

Identification of resistant sources and management of Bean Common Mosaic Virus (BCMV) infecting cowpea

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Received: May 2025; Revised Accepted: August 2025

ABSTRACT

The present investigation was undertaken to identify the resistance source and to find out the effectiveness of different pesticides for the management of the Bean Common Mosaic Virus (BCMV) infecting cowpea through aphid vector management. Screening was undertaken to test the resistance of 100 minicore collection of cowpea against BCMV under field conditions at College of Agriculture, Vijayapur during Kharif 2022-23. A local check (DC 15) was planted after every ten lines and along the four sides of the field to serve as a source for the disease through infector row technique. The per cent disease incidence was recorded at 15 days interval starting from 15 days after sowing up to maturity. The results reflected that among the 100 minicore accessions screened against BCMV, 15 germplasm lines showed immune reaction with no infection i.e., EC723782, EC724420, EC723677, EC724774, EC723836, EC724035, EC723741, EC724453, EC72808, EC723693, EC724051, EC723800, EC724500, EC724516 and IC91556. To know the effectiveness of different pesticides against aphids transmitting Bean Common Mosaic Virus, the experiment consisting of eight treatments with three replications was initiated. Different treatments were imposed at 15 days after sowing and subsequent sprays at 15 days interval (three times). Then, BCMV disease incidence was worked out at 30 days, 45 days, 60 days, 75 days and 90 days after sowing. Amongst eight treatments, imidacloprid 30.5 SC @ 0.3 ml/l had the highest reduction of aphid population over control and also had the lowest disease incidence and the maximum yield of 11.18 q/ha with the highest B: C ratio of 2.83. Flonicamid 50 WG @ 0.5 g/l and thiamethoxam 25% WG @ 0.2g/ l also reduced the disease incidence over control by more than 58 per cent. The aphid population and incidence of disease decreased after each spray.

Keywords: Aphids, BCMV, Cowpea, Management, Resistance

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Wilczek] is an important pulse crop, which belongs to family *Fabaceae*. It is also known as “black eyed bean” or Southern pea in English, while chola or choli, chavli, lobia in various vernacular languages in India. It is used as a vegetable, grain legume, fodder and as a green manure crop. The seeds of cowpea contain 23.40 per cent protein, 18.00 per cent fat, 60.30 per cent carbohydrate and are a rich source of lysine and tryptophan. Like other le-

gumes, cowpea has important beneficial effects in increasing soil fertility status because of its ability to fix atmospheric nitrogen (Sharma *et al.*, 2019). In India, it is grown as a minor crop in states of Punjab, Haryana, Delhi and Uttar Pradesh, along with a considerable area in Rajasthan, Karnataka, Kerala, Tamil Nadu, Maharashtra and Gujarat. In India, cowpea occupies an area of about 3.24 lakh ha, with an annual production of 1.98 lakh tonnes and average productivity of 822 kg/ha. In Karnataka, area under cowpea is 78,446 ha with annual production of 35,759 t with an average productivity of 460 kg/ha (Harshitha and Prema, 2024). Cowpea thrives in dry conditions,

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which makes it an important crop in arid, semi-desert regions (Obatolu, 2003). It is an important source of food for humans, used as feed for livestock and effectively intercropped with sorghum, millet and maize (Quin *et al.*, 1997).

Cowpea is susceptible to fungal, bacterial and viral diseases to a greater extent along with insects. Disease of cowpea are anthracnose, rust, *Cercospora* and *Pseudocercospora* leaf spot, *Fusarium* wilt, powdery mildew, *Rhizoctonia* seedling blight, southern blight, stem blight, bacterial blight and viral disease. Among them, Bean Common Mosaic Virus (BCMV) is a major viral disease in cowpea resulting in significant yield losses to a tune of 70 per cent. BCMV infecting cowpea produce symptoms like alternate dark and green patches showing severe mosaic mottling on leaves, vein banding, reduction in leaf size, leaf deformation, puckering and downward curling of apical tip of leaves (Aliyu *et al.*, 2012). BCMV is a viral disease that affects cowpea and cause significant yield loss (Taiwo and Gonsalves, 1982). The virus is transmitted mechanically, by aphids in a non-persistent manner and through seeds. In the recent years, there is an increase in the incidence of BCMV infecting cowpea in northern Karnataka (Shilpashree, 2006). By considering this, the present investigation was undertaken to identify the resistance source and to find out the effectiveness of different pesticides for the management of the Bean Common Mosaic Virus infecting cowpea through aphid vector management.

MATERIAL AND METHODS

Screening was undertaken to test the resistance of 100 minicore collection of cowpea against BCMV under natural field conditions at College of Agriculture, Vijayapur during *Kharif* 2022-23. Each germplasm line was sown in 2 m long row with spacing of 45 cm x 15 cm. A local check (DC

15) was planted after every ten lines and along the four sides of the field to serve as a source for the disease (infecter row technique). The per cent disease incidence was recorded at 15 days interval starting from 15 days after sowing up to maturity. The disease incidence for individual germplasm line was recorded on the basis of number of plants infected to the total number of plants examined.

$$\text{Per cent disease incidence} = \frac{\text{Number of disease plants}}{\text{Total number of plants examined}} \times 100$$

The genotypes were later grouped into different categories based on 0-5 scale (Table 1) from immune to highly susceptible (Diwakar and Mali, 1976).

To know the effectiveness of different pesticides against aphids transmitting BCMV, the experiment was conducted during 2022-23 at College of Agriculture, Vijayapur (Table 2).

Details of the experiment

Location : College of Agriculture, Vijayapur
Design : Randomized Block Design (RBD)
Plot size : 4x 2 sq. mt.
Variety : DC 15
Spacing : 45 cm x15 cm
Treatments : 8
Replications : 3

The standard package of practices was followed to maintain the crop. Different treatments were imposed at 15 days after sowing except seed treatment and subsequent sprays at 15 days interval (three times). The total number of aphids on cowpea plants was recorded 1 day before spraying, 1 day after spraying, 3 days after spraying, 5 days after spraying and 7 days after spraying. The transformation of vector population was done by using poison formula $\sqrt{X} + 0.5$, where X is the average number of vectors and analyzed statistically. Then, BCMV disease incidence was

Table 1. Disease scoring scale for BCMV infecting cowpea

Scale	Description	Category
0	No plants showing symptoms	Immune
1	1-5 per cent of plants showing symptoms	Resistant
2	>5-15 per cent of plants showing symptoms	Moderately resistant
3	>15-25 per cent of plants showing symptoms	Moderately susceptible
4	>25-50 per cent of plants showing symptoms	Susceptible
5	>50 per cent of plants showing symptoms	Highly susceptible

Table 2. Different insecticides used for the management of BCMV infecting cowpea

Sl. No.	Treatments	Dosage	Method and time of application
1	Seed treatment with imidacloprid 70% WG	5 g/kg seed	Seed treatment at the time of sowing
2	Thiamethoxam 25% WG	0.2 g/l	Foliar Spray at 15, 30 and 45 DAS*
3	Fipronil 5% SC	1 ml/l	Foliar Spray at 15, 30 and 45 DAS
4	Imidacloprid 30.5 SC	0.3 ml/l	Foliar Spray at 15, 30 and 45 DAS
5	Flonicamid 50 WG	0.5 g/l	Foliar Spray at 15, 30 and 45 DAS
6	Neem seed kernel extract 5%	50 ml/l	Foliar Spray at 15, 30 and 45 DAS
7	Neem oil	3 ml/l	Foliar Spray at 15, 30 and 45 DAS
8	Control	-	-

*DAS: Days after sowing

worked out at 30 days, 45 days, 60 days, 75 days and 90 days after sowing. The yield was recorded and the data was analyzed statistically.

RESULTS AND DISCUSSION

Identification of resistant sources of cowpea against BCMV

Among 100 minicore accessions screened against BCMV, 15 germplasm lines showed immune reaction (scale 0) with no infection *i.e.*, EC723782, EC724420, EC723677, EC724774, EC723836, EC724035, EC723741, EC724453, EC72808, EC723693, EC724051, EC723800,

EC724500, EC724516 and IC91556. None of the germplasm lines showed resistant reaction (scale 1) with 1- 5 per cent infection. Ten germplasm lines showed moderate resistant reaction (scale 2) with >5- 15 per cent infection *i.e.*, EC724601, EC724642, EC724556, EC724751, IC202784, EC724681, EC724045, EC724452, EC723776 and IC402166 (Table 3). Two germplasm lines showed moderate susceptible reaction (scale 3) with >15- 25 per cent infection *i.e.*, EC723696 and EC528457, 33 germplasm lines showed susceptible reaction (scale 4) with >25- 50 per cent infection, 40 germplasm lines showed highly susceptible reaction (scale 5) with >50 per cent infection (Table 3).

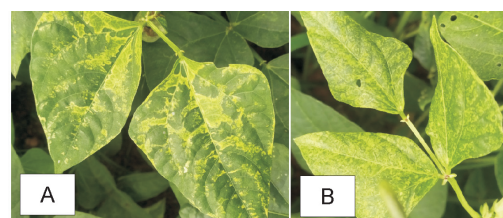
Table 3. Grouping of minicore accessions of cowpea based on their reaction against BCMV

Reaction	Number of genotypes	Description	Genotypes
Immune	15	No infection	EC723782, EC724420, EC723677, EC724774, EC723836, EC72808, EC723693, EC724051, EC723800, EC724500, EC724516, IC91556, EC724035, EC723741 and EC724453
Resistant	0	1-5%	-
Moderately resistant	10	>5-15%	EC724601, EC724642, EC724556, EC724751, IC202784, EC724681, EC724045, EC724452, EC723776 and IC402166
Moderately susceptible	2	>15-25%	EC723696 and EC528457
Susceptible	33	>25-50%	EC724385, EC724426, EC724358, EC733806, EC724758, EC724321, IC398755, EC723796, EC723795, EC723704, EC723747, EC528687, EC723801, EC723978, EC723995, EC738125, EC724366, EC724707, EC723946, EC724378, EC366776, EC724537, EC724396, EC724678, EC723971, EC724680, EC724454, EC724580, EC724413, EC723646, IC4506 and IC249586
Highly susceptible	40	>50%	EC724644, EC723732, EC723805, EC724422, EC724521, EC724565, EC724342, EC724510, EC724465, EC528689, EC723965, EC528697, EC7237960, EC724427, EC528407, EC528429, EC724054, EC724474, EC724744, EC724395, EC723739, EC724611, EC723984, EC724532, EC724760, IC536543, EC723792, EC723786, EC701966, EC24372, EC724424, IC338832, EC724033, EC528405, EC725119, EC724039, EC723925, EC723752, EC724382 and EC72377

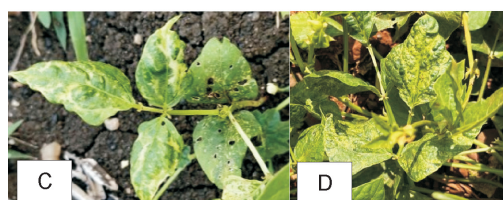
In screening, the highest per cent of disease incidence was observed in EC723925 (100 %) and the lowest per cent in EC724556 (12.50 %). Symptoms of BCMV disease observed in screening plot are shown in Figure 1. Similar type of germplasm evaluations were previously documented by several workers such as Salgar *et al.* (2021), Basavaraja *et al.* (2022) and Sofi *et al.* (2022) who identified the resistance in cowpea against BCMV.

Out of sixty french bean germplasm lines, none of the germplasm was found free from BCMV. Eleven germplasm lines *viz.*, GK-1, GK-2, PDR-14 (R-952), Jampa improved type, Arka Suvidha, Sevil, Vaishnavi, EC28304, Laxmi, Parner-1 and Akole- 3 showed 1-10 per cent disease incidence; thirteen germplasm *viz.*, Phule Surekha, Contender, Kanpur-1, GK-13, Jampa Improved, GRB-9410, GK-5-1, Kanpur-3, PRJ-125, Arka Komal, Junner-1, Junner-7 and Junner-9 showed 11-40 per cent disease incidence; twenty-five germplasm showed 41-75 per cent disease incidence, eight germplasm showed 76-90 per cent disease incidence and three germplasm showed 91-100 per cent disease incidence (Salgar *et al.*, 2021).

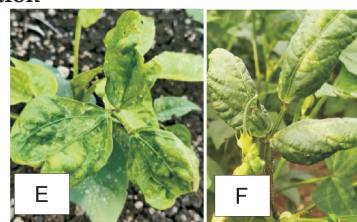
Basavaraja *et al.* (2022) concluded that BCMV



(a and b): Cowpea leaves showing mosaic symptoms



(c and d): Cowpea leaves showing blistering and leaf distortion



(e and f): Cowpea leaves showing puckering and cupping symptoms

Fig. 1. (a, b, c, d, e and f): Symptoms of BCMV infecting cowpea

Table 4. Effect of different pesticides on aphid population at 15 DAS on cowpea

Treatments	Aphid population per 5 cm stem or twig					Mean	Per cent reduction of aphid population over control
	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS		
T1.Seed treatment with imidacloprid 70%WG	15.65 (4.01)*	13.83 (3.76)	10.16 (3.25)	6.57 (2.64)	4.39 (2.20)	8.74 (2.96) ^{abc}	53.25
T2. Thiamethoxam 25%WG	18.04 (4.28)	11.23 (3.41)	7.47 (2.81)	5.15 (2.36)	5.06 (2.33)	7.22 (2.73) ^{abc}	61.34
T3. Fipronil 5%SC (4.52) (3.60)	20.07 (3.05)	12.71 (2.54)	8.87 (2.53)	6.00 (2.93) ^{abc}	5.97	8.39	55.13
T4. Imidacloprid 30.5 SC	18.98 (4.39)	9.04 (3.06)	5.63 (2.46)	3.17 (1.90)	3.17 (1.88)	5.25 (2.33) ^a	71.89
T5. Flonicamid 50WG	18.9 (4.39)	10.86 (3.34)	7.18 (2.75)	4.88 (2.30)	4.53 (2.23)	6.86 (2.65) ^{ab}	63.28
T6. Neem seed kernel extract 5%	19.35 (4.43)	17.46 (4.22)	12.81 (3.64)	10.53 (3.31)	8.38 (2.98)	12.30 (3.54) ^c	34.21
T7. Neemoil (4.41) (4.10)	19.14 (3.53)	16.45 (3.17)	12.23 (2.79)	9.73 (3.40) ^{bc}	7.41	11.46	38.70
T8. Control	20.72 (4.57)	24.59 (4.99)	14.34 (3.81)	14.91 (3.90)	20.91 (4.62)	18.69 (4.33) ^d	
SEm $\pm$ 0.33	0.30	0.27	0.23	0.21	0.18		
CD 5% 1.01	0.91	0.81	0.69	0.64	0.55		

*Figures in parenthesis are square root transformed values; DBS: Days before spray, DAS: Days after spray

Note: No spray was given for T1

disease-resistant accessions like IC360831, ET4515, EC150250, IC340947, IC564797B, EC565693 and ET8409 could be of value for dry bean improvement. Sofi *et al.* (2022) evaluated 110 common bean germplasm lines between 2019-2021 for BCMV resistance. WB-206, WB-1129, WB-216, N-10, WB-45 recorded stable resistance to BCMV while as 11 accessions N-1, WB-1691, WB-916, WB-765, WB-1131, WB-1680, WB-1256, Arka Anup, WB-1710, WB-1634, WB-373 were moderately resistant to BCMV in common bean.

The results of use of different pesticides for the management BCMV disease infecting cowpea through aphid (*Aphis craccivora*) management are presented in Table 4, 5, 6, 7 and 8.

Effect of different pesticides on aphid population at different days after sowing

The experiment consisted of eight treatments, and the results showed that all the treatments were superior to the control. After first spray (15 DAS), foliar spray of imidacloprid 30.5 SC @ 0.3 g/l (T4) recorded highest per cent reduction of aphid population over control (71.89%), followed by foliar spray of flonicamid 50 WG @ 0.5 g/l (T5) (63.28%), foliar spray of thiamethoxam 25% WG

@ 1 ml/l (T2) (61.34%). The next best treatments were foliar spray of fipronil 5% SC @ 1 ml/l (T3), seed treatment with imidacloprid 70% WG @ 5 g/kg (T1), foliar spray of neem oil @ 3 ml/l (T7) and foliar spray of NSKE 5% @ 50 ml/l (T6) which recorded per cent reduction of 55.13 per cent, 53.25 per cent, 38.70 per cent and 34.21 per cent, respectively (Table 4).

After second spray (30 DAS), foliar spray of imidacloprid 30.5 SC @ 0.3 g/l (T4) recorded highest per cent reduction of aphid population over control (82.11%), followed by foliar spray of flonicamid 50 WG @ 0.5 g/l (T5) (77.26%), foliar spray of thiamethoxam 25% WG @ 1 ml/l (T2) (74.40%). The next best treatments were foliar spray of fipronil 5% SC @ 1 ml/l (T3), foliar spray of neem oil @ 3 ml/l (T7), foliar spray of NSKE 5% @ 50 ml/l (T6) and seed treatment with imidacloprid 70%WG @ 5 g/kg (T1) which recorded per cent reduction of 72.66 per cent, 48.25 per cent, 45.09 per cent and 36.14 per cent, respectively (Table 5).

After third spray (45 DAS), foliar spray of imidacloprid 30.5 SC @ 0.3 g/l (T4) recorded highest per cent reduction of aphid population over control (95.34%), followed by foliar spray of

Table 5. Effect of different pesticides on aphid population at 30 DAS on cowpea

Treatments	Aphid population per 5 cm stem or twig					Mean	Per cent reduction of aphid population over control
	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS		
T1. Seed treatment with imidacloprid 70% WG	24.56 (5.30)*	27.71 (4.98)	29.21 (5.44)	31.83 (5.67)	32.60 (5.74)	30.34 (5.54) ^c	36.14
T2. Thiamethoxam 25% WG	22.77 (3.89)	14.94 (4.80)	13.60 (3.73)	10.71 (3.33)	9.40 (3.13)	12.16 (3.52) ^b	74.40
T3. Fipronil 5% SC	23.37 (3.97)	15.43 (4.86)	13.89 (3.77)	11.82 (3.48)	10.81 (3.34)	12.99 (3.64) ^b	72.66
T4. Imidacloprid 30.5 SC	20.15 (3.31)	10.62 (4.53)	9.14 (3.07)	7.42 (2.79)	6.83 (2.68)	8.50 (2.96) ^b	82.11
T5. Flonicamid 50 WG	21.64 (3.68)	13.20 (4.69)	11.92 (3.51)	9.86 (3.21)	8.22 (2.94)	10.80 (3.33) ^b	77.26
T6. Neem seed kernel extract 5%	29.15 (5.50)	29.79 (5.44)	26.84 (5.21)	24.84 (5.01)	22.87 (4.81)	26.09 (5.14) ^c	45.09
T7. Neem oil	27.45 (5.19)	26.67 (5.27)	25.32 (5.07)	23.84 (4.92)	22.51 (4.79)	24.58 (4.99) ^c	48.25
T8. Control	41.55 (6.64)	43.74 (6.47)	46.92 (6.87)	49.22 (7.04)	50.14 (7.11)	47.51 (6.92) ^d	
SEm ±	0.33	0.30	0.29	0.28	0.26	0.28	
CD 5%	0.99	0.92	0.89	0.84	0.79	0.84	

*Figures in parenthesis are square root transformed values; DBS: Days before spray, DAS: Days after spray
Note: No spray was given for T1

flonicamid 50 WG @ 0.5 g/l (T5) (89.00%), foliar spray of thiamethoxam 25% WG @ 1 ml/l (T2) (85.93%). The next best treatments were foliar spray of fipronil 5% SC @ 1 ml/l (T3), foliar spray of neem oil @ 3 ml/l (T7), foliar spray of NSKE 5% @ 50 ml/l (T6) and seed treatment with Imidacloprid 70% WG @ 5g/kg (T1) which recorded per cent reduction of 80.94 per cent, 73.60 per cent, 71.18 per cent and 13.44 per cent, respectively (Table 6).

Effect of different pesticides on incidence of BCMV infecting cowpea

The effect of eight different treatments on per cent disease incidence of BCMV infecting cowpea was recorded from 30 DAS to 90 DAS at 15 days interval. The results showed that all the treatments reduced the disease incidence significantly compared to control which were presented in Table 7.

At 30 DAS, the results showed that foliar spray of imidacloprid 30.5 SC @ 0.3 ml/l (T4) recorded lowest disease incidence of 18.59 per cent, followed by foliar spray of flonicamid 50 WG @ 0.5 g/l (T5) with disease incidence of 20.06 per cent. The next best treatments were seed treatment with

imidacloprid 70% WG @ 5 g/kg (T1), foliar spray of thiamethoxam 25% WG @ 0.2 g/l (T2), foliar spray of fipronil 5% SC @ 1 ml/l (T3), foliar spray of neem oil @ 3 ml/l (T7) and foliar spray of NSKE 5% @ 50 ml/l (T6) with disease incidence of 21.32 per cent, 22.99 per cent, 25.66 per cent, 29.88 per cent and 31.80 per cent, respectively. The per cent disease incidence recorded in control (T8) was 36.42 per cent.

At 45 DAS, the results showed that foliar spray of imidacloprid 30.5 SC @ 0.3 ml/l (T4) recorded lowest disease incidence of 21.89 per cent, followed by foliar spray of flonicamid 50 WG @ 0.5 g/l (T5) with disease incidence of 22.71 per cent. The next best treatments were foliar spray of thiamethoxam 25% WG @ 0.2 g/l (T2), foliar spray of fipronil 5% SC @ 1 ml/l (T3), seed treatment with imidacloprid 70% WG @ 5 g/kg (T1), foliar spray of neem oil @ 3 ml/l (T7) and foliar spray of NSKE 5% @ 50 ml/l (T6) with disease incidence of 26.33 per cent, 29.50 per cent, 39.38 per cent, 45.60 per cent and 51.18 per cent, respectively. The per cent disease incidence recorded in control (T8) was 71.57 per cent.

At 60 DAS, the results showed that foliar spray of imidacloprid 30.5 SC @ 0.3 ml/l (T4) recorded

Table 6. Effect of different pesticides on aphid population at 45 DAS on cowpea

Treatments	Aphid population per 5 cm stem or twig					Per cent reduction of aphid population over control	
	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	Mean	
T1. Seed treatment with imidacloprid 70% WG	59.95 (7.76)*	64.43 (8.06)	68.50 (8.31)	73.43 (8.60)	73.40 (8.65)	69.94 (8.29) ^d	13.44
T2. Thiamethoxam 25% WG	31.97 (5.66)	14.75 (3.90)	12.72 (3.64)	9.23 (3.12)	8.95 (3.07)	11.41 (3.47) ^b	85.93
T3. Fipronil 5% SC	33.32 (5.79)	18.34 (4.34)	16.66 (4.14)	13.92 (3.80)	12.89 (3.66)	15.45 (4.02) ^{bc}	80.94
T4. Imidacloprid 30.5 SC	20.83 (4.58)	6.12 (2.58)	5.22 (2.39)	2.57 (1.75)	1.21 (1.31)	3.78 (2.06) ^a	95.34
T5. Flonicamid 50 WG	27.07 (5.23)	11.43 (3.45)	10.51 (3.32)	7.61 (2.85)	6.13 (2.55)	8.92 (3.10) ^{ab}	89.00
T6. Neem seed kernel extract 5%5%	47.55 (6.92)	27.18 (5.27)	25.12 (5.06)	21.34 (4.67)	19.84 (4.52)	23.37 (4.90) ^c	71.18
T7. Neem oil	44.70 (6.70)	25.33 (5.08)	22.67 (4.81)	20.01 (4.50)	17.62 (4.26)	21.41 (4.69) ^c	73.60
T8. Control	68.10 (8.28)	75.56 (8.72)	79.72 (8.96)	83.04 (9.14)	86.03 (9.30)	81.09 (9.05) ^d	
SEm ±	0.39	0.34	0.32	0.28	0.27	0.29	
CD 5%	1.17	1.04	0.96	0.85	0.83	0.87	

*Figures in parenthesis are square root transformed values; DBS: Days before spray, DAS: Days after spray

Note: No spray was given for T1

lowest disease incidence of 23.94 per cent, followed by foliar spray of flonicamid 50 WG @ 0.5 g/l (T5) with disease incidence of 26.23 per cent. The next best treatments were foliar spray of thiamethoxam 25% WG @ 0.2 g/l (T2), foliar spray of fipronil 5% SC @ 1 ml/l (T3), foliar spray of neem oil @ 3 ml/l (T7), foliar spray of NSKE 5% @ 50 ml/l (T6) and seed treatment with imidacloprid 70% WG @ 5 g/kg (T1) with disease incidence of 31.43 per cent, 34.47 per cent, 50.50 per cent, 55.29 per cent and 59.10 per cent, respectively. The per cent disease incidence recorded in control (T8) was 75.75 per cent.

At 75 DAS, the results showed that foliar spray of imidacloprid 30.5 SC @ 0.3 ml/l (T4) recorded lowest disease incidence of 27.61 per cent, followed by foliar spray of flonicamid 50 WG @ 0.5 g/l (T5) with disease incidence of 30.33 per cent. The next best treatments were foliar spray of thiamethoxam 25% WG @ 0.2 g/l (T2), foliar spray of fipronil 5% SC @ 1 ml/l (T3), foliar spray of neem oil @ 3 ml/l (T7), foliar spray of NSKE 5% @ 50 ml/l (T6) and seed treatment with imidacloprid 70% WG @ 5 g/kg (T1) with disease incidence of 34.20 per cent, 35.62 per cent, 56.13 per cent, 59.47 per

cent and 65.39 per cent, respectively. The per cent disease incidence recorded in control (T8) was 85.61 per cent.

At 90 DAS, the results showed that foliar spray of imidacloprid 30.5 SC @ 0.3 ml/l (T4) recorded lowest disease incidence of 27.61 per cent, followed by foliar spray of flonicamid 50 WG @ 0.5 g/l (T5) with disease incidence of 30.31 per cent. The next best treatments were foliar spray of thiamethoxam 25% WG @ 0.2 g/l (T2), foliar spray of fipronil 5% SC @ 1 ml/l (T3), foliar spray of neem oil @ 3 ml/l (T7), foliar spray of NSKE 5% @ 50 ml/l (T6) and seed treatment with Imidacloprid 70% WG @ 5g/ kg (T1) with disease incidence of 34.69 per cent, 37.56 per cent, 59.45 per cent, 56.53 per cent and 66.17, respectively. The per cent disease incidence recorded in control (T8) was 89.15 per cent.

Effect of different pesticides on average disease incidence of BCMV infecting cowpea

Out of the eight treatments, foliar spray of imidacloprid 30.5 SC @ 0.3 ml/l (T4) recorded the lowest average disease incidence of 23.93 per cent with a per cent reduction over control of 66.63

Table 7. Effect of different pesticides on BCMV infecting cowpea and grain yield

Treatments	Disease incidence (%)					Average disease incidence (%)	Per cent reduction over control at harvest	Yield (q/ha)	B:C ratio
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS				
T1. Seed treatment with imidacloprid 70% WG	21.32 (27.47)*	39.38 (38.79)	59.10 (50.37)	65.39 (54.28)	66.17 (54.80)	50.27 (45.14) ^d	29.89	8.37	2.10
T2. Thiamethoxam 25% WG	22.99 (28.51)	26.33 (30.83)	31.43 (34.08)	34.20 (35.76)	34.69 (36.06)	29.93 (33.05) ^{cb}	66.63	10.45	2.38
T3. Fipronil 5% SC	25.66 (30.42)	29.50 (32.89)	34.47 (35.95)	35.62 (36.64)	37.56 (37.79)	32.56 (34.74) ^c	54.58	8.70	2.21
T4. Imidacloprid 30.5 SC	18.59 (25.44)	21.89 (27.88)	23.94 (29.29)	27.61 (31.70)	27.61 (31.70)	23.93 (29.20) ^a	64.12	11.18	2.97
T5. Flonicamid 50 WG	20.06 (26.59)	22.71 (27.76)	26.23 (30.78)	30.33 (33.36)	30.31 (33.29)	25.73 (30.36) ^{ab}	58.26	10.93	2.77
T6. Neem seed kernel extract 5%	29.88 (33.11)	51.18 (45.68)	55.29 (48.06)	59.47 (50.50)	59.45 (50.49)	51.05 (45.57) ^d	28.79	6.99	1.71
T7. Neem oil	31.80 (34.22)	45.60 (42.47)	50.50 (45.28)	56.13 (48.53)	56.53 (48.77)	48.11 (43.86) ^d	32.90	6.42	1.74
T8. Control	36.42 (36.88)	71.57 (58.19)	75.75 (61.28)	85.61 (68.89)	89.15 (71.82)	71.70 (59.41) ^e		4.20	1.13
SEm ±	2.09	2.43	2.97	3.12	3.17	2.60		0.65	
CD 5%	6.33	7.37	9.00	9.45	9.62	7.89		1.98	

*Figures in parenthesis are square root transformed values; DAS: Days after sowing

Note: No spray was given for

per cent. Foliar spray of imidacloprid 30.5 SC @ 0.3 ml/l (T4) was comparable with foliar spray of flonicamid 50 WG @ 0.5 g/l (T5) and foliar spray of thiamethoxam 25% WG @ 0.2 g/l (T2) with the average disease incidence of 25.73 per cent and 29.93 per cent, respectively with a per cent reduction over control of 64.12 per cent and 58.26 per cent, respectively. Foliar spray of fipronil 5% SC @ 1 ml/l (T3), foliar spray of neem oil @ 3 ml/l (T7), seed treatment with imidacloprid 70% WG @ 5 g/kg (T1) and foliar spray of NSKE 5% @ 50 ml/l (T6) showed an average disease incidence of 32.56 per cent, 48.11 per cent, 50.27 per cent and 51.05 per cent, respectively and a per cent reduction over control at harvest of 54.58 per cent, 32.90 per cent, 29.89 per cent and 28.79 per cent, respectively. The average disease incidence recorded in T8 (control) was 71.70 per cent (Table 7).

Effect of different pesticides on yield of cowpea infected by BCMV

Grain yield of cowpea crop infected with BCMV was calculated per plot after harvesting and was converted into grain yield (q) per hectare. Maximum yield per hectare was recorded in T4 (foliar spray of imidacloprid 30.5 SC @ 0.3 ml/l) which recorded seed yield of 11.18 q/ha with the highest B:C ratio of 2.83, followed by T5 (foliar spray of flonicamid 50 WG @ 0.5 g/l) and T2 (foliar spray of thiamethoxam 25% WG @ 0.2 g/l) which recorded seed yield of 10.93 q/ha and 10.45 q/ha, respectively with the B:C ratio of 2.49 and 2.77, respectively. T2 (foliar spray of thiamethoxam 25% WG @ 0.2 g/l) recorded higher B:C ratio than T5 (foliar spray of flonicamid 50WG @ 0.5 g/l). T3 (foliar spray of fipronil 5% SC @ 1 ml/

l), T1 (seed treatment with imidacloprid 70% WG @ 5 g/kg), T7 (foliar spray of neem oil @ 3 ml/l) and T6 (foliar spray of NSKE 5% @ 50 ml/l) recorded seed yield of 8.70 q/ha, 8.37 q/ha, 6.99 q/ha and 6.42 q/ha, respectively with the B:C ratio of 2.21, 2.10, 1.74 and 1.71, respectively. The minimum yield per hectare was recorded in T8 (control) which recorded a seed yield of 4.33 q/ha with B: C ratio of 1.13 (Table 7 and 8).

Previously, several workers such as Swarnalata *et al.* (2015), Choudhary *et al.* (2017) and Thummar (2021) have documented similar type of management results. Swarnalata *et al.* (2015) evaluated eleven insecticides against cowpea aphids (*Aphis craccivora*) and the treatment imidacloprid 0.005 per cent (0.19 aphid index/plant) was found to be most effective followed by thiamethoxam 0.01 per cent (0.33 aphid index/plant).

Choudhary *et al.* (2017) conducted bio-efficacy of newer insecticides like imidacloprid, thiamethoxam and dimethoate, which were found effective against the on cowpea pests whereas, the azadirachtin and malathion were found least effective against the pest. The highest grain yield of 20.38 q/ha was recorded in the plots treated with imidacloprid, followed by thiamethoxam (19.32 q/ha). The minimum grain yield of 11.98 q/ha was obtained in the plots treated with azadirachtin (0.002) followed by the treatment malathion 0.05 per cent (12.02 q/ha) which was found statistically at par with each other. The highest B: C ratio (19.01:1) was recorded in the treatment of thiamethoxam followed by imidacloprid 0.005 per cent and dimethoate 0.03 per cent, which resulted in a benefit: cost ratio of

Table 8. Economics of management of BCMV infecting cowpea

Treatments	Yield (q/ha)	Gross returns (Rs.)	Cost of cultivation (Rs.)	Net returns (Rs.)	BC ratio
T1. Seed treatment with imidacloprid 70% WG	8.37	41833.33	19892.00	21941.33	2.10
T2. Thiamethoxam 25% WG	10.45	52250.00	18851.00	33399.00	2.77
T3. Fipronil 5% SC	8.70	43520.83	19692.00	23828.83	2.21
T4. Imidacloprid 30.5 SC	11.18	55895.83	19752.00	36143.83	2.83
T5. Flonicamid 50 WG	10.93	54666.67	21917.00	32749.67	2.49
T6. Neem seed kernel extract 5%	6.42	32104.17	18742.00	13362.17	1.71
T7. Neem oil	6.99	34958.33	20142.00	14816.33	1.74
T8. Control	4.33	21000.00	18642.00	2358.00	1.13

MSP: Rs. 5000/q

16.52: 1 and 8.74: 1, respectively whereas, lowest benefit: cost ratio of 1.21: 1 was recorded from plots treated with chlorantraniliprole 0.005 per cent.

Thummar *et al.* (2021) concluded that out of ten treatments, flonicamid 50 WG, imidacloprid 17.8 SL and clothianidin 50 WDG were found highly effective for the control of aphid population in Fenugreek. The maximum seed yield was obtained in plots treated with flonicamid 50 WG followed by imidacloprid 17.8 SL and clothianidin 50 WDG. The maximum ICBR was registered in imidacloprid 17.8 SL followed by dimethoate 30 EC and thiamethoxam 25 WG.

CONCLUSION

The best way to prevent BCMV disease of cowpea is to choose resistant cultivars. Across all crops, host plant resistance has shown to be the most efficient and economical means of managing diseases. Additionally, the resistant cultivars save money, time, and energy in addition to conserving natural resources as compared to conventional disease management techniques. In order to have a better understanding of the progression

of BCMV disease on cowpea, disease screening was carried out. Experimental results revealed fifteen immune germplasm lines *i.e.*, EC723782, EC724420, EC723677, EC724774, EC723836, EC724035, EC723741, EC724453, EC72808, EC723693, EC724051, EC723800, EC724500, EC724516 and IC91556. In management studies, imidacloprid 30.5 SC @0.3 ml/l had the highest reduction of aphid population over control with lowest disease incidence and the maximum yield of 11.18 q/ha with the highest B:C ratio of 2.83. Flonicamid 50 WG @0.5 g/l and thiamethoxam 25% WG @0.2 g/l also reduced the disease incidence over control by more than 58 per cent. The germplasm lines with immune reaction could be utilized in breeding programme of cowpea against BCMV. Pesticides such as imidacloprid 30.5 SC @ 0.3 ml/l, flonicamid 50 WG @ 0.5 g/l and thiamethoxam 25% WG @ 0.2 g/l as foliar spray were effective in the management of aphids transmitting BCMV of cowpea.

ACKNOWLEDGMENT

The author acknowledges National Bureau of Plant Genetic Resources (NBPGR), New Delhi for providing mini core collection of cowpea.

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