5. PROBLEMS WITH GRAMINICOLOUS DOWNY MILDEWS IN ISRAEL TO DATE

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In Israel, sorghum downy mildew disease (*Sclerospora sorghi*), on sorghums and maize, and graminicola downy mildew disease (S. graminicola), on pearl millet and maize, have had checkered careers since they were first noticed in fall, 1963. The latter disease appeared already widespread at that time and was very destructive to irrigated pearl millet, but to date is a rarity on maize, never rising above one stricken plant per thousand. *S. sorghi* remained limited for two years to two restricted localities in the north of Israel on irrigated sudangrass, and was noticed there also in a few fields of maize for forage at about one plant per 10,000, and in one instance, at one plant per thousand. Although a few indigenous wild johnsongrass plants (*Sorghum halepense*) were found stricken at that time, one with systemic infection, only a few new examples of the disease on that species were discovered until lately, and only in the north; it is surmised that most individuals are highly resistant or immune, which is fortunate, as it is perennial, and ubiquitous in Israel, and would otherwise serve as a reservoir for the disease, impossible to eliminate.

This year, however, we found two localities in the South (one within a field of stricken sweet corn) in which quite a few johnsongrass plants were attacked by *S. sorghi*, with local lesions. In order to become a primary source of inoculum, initiating the disease in the field, these plants would have to be systemically diseased, in rhizomes, and none were.

Both diseases waxed, but then waned,—graminicola downy mildew gradually over 10 years, sorghum downy mildew during the past two years. The reasons for their spread and relative drop in frequency are linked largely with the great lability of farming practices in Israel, where over a short period new crops come into favor or are almost discarded, and agrotechnical changes frequently occur.

S. graminicola: Pearl millet, the major host, grown for green fodder, dropped from 1,100 ha. in 1964 to 300 ha. in 1971, and is altogether a rarity in 1974. No other cultivated (or wild) plant has been found to be a host here, *Setaria* spp. being immune rather than susceptible as in some other lands, and popcorn, susceptible in U.S.A. being a very minor crop here (210 ha.). An agrotechnical method for growing pearl millet, tried first about 1960, exacerbated the disease: Rather than sowing only once, often in soil too cool for infection by oospores, allowing regrowth, and cutting twice, the crop was sown four times in succession, in the same field, permitting new infections by oospores in warm soil the last three times. The new method was discontinued a few years after the disease was discovered in the country. Prognosis: Although pearl millet is still often stricken wherever sown, the acreage is so restricted that the disease will not be a problem on maize.

S. sorghi: With the rise in popularity, starting in 1966, of the newly developed susceptible sorghum×sudangrass hybrids (cv. Vidan), which provided under irrigation 3–4 cuttings a season of as much as 100tons green fodder/ha., the disease spread through-

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out the country by 1969; furthermore, irrigated maize fields in their vicinity, or sown late on oospore-infested soil, showed more systemic infection by the year. This reached 2.5% in some fields in 1969, and 5% in 1970; part of one field of forage corn (N.Y. 170) showed 28% infection. These were the same open-pollinated varieties and top-crossed hybrids that had displayed such low incidence in the field in 1964–5. We had no difficulty from the start in inducing infection on them in greenhouse and field row tests using oospores from Vidan, and later, by conidia from Vidan.

Although grain sorghum covers a large area in this small country (12,700 ha. in 1972), it plays almost no part in dissemination and carryover of this disease in Israel, for the following reasons, even though the hybrids grown had proven susceptible in greenhouse and field tests here: (1) It is sown early in Spring, in cold soil, thus preventing initial systemic infection. (2) Any tillering occurs while the soil is still cold. (3) It is grown mostly without irrigation (10,300 ha.), in widespread rows allowing foliage to quickly dry after dews in our rainless summers, thus preventing local lesion infections. (4) Most fields are rather distant from stricken crops (mostly Vidan and sudangrass, partly maize), grown under irrigation close to settlements; these fields are probably almost free of oospores, and living conidia could seldom reach them.

Maize: About 6,500 ha. are grown in Israel now, almost all under irrigation. About half is for green fodder, much is for silage, and over 2,000 ha. is hybrid sweet corn for canning and for the fresh market (mostly Jubilee from the U.S.A.). Maize seed for sowing, aside from sweet corn, is locally produced. Maize may be stricken here if sown late in oospore-infested soil. Although oospores often form in a number of maize varieties and hybrids, they are generally sparse and usually near the base of chlorotic leaf blades; as conidia are also usually sparse, this would rule out maize as a major source of inoculum. This summer, we found great numbers of oospores in leaves and bracts attached to shanks and ears of Jubilee sweet corn in a number of fields, and rather heavy sporulation on these plants. The striping symptoms on these leaves differed considerably from the typical chlorotic symptoms of *S. sorghi* on normal leaves along the main stem. Shanks were invariably very long. The key to the future of the disease in Israel on maize seems to be in three factors:

(1) The precipitous rise in sweet corn production here, starting from 1970, when only ca 500 ha. was grown. As the hybrids in use now were shown a few years ago to be particularly susceptible to the disease, this should bode no good for the future. Over half is sown late, in warm soil where oospores can be infective. This summer, there was a sharp rise in disease incidence, in late-sown fields of Jubilee sweet corn (20–40 ha. each), systemically stricken from 5 to 50%. Early-sown Jubilee was completely free of the disease. As maize from the same seed-lots were not infected in some other late-sown fields, and as all the seeds came from the northwest of the U.S.A., when the disease is not yet present, it could not have been seed-transmitted. Possible explanations for the sudden epiphytotic are: (a) The manuring of some of these fields as long ago or 4 years with low dung derived from forage sorghum (cv. Vidan) from stricken fields. (b) Oospores from naturally shredded Vidan leaves in the vicinity in recent years. (c) Conidial showers this summer from Vidan fields. The distance would have had to been 2.5 km to explain the outbreak in some fields, but although viable conidia normally spread only short distances, it might have been possible that the rolling morning mists sometimes present in that region carried living conidia that distance. We do know now that under certain conditions the disease can spread from Vidan to Vidan at least 200 m, when morning winds follow dewy nights. Wind direction at the right time is all-important.

(2) Sowing maize densely (at 100 Kg. ha.) for green forage and hay is becoming popular of late, and the effect of dense stands on systemic infection and oospore forma-

tion is unknown. As mentioned, large amounts of oospores were produced this year in row-sown sweet corn. Profuse oospore production is therefore not necessarily a function of crowing. Precocious oospore production in stricken maize and sorghum occurs in the greenhouse, where no sporulation was allowed; this would fit in with Safeeulla's findings that it is inversely proportional to the amount of sporulation. Other possible reasons for precocious oospore formation there are the small size of plants, grown in flats, or the filtering out of U.V. radiation in the greenhouse.

(3) Vidan growing: As it has generally been sown in warm soil, and has a constantly rising disease incidence (systemic and local lesioning) after each cutting, it provides most of the inoculum potential for maize infection: (a) Oospores which can survive here at least 3 years, (b) great quantities of conidia which may rain down on adjacent fields of later-sown maize, effecting systemic infection on seedlings of up to to two weeks of age at least. Vidan reached its peak in Israel in 1970 (ca 1,500 ha.), but smallholders, the principal growers, became discouraged by losses from this disease and *Helminthosporium turcicum*, as well as from shoot-fly. A new commercial sorghum ×sudangrass hybrid (a Vidan) has now been developed here, as well as a sorghum× sweet sorghum hybrid (cv. Golan), both of which can be sown very early, and they should largely escape primary systemic infection by way of oospores. They are grown without irrigation, or with supplementary irrigation, for only one (or two) cuttings for hay (Vidan) or silage (Golan), thus preventing disease increment and consequent inoculum build-up that would threaten maize. In this manner, it might be possible to solve the downy mildew problem without recourse to finding sources of resistance in maize and sorghums.

Question and Answer

T. Kajiwara, Japan: How about the symptoms on maize caused by *S. graminicola?* In Japan, this fungus attacks foxtail millet (*Setaria italica*), but we have never found it on maize.

Answer: Apparently, when it does exist on maize in any country, it is rare; Melbus et al. (1928) in Iowa found no difficulty in inoculating various popcorns e.g. Japanese Hulless, Yellow Pearl etc., sweet corn, e.g. Golden Bantam, and dent corn, with oospores from various *Setaria* species, and described such symptoms as streaked leaves or longitudinal stripes or irregular mottling of leaves; stunting by extreme shortening of internodes always occurred; oospores never appeared. Maize was occasionally found stricken in Iowa and nearby states. Mention of this disease on maize in South Africa might possibly refer actually to *S. sorghi.* In Israel, the disease on maize, presumably from pearl millet, is rare; it invariably caused dwarfing, sometimes severe deformation of tassels and ears, and the leaves were always thicker than normal, corrugated, brittle, and had a closed symptom of longitudinal stripes extending from the base of the blade to the apex. There was a solid yellow color at the center of the leaf. Sporulation was rather sparse and oospores formed in the deformed inflorescences.

K. M. Safeeulla, India: What was the age of maize plants on which local lesions were found? We have not found local lesion symptoms in India on maize. But on sorghum, those symptoms are common.

Answer: Long, discrete and fairly heavily sporulating lesions appeared on the leaves of the middle tier of plants just prior to and during tasseling. They appeared singly or even in great numbers. A number of years ago, we found local lesions (sporulating) on the very lowest leaves of sweet corn plants at 6–8 leaf stage.

K. M. Safeeulla, India: There is no *S. graminicola* on maize in India. Even cross-inoculation experiments have failed to infect. This suggests that *S. graminicola* in India and Israel may be different races or varieties.

Answer: I agree that it is quite possible that they are different entities in these two countries. Morphologically, there was no difference between *S. graminicola* on maize and on pearl millet in Israel, as far as sporangiophores, sporangia and oospores are concerned. In India, one could try cross-inoculations with isolates from pearl millet from different regions of the country, or from *Setaria* on which the disease also appears.

S. Lal, India: How much natural infection of *S. graminicola* do you get in your country? How you would like to differentiate this with that which occurs in India on pearl millet? In India we have never observed it on maize, even in adjoining fields of pearl millet with heavy mildew incidence. Do you get systemic infection or not?

Answer: In Israel, we have only rarely found this disease on maize, and it was always associated with fields adjacent to pearl millet or grown on fields in which stricken pearl millet had formerly been grown. The most we have ever found was 14 plants in a field of 13,500. In one maize field we found two diseases present, *S. graminicola* and *S. sorghi* and had no difficulty in differentiating between them by symptoms, and verifying by microscopic examination.