EFFECT OF THE GRAIN APHID ON YIELD AND QUALITY OF WHEAT

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Summary

Under ideal conditions for grain aphid *Macrosiphum miscanthi* (Tak) development, grain yields were consistently reduced from between 32 and 82% depending on the time of infestation in relation to flowering. Aphids present at flowering suppressed yields by reducing the number of seed set per spikelet and the individual grain weight. A significant correlation between aphid numbers and yield was demonstrated. In the field, an increase in yield of 9.6 bu/acre was obtained by a single spray application, at flowering, of a systemic organophosphorus insecticide. Delaying the spray by 13 days reduced this yield difference to 5.1 bu/acre. A marked increase in the amylase activity in the ripe grain was noted from areas of high aphid infestation and grown under natural conditions, but not from ripe grain grown under glass or aphid cages.

INTRODUCTION

ALTHOUGH the grain aphid (*Macrosiphum miscanthi* (Tak)) has been recorded in New Zealand for many years (Cottier, 1953*; Lowe, 1969), 1967-8 was the first season in which *M. miscanthi* was associated with serious damage in cereals. Damaged wheat crops were mainly confined to the Rangiora, Rakaia and the Kingsdown areas, where such crops were easily recognized by their muddy-brown appearance and by numerous dark brown to black patches 3 to 6 ft in diameter. These corresponded to areas of high aphid numbers, 200 to 300 aphids per head being common. Ripe grain from affected areas, when tested for baking quality by the Wheat Research Institute, of the Department of Scientific and Industrial Research, gave loaves with a poor crumb structure and also "sprout" values of S6-S12, indicating a high alpha-amylase activity, normally present only in immature or germinating grain. A field trial carried out during this period consisted of one application, on December 11, of demeton-S-methyl, a systemic organophosphorus insecticide. (Although demeton-S-methyl was used in this instance, any organophosphorus systemic insecticide would have been as effective.) This one spray resulted in a yield increase of 10 bu/acre. The implications arising from this preliminary work were that the losses in yield were not due to a late infection of barley yellow dwarf virus (BYDV) but rather to the direct competition by the aphid reducing the sap flow to the developing grain.

*As *Macrosiphum avenae* (Eastop, 1966).

Since the closely related species *M. avenae* (F.) has been found to cause appreciable losses in yield, to lower the gluten quality, and to reduce the germination, though at the same time to have no effect on the starch quality (Rautapaa, 1966), an investigation was carried out during 1968-9 to determine the effect of *M. miscanthi* on the yield and quality of wheat.

METHODS AND RESULTS

Virus-free aphids were used throughout the experiments. Single, fully-grown aphids were placed on a healthy wheat leaf lying on damp filter paper in separate plastic containers. These containers were kept in a cool place until one or two nymphs were produced. These nymphs were then removed using a small, moist, sable brush and placed on Aotea wheat seedlings, which had been covered since emergence. To increase aphid numbers, five pots, each with five wheat seedlings, were kept under a nylon cage and healthy nymphs were placed on these approximately four weeks before being used in a trial.

Wheat plants to be used in glasshouse experiments were grown in boxes 2 ft × 1 ft × 8 in. and thinned to 50 tillers per box at heading. For the first experiment, 20 aphids were transferred to each of 10 heads per box (A) at flowering, and (B) 1 week after flowering. A total of five boxes was used per treatment. These 10 heads were labelled and recorded every other day for aphid numbers on a 0 to 5 scale.

0 = no aphids	3 = 26 to 100
1 = 1 to 10 aphids	4 = 101 to 250
2 = 11 to 25 aphids	5 = 250 +

Ten heads were also recorded for aphid numbers per spikelet. Aphids were allowed to build up and feed on these heads for (A) 27 days, and (B) 20 days before being sprayed with an insecticide. After ripening, all grains from the labelled heads were weighed individually. There was a set of five boxes which were not infested (Treatment C).

Because of the large variation in individual grain weights harvested in this trial, no significant correlation was obtained between aphid numbers and grain weight, nor between grain weight in relation to aphid position on the head (Table 1). As 767 grains were harvested from Treatment A the number of grains used in Treatments B and C were adjusted to this figure before being weighed and subsequently plotted as a weight distribution curve (Fig. 1). By making this correction, the actual effect of *M. miscanthi* feeding on the developing grain could be established.

TABLE 1

	Aphids Transferred to Heads		
	At Flowering	1 Week after Flowering	Aphid-free Heads
	A	B	C
Weight of 767 seeds (g)	8.6	12.8	21.1
% Loss of yield due to aphids feeding	59.4	39.2	0
Total seed weight (g)	8.6	17.5	26.2
% Total loss	67.2	38.0	0

FIG. 1: Effect of grain aphids introduced at flowering and one week after flowering on the weight of individual grains from infested heads, as compared with grain from aphid-free heads.

Not only was the individual grain weight reduced by the aphids when introduced at flowering (21.8 to 8.6 g) but also the number of seed set per spikelet (Table 2).

TABLE 2

	No. of Seed Set per Spikelet		
	1	2	3
Aphids at flowering (A)	36%	56%	8%
Aphid-free heads (C)	23%	39%	38%

Only 8% of the spikelets on heads infested at flowering contained 3 seeds compared with 38% of those of check heads. This represents a further loss of yield of about 20%. This combined effect was a net loss of yield, when aphids were introduced at flowering, of 67.2% (26.2 to 8.6 g) compared with 38% (26.2 to 17.5 g) for the aphids one week after flowering (Table 1).

The second glasshouse trial was on a slightly larger scale and was designed to follow the pattern of infection likely to occur in the field. Twenty aphids were transferred to each of 10 heads per box 4 days after flowering. Ten boxes were used per treatment. A random sample of heads was recorded for aphids prior to being sprayed 32 days after transfer. All heads were harvested and threshed. Although only 10 out of the 50 heads were initially infested the remaining heads rapidly became infested by winged aphids. The results were similar to those of Experiment 1, where aphids were applied after flowering, with the yield from infested heads being reduced by 32.25% (402.3 to 286.3 g) — Table 3.

TABLE 3

					<i>Infested</i>	<i>Check</i>
Total No. of seeds	....	....	....	....	13,003	12,392
Wt. of seed (12,392) (g)	....	....	....	....	286.3	402.3
% loss of yield	....	....	....	....	32.25	0
Volume of seed (cc)	....	....	....	....	460	580
Bushel weight (lb)	....	....	....	....	51	60

Again, as in the first experiment, when the aphids were introduced after flowering there was no real reduction in the number of seed set (13,003 as compared with 12,392).

To test a number of wheat varieties for resistance to grain aphid damage, two cages each 55 ft long $\times$ 12 ft wide with 5 ft high walls and a 9 ft high ridge were constructed from $\frac{1}{2}$ in. galvanized water pipe, joined with "key clamp" connections and covered with 24 mesh "Tygan" nylon netting. These cages were placed in an east-west direction across 7 wheat varieties in the demonstration area at Crop Research Division, DSIR, Lincoln. Varieties were sown in 10 drill row plots, measuring 5 ft across, with a 3 ft path between each variety. A 1 ft path was cut down the centre of each cage, dividing the varieties into two replicates each of 5 ft 6 in. $\times$ 5 ft. Ten aphids were transferred to each of 50 heads in the northern replicate of each variety on November 8 and 15. The second cage was sprayed with an insecticide on November 11 and 18 to kill

FIG. 2: Correlation between aphid populations present on seven wheat varieties and the subsequent loss of yield. The aphid indices given here are related to but converted from the figures in Table 4.

off the natural infestation of *M. miscanthi* which was building up in these plots at the time. Forty heads of each variety were labelled and recorded on a 0 to 5 scale on six occasions between November 21 and December 20. The change in aphid numbers was assumed to be equally large every day, and on this assumption the aphid score for the 40 heads on the intervening days was calculated. The aphid index represented the sum of the aphid scores (0 to 5) of the 40 heads, each day, for the period November 21 to December 20. Plots were cut, 5 rows at a time, and tied in bundles at harvest, thus making a total of 4 replicates per variety. All bundles were stored in the glasshouse until threshing. Fifty heads were threshed individually from each of the 4 bundles and grain weight and grain numbers recorded. Total grain weight from each variety was also recorded.

Owing to differences in the rate of aphid population build-up between the seven varieties, a wide range in population index for these varieties was recorded (Table 4) ranging from 706 (Arawa) to 1,627 (1020.01). When these aphid population indices were plotted against yield, a significant correlation ($r = 0.844^*$, $y = 27.07 + 0.977 A$) emerged and is in Fig. 2. Aphid numbers rapidly declined after December 20 owing to an infection of *M. miscanthi* by an *Entomophthora* sp. and to the ripening off of the plants.

TABLE 4

				Aphid Index	% Loss of Yield		Flowering Date
Variety					50 Heads	Total	Nov., 1968
1053.01	....	....	....	793	41.9	37.5	18
Arawa	....	....	....	706	51.5	45.0	17
Cross 7 61	....	....	....	1011	55.6	61.2	16
Aotea	....	....	....	1226	63.9	70.4	18
Hilgendorf	....	....	....	1543	56.1	54.7	12
1020.01	....	....	....	1627	64.8	64.2	18
790.01	....	....	....	1578	75.6	82.3	21

Following a survey of the Lincoln College wheat crops for grain aphids, a 20-acre paddock of Aotea was selected as being suitable for a field trial. The crop was divided into 6 plots, each 3.5 acres. The location and numbering of the plots can be seen in Fig. 3. Dimethoate, a systemic organophosphorus insecticide, was applied from the air at the rate of 4.8 oz a.i./acre on November 27 and December 10. The crop, at the time of the first spraying, was at the late flowering stage (Feekes scale 10.5.2). Three pounds of "Lanasol red G" a water-soluble dye, was added to the water in the spray tank of the aircraft, and a strip of 4.5 in. wide paper laid out across the end of the plot to observe the spray distribution. Four runs were made over plots 2 and 4 sprayed on November 27. Because of the spray distribution and the area covered on the first spraying, only 3 runs were made over plot 5 sprayed on December 10.

Only a limited number of aphid counts were made before the initial spraying. On November 20, about 25% of heads were infested with aphids in plot 1, with the numbers increasing steadily to about 55% in plot 6. This gradation was still apparent in the unsprayed plots (1, 3, and 6) six days after the first spraying (Table 5). By December 23, 26 days after

the first spray, this pattern had disappeared. Although 30% of the heads in plot 5 still contained aphids at this stage, the average number per head was very low, whereas in the check unsprayed plots (1, 3, and 6) 100 to 150 aphids per head were common. There were two factors contributing to the residual aphid population in plot 5 and these were:

- (1) The three markers used by the aircraft were too far apart and the two subsequent misses between the 3 swathe paths running across this plot can be seen in Fig. 3 (arrows represent the position and direction of the three swathes).
- (2) Insufficient time was allowed for the mixing of the insecticide and the dye in the tank of the aircraft before the commencement of spraying. This was suspected at the time by the very low concentration of the dye collected on the strip of paper at the end of the plot. The increase in the effectiveness of the spray can be seen along the three swathes (from right to left) in Fig. 3.

At harvest, two 6 ft square samples were cut from (a) the darker areas within the unsprayed plots (1 and 3) representing the areas of high aphid infestation, (b) adjacent lighter areas of low aphid infestation, and (c) from the early sprayed and aphid-free plots (2 and 4). Grain harvested from these samples was tested by the Wheat Research Institute (Table 6). Yield was obtained by making three 12 ft header cuts lengthwise in each plot. Grain samples from bags off each run were also tested by the Wheat Research Institute.

TABLE 5

Treatment	Plot	Yield (bu/acre)	Aphid Population % Heads Infested	
			3/12/68	23/12/68
Unsprayed	1	50.12	32	84*
Unsprayed	3	50.02	34	81
Unsprayed	6	50.57	62	66
Sprayed 27/11/68	2	60.52	5	7†
Sprayed 27/11/68	4	59.18	2	0
Sprayed 10/12/68	5	55.36	57	30‡

*100 to 150 aphids per head common.

†1 to 2 aphids per head, mostly winged.

‡Average of 3 aphids per head.

It can be seen from Table 5 that one spray at flowering was sufficient to maintain control of *M. miscanthi* for at least 26 days. No aphids were found on heads in plot 4 at the end of this period, though 7% of heads in plot 2 did contain some aphids, though mostly winged adults. Because of the uneven coverage obtained from the second application of insecti-

FIG. 3: Aerial photograph of the spray trial at Lincoln College in 1968-9 season. Plots 1, 3 and 6 were not sprayed and they yielded 50.3 bu/acre; plots 2 and 4 treated on November 27 yielded 59.9 bu; plot 5 treated on December 10 yielded 55.5 bu. The three arrows above plot 5 indicate the position and direction of the three runs by the aircraft over this plot.

cide, aphid control in this plot was hard to assess. However, although 30% of the heads on 23/12/68 had some aphids, the overall population was still very low. Header cuts through this plot were made using the same markers put out for the aircraft. This meant that each cut was made down the centre of a spray run.

As in the earlier experiments, the importance of aphid infestation in relation to the maturity of the crop was demonstrated. The difference in yield of 9.6 bu/acre between the early sprayed and unsprayed plots was reduced to 5.1 bu/acre through delaying the spray by 13 days (Table 6).

Unlike the varietal experiment where heavy aphid infestation apparently had little or no effect on grain quality, a marked increase in the alpha-amylase activity was noted in the grain grown under natural conditions in the field. This effect, however, was masked in the bulked samples taken off the header.

TABLE 6

	Sprayed	Unsprayed	
		Low Aphid Nos.	High Aphid Nos.
Yield (g)	2265	2125	905
% Loss	0	6	60
Hagberg penetrometer No.	5	5	23
Hagberg falling No.	215	190	103
Amylogram active	163	80	18
Amylogram inactive	852	830	714
Protein content of flour (%)	10.2	10.1	12.9

DISCUSSION

Smith *et al.* (1968) demonstrated that *Macrosiphum miscanthi* is a poor vector of the BYDV strains present in New Zealand, producing only mild symptoms which are slow to develop. Because of the lateness of aphid infestation, it is unlikely that BYDV is of importance in this context.

As conditions for the propagation of the grain aphid in both the glass-house and under the aphid cages in the field were extremely favourable, high aphid populations were obtained in relatively short periods. Under the aphid cages, aphid numbers rose above the maximum which could be supported by any one head, consequently aphids also became established in large numbers on the culm below the head. Similarly, conditions were also favourable for the natural parasites and the aphid populations were drastically reduced towards the end of each experiment by species of *Entomophthora*. Under these artificial conditions provided in the glass-house and in the aphid cages, grain yields were reduced from between 32 and 82% depending on the time of infection in relation to flowering. A direct correlation between increasing aphid numbers and loss of yield was also demonstrated. However, it is not known at this stage whether a given number of aphids present at flowering have a greater effect than the same number and a natural increase when applied one or two weeks later. On the other hand, an aphid infestation, at flowering, can suppress yields by reducing the total number of seed set per spikelet.

In the field conditions were not ideal for grain aphids during November and December, owing to continuous north-east winds and low temperatures. Aphid movement within the crop was therefore very limited. In

those areas where large aphid populations did become established, a 60% reduction in yield was recorded, compared with only 6% for the adjacent areas within the unsprayed plots. The net result through spraying at flowering was to increase the yield by 9.6% bu/acre (in this instance by about 20%). On present-day prices, this represents a net saving to the farmer of just under \$10 per acre. Delaying the spray application by two weeks reduces this figure by 50% and represents an increase in yield of only \$5.1 bu/acre.

Flat recommendations are both difficult and dangerous to make, as final yield losses are dependent on aphid population, time of infestation, and weather conditions, along with a number of agronomic factors such as soil moisture and soil type. What can be said with certainty is that the grain aphid can build up alarmingly under warm, dry conditions and produce appreciable yield losses. Similarly, one application of a systemic organophosphorus spray, if applied at the most critical stage — *i.e.*, at flowering — can reduce these losses and produce a good economic return from spraying.

Only following a very severe attack of grain aphid is the sample likely to be rejected through "sprout". In both the field trials carried out during 1967 and 1968, selected samples of grain, when tested, produced "sprout" values; however, this effect was masked when header samples were tested. During the past two seasons, a small number of samples have been rejected for baking because of "sprout", although no such grains were present in the samples. The "sprout" in these instances may have resulted from a heavy attack of grain aphid.

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