Etiology

Grain Sink Size and Predisposition of *Zea mays* to Stalk Rot

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ABSTRACT

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Corn (*Zea mays*) plants with rotted stalks had more kernels than genetically identical neighboring plants with healthy stalks. This was observed in comparisons of adjacent rotted and healthy plants of 30 hybrids at many USA locations and in another study of seven hybrids in two plant populations in one location. Relationship of data to effects of rate of carbohydrate translocation to grain and roots, including the photosynthetic stress-translocation balance concept of predisposition of corn to stalk rots is discussed.

Additional key word: root rot.

A photosynthetic stress-translocation balance (PS-TB) concept of predisposition of corn to stalk rot was proposed in 1977 (2), and for sorghum to stalk rot in 1978 (3). Development of this concept was an attempt to explain host, pathogen, and environmental interactions observed in the corn and sorghum stalk rots. Supportive evidence from the literature (2) included studies showing: that environmental stresses reduce photosynthetic capabilities of host plants; that stalk rot-susceptible plants have less reducing sugar and sucrose in the lower stalk than do the same tissues of resistant plants; that pith cell senescence occurs more rapidly in susceptible plants, that root rots precede stalk rots, and that the *Gibberella, Fusarium,* and *Diplodia* spp. associated with corn stalk rots are weak pathogens.

Further support of the concept included: data showing a negative correlation between date of premature death and numbers of kernels per plant (kernel number) divided by the distance between plants, the 1976 observation that plants with rotted stalks had 13.5% more kernels than did adjacent nonrotted plants, and data showing that stalk inoculations (common inoculation techniques) with several fungi had no influence on the occurrence of rotted plants (2). Studies reported here were designed to compare kernel number and stalk rot interactions when plant densities (population densities) were constant and to obtain kernel number and stalk rot data for corn growing in a variety of environments during a second season.

MATERIALS AND METHODS

Seven single-cross hybrids of corn (*Zea mays* L.) adapted to northern Illinois were used in this 1978 study near Aurora, IL. Each was hand-planted in three-row plots, 6.1 m long and with a row spacing of 76 cm. Each hybrid was planted at in-row distances of 15 and 20 cm, which gave plant densities of 82,800 and 65,000 plants per hectare, respectively.

The center 20 plants, at least four plants from either end, in the middle row of each three-row plot were used for data. Each plant was tagged for identification. On 26 September, approximately 60 days after flowering, each plant was recorded as being green or wilted. On 24 October, color of the outer rind of the lower internodes and the rotted or solid conditions of the stalks were recorded. Rotted stalks were those that broke when pushed and generally had brown outer rinds. Plants with green, solid lower stalks were designated healthy.

Kernel numbers for each plant were recorded. Mean kernel numbers on rotted plants were compared with mean kernel numbers on healthy plants of each hybrid at both in-row spacings. Student's paired *t*-test method was used to compare kernel numbers of rotted versus healthy plants. Two hybrids had no stalk rot in the 20-cm (in-row plant spacing) plot and therefore could not be compared at that plant density.

In a second experiment at five Illinois and Indiana locations, observations were made of individual pairs of plants consisting of a rotted plant and an adjacent healthy plant. Each location was a demonstration plot of adapted commercial corn hybrids on good soil managed with typical, good cultural methods. Sixty-five comparisons of 30 single-cross hybrids (six seed companies represented) were studied. In each pair, plants with apparently normal, fully pollinated ears were chosen and the kernels on each plant were counted. Student's *t*-test was used to analyze the data for pairs of plants.

RESULTS

In the first experiment, the stalks of all plants that had wilted by 26 September had rotted by 24 October. All brown stalks had rotted and all green stalks were solid. There was a tendency for more stalk rot at higher plant density (49.6 compared to 41% at lower plant density), but the difference was not statistically significant ($P = 0.05$) except for one hybrid (231070). Hybrids that had more stalk rot at the higher plant density also had more stalk rot at the lower density (r = .87). Although several fungi usually were present in rotted stalks at the Aurora, IL, location (J. L. Dodd, *unpublished*), perithecia of *Gibberella zeae* (Schw.) Petch were observed on many rotted stalks.

Kernel number was greater on rotted plants than on healthy plants at both 15- and 20-cm in-row plant spacing, by 11.6 and 12.0%, respectively (Table 1). Although there was a tendency for plants to produce more kernels when planted at lower density,

TABLE 1. The effect of two in-row plant spacings on numbers of kernels produced by rotted or healthy stalks of seven corn hybrids

	Kernels produced per plant with in-row spacing of:					
	15 cm			20 cm		
Hybrid[a]	Rotted	Healthy	(R−H)	Rotted	Healthy	(R−H)
253229	517.8	456.0	61.8	591.3	525.3	66.0
253228	773.5	729.1	44.4	757.7	732.7	25.0
29622	548.0	500.5	48.5	608.4	573.7	34.7
112165	700.0	631.1	68.9		669.6	
19324	558.0	489.0	69.0	617.7	488.8	128.9
29034	561.3	518.0	43.3		530.3	
231070	558.8	455.8	103.0	622.0	534.0	88
$\bar{X}$[b]	602.5	539.9	62.6**	639.4	570.9	68.5*

[a] Numbers refer to hybrids developed by Cargill.

[b] *, ** Data were analyzed by Student's *t* -test to identify significant differences, $P = 0.05$ for single and $P = 0.01$ for double asterisks.

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mean differences between numbers of kernels for rotted plants (36.9) and healthy plants (31.0) were not statistically significant ($P = 0.05$).

Comparisons of 65 pairs of genetically identical neighboring plants in apparently equal environments showed that plants with stalk rot had an average of 60.8 more kernels ($P = 0.001$) (Table 2). There were 10.4% more kernels on rotted than on healthy plants.

TABLE 2. Comparison of numbers of kernels per stalk produced by plants with rotted stalks and by adjacent plants with healthy stalks

Year	No. of hybrids	No. of pairs	Numbers of kernels per plant Rotted	Healthy	Difference[a]
1976[b]	40	112	561.9	495.0	66.9***
1978	30	65	647.6	586.8	60.8***

[a] Triple asterisks indicate significance at $P = 0.001$.
[b] From Dodd (3).

DISCUSSION

The evidence from this research supports the photosynthetic stress-translocation balance (PS-TB) hypothesis of predisposition of corn to stalk rot. According to this hypothesis, predisposition is associated with carbohydrate shortage in root tissue, which is caused by the combination of reduction of photosynthesis and intraplant competition for carbohydrate by the developing kernels of grain. Consequently, root tissue has a weakened cellular defense system, allowing invasion and degeneration by soil microorganisms. Roots are then rotted, the plant wilts, and stalk rot develops.

When interplant spacing and genotypes were constant, plants with stalk rot had more kernels. According to the PS-TB concept, higher numbers of kernels represent an increased grain sink, resulting in a carbohydrate movement imbalance detrimental to the root tissue. Grain sink size refers to the *rate* of translocation to the ear on a plant, not the total carbohydrate deposited in ears by the end of a season. Comparing total grain weight of rotted and healthy plants after normal completion of the grain-filling period will not reflect differences in rate of translocation because rotted plants invariably died prematurely. Consequently duration of translocation to grain is not the same between plants with rotted stalks and those with healthy stalks, the former frequently wilting 15–20 days before normal grain abscission layer formation (J. L. Dodd, *unpublished*). Furthermore, a positive correlation was found between length of time from flowering to wilting and weight per kernel. Although each genotype probably varies in rate of translocation per kernel, that the daily rate within a genotype is constant can be deduced from results of Hanway and Russell (4).

Translocation competition also can be inferred from observations in this study that most stalk-rotted plants showed wilt symptoms before 60 days after flowering. Translocation of carbohydrates to grain in most Corn Belt hybrids stops at 50–55 days after flowering (4). After this time, the remaining and subsequently produced photosynthate should be available to root tissue, and senescence should be delayed.

Photosynthetic stresses affecting carbohydrate production also interact with grain sink size on predisposition to stalk rot. When interplant distance was reduced from 20 to 15 cm, mean number of kernels on plants with stalk rot also was reduced. Higher plant densities reduce the water, light, and minerals available to each plant. Mortimore and Gates (6) showed that, under their conditions, light reduction at higher plant density was the main factor predisposing corn to stalk rot. In this study, kernel numbers generally were less on plants at the higher plant density. Apparently plants were less able to supply carbohydrate to both the smaller grain sink and the roots. The effect of high plant density on stalk rot predisposition, therefore, depends upon grain sink size and the plant's photosynthetic capability.

Results of this survey of 30 hybrids at five locations are similar to those of the 1976 study (2) in which rotted plants had an average of 66.9 more kernels than did nonrotted plants, when interplant spaces were approximately equal. Although mean kernel numbers differed for the 2 yr, a very highly significant difference ($P = 0.001$) in kernel numbers between rotted and nonrotted plants occurred both years. It is important to note that plants in these comparisons had full pollination and that members of each pair were adjacent in the same row. It can be assumed that rotted and healthy plants in each pair had identical macroenvironments and, being single crosses, were genetically similar.

These studies reflect the effect of microenvironmental differences upon establishment of kernel number. Rate of photosynthesis in each plant is affected by soil microenvironmental factors, leaf damage, and plant competition; but larger macroenvironmental stresses such as cloudiness, drought, fertilizer imbalance, poor soil waterholding capacity, and leaf disease epidemics probably are more important. Preflowering environments and inherited limitations influence kernel numbers and, therefore, rates of carbohydrate translocation to the ear. Postflowering environments and inherited limitations affect the plant's ability to meet this grain sink commitment and, at the same time, to maintain root integrity.

The nonaggressive nature on nonsenescing stalk tissue by most fungi, including *Gibberella zeae*, associated with corn stalk rot was reviewed (2). The ubiquitous nature of these fungi, their weak pathogenicity, and their association only with rotted plants, emphasize the significance of predisposition of corn plants in the occurrence and distribution of this disease. Reducing the severity of this disease can be accomplished best by identifying and controlling environmental factors and inherited physiological features rather than emphasis on kinds of fungi associated with the rotted stalks.

Results reported in these studies are consistent with the PS-TB concept of predisposition to stalk rot, but there is need for more physiological studies to prove the hypothesis. Although studies have shown that stalk rot-susceptible genotypes have less reducing sugar and a greater rate of senescence in the pith of the lower stalks (1,5,7–9), there are no reports concerning sugar levels in mature corn roots despite good field evidence that root rot precedes stalk rot (10). In order to relate to the hypothesis, physiological studies must be designed to be consistent with environment-host-pathogen interactions affecting corn.

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