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Soil Fertility and Damage by *Chilo zonellus*[1] to Grain Sorghum[2,3]

K. J. STARKS, G. SCHUMAKER, and S. A. EBERHART[4]

ABSTRACT

Two field trials were done in Uganda in 1968 to study the influence of soil fertility (levels of nitrogen and phosphorous fertilizer) on the damage caused by *Chilo zonellus* (Swinhoe) to grain sorghum by comparing treated (endosulfan) and borer-infested plots. The number of sorghum heads and the plant height increased with increasing amounts of fertilizer, but borers decreased both of these measurements. Also, phosphorous fertilizer tended to shorten the flowering period, but nitrogen fertilizer and borers extended it. Stand and number of stalks were not influenced by borers, perhaps because the infestation came late in the season, but there were about 3 times as many seedless heads in infested plots as in treated plots. More borers per plot were found when phosphorous fertilizer was used. Both fertilizers contributed to increased yield of grain, but borers prevented a maximum response to soil fertility.

Much of the success of developing countries in increasing crop production will depend on how effectively fertilizers are used. In this regard, researchers must consider the influence of increased fertility on other factors that limit yield, such as insect activity. A few studies of this type were made, mainly in developed countries and largely with nitrogen fertilizer. For example, Mistric (1968) found that both cotton yield and weevil damage increased as nitrogen fertilization was increased. Among cereal crops, work on the interaction between fertilizers and insects was done on rice and corn. Sasamoto (1961) studied the tolerance of rice to the Asiatic rice borer, *Chilo suppressalis* (Walker), in relation to silicate and nitrogenous fertilizers. Bowling (1963) found that increasing the nitrogen level in rice increased populations of the rice water weevil, *Lissorhoptrus oryzophilus* Kuschel, but did not significantly increase the number and length of adult feeding scars: increases in yield were about linear with increases in nitrogen in both treated and untreated plots. Scott et al. (1965) concluded that nitrogen increased the survival of the European corn borer, *Ostrinia nubilalis* (Hübner), in corn, and Cannon and Ortega (1966) related both nitrogen and phosphate fertilizer to borer survival in selections of corn. Rao and Rao (1956) found that in some years a significantly greater number of a sorghum shoot fly, *Atherigona varia* Meigen, occurred on manured plots of sorghum (theirs is one of the few fertilizer-insect studies on sorghum).

The intent of the research reported here was to study the relationship between nitrogen and phosphorous, the 2 elements that commonly need to be added to Ugandan soils, to the injury of grain sorghum caused by a spotted stalk borer, *Chilo zonellus* (Swinhoe) (= *C. partellus*). This insect causes damage similar to that of the European corn borer and probably is the most important borer pest of sorghum in Eastern Africa.

MATERIALS AND METHODS.—Two hand-planted field tests were conducted in 1968, one in each rainy season. Test designs differed only in that the row spacing was 60 cm in the 1st test and 30 cm in the 2nd (spacing of plants within the rows was 30 cm in both plantings) and in that some measurements of borer activity recorded from the 2nd test were not taken in the 1st one. Both tests were factorial designs of 3 replications each with nitrogen (NO_3) and phosphate (P_2O_5) rates of 0, 0.9, and 1.8 quintals/ha (0, 80, and 160 lb/acre) in all possible combinations to plots that were uninfested with borers as a result of treatment with insecticide or infested artificially with borers. Plots designated as uninfested were sprayed weekly with endosulfan at ca. 1.1 kg/ha (1 lb/acre) until after they headed, at which time the plants were less attractive for oviposition. Infested plots received 3 early applications of endosulfan to protect against the sorghum shoot fly, but they were not treated after manual infestation with borers. Manual infestation was accomplished between 20 and 27 days after plant emergence by placing egg masses from a laboratory culture reared either on stalk sections or on artificial diet (Guthrie et al. 1965) in the whorls at a rate of 3 masses/plant (each mass contained 15–25 viable eggs). Infested plots also had some extraneous borers including species other than *C. zonellus*, but this natural infestation should not have altered the results appreciably.

An East African sorghum cultivar of potentially high yield, 'Serena,' was used in both tests. Plot size was 3.7×4.9 m, but agronomic data were collected only from the center 2.4×3.6-m area. Plant height, the distance from the ground to the tip of the longest leaf, was measured ca. 6 weeks after planting. Other data were collected near or at the time of harvest. Numbers and activity of borers in infested plots were based on the examination of 20 stalks/plot. However, egg masses were put only in the center 2.4×3.7-m portion of the plots to prevent movement from plot to plot, but the borer samples were taken from rows at the edges of the plots, since the plants had to be destroyed to recover larvae and thus would not be available for data which needed to be taken later.

RESULTS AND DISCUSSION.—Tables 1 and 2 give some of the agronomic data obtained in the tests. Since the row width was 60 cm in the 1st test and 30 cm in the 2nd, though the spacing within the row was the same, a difference would be expected in stand and number of heads. Also, the plant population probably influenced the days to flowering, the plant height, and the yield, although the differences in the 2 growing seasons also may have had a confounding effect on agronomic data. Only the number of seedless heads did not differ significantly between the 2 tests. However, the means of the results for the 2

[1] Lepidoptera: Pyralididae.

[2] Contribution from the East African Agriculture and Forestry Research Organization, East African Community, with the U. S. Agency for International Development, the Entomology Research Division, the Soil and Water Division, and the Crops Research Division, Agr. Res. Serv., USDA, cooperating. Received for publication July 16, 1970.

[3] Mention of a pesticide or a proprietary product does not constitute recommendation or endorsement by the USDA.

[4] Research Entomologist (presently at Stillwater, Okla.), Soil Agronomist (presently at Serere, Uganda), and Research Geneticist (presently at Ames, Iowa), Agr. Res. Serv., USDA, respectively.

Table 1.—Number of plants, stalks, heads, and days to flowering of sorghum in plots varying in amount and type of fertilizer and level of borer infestation. Serere, Uganda. 1968.[a]

Fertilizer (quintals/ha)		No. plants/plot			No heads/plot[b]		Days from planting to 50% flower	
NO_3	P_2O_5	Uninfested plots	Infested plots	No. stalks/plot	Uninfested plots	Infested plots	Uninfested plots	Infested plots
0	0	27.2	28.3	60.1	46.0	45.0	65.8	67.0
0	0.9	28.5	32.8	67.8	51.0	49.7	65.2	66.8
0	1.8	29.3	27.7	64.3	55.8	47.3	65.5	66.8
0.9	0	30.7	27.2	64.1	49.3	49.2	66.3	67.5
.9	.9	30.3	28.0	67.7	55.3	48.8	65.8	67.2
.9	1.8	31.0	29.5	73.7	64.0	55.8	65.3	67.3
1.8	0	29.0	29.7	63.0	52.7	47.8	66.7	67.3
1.8	.9	28.5	30.5	67.2	55.2	54.7	66.5	67.7
1.8	1.8	31.0	28.7	69.8	62.8	54.0	66.0	66.7
Mean		29.5	29.1		54.7	50.3	65.9	67.1
LSD ($P = 0.05$)		2.3	2.3	8.76	7.6	7.6	0.6	0.6
CV (%)		9.3	9.8	16.1	17.3	17.3	2.0	2.0

[a] Data are averages of 2 trials.
[b] Not all stalks had heads. Seedless heads were included in the data.

seasons were averaged to give easier comparisons of borer-infested and uninfested plots in fewer tables.

Increasing the rates of nitrogen and of phosphorous increased the number of heads per plot and the plant height. Borer activity decreased the number of heads by ca. 4.4/plot and the plant height by ca. 9.8 cm/plant.

The days to flowering also were influenced by the fertilizers, but, in general, nitrogen caused a later flowering date and phosphorous caused an earlier one. Also, borers caused a later flowering period, an average of ca. 1.2 days longer. In our test, borers did not appreciably reduce stand, which is contrary to other reported results (Pradham 1966). However, reductions in stand usually have been associated with early infestations of *C. zonellus;* our plots were intentionally infested late so the plants would have sufficient time to respond to the fertilizers. Moreover, unlike the sorghum shoot fly, the borers did not induce tillering in Serena variety during the late infestation, though the increased levels of phosphorous did tend to increase the number of tillers. Infested plots had ca. 3 times as many seedless sorghum heads as uninfested plots, and this ratio generally prevailed during both seasons, no matter which fertilizer was used or at what rate. (Seedless heads are presumably caused by borer larvae severing the vascular bundles in the peduncle before the grain develops.)

The data on yield were based on amounts of threshed grain dried to ca. 15% moisture. As expected, nitrogen and phosphorous increased yield, especially when applied in combination. Also, yields were ca. 27% higher in uninfested plots. Fig. 1 shows the predicted yield response to nitrogen and phosphate in borer-infested and uninfested sorghum. Without borer damage, the maximum predicted response to phosphate occurred when the rate of application was about 1.8 quintals/ha. If borers are limiting yield, little or no increase could be expected beyond 0.9 quintals/ha of phosphate and nitrogen. In contrast, when borers are controlled, a yield in-

Table 2.—Plant height, number of seedless heads, and grain yields of sorghum in plots varying in amount and type of fertilizer applied and levels of borer infestations. Serere. 1968.[a]

Fertilizer (quintals/ha)[b]		Avg plant height (cm)		No. seedless heads/plot		Grain yield (quintals/ha)	
NO_3	P_2O_5	Uninfested plots	Infested plots	Uninfested plots	Infested plots	Uninfested plots	Infested plots
0	0	136.8	121.2	1.2	4.3	39.5	26.8
0	0.9	143.7	131.7	0.8	4.0	43.4	30.3
0	1.8	144.2	133.3	1.2	3.5	42.3	29.2
0.9	0	130.5	129.8	1.7	2.5	41.5	34.4
.9	.9	155.2	136.5	1.2	3.8	62.7	46.1
.9	1.8	155.3	142.5	1.8	3.2	63.5	45.7
1.8	0	134.2	129.5	.7	3.7	41.3	31.5
1.8	.9	148.7	144.2	.7	3.0	56.0	47.9
1.8	1.8	155.7	146.8	1.0	3.7	63.5	40.1
Mean		144.9	135.1	1.1	3.5	50.4	36.9
LSD ($P = 0.05$)		8.0	8.0	1.4	1.4	0.6	0.6
CV (%)		7.0	7.0	74.0	74.0	11.0	11.0

[a] Data are averages of 2 trials.
[b] To change quintals/hectare to lb/acre multiply by 89.2.

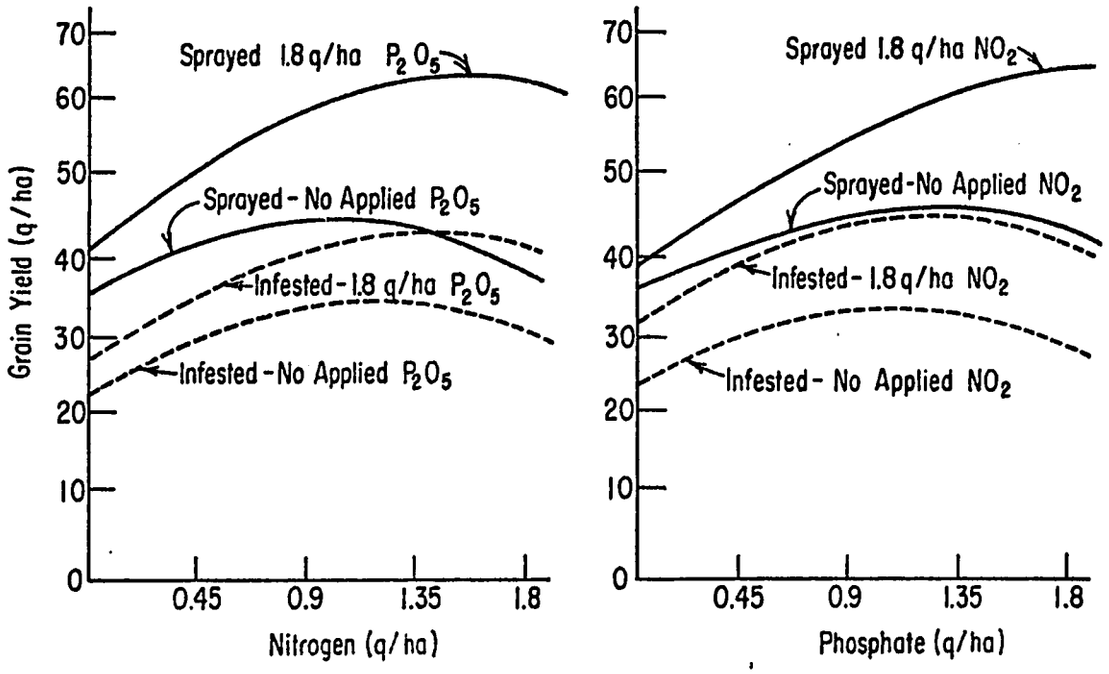

FIG. 1.—Effects of borer damage on the predicted grain yield of sorghum when no fertilizer was applied and when 1.8 quintals/ha each of nitrogen and phosphate were applied.

crease of ca. 170% above the control (infested plots with no fertilizer) can be expected with 1.8 quintals/ha each of nitrogen and phosphate. However, before adopting such a practice the economics involved in the use of both agricultural chemicals must be considered.

Table 3 gives data on the number and activity of borers. The number of exit holes indicated that almost half the larvae had left the stalks before stalks were cut and examined. These sampled areas may have been exposed to some drift from sprayed plots, since the plots were relatively small. Thus, a high variability would be expected, and the borers reported should have been fewer than those actually present in the infested area of the plots. Even so, infestations and damage were not nearly so great as observed in some fields with natural infestations, perhaps because

Table 3.—Number of borers and activity in manually infested plots varying in type and amount of fertilizer applied. Serere. 1968.

Fertilizer (quintals/ha)		No. borers per		Length tunneling/ stalk (cm)	No. exit holes/ stalk
NO_2	P_2O_5	Stalk	Plot		
0	0	2.2	131	13	2.3
0	0.9	2.9	187	14	2.0
0	1.8	2.7	171	17	2.8
0.9	0	2.5	134	14	1.9
.9	.9	2.3	146	18	1.4
.9	1.8	2.2	151	22	2.4
1.8	0	2.1	134	16	1.9
1.8	.9	3.0	201	17	2.4
1.8	1.8	3.1	195	20	3.0
Mean		2.6	161	17	2.2
LSD (P = 0.05)		0.75	58.0	12.3	1.55
CV (%)		25.4	30.9	42.3	39.8

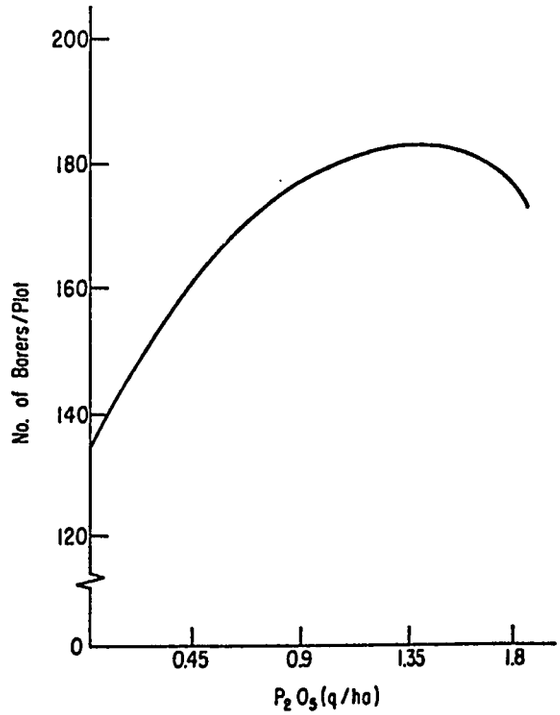

FIG. 2.—Effect of amounts of phosphate fertilizer on predicted survival of borers.

of the unusually large amount of insecticide used to keep out extraneous borers. Naturally infested fields in Uganda sometimes have several times more larvae per stalk, tunneling the entire length of the stalks, and practically no grain yield in a crop important for human food.

Table 3 shows that plots with no phosphorous compared with plots receiving 0.9 and 1.8 quintals/ha of phosphorus had ca. ¼ fewer borers per plot and a similar reduction in tunneling per stalk. Fig. 2 shows this relationship graphically. We know of no biological explanation for the fewer borers in fields treated with 1.8 quintals/ha phosphorous compared with those treated with 0.9 quintals/ha. Data on the effect of nitrogen on the borers and the number of exit holes for all treatments were inconclusive.

No single measured effect of the borers can account for the reduced yield in plots infested with borers. The 8% decrease in the number of heads, the 7% reduction in plant height, the 2% lengthening of the flowering period, and the 6% occurrence of seedless heads could each have been overcome in regard to yield by the sorghum plant during its development. However, the total influence of all these events and that of such unmeasured damage as water loss and nutritional loss or imbalance were apparently sufficient to reduce yields substantially regardless of the soil fertility. With a higher infestation of larvae and the increased tunneling that would result, the percentage decreases would probably be larger and the yield smaller.

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