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CONTROL OF WHEAT BULB FLY IN WINTER WHEAT
I. CHEMICAL METHODS
II. VARIETAL SUSCEPTIBILITY

by

J. E. B. YOUNG

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CONTROL OF WHEAT BULB FLY IN WINTER WHEAT
I. CHEMICAL METHODS

by

J. E. B. YOUNG
ADAS BOXWORTH

Final report of a four-year project at ADAS Boxworth (Cambridge), Brooklands Avenue, Cambridge CB2 2BL. The work commenced in August 1987 and was supported by a grant of £20,590 from the Home-Grown Cereals Authority (Project Number 0053/2/87).

SUMMARY

From 1987 to 1991, sixteen trials were done in eastern England to evaluate a range of chemical control strategies for the control of wheat bulb fly (*Delia coarctata*) in winter wheat. The risk of wheat bulb fly damage was estimated by sampling egg populations in the autumn. Four trials were done in each of the following categories of risk: Category A, low risk, fewer than 1.0 million eggs/ha; Category B, medium risk, 1.0 - 2.5 million eggs/ha; Category C, high risk, 2.5 - 5.0 million eggs/ha; Category D, very high risk, more than 5.0 million eggs/ha. Each trial included early (October) and late (November) sowing dates to create a varying order of crop susceptibility to wheat bulb fly damage. There were four core treatments at each site: 1) untreated; 2) omethoate, applied when larval damage was first seen (deadheart spray); 3) a full treatment of fonofos seed treatment, fonofos granules applied at sowing, fonofos spray applied at the start of egg hatch and omethoate spray applied at the deadheart stage; 4) fonofos seed treatment. The full treatment was not applied as a commercially viable recommendation but to give maximum elimination of wheat bulb fly for damage assessment purposes. In addition to the core treatments, combinations of preventive treatments (including fonofos seed treatment, fonofos granules at sowing, fonofos spray at sowing or at the start of egg hatch and a mixture of chlorpyrifos plus dimethoate applied at peak egg hatch) were used in conjunction with the varying levels of risk to wheat bulb fly damage.

Two successive mild winters, in 1988/89 and 1989/90, stimulated crop growth and offset the severity of wheat bulb fly damage. Assessment of risk, based on wheat bulb fly egg populations, was in some cases unreliable owing to a large mortality of eggs or larvae prior to plant invasion, particularly in the very high risk Category D sites. This observation is reflected in the reduced levels of pest attack and the lack of yield response to treatment in the Category D sites.

Wheat sown before November did not show statistically significant or economically profitable yield increases in response to treatment when subjected to wheat bulb fly egg populations less than the accepted threshold for autumn sowings of 2.5 million wheat bulb fly

OBJECTIVES

To evaluate chemical measures adopted for wheat bulb fly control at sites representing the varying levels of risk to field attack, enabling the identification of the most appropriate and cost-effective control strategies for UK cereal growers. This project complements an investigation on the more fundamental aspects of wheat bulb fly loss assessment in relation to damage thresholds, which was funded by the Ministry of Agriculture Fisheries and Food and is represented by the three core treatments of the study (Table 3).

INTRODUCTION

Wheat bulb fly (*Delia coarctata*) is an important pest of winter wheat and barley in eastern areas of England. Spring wheat and barley, sown before April, are also damaged. Egg laying occurs in July and August on the exposed soil surface found in fallows, freshly harvested or cultivated fields, or on the soil beneath the canopy of root crops. On hatching in January or February, the larvae die unless the field has been sown with a suitable host crop. Wheat, rye and barley are susceptible to attack when they are sown after fallow, potatoes, sugar beet, peas or early-harvested crops such as oilseed rape which allow soil cultivation during the egg-laying period. There are three larval instars (stages), passed inside the host plant. Older larvae may move between plants as well as between tillers (shoots), so that damage increases with time. Larval feeding causes "deadhearts" which are visible as withered and yellow central leaf shoots. Pupation takes place in the soil in April and May. Adult flies emerge in June, completing a single generation per year.

Late-sown crops of winter wheat (or early-sown spring wheat or barley) are inherently very susceptible to wheat bulb fly damage, as they often remain at pre-tillering growth stages during the critical January to March period when wheat bulb fly larvae are invading the crop. Early autumn sowing, which is an effective cultural means of

MATERIALS AND METHODS

Each trial included a randomised block design with two sowing dates (Table 1). The treatments applied (Tables 2 & 3) varied according to the risk of wheat bulb fly infestation, classified according to the number of wheat bulb fly eggs estimated by soil sampling in the autumn (Tables 1 & 3).

Plots, 24m x 2m, were sown using an Oyjord/Falcon drill. Seed rates ranged from 350 to 450 seed/sq.m. Seed treatments were applied by the seed merchant. Insecticide granules were applied by combine drilling with the seed, except at sites located at Drayton and Terrington Research Centres where the granules were broadcast manually prior to surface incorporation at drilling. Sprays were applied at a volume of 200 litres/ha, using a carbon dioxide gas pressurised knapsack sprayer operating at 200 kPa, with medium spray quality nozzles.

The wheat bulb fly egg population at each site was determined from 32 x 7.2 cm diameter soil cores sampled from each field. Soil core depth was varied according to the depth of cultivation, up to a maximum of approximately 25 cm. Wheat bulb fly eggs were separated from the soil by a process of wet sieving, elutriation and flotation, adapted from that described by Gough (1947).

The timing of application for egg hatch and deadheart sprays was determined by monitoring the progress of wheat bulb fly egg hatch and plant invasion at selected sites. Egg hatch was monitored in soil samples taken at intervals of seven to ten days. Plant invasion was monitored in randomly selected samples of 50 plants taken from discard plots at intervals of seven to ten days.

When crop emergence was complete, and prior to the start of wheat bulb fly egg hatch, plant establishment populations were determined from six pairs of 0.5 m rows per plot or in eight 0.1 m^2 quadrats per plot.

At sites deemed to be at risk of damage from yellow cereal fly (*Opomyza florum*), a spray of a synthetic pyrethroid was applied

RESULTS AND DISCUSSION

Sixteen trials were done over the four-year period 1987-1991. During that time the trials were subject to two extremely mild winters (1988/89 & 1989/90). The mild winters stimulated crop growth which in turn tended to offset the severity of wheat bulb fly damage experienced in the trials. Despite this, the trials have produced a useful set of results, representative of present-day farming conditions and of practical value to all involved in the management of wheat bulb fly.

The effects of insecticidal treatment on percentage tillers attacked by wheat bulb fly are presented in Tables 4-7; larval survival in Tables 8-11; grain yield in Tables 12-15; and financial return in Tables 16-19. The results of plant establishment (except 1987/88 sites), fertile tiller and grain quality assessments are not presented here as the findings did not indicate any important differences between treatments.

In the first year of work (1987/88), an organo-mercury seed treatment was not applied. Consequently, plant establishment was greater in treatments where fonofos seed treatment was used (Table 20). This effect was most prominent in the early sowings at Sites 5 and 9 and both sowings at Site 13. Seed-bed pests were not found at any of the affected sites; therefore, it is possible that the fonofos seed treatment exerted a mild fungicidal effect against seedling pathogens during germination of the crop. The greater plant establishment that resulted from the use of fonofos seed treatments without organo-mercury had a profound effect on yield, the results of which have not been included in the assessment of the efficacy of fonofos seed treatment against wheat bulb fly. In subsequent trials, all seed was treated initially with an organo-mercury compound.

At Site 5, a plant dissection assessment could not be carried out in the late sowing due to some very low plant populations. At Site 6, the late drilling was abandoned when the area in question was sown in error with the farm crop.

TABLE 2: Formulation, rates, costs and timing of application of insecticide treatments applied in wheat bulb fly trials 1987-1991.

Insecticide	Formulation	Product/ha	ai/ha	Approx cost/ha (£)	Time of application
Omethoate as Folimat (Bayer)	Emulsifiable concentrate (50% w/w)	1.1 litres	0.64	18	At the appearance of symptoms (deadheart)
Fonofos seed treatment (ICI)	Microencapsulated seed treatment	NA	1.0 a.i./kg seed	9	At sowing
Fonofos as Dyfonate MS (Farm Protection)	Microencapsulated aqueous suspension (50% w/w)	2.5 litres at sowing or 1.6 litres at egg hatch	1.38 kg or 0.88 kg	33 21	At sowing or at start of egg hatch
Fonofos as Dyfonate 10G (Farm Protection)	Granules (10%)	14 kg	1.4 kg	39	At sowing
Chlorpyrifos as Dursban 4 (Dow Elanco)	Emulsifiable concentrate (41% w/w)	1.5 litres	0.72	18	At peak egg hatch (mixed with dimethoate)
Dimethoate 40 (BASF)	Emulsifiable concentrate (37% w/w)	1.7 litres	0.68 kg	6	At peak egg hatch (mixed with chlorpyrifos)

TABLE 4: Effect of insecticidal treatments upon larval damage, expressed as angular transformations of percentage tillers attacked, Category A Sites.

Treatment	Site 1 E	Site 1 L	Site 2 E	Site 2 L	Site 3 E	Site 3 L	Site 4 E	Site 4 L
1. Untreated control	13.4	12.2	18.2	21.5	0	4.0	15.5	17.2
2. Omethoate spray at deadheart	8.8	7.6*	13.4*	17.3*	0	1.8	14.9	14.4
3. Full treatment fonofos granules at sowing + fonofos seed treatment + fonofos spray at egg hatch + omethoate spray at deadheart	5.5*	1.4*	8.8*	7.4*	1.0	3.7	11.8*	3.4*
4. Fonofos seed treatment	12.2	9.0	17.3	19.3	0.9	4.7	13.1	14.8
SED (9 d.f)	2.35	1.71	1.70	1.79	1.03	2.52	1.42	3.05

E = Early sowing
L = Late sowing

* Significantly different from untreated at $P < 0.05$.

TABLE 6: Effect of insecticidal treatment upon larval damage, expressed as angular transformations of percentage tillers attacked, Category C sites.

Treatment	Site 9 E	Site 9 L	Site 10 E	Site 10 L	Site 11 E	Site 11 L	Site 12 E	Site 12 L
1. Untreated control	17.2	19.3	21.0	23.2	22.7	21.0	13.1	12.2
2. Omethoate spray at at deadheart	16.8	17.0	18.4	21.8	20.7	14.6	11.4	8.0
3. Full treatment: fonfos granules at sowing + fonofos seed treatment + fonofos spray at egg hatch + omethoate spray at deadheart	3.9*	6.9*	11.0*	12.4	4.4*	8.6	7.9	5.7*
4. Fonofos seed treatment	14.0	16.5	17.8	22.1	23.8	18.9	9.5	7.5*
5. Fonofos seed treatment + omethoate spray at deadheart	16.9	14.7	16.7	19.6	21.9	15.5	11.0	7.5*
6. Fonofos spray at egg hatch	13.6	15.2	18.8	20.1	20.4	15.4	11.8	11.1
7. Fonofos seed treatment + fonofos at egg hatch	10.9	10.1*	22.3	19.3	16.3	14.7	11.2	6.8*
8. Chlorpyrifos tank mixed with dimethoate at peak egg hatch	10.9	14.3	15.8	19.7	20.2	18.8	10.6	9.8
S.E.D. (14 d.f.)	2.64	2.37	2.39	3.15	3.54	4.14	1.94	1.85

E = Early sowing L = Late sowing * Significantly different from untreated at $P < 0.05$

TABLE 8: **Effect of insecticidal treatment on larval survival, expressed as live larvae/m^2, Category A sites.**

Treatment		**Site**							
		1		**2**		**3**		**4**	
		E	L	E	L	E	L	E	L
1.	Untreated control	21.2	15.6	79.5	72.3	0	0.7	58.4	12.0
2.	Omethoate spray at deadheart	14.5	4.2*	27.6*	30.1*	0	0	41.2	6.9
3.	Full treatment: fonofos granules at sowing + fonofos seed treatment + fonofos spray at egg hatch + omethoate spray at deadheart	1.2*	0*	5.2*	12.3*	0	0.6	24.4	0.3*
4.	Fonofos seed treatment	22.1	5.0*	74.4	42.9*	0.9	2.7	32.2	10.3
	S.E.D. (9 d.f.)	3.93	4.07	13.46	9.69	0.65	1.46	11.82	3.21

E = Early sowing
L = Late sowing

* Significantly different from untreated at $P < 0.05$

TABLE 10: Effect of insecticidal treatment on larval survival, expressed as live larvae/m^2, Category C sites.

Treatment	Site 9		Site 10		Site 11		Site 12	
	E	L	E	L	E	L	E	L
1. Untreated control	9.4	13.6	77.3	79.3	40.8	40.3	11.3	5.8
2. Omethoate spray at deadheart	1.4	0.9*	64.2	58.6	37.8	21.0	4.4	3.1
3. Full treatment: fonofos granules at sowing + fonofos seed treatment + fonofos spray at egg hatch + omethoate spray at deadheart	0*	0*	23.2	7.0	3.3*	1.5	0	0
4. Fonofos seed treatment	13.8	4.9*	88.7	52.2	72.2*	42.6	2.3	1.5
5. Fonofos seed treatment + omethoate spray at deadheart	4.8	1.3*	48.2	37.0	35.7	16.5	5.6	1.3
6. Fonofos spray at egg hatch	1.5	5.4*	115.6	58.2	42.6	10.1	5.0	8.2
7. Fonofos seed treatment + fonofos at egg hatch	6.3	1.3*	108.6	51.2	29.0	14.2	8.4	1.5
8. Chlorpyrifos tank mixed with dimethoate at peak egg hatch	0*	4.0*	73.0	46.6	36.1	26.7	6.3	7.6
S.E.D. (14 d.f.)	3.89	2.42	36.91	19.63	10.99	13.67	3.25	4.55

E = Early sowing
L = Late sowing

* Significantly different from untreated at $P < 0.05$

TABLE 12: Effect of insecticidal treatment on grain yield, expressed as percentage of control yield, in Category A sites.

Treatment	Site 1		Site 2		Site 3		Site 4	
	E	L	E	L	E	L	E	L
1. Control yield (t/ha)	8.47	7.10	8.72	7.50	6.43	4.54	8.42	6.54
2. Omethoate spray at deadheart	100	102	103	107	97	98	102	95
3. Full treatment: fonofos granules at sowing + fonofos seed treatment + fonofos spray at egg hatch + omethoate spray at deadheart	99	110*	107*	109	102	94	102	100
4. Fonofos seed treatment	102	111*	100	100	99	98	99	91*
S.E.D. (9 d.f.)	0.175	0.122	0.128	0.302	0.248	0.184	0.240	0.220

E = Early sowing
L = Late sowing

* Significantly different from untreated at $P < 0.05$

TABLE 14: **Effect of insecticidal treatment on grain yield, expressed as percentage of control yield, in Category C sites.**

Treatment	Site 9 E	Site 9 L	Site 10 E	Site 10 L	Site 11 E	Site 11 L	Site 12 E	Site 12 L
1. Control yield (t/ha)	2.95	4.49	6.97	5.51	7.05	4.76	8.08	7.41
2. Omethoate spray at deadheart	113*	99	101	106	98	115*	102	100
3. Full treatment: fonofos granules at sowing + fonofos seed treatment + fonofos spray at egg hatch + omethoate spray at deadheart	179*	112*	107	121*	108*	137*	103	104*
4. Fonofos seed treatment	140*	95	101	105	100	123*	101	103*
5. Fonofos seed treatment + omethoate spray at deadheart	148*	96	101	111*	99	134*	103	102*
6. Fonofos spray at egg hatch	121*	107	99	107	101	122*	102	104*
7. Fonofos seed treatment + fonofos at egg hatch	154*	111*	104	107	102	131*	101	103*
8. Chlorpyrifos tank-mixed with dimethoate at peak egg hatch	112*	104	104	110*	97	111*	101	102*
S.E.D. (14 d.f.)	0.150	0.150	0.195	0.228	0.180	0.188	0.093	0.057

E = Early sowing L = Late sowing * Significantly different from untreated at $P < 0.05$

TABLE 16: Effect of insecticidal treatment on financial return, based on grain @ £100/tonne but excluding application costs, in Category A sites (£/ha).

Treatment	Site 1		Site 2		Site 3		Site 4		Mean	
	E	L	E	L	E	L	E	L	E	L
2. Omethoate spray at deadheart	-15	-3	+11	+31	-39	-19	-4	-53	-12	-11
3. Full treatment: fonofos granules at sowing + fonofos seed treatment + omethoate spray at deadheart	-93	-16	-29	-20	-76	-114	-73	-85	-68	-59
4. Fonofos seed treatment	+10	+67	-8	-7	-15	-20	-19	-70	-8	-8

E = Early sowing
L = Late sowing

TABLE 18: Effect of insecticidal treatment on financial return, based on grain @ £100/tonne but excluding application costs, in Category C sites (£/ha).

Treatment	Site 9		Site 10		Site 11		Site 12		Mean	
	E	L	E	L	E	L	E	L	E	L
2. Omethoate spray at deadheart	+21	-21	-10	+17	-35	+53	-4	-21	-7	+7
3. Full treatment: fonofos granules at sowing + fonofos seed treatment + fonofos spray at egg hatch + omethoate spray at deadheart	*	-34	-39	+31	-30	+90	-63	-59	-44	+7
4. Fonofos seed treatment	*	-30	+1	+21	-8	+98	-1	+13	-3	+26
5. Fonofos seed treatment + omethoate spray at deadheart	*	+3	-17	+31	-36	+133	-7	-13	-20	+39
6. Fonofos spray at egg hatch	+40	+9	-30	+18	-17	+84	-9	+6	-4	+29
7. Fonofos seed treatment + fonofos at egg hatch	*	+18	0	+11	-17	+115	-25	+2	-14	+34
8. Chlorpyrifos tank-mixed with dimethoate at peak egg hatch	+10	-8	+1	+32	-43	+27	-18	-12	-13	+10

E = Early sowing
L = Late sowing

* Not applicable owing to effect of seed treatment on plant establishment

TABLE 20: The effect of fonofos seed treatment on plant establishment during autumn 1987 (plants/m^2).

Treatment (continued overpage)	Site 5		Site 9		Site 13	
	E	L	E	L	E	L
1. Untreated control	54	25	61	120	90	55
2. Omethoate spray at deadheart	52	27	70	100	86	27
3. Full treatment: fonofos granules at sowing + fonofos seed treatment + fonofos spray at egg hatch + omethoate spray at deadheart	112*	47	135*	85	157*	96*
4. Fonofos seed treatment	88*	57	159*	103	161*	80
5. Fonofos seed treatment + omethoate at deadheart	120*	47	141*	87		
6. Fonofos at egg hatch	-	-	54	128	83	55
S.E.D (d.f. in parentheses)	13.7(12)	14.4(12)	19.2(14)	12.7(14)	12.4(16)	16.9(16)

E = Early sowing
L = Late sowing

* Significantly different from untreated at $P < 0.05$

TABLE 21: **Proposed chemical control strategies for wheat bulb fly.**

Risk category	**Sowing date**		
	September-October	**November-December**	**January-March**
A Low risk < 0.9 million eggs/ha	No treatment	No treatment	A
B Medium risk 1.0-2.4 million eggs/ha	No treatment	A Optional D	A Optional D
C High risk 2.5-4.9 million eggs/ha	Optional D	A Optional C or D	A B Optional D
D Very high risk > 5.0 million eggs/ha	C Optional D	A C Optional D	A B Optional D

Key:
A, seed treatment e.g. fonofos or chlorfenvinphos
B, seed-bed treatment e.g. chlorfenvinphos or chlorpyrifos sprays
C, egg hatch spray e.g. chlorfenvinphos or chlorpyrifos
D, deadheart spray e.g. dimethoate or omethoate

occurred at the high-risk (Category C) sites, notably that of Site 11 where a 37% (0.71 t/ha) increase in yield was noted ($\underline{P} < 0.05$).

Site 13 was the only one of four Category D (very high risk) sites which resulted in statistically significant ($\underline{P} < 0.05$) yield increases following the full treatment. However, this increase, together with those of the early sowings of Sites 5 & 9, is not valid owing to the effect of the fonofos seed treatment on plant establishment (see page 8). The lack of significant yield increases in the Category D sites contrasts strongly with the significant increases obtained by the full treatment at seven out of twelve lower-risk sites (Categories A, B and C). The reasons for this anomaly are discussed below under "Egg Numbers in Relation to Damage" (page 36).

Fonofos seed treatment. Wheat bulb fly seed treatments such as fonofos and chlorfenvinphos are useful preventives, particularly for late-sown (November onwards) wheat, which often follows sugar beet or potatoes in high-risk areas such as the fens of East Anglia. Although wheat bulb fly seed treatments have the advantage of low cost, when severe outbreaks of wheat bulb fly occur they often work to better effect in combination with other methods of treatment.

The fonofos seed treatment was applied at all sixteen sites. Discounting the effects of fonofos seed treatment on plant establishment discussed above, the results obtained were variable and tended to be better in the late sowings. Reductions in tiller damage or larval survival ($\underline{P} < 0.05$) were noted in the early sowings of Sites 11 and 13 and the late sowings of Sites 1, 2, 8, 9, 12 & 16 (Tables 4-11). Apart from Sites 5, 9 & 13, where plant establishment effects occurred, yield increases over control were restricted to the late sowings at Sites 1, 8, 11 & 12 ($\underline{P} < 0.05$). The financial return on treatment where these increases occurred was on average £56/ha (Tables 16-19). The results indicate the cost-effectiveness of using fonofos seed treatment in both low-risk and high-risk situations, and confirm much earlier work demonstrating seed treatments were more effective in controlling wheat bulb fly the later the wheat was sown in the autumn (Gough *et al.*, 1961).

The treatment reduced tiller damage in the late sowings of Sites 9 & 12 and also larval survival in the late sowing of Site 9 ($P < 0.05$). Yield increases over control ($P < 0.05$) were restricted to the late sowings of Sites 9, 11 & 12, excluding the increase in early sowing of Site 9 owing to the seed treatment effect on plant establishment. Financial returns on treatment (in conjunction with the above yield increases) averaged £45/ha, once again proving that late-sown winter wheat was more responsive than early sowings to wheat bulb fly control.

Chlorpyrifos tank-mixed with dimethoate at peak egg hatch. This treatment was applied only at the eight Category C & D high-risk sites. The tank mixture has been developed as a commercial practice, intended for use in high-risk fields where the application of a spray at the start of egg hatch is delayed and larval invasion of the crop already underway. Therefore, when this treatment is applied in mid- or peak egg hatch, the chlorpyrifos element of the mixture prevents further larval invasion, whilst the systemic dimethoate (normally applied as a deadheart spray) is toxic to larvae which are already present within the crop.

The tank-mixture treatment reduced tiller damage in both sowings at Site 13 and in the late sowing at Site 16 ($P < 0.05$). Larval survival was decreased in both sowings at Site 9 and in the early sowing of Site 16 ($P < 0.05$). Yield increases over control were noted in the early sowings of Sites 9 & 13, and in the late sowings of Sites 10, 11 & 12 ($P < 0.05$). The average financial return associated with the above yield increases was £20/ha.

Fonofos granules at sowing. Maskell & Gair (1986b) reported that fonofos granules gave a consistently high standard of control of wheat bulb fly in both organic and mineral soils. In commercial practice, the use of fonofos granules is restricted owing to the high cost (£39/ha). Fonofos granules are recommended, therefore, only for fields known or suspected to be at very high risk of attack, i.e. Category D - more than 5 million wheat bulb fly eggs/ha.

Fonofos granules alone were applied only at the four Category D expected level of larval attack. The possible reasons for this discrepancy are discussed below under "Egg Numbers in Relation to Damage" (page 36).

Effect of sowing date on insecticide performance. It is well documented that late-sown wheat (i.e. November onwards) is far more vulnerable to damage by wheat bulb fly than early autumn-sown crops (Bardner, 1968). The work reported here confirmed this observation. Of the 159 insecticidal treatments considered, a total of 23 significant ($\underline{P} < 0.05$) yield increases over control occurred in the late sowings, compared with 10 in the early sowings. All of the early sowings took place during October, whilst the late sowings were done in November or early December.

Wheat bulb fly seed treatments have long been known to be more effective on late sowings (Gough *et al.*, 1961). Maskell & Gair (1986a) concluded that wheat bulb fly seed treatments were most effective when sown after mid-October. The results of the work reported here support these earlier findings and clearly demonstrate that the fonofos seed treatment was more effective in the late (November) sowings than in the early (October) sowings.

Egg numbers in relation to damage. In general, there was a poor correlation between the wheat bulb fly egg population, as assessed by soil sampling in the autumn, and the amount of crop damage or larval numbers in the spring. This observation calls into question the validity of forecasting the risk of damage from egg numbers. As long as 45 years ago Gough (1947) pessimistically concluded that egg counts were unlikely to be of any value in forecasting outbreaks. He stated that the effect of soil and weather on crop growth were likely to be more important than larval numbers in determining crop loss from wheat bulb fly. Long (1959) also questioned the reliability of egg counts as a forecasting method. He also considered that the high variation of the local distribution of eggs, together with variation in egg viability and larval or egg mortality, rendered forecasts of damage based on egg counts too unreliable for practical purposes.

Strategies for wheat bulb fly control. The proposed strategies for the control of wheat bulb fly, based on the findings of the work reported here, are listed in Table 22. Seed treatments are reserved for use only in crops sown from November onwards. Crops sown earlier than November do not warrant preventive treatment unless rated as very high risk (Category D, more than 5 million eggs/ha). The results have shown that October sowings are often able to withstand substantial damage without suffering any major yield loss.

Crops sown from November onwards are inherently more susceptible to wheat bulb fly damage. Damage can be particularly severe if the crop has not progressed beyond the single shoot growth stage by the time of wheat bulb fly larval invasion during the January to March period. The higher levels of preventive insecticide treatment suggested for late sowings therefore reflect the extra vulnerability of late-sown wheat to wheat bulb fly.

The fonofos spray (Dyfonate MS) was withdrawn from sale as of 31 March 1992 when its provisional Approval lapsed. Fonofos granules, as Dyfonate 10G, will continue to be available as a horticultural insecticide, but the Approval for use in cereals lapsed on 31 March 1992. There are currently no plans to re-submit either formulation of fonofos for new Approval. Fonofos seed treatment will continue to be available. Suitable alternatives to fonofos spray or granules are available for wheat bulb fly control in the form of chlorfenvinphos (as Birlane 24 or Sapecron 240 EC) or chlorpyrifos (as Dursban 4 or Spannit) sprays.

Forecasting wheat bulb fly. The strategies proposed for the control of wheat bulb fly rely on classification of risk according to egg numbers in individual fields. Egg sampling for advisory purposes is done by ADAS in the autumn months. However, only a small proportion of fields at risk can be sampled in this way. More reliable methods of forecasting wheat bulb fly damage are required in order to establish the most appropriate and cost-effective combination of control measures. This would help ensure that insecticides are correctly targeted to high-risk fields, and minimise environmentally undesirable and economically wasteful applications.

CONCLUSIONS

The trials were done to test the various options available for the chemical control of wheat bulb fly at the varying levels of risk encountered in the field and to identify the most appropriate control measures. Assessment of risk, based on wheat bulb fly egg numbers, was in some cases unreliable owing to a large mortality of eggs or larvae prior to plant invasion.

Control strategies for the management of wheat bulb fly have been proposed (Table 21), based on the findings of the trials. Crops sown before November rarely suffer economic losses below the action threshold of 2.5 million eggs/ha. In most instances, preventive treatment is not justified on well established crops sown before November.

Sowing before November is an effective cultural means of reducing yield losses caused by the pest. Wheat sown from November onwards is inherently more vulnerable to wheat bulb fly damage than earlier sowings, particularly if the crop remains at pre-tillering growth stages at the time of larval invasion.

The performance of fonofos seed treatment was better in the late sowings. Wheat bulb fly seed treatments are a cost-effective preventive control measure, most suitable for crops sown later than October. Seed treatments have the advantage of low cost, accurate targeting and minimal application of insecticide to the environment.

Seedbed treatments, egg hatch and deadheart sprays all demonstrated their viability in controlling wheat bulb fly. Deadheart sprays are a particularly useful option as they can be applied in response to the level of larval damage in the crop, assessed towards the end of the egg hatch. However, the yield responses associated with the deadheart spray have shown considerable variation, indicating the importance of reliable action thresholds to ensure cost-effective use of this treatment.

Multiple treatments can be cost-effective in high-risk fields. Complete control of severe attacks cannot usually be obtained by

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HGCA PROJECT REPORT No. 67

CONTROL OF WHEAT BULB FLY IN WINTER WHEAT
II. VARIETAL SUSCEPTIBILITY

by

J. E. B. YOUNG
ADAS BOXWORTH

Final report of a three-year project at ADAS Boxworth (Cambridge), Brooklands Avenue, Cambridge CB2 2BL. The work commenced in August 1988 and was supported by a grant of £29,520 from the Home-Grown Cereals Authority (Project Number 0077/2/87).

SUMMARY

Six field trials, of a randomised block factorial design, were done in eastern England from 1988 to 1991 to evaluate the susceptibility of contemporary varieties of winter wheat to wheat bulb fly (*Delia coarctata*). The trials were sited on organic (fen peat) or mineral soils with wheat bulb fly populations in excess of five million eggs/ha, assessed by soil sampling in the autumn. Each year, six varieties of winter wheat were sown: Apollo, Mercia and Tonic in all years, plus Apostle and Slejpner in 1988, Hornet in 1988 and 1989, Beaver in 1989 and 1990, and Hereward and Riband in 1990. Each trial included early (October) and late (November) sowing dates to create a varying order of crop susceptibility to wheat bulb fly damage. Three treatments were imposed on the wheat varieties: i) an untreated control; ii) an intensive (full) treatment regime, for maximum reduction of wheat bulb fly damage, of fonofos granules applied at drilling, a fonofos spray applied at the start of wheat bulb fly egg hatch and an omethoate spray applied at the onset of symptoms (deadheart) in March; iii) a single spray of omethoate applied at the onset of symptoms in March (deadheart spray). The susceptibility of the wheat varieties to wheat bulb fly damage and their response to treatment were assessed by examining the plant population prior to wheat bulb fly invasion, the proportion of damaged tillers in March or April, numbers of ear-bearing tillers in July and grain yield and quality at harvest.

Pheasant damage caused a reduction in plant establishment at one site, where the variety Riband was, for unknown reasons, worse affected than the other varieties. The tillering ability of the varieties as assessed in March or April indicated that the early sowings produced on average 0.4 tillers/plant more than the late sowings. The growth differential between the two sowings and the degree of wheat bulb fly damage was offset by the mild winters of 1988/89 and 1989/90, which induced strong vegetative growth. The feed varieties such as Beaver, Riband and Apollo tended to produce an average of 0.5 tillers/plant more than the bread-making quality varieties such as Mercia, Tonic and Hereward. The percentage of tillers damaged averaged 18% in untreated plots. There were insufficient differences in the amount of tiller damage between the

OBJECTIVES

To evaluate modern varieties of wheat for their susceptibility to and recovery from wheat bulb fly damage.

INTRODUCTION

The development of varieties of wheat resistant to wheat bulb fly (*Delia coarctata*) has not been fully investigated. Three main possible categories of plant resistance mechanisms have been distinguished (Raw, 1967):

1. *Preference and non-preference:* in which resistance depends on the effect of the plant on the behaviour of the insect and thereby determines the amount of infestation.

2. *Antibiosis:* in which resistance depends on the plant affecting the growth and survival of the insect.

3. *Tolerance:* in which resistance depends on the ability of the plant to withstand attack without loss of vigour or yield.

In relation to wheat and wheat bulb fly, Raw (1967) considered that preference and tolerance were closely linked and are probably also linked to the presence or absence of antibiosis. Oats show a true resistance and are virtually immune to invasion by wheat bulb fly (Gough, 1946; Scott, 1974).

In the 1960s, Rothamsted Experimental Station, the Plant Breeding Institute and the National Agricultural Advisory Service (NAAS, now ADAS) collaborated in studying the possibility of selecting varieties resistant to wheat bulb fly (Raw, 1967; Lupton & Bingham, 1967). At Rothamsted, Raw found that wheat varieties did not differ in the percentage of shoots infested but there were differences in their tillering capacity. Although varieties with the most tillers tolerated and survived attack better than those with few tillers, there was a positive correlation between the tiller (shoot) density

MATERIALS AND METHODS

Each trial was of a randomised block three-way factorial design comprising of six wheat varieties, three insecticidal treatments and two drilling dates all replicated four times. Details of the varieties sown in each year, site location, soil type, previous cropping and wheat bulb fly egg numbers are given in Table 1.

Plots, 12m x 2m (minimum) were sown using an Oyjord/Falcon drill. Seed rates were standardised in each trial at 350 or 400 seeds/m^2. The following insecticidal treatments were applied:

1) Untreated control.

2) Full treatment: fonofos (Dyfonate 10G, 10% granules; Farm Protection) at 1.4kg a.i./ha applied at drilling; fonofos (Dyfonate MS, 49.7% microencapsulated aqueous suspension; Farm Protection) at 0.88 kg a.i./ha applied at the start of wheat bulb fly egg hatch in early January; omethoate (Folimat, 50% e.c.; Bayer) at 0.64 kg a.i./ha applied at onset of wheat bulb fly symptoms (deadheart) in February or March.

3) Deadheart spray: omethoate (Folimat, 50% e.c.; Bayer) at 0.64 kg a.i./ha applied at the onset of wheat bulb fly symptoms (deadheart) in February or March.

The insecticide granules were applied by combine drilling with the seed, except at sites located at ADAS Drayton and ADAS Terrington where the granules were broadcast manually prior to surface incorporation at drilling. Sprays were applied at a volume of 200 litres/ha using a carbon dioxide gas pressurised knapsack sprayer operating at 200 kpa with medium spray quality nozzles.

The timing of application for egg hatch and deadheart sprays was determined by monitoring the progress of wheat bulb fly egg hatch and plant invasion at selected sites. Egg hatch was monitored in soil samples taken at intervals of seven to ten days. Plant invasion was monitored in randomly selected samples of 50 plants taken from discard plots at intervals of seven to ten days.

RESULTS AND DISCUSSION

Owing to the factorial design of the trials, there are many levels of statistical comparison available. The SEDs quoted in the following tables are for comparisons made between varieties (30 d.f.), drilling x varieties (30 d.f.), or drillings x varieties x treatments (72 d.f.). The associated least significant differences (LSD) are cited only where the analysis of variance F value indicated statistically significant differences ($\underline{P} < 0.05$) at the respective level of comparison.

TABLE 2: Effect of variety and sowing date on plant establishment (plants/m^2) prior to wheat bulb fly egg hatch.

Variety	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
	E	L	E	L	E	L	E	L	E	L	E	L
Apollo	309	291	279	227	241	282	315	319	268	110	238	172
Apostle	327	325	305	271								
Hornet	328	319	324	287	234	265	300	333				
Mercia	361	329	330	280	235	282	302	313	258	127	220	182
Slejpner	345	302	304	295								
Tonic	329	301	314	294	230	274	326	329	275	132	248	196
Beaver					218	259	292	319	265	116	241	192
Pastiche					221	261	314	313				
Hereward									247	110	242	174
Riband									285	69	232	133
SED (30 d.f.)	14.1		18.8		17.6		9.6		12.8		26.1	
LSD	NS		NS		NS		NS		26.1		53.1	

E = Early sowing L = Late sowing

TABLE 4: **Effect of variety, sowing date and insecticide upon larval damage expressed as angular transformations of the percentage of tillers attacked – organic soil sites (1,3 & 5).**

Variety	Site 1						Site 3						Site 5					
	E			L			E			L			E			L		
	U	F	D	U	F	D	U	F	D	U	F	D	U	F	D	U	F	D
Apollo	21	20	19	19	19	19	11	16	12	10	9	14	21	21	24	32	15	37
Apostle	20	17	20	19	18	17												
Hornet	19	16	19	19	15	18	18	14	16	12	11	12						
Mercia	25	23	20	18	22	22	19	19	20	16	11	13	25	17	27	42	21	37
Slejpner	20	19	16	21	18	18												
Tonic	21	20	20	23	17	20	20	14	20	11	10	11	26	21	24	32	23	34
Beaver							16	14	17	11	11	9	19	20	21	36	14	44
Pastiche							18	17	18	12	11	14						
Hereward													23	21	27	32	17	36
Riband													27	23	26	50	24	39
SED (72 d.f.)			2.5						2.6						4.1			
LSD			NS						NS						NS			

E = Early sowing L = Late sowing U = Untreated F = Full treatment D = Deadheart treatment

TABLE 6: Effect of variety, sowing date and insecticide on ear-bearing population (ears/m^2) - organic soil sites (1, 3, and 5).

Variety	Site 1						Site 3						Site 5					
	E			L			E			L			E			L		
	U	F	D	U	F	D	U	F	D	U	F	D	U	F	D	U	F	D
Apollo	629	646	651	669	678	676	619	598	518	596	592	587	715	707	689	632	707	583
Apostle	589	573	610	605	592	582												
Hornet	437	466	475	518	529	525	603	546	657	521	500	500						
Mercia	722	664	685	709	744	751	679	700	736	716	705	698	821	874	872	599	716	600
Slejpner	558	617	617	602	615	620												
Tonic	576	612	616	708	699	743	695	641	658	832	777	749	691	625	675	526	666	628
Beaver							565	572	623	589	621	596	738	610	651	571	622	466
Pastiche							506	604	534	476	540	578						
Hereward													655	614	623	533	643	457
Riband													575	646	647	286	468	358
SED (72 d.f.)	31.9						73.6						68.8					
LSD	NS						NS						NS					

E = Early sowing L = Late sowing U = Untreated F = Full treatment D = Deadheart treatment

TABLE 8: Effect of variety, sowing date and insecticide on grain yield (t/ha @ 85% d.m.), expressed as a percentage of the untreated - organic soil sites (1,3 and 5)

Variety	Site 1						Site 3						Site 5					
	E			L			E			L			E			L		
	U	F	D	U	F	D	U	F	D	U	F	D	U	F	D	U	F	D
Apollo	11.2	102	93	9.2	107	102	10.2	98	93	8.5	103	108	7.9	96	94	4.1	156	89
Apostle	8.9	104	103	8.4	106	101												
Hornet	10.1	108	107	9.7	106	96	9.8	94	106	8.8	96	96						
Mercia	9.7	97	101	8.9	107	98	8.6	106	102	7.0	105	107	6.9	98	93	3.4	182	110
Slejpner	9.6	107	107	9.2	108	100												
Tonic	9.4	105	102	9.0	114	105	9.7	102	95	7.9	109	104	7.8	98	99	4.8	133	120
Beaver							11.0	100	102	9.9	102	104	8.0	105	107	4.6	172	87
Pastiche							8.4	94	101	6.9	99	99						
Hereward													7.9	102	99	4.0	164	92
Riband													7.6	105	101	1.1	421	225
SED (72 d.f.)	0.48						0.51						0.52					
LSD	NS						NS						NS					

E = Early sowing L = Late sowing U = Untreated F = Full treatment D = Deadheart treatment

Table 10: Effect of variety and sowing date on grain specific weight (Kg/hl)

Variety	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
	E	L	E	L	E	L	E	L	E	L	E	L
Apollo	78	76	76	77	81	80	82	81	80	80	81	81
Apostle	77	76	74	74								
Hornet	75	74	73	74	80	78	78	78				
Mercia	78	79	75	77	81	80	81	82	80	80	81	80
Slejpner	76	75	75	75								
Tonic	77	76	73	74	80	79	79	78	79	80	80	79
Beaver					78	76	78	76	75	75	79	78
Pastiche					80	78	79	79				
Hereward									81	80	82	81
Riband									73	72	77	76
SED (30 d.f.)	0.4		NA		0.5		NA		0.6		0.7	
LSD	0.8		NA		0.9		NA		NS		NS	

E = Early sowing L = Late sowing

Table 12: Effect of variety and sowing date on Hagberg falling number.

Variety	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
	E	L	E	L	E	L	E	L	E	L	E	L
Apollo	335	326	324	344	334	358	343	350	346	336	247	353
Apostle	360	343	375	367								
Hornet	196	179	248	230	315	328	289	311				
Mercia	328	332	310	329	257	365	358	341	354	336	343	328
Slejpner	359	362	345	349								
Tonic	352	311	336	379	368	381	333	351	362	340	345	332
Beaver					331	343	276	310	281	270	259	251
Pastiche					408	396	381	380				
Hereward									264	264	339	337
Riband									299	304	256	257

E = Early sowing L = Late sowing

TABLE 14: Grand means of the number of tillers per plant in March or April

Variety	Site						Grand mean
	1	2	3	4	5	6	
Beaver			5.4	5.2	4.9	6.0	5.4
Apostle	5.3	4.5					4.9
Riband					3.9	5.8	4.9
Hornet	5.3	4.7	4.9	4.6			4.9
Slejpner	5.1	4.4					4.8
Apollo	4.6	4.3	3.7	4.4	4.6	6.0	4.6
Hereward					3.7	4.9	4.3
Pastiche			4.3	4.7			4.5
Mercia	4.6	3.9	3.7	4.2	3.7	5.1	4.2
Tonic	4.6	3.7	3.9	4.3	3.5	4.6	4.1
SED (30 d.f.)	0.19	0.19	0.13	0.13	0.11	0.22	NA
LSD	0.39	0.39	0.27	0.27	0.22	0.45	NA

TABLE 16: Grand means of the number of tillers/m^2 in March or April.

Variety	Site 1	2	3	4	5	6	Grand mean
Beaver			1307	1591	931	1302	1283
Apostle	1728	1296					1512
Riband					690	1056	873
Hornet	1712	1438	1264	1454			1467
Slejpner	1652	1320					1486
Apollo	1380	1088	966	1395	869	1230	1155
Hereward					659	1019	839
Pastiche			1032	1476			1254
Mercia	1587	1190	944	1294	710	1025	1125
Tonic	1449	1125	956	1410	711	1021	1112

TABLE 18: Grand means of grain yield (t/ha @ 85% d.m.)

Variety	Site 1	2	3	4	5	6	Grand mean
Beaver			10.6	9.9	6.9	11.0	9.6
Apostle	8.7	6.9					7.8
Riband					7.7*	10.4	9.1
Hornet	10.2	7.2	9.2	8.1			8.7
Slejpner	9.7	7.4					8.6
Apollo	10.2	7.4	9.3	9.7	6.1	9.7	8.7
Hereward					6.3	9.7	8.0
Pastiche			7.6	8.1			7.9
Mercia	9.2	6.9	8.1	8.5	5.5	9.7	8.0
Tonic	9.4	6.1	8.9	8.3	6.7	9.9	8.2
SED (30 d.f.)	0.20	0.11	0.17	0.10	0.21	0.10	NA
LSD	0.41	0.22	0.35	0.20	0.43	0.20	NA

* excluding late sowing - see plant population section of Discussion

invasion by wheat bulb larvae. The grand means of tillers/m^2 calculated as a product of plant population (Table 2) and tillers/plant in April/May (Table 3) are shown in Table 16. The varieties with the lowest density of tillers tended to suffer the highest levels of tiller damage. This observation supports the view that the minor differences in tiller damage are caused by fluctuations of the host tiller density available to the invading wheat bulb fly larvae.

Ear population. The number of ear-bearing tillers/m^2 (Tables 6 & 7) was poorly correlated to initial plant and tiller populations. The grand means of ear population according to variety are given in Table 17. In contrast with the tiller density and plant populations discussed above, Mercia and Tonic produced the highest ear densities.

Grain yield and quality, (Tables 8-13). The soft-endosperm feed wheats produced the highest yields (Table 18). Grain quality in terms of specific weight, thousand grain weight, Hagberg falling number and protein content was generally good and overall within acceptable limits for each variety (*cf.* Anon., 1989, 1990, 1991, 1992). Specific weights were all well above the intervention standard (>72 kg/hl) and Hagberg falling numbers were mostly in the high or very high categories (>220 & >260 respectively). No significant differences were noted in the yield responses of the varieties to insecticidal treatment.

Effect of sowing date. The date of sowing influenced many factors. Plant establishment was, on average, 37 plants/m^2 greater in the early sowings. The number of tillers per plant in April/May and ear densities were also greater in the early sowings by 0.4 tillers/plant and 45 ears/m^2 respectively. The superior crop establishment and structure of the early sowings was reflected in yield. The yield of the early sowings (October) average 9.09 t/ha, 1.37 t/ha (18%) greater than that of the late sowings (November) which averaged 7.72 t/ha. These findings agree in principle with those outlined by Fielder (1988) in his review of interactions between variety and sowing date. The amount of wheat bulb fly tiller damage was not substantially higher in the late sowings; the sowings respectively (Table 19). This difference was probably due to a greater loss of persistence of the fonofos granules in the early sowing. As would be expected, the degree of control obtained from the deadheart spray was far less than that of the full treatment. Deadheart sprays are normally applied as a curative measure in response to the appearance of unacceptable levels of wheat bulb fly larval invasion as symptoms begin to appear in February and March.

The standard of control of tiller damage was evidently better in mineral soil than in organic soil (Table 19). This observation may be due to the pesticide absorption effect displayed by highly organic fen peat soil, which is known to reduce the efficacy of residual soil-active insecticides.

The degree of control of wheat bulb fly tiller damage was reflected in the grain yield responses (Table 19). The full treatment significantly increased yield of the late sowings at mineral soil sites 2, 4 and 6 and organic soil site 6 ($\underline{P} < 0.05$). No significant yield increases occurred in the early sowings. According to the grand means (Table 19) the full treatment resulted in an overall 12% (0.89 t/ha) increase in yield in the late sowings, compared with less than 1% in the early sowings. These findings concur with Part I of this report, indicating the value of early sowing as a means of minimising the impact of wheat bulb fly attack.

In contrast, no significant yield increases occurred in conjuction with the deadheart spray treatment. The grand means (Table 19) show that the deadheart spray gave only a small increase over untreated of 2% (0.14 t/ha) in the late sowings on the organic soil sites. This observation is not unexpected as all of the variety trials were conducted in fields subjected to a heavy attack by the pest, where a single deadheart spray was unlikely to give optimum control. In such conditions, a multiple treatment strategy incorporating preventive measures such as seed or soil-based insecticides is known to be the most effective of control as highlighted in Part I of this report.

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