Managing interference in a sweet corn-white clover living mulch system.

Albert Fischer and Larry Burrill[1]

Abstract. *Living mulches are vegetative covers that can be grown in association with row crops to reduce soil erosion, improve trafficability, and suppress weeds. Interference by the living mulch can reduce yields of an associated crop. The interference between a white clover (Trifolium repens L. "New Zealand") living mulch and sweet corn (Zea mays L. "Golden Jubilee") was studied using an established clover sward that was mowed and then sprayed with 1 to 1.5 kg ai ha-1 of atrazine [6-chloro-N-ethyl-N'-(1-methyl-ethyl)-1,3,5,triazine-2,4-diamine]. Corn, at different densities and planting arrangements, was planted into a narrow band tilled in the clover. Interference by clover reduced corn yields by 12 to 39%. However, when corn row width was reduced from 0.76 to 0.38 m, competition among corn plants declined, they became more vigorous and clover-suppressive, reached even higher yields than conventional (no mulch) 0.76-m-row corn. Similarly, a range of sweet corn densities, planted on a clover*

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mulch killed by atrazine, yielded more in equidistant planting than in wide (0.76 m) rows. A near equidistant corn planting arrangement can, therefore, be a low-input alternative to achieve season-long clover suppression, and thus minimize its competition with the intercropped corn.

Key words: Interference, systematic designs, densities, row width, intercropping, planting arrangement, competition.

Introduction

Weather conditions in western Oregon make agricultural fields prone to rain and wind erosion when the soil surface is without a protective vegetation cover. The breaking of soil aggregates by rain results in a surface crust that reduces water infiltration and promotes runoff and soil loss (Harvard et al., 1980). Soil, organic matter, fertilizers, and pesticides may also be moved from fields and deposited in streams and rivers (Burwell et al., 1975; Harvard et al., 1980; Daniel et al., 1980).

Sweet corn in Oregon may be harvested in the fall when abundant rains fall and the soil surface is sparsely covered by vegetation, making the harvest difficult and the fields vulnerable to erosion. This situation is worsened by weed control practices that leave much of the soil surface exposed.

Living covers (white clover, vetch, and others) growing in association with corn reduce erosion and suppress weeds (Hargrove, 1982; Sweet, 1982). According to Vrabel (1983), intercropping sweet corn with a legume cover crop also increases nitrogen availability to sweet corn. Unsuppressed white clover intercropped with sweet corn usually will lower corn yields (Hartwig, 1977; Lang et al, 1956; Sweet, 1982). Such interference[1] needs to be minimized without significant cost increases, for living mulches to be an alternative feasible to farmers. Management practices should optimize the capacity of sweet corn to suppress the growth of the mulch. Before management practices for these intercropped species can be defined, the factors involved in sweet corn-white clover interference must be known.

Research reported here focused on: (a) interactions among sweet corn plants, and between these and white clover, when sweet corn grew with a white clover living mulch; and on (b) finding a cropping situation to minimize corn yield reduction from clover interference.

Two types of experiments were conducted: (1) conventional field experiments were used to quantify the effect of clover on sweet corn yield, to study sweet corn and clover responses to changes in sweet corn densities and planting patterns, and to assess the ability of sweet corn to suppress clover growth; and (2)

[1] Interference is the negative effect of one plant upon another through either competition, allelopathy, or both.

productivity of corn growing in a suppressed clover sward was evaluated for a range of densities within two different planting arrangements, using systematic[2] designs (Bleasdale, 1966; Nelder, 1962; Freyman and Dolman, 1971).

Materials and Methods

Sweet corn density and planting pattern in the presence of a living mulch.

The effect of corn densities and planting patterns on the yield of sweet corn (*Zea mays* L. var. "Golden Jubilee") growing in association with white clover (*Trifolium repens* L. var. "New Zealand") was assessed near Corvallis, Oregon, on a fine-silty, mixed mesic Cumulic Ultic Haploxeroll soil. The experimental treatments were combinations of high and low sweet corn densities with two row spacings. Thus four planting patterns of sweet corn were evaluated (Table 1).

Plots were 6 by 10 m, and treatments were arranged in a randomized complete block design with four replications. A 2-year-old white clover sward was mowed prior to planting corn in 10 to 15-cm wide strips tilled through the clover at selected row spacings. Two John Deere Flexiplanter 70 units mounted behind the tiller placed corn seeds 2-cm deep into the tilled band. The

[2] Experimental layout where a species' density increases systematically in the field.

experiment was conducted under sprinkler irrigation in 1984 and 1985. The sequence of tillage, planting, clover suppression, and fertilizing are shown in Table 2.

To assess clover interference with corn growth, corn plants were sequentially sampled for growth analysis in both growing seasons. The sampling schedule for 1984 was at 20, 35, 50, 64, and 121 days after planting (DAP) corn; and in 1985, at 25, 46, 64, and 98 DAP. Total above-ground biomass of two representative corn plants per plot was harvested at each sampling date, and leaf area and dry matter were determined for each plant (plants were dried for 5 days at 70 C and weighed). From these data, mean crop growth rates (CGR) were calculated following Hunt (1982).

Clover foliage was sampled in 1985 by clipping at 64 DAP an 18 by 50 cm area between sweet corn rows. The clover samples were dried for 3 days at 70 C, and weighed. At 52 DAP, high contrast photographs of the corn canopy were taken with a 7.5 mm fisheye lens mounted on a 35 mm camera, using Kodalith orthofilm 6556 type 3. The camera was placed on the ground at the center of each plot, pointing skyward. With the resulting high-contrast slides allowed estimates of percent canopy coverage were made following Chan et al. (1986).

In both years, when corn moisture was 72%, ears with husks were harvested from three 1-meter sections of row per plot. Only ears with husks longer than 15 cm (harvestable ears) were harvested, and their fresh weight recorded.

Conventional vs. mulch systems

The interference of a clover mulch with sweet corn productivity was studied in 1984 and 1985. The treatments were: (a) conventional surface tillage (no mulch) with a rotary tiller (1984) or a mouldboard plow (1985), with sweet corn (66,000 plants ha-1) planted in rows 76 cm apart; (b) same row width and density of sweet corn as in (a) but planted into a 2-year-old herbicide-suppressed white clover sward; (c) sweet corn (79,000 plants ha-1) seeded into herbicide-suppressed clover in 38 cm rows. This treatment was added in 1985 to assess the effect of narrow rows on sweet corn yield and clover growth (in this treatment the planting procedure resulted in a corn density 1.26 times higher than in the other treatments). In treatments (b) and (c) corn was seeded in a band tilled in the clover sod as described in the preceding section.

Soil type, timing and procedures for tillage, planting, clover suppression, biomass sampling, irrigation, fertilization, and harvest were the same as in the preceding experiment (Table 2).

Density experiments

To determine best sweet corn density and seeding pattern to grow under the influence of a constant background level of white clover, sweet corn was planted in 1985 at systematically increasing densities, and in two different planting patterns, into a suppressed clover sward. Two experimental designs were used:

(a) A fan design (Bleasdale, 1967; Nelder, 1962) where the almost square geometry between corn plants remained constant, and twelve corn densities ranging from 25,000 to 173,000 plants ha^{-1} were placed in successive rows (arches in Figure 1a), in four 7 by 5 m plots placed at different orientations on a 3-year-old white clover sward. Clover was mowed and a 10-cm planting band was tilled over each arch with a rotary tiller. Corn was hand planted (June 23) into the tilled band. Fertilizer was broadcast over the plots 7 DAP (30 kg N and 68 kg P ha^{-1}), and 15 DAP (90 kg N ha-1). Atrazine plus crop oil (1.5 kg ai ha^{-1} plus 2 L ha^{-1}) were applied 8 DAP to suppress clover growth. Five corn plants per density were harvested when kernel moisture was 70%, and the weight of husked ears more than 15 cm long was recorded. One arch at either extreme of the plots was discarded as a border row.

(b) In a second experiment, the systematic design of Freyman and Dolman (1971) was used, where row width was held constant (76 cm) for all densities (Figure 1b). Thus a sequence of 11 densities

(25,000 to 172,000 plants ha-1) was planted in 11 parallel rows placed in each of four 8 by 7 m plots. The plots were established at different orientations on a 3-year-old white clover sward. Planting, fertilizing, clover suppression, and harvesting were conducted as in experiment (a).

The experiments were conducted on a fine-silty, mixed mesic Cumulic Ultic Haploxeroll soil. The results from both systematic experiments were analyzed by regression.

Results and discussion

Clover interference and sweet corn planting patterns.

When corn was planted in conventional 0.76 m rows, its growth and productivity were depressed when clover was present (Tables 3a and 4a). Competition for water and nutrients is usually involved in such interference (Altieri and Liebmann, 1986). Although yield reduction in 1985 was not significant, clover should be suppressed for this system to work successfully (Sweet, 1982).

Sweet corn growing with a clover mulch in narrow rows showed higher corn growth rates (Table 3), more marketable ears per plant (Table 5), and crop yields even higher than those obtained in conventional plots without clover (Table 4). Enhanced productivity with narrow rows had also been observed with corn growing alone (Mack, 1972), or with alfalfa (Peterson, 1985). Also, as noted by Harper et al. (1980), corn in narrow rows was more suppressive of clover growth (Table 4) since higher growth rates in this planting arrangement resulted in leafier corn plants (Table 4) thus providing more complete ground shading (Table 6). Increasing ground cover suppressed clover growth (R^2=0.33, p=0.02). Plants in wide rows grew close to each other within the row (Table 1), whereas better spacing in the narrow rows reduced competition among corn plants which were then more productive and clover-suppressive, as also noted by Altieri and Liebmann (1986), and Fischer and Myles (1973).

Doubling corn density in either planting arrangement did not increase neither yields nor clover suppression (Table 4b). High corn density resulted in more crowded plants with fewer marketable ears (Table 5). In the 76-cm rows, in spite of the high density, there still remained much uncovered ground (Table 6), allowing for considerable clover growth and competition (Table 4b).

Stepwise regression analysis (models with high coefficients of determination and low mean square errors were selected) identified those aspects of corn growth and clover suppression most closely affecting marketable corn ear production. In 1984 corn LA/plant and plant biomass accounted for 70% of corn yield variability; and in 1985 corn and clover biomass, and canopy ground cover, were the parameters most closely associated with corn yields ($R^2 = 0.87$). Changes in corn densities and planting arrangements affected these parameters (Tables 3, 4, and 6).

Systematic density experiments

The addition of oil made the atrazine suppression too harsh and killed the recently-mowed clover sward. Corn was thus planted onto a dead clover cover.

In both planting arrangements, corn planted in a nearly equidistant pattern yielded more than in 76-cm rows (Figure 2) where plants were more crowded within the rows. Therefore, higher competition among corn plants should have occurred in the wide row arrangement, explaining the lower yields obtained with this planting method (Brown et al., 1970). The higher productivity of the narrow row arrangement, observed in the preceding section, was confirmed by this experiment over a wide range of planting densities. The absence of a competing clover mulch may explain why yields were not curbed at high densities as in the preceding experiments where twofold density increases did not improve yields (Table 4b).

Summary and Conclusions

It was the primary objective of this investigation to study the competitive interactions in a system involving sweet corn and a white clover living mulch. A cropping situation minimizing clover interference with corn was sought. Sweet corn was grown on conventionally-tilled soil, and also intercropped with a clover living mulch at different densities and planting arrangements. Yield losses occurred when sweet corn was intercropped with the clover mulch. Clover growth needs to be strongly suppressed to prevent excessive competition with the associated crop. Since clover is intended as a perennial living cover, however, suppression should not kill it completely. Season-long clover suppression would thus require several chemical or mechanical interventions. Therefore, complementary vegetation management techniques are needed for prolonged living mulch suppression, while keeping external inputs low. A near-equidistant corn planting approach using narrow rows can be a feasible option to mitigate corn yield losses in a corn-clover living mulch system.

Serious erosion and trafficability problems seem the strongest reasons for living mulch use by sweet corn growers in Oregon. Other benefits from the mulch, such as reduced annual weed populations, increased soil nitrogen availability, and use of clover as a forage to be sold or consumed on the farm, may also be relevant to farmers. Managing this cropping approach may be complex, and would require technical support and changes in farming practices such as adapting the harvesting equipment to work in narrow rows.

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Figure 1.(a) Systematic density design with an approximately square planting arrangement. (b) Systematic density design for spacing experiments with set row widths.

Figure 2 Yields of marketable sweet corn ears in 1985, when it was planted at different densities, in a nearly equidistant pattern or in rows 76 cm apart. The regression lines are statistically different ($p < 0.01$) according to an F test comparing all the coefficients in the models.

Table 1. Treatments in the sweet corn density and planting pattern experiment in the presence of a white clover living mulch.

	Treatments			
Density (plants ha^{-1})	66,000	131,000	79,000[1]	131,000
Row width (cm)	76	76	38	38
Plant spacing within rows (cm)	20	10	33	20

[1] The corn planter used did not allow seeding at 66,000 plants ha^{-1} in rows 38 cm apart, the closest density was 79,000.plants ha^{-1}.

Table 2. Sequence of tillage, sweet corn planting, fertilization, and clover suppression operations.

Days from planting	1984
-8	Surface tillage in the treatment without clover.
0	Strip tillage in clover, and corn planting (June 25). Fertilization: N, P, and K at 4, 6, and 4 kg ha^{-1} banded[1]. Clover suppression: atrazine + alachlor at 1.7 + 2.2 kg ai[2] ha^{-1} were sprayed[3] on a 15 cm band over the seeded rows.
36	Fertilization: 100 kg N ha^{-1} basal application.
42	Clover suppression: atrazine at 1.1 kg ai ha^{-1}.
	1985
-11	Surface tillage in the treatment without clover.
-4	Strip tillage and fertilization (N and P at 30 and 63 kg ha^{-1} applied 10 cm deep in the tilled band).
0	Sweet corn planting (June 3).
1	Clover suppression: atrazine + crop oil at 1.5 kg ai ha^{-1} + 2 L ha^{-1} sprayed over 15-cm-tall clover.
10	Clover suppression: clover mowed between corn rows.
45	Fertilization: 90 kg N ha^{-1}, basal application.

[1] 2.5 cm to the side and below corn seeds.

[2] Active ingredient.

[3] Spray volume was 200 L ha^{-1}.

Table 3. Effect of planting densities, row width, and clover mulch on mean crop growth rate (CGR) of corn. Data are from two separate sets of experiments (a and b)

Treatments				CGR	
No.	Row width	Corn density	Clover Presence	1984	1985
	(cm)	(plants ha^{-1})		---- ($g\ m^{-2}\ day^{-1}$) ----	
(a)					
	76	66,000	no	16.2a[1]	26.9a
	76	66,000	yes	6.7b	7.6c
	38	79,000	yes		13.5b
LSD (0.05)				7.8	5.3
CV (%)				30	19
(b)					
	76	66,000	yes	3.4d	15.2b
	38	79,000	yes	9.5b	20.9ab
	76	131,000	yes	7.1c	27.4a
	38	131,000	yes	13.4a	24.1a
LSD (0.05)				1.9	8.5
CV (%)				15	24

[1] Values followed by the same letter are not statistically different according to Fisher's protected LSD (p=0.05).

Table 4. Effect of planting densities, row width, and a clover mulch on sweet corn yield, leaf area index, and clover growth. Data are from two separate sets of experiments (a and b).

No.	Row width	Corn density	Clover mulch	Yields of marketable ears 1984	Yields of marketable ears 1985	Clover dry matter 64 DAP[1], 1985	Leaf area index 47 DAP 1984	Leaf area index 47 DAP 1985
	(cm)	(plants ha^{-1})		----(kg ha^{-1})----		(kg ha^{-1})	---($cm^2 cm^{-2}$)---	
(a)								
	76	66,000	no	29,280a[2]	33,594b	---	5.9a	2.9a
	76	66,000	yes	17,760b	29,519b	1,811a	1.2b	1.3b
	38	79,000	yes	---	42,522a	711b	---	2.6a
LSD (0.05)				8,552	8,799	323	2.3	1.1
CV (%)				16	14	11	29	29
(b)								
	76	66,000	yes	13,678c	22,820b	1,580ab	0.61c	1.07b
	38	79,000	yes	32,710a	37,660a	1,090b	1.58b	1.33b
	76	131,000	yes	10,469c	25,298b	2,030a	1.03c	1.62b
	38	131,000	yes	28,452b	35,980a	1,090b	2.98a	3.80a
LSD (0.05)				3,407	5,062	623	0.55	0.84
CV (%)				10	10	27	8	14

[1] Days After Planting.

[2] Within columns, values followed by the same letter are not statistically different according to Fisher's protected LSD (p=0.05).

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	(cm)	(plants ha^{-1})		----(kg ha^{-1})----		(kg ha^{-1})	---(cm^{2}cm^{-2})---	
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CV (%)				10	10	27	8	14

[1] Days After Planting.

[2] Within columns, values followed by the same letter are not statistically different according to Fisher's protected LSD (p=0.05).

Table 5. Effect of planting density and row width on the number of marketable ears of sweet corn growing with a clover living mulch.

Treatments: Row width	Plants per ha	Clover mulch	Ears > 15 cm long: 1984	1985
(cm)			(no./plant)	
76	66,000	yes	0.6b[1]	1.03b
38	79,000	yes	0.9a	1.44a
76	131,000	yes	0.3c	0.58c
38	131,000	yes	0.6b	0.79bc
LSD (0.05)			0.28	0.26
CV (%)			29	17

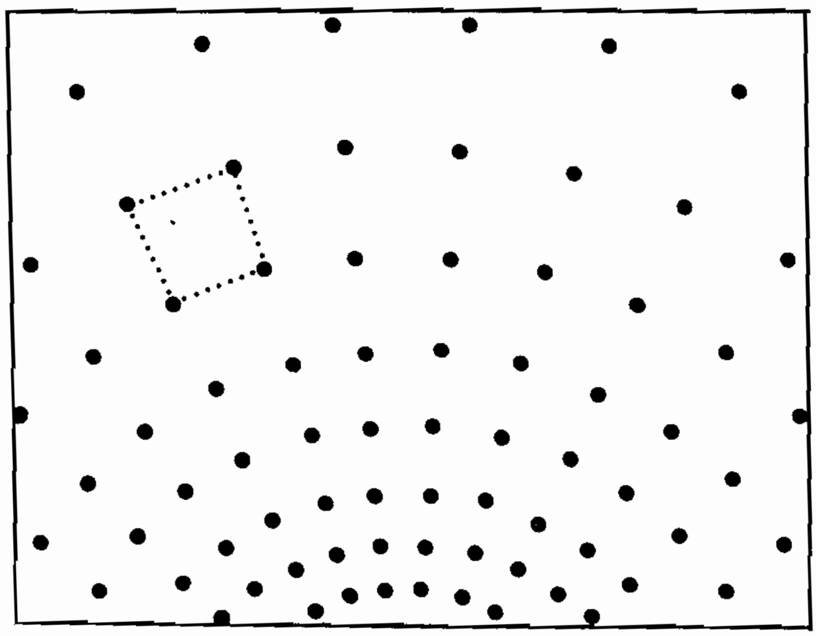
[1] Within columns, values followed by the same letter are not statistically different according to Fisher's protected LSD (p=0.05).

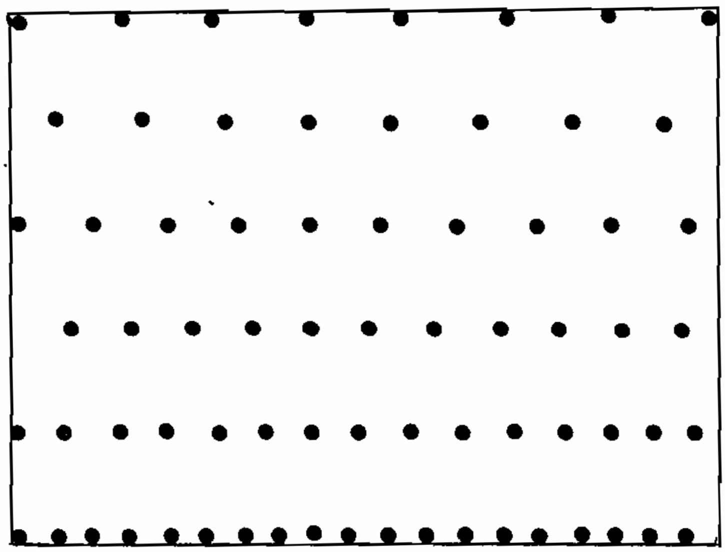
Table 6. Between-row ground cover by sweet corn canopies[1] growing with clover in four planting arrangements or as conventional sweet corn monoculture.

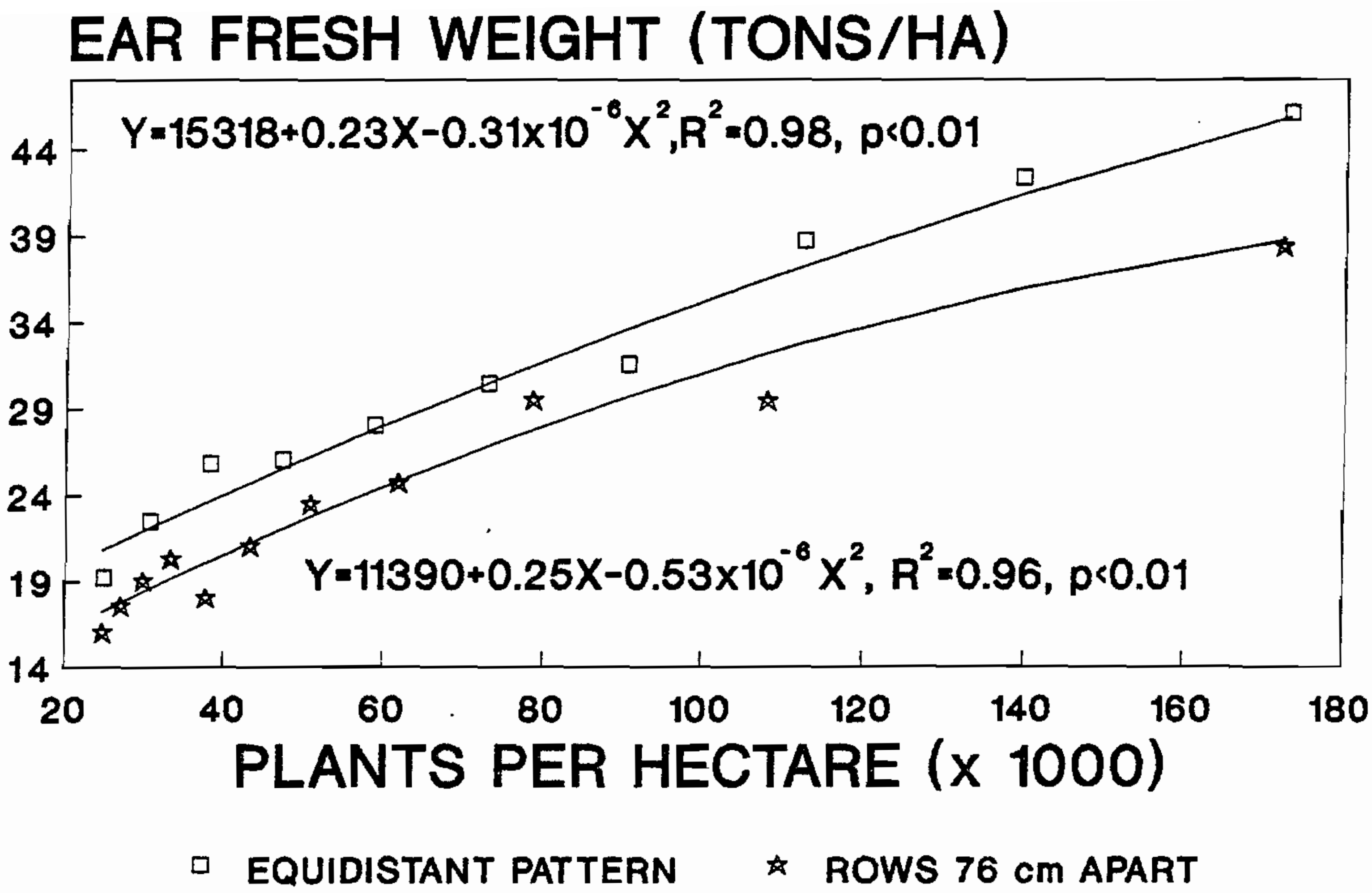
Corn population	Row width	Clover mulch	Percent ground cover
(plants ha^{-1})	(cm)		(%)
66,000	76	no	67a[2]
66,000	76	yes	28c
79,000	38	yes	53ab
131,000	76	yes	42b
131,000	38	yes	68a
LSD (0.05)			15
CV (%)			19

[1] Recorded 56 days after planting.

[2] Within columns, values followed by the same letter are not statistically different according to Fisher's protected LSD (p = 0.05).






EAR FRESH WEIGHT (TONS/HA)
Y=15318+0.23X-0.31x10⁻⁶X²,R²=0.98, p<0.01
Y=11390+0.25X-0.53x10⁻⁶X², R²=0.96, p<0.01
44
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PLANTS PER HECTARE (x 1000)
EQUIDISTANT PATTERN
ROWS 76 cm APART