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Optimization of spray schedule for shoot weevil management in Bt cotton

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Abstract
The field experiment was carried out on optimization of spray schedule for shoot weevil management in Bt cotton at B. Gudihal village (Kalghatgi Taluk) during 2013-14 and 2014-15 *kharif* seasons under rainfed conditions. Results revealed the superiority of Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS by registering A significantly lowest adult population of 7.19 per plot and grub infestation of 17.78 per cent. Similarly, treatment, Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS recorded the lowest number of grubs (0.53/plant), shortest tunnel length (4.83 cm) and the lowest number of broken branches (4.5/10 infested plants) was found to be superior to the rest of the treatment. Treatment Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS recorded significantly higher seed cotton yield (21.45 q/ha), net returns (Rs. 49,559.54/ha) and B:C ratio (2.34) and found to be a promising treatment.

Keywords: Optimization, spray schedule, shoot weevil, Bt cotton

1. Introduction
Cotton (*Gossypium hirsutum* L.) is an important cash crop in India and plays a significant role in the national economy. Cotton is being cultivated in 113 countries of the world and India is the second largest cotton growing country with an area of 115.53 lakh hectares and production of 375 lakh bales of cotton lint with an average productivity of 552 kg/ha. Whereas, in Karnataka, the area under cotton cultivation is 5.78 lakh ha with production of 18.00 lakh bales with an average productivity of 529.00 kg/ha during 2013-14 [1]. The low yield level prevailing in the country could be attributed to genetic, agronomic, entomological, pathological and physiological factors besides climatic factors. Among these, the ravages caused by insect pests are the single largest factor jeopardising the cotton production. Among the insect pests, shoot weevil, *Alcidodes affaber* Aurivillius is causing damage to an extent of 60 to 80 per cent particularly in moderate to high rainfall ecosystem of northern Karnataka after the introduction of Bt cotton. Chemical control is still adoptable as one of the technique for combating this pest. With this background, the present investigation was under taken to study the optimization of spray schedule for shoot weevil management in Bt cotton.

2. Materials and Method
The field experiment was conducted at B. Gudihal village (Kalghatgi Taluk) during 2013-14 and 2014-15 *kharif* seasons under rainfed conditions. The susceptible MRC-7351 hybrid was raised in plots measuring 6.0 x 5.4 sq m with the spacing of 90 x 60 cm between rows and plant. Each experimental plot accommodated 60 plants. All standard agronomic practices recommended for Bt cotton were followed to raise a good crop. The experiment was laid out in randomized block design with eleven treatments and replicated three times. The crop was also sprayed with acetamiprid 20 SP (0.20 g/L) and fipronil 5 SC (1 mL/L) thrice at 60, 90 and 120 days after sowing to manage sucking pest infestation. Observations were recorded on the number of adult weevils per plot and grub infestation at 15 (pre count), 25, 35, 45, 55 and 65 days after the sowing in each treatment. At 90 days after sowing, destructive sampling was carried out in ten randomly selected infested plants to record number of grubs, tunnel length and number of broken branches. Besides, seed cotton yield was harvested from each plot and worked out cost economics for each treatment.

3. Results and Discussion
3.1 Adult Population and grub infestation
The field experiment on optimization of spray schedule was conducted during 2013-14 and

2014-15 kharif. During 2013-14, data revealed that, mean adult population recorded from 15 to 65 days indicated the superiority of Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS by which recording significantly lowest population of 7.61/plot followed by 10.11 and 11.44/plot in Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS and Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS, respectively (Table 1.). However, during 2014, adult mean population of shoot weevil indicated the superiority of Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS by registering significantly lowest population of 6.78/plot and was on par with Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS (7.89/plot) followed by Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS (8.28/plot), Profenophos 50 EC @ 2 mL/L at 15 DAS + 45 DAS (9.00/plot) and Profenophos 50 EC @ 2 mL/L at 15 DAS + 60 DAS (9.33/plot). Similarly the pooled data of consecutive years on mean adult population indicates the superiority of Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS by recording lowest population of 7.19 per plot followed by 9.00 and 9.86 per plot in Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS and Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS, respectively which were on par with each other.

Similar trend was noticed with respect to the grub infestation. During 2013-14, Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS was found to be quite effective by recording significantly lowest grub infestation of 20.56 per cent followed by 21.48, 22.59 and 23.15 per cent in Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS, Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS and Profenophos 50 EC @ 2 mL/L at 30 DAS, respectively. However, during 2013-14, data reveals the superiority of Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS which recorded significantly lowest grub infestation of 15.00 per cent followed by 17.13 and 17.87 per cent in Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS and Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS, respectively. Pooled data of consecutive years indicates that, superiority of Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS over other treatments by recording lowest grub infestation of 17.78 per cent followed by 19.31 and 20.23 per cent in Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS and Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS, respectively (Table 1.).

3.2 Number of grubs, broken branches and tunnel length

Further observations were made on number of grubs per plant, tunnel length and number of broken branches at 90 DAS to see the efficacy of the different treatments. The treatment, Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS recorded least number of grubs per plant (0.67/plant) and was statistically on par with Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS (0.90/plant) and Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS (1.17/plant) during 2013-14. Similar trend was noticed even during 2014-15 by recording least number of grubs per plant (0.40/plant) by Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS which was statistically on par with Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS (0.60/plant). Whereas, pooled data of two consecutive years indicated that, Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS was found to be superior by recording the least number of grubs per plant (0.53/plant) and was on par with Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS (0.75/plant) (Table 2.).

Stem tunnel length caused due to shoot weevil infestation was taken as criteria to assess the efficacy of the treatments. During 2013-14, among the treatments, the lowest tunnel length of 5.90 cm was recorded in Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS treatment followed by Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS (8.07 cm) and Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS (9.67 cm). Significantly highest tunnel length of 19.67 cm and 24.00 cm was recorded in Profenophos 50 EC @ 2 mL/L at 60 DAS and untreated control, respectively. However, the significantly lowest tunnel length of 3.75 cm was measured in Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS followed by Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS (4.60 cm) and Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS (5.33 cm) and were statistically on par with each other. However, pooled data of consecutive years indicates the superiority of Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS by recording least tunnel length of 4.83 cm. On the other hand, significantly longest tunnel length of 19.86 cm was recorded in untreated controls (Table 2.).

Similar observation on the number of broken branches due to weevil infestation during 2013-14 revealed the superiority of Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS over the rest of the treatment by recording least number of broken branches (6.00/10 plants) and was statistically on par with Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS (9.00/10 plants). Similar trend was noticed even during 2014-15 by recording the lowest number of broken branches per plant (3.00/10 plants) in Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS and was on par with Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS (5.00/10 plants). Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS (7.00/10 plants) was found to be next best treatment as compared to rest of the treatments (Table 2.). However pooled data of consecutive years on the number of broken branches per 10 infested plants revealed that, Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS recorded a significantly least number of broken branches (4.50/10 plants) and was statistically on par with Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS (7.00/10 plants).

3.3 Cost Economics

Treatment Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS was continued to be a superior over the rest of the treatment by recording significantly higher seed cotton yield of 21.45 quintal per hectare followed by Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS (19.27 q/ha) and Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS (17.81 q/ha). Economic analysis revealed that, Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS accounted highest net returns of Rs. 49,559.54 per hectare and benefit cost ratio of 2.34 followed by Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS (Rs. 40,688.58/ha and 2.10), Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS (Rs. 34,690.59/ha and 1.93), Profenophos 50 EC @ 2 mL/L at 30 DAS (Rs. 31,104.70/ha and 1.86) and Profenophos 50 EC @ 2 mL/L at 15 DAS + 45 DAS (Rs. 30,355.91/ha and 1.82). However, a lowest net return of Rs. 1,124.32 per hectare with a benefit cost ratio of 1.03 was accounted in untreated control (Table 3.).

Among the different spray schedules imposed, two sprays with Profenophos 50EC @ 2 mL/L at 30 DAS and 45 DAS was found to be most effective spray schedule as compared to rest of the schedules by recording lowest shoot weevil infestation followed by two sprays with Profenophos 50EC @ 2 mL/L at 30 DAS and 60 DAS (Table 3.). The information on similar studies on the shoot weevil in cotton is lacking to compare the present findings. However, it could be comparable with [2] who reported two sprays at 30 and 50 DAS of each with Thiodicarb 70 WP @ 1 g/L + DDVP 76 EC @ 1 mL/L, Profenophos 50EC @ 2 mL/L + DDVP 76 EC @ 1 mL/L and Thiodicarb 70 WP @ 1 g/L alone were found to be effective against cotton shoot weevil, *A. affaber*. Significantly, higher net returns was registered with Profenophos 50EC @ 2 mL/L at 30 DAS and 45 DAS and Profenophos 50EC @ 2 mL/L at 30 DAS and 60 DAS owing to their efficacy in reducing the shoot weevil menace that contributed for significantly higher seed cotton yield which ultimately resulted in more net profit per unit area as compared to rest of the spray schedules.

Table 1: Effect of different spray schedules on the adult population and grub infestation of shoot weevil, *Alcidodes affaber* A. in Bt cotton

Treatment details	Mean adult population			Mean grub infestation (%)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
T_1-Profenophos 50 EC @ 2 mL/L at 15 DAS	14.5 (3.87)^{ef}	11.5 (3.46)^{c}	13.00 (3.67)^{ef}	24.54 (29.68)^{d}	20.56 (26.95)^{e}	22.55 (28.34)^{e}
T_2-Profenophos 50 EC @ 2 mL/L at 30 DAS	13.22 (3.7)^{de}	11.67 (3.49)^{cd}	12.44 (3.60)^{e}	23.15 (28.75)^{c}	21.11 (27.34)^{f}	22.13 (28.05)^{d}
T_3-Profenophos 50 EC @ 2 mL/L at 45 DAS	14.78 (3.91)^{f}	11.67 (3.49)^{cd}	13.22 (3.70)^{ef}	25.83 (30.54)^{e}	22.50 (28.31)^{g}	24.17 (29.43)^{f}
T_4-Profenophos 50 EC @ 2 mL/L at 60 DAS	15.17 (3.96)^{f}	13.39 (3.73)^{de}	14.28 (3.84)^{f}	26.30 (30.84)^{e}	22.78 (28.50)^{g}	24.54 (29.68)^{g}
T_5-Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS	11.44 (3.46)^{c}	8.28 (2.96)^{b}	9.86 (3.22)^{bc}	22.59 (28.37)^{c}	17.87 (25.00)^{c}	20.23 (26.72)^{c}
T_6-Profenophos 50 EC@ 2 mL/L at 15 DAS + 45 DAS	13.00 (3.67)^{d}	9.00 (3.07)^{b}	11.00 (3.39)^{cd}	24.35 (29.56)^{d}	19.17 (25.95)^{d}	21.76 (27.79)^{d}
T_7-Profenophos 50 EC @ 2 mL/L at 15 DAS + 60 DAS	14.61 (3.89)^{f}	9.33 (3.14)^{b}	11.97 (3.53)^{de}	24.72 (29.8)^{d}	19.44 (26.15)^{d}	22.08 (28.02)^{d}
T_8-Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS	7.61 (2.85)^{a}	6.78 (2.70)^{a}	7.19 (2.77)^{a}	20.56 (26.95)^{a}	15.00 (22.78)^{a}	17.78 (24.93)^{a}
T_9-Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS	10.11 (3.25)^{b}	7.89 (2.90)^{ab}	9.00 (3.08)^{b}	21.48 (27.6)^{b}	17.13 (24.44)^{b}	19.31 (26.05)^{b}
T_{10}-Profenophos 50 EC @ 2 mL/L at 45 DAS + 60 DAS	14.89 (3.92)^{f}	11.28 (3.43)^{c}	13.08 (3.69)^{ef}	24.72 (29.8)^{d}	19.44 (26.15)^{d}	22.08 (28.02)^{d}
T_{11}- Untreated control	17.50 (4.24)^{g}	14.33 (3.85)^{e}	15.92 (4.05)^{g}	28.80 (32.44)^{f}	25.09 (30.05)^{h}	26.94 (31.26)^{h}
S. Em±	0.05	0.07	0.04	0.15	0.07	0.09
CD (P=0.05)	0.15	0.21	0.12	0.46	0.21	0.25

Figures in parentheses are arcsin transformation values, DAS- Days after sowing, POC- Per cent reduction over control
Means followed by same alphabets in the vertical column do not differ significantly by DMRT (p=0.05)

Table 2: Effect of different spray schedules on grub load, tunnel length and broken branches (At 90 DAS)

Treatment details	No. of grubs per plant (Mean from 10 infested plants)			Average tunnel length from 10 infested plants (cm)			No. of broken branches per 10 infested plants		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
T_1-Profenophos 50 EC @ 2 mL/L at 15 DAS	1.87 (1.54)^{cde}	1.20 (1.30)^{cd}	1.53 (1.43)^{d}	14.90 (3.92)^{e}	9.00 (3.07)^{e}	11.95 (3.53)^{f}	20.00 (4.56)^{ef}	18.00 (4.30)^{ef}	19.00 (4.43)^{ef}
T_2-Profenophos 50 EC @ 2 mL/L at 30 DAS	1.57 (1.44)^{cde}	1.07 (1.25)^{cd}	1.32 (1.35)^{cd}	13.67 (3.76)^{de}	8.80 (3.05)^{e}	11.23 (3.43)^{ef}	16.00 (4.14)^{cde}	15.00 (3.94)^{de}	15.50 (4.04)^{de}
T_3-Profenophos 50 EC @ 2 mL/L at 45 DAS	2.07 (1.60)^{def}	1.43 (1.39)^{d}	1.75 (1.50)^{de}	17.33 (4.22)^{f}	10.20 (3.27)^{f}	13.77 (3.78)^{g}	23.00 (4.88)^{fg}	20.00 (4.56)^{f}	21.50 (4.74)^{fg}
T_4-Profenophos 50 EC @ 2 mL/L at 60 DAS	2.40 (1.70)^{ef}	2.07 (1.60)^{e}	2.23 (1.65)^{e}	19.67 (4.49)^{g}	12.01 (3.54)^{g}	15.84 (4.04)^{h}	27.00 (5.27)^{gh}	23.00 (4.88)^{fg}	25.00 (5.10)^{gh}
T_5-Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS	1.17 (1.29)^{abc}	0.87 (1.17)^{bc}	1.02 (1.23)^{bc}	9.67 (3.18)^{c}	5.33 (2.41)^{bc}	7.50 (2.83)^{c}	11.00 (3.39)^{bc}	7.00 (2.80)^{bc}	9.00 (3.13)^{bc}
T_6-Profenophos 50 EC@ 2 mL/L at 15 DAS + 45 DAS	1.37 (1.37)^{bcd}	1.10 (1.26)^{cd}	1.23 (1.32)^{cd}	11.93 (3.53)^{d}	6.00 (2.55)^{c}	8.97 (3.08)^{d}	13.00 (3.76)^{bcd}	9.00 (3.08)^{c}	11.00 (3.39)^{cd}
T_7-Profenophos 50 EC @ 2 mL/L at 15 DAS + 60 DAS	1.57 (1.44)^{cde}	1.43 (1.39)^{d}	1.50 (1.41)^{cd}	12.93 (3.67)^{de}	7.60 (2.85)^{d}	10.27 (3.28)^{e}	16.00 (4.14)^{cde}	11.00 (3.39)^{cd}	13.50 (3.76)^{cd}
T_8-Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS	0.67 (1.08)^{a}	0.40 (0.95)^{a}	0.53 (1.02)^{a}	5.90 (2.53)^{a}	3.75 (2.06)^{a}	4.83 (2.31)^{a}	6.00 (2.60)^{a}	3.00 (1.87)^{a}	4.50 (2.27)^{a}
T_9-Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS	0.90 (1.14)^{ab}	0.60 (1.05)^{ab}	0.75 (1.11)^{ab}	8.07 (2.93)^{b}	4.60 (2.26)^{b}	6.33 (2.61)^{b}	9.00 (3.13)^{ab}	5.00 (2.35)^{ab}	7.00 (2.77)^{ab}
T_{10}-Profenophos 50 EC @ 2 mL/L at 45 DAS + 60 DAS	1.67 (1.47)^{cde}	1.10 (1.26)^{cd}	1.38 (1.37)^{cd}	13.80 (3.79)^{de}	7.70 (2.86)^{d}	10.77 (3.36)^{ef}	17.00 (4.26)^{de}	15.00 (3.94)^{de}	16.00 (4.14)^{de}
T_{11}- Untreated control	2.90 (1.84)^{f}	2.87 (1.83)^{f}	2.88 (1.84)^{f}	24.00 (4.95)^{h}	15.72 (4.03)^{h}	19.86 (4.51)^{i}	33.00 (5.84)^{h}	27.00 (5.27)^{g}	30.00 (5.57)^{h}
S. Em±	0.07	0.04	0.04	0.08	0.06	0.04	0.06	0.04	0.04
CD (P=0.05)	0.21	0.12	0.13	0.23	0.17	0.13	0.18	0.12	0.12

Figures in parentheses are $\sqrt{x+0.5}$ transformation values, DAS- Days after sowing
Means followed by same alphabets in the vertical column do not differ significantly by DMRT (p=0.05)

Table 3: Effect of different spray schedules on seed cotton yield and net returns of Bt cotton (Pooled)

Treatment details	Cost of cultivation (Rs/ha)	Cost of plant protection (Rs/ha)	Total cost of production (Rs/ha)	Yield (q/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C
T1-Profenophos 50 EC @ 2 mL/L at 15 DAS	35250	900	36150	14.06	56619.62	20469.62	1.57
T2-Profenophos 50 EC @ 2 mL/L at 30 DAS	35250	900	36150	16.69	67254.7	31104.7	1.86
T3-Profenophos 50 EC @ 2 mL/L at 45 DAS	35250	900	36150	13.83	55729.17	19579.17	1.54
T4-Profenophos 50 EC @ 2 mL/L at 60 DAS	35250	900	36150	12.43	50100.81	13950.81	1.39
T5-Profenophos 50 EC @ 2 mL/L at 15 DAS + 30 DAS	35250	1800	37050	17.81	71740.59	34690.59	1.93
T6-Profenophos 50 EC@ 2 mL/L at 15 DAS + 45 DAS	35250	1800	37050	16.75	67405.91	30355.91	1.82
T7-Profenophos 50 EC @ 2 mL/L at 15 DAS + 60 DAS	35250	1800	37050	15.63	62970.43	25920.43	1.70
T8-Profenophos 50 EC @ 2 mL/L at 30 DAS + 45 DAS	35250	1800	37050	21.45	86609.54	49559.54	2.34
T9-Profenophos 50 EC @ 2 mL/L at 30 DAS + 60 DAS	35250	1800	37050	19.27	77738.58	40688.58	2.10
T10-Profenophos 50 EC @ 2 mL/L at 45 DAS + 60 DAS	35250	1800	37050	15.96	64213.71	27163.71	1.73
T11- Untreated control	35250	0	35250	9.02	36374.33	1124.328	1.03

Average market price of seed cotton: Rs. 4050/q
Chemical rate: Profenophos 50 EC- Rs. 900/l

4. References

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