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Seed Spacing for Nonthinned Sugarbeet Production

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ABSTRACT

Irrigated sugarbeet growers traditionally overseed their crop to assure adequate stands, then hand thin to a final population. The extra seed and hand labor costs may possibly be eliminated. The objective of this study was to determine optimum seed spacing for the greatest sucrose production in nonthinned sugarbeet. 'AC-102' sugarbeet (*Beta vulgaris* L.) was planted at 10-, 15-, 19-, and 23-cm intrarow seed spacings for 4 yr in Sidney, MT, to determine optimum seed spacing for greatest sucrose production of nonthinned sugarbeet. The fall ridging/spring deridging system was used to assure sufficient moisture for emergence. Successful stands were established without supplemental irrigation in 1984, 1985, and 1986, but in 1987, rains after planting and before emergence caused severe crusting of the soil which reduced stands. Seedling and harvest plant densities decreased with wider seed spacing in all years. Sucrose content decreased and impurities increased as seed spacing increased. Yields varied across years, but increased sucrose content and decreased impurities of beets planted with the 10- and 15-cm spacings generally resulted in highest gross sucrose and estimated recovered sucrose yields.

SUGARBEET is traditionally planted at high densities and hand labor is used to thin the stand to desired plant populations. This practice increases the cost for seed and field labor. Reports on optimum stand for root yield and sucrose yield are conflicting. Kern (1976) reported in a study of sugarbeet grown at intrarow spacings of 15, 23, 31, and 38 cm on 56-cm rows (119 000, 77 600, 57 000, and 47 000 plants/ha, respectively) that the lowest root yields occurred with the 15-cm spacing and the greatest root yields occurred with the 31-cm spacing. Intrarow plant spacing did not affect sucrose content. Suzuku et al. (1977) grew six sugarbeet hybrids at 15, 31, and 46 cm intrarow plant spacings on 56-cm beds (119 000, 57 600, and 38 800 plant/ha, respectively). The 31-cm spacing resulted in the greatest root yield, whereas sucrose content was not affected. Smith and Martin (1977) grew sugarbeet in 56-cm rows at plant spacings of 15, 30, 60, and 90 cm (119 000, 59 500, 29 800, and 19 800 plants/ha, respectively) and reported that impurity contents increased with wider intrarow plant spacings. Smith (1980) reported no difference in root yield between sugarbeet grown at 10- and 15-cm spacings on 56-cm rows (178 600 and 119 000 plants/ha), while root yields at 20-cm spacing (89 300 plants/ha) were reduced. As intrarow seed spacing increased, sucrose content decreased. Fornstrom (1980) planted sugarbeet to stand using 10-, 13-, 15-, 18-, and 20-cm spacings on 56-cm rows (178 600, 137 400, 119 000, 99 200, and 89 300 plant/ha, respectively). Plant spacing did not affect sucrose content, but root yield dropped at spacings of 15 cm and greater. Winter (1980) reported that on 76-cm rows, root yield and sucrose content were reduced with intrarow plant spacings of greater than 25 cm (52 600 plants/ha) and root yield, but not sucrose content, was reduced at plant spacings of less than 14 cm (94 000 plants/ha). O'Connor (1983) grew sugarbeet at plant populations of 50 000, 65 000, 80 000, and 100 000 plants/ha (33-, 25-, 21-, and 17-cm intrarow seed spacings on 61-cm rows). Root yields were greater at wider spacings, but sucrose contents were greater at narrower spacings. Generally, sugarbeet grown at narrower spacings had lower impurity contents, particularly amino-N and K. Fornstrom and Jackson (1983) reported that although root yields varied over years and locations, wider plant spacing always resulted in lower sucrose contents. Sugarbeet in a reduced tillage study had greater sucrose content and sucrose yield when planted at 10-cm spacings in 61-cm rows, with an average harvest stand of 73 800 plants/ha, than when planted at 15-cm spacings, with an average harvest stand of 39 700 plants/ha (Halvorson and Hartman, 1984).

Conservation of seedbed moisture is important for uniform germination, especially with lower seeding rates. Soil water content of sugarbeet seedbeds can be

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Abbreviations: RY, root yield; SC, sucrose content; GS, gross sucrose; II, impurity index; CJP, clear juice purity; EESC, estimated extractable sucrose content; ERS, estimated recovered sucrose; HS, harvest stand; and SS, seedling stand.

increased by the use of the fall-ridging/spring-deridging process described by Klassen (1978). Ridges are established in the fall where sugarbeet rows will be planted the following spring. Prior to planting in the spring, the ridges are scraped into interrow furrows, resulting in a flat seedbed with exposed moist soil. Seed are planted as soon as the seedbed is dry enough to allow seeding equipment into the field. This process increases seedbed moisture at planting compared to conventional techniques and increases the chance of obtaining adequate sugarbeet populations with reduced seeding rates.

Research to evaluate seed spacings for nonthinned sugarbeet on fall-ridged/spring-deridged beds has not been reported. The objective of this experiment was to determine optimum intrarow seed spacings for maximum sucrose harvest of nonthinned sugarbeet using fall-ridged/spring-deridged seedbeds.

MATERIALS AND METHODS

The experiment was conducted from 1984 through 1987 at the Montana State University Eastern Agricultural Research Center in Sidney. Soil was a fine, montmorillonitic Typic Argiboroll (Savage silty clay). Each year, experimental sites were sampled to a 1.2-m depth and soil samples were analyzed for N, P, and K. Nitrogen was applied in the form of ammonium nitrate (34-0-0) so that applied N, plus residual N, and N expected to be mineralized from organic matter totaled 280 kg N/ha. Residual P and K were adequate in all years. Sites were disked, irrigated, plowed, mulched, and leveled prior to fall ridging. Ethofumesate (2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranol methanesulfonate) at 3.9 kg ai/ha was applied in 18-cm bands and soil was immediately ridged over the herbicide. Experimental sites were deridged prior to planting. A Kirchner Machine LTD (Lethbridge, Alberta) bedder was used to ridge and deridge. 'AC-102' sugarbeet was planted at 10-, 15-, 19-, and 23-cm intrarow seed spacings on 61-cm rows using a Heath (Heath Farm Equipment, Inc., Fort Collins, CO) vacuum air planter. Experimental design was a randomized complete block with six replications. Seed lots were large (9–10 mm), noncoated seeds with 95% germination. Seed were treated with the fungicide pentachloronitrobenzene. Carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranol methylcarbamate) insecticide at 2.2 kg ai/ha was applied in 18-cm bands and incorporated over the seed. Plots consisted of six 30.4-cm rows. Seedlings were counted in the center two rows of each plot. Plots were mechanically cultivated and furrow irrigated. Plots were defoliated at harvest and plants in the center two rows of each plot were counted. A single-row harvester was used to harvest 9 m from one of the center two rows of each plot. Root yield (RY) and sucrose content (SC) were determined by Imperial Holly Sugar Corporation, Sidney, Montana. Gross sucrose (GS) was calculated by multiplying RY by SC. Sodium, K, and amino-N contents were determined by Inter-Mountain Laboratories, Inc., Sheridan, Wyoming, and used to calculate impurity index (II), clear juice purity (CJP), estimated extractable sucrose content (EESC) and estimated recovered sucrose (ERS) as follows (Carruthers et al., 1962):

$$II = [(3.5 \times Na) + (2.5 \times K) + (9.5 \times amino\text{-}N)]/SC$$
$$CJP = 97.09 - (II \times 0.00208)$$
$$EESC = (SC - 0.3)\{1 - [1.667 \times (100 - CJP)/CJP]\}$$
$$ERS = (EESC/100) \times yield$$

Analyses of variance and linear regression analyses were used to analyze the data, and were calculated using MSU-STAT Version 4.10 developed by Dr. Richard Lund, Montana State University, Bozeman.

RESULTS AND DISCUSSION

Seedling (SS) and harvest stands (HS) were negatively correlated with seed spacing across years (Fig. 1 and 2), while HS was positively correlated with SS across years (HS = 0.0 + 0.87 SS, $r = 0.9838$). Seedling and harvest stands were similar in 1984, 1985, and 1986. Heavy rain between planting and emergence in 1987 resulted in severe crusting of the soil surface which greatly reduced emergence at all seed spacings. The 10-cm spacing resulted in fewer plants in 1987 than the 15-cm spacing in all years, while the 15-cm spacing in 1987 resulted in fewer plants in the final stand than both the 19- and 23-cm spacings in 1984 and 1986.

Yield and quality data of sugarbeet at four in-row seed spacings were linearly regressed against seed spacing and are shown in Table 1. Less competition among plants in the more widely spaced rows generally resulted in larger beets with lower SC and greater impurities, particularly K and amino-N. Data across years were regressed against harvest stand. Sucrose content, GS, and ERS were positively correlated with

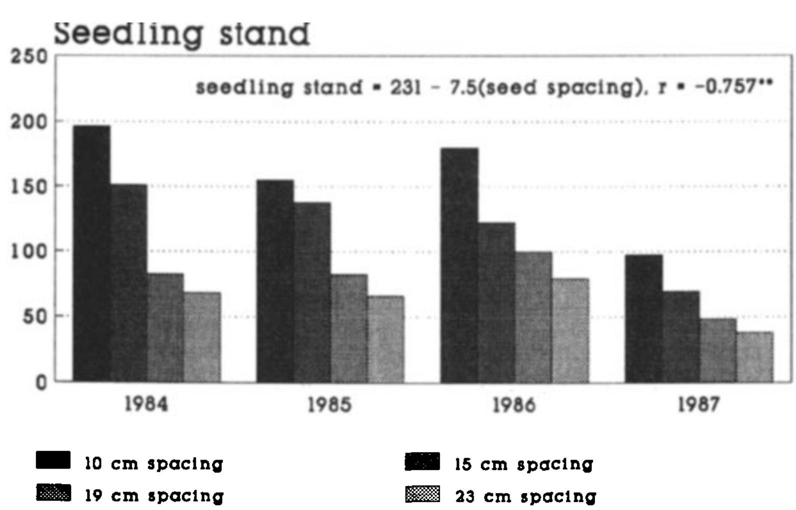

Fig. 1. Number of sugarbeet seedlings in 30.4 m at four seed spacings.

Table 1. Root yield (RY), sucrose content (SC), gross sucrose (GS), impurities, estimated extractable sucrose content (ESSC), and estimated recovered sucrose (ERS) of sugarbeet at four seed spacings. Data were linearly regressed against seed spacing.

Year	Seed spacing	RY†	SC	GS†	Na	K	Amino N	EESC	ERS†
		Mg/ha	g/kg	kg/ha	ppm	ppm	ppm	g/kg	kg/ha
1984	10 cm	50.0	172.5	8618	1432	2330	303.7	156.2	7802
	15 cm	56.5	172.3	9736	1453	2356	318.9	155.5	8784
	19 cm	53.1	166.5	8846	1520	2455	318.7	150.0	7969
	23 cm	58.1	163.3	9485	1562	2569	353.7	149.5	8692
	slope	0.50*	−0.76**	NS	10.4*	18.6**	3.45*	−0.59**	NS
	intercept	46.1	181.4	–	1317	2115	266.0	162.6	–
1985	10 cm	42.6	185.3	7883	1375	2554	161.8	168.5	7168
	15 cm	39.1	183.4	7180	1336	2666	176.0	166.6	6521
	19 cm	39.7	180.6	7182	1504	2925	209.8	163.8	6517
	23 cm	34.8	178.8	6217	1484	2918	209.5	161.7	5623
	slope	−0.53*	−0.52**	−116**	NS	31.4**	4.11**	−0.54**	−107**
	intercept	47.9	190.7	9057	–	2241	120.5	174.2	8261
1986	10 cm	54.4	190.2	9983	1071	1932	197.0	174.0	9137
	15 cm	48.3	190.6	9165	1067	2011	178.0	174.4	8383
	19 cm	53.8	182.4	9816	1220	2002	260.2	166.2	8940
	23 cm	59.3	177.9	10561	1323	2167	278.6	162.0	9619
	slope	0.58*	−1.0**	NS	20.6*	16.0**	7.39*	−0.98*	NS
	intercept	43.7	202.5	–	823.8	1759	104.7	186.1	–
1987	10 cm	61.6	174.8	10806	1263	2056	306.2	158.5	9803
	15 cm	60.7	166.8	10095	1513	2185	351.4	150.5	9098
	19 cm	50.7	174.2	8808	1277	2287	339.3	157.7	7972
	23 cm	50.5	166.9	8306	1397	2223	324.8	150.7	7488
	slope	−1.0*	NS	−204**	NS	NS	NS	NS	−187**
	intercept	72.6	–	12910	–	–	–	–	11720
All Years	10 cm	51.6	180.7	9319	1285	2218	242.2	164.3	8477
	15 cm	51.2	178.3	9041	1342	2304	256.1	161.8	8197
	19 cm	49.3	175.9	8866	1381	2417	282.0	159.4	7850
	23 cm	50.7	171.7	8641	1441	2469	291.6	156.0	7856
	slope	NS	−0.67**	NS	11.8*	20.1*	4.04*	−0.63**	NS
	intercept	–	187.9	–	1165	2015	200.3	170.9	–

*,** Correlation coefficient significant with probability = 0.05 and 0.01, respectively. NS indicates no significant correlation.
† Significant seed spacing-by-year interaction.

HS, while K and amino-K were negatively correlated with HS. Sodium was not correlated with HS. Regression equations across years were

$$SC = 168.7 + 0.085HS \ (r = 0.287^{**})$$
$$GS = 8055 + 9.15HS \ (r = 0.217^{*})$$
$$ERS = 7290 + 8.60HS \ (r = 0.220^{*})$$
$$K = 2015 - 20.12HS \ (r = -0.287^{**})$$
$$\text{Amino-N} = 320.4 - 0.560HS \ (r = -0.243^{*}).$$

Because wider seed spacing resulted in fewer plants at harvest, wider seed spacing generally produced lower GS and lower ERS than narrower intrarow seed spacings. When analyzed across years, SC, GS, EESC, and ERS decreased as seed spacing increased, although correlation coefficients of GS and ERS were not significant when they were regressed against seed spacing.

Root yield, GS, and ERS showed significant seed spacing-by-year interaction. Since root yield was used to calculate GS and ERS, these characters varied across years as RY varied. Root yield among the different seed spacings varied across years, with a positive correlation between RY and seed spacing in 1984 and 1986, and a negative correlation between RY and seed spacing in 1985 and 1987. A definite trend was apparent in 1985 and 1987, in which RY decreased as seed spacing increased. The negative correlations be-

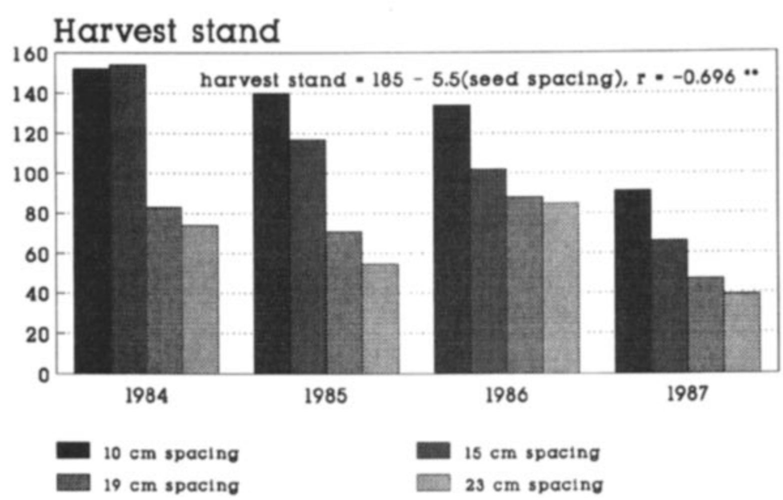

Fig. 2. Number of harvested sugarbeets in 30.4 m at four seed spacings.

tween RY and seed spacing in 1985 and 1987 may have occurred because the harvest stands in those 2 yr were generally lower, and gaps in the rows were great enough at the 19- and 23-cm spacings so that increased beet size did not compensate for the lower stands. Root yields in the 19- and 23-cm spacings were apparently compensated for by larger roots in 1984 and 1986, the years with the better stands. No trend was apparent in those years, and differences were probably due to field variation. This study and previous conflicting reports on optimum plant populations for highest RY indicate that other factors, such as length of growing season, influence RY more than seed spacing and harvest stand. Variation in RY was apparently not due to differences in plant population because no correlation was indicated when RY was regressed against seed and harvest stands within years or across years.

Sugarbeet stands were lower in 1987 than in other years, but average RY in 1987 was greatest in that year. Seeding occurred about 2 wk earlier in 1987 than other years, and a long frost-free season allowed a later harvest date than other years. This long growing season contributed to the higher yields in 1987.

Reports of optimum plant stand at harvest for maximum root and sucrose yield include 57 600 plants/ha (Kern, 1976; Suzuku et al., 1977), 52 600 to 92 100 plants/ha (Winter, 1980), and greater than 119 000 plants/ha (Fornstrom, 1980). The 10-cm seed spacing resulted in plant populations at harvest of 89 280, 82 240, 78 700, and 53 400 plants/ha in the 4 yr of this study. The lowest stand achieved at the 10-cm spacing is at the lowest end of the range of optimum plant stands reported, and was achieved under very poor conditions for emergence.

Sugarbeet was successfully planted to stand without supplemental irrigation using the fall-ridging/spring-deridging process. Average root yields achieved by commercial growers in the lower Yellowstone River Valley were 37.4, 43.0, 48.4, and 54.9 Mg/ha in 1984 through 1987 respectively, and the average sucrose contents of commercial sugarbeets for those years were 168.4, 169.3, 181.7, and 188.3 g/kg, for harvested GS of 6298, 7280, 8794, and 10 338 kg/ha (D. Melin, Imperial Holly Sugar Corp., 1990, personal communication). Gross sucrose yields achieved at the 10- and 15-cm seed spacings were similar to or greater than those achieved by commercial growers in all years. The 10- and 15-cm seed spacings in this study achieved plant populations which did not reduce sucrose yields. Harvested sucrose was generally greater at these spacings than at the wider spacings, while impurities were generally lower at these seed spacings.

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