Effect of Temperature and Fungicides on Survival of Corn Grown From Kernels Infected with Helminthosporium maydis

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ABSTRACT

Kernels of corn infected with *Helminthosporium maydis* race T and sown early in May in the field resulted in 0-2% wilted seedlings, but those sown 2 weeks later yielded 0-30% (avg 8%) wilted seedlings despite a better seedling stand at the later date. In the greenhouse, a high temperature (24 C) increased losses from preemergence blight, root rot, and wilt, attributable to *H. maydis*, whether plants were maintained at 24 C or started at 18 C and transferred to 24 C. Seedlings that started growth at 18 C wilted 17-21%, but those that started at 24 C wilted 27-30%. A seed lot containing a high percentage of kernels infected with *H. maydis* was treated with 16 fungicides or combinations thereof. Of these, thiram plus either carboxin or benomyl gave the best seedling stands.

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We previously reported the incidence of *Helminthosporium maydis* Nisikado & Miyake in 403 seed lots of seed corn (*Zea mays* L.), including hybrids with normal and male-sterile (Tms) cytoplasm (1, 3). Those results suggested that temperature at and following germination influenced the incidence of seedlings wilting from infection by *H. maydis*, race T. Here we report results of trials made to determine the role of temperature during and following germination on incidence of wilted seedlings attributable to kernels infected with *H. maydis*, and the efficacy of fungicides on stand and ear number at harvest.

MATERIALS AND METHODS.—The corn hybrid used was a single cross ($A556_{Tms}$ X A619) produced in 1970 and found to contain 18% black kernels (caused by *H. maydis* based on plating tests) and which when sown in the field resulted in 26% wilted seedlings (1). Kernels were sown in the field in 1971 with a hand planter in the date-of-planting trial, and with a John Deere Plateless Planter in the fungicide trial. For the date-of-planting trial, 42 rows (50 kernels/row) were sown 13 May, and 51 rows (100 kernels/row) were sown 28 May. Kernels were sown singly about 25 cm apart in both trials. Soil temperatures were measured daily at the 5-cm soil depth for 18 days at and following each planting date and were reported as means of daily means for each 18-day period. Soil temperatures, computed by D. Baker, Department of Soil Science, averaged 3 C lower than air temperatures for the same time.

In the greenhouse, kernels were sown in field soil in 48 galvanized metal flats so that there were, at the end of the trial, six flats of 50 kernels/flat at each temperature or temperature combination. One greenhouse room was set at 18 C (range 16-24 C) and another at 24 C (range 21-29 C), and flats were changed from one to the other to ascertain the effect of a given temperature and its duration on seedling emergence, stand, root rot, and wilt.

Sixteen fungicides, or combinations, were applied to kernels in a paper bag. An amount was added which provided some excess; after shaking kernels in the bag the excess was removed. One fungicide (Hinosan) was a liquid, and kernels were coated with this fungicide and allowed to dry overnight in a hood. Some fungicides tested were not designed for seed treatment, and thus, effective rates of application were unknown. Kernels were sown in the field in 1971. Stand counts were taken 2 months after emergence and ear counts were made at harvest.

The fungicides used in the field trial were as follows: Anilazine (2, 4-dichloro-6-*o*-chloroanilino-*s*-triazine), 50% active; benomyl, 50% active; captan, 50% active; carboxin, 70% active; chloroneb, 65% active; chlorothalonil, 75% active; diazoben (*p*-dimethylaminobenzenediazo sodium sulfonate), 70% active; Hinosan (*O*, ethyl-*S*,*S*-diphenyl-dithiophosphate), 25% active; mancozeb (maneb [80%] plus zinc); maneb, 80% active; MC-833 [*N*-(dimethyldithiocarbamoylmethyl) morpholine], 75% active; metiram [ethylenebis dithiocarbamate plus dithiobis (thiocarbonyl) iminoethylene bisdithiocarbamate zinc (3:1)], 80% active; Thiabendazole [2-(4-thiazolyl) benzimidazole], 60% active.

RESULTS AND DISCUSSION.—*Date of planting in the field*.—Corn kernels from the Tms seed lot found previously (1) to be infected with *Helminthosporium maydis* race T were sown in the field on 13 and 28 May. At the earlier date, the soil temperature averaged 16 C (range 6-24 C), and at the later date it averaged 25 C (range 14-32 C), for the daily mean temperatures over an 18-day period after each planting date. Seedling emergence was 42% for 13 May and 53% for 28 May planting dates; however, only 0.9% of 882 seedlings wilted (range 0-2%) for the early date, and 8% of 2,703 seedlings wilted (range0-30%) for the later date. We previously reported that seedlings from this same seed lot wilted at 24 C but not at 18 C in the greenhouse (1, 3).

Kernels in the first planting had been treated with antagonistic bacteria, whereas those in the second planting were treated with fungicides. However, statistical analysis of data showed no significant differences within the two trials in incidence of wilted plants that could be attributed to seed treatment so that the two trials could be considered a date-of-planting trial. There was a statistically significant difference in number of wilted plants due to the different date of planting, due probably to difference in soil temperatures.

It is possible that some seedlings that might have wilted later succumbed to seedling blight fungi other than *H. maydis* in the colder soil of the first planting, and thereby might not have been present to wilt at the later date. Nevertheless, the data suggested a definite effect of soil temperature on incidence of seedlings wilting from *H. maydis*; consequently another test was made in the greenhouse to better ascertain the effect of temperature on wilt. Some of these results were reported briefly (2).

Seedlings transferred from 18 to 24 C in greenhouse.—Two kinds of experiments were designed to run concurrently with the same seed lot used in the field. In one trial, nontreated kernels were sown at 18 C in 24 flats (50/flat) and after 1 week, one-fourth of the number of flats was transferred to 24 C; after 2 and after 3 weeks another one-fourth of the number of flats was transferred each time to 24 C. Thus, six flats were kept at 18 C for 4 weeks; six at 18 C for 3 weeks, then 1 week at 24 C; six at both temperatures for 2 weeks each; and six at 18 C for 1 week and 24 C for 3 weeks.

The number of diseased seedlings 1 month after planting kernels was greater in those flats maintained for only 1 week at 18 C and 3 weeks at 24 C than in those maintained for 4 weeks at 18 C; this difference was highly significant ($P = .01$) statistically (Fig. 1). Diseased seedlings comprised those resulting from seed decay or blight before emergence, and root rot or wilt after emergence.

Seedlings transferred from 24 to 18 C in greenhouse.—In the second of two concurrent trials, nontreated kernels were sown at 24 C and after 1 week, one-fourth of the 24 flats were transferred to 18 C; after 2 and 3 weeks, another one-fourth of the number of flats each time was transferred to 18 C. Thus, in reverse of the previous experiment, six flats were kept at 24 C for 4 weeks, six at 24 C for 3, 2, and 1 week and correspondingly longer times at 18 C. The increased time at 24 C from 1 to 4 weeks increased the incidence of diseased plants (Fig. 1).

Comparison of 18 versus 24 C.—The higher temperatures have the effect of increasing losses in seedlings whether plants were started at 18 or at 24 C, but the losses were greater when plants were started and kept for at least 1 week at the higher temperature. When started at 18 C, 14-21% of the seedlings wilted, and when started at 24 C, 27-30% of the seedlings wilted.

Another comparison can be made of plants exposed to both temperatures for 2 weeks at each temperature (Fig. 1). When started at 18 C and transferred to 24 C after 2 weeks, 24% of the plants wilted, but when started and kept at the higher temperature for 2 weeks prior to transfer, 27% of the plants wilted. Moreover, plants with root rot numbered only 2% when started, and kept at 18 C for 2 weeks, but reached 12% for plants started and kept for 2 weeks at 24 C. Total loss was 59% in stand for

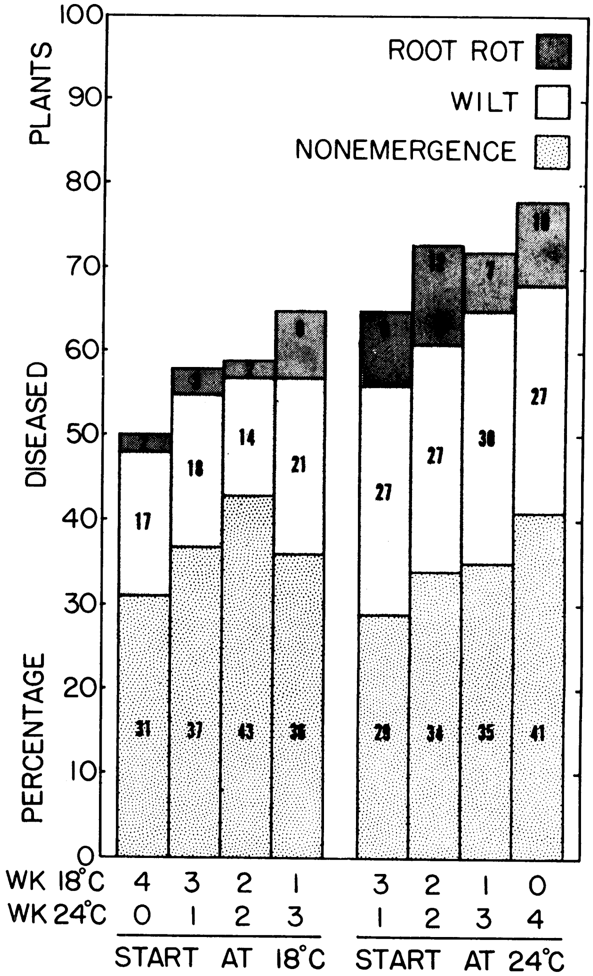

Fig. 1. The incidence of corn seedlings with root rot, wilt or preemergence blight (nonemergence) attributable to *Helminthosporium maydis* and influenced by starting plants at 18 or 24 C in the greenhouse and transferring them each week to the alternate temperature. Each value is an average of six replicates of 50 plants/replicate. Numbers in the bars indicate percentages of nonemerged, wilted, and rotted roots of plants at each temperature or temperature combination.

plants at 18 C for 2 weeks before transfer but was 73% for plants at 24 C for 2 weeks before transfer (Fig. 1). The 2-week exposure initially to 24 C was more damaging than a 2-week exposure to that temperature after an initial 2 weeks at the lower temperature.

Thus, it is apparent that when kernels are sown at the lower temperature, the number of apparently healthy plants is greater, incidence of seedlings that wilt or get root rot is less, and the amount of preemergence loss attributable to *H. maydis* is less. In the field trial, the preemergence loss was greater at the earlier planting date when soil temperatures were lower. That loss was probably the loss from *H. maydis* infection plus loss from other seedling blight fungi in soil which were not active at the higher temperatures. The longer exposure to higher temperatures increases the losses from planting a seed lot with a high percentage of infected kernels, and this effect is accentuated by starting the seed lot at the higher temperature.

The incidence of wilted seedlings was higher in greenhouse trials than in field trials, both in previous studies (3) and in the present tests. It is likely that infected plants in the greenhouse emerge and then succumb to wilt, whereas in the field, infected kernels germinate but fail to emerge. The preemergence loss in the field eliminates seedlings that might have emerged and then wilted.

The experience with *H. maydis* also illustrates that higher temperatures can increase seedling wilt or blight, whereas with most other root pathogens of corn, a lower soil temperature favors seedling blight.

Seed treatment for seedling wilt.—All but one of the 16 fungicides applied to kernels were as good as or better than the nontreated control for both seedling stand and ear number at harvest (Table 1). An analysis of variance indicated that differences existed that were highly significant. Using Tukey's *w*-procedure for comparison of means, none of the fungicides gave significantly better stands at the 5% level, but both the combinations of thiram plus either carboxin or benomyl gave significantly better stands at the 10% level.

In the treatment effects on ear number per 100 kernels sown, thiram plus benomyl gave significantly better yields at the 5% level, and thiram plus carboxin at the 10% level of significance (Table 1). The inadequate or lack of pollination of Tms corn kernels meant that grain yield could not be measured, so ear number was determined as an effect of treatment. Statistical analyses of a previous experiment (*unpublished data*) with 27 replications of 100 plants/-replicate showed a close correlation between ear number/100 plants and grain yield.

Thus, it would appear that thiram plus either carboxin or benomyl might be better for use as seed treatment chemicals than the more generally used captan, if the seed lot is suspected to contain a high percentage of kernels infected with *H. maydis*.

TABLE 1. The effect of fungicidal treatment of corn kernels on seedling stand and yield of ears from a Tms single-cross corn hybrid infected with *Helminthosporium maydis* race T and planted in the field in 1971

Fungicide[a]	Seedling stand[b]	Ear yield[b]
	%	*no.*
Hinosan	44	99
None (control)	48	108
Thiabendazole	48	114
Captan + maneb[c]	53	125
Benomyl	54	126
MC-833	55	127
Chlorothalonil	55	119
Captan	55	119
Metiram	57	123
Chloroneb	57	119
Mancozeb	59	128
Thiram	60	132
Carboxin	61	132
Anilazine	61	135
Diazoben	62	133
Thiram + carboxin[d]	64	140
Thiram + benomyl[e]	65	145
HSD[f] (.05)	18	36
HSD[f] (.10)	16	33

[a] Fungicides were applied to kernels in a paper bag, and the excess was removed after kernels were shaken in the fungicide.

[b] Values are averages of three replicates, about 100 plants/replicate.

[c] Mixture consisted of 10% active ingredient of captan and 35% of maneb.

[d] Mixture consisting of 35% active of each chemical.

[e] Mixture consisting of 35% active for thiram and 25% active for benomyl.

[f] HSD = Honestly significant difference: Tukey's *w*-procedure for comparison of means.

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