Rotary Hoe Cultivation in Sweet Corn

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Summary. **A 2-year study was conducted to assess sweet corn (*Zea mays*) susceptibility to mechanical weeding using a rotary hoe at preemergence to six-leaf stages of corn development and at different combinations of stages. Three sweet corn cultivars: early ('Quickie'), mid ('July Gem'), and late season ('Sensor') were seeded at two sowing dates. The experiment was conducted in a weed-free environment. In general, sweet corn could be cultivated with the rotary hoe at least once without yield reduction from preemergence to the six-leaf stage. Cob numbers were reduced and maturity delayed after three or four cultivations with the rotary hoe. The rotary hoe could be an effective tool in controlling weeds in an integrated weed management approach or for organic sweet corn production since it cultivates both within and between the rows. The rotary hoe, which covers a large area in a short time, can be used at later growth stages, extending the time period during which it can be used without damaging the crop and reducing yield.**

Sweet corn is the most commonly grown vegetable in Canada with Québec accounting for 33% of Canada's total sweet corn area (Statistics Canada, 2004). Large quantities of herbicides are currently used in commercial production with 95% of the crop area receiving one to two applications per year. Sweet corn producers are under increased pressure to decrease herbicide usage in response to environmental concerns (Giroux, 2002). This situation coupled with an increased demand for pesticide-free crops has promoted an interest in the use of alternatives, such as mechanical weed control, in sweet corn management.

Smith et al. (1996) were able to control weeds with mechanical weeders in grain or fodder corn (*Z. mays*). Mechanical weeding of field corn usually requires two weeders; one to cultivate broadcast over the corn row and between the rows at the beginning of the season and a second cultivator to weed between corn rows later in the season when the crop is more developed (Leblanc and Cloutier, 2001). Unfortunately, sweet corn has been reported to be more susceptible than grain corn to damage caused by intra-row cultivation (Colquhoun et al., 1999; Lareau, 1997). Inter-row weeding has been generally well mastered using cultivators (Cloutier and Leblanc, 2001; Colquhoun et al., 1999). However, selective intra-row weeding at the beginning of the growing season is more problematic. Weeds that become established during this period can cause considerable yield losses and therefore, intra- and inter-row weeds must be removed as early as possible. One of the few weeders currently available that can perform this task is the rotary hoe. The rotary hoe can cultivate two to four times faster than a regular inter-row weeder and this implement is most effective when it is used on germinating weeds prior to emergence or at the cotyledon stage (Cloutier et al., 1996; Gunsolus, 1990). However, there is the possibility of damage to the crop since the rotary hoe cultivates on the row.

The primary objective of this project was to determine the susceptibility of various growth stages of sweet corn to physical damage caused by rotary hoe cultivation. Sweet corn is normally planted at different dates during the growing season to spread corn harvesting over weeks and cultivars have different growth and development characteristics. Therefore, different planting dates were also included in this project along with three cultivars to determine if differences in susceptibility existed between cultivars and/or different planting dates.

Materials and methods

Five field experiments were conducted both in 1999 and 2000 at the research station of the Institut de recherche et de développement en agroenvironnement, Saint-Hyacinthe, Québec, Canada. Three sweet corn cultivars: early ['Quickie', a heterozygous sugary enhanced (sesu) hybrid, 59 d to maturity], mid-season ['July Gem', a homozygous sugary enhanced (sese) hybrid, 69 d to maturity] and late-season ['Sensor', a homozygous sugary enhanced (sese) hybrid, 78 d to maturity] were used in the trials. A four-row John Deere Max Emerge2 7200 planter (Deere & Co. Moline, Ill.) sowed the seeds 3 cm deep in 30-inch rows at a density of 51,800 seeds/ha on 29 Apr. 1999 and 3 May 2000. The mid-season and the late-season cultivar had a second sowing date on 20 May 1999 and 23 May 2000. In 1999, the soil used for the first and second seeding date was a Duravin loam (coarse-loamy over clayey, mixed, mesic, Typic Endoaquept). In 2000, the soil used for the first and second seeding date was a Duravin loam and a Dujour clay loam (fine clayey, mixed, mesic, Aeric Humaquept), respectively. Fields were fall plowed and spring harrowed and fertilized according to soil analysis and provincial recommendations (Conseil des Productions Végétales du Québec Inc., 1994). In order to prevent confounding with weed interference, this project was conducted in a weed-free

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
1.1209	lb/acre	$kg \cdot ha^{-1}$	0.8922
1.6093	mph	$km \cdot h^{-1}$	0.6214

environment by treating the field with selective herbicides. Metolachlor and cyanazine were applied pre-emergence at rates of 1.92 kg·ha^{-1} a.i. and 1.80 kg·ha^{-1} a.i., respectively. Due to weed escapes, in the early-season cultivar, a post-emergence atrazine and corn oil was applied at rates of 1.44 kg·ha^{-1} a.i. and 1.25% v/v, respectively.

The experimental design was a randomized complete block with four replications. Plots were 3 m wide (four rows) and 10 m long. Grain corn was planted around and between blocks to minimize edge effects. A distance of 20 m was left between blocks in order to enable the tractor to reach the proper operating speed when cultivating the plots. The rotary hoe used in this project was a high ground clearance model (3412) from Yetter (Yetter Manufacturing Co. Inc., Colchester, Ill.). The hoe was 3 m wide and the speed of operation was 15 km·h^{-1} and the working depth varied from 4 to 5 cm. Treatments consisted of systematically cultivating every crop growth stage once, from pre-emergence (L0=BBCH-06) to the sixth-leaf stage (L6=BBCH-16) (Bleiholder et al., 1997) [BBCH = Biologische Bundesanstalt, Bundessortenamt and Chemische Industrie (German Federal Biological Research Centre for Agriculture and Forestry, German Federal Office of Plant Varieties, Chemical Industry)]. Other treatments involved combinations of cultivations at different growth stages. In addition, a non-cultivated control treatment was included. Five meters of row in the two center rows of each plot were harvested manually for yield data. In 1999, early, mid-season and late-season corn were harvested on 14, 21, and 30 July, respectively, for the first seeding date. For the second seeding date, mid-season and late-season corn were harvested on 29 July and 10 Aug., respectively. In 2000, early, mid-season and late-season corn were harvested on 3, 11, and 18 Aug., respectively, for the first seeding date. For the second seeding date, mid-season corn was harvested on 16 Aug. The late-season corn in the second planting in 2000 was not harvested due to uneven crop emergence. At harvest, crop stand and cob number per hectare were recorded. Afterwards, cobs were husked and the percentage of non-marketable cobs determined based on cob maturity, disease and insect damage (Canadian Food Inspection Agency, 1999). For marketable cobs, length, diameter, and length of the undeveloped cob tips were measured. Data were subjected to analysis of variance using SAS (version 6; SAS Institute Inc., Cary, N.C.) and tested for normality. Statistically, the different cultivars or planting dates could not be combined. Data were transformed when required using either square root or log transformations to attain homogeneity of variance. For clarity, untransformed data with SE of the mean are presented in the tables. Treatments were compared with orthogonal contrasts.

Results and discussion

EARLY-SEASON CULTIVAR. In 1999, the crop could be cultivated up to four times without a significant reduction in total yield compared with the non-cultivated control (Table 1). Seventy seven percent of the yield was marketable for plants cultivated up to three times, whereas four cultivations reduced the marketable cobs to 64.9% of the total yield. Control plants or those cultivated once had significantly greater marketable yields than plants cultivated four times. In 2000, no significant differences in crop stand, total and marketable yield were observed between the cultivation treatments and the control. Treatments cultivated two or three times had significantly lower crop stand, total and marketable yields than treatments cultivated once. As the number of cultivations increased the chance of damaging the crop also increased. A significant increase in marketable yield was recorded for plants cultivated at the six-leaf stage compared with other single cultivation treatments (Table 1). Cob diameter (41 mm) was unaffected by rotary hoeing in both years (data not shown). In 1999, cobs were significantly longer when corn was cultivated once (17.3 cm), twice (17.4 cm) or three times (17.6 cm) compared with the non-cultivated control (16.5 cm; Table 1). However, in 2000, corn cultivated two or four times had 1.8 and 1.2% shorter cobs than the non-cultivated control (16.6 cm) or treatments cultivated once (16.5 cm). In 1999, all cultivation treatments significantly reduced the length of the undeveloped cob tip (5.2%) compared with the non-cultivated control (7.2%). In 2000, there was no significant difference among treatments with an overall mean of 8.3% of the cob length unfilled. This would make the sweet corn growth stage L1 the most susceptible to damage by cultivation. There was no significant difference among treatments in the percentage of cobs that were rejected due to insect damage, disease and lack of uniformity (data not shown). Cultivating the crop with the rotary hoe affected cob maturity and hence percentage cob rejection (Table 1). In 1999, a single cultivation at the L1 stage significantly increased the percentage of immature cobs compared with a single cultivation at any other stage of development. There was no difference when the crop was cultivated once or twice. However, there was a significant increase in the number of immature cobs at four cultivations (Table 1). The number of immature cobs in the non-cultivated control was significantly lower than that of plots cultivated four times. In 2000, there was no difference in the percentage of immature cobs between the single cultivation treatments and the control. Control plants had significantly less immature cobs than plots cultivated three or four times. A single cultivation with the rotary hoe regardless of the stage of development of the crops had significantly less immature cobs than all other cultivation treatments.

MID-SEASON CULTIVAR. For the first seeding, total yield, for both years, was reduced by 21%, 26%, and 50% in the treatments that received two, three, or four cultivations, respectively, compared with the non-cultivated control (Table 2). Crop stand in 2000 followed the same trend. Sweet corn cultivated once had marketable yields similar to those of the control. Otherwise, marketable yield followed a trend similar to that of total yield. In 1999 and 2000, there were no significant differences in cob diameter (45–47 mm; data not shown), and length (17.7–19.2 cm). In 1999, one, three, or four cultivations significantly reduced the length of the undeveloped cob tip compared with the control plants. In 2000, the control plants had more undeveloped cob length than those plants which had been cultivated four times. Among treatments, there was no significant difference in the number of immature cobs and in the number of cobs rejected due to disease, insect damage, or lack of uniformity (data not shown). Immature cobs accounted for the greatest percentage of rejection (20%) (data not shown).

Table 1. Effect of rotary hoeing at different crop growth stages on the marketable yields and cob characteristics of early-season sweet corn 'Quickie' planted at the first seeding date in 1999 and 2000 (mean ±se).[z]

Growth stages[y]	Crop stand (plants/ha)[x]	Total yield (cobs/ha)[x]		Marketable yield (cobs/ha)[x]		Cob length (cm)[x]		Undeveloped cob tip (cm)[x]		Immature cobs (%)[w]	
	2000[v]	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
L0	25840 ± 621	50987 ± 3009	42434 ± 2302	37171 ± 2364	38487 ± 2541	17.6 ± 0.1	16.7 ± 0.2	1.01 ± 0.15	1.16 ± 0.22	9.1 ± 3.6	2.9 ± 1.2
L1	26220 ± 1405	41776 ± 6204	40790 ± 930	30263 ± 7147	35526 ± 1074	17.7 ± 0.3	16.6 ± 0.1	0.76 ± 0.09	1.31 ± 0.17	22.1 ± 8.7	6.4 ± 3.7
L2	25460 ± 3544	47040 ± 2541	39474 ± 3440	40790 ± 3086	33224 ± 3149	17.6 ± 0.2	16.5 ± 0.2	0.89 ± 0.11	1.13 ± 0.18	6.5 ± 1.6	6.0 ± 1.9
L3	27740 ± 1260	48355 ± 4409	42105 ± 1421	41447 ± 4213	36513 ± 2541	17.6 ± 0.3	16.5 ± 0.2	0.83 ± 0.13	1.27 ± 0.17	7.3 ± 3.6	3.1 ± 1.3
L4	26030 ± 2020	46382 ± 8311	40790 ± 2739	37500 ± 8769	31908 ± 3284	17.0 ± 0.4	16.6 ± 0.2	0.94 ± 0.04	1.51 ± 0.15	8.8 ± 5.1	6.1 ± 3.4
L5	27930 ± 1922	46053 ± 4195	42763 ± 2548	32895 ± 2991	37500 ± 3583	17.2 ± 0.3	16.4 ± 0.2	1.06 ± 0.06	1.65 ± 0.14	14.6 ± 5.1	4.8 ± 2.0
L6	29640 ± 2035	51645 ± 2303	46711 ± 1566	39474 ± 2991	43750 ± 2174	16.6 ± 0.4	16.5 ± 0.1	1.00 ± 0.09	1.52 ± 0.15	10.3 ± 2.4	1.4 ± 0.8
L0, L2	25650 ± 1434	42434 ± 2706	41776 ± 2706	33224 ± 1965	35197 ± 3775	17.2 ± 0.3	16.4 ± 0.1	0.79 ± 0.10	1.30 ± 0.17	12.8 ± 3.0	10.0 ± 5.9
L1, L3	22040 ± 1551	44408 ± 5163	33882 ± 2811	34210 ± 4264	28290 ± 3502	17.6 ± 0.3	16.0 ± 0.2	0.91 ± 0.17	1.44 ± 0.13	13.2 ± 5.1	11.5 ± 3.8
L0, L2, L4	25080 ± 2342	49342 ± 1370	38487 ± 3149	36842 ± 1421	32237 ± 3289	17.7 ± 0.3	16.5 ± 0.2	0.92 ± 0.09	1.51 ± 0.13	18.5 ± 3.0	10.5 ± 1.9
L1, L3, L5	22420 ± 2183	44737 ± 5010	37171 ± 2861	33553 ± 5304	29276 ± 2483	17.6 ± 0.1	16.1 ± 0.3	0.84 ± 0.15	1.30 ± 0.14	16.1 ± 3.4	12.3 ± 4.7
L0, L2, L4, L6	25080 ± 2827	44079 ± 1566	39803 ± 4409	28618 ± 2174	30921 ± 5194	16.8 ± 0.6	16.0 ± 0.2	0.78 ± 0.12	1.64 ± 0.18	27.7 ± 3.7	16.1 ± 6.0
Control (no rotary hoeing)	26790 ± 2113	50658 ± 1899	40790 ± 4195	40132 ± 2918	34539 ± 3961	16.5 ± 0.4	16.6 ± 0.2	1.18 ± 0.10	1.24 ± 0.16	15.6 ± 3.0	2.5 ± 1.8
Contrasts											
L1 vs. other single cultivations	NS	NS	NS	NS	NS	NS	NS	*	NS	**	NS
L6 vs. other single cultivations	NS	NS	NS	NS	**	*	NS	NS	NS	NS	NS
1 vs. 2 cultivations	*	NS	*	NS	*	NS	**	NS	NS	NS	*
1 vs. 3 cultivations	*	NS	*	NS	*	NS	NS	NS	NS	NS	*
1 vs. 4 cultivations	NS	NS	NS	*	NS	NS	**	NS	NS	***	**
2 vs. 3 cultivations	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
2 vs. 4 cultivations	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS
3 vs. 4 cultivations	NS	NS	NS	NS	NS	*	NS	NS	NS	*	NS
Control vs. 1 cultivation	NS	NS	NS	NS	NS	*	NS	*	NS	NS	NS
Control vs. 2 cultivations	NS	NS	NS	NS	NS	*	*	**	NS	NS	NS
Control vs. 3 cultivations	NS	NS	NS	NS	NS	**	NS	*	NS	NS	*
Control vs. 4 cultivations	NS	NS	NS	*	NS	NS	**	**	NS	*	**

[z]Planting dates were 29 Apr. 1999 and 3 May 2000. Data were pooled when variances were homogeneous and there were no significant interaction between years and treatments.
[y]Crop growth stages are designated L0 for the preemergence to L6 for the sixth leaf stage.
[x]1 ha = 2.4711 acres; 1 cm = 0.3937 inch; 1 mm = 0.0394 inch.
[w] Expressed as percent total harvested cobs.
[v] Data were not available in 1999.
[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 2. Effect of rotary hoeing at different crop growth stages on the marketable yields and cob characteristics of mid-season sweet corn 'July Gem' planted at the first seeding date in 1999 and 2000 (mean ± SE).[z]

Growth stages[x]	Crop stand (plants/ha)[y] 2000[v]	Total yield (cobs/ha)[y]	Marketable yield (cobs/ha)[y]	Undeveloped cob tip (cm)[y] 1999	2000
L0	26220 ± 1925	40296 ± 2856	31743 ± 2957	0.12 ± 0.05	0.83 ± 0.35
L1	23940 ± 2183	35855 ± 2940	28618 ± 2276	0.20 ± 0.10	0.30 ± 0.11
L2	28500 ± 1975	40625 ± 2145	27303 ± 2221	0.09 ± 0.05	0.31 ± 0.10
L3	27930 ± 1623	40954 ± 2718	29112 ± 1279	0.18 ± 0.02	0.39 ± 0.15
L4	29070 ± 843	40296 ± 3516	28125 ± 2079	0.09 ± 0.04	0.18 ± 0.07
L5	28120 ± 2081	38816 ± 3035	28290 ± 2878	0.20 ± 0.12	0.41 ± 0.13
L6	29830 ± 1434	39309 ± 3009	29112 ± 3512	0.05 ± 0.03	0.22 ± 0.14
L0, L2	24320 ± 1938	34046 ± 1581	25987 ± 1286	0.11 ± 0.06	0.29 ± 0.08
L1, L3	25270 ± 478	37829 ± 2001	26480 ± 2442	0.25 ± 0.08	0.26 ± 0.08
L0, L2, L4	25650 ± 898	35691 ± 2012	24671 ± 3479	0.11 ± 0.06	0.65 ± 0.18
L1, L3, L5	20710 ± 1765	31579 ± 2548	22368 ± 2279	0.09 ± 0.05	0.07 ± 0.04
L0, L2, L4, L6	16720 ± 1987	23026 ± 2953	16776 ± 2289	0.09 ± 0.09	0.19 ± 0.07
Control (no rotary hoeing)	32870 ± 1532	45724 ± 2687	33388 ± 1629	0.32 ± 0.15	0.55 ± 0.08
Contrasts					
L1 vs. other single cultivations	*	*	NS	NS	NS
L6 vs. other single cultivations	NS	NS	NS	NS	NS
1 vs. 2 cultivations	*	*	NS	NS	NS
1 vs. 3 cultivations	**	***	**	NS	NS
1 vs. 4 cultivations	***	***	***	NS	NS
2 vs. 3 cultivations	NS	NS	NS	NS	NS
2 vs. 4 cultivations	***	***	***	NS	NS
3 vs. 4 cultivations	**	***	**	NS	NS
Control vs. 1 cultivation	**	**	NS	*	NS
Control vs. 2 cultivations	***	***	*	NS	NS
Control vs. 3 cultivations	***	***	***	*	NS
Control vs. 4 cultivations	***	***	***	*	*

[z]Planting dates were 29 Apr. 1999 and 3 May 2000. Data were pooled when variances were homogeneous and there were no significant interaction between years and treatments.
[y]1 ha = 2.4711 acres; 1 cm = 0.3937 inch; 1 mm = 0.0394 inch.
[x]Crop growth stages are designated L0 for the preemergence to L6 for the sixth-leaf stage.
[w]Expressed as percentage of total harvested cobs.
[v]Data were not available in 1999.
[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

For the second seeding, four cultivations with the rotary hoe significantly decreased crop stand and total yield in both years (Table 3). Three or four cultivations decreased marketable yield between 13% and 44% compared with sweet corn cultivated once or non-cultivated. In 1999, cob diameter was significantly greater for corn cultivated four times (44.7 mm) than for all other treatments. In 2000, cob diameters of plants cultivated three times were significantly smaller than those of the control plants. In both years, cob length varied between 16.9 and 18.6 cm with no significant differences among treatments (data not shown). Cobs had in general less than 3% of the length undeveloped in 1999. In 2000, the undeveloped cob tip varied between 3.1% and 8.7% of the cob length. The undeveloped tip was shorter for corn cultivated four times (3.1%) compared with the control (6.1%) and plots cultivated once (5.8%) or three times (7.0%). In both years, corn cultivated three (30.8%) or four times (35.3%) had a greater percentage of immature cobs than treatments cultivated once or twice (mean value 21.7%).

LATE-SEASON CULTIVAR. For the first seeding, in 1999, up to two cultivations did not significantly reduce total yield (Table 4). However, the marketable yield decreased as the number of cultivations increased, although differences were only significant between plants cultivated four times and those cultivated once or not at all. There was no difference among treatments in the percentage of yield that was marketable (65%). In 2000, two, three, or four cultivations reduced the percentage of the crop that was marketable and reduced yields by 42%, 47%, and 49%, respectively, compared with corn cultivated once or non-cultivated. In both years, corn cultivated four times had a cob diameter between 2% and 3% smaller than those with one (41.4 mm), two (41.2 mm), or three (41.2 mm) cultivations. There were no significant differences in either cob length or undeveloped cob tip. Plots cultivated four times had significantly more immature cobs than those cultivated once. In 2000, either no cultivation or only a single cultivation resulted in fewer immature cobs than all other treatments. The significantly greater percentage of non-marketable cobs was due to the increased immaturity of corn with increasing number of cultivations (Table 4).

For the second seeding, there were no significant differences in marketable yield, cob diameter (39.1–41.0 mm), cob length (21.8–22.5 cm), and undeveloped end (0.06–0.38 cm) among the treatments (Table 5).

Table 3. Effect of rotary hoeing at different crop growth stages on the marketable yields and cob characteristics of mid-season sweet corn 'July Gem' planted at the second seeding date in 1999 and 2000 (mean ± SE).[z]

Growth stages[y]	Crop stand (plants/ha)[x]	Total yield (cobs/ha)[x]	Marketable yield (cobs/ha)[x]	Cob diam (mm)[x]		Undeveloped cob tip (cm)[x]		Immature cobs (%)[w]
				1999	2000	1999	2000	
L0	23655 ± 1671	39145 ± 2276	28618 ± 1186	42.4 ± 0.2	42.8 ± 0.7	0.16 ± 0.05	1.03 ± 0.14	18.3 ± 4.0
L1	23560 ± 1285	37993 ± 1748	26151 ± 1731	43.7 ± 0.4	42.9 ± 0.9	0.09 ± 0.05	1.12 ± 0.24	23.7 ± 5.6
L2	21565 ± 1457	34868 ± 2398	25329 ± 2303	42.9 ± 0.1	43.2 ± 1.1	0.19 ± 0.03	0.87 ± 0.18	21.9 ± 3.8
L3	20140 ± 1202	32895 ± 1268	23849 ± 1279	44.0 ± 0.2	43.0 ± 0.8	0.00 ± 0.00	1.11 ± 0.28	16.4 ± 2.7
L4	22610 ± 783	36184 ± 1686	25822 ± 1809	43.8 ± 0.3	44.0 ± 0.7	0.06 ± 0.03	1.15 ± 0.11	24.2 ± 5.0
L5	21565 ± 1201	36184 ± 1741	24671 ± 1379	43.7 ± 0.2	43.3 ± 1.2	0.11 ± 0.06	1.09 ± 0.28	23.8 ± 3.9
L6	23845 ± 1005	37500 ± 1861	27303 ± 1401	43.7 ± 0.2	43.6 ± 1.1	0.06 ± 0.02	0.84 ± 0.16	20.9 ± 2.0
L0, L2	21945 ± 1162	35691 ± 1581	25658 ± 2153	43.0 ± 0.2	42.8 ± 0.9	0.14 ± 0.03	0.96 ± 0.37	22.1 ± 4.4
L1, L3	19760 ± 1878	31250 ± 2545	19901 ± 1302	43.8 ± 0.3	43.8 ± 1.1	0.05 ± 0.02	0.90 ± 0.18	24.2 ± 6.3
L0, L2, L4	20520 ± 2150	32730 ± 3564	21382 ± 2471	43.4 ± 0.6	42.4 ± 0.6	0.02 ± 0.02	1.47 ± 0.30	30.8 ± 1.7
L1, L3, L5	19855 ± 1516	32730 ± 2244	20230 ± 2124	43.7 ± 0.3	42.9 ± 0.6	0.04 ± 0.02	1.00 ± 0.18	30.9 ± 3.9
L0, L2, L4, L6	15770 ± 1182	25329 ± 1771	14803 ± 1379	44.7 ± 0.3	43.0 ± 0.4	0.03 ± 0.02	0.57 ± 0.06	35.3 ± 2.8
Control (no rotary hoeing)	22325 ± 963	37171 ± 1466	28125 ± 1138	43.0 ± 0.4	44.2 ± 0.9	0.05 ± 0.03	1.08 ± 0.21	15.6 ± 3.3
Contrasts								
L1 vs. other single cultivations	NS	NS	NS	NS	NS	NS	NS	NS
L6 vs. other single cultivations	NS	NS	NS	NS	NS	NS	NS	NS
1 vs. 2 cultivations	NS	NS	*	NS	NS	NS	NS	NS
1 vs. 3 cultivations	*	*	***	NS	NS	*	NS	***
1 vs. 4 cultivations	***	***	***	***	NS	NS	*	***
2 vs. 3 cultivations	NS	NS	NS	NS	NS	NS	NS	*
2 vs. 4 cultivations	**	***	***	**	NS	NS	NS	**
3 vs. 4 cultivations	***	**	***	**	NS	NS	**	NS
Control vs. 1 cultivation	NS	NS	NS	NS	NS	NS	NS	NS
Control vs. 2 cultivations	NS	NS	*	NS	NS	NS	NS	NS
Control vs. 3 cultivations	NS	*	***	NS	*	NS	NS	***
Control vs. 4 cultivations	***	***	***	***	NS	NS	*	***

[z]Planting dates were 20 May 1999 and 23 May 2000. Data were pooled when variances were homogeneous and there were no significant interaction between years and treatments.
[y]Crop growth stages are designated L0 for the preemergence to L6 for the sixth-leaf stage.
[x]1 ha = 2.4711 acres ; 1 cm = 0.3937 inch; 1 mm = 0.0394 inch.
[w]Expressed as percentage of total harvested cobs.
NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

There was no significant difference in the percentage of immature cobs among treatments. The percentage of non-marketable cobs varied between 57% to 81% and was primarily due to insect damage. There was significantly less insect damage in sweet corn which had been cultivated three times than in those that had been cultivated once, twice, or not at all. Similar results were reported by Weber et al. (1990), who noted a reduction in cob infestation by corn borer in cultivated plots.

In summary, this research indicates that sweet corn cultivar and date of seeding influenced this crop susceptibility to rotary hoeing. Sweet corn can be cultivated once with the rotary hoe at any growth stage, from preemergence to sixth-leaf stage without a yield reduction. The percentage of marketable cobs decreased primarily due to an increase in the number of immature cobs when the rotary hoe was used more than twice for the later-seeded mid-season cultivar or late-season cultivar. This might partly be because any given experiment was harvested on a single date, and therefore the marketable yield might have been reduced due to the number of immature cobs. However, in a normal production system, producers harvest several times the same field and consequently, the number of immature cobs would be significantly less than in these experiments. Insects were a problem only for the late-season cultivar. It was observed that occurrence of insect damage on cobs tended to be less when corn was cultivated more than twice. The type and condition of soil could play an important role in the susceptibility of corn to cultivation with the rotary hoe. It was observed that risks of crop damage increased at early stages with dry light soils or heavy wet soil (Cloutier and Leblanc, 2003). Seeding in light soil should be as deep as possible in order to minimize the risks of damaging sweet corn. The rotary hoe could be an effective tool in controlling weeds in an integrated weed management approach or for organic sweet corn production since it cultivates both within and between the rows. The rotary hoe, which covers a large area in a short time, can be used at later growth stages, extending the time period during which it can be used without damaging the crop and reducing yield.

Table 4. Effect of rotary hoeing at different crop growth stages on the marketable yields and cob characteristics of late-season sweet corn 'Sensor' planted at the first seeding date in 1999 and 2000 (mean ± SE).[z]

Growth	Crop stand (plants/ha)[x]	Total yield (cobs/ha)[x]		Marketable yield (cobs/ha)[x]		Cob length (cm)[x]		Cob diam	Immature cobs (%)[w]	
stages[y]	2000[v]	1999	2000	1999	2000	1999	2000	(mm)[x]	1999	2000
L0	27930 ± 1256	34211 ± 4494	48684 ± 537	26316 ± 5290	38158 ± 2081	19.8 ± 0.4	19.7 ± 0.2	41.0 ± 0.4	6.2 ± 3.1	19.6 ± 4.0
L1	25270 ± 1135	30263 ± 4364	45066 ± 1965	18750 ± 1459	32237 ± 2491	20.3 ± 0.3	19.9 ± 0.1	41.3 ± 0.3	10.7 ± 3.6	25.2 ± 3.9
L2	29070 ± 2350	32895 ± 4774	49342 ± 4967	23355 ± 4694	41776 ± 4570	19.9 ± 0.3	20.0 ± 0.2	41.7 ± 0.6	19.0 ± 6.2	12.9 ± 3.9
L3	26220 ± 1097	26974 ± 5847	47040 ± 987	14474 ± 3683	38487 ± 630	20.2 ± 0.2	20.2 ± 0.2	41.4 ± 0.3	16.3 ± 3.2	16.8 ± 1.6
L4	29070 ± 1256	35855 ± 1459	51316 ± 1937	26316 ± 2991	38816 ± 2046	20.2 ± 0.1	20.4 ± 0.1	41.6 ± 0.6	10.5 ± 5.5	23.0 ± 3.9
L5	32110 ± 843	36184 ± 4446	54276 ± 987	24342 ± 5277	40460 ± 2706	19.8 ± 0.4	20.0 ± 0.1	41.6 ± 0.6	13.5 ± 5.2	23.5 ± 5.2
L6	30210 ± 1091	31579 ± 5452	51974 ± 3929	20395 ± 4698	41118 ± 4963	20.0 ± 0.2	19.9 ± 0.3	41.1 ± 0.4	19.9 ± 3.8	18.0 ± 4.4
L0, L2	21470 ± 2113	26974 ± 1260	39803 ± 2652	14145 ± 2303	28618 ± 1730	19.7 ± 0.3	20.2 ± 0.1	41.1 ± 0.8	32.4 ± 12.9	27.0 ± 3.6
L1, L3	20330 ± 2799	33224 ± 8751	38158 ± 4430	22697 ± 7791	18092 ± 3009	19.9 ± 0.3	20.2 ± 0.2	41.4 ± 0.7	11.8 ± 4.7	53.5 ± 2.9
L0, L2, L4	22420 ± 1181	22040 ± 3009	41776 ± 1555	14145 ± 1964	23684 ± 2215	20.0 ± 0.2	20.3 ± 0.2	41.0 ± 0.6	20.9 ± 8.0	41.5 ± 6.1
L1, L3, L5	18430 ± 3855	23355 ± 4409	36842 ± 5452	16118 ± 2960	19079 ± 4109	20.0 ± 0.1	19.9 ± 0.2	41.5 ± 0.3	14.3 ± 5.7	47.7 ± 8.0
L0, L2, L4, L6	22610 ± 2245	25329 ± 6273	40132 ± 1370	14474 ± 5372	20395 ± 3333	20.4 ± 0.4	20.3 ± 0.2	40.3 ± 0.5	36.2 ± 10.7	47.4 ± 7.4
Control (no rotary hoeing)	30400 ± 1029	34868 ± 4938	51645 ± 1645	25329 ± 6015	40132 ± 3502	19.9 ± 0.2	20.0 ± 0.2	41.0 ± 0.7	18.5 ± 10.6	20.8 ± 5.0
Contrasts										
L1 vs. other single cultivations	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
L6 vs. other single cultivations	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1 vs. 2 cultivations	***	NS	***	NS	***	NS	NS	NS	NS	***
1 vs. 3 cultivations	***	**	***	NS	***	NS	NS	NS	NS	***
1 vs. 4 cultivations	**	NS	**	*	***	NS	NS	**	**	***
2 vs. 3 cultivations	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
2 vs. 4 cultivations	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
3 vs. 4 cultivations	NS	NS	NS	NS	NS	NS	NS	*	*	NS
Control vs. 1 cultivation	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control vs. 2 cultivations	***	NS	**	NS	***	NS	NS	NS	NS	***
Control vs. 3 cultivations	***	*	**	NS	***	NS	NS	NS	NS	***
Control vs.4 cultivations	**	NS	*	*	***	NS	**	NS	NS	***

[z]Planting dates were 29 Apr. 1999 and 3 May 2000. Data were pooled when variances were homogeneous and there were no significant interaction between years and treatments.
[y]Crop growth stages are designated L0 for the preemergence to L6 for the sixth-leaf stage.
[x]1 ha = 2.4711 acres ; 1 cm = 0.3937 inch; 1 mm = 0.0394 inch.
[w]Expressed as percentage of total harvested cobs.
[v]Data were not available in 1999.
[NS, *, **, ***]Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 5. Effect of rotary hoeing at different crop growth stages on the marketable yields and cob characteristics of late-season sweet corn 'Sensor' planted at the second seeding date in 1999 (mean ± SE).[z]

Growth stages[y]	Crop stand (plants/ha)[x]	Total yield (cobs/ha)[x]	Marketable yield (cobs/ha)[x]	Insect damage (%)[w]
L0	18810 ± 3663	35856 ± 4601	10526 ± 3798	52.3 ± 11.2
L1	18050 ± 2799	34868 ± 3418	8553 ± 1656	49.5 ± 8.6
L2	16720 ± 1551	31579 ± 2341	5592 ± 1554	55.1 ± 10.7
L3	18050 ± 2180	30592 ± 4208	9539 ± 3009	36.4 ± 3.7
L4	18430 ± 1623	27961 ± 5050	9868 ± 2182	32.8 ± 6.1
L5	20900 ± 1335	37829 ± 3056	8224 ± 1459	54.5 ± 6.5
L6	21660 ± 728	39474 ± 930	10526 ± 2791	44.9 ± 4.1
L0, L2	22040 ± 878	41776 ± 630	11842 ± 1699	48.0 ± 4.3
L1, L3	15390 ± 1135	29605 ± 380	10197 ± 2706	43.3 ± 8.8
L0, L2, L4	15580 ± 2070	30592 ± 3997	12829 ± 1645	30.2 ± 4.1
L1, L3, L5	15770 ± 783	26974 ± 1741	9868 ± 1741	30.2 ± 5.0
L0, L2, L4, L6	14060 ± 1298	26974 ± 2548	9868 ± 849	41.8 ± 4.2
Control (no rotary hoeing)	21090 ± 1897	44079 ± 4729	13487 ± 1245	50.2 ± 7.3
Contrasts				
L1 vs. other single cultivations	NS	NS	NS	NS
L6 vs. other single cultivations	NS	NS	NS	NS
1 vs. 2 cultivations	NS	NS	NS	NS
1 vs. 3 cultivations	*	*	NS	**
1 vs. 4 cultivations	**	*	NS	NS
2 vs. 3 cultivations	NS	*	NS	*
2 vs. 4 cultivations	*	*	NS	NS
3 vs. 4 cultivations	NS	NS	NS	NS
Control vs. 1 cultivation	NS	**	NS	NS
Control vs. 2 cultivations	NS	*	NS	NS
Control vs. 3 cultivations	**	***	NS	*
Control vs. 4 cultivations	**	***	NS	NS

[z]Planting date was 20 May 1999. Data were pooled when variances were homogeneous and there were no significant interaction between years and treatments.
[y]Crop growth stages are designated L0 for the preemergence to L6 for the sixth-leaf stage.
[x]1 ha = 2.4711 acres
[w]Expressed as percentage of total harvested cobs.
NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

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