seed percentage, velocity and uniformity of germination and decrease in germinable standard seed yield. Eventually, the highest seed yield (1208 kg ha^{-1}) was obtained by using steckling weight of 200-300 g and planting density of 65×60 cm.

Key words: Sugar beet, seed production, steckling weight, planting density, seed yield, germination rate

INTRODUCTION

Although 7-16 g steckling supply is required for the initiation of sugar beet (*Beta vulgaris* L.) reproductive growth and plant emergence (Balan *et al.*, 1991), this does not override the considerable effects of steckling weight on the seed yield and growth trend of this crop. Several studies have shown that the growth and seed yield increase as the steckling weight increases (Saini *et al.*, 1977; Balan *et al.*, 1978; Nicolau, 1978; Podlaski, 1987b). However, the decrease in steckling weight can be compensated by the increase in planting density without any negative effects on the seed qualitative characteristics (Balan and Zagorodnii, 1986). It is shown that the stecklings with the weights of 200 g are appropriate for silage (in transplanting method) and heavier stecklings (600 g) are damaged by freeze (Korzhenko and Tretyak, 1980).

Kockelman and Meyer (2005) believed that all techniques in steckling fields goal for an optimal top diameter of 2-4 cm and a weight of 40-80 g and good nursery production should results in 300,000-400,000 plantable stecklings in hectare. The date of sowing and sowing density of basic seed affect the result. The late sowing decrease the average steckling weight and cause the production of small plants which are not developed enough for transplanting. They also say that early sowing dates in France or Italy, end of July to beginning of August, need high seeding densities of about 1.1 million germinating seeds per ha to obtain a good number of even-sized stecklings. With the row of width of 20-25 cm, spacing within the row is 3-5 cm. The fields good preparing allow sowing depths of 1.5-2 cm. Basic seed sowing should be ended by the end of August in order to reach a high recovery of usable stecklings. In late sowing, the planting rate should be reduced by about 10-20% cause the development of single plants with the less competition between the plants.

Balan and Zagorodnii (1986) reported that the increase in steckling weight (from 50-300 to 150-800 g) and planting density (from 70×70 to 70×35 cm) led to an increase in seed yield (1.83 and 2.37 t ha^{-1}, respectively) as well as affected plants growth characteristics such as plant branching and hastened the flowering period by 4-6 days. Podlaski (1987b) by increasing density from 50×50 to 30×30 cm reported a decrease in seed yield from 34.2 to 13.3 g $plant^{-1}$. Also Bordei and Tapus (1981) indicated that the seed yield increased from 0.71

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(3 plants m^{-2}) to 0.97 t ha^{-1} (5 plants m^{-2}). Kaw and Mir (1975) studied the effects of variation in planting density via changing row interspaces (30, 45, 60 and 75 cm) and showed that the maximum seed yield (1.60 and 2.52 t ha^{-1}) was obtained in narrower rows (30 and 45 cm, respectively).

Agronomical factors such as planting density, steckling weight, harvesting date and method as well as the application of chemical materials affected qualitative characteristics of sugar beet seed-bearing plants through affecting plants ripening uniformity (Bordei and Tapus, 1981). It has been shown that the increase in steckling weight from 150 to 700 g led to an increase in seed yield as well as seed germination rate (Podlaski, 1987a) while Saini *et al.* (1977) found that the increase in steckling weight did not affect the seed maturity and germination rate and thousand-seed weight. Scott and Longden (1973) reported that narrower row (25 cm in comparison to 50 cm) caused an increase in seed yield and germination vigor. But Lachowski and Howwicki (1973) indicated that an increase in planting density did not affect qualitative characteristics such as thousand-seed weight and purity.

Because of the importance of the effects of steckling weight and planting density on sugar beet seed production, the experiment was conducted in Ardabil region as the centre of commercial production of sugar beet seed in Iran, aiming to study the relationships between these factors with produced seed qualitative and quantitative characteristics.

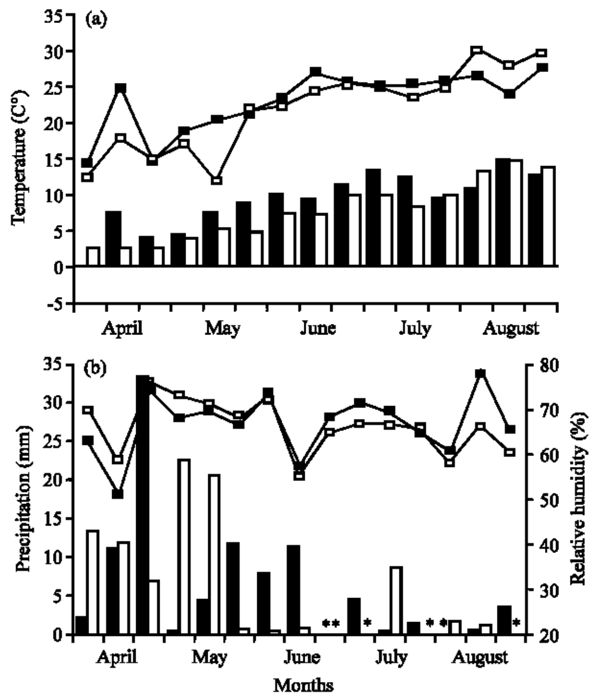

Fig. 1: (a) Temperature (hatch = minimum and line = maximum) and (b) precipitation (hatch) and relative humidity (line) of the growing period (April to August) in 2002 (■) and 2003 (□) (histograms and lines are average of decades of each year, *: indicates no precipitation)

MATERIALS AND METHODS

The split-plot experiment was conducted in Agricultural Research Station of Ardabil-Iran (Long. 48°30'E. and Lat. 38°30' N.) with 5 replications during 2002-2003. Steckling weights in three levels (W_1 = 100 g, W_2 = 100-200 g and W_3 = 200-300 g) as the main factor and row spacings (the space between plants) in three levels (D_1 = 40 cm, D_2 = 50 cm and D_3 = 60 cm) as the sub factor were used. The weather condition of the region during the study years is shown in Fig. 1.

The stecklings of elite monogerm (Cv. 9597) were planted at late of March in each year. During cropping year, the fertilizer 100 kg N ha^{-1}+100 kg P ha^{-1}, twice weeding and 4 or 5 times irrigations (depending of plants' needs) were used. Seed yields were harvested at second half of August each year and after a week of winding they were threshed.

Every sub plot had six rows with the interspacing of 65 cm. Since there were not any unplanted lines in subplots, one of five plants at two border rows which was randomly selected, was sampled a day before harvesting to determine the morphological characteristics; then main and auxiliary branches no. and seed yield/plants were measured in each plant. The final seed yield was obtained from an area of 10.4 m^2 due to eliminating two border rows.

Produced seeds winnowed by the facilities of Seed Technology Laboratory of Seed Production and Breeding Office of Ardabil and after measurement of crude seed yield and seed moisture content were transferred to SBSI (Sugar Beet Seed Institute) of Iran to measure the qualitative characteristics such as the distribution of seed size (with diameters of <3.5 mm, 3.5-4.5 mm and >4.5 mm), germination rate (%), thousand-germ weight (g), germination uniformity (days), monogerm seed percentage and standard seed percentage (According to ISTA rules). Crude seed yield was obtained from record area in any plot and after primary winnowing, adjusting of moisture content (at 12% level) and erase of inert matters. The software SAS was used for ANOVA and comparison of means (Duncan`s Multiple Range Test; $p<0.05$) and graphs were drawn by software STATISTICA.

RESULTS AND DISCUSSION

The increase in steckling weight significantly (p<5%) led to the increase in main branch No./plant (Table 1) that shows the escalation of seed-bearing plants branching power with the increase in steckling size (Podlaski, 1987b; Balan and Zagorodnii, 1986). The change in plant interspacing had a significant effect on auxiliary branch No. and seed yield/plant on the probability levels of 1 and 5%, respectively (Table 1) so that the increase in plants interspacing from 40 to 60 cm led to the increase in auxiliary branch No./plant from about 46.5 to 66.3, respectively (Table 1). This shows that seed-bearing plants had a compensatory response to the increase in plant interspacing in order to cover the additional spaces. In other words, sugar beet seed-bearing plants can partly compensate the decrease in population density through increased branching. Using two planting patterns of 35×70 and 70×70 cm, Balan and Zagorodnii (1986) showed that the decrease in plant density led not only to the increase in seed yield/plant but also to the increase in multi-branch plants through affecting the growth characteristics of the plants. On the other hand, the increase in plant interspacing from 40 to 50 and 60 cm (which followed by the decrease in plants population by 20 and 33.5%, respectively) caused the increase in seed yield/plant by 14.4 and 42.8%, respectively (Table 1).

The increase in steckling weight led to an increase in the portion of 3.5-4.5 mm seeds (standard size) and a decrease in the portions of >4.5 and <3.5 mm seeds (Fig. 2a). In other words, with the increase in steckling weight from about 100 g to 100-200 and 200-300 g, the portion of 3.5-4.5 mm seeds increased by 5.2 and 6.2%, respectively, compared with control. On the other hand, the effect of increase in stecklings weight on the germinated seeds percentage caused that despite the decrease in crude seed yield by 4%, standard and viable seed yield increased by 11% (Fig. 2b, Table 1). On the other hand, the increase in steckling weight led to the decrease in germination rate and uniformity by 2 and 6%, respectively (Fig. 2c) as well as statistically significant increases in thousand-germ weight and monogerm seeds percentage. Using stecklings with two sizes of 50-300 and 150-800 g, Balan and Zagorodnii (1986) showed that the increase in steckling weight led to an increase in seed yield (1.83 and 2.37 t ha^{-1}, respectively). Using four different seed-bearing steckling sizes, Nicolau (1978) reported a raise in seed yield of sugar beet with the

Table 1: Mean of main and auxiliary branches plant^{-1}, seed yield plant^{-1}, seed size distribution, 1000 germs weight, germination characteristics, monogermity and crude and standard-viable seed yield, as a function to steckling weight and planting density

Treatments	Main branch plant^{-1} (a)	Auxiliary branch plant^{-1} (d)	Seed yield (g plant^{-1})	Seed size distribution (%)(e) <3.5 (mm)	3.5-4.5 (mm)	>4.5 (mm)	1000 germs weight (g)	Germination(f) Rate (%)	Velocity (days)	Uniformity (days)	Monogermity (%)	Seed yield (kg ha^{-1}) Crude(g)	Standard-viable(h)
Year (Y)													
2002	6.71b(b)	42.16b	84.62b	9.13	24.68	66.21	4.71	74.31b	5.13	3.80	88.02	1094	189.14
2003	8.25a	56.28a	101.34a	9.06	22.80	68.13	4.68	80.94a	5.25	3.67	90.18	1120	202.86
significance	**(c)	**	**	ns	ns	ns	ns	**	ns	ns	ns	ns	ns
Steckling weight (W)													
100 g	7.17b	47.54	85.46	9.26	25.48	65.26	4.56	78.24	5.23	3.86	89.13	1053b	170.80
100-200 g	9.87a	53.15	89.08	9.03	26.80	64.15	4.65	79.07	5.26	3.64	90.69	1013b	201.17
200-300 g	9.89a	59.16	83.18	9.14	27.10	63.81	4.77	78.09	5.15	3.73	89.70	1180a	211.21
significance	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns
Planting density (D)													
65×40 cm	8.32	46.46b	72.13c	9.63	26.76	63.55	4.53	78.83	5.15	3.67	88.85	1102	211.66
65×50 cm	9.17	47.04b	82.54b	8.60	25.84	65.55	4.64	78.54	5.23	3.74	88.79	1088	194.03
65×60 cm	9.44	66.35a	102.97a	9.14	26.78	64.08	4.82	78.06	5.26	3.82	92.07	1058	197.48
significance	ns	*	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Interactions													
Y×W	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Y×D	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
W×D	*	ns	ns	*	*	ns	ns	ns	ns	ns	*	ns	ns
Y×W×D	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV(%)	10.43	17.38	16.08	24.02	7.81	14.65	8.95	7.24	6.54	14.69	4.95	8.82	18.36

(a) The main branch include of branch(es) that originated from crown, (b) Means followed by similar letter(s) in each column are not significantly different at 5% probability level, (c) ns: non-significant and *, **: Significant at 5 and 1% probability levels, respectively, (d) The auxiliary branch include of branches the originated from main branch, (e) In first stage, harvested crude seed were passed into 3.5 mm (down) and 6.0 mm (up) around sieves and seed lot were distribute in three sections of <3.5 mm, >6.0 mm and 3.5-6.0 mm and then 3.5-6.0 mm portion of seeds were passed into 4.5 mm (down) and 6.0 mm (up) sieves, seed dividing to two sections of 3.5-4.5 mm and 4.5-6.0 mm seed portions, (f) Germination test was carried out in SBSI seed technology laboratory and (g) Crude seed yield was obtained from record area in any plots and after primary wiunowing, adjusting of moisture content (at 12% level) and erase of inert matters, (h) Standard-viable seed yield was obtained by multiply of 3.5-4.5 mm seed portion in germination rate

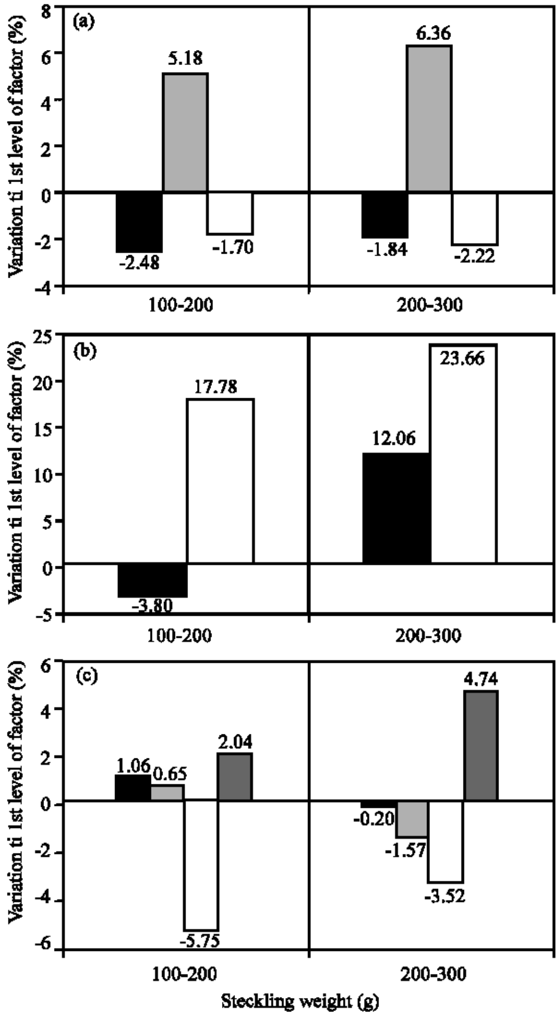

Fig. 2: Variation of (a) <3.5 mm (■), 3.5-4.5 mm (■) and >4.5 mm (□) seed size distribution (b) crude (■) and viable-standard (□) seed yield and (c) germination rate (■), germination uniformity (■), 1000-germs weight (□) and monogermity (■) to 1st level of steckling weight (100 g) (the numbers on the columns shows percent of variation)

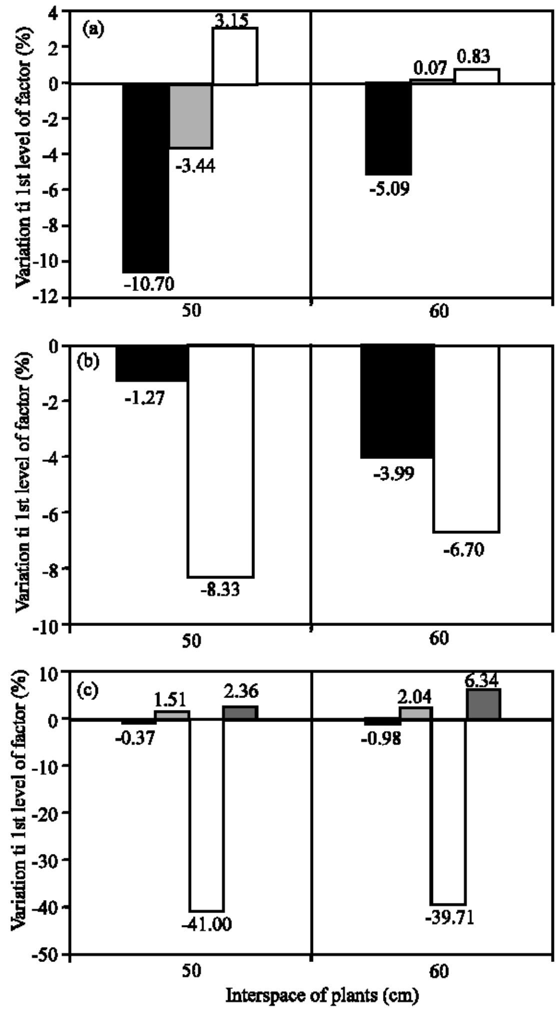

Fig. 3: Variation of (a) <3.5 mm (■), 3.5-4.5 mm (■) and >4.5 mm (□) seed size distribution (b) crude (■) and viable-standard (□) seed yield and (c) germination rate (■), germination uniformity (■), 1000-germs weight (□) and monogermity (■) to 1st level of interspace of plants(40 cm) (the numbers on the columns shows percent of variation)

increase in steckling size. Podlaski (1987a) showed that the increase in steckling weight from 150 to 700 g caused an increase in seed yield, whereas seeds of heavier stecklings had higher germination percentage. However, no significant effect of steckling weight of seed germination percentage, rate and uniformity was observed in this study (Table 1).

The results of the study indicated that the increase in the interspacing of seed-bearing plants led to the production of seeds with bigger size and an increase in >4.5 mm seed portion in the expense of a decrease in standard seed portion (3.5-4.5 mm) by 4% (Fig. 3a). Pospisil and Mustapic (1999) showed that the increase in plant density was accompanied by an increase in 3.5-4.5 mm seed portion and a decrease in >4.5 mm seed portion. Slavov *et al.* (1997) reported that the increase in plant density led to the decrease in seed size and germination rate.

The decrease in standard seed portion eventually led to the fall in standard, viable seed yield as well as a decrease in such important characteristics as seed germination percentage, so that with the increase in interspacing from 40 to 60 cm, the yield of such seeds decreased by 9% (Fig. 3b). The effect of change in

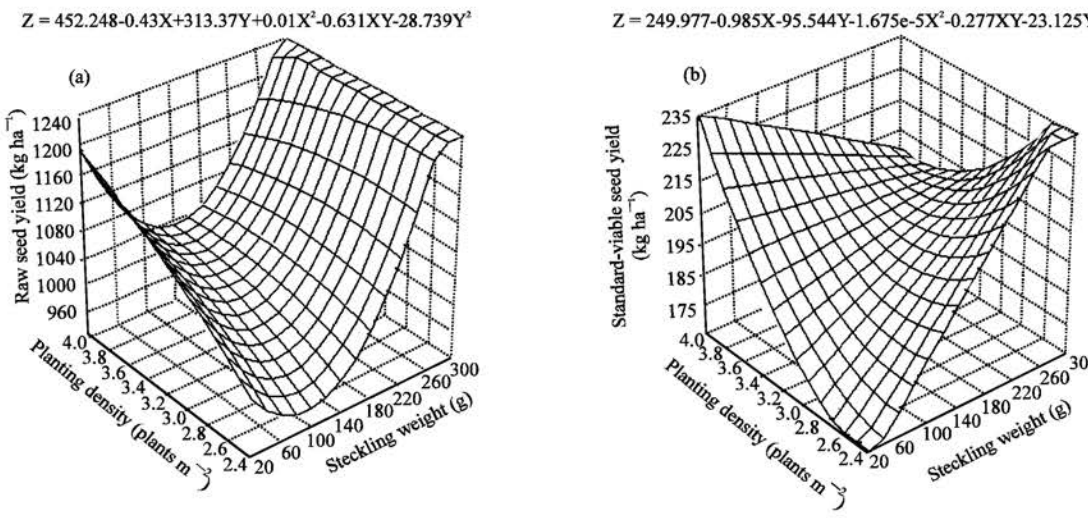

Fig. 4: Variation of raw (a) and standard-viable (b) seed yield as function of steckling weight and interspace of plants interactions

interspacing on seed yield was additive and with the increase in interspacing from 40 to 60 cm, the seed yield increased by 43%. However it is noteworthy that the increase in interspacing from 40 to 60 cm led to the decrease in plant density by 33.5%, but considering the increase in seed yield/plant by 43%, the approach of enhancing seed yield via increasing interspacing is recommendable. Podlaski (1987b) planted stecklings in two densities of 30×30 and 50×50 cm whose seed yield plant^{-1} was 13.3 and 34.2 g plant^{-1}, respectively, which justifies the results of this study. Bordei and Tapus (1981) observed that with the increase in plant density from 30,000 to 50,000 plant ha^{-1}, seed yield decreased from 0.70 to 0.97 t ha^{-1}. In a study on planting and plant density proportion of hybrid parents, Leibovich *et al.* (1993) showed that albeit the highest seed yield obtained with the parents proportion of 1 (pollinator): 3 (male sterility) and density of 70×30 cm, the highest economical efficiency was obtained through planting system of 1:2 and density of 70×70 cm. From the viewpoint of the effects on planting density on seed qualitative characteristics, in contrast to stecklings weight, the increase in interspacing led to the increase in germination rate (by 2%) and uniformity (by 4%) (Fig. 3c). Finally, the decline in plant density was accompanied by an increase in thousand-germ weight and monogerm seed percentage.

CONCLUSIONS

The effect of planting density on crude seed yield is more definitive than that of steckling weight. Therefore, in order to increase the crude seed yield, increasing planting density via decreasing interspacing can be considered (Fig. 4a). However, the effect of steckling weight is stronger than that of planting density on the viable standard seed yield (Fig. 4b). Hence, considering unequal effects of studied factors on crude and standard-viable seed yield, the terms of seed procurement must be reviewed, since agronomical factors do not necessarily have similar effects on raw and usable seed yields.

Consequently, in order to increase sugar beet seed yield in Ardabil Region and considering the results of this study, it is recommended to use the stecklings with the weight of 200-300 g and planting density of 65×60 cm.

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