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EFFECT OF POPULATION DENSITY ON DEVELOPMENT OF SCLEROTINIA WILT AND YIELD OF SUNFLOWER

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INTRODUCTION

In early studies on sunflower *(Helianthus annuus* L.) wilt caused by *Sclerotinia sclerotiorum* (Lib.) de Bary, Young and Morris (7) observed that wilt incidence decreased with increasing distance between plants, and suggested that by root contact between adjacent plants the pathogen spread rapidly along the rows unless the stalks were 30 cm apart. Huang and Hoes (2) showed that infection from sclerotia, the primary source of inoculum, gave rise to primary infection loci, and supplied direct evidence of secondary spread of the pathogen to neighbouring plants in sequential order when lateral roots intermingled. Plant spacing affected efficiency and time of spread to adjacent plants, and the number of new infections that developed from each primary infection locus.

This paper reports the results of a study on the effects of row spacing and within-row plant spacing on yield and disease development in sunflower grown in a field, naturally infested with *S. sclerotiorum.*

MATERIALS AND METHODS

Population densities — On May 20, 1975, sunflower cv. 'Peredovik' was planted in a field known to be heavily infested by *S. sclerotiorum.* Treatments consisted of 12 population densities, obtained by combining each of three row spacings with each of four within-row plant spacings. The 6 m long rows were overseeded and when plants were at the 2-leaf stage, were thinned with the aid of a graduated measuring stick to near uniform distances, averaging

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14.5, 24.5, 35.5, or 47.3 cm. Plots were 9 m wide and consisted of 31, 16 and 11 rows, spaced at distances of 30, 60 and 90 cm respectively. Treatments were replicated four times and arranged in a randomized block.

Disease development — Every plant was mapped, and the incidence of wilt monitored throughout most of the growing season by weekly or biweekly inspections, starting on June 27 (week 1) when the first wilted plants occurred, and ending on September 15 when plants were nearly mature. Plants were classified as wilted when the stem base showed the lesion typical of Sclerotinia infection. Diseased plants occur in shorter or longer series and the first plant in such a series is a primary infection locus (2). Primary infection loci arising in the same row are differentiated by the presence of at least one healthy plant at a given time. The number of loci per unit area was determined and measured the level of sclerotial inoculum.

Plants that are adjacent may become diseased from infection from randomly distributed sclerotia or from secondary spread from a primary infection locus. The "doublet" method (5) used in earlier studies (2) determines whether adjacent wilted plants are randomly distributed or not, and indicates lack of pathogen transmission or not. The results were considered to be significant or highly significant depending whether the differences between the actual and theoretical numbers of doublets was at least two or three times the standard error, respectively.

Agronomic data — At maturity on September 22, seed-yielding heads were harvested from the central 5.4 m of plots, comprising 19, 10 and 7 rows at the 30, 60 and 90 cm spacings, respectively. Productive heads were counted, air dried, threshed, and the seed (achenes) cleaned and weighed.

In all plots, the condition of each plant was known, whether healthy, wilted or wind-broken at an early age and thus non-productive. The number of productive plants often exceeded the number of healthy plants. Obviously, some wilted plants produced seed, and their numbers were computed. For instance, if a plot contained 60 healthy and 40 wilted plants, and yielded 75 productive heads, 15 wilted plants were productive while 25 others were not.

RESULTS

Disease development — Increase in row and within-row plant spacing each decreased the density of primary infection loci (Table

1). The effects were linear and highly significant. The first wilted plants were found on June 27 (week 1), about 6 weeks after planting. At the final inspection on September 15 (week 12), disease incidence varied from a low of 17.2% in a 90 x 35.5 (row spacing x within-row plant spacing) plot to a high of 84.7% in a plot at the 60 x 25.5 treatment. Variability in wilt incidence was large and treatment differences were non-significant. Taken over all plants in all plots, the wilt incidence increased slowly to 7.3% at the beginning of flowering on July 28 (week 5), and then linearly to 55.5% on September 15. The increase of the last 7 weeks averaged about 6.9%. A similar increase of about 6% in wilt incidence was found during the post-bloom period in studies by Dorrell and Huang (1). Disease spread appeared to be determined solely by within-row plant spacing. Significantly more doublets at all row spacings were produced consistently and early at 14.5 cm plant spacing, and less often and somewhat later at 25.5 cm spacing. Disease spread rarely occurred at the 35.5 cm spacing, and not at all at the 47.3 cm spacing (Table 2). Doublets did occur, however, at all row spacings at the 35.5 and 47.3 cm plant spacings, and the indicated lack of disease spread suggests that most if not all disease was due to infection from sclerotia. Consequently, the mean number of diseased plants per m^2 will reflect the sclerotial density. The number of wilted plants/m^2 at the 30 ' 35.5 treatment in the four replicates varied from 2.8 to 6.9, averaging 4.5, and is an estimate of the number of sclerotia per m^2 that occurred in the soil profile occupied by the root system.

Agronomic data — Seed yield varied highly significantly from 832 kg/ha at the 30 x 14.5 treatment to 1382 kg/ha at the 60 x 47.3 treatment (Table 1). The number of healthy and thus productive plants varied non-significantly, and averaged 45.3%. That of wilted productive, however, varied highly significantly from 2.3% at the 30 x 24.5 treatment to 34.3% at the 90 x 24.5 treatment. Correspondingly, the number of wilted non-productive plants varied highly significantly from 16.8% at the 90 x 47.3 treatment to 51.0% at the extreme treatment of 30 x 14.5 (Table 1). Row and within-row spacing each affected highly significantly yield, productive wilted plants plants and non-productive wilted plants. Yield was morw strongly correlated with within-row spacing (Coef. = 0.56) than with row spacing (Coef. = 0.35), and more strongly though negatively with % non-productive wilted plants (Coef. = 0.75). Multiple regression analysis showed that Yield = 1521.8 + 0.66 X_1 + 6.36 X_2 — 16.7 X_3, where X_1, X_2 and X_3 are row spacing, plant spacing and % non-productive wilted plants, respectively. The regression was highly

TABLE 1

Effect of row and within-row plant spacings on disease parameters and yield of sunflower in a field naturally infested with Sclerotinia sclerotiorum

Row spacing (cm)	Within-row spacing (cm)	Plants per ha (X1000)	Primary infection loci per m^2	Wilted Plants: Non-productive (%)	Wilted Plants: Productive (%	Yield (kg/ha)
30	14.5	226	2.9 a *	51.0 a	5.0 cd	832 e
	24.5	136	2.3 b	34.2 bcd	2.7 d	1124 bcd
	35.5	96	2.3 b	35.3 bcd	10.5 bcd	1210 abcd
	47.3	75	2.0 b	35.3 bcd	13.6 bcd	1194 abcd
60	14.5	113	2.1 bc	43.8 ab	24.7 ab	970 de
	24.5	67	1.6 cd	39.5 abc	29.2 ab	1059 cde
	35.5	49	1.3 de	33.4 bcd	20.9 abc	1267 abc
	47.3	36	0.9 efg	31.2 bcd	19.6 abc	1382 a
90	14.5	79	1.2 def	28.6 cde	32.4 a	1156 abcd
	24.5	45	1.0 defg	26.5 cde	34.3 a	1267 abc
	35.5	33	0.7 fg	21.7 de	23.8 ab	1354 ab
	47.3	26	0.6 g	16.8 e	26.8 ab	1318 ab

* Means within columns followed by the same letter are not significantly different (Duncan's multiple range test; O.05 level).

significant (P = 0.01) and the percent variation due to regression was 64%, and higher than with any other combination of parameters; t-values of the regression coefficients were all highly significant.

DISCUSSION

The data conclusively show that disease losses in sunflower due to Sclerotinia wilt can be minimized by manipulation of row and within-row plant spacing. Highest yield varying from 1194 to 1382 kg/ha were obtained at populations of 26,000 to 96,000 plants/ha, at within-row spacings of 35.5 cm and wider. Increase in row and within-row spacing decreased the number of non-productive wilted plants, and increased yield. Yield increase was also accompanied by a decrease in the number of primary infection loci/m^2 at the within-row spacings of 24.5 cm and lower. Spacings of 30 cm or greater prevented spread effectively, a conclusion in agreement with that of

TABLE 2

Development of Sclerotinia wilt on sunflower: week at which the number of doublets exceeded expectation significantly *

Within-row spacing (cm)	30	60	90
14.5 % Wilt	Wk. 5 & 6; all reps 0.2 — 10.5	Wk. 5 & 6; all reps 7.7. — 22.3	Wk. 5; all reps 3.0 — 4.5
25.5 % Wilt	Wk. 6 & 10; 2/4 reps 11.0 — 28.0	Wk. 5; 2/4 reps 14.5 — 40.2	Wk. 10; 1/4 reps 38.6
35.5 % Wilt	Wk. 6; 1/4 reps 17.9	—	—
47.3	—	—	—

* Planted May 20, 1975; week 1 = June 27.

Young and Morris (7), and also reached in earlier work by Huang and Hoes (2).

In these studies yield will have been affected by population *per se* as well as by wilt. In the absence of disease, Putt and Fehr (3) found that sunflower seed yield in Manitoba was highest at spacings of about 45 x 45 cm, i.e. a population of about 50,000 plants/ha. Vijayalakshmi et al. (6) found that under dryland conditions in Saskatchewan yields at populations of 25,000 plants/ha were 28% higher than those at 125,000 plants/ha but were not significantly different from yields at the 75,000 plants/ha population; row spacings of 36 to 89 cm had no effect on yield. Robinson et al. (4) from studies in Minnesota recommend populations from 37,000 to 85,000 plants/ha depending on soil fertility, and row spacings of 55 to 95 cm were relatively unimportant.

Populations at which disease losses due to Sclerotinia wilt were minimized in this study are generally within the range of populations that reportedly (3, 4, 6) maximize sunflower yields under disease-free conditions.

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