FIELD TESTS WITH A FLUORESCENT BRIGHTENER TO ENHANCE INFECTIVITY OF FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE) NUCLEAR POLYHEDROSIS VIRUS

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ABSTRACT

The nuclear polyhedrosis virus (NPV) of fall armyworm, *Spodoptera frugiperda* (J. E. Smith), was applied in combination with Fluorescent Brightener 28 (Calcofluor White M2R, Tinopal LPW) to whorl-stage corn. Concentrations of NPV ranged from 5 larval equivalents (1 LE = 6 x 10^9 polyhedral occlusion bodies) to 1235 LE per ha. Concentrations of fluorescent brightener ranged from 0.1 to 5% by weight in water and the water volume ranged from 234 to 926 liters per ha. Two days after treatment, fall armyworm larvae were collected from the treated plants and held on bean diet to observe mortality due to NPV, parasitoids, and ascovirus. The fluorescent brightener interacted significantly with virus concentration and with water volume to increase larval mortality. There was no increase in mortality due to NPV as the percent fluorescent brightener increased beyond 1%. In the higher volumes of water, 0.25% fluorescent brightener resulted in the highest percent mortality due to NPV. *Cotesia marginiventris* was the most abundant parasitoid recovered from fall armyworm in these tests, and as the percent mortality due to NPV increased, the percent mortality due to parasitoids and ascovirus decreased. Thus, the total mortality was not affected as greatly as the percent mortality due to NPV by changes in water volume or fluorescent brightener concentration. The reduction in mortality due to parasitoids did not appear to be a direct effect of the fluorescent brightener on the parasitoids. However, increased infectivity of the NPV and earlier mortality from NPV associated with the fluorescent brightener resulted in more host larvae dying of NPV before the parasitoids could complete development.

Key Words: *Spodoptera frugiperda*, nuclear polyhedrosis virus, fluorescent brightener, biocontrol, corn, *Cotesia marginiventris*

RESUMEN

El virus de la polihedrosis nuclear (VPN) del gusano trozador, *Spodoptera frugiperda* (J. E. Smith), fue aplicado en combinación con Fluorescent Brightener 28 (Calcofluor White M2R, Tinopal LPW) a plantas de maíz en estado vegetativo. Las concentraciones del VPN estuvieron en el rango de los 5 a 1235 equivalentes larvales (EL) por ha (1 EL = 6 x 10^9 cuerpos polihedrales de oclusión). Las concentraciones de Fluorescent Brightener estuvieron en el rango de 0.1 a 5% por peso en agua y el volumen del agua en el rango de 234 a 926 litros por hectárea. Dos días después del tratamiento las larvas del gusano trozador fueron colectadas de las plantas tratadas y mantenidas en dieta de frijoles para observar la mortalidad debida al VPN, parasitoides, y ascovirus. Fluorescent Brightener interactuó significativamente con la concentración del virus y con el volumen del agua para aumentar la mortalidad larval. No hubo aumento de la mortalidad debido al VPN cuando el porcentaje de Fluorescent Brightener aumentó a más del 1%. En los volúmenes más altos de agua, el 0.25% de Fluorescent Brightener produjo el porcentaje de mortalidad más alto. *Cotesia marginiventris* fue el parasitoide más abundantemente recobrado del gusano trozador en estas pruebas y en la medida en que aumentó el porcentaje de mortalidad debido al VPN, el producido por los parasitoides y ascovirus disminuyó. De esta manera, la mortalidad total no fue afectada tanto como el porcentaje de mortalidad debido al VPN por los volúmenes de agua o la concentración de Fluorescent Brightener. La reducción en la mortalidad producida por los parasitoides no pareció deberse al efecto del marcador en los mismos. Sin embargo, el incremento de la infectividad del VPN y la mortalidad temprana debidos al virus asociado con el Fluorescent Brightener provocaron que más larvas murieran por el VPN antes que los parasitoides pudieran completar su desarrollo.

The nuclear polyhedrosis virus (SfNPV) is a naturally occurring pathogen of fall armyworm, *Spodoptera frugiperda* (J. E. Smith), (Gardner & Fuxa 1980, Fuxa 1982). However, field tests with SfNPV have resulted in rather low levels of control of fall armyworm larvae (Hamm & Young 1971, Hamm & Hare 1982). In these earlier tests, the virus was not formulated with adjuvants to protect the virus from sunlight or to otherwise enhance its infectivity. Recently, however, Shapiro (1992) demonstrated that UV protection was possible using a series of optical or fluorescent brighteners (FB). More importantly, five of the optical brighteners, including Tinopal LPW, enhanced the infectivity of an NPV that infects gypsy moth larvae, even when the virus was not exposed to UV irradiation (Shapiro & Robertson 1992). Later, Hamm & Shapiro (1992) demonstrated significant enhancement of the SfNPV by Tinopal LPW in laboratory bioassays. Because of this unique enhancement of viral infectivity for lepidopterous larvae, a patent for the use of fluorescent brighteners in biological control was awarded 23 June 1992 (Shapiro et al. 1992).

The field tests reported here were conducted to determine if adding FB to the SfNPV would increase the level of control of fall armyworm larvae in whorl-stage corn. Because parasitoids (Ashley 1986) and ascovirus (Hamm et al. 1986) contribute to the natural control of fall armyworm, the effects of SfNPV and FB on parasitoids and ascovirus were studied also. Control of fall armyworm on corn is difficult, even with insecticides, because the larvae feed down into the whorl. Therefore, the insecticides are generally applied in the maximum amount of water that can be applied economically with ground equipment (94-468 liters per ha). Consequently, the relationship between water volume, SfNPV, and FB was also evaluated.

Materials and Methods

Materials

The SfNPV was produced in the laboratory in fall armyworm larvae. The polyhedral occlusion bodies (POB) were partially purified by slow and high speed centrifugation and suspended in 0.1 m phosphate buffer (pH 7) containing 100 µg/ml garamycin and stored at 6°C. The virus was quantified by counting POB with a Petroff-Houser bacterial counter. Concentrations were expressed as Larval Equivalents (LE), the approximate number of POB produced per larva, based on 6×10^9 POB per LE. Fluorescent Brightener 28 (Calcofluor white M2R, Tinopal LPW) was obtained from Sigma Chemical Co. No other UV screens, wetting agents, or feeding stimulants were used.

General Procedures

Tests were conducted in whorl-stage corn in Tift Co. GA. Plots were single rows 6 to 7.6 m long separated by 6 m of untreated corn on the ends and five rows of untreated corn (4.6 m) on the sides. There were five replications of each treatment arranged in randomized complete blocks. Corn plants were artificially infested in early season tests conducted in May and June of 1989 and 1991. Newly hatched fall armyworm larvae from the Insect Biology and Population Management Research Laboratory colony in Tifton, GA, were mixed with corncob grits to the desired concentration (Wiseman & Widstrom 1980) and applied to the whorl-stage corn with a pushcart applicator (Sumner et al. 1992). Corn plots were sprayed 3 days after being artificially infested, except for May 1991 when (due to cool weather) treatments were applied 5 days after infestation. Late season tests in August and September of 1993 were naturally-infested.

All viruses were applied using a Ford 4000 hi-clearance tractor equipped with a single row spray boom with a single agricultural spray nozzle and tanks pressurized with compressed air. Spray nozzles were changed, pressure adjusted, and tractor velocity set to accommodate the amounts of material applied per ha for each test. Two days after treatment, plants were cut and brought into the laboratory. Up to 30 larvae per plot were collected from these plants and placed individually in 30-ml plastic cups containing bean diet. Larvae were held for observation for 8 days.

Larvae that died the first day after collection were considered to have died from injury during collection and were subtracted from the number collected. After the first day, mortality was attributed to either parasitoids, SfNPV, or ascovirus. Parasitoids were observed to emerge from the larvae and spin cocoons. Almost all parasitoids recovered were *Cotesia marginiventris* (Hymenoptera: Braconidae). SfNPV was indi-

TABLE 1. MEAN PERCENT MORTALITY AND STANDARD DEVIATION DUE TO NPV, PARASITOIDS, ASCOVIRUS, AND TOTAL MORTALITY OF FALL ARMYWORM LARVAE TREATED ON WHORL-STAGE CORN WITH SFNPV AND FB IN 246 LITERS PER HA OF WATER, 15 MAY 1989.

		NPV		Parasitoids		Ascovirus		Total	
NPV in LE per ha	% FB	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	0	0	0	35.9	8.7	8.7	8.0	46.8	9.1
0	0.1	0	0	35.5	14.1	6.1	4.5	41.6	17.4
0	1	0	0	27.9	10.5	9.5	9.8	38.9	10.5
5	0	6.3	4.7	35.9	7.5	9.6	7.1	51.8	10.7
5	0.1	17.4	8.8	33.2	8.8	2.1	3.2	52.7	9.4
5	1	15.1	9.9	38.8	11.5	5.5	5.1	60.0	9.4
50	0	25.9	6.8	21.4	14.2	2.8	3.0	50.1	10.7
50	0.1	25.8	9.9	26.3	14.1	4.0	5.4	56.8	15.0
50	1	36.6	13.3	17.6	12.3	5.0	1.9	60.0	10.9
500	0	58.9	12.0	15.1	12.0	1.5	3.4	75.5	5.2
500	0.1	48.4	10.0	23.0	7.1	2.1	2.0	74.3	12.2
500	1	72.4	14.7	6.8	4.2	2.0	2.0	81.2	14.2

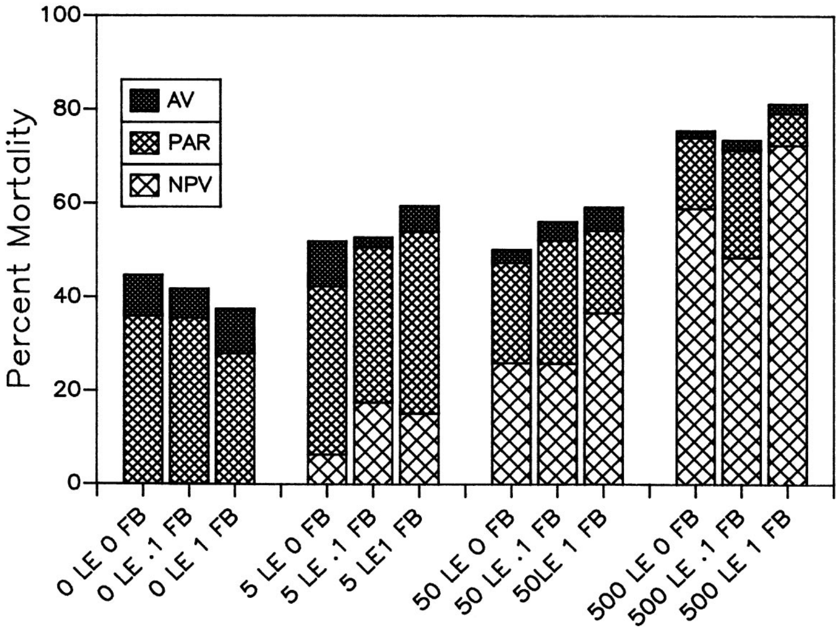

Fig. 1. Mean percent mortality of fall armyworm larvae on whorl-stage corn caused by NPV, parasitoids (PAR), and ascovirus (AV); treated 15 May 1989 with 4 levels of NPV in 3 levels of fluorescent brightener in 246 liters per ha of water.

cated when the larvae melted and/or contained POB typical of NPV. Ascovirus was indicated when the larvae remained small and contained the vesicles typical of ascovirus.

Percent mortality was determined by dividing the number that died from each cause by the number of larvae collected (minus the number that died the first day after collection). Total percent mortality was computed by adding the mortality factors

TABLE 2. MEAN PERCENT MORTALITY AND STANDARD DEVIATION DUE TO NPV, PARASITOIDS, ASCOVIRUS, AND TOTAL MORTALITY OF FALL ARMYWORM LARVAE TREATED ON WHORL-STAGE CORN WITH NPV AND FB IN 486 LITERS PER HA OF WATER, 12 JUNE 1989.

		NPV		Parasitoids		Ascovirus		Total	
NPV in LE per ha	% FB	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	0	0	0	2.4	2.4	0	0	2.4	2.4
50	0	44.6	10.3	0	0	1.0	2.1	45.6	9.1
50	0.1	46.1	19.0	0	0	0	0	46.1	19.0
50	1	68.4	19.8	0	0	0	0	68.4	19.8
50	5	37.9	12.3	0	0	4.0	9.0	41.9	7.3

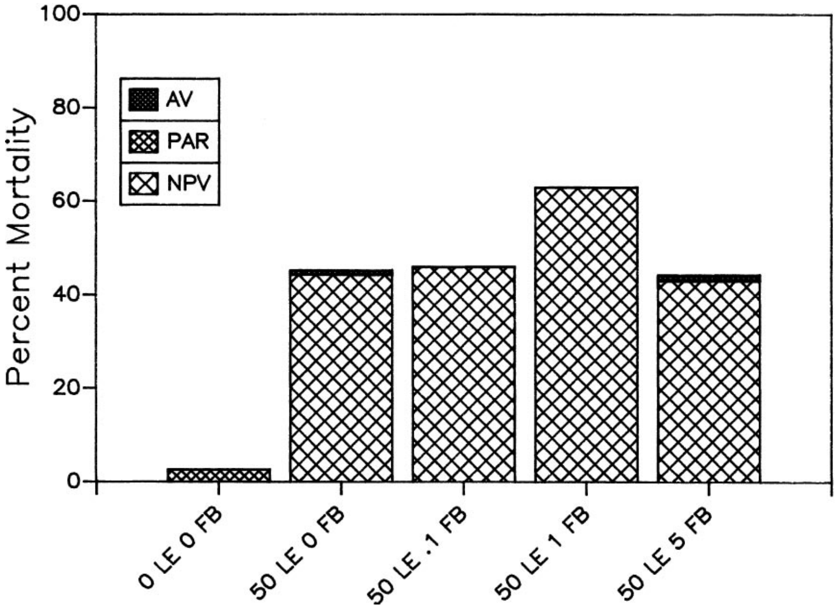

Fig. 2. Mean percent mortality of fall armyworm larvae on whorl-stage corn caused by NPV, parasitoids (PAR), and ascovirus (AV); treated 12 June 1989 with 50 LE per ha of NPV in 0, 0.1, 1, and 5% fluorescent brightener in 486 liters per ha of water plus an untreated control.

together. Means and standard deviations were calculated for each morality variable. A GLM procedure (SAS 1985) was conducted for each data set using both the percent mortality and the arcsin of the square root of the percent. Percentages are shown in the tables, but the interactions are based on the analyses of the transformed percentages. Regression analyses were conducted to determine linear and quadratic effects.

Rates of Virus, Fluorescent Brightener, and Water Applied

The first test, in May 1989, consisted of 12 treatments: 0, 5, 50 and 500 LE per ha of SfNPV, each applied in 0, 0.1%, and 1% FB in 246 liters per ha of water.

In the second test, June 1989, the amount of water was increased to 486 liters per ha and a single level of SfNPV, 50 LE per ha, was applied in 4 levels of FB, 0, 0.1, 1, and 5 percent.

In 1991, two tests were conducted in which there was an untreated control; in all other treatments a constant amount of SfNPV in varying amounts of water and FB. SfNPV at 618 LE per ha was applied in 234 liters per ha water containing 0, 0.25, 0.5, 1, and 2% FB, or in 468 liters per ha water containing 0, 0.25, 0.5, and 1% FB, or in 936 liters per ha water containing 0, 0.25, or 0.5% FB. The amount of FB applied was 585, 1,169, 2,338, and 4,677 g per ha. The whorl-stage corn was infested 17 May, but due to cool, rainy weather it was not treated until 22 May, 5 days after infestation rather than 3 days as in other tests. When the test was repeated, the corn was infested 31 May and treated 3 June.

In 1993, 2 tests were conducted using naturally-infested whorl-stage corn. Treatments were applied 27 August and 27 September with 936 liters per ha water containing 0 virus and 0 FB, 124 LE in 0 FB, 124 LE in 0.25% FB, 1,235 LE in 0 FB, or 1,235 LE in 0.25% FB. Thus all treatments receiving FB received 2,340 g per ha of the adjuvant.

RESULTS AND DISCUSSION

The 1989 treatment means and standard deviations for the first test are shown in Table 1 and the mean percent mortality due to NPV, parasitoids, and ascovirus are presented graphically in Fig. 1. GLM analysis showed an interaction between linear effects of NPV concentration and linear effects of FB concentration on percent mortality due to NPV. Percent mortality due to parasitoids, ascovirus, and percent total mortality showed only linear effects of NPV concentration. The greatest percent mortality due to NPV, 72.4%, occurred in the 500 LE per ha treatment with 1% FB. The greatest mortality due to NPV in a 50 LE per ha treatment was also in 1% FB. There was a general increase in percent mortality attributable to NPV with increasing NPV concentration and with increasing FB concentration. However, there was a general decrease in the percent mortality caused by parasitoids and ascovirus as the percent mortality due to NPV increased.

Treatment means and standard deviations for test 2 in 1989 are shown in Table 2. The mean percent mortality due to NPV, parasitoids, and ascovirus is presented

TABLE 3. MEAN PERCENT MORTALITY AND STANDARD DEVIATION DUE TO NPV, PARASITOIDS, AND TOTAL MORTALITY OF FALL ARMYWORM LARVAE TREATED ON WHORL-STAGE CORN WITH 618 LE PER HA OF NPV IN VARIOUS VOLUMES OF WATER AND CONCENTRATIONS OF FB, 22 MAY 1991.

Treatments								
Water	FB		NPV		Parasitoids		Total	
Liters per ha	%	g per ha	Mean	SD	Mean	SD	Mean	SD
Untreated Control			0.7	1.5	53.4	9.1	54.1	9.8
234	0	0	36.9	11.7	43.0	8.7	79.9	14.7
468	0	0	21.3	6.8	55.4	10.4	76.7	6.8
936	0	0	36.9	5.0	41.7	9.9	78.5	7.2
234	.25	585	34.7	8.7	48.0	8.0	82.7	6.8
468	.25	1170	34.8	11.1	39.2	7.6	74.0	10.0
936	.25	2340	29.2	13.9	58.7	17.6	87.9	9.5
234	.5	1170	31.5	5.7	43.1	16.8	74.6	18.3
468	.5	2340	39.2	8.3	43.3	7.8	82.5	6.2
936	.5	4680	51.3	6.2	33.8	7.1	85.1	1.9
234	1	2340	39.5	12.1	48.4	9.4	87.9	5.1
468	1	4680	42.0	7.3	40.7	9.2	82.7	2.9
234	2	4680	33.8	13.6	52.5	8.6	86.3	6.4

TABLE 4. MEAN PERCENT MORTALITY AND STANDARD DEVIATION DUE TO NPV, PARASITOIDS, AND TOTAL MORTALITY OF FALL ARMYWORM LARVAE TREATED ON WHORL STAGE CORN WITH 618 LE PER HA OF NPV IN VARIOUS VOLUMES OF WATER AND CONCENTRATIONS OF FB, 3 JUNE 1991.

Treatments								
Water	FB		NPV		Parasitoids		Total	
Liters per ha	%	g per ha	Mean	SD	Mean	SD	Mean	SD
Untreated Control			4.1	4.5	19.7	4.4	23.8	6.4
234	0	0	28.5	16.2	20.3	5.3	48.8	12.7
468	0	0	27.0	13.7	14.7	7.6	41.7	14.9
936	0	0	33.7	10.7	15.0	11.6	48.7	10.7
234	.25	585	22.7	13.1	16.8	4.1	39.5	13.4
468	.25	1170	39.3	7.2	8.0	5.5	47.3	9.5
936	.25	2340	61.7	16.7	9.5	4.5	71.3	14.8
234	.5	1170	9.5	7.5	17.4	6.4	26.9	10.1
468	.5	2340	39.9	7.5	10.1	5.7	50.0	3.2
936	.5	4680	46.6	14.0	12.3	8.1	58.9	8.8
234	1	2340	40.4	10.5	10.1	7.0	50.5	14.5
468	1	4680	33.5	10.6	16.2	10.1	49.7	1.8
234	2	4680	27.1	9.4	17.0	5.6	44.0	11.5

graphically in Fig. 2. Because all treatments (except the untreated control) contained the same concentration of virus, the untreated control was omitted from the GLM analysis so that virus concentration would not be a factor. Thus, the effect of FB concentration at the given level of virus could be clearly demonstrated. GLM analysis showed a quadratic effect of FB on percent mortality due to NPV and percent total mortality, but no significant effect on percent mortality due to ascovirus. There was no mortality due to parasitoids in any of the virus treatments and much less mortality due to parasitoids in the control for this test than in the first test. An increase in the FB from 1% (4,860 g per ha) to 5% (24,300 g per ha) resulted in a decrease in percent mortality due to NPV.

The 1991 tests were designed to test both the effects of water volume and concentration, or amount, of FB on mortality due to NPV. Thus, the virus level remained constant except for the untreated control which was omitted from the analysis so that virus concentration would not be a factor. The treatment means and standard deviations are shown in Tables 3 and 4. No mortality due to ascovirus was detected in the 1991 tests. Mortality due to parasitoids was much higher (53.4% in the untreated control) in the 22 May test, which was treated 5 days after infestation, than in the 3 June test (19.7% in the untreated control) which was treated 3 days after infestation.

In the 22 May test, with the higher rate of parasitoids, the interactions between water and FB were similar when FB was expressed as either percent or as g per ha (Fig. 3). There were interactions between quadratic effects of water and quadratic effects of FB for both percent mortality due to NPV and percent mortality due to parasitoids; again, as the mean percent mortality due to NPV increased the

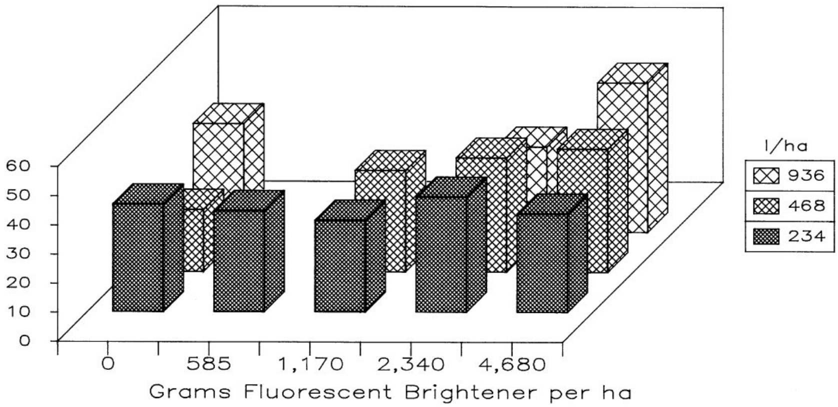

Figure 3. Mean percent mortality of fall armyworm larvae on whorl-stage corn caused by NPV following treatment on 22 May 1991 with 618 LE per ha of NPV in 5 levels of fluorescent brightener in 3 volumes of water.

mean percent mortality due to parasitoids decreased. However, percent total mortality showed only a linear effect of FB (Fig. 4).

In the 3 June test, lower rates of parasitism interfered less with the effects of water and FB on mortality due to NPV; thus, the interactions between water and FB were different when FB was expressed as percent than when it was expressed as g per ha. When FB was expressed as percent (Fig, 5), there was an interaction between the linear effects of water and the quadratic effects of FB on both percent mortality due to NPV and total mortality. However, there was no significant effect of water or FB on percent mortality caused by parasitoids. When FB was expressed in g per ha, there was a quadratic effect of FB on both percent mortality attributable to NPV (Fig. 6) and percent mortality due to parasitoids. Again, a decrease in mortality due to parasitoids was associated with the increase in mortality due to NPV. There was an inter-

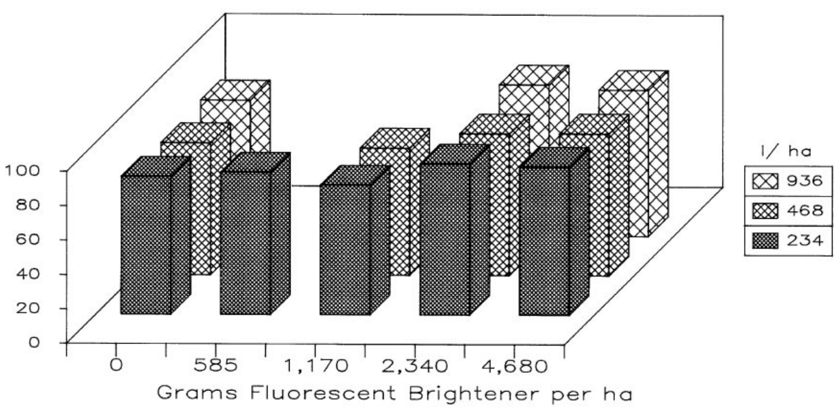

Fig. 4. Mean percent total mortality (NPV and parasitoids) of fall armyworm larvae on whorl-stage corn, treated 22 May 1991 with 618 LE per ha of NPV in 5 levels of fluorescent brightener in 3 volumes of water.

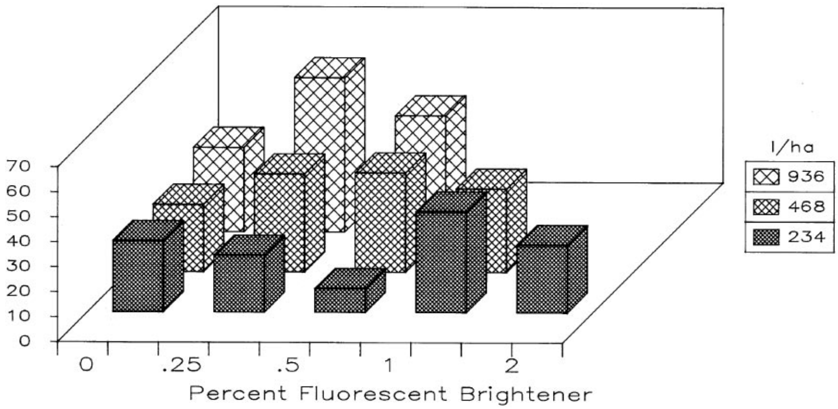

Fig. 5. Mean percent mortality of fall armyworm larvae on whorl-stage corn caused by NPV following treatment on 3 June 1991with 618 LE per ha of NPV in 5 levels of fluorescent brightener expressed as percent of 3 volumes of water.

action between the linear effects of water and the quadratic effects of FB on total mortality (Fig. 7).

In the 1993 tests, a high volume of water, 936 liters per ha, was used to compare effects of 0.25% FB vs 0 FB at 3 levels of virus. The treatment means and standard deviations are shown in Tables 5 and 6. The percent mortality due to NPV, parasitoids, and ascovirus are shown graphically in Figs. 8 and 9. The 27 August test showed an interaction between the quadratic effects of virus and the linear effects of FB on percent mortality due to NPV, but only the quadratic effect of virus was noted for total mortality. There were no significant effects on percent mortality due to parasitoids and no mortality due to ascovirus. The 27 September tests showed quadratic effects of virus on percent mortality due to NPV, ascovirus, and total mortality. There was a

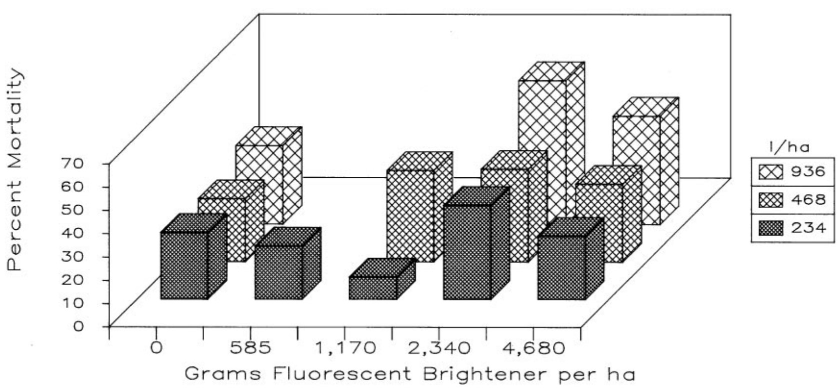

Fig. 6. Mean percent mortality of fall armyworm larvae on whorl-stage corn caused by NPV following treatment on 3 June 1991 with 618 LE per ha of NPV in 5 levels of fluorescent brightener in 3 volumes of water.

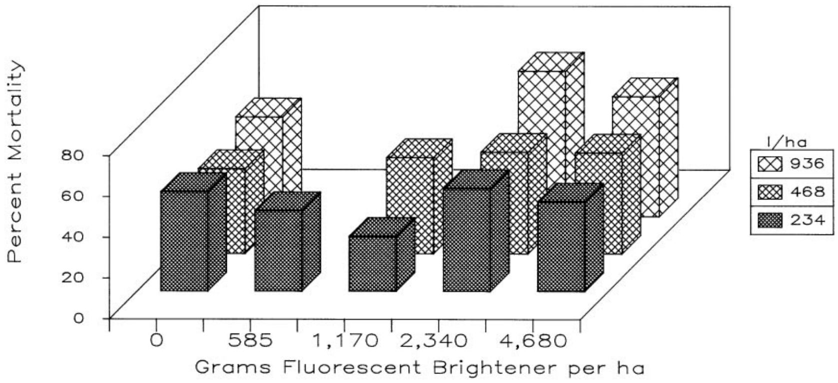

Fig. 7. Mean percent total mortality (NPV and parasitoids) of fall armyworm larvae on whorl-stage corn treated 3 June 1991 with 618 LE per ha of NPV in 5 levels of fluorescent brightener in 3 volumes of water.

significant interaction between the linear effects of virus and linear effects of FB on percent mortality due to parasitoids.

SUMMARY

Many factors are important to the successful control of fall armyworm with the SfNPV. First the virus must be placed where the larvae are feeding and in a concentration sufficient for the larvae to ingest a lethal dose. In these tests, mortality due to SfNPV increased with increasing virus concentration up to the highest rate tested, 1235 LE per ha. It is apparent from these tests that increasing the volume of water, up to 936 liters per ha, helped to deliver the virus deep into the whorl of the corn plant

TABLE 5. MEAN PERCENT MORTALITY AND STANDARD DEVIATION DUE TO NPV, PARASITOIDS, AND TOTAL MORTALITY OF FALL ARMYWORM LARVAE TREATED ON WHORL-STAGE CORN WITH NPV AND FB IN 936 LITERS PER HA OF WATER, 27 AUGUST 1993.

Treatments		NPV		Parasitoids		Total	
NPV in LE per ha	% FB	Mean	SD	Mean	SD	Mean	SD
0	0	0.8	1.9	7.3	6.2	8.1	6.7
0	.25	0	0	10.3	4.9	10.3	4.9
124	0	11.8	7.9	8.5	4.7	20.5	11.4
124	.25	28.7	13.3	8.0	7.0	36.7	8.0
1235	0	40.7	12.1	8.7	7.2	49.4	11.6
1235	.25	52.6	9.8	4.9	5.1	57.5	9.2

TABLE 6. MEAN PERCENT MORTALITY AND STANDARD DEVIATION DUE TO NPV, PARASITOIDS, ASCOVIRUS, AND TOTAL MORTALITY OF FALL ARMYWORM LARVAE TREATED ON WHORL-STAGE CORN WITH NPV AND FB IN 936 LITERS PER HA OF WATER, 27 SEPTEMBER 1993.

		NPV		Parasitoids		Ascovirus		Total	
NPV in LE per ha	% FB	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	0	.7	1.5	7.9	6.7	8.4	5.5	20.0	6.1
0	.25	0	0	16.5	4.3	4.2	6.1	22.9	9.1
124	0	36.3	12.0	12.1	7.0	0.7	1.5	49.3	8.5
124	.25	47.3	4.8	9.1	6.5	0.7	1.6	58.1	10.8
1235	0	69.3	8.4	10.8	4.4	1.4	3.2	82.9	6.0
1235	.25	84.6	4.9	0.7	1.5	0.7	1.5	86.5	5.6

where the larvae were feeding. The FB interacted significantly with virus concentration and water volume to increase mortality caused by NPV. However, there was no increase in mortality due to NPV as the percent FB increased beyond 1%. In higher volumes of water (468 and 936 liters per ha) 0.5 and 0.25% FB resulted in the highest percent mortality due to NPV. Of the FB rates, expressed as weight, 2,340 g per ha in

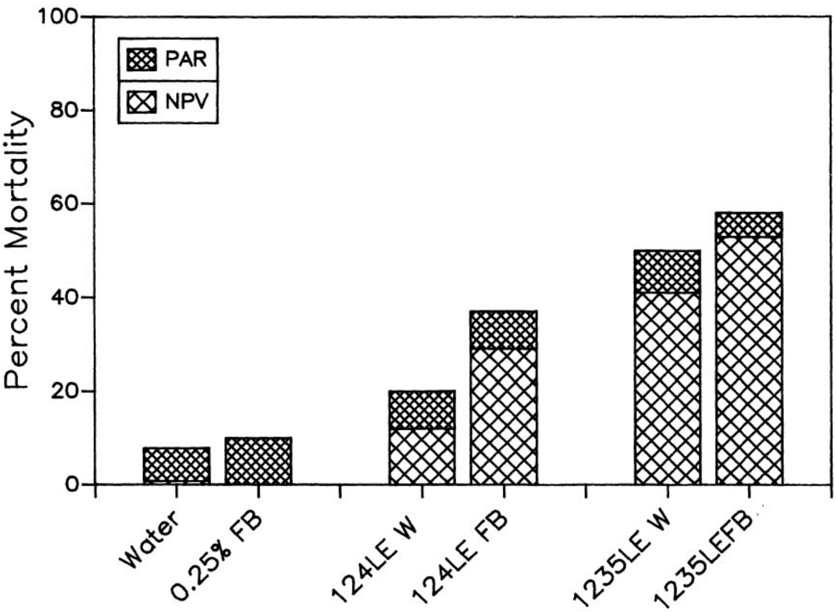

Fig. 8. Mean percent mortality of fall armyworm larvae on whorl-stage corn due to NPV and parasitoids (PAR), following treatment on 27 August 1993 with 3 levels of NPV in 2 levels of fluorescent brightener in 936 liters per ha of water.

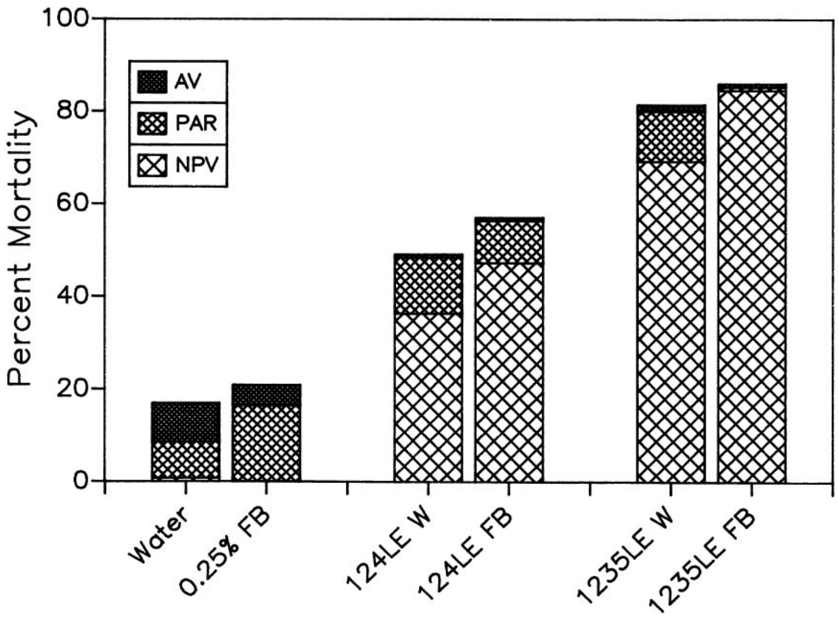

Fig. 9. Mean percent mortality of fall armyworm larvae on whorl-stage corn due to NPV, parasitoids (PAR), and ascovirus (AV), treated 27 September 1993 with 3 levels of NPV in 2 levels of fluorescent brightener in 936 liters per ha of water.

936 liters per ha resulted in the highest percent mortality due to NPV. In general, as the percent mortality due to NPV increased the percent mortality due to parasitoids and ascovirus decreased. This did not appear to be a direct effect of FB on the parasitoids. The increased infectivity of the NPV and earlier mortality of larvae due to NPV associated with the FB resulted in death of host larvae attributable to NPV before the parasitoids could complete development. Thus, the total mortality was not affected as greatly as the percent mortality due to NPV by changes in water volume or FB concentration.

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REFERENCES CITED

ASHLEY, T. R. 1986. Geographical distributions and parasitization levels for parasitoids of the fall armyworm, *Spodoptera frugiperda*. Florida Entomol. 69: 516-524.

FUXA, J. R. 1982. Prevalence of viral infections in populations of fall armyworm, *Spodoptera frugiperda*, in southeastern Louisiana. Environ. Entomol. 11: 239-242.

GARDNER, W. A., AND J. R. FUXA. 1980. Pathogens for the suppression of the fall armyworm. Florida Entomol. 63: 439-447.

HAMM, J. J., AND W. W. HARE. 1982. Application of entomopathogens in irrigation water for control of fall armyworms and corn earworms (Lepidoptera: Noctuidae) on corn. J. Econ. Entomol. 75: 1074-1079.

HAMM, J. J., S. D. PAIR, AND O. G. MARTI, JR. 1986. Incidence and host range of a new ascovirus form fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Florida Entomol. 69: 524-531.

HAMM, J. J., AND M. SHAPIRO. 1992. Infectivity of fall armyworm (Lepidoptera: Noctuidae) nuclear polyhedrosis virus enhanced by a fluorescent brightener. J. Econ. Entomol. 85: 2149-2152.

HAMM, J. J., AND J. R. YOUNG. 1971. Value of virus presilk treatment for corn earworm and fall armyworm control in sweet corn. J. Econ. Entomol. 64: 144-146.

SAS INSTITUTE. 1985. SAS/STAT User's Guide. SAS Institute, Cary, NC.

SHAPIRO, M. 1992. Use of optical brighteners as radiation protectants for gypsy moth (Lepidoptera: Lymantriidae) nuclear polyhedrosis virus. J. Econ. Entomol. 85: 1682-1686.

SHAPIRO, M., E. M. DOUGHERTY, AND J. J. HAMM. 1992. Compositions and methods for biocontrol using fluorescent brighteners. U.S. Patent no. 5,124,149.

SHAPIRO, M., AND J. L. ROBERTSON. 1992. Enhancement of gypsy moth (Lepidoptera: Lymantriidae) baculovirus activity by optical brighteners. J. Econ. Entomol. 85: 1120-1124.

SUMNER, H. R., H. R. GROSS, AND B. R. WISEMAN. 1992. Pushcart mounted rotary applicator for infesting plants with the larvae of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). J. Econ. Entomol. 85: 276-280.

WISEMAN, B. R., AND N. W. WIDSTROM. 1980. Comparison of methods of infesting whorl-stage corn with fall armyworm. J. Econ. Entomol. 73: 440-442.

YOUNG, J. R. 1980. Suppression of fall armyworm populations by incorporation of insecticides into irrigation water. Florida Entomol. 63: 447-450.