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Effects of Sowing Date and Insecticides on Cereal Aphid Populations and Barley Yellow Dwarf Virus on Barley in Kenya

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With five tables

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Abstract

The effects of the date of sowing and insecticide sprays on aphid populations and barley yellow dwarf virus (BYDV) incidence in barley was studied in Mau Narok, Kenya. *Rhopalosiphum padi* (L.) and *Metopolophium dirhodum* (WLK.) were common aphid species, but other cereal aphids present were *Rhopalosiphum maidis* (Fitch), *Stiobion avenae* (F.), *Schizaphis graminum* (Rond.) and *Hysteroneura setaria* Thom. The incidence of BYDV was significantly decreased in plots sown with seed that had been treated with imidacloprid (NTN-33893, Gaucho) and subsequently sprayed with foliar insecticide (Cypermethrin). Yield loss due to BYDV was also significantly different between the treatments and between the early-planted and the late-planted crop ($P < 0.05$). Grain yield and 1 000-grain weight were not significantly different among insecticide treatments in the early-planted crop. In the late-planted crop, the yield increase with seed treatment alone was highly significant ($P < 0.001$), with a yield increase of 36–43%, more than that of the untreated control. Grain yield was significantly ($P < 0.05$) negatively correlated with the total number of cereal aphids, as well as with the numbers of *R. padi* alone.

Zusammenfassung

Einfluß des Aussaattermins sowie von Insektiziden auf Getreideblattlauspopulationen und das Barley Yellow Dwarf Virus der Gerste in Kenia

Untersucht wurden die Einflüsse des Aussaattermins sowie Insektizidbehandlungen auf die Blattlauspopulationen und das Auftreten des barley yellow dwarf Virus (BYDV) in der Gerste in Mau Narok, Kenia. Häufig traten die Blattlausarten *Rhopalosiphum padi* und *Metopolophium dirhodum* auf, andere Arten wie *Rhopalosiphum maidis*, *Stiobion avenae*, *Schizaphis graminum* und *Hysteroneura setaria* wurden auch gefunden. Das Vorkommen des BYDV wurde signifikant in den Versuchsparzellen reduziert, die mit Imidacloprid (NTN-33893, Gaucho) gebeiztem Saatgut ausgesät worden waren und anschließend mit den Blattinsektizid Cypermethrin behandelt wurden. Signifikante Unterschiede der Ertragsverluste durch BYDV wurden zwischen den unterschiedlichen Behandlungen und zwischen den früher bzw, später ausgesäten Beständen ($P < 0.05$) nachgewiesen. Es gab keine signifikanten Unterschiede im Ertrag sowie 1 000 Komgewicht zwischen den Insektizidbehandlungen bei den frühausgesäten Beständen. Bei den später ausgesäten Beständen konnte eine signifikant hohe Ertragssteigerung ($P < 0.001$), mit einer Ertragszunahme von 36–43% über der Kontrolle, ermittelt werden. Der Körnerertrag war signifikant ($P < 0.05$) negativ korreliert mit der gesamten Blattlauszahl, sowie mit der Anzahl von *R. padi* allein.

Introduction

Wheat (*Triticum aestivum*) is the second most important cereal crop after maize in Kenya, both in production and consumption, whereas barley (*Hordeum vulgare*) is produced mainly for the malting industry and for animal feed. Barley yellow dwarf viruses (BYDV) PAV, MAV and RPV occur in both barley and wheat crops (Wangai, 1990).

In temperate regions, BYDV can readily be controlled with insecticide sprays or by delaying the drilling of autumn-sown crops to avoid infection by migrating viruliferous aphids (Hooper, 1978) and in areas with a Mediterranean climate (e.g., S.E. Australia and California) resistance is the principal method of control. However, for spring-sown crops early sowing helps to avoid infection, and insecticide sprays are of little benefit (Plumb, 1984). In Kenya, systemic insecticides are widely used to control BYDV in wheat and barley crops (Anon, 1991). To minimize operational costs, these insecticides are usually sprayed in tank mixes with herbicides and the time of application is not related to the level of aphid infestation or the incidence of BYDV. Thus, there has been much unnecessary usage of insecticides which leads

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Table 1
Insecticide treatments and their application timing in the two trials in Mau Narok, Kenya

Expt 1	Expt 2	Insecticide treatment (seed and/or foliar)								
Application dates		ST* +0	ST* +7	+6	+5	+4	+3	+2	+1	+0
4.9.92	4.11.92	ST	ST	–	–	–	–	–	–	
29.9.92	2.12.92	–	+	+	+	+	+	+	+	–
13.10.92	16.12.92	–	+	+	+	+	+	+	–	–
27.10.92	3.1.93	–	+	+	+	+	+	–	–	–
18.11.92	13.1.93	–	+	+	+	+	–	–	–	–
2.12.92	27.1.93	–	+	+	+	–	–	–	–	–
16.12.92	10.2.93	–	+	+	–	–	–	–	–	–
30.12.92	25.2.93	–	+	–	–	–	–	–	–	–
13.1.93	11.3.93	–	–	–	–	–	–	–	–	–

*ST, Seed treatment with imidacloprid (NTN-33893, Gaucho, Bayer) at 0.7 g a.i./kg seed;
+, Number (0–7) of insecticide sprays with Cypermethrin (Ambush 25, Crop Protection) at 0.1 g a.i./l;
–, No insecticide application on these dates.

to environmental pollution and detriment to human health, often without any benefit to yield and quality. There was, therefore, a need to investigate the consequences of different dates of planting and insecticide application in order to recommend strategies for controlling this disease, especially in barley, in the most cost-effective way

Materials and Methods

Location

The trials were in Mau Narok (altitude 2 800 m above sea level), longitude 35°38′ E, latitude 0°30′ S.

Treatment

There were two trials, sown on 4 September (expt 1) and 4 November 1992 (expt 2), of the barley cv. Tumaini which is commercially available and known to be susceptible to BYDV. Each trial consisted of four randomized blocks of nine plots, each 6 m × 1.5 m. The insecticide treatments and their dates of application were as in Table 1.

The seed was treated with imidacloprid at 0.7 g a.i./kg, supplied by Bayer, Germany. The Cypermethrin sprays (+ 1–7 foliar applications) were applied using a knapsack sprayer with a hand-held boom (0.1 g a.i./l). The plots were drilled at 90 kg/ha using an eight-row drill. The drill was calibrated for seed with and without imidacloprid to ensure the seed rates were the same.

Aphid sampling

Plants were sampled *in situ* for the presence of aphids at 2 week intervals, immediately before a spray treatment was applied. Fifteen shoots were examined in one row of a randomly selected 1 m quadrant. As far as was possible, the aphids present were identified to species.

Disease assessment

The incidence of BYDV was assessed at intervals during the growing season by estimating the percentage of yellow shoots per plot. The severity of the infection was also recorded using the quantitative 0–9 scale devised by Qualset (1984).

Yield

The central 4 m of each 6 m long plot was harvested and then threshed by hand. From the grain sample the 1 000-grain weight was obtained. Results were analysed by ANOVA using the GENSTAT 5 statistical package.

Results

Aphid populations

In expt 1, *Metopolophium dirhodum* (Wlk.) was the most numerous aphid species. It was first found only 3 weeks after sowing, and reached a maximum population of 1.5 aphids/shoot on the untreated plots 12–16 weeks after sowing. *Rhopalosiphum padi* (L.) rapidly increased to reach a maximum population of 0.7/shoot 8 weeks after sowing but thereafter declined rapidly. *Rhopalosiphum maidis* (Fitch) and *Stiobion avenae* (F.) were much less numerous, with maximum populations of 0.1 and 0.02/shoot, respectively. *Hysteroneura setariae* Thom. did not occur on untreated controls although a few were present on other plots. No *Schizaphis graminum* (Rond.) were seen in this experiment. The total populations recorded for each treatment are given in Table 2. There were significant differences only for *R. padi* and *M. dirhodum* ($P < 0.05$) between treatments. Increasingly, for *M. dirhodum*, several of the treatments that included sprays, including the combination of seed treatment and seven sprays, had larger populations than either seed treatment alone or no treatment. For *R. padi*, both seed treatments and sprays generally decreased the populations (Table 2).

In expt 2, *M. dirhodum* and *R. padi* were again the most numerous species, and both reached their maximum populations 5 weeks after sowing and thereafter declined rapidly. All other species were infrequent, although *S. avenae* was present on most treatments but usually at less than 0.1/tiller; *H. setariae* was present in the late-grown crop (Table 3).

Only populations of *R. padi* showed any significant effect of insecticide treatment; populations were decreased by the seed treatment with and without additional sprays. Total populations of aphids were also decreased by these two treatments, but the untreated

Table 2
Means of the total aphids on 15 tillers of barley in Narok, expt 1 treated with insecticides for varying periods

	Treatments									
	ST+0	ST+7	+6	+5	+4	+3	+2	+1	+0	L.S.D. (d.f. = 35)
Aphid species										
M. dirhodum	35.3	91.2	73.1	40.0	68.2	61.7	38.1	49.5	47.2	0.119
	(1.560)[a]	(1.965)[b]	(1.870)[b]	(1.613)[a]	(1.840)[b]	(1.797)[b]	(1.592)[a]	(1.703)[a]	(1.683)[a]	
S. avenae	0.9	0.9	0.2	2.3	3.7	4.6	3.7	2.8	2.0	
	(0.287)[a]	(0.278)[a]	(0.075)[a]	(0.516)[a]	(0.670)[a]	(0.746)[a]	(0.670)[a]	(0.584)[a]	(0.301)[a]	0.313
R. padi	16.9	15.9	62.1	43.7	51.4	59.1	39.6	21.6	39.2	
	(1.254)[a]	(1.229)[a]	(1.800)[b]	(1.605)[b]	(1.719)[b]	(1.779)[b]	(1.608)[b]	(1.355)[a]	(1.604)[b]	0.1767
S. graminum	0	0	0	0	0	0	0	0	0	
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	0
R. maidis	4.7	1.1	0.9	3.2	2.2	9.7	6.2	4.3	1.1	
	(0.758)[a]	(0.314)[a]	(0.270)[a]	(0.625)[a]	(0.345)[a]	(1.029)[a]	(0.857)[a]	(0.722)[a]	(0.314)[a]	0.3137
H. setariae	0	0	2	0.6	0.4	0	0	0	0	
	(0)[a]	(0)[a]	(0.301)[a]	(0.195)[a]	(0.151)[a]	(0)[a]	(0)[a]	(0)[a]	(0)[a]	0.1289
Total	57.8	109.1	138.3	89.8	125.9	135.1	87.6	78.2	89.5	
aphids	(1.809)[a]	(2.060)[b]	(2.158)[b]	(1.970)[a]	(2.116)[b]	(2.176)[b]	(2.024)[b]	(1.943)[a]	(1.996)[a]	0.0936

The figures in brackets ( ) denote the transformed values ($\log_{10}+1$) used in the analysis of variance. Values in rows folowed by similar letters are not significantly different (P = 0.05).

Table 3
Means of the total aphids on 15 tillers of barley in Narok, expt 2 treated with insecticides for varying periods

	ST+0	ST+7	+6	+5	+4	+3	+2	+1	+0	L.S.D. (d.f. = 35)
Aphid species										
M. dirhodum	13.8	21.8	24.4	25.3	28.2	9.7	26.3	14.1	27.2	
	(1.169)[a]	(1.358)[a]	(1.404)[a]	(1.420)[a]	(1.465)[a]	(1.031)[a]	(1.436)[a]	(1.180)[a]	(1.450)[a]	0.174
S. avenae	0.6	0.9	0.2	0.7	1.1	0.2	1.0	2.3	1.5	
	(0.195)[a]	(0.270)[a]	(0.075)[a]	(0.226)[a]	(0.314)[a]	(0.075)[a]	(0.294)[a]	(0.520)[a]	(0.406)[a]	0.214
R. padi	6.1	9.3	46.9	29.3	29.7	26.5	51.5	42.8	29.8	
	(0.906)[a]	(1.011)[a]	(1.681)[b]	(1.481)[b]	(1.487)[b]	(1.444)[b]	(1.720)[b]	(1.641)[b]	(1.489)[b]	0.257
S. graminum	0	0	0	0	0	0	1.6	0	0.2	
	(0)[a]	(0)[a]	(0)[a]	(0)[a]	(0)[a]	(0)[a]	(0.401)[a]	(0)[a]	(0.075)[a]	0.151
R. maidis	0	0	0.2	0	0.2	0.9	0.4	0.3	0.2	
	(0)[a]	(0)[a]	(0.075)[a]	(0)[a]	(0.075)[a]	(0.287)[a]	(0.151)[a]	(0.119)[a]	(0.075)[a]	0.145
H. setariae	0	0	0	1.4	0.3	1.4	0.2	0.7	0.2	
	(0)[a]	(0)[a]	(0)[a]	(0.4756)[a]	(0.127)[a]	(0.4569)[a]	(0.0782)[a]	(0.2533)[a]	(0.0782)[a]	0.166
Total	20.5	32.0	71.7	56.7	59.5	38.7	81.0	60.2	59.1	
aphids	(1.374)[a]	(1.559)[a]	(1.926)[b]	(1.809)[b]	(1.837)[b]	(1.696)[b]	(2.008)[c]	(1.801)[b]	(1.822)[b]	0.141

The figures in brackets ( ) denote the transformed values ($\log_{10}+1$) used in the analysis of variance. Values in rows folowed by similar letters are not significantly different (P = 0.05).

plots had no more aphids than the plots treated with 1–6 sprays, and had fewer than those sprayed only twice early in growth.

BYDV incidence and severity

In expt 1 there was most infection (50%) in untreated plots, compared with 20% in fully protected (ST+7 foliar sprays) plots. However, plots +6 and +3 had as much infection as the untreated and the +5 and +2 plots had less infection, 18 and 12% respectively, than those fully protected. Disease severity generally followed BYDV incidence with scores ranging between 3 and 6. For the second experiment, the effects of the pesticide treatments were more obvious. There was the least amount of virus (25%) in those plots that received sprays in addition to seed treatment. Plots that were sprayed 1–6 times had between 60–70% BYDV infection, and there was no difference among treatments. Plots that were untreated had most virus infection (80%). Disease severity records followed the same pattern as virus incidence with the most severe disease score of 6.0 in untreated plots or plots sprayed only once.

Yield

In expt 1 there were no significant effects of treatment on plot yield or 1 000-grain weight (Table 4), although fully protected plots yielded 50% more and had 1 000-grain weights that were 11% larger than in untreated plots. In expt 2, the two treatments that included treated seed, ST+0 and ST+7, gave the highest yields, which were significantly larger than all other treatments and 43.4 and 36.4% more than those of untreated plots. There were

Table 4
The mean grain yields and 1 000-grain weight from plots treated with insecticides starting at different dates after sowing (expt 1)

Insecticide treatments (seed and/or foliar)	Date treatment commenced	Grain yield (g) per plot	1 000-grain weight (g)
ST+0	14.9.92	1305[a]	35.2[a]
ST+7	29.9.92	1970[a]	38.2[a]
+6	13.10.92	1313[a]	35.5[a]
+5	27.10.92	1283[a]	36.2[a]
+4	18.11.92	1371[a]	36.5[a]
+3	1.12.92	1261[a]	36.5[a]
+2	16.12.92	1303[a]	37.0[a]
+1	30.12.92	1278[a]	36.5[a]
+0	No chemical	1252[a]	34.5[a]
	SED	305.2	1.8

ST = Seed treatment;
+ = No. (0–7) of foliar sprays;
Values in a column followed by similar letters are not significantly different (P = 0.05).

Table 5
The mean grain yield and 1 000-grain weight from plots treated with insecticides starting at different dates after sowing (expt 2)

Insecticide treatment (seed and/or foliar)	Treatment date	Grain yield (g) per plot	1 000-grain weight (g)
ST+0	4.11.92	3320[a]	40.7[a]
ST+7	2.11.92	3159[a]	41.9[a]
+6	16.11.92	2492[b]	40.4[a]
+5	30.11.92	2341[b]	39.7[a]
+4	13.11.93	2405[b]	42.9[a]
+3	27.11.93	2546[b]	41.9[a]
+2	10.11.93	2542[b]	40.1[a]
+1	25.11.93	2375[b]	39.5[a]
+0	No chemical	2316[b]	39.2[a]
	SED (d.f. = 35)	214.2	1.92

ST = Seed treatment;
+ = No. (0–7) of foliar sprays;
Values in a column followed by similar letters are not significantly different (P = 0.05).

no differences among treatments in 1 000-grain weights (Table 5).

The grain yield was negatively correlated to the total number of aphids as well as to the population of *R. padi* ($P < 0.05$) in expt 2 but not in expt 1.

Discussion

Only the aphids *M. dirhodum* and *R. padi* were apparently sufficiently numerous to have been important in the transmission of BYDV. While populations of these two species were similar in the two experiments, in total there were fewer aphids but more virus infection in the later drilled experiment. The reasons for this appear to be because in expt 2 the largest aphid populations occurred early in crop growth (6 weeks after sowing) but in the earlier drilled crop the maximum populations only occurred 12 weeks after sowing. As a consequence, the effects of seed treatment and sprays in the first experiment were very variable and, although the unprotected plots yielded least and the fully protected (ST+7) plots yielded most, there was no consistent effect on yield of the other treatments. The lack of yield response in the seed-treated plots compared with the untreated plots is surprising as there was a large difference in virus incidence (ST, 27%; Untreated, 50+%), and the total aphid populations were slightly decreased on ST plots. The very marked distinction between plots sown with treated and untreated seed in the later-sown experiment demonstrates the importance of early infection in that crop. Clearly the sprays had little or no effect even when used in addition to seed treatment.

The contrast between the two crops is clear. For the earlier-sown crop, aphid populations, and thus virus infection, took sometime to develop and no treatment had a significant effect on virus incidence or grain yield. However, it appears that the infective aphid population built up in this crop, which then moved into the newly emerged November-sown crop and caused up to 80% infection. The benefits of seed treatment are clear and economic, but the subsequent sprays were of no value. With the much greater incidence of BYDV on the later-sown crop it is surprising that the untreated late-sown plots out-yielded the best yield of the early-sown plots by 12% and the mean yield of all treatments (2 610 g) was almost double that of the earlier-sown crop (1 317 g). The reason for such a large difference appears to be the rainfall received by each crop. The early-drilled crop suffered drought stress during grain filling and this may have restricted yield and minimized any responses to differential BYDV infection. Unseasonal rains boosted the yield of the late-sown crop. September sowing is normal in the Mau Narok region but fluctuations in rainfall make it difficult to predict yield and thus the cost–benefit of virus control.

There is a need to control cereal aphids in order to effectively manage BYDV disease. Effective control of BYDV and the cereal aphids using imidacloprid has been reported (Gourmet et al., 1996; Gray et al., 1996; McKirdy and Jones, 1997). Studies on the effect of imidacloprid on flight movement of *R. padi* and the subsequent BYDV spread showed that the aphids often dropped off the plants and were often unable to recolonize them (Gourmet et al., 1994).

As a general rule it seems that the first crops to be drilled, while not avoiding BYDV infection, do avoid the infection early in growth that causes so much damage. Therefore, sequential sowings should be avoided as the early sowing can allow a build-up of inoculum for those sown later. Seed treatment can be beneficial but spraying crops sown at any time gives little benefit.

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