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## Research Article

### Eco-Friendly Management of *Pentalonia nigronervosa*: The Vector of BBTV on Banana Crop

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#### ABSTRACT

The Banana bunchy top virus (BBTV) is one of the most destructive viral diseases of banana worldwide, causing severe reductions in fruit yield and quality. Its vector, the banana aphid *Pentalonia nigronervosa* (Coquerel), is an efficient transmitter of BBTV and occurs wherever bananas are cultivated. This pest is regarded as one of the most serious and economically important insect pests of banana fields globally, including in Sindh Province, Pakistan. The present study was conducted to evaluate the effectiveness of various eco-friendly approaches for the management of *P. nigronervosa* under field conditions. Pheromone traps were installed at four different heights in banana plantations on the ground surface, 1, 2, and 3 meters (T<sub>4</sub>), to determine the optimal placement for aphid monitoring. Aphid populations were recorded weekly for four weeks. A significant reduction ( $P < 0.05$ ) in aphid density was observed in traps installed at 2 m height (T<sub>3</sub>), which proved to be the most effective height for monitoring and suppressing *P. nigronervosa* populations compared with other levels. In a second field experiment, the insecticidal efficacy of four botanical extracts, neem oil (T<sub>1</sub>), tobacco solution (T<sub>2</sub>), neem leaf powder (T<sub>3</sub>), and eucalyptus extract (T<sub>4</sub>) was tested against an untreated control. Each extract was prepared separately and applied as a foliar spray. Aphid counts were taken one day before application and at 1, 3, and 6 days after treatment. Among the botanicals, the tobacco solution (T<sub>2</sub>) caused the greatest reduction in aphid population (25.64 aphids per plant,  $P < 0.05$ ), followed by neem oil (28.36), neem powder (30.39), and eucalyptus (30.39), compared with the control (45.67). The suppression achieved by the tobacco extract was significantly higher than that of eucalyptus but statistically similar to neem oil and neem powder. Overall, the findings suggest that pheromone traps installed at 2 m height and tobacco extract sprays are highly effective, eco-friendly tools for the management of *P. nigronervosa* in banana plantations, offering a sustainable alternative to conventional chemical insecticides.

**Keywords:** Banana, Aphid, Eco-friendly management.



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#### INTRODUCTION

Banana (*Musa paradisiaca* L.) is one of Pakistan's most important fruit crops, cultivated on approximately 34,800 hectares, of which nearly 87% lies within Sindh Province (Memon et al., 2016). The major banana-producing districts include Thatta, Badin, Hyderabad, Mirpurkhas, Sanghar, Shaheed Benazirabad, and Khairpur. The banana aphid, *Pentalonia nigronervosa* Coquerel (Hemiptera: Aphididae), is a sap-sucking insect belonging to the superfamily Aphidoidea. It feeds primarily on *Musa* species (Footit & Miller, 2010) and is distributed wherever bananas are grown, though it is presumed to have originated in Southeast Asia (Waterhouse, 1989).

This aphid is the principal vector of the Banana bunchy top virus (BBTV), the etiological agent of Banana bunchy top disease (BBTD), which represents one of the most serious constraints on banana production worldwide. Globally, several management strategies are employed against aphids infesting banana plantations. Although chemical control through insecticides remains the most widely used and often the most effective approach (Lohar & Rahoo, 1995), overreliance on synthetic pesticides has led to serious ecological and economic problems. These include the resurgence of non-target pests, development of insecticide resistance in target species, elimination of beneficial fauna such as predators and parasitoids, and increased environmental contamination and human health risks (Singh & Kumar, 2003). In contrast, eco-friendly pest management approaches offer sustainable alternatives that reduce or eliminate the need for hazardous chemicals. Such methods collectively referred to as Integrated Pest Management (IPM) are based on the integration of biological, cultural, physical, and botanical tactics (Bush, 2001; Kogan, 1998; Krishna, 2003).

Eco-friendly practices include the cultivation of insect-resistant varieties, conservation and augmentation of natural enemies, application of plant-derived extracts, use of repellents, and deployment of traps such as pheromone, light, and colour traps, or trap crops. Natural enemies, in particular, play a vital role in maintaining pest populations below economic threshold levels through “natural regulation,” a key component of the ecological balance within agro-ecosystems (Evans, 1998; Solangi et al., 2010). Botanical insecticides provide several advantages to farmers. They degrade rapidly, minimizing residue risks on food, and generally exhibit short pre-harvest intervals and broad crop safety margins.

Their multiple modes of action delay the development of insect resistance compared with conventional pesticides. Moreover, most plant-based formulations act rapidly by disrupting insect feeding and digestion, and they tend to decompose quickly in the environment while remaining relatively selective to target pests and less harmful to beneficial insects (BPIA, 2011). Trap cropping is another eco-friendly tactic for pest suppression. As reported by Vaiyapuri et al. (2007), the use of a more attractive companion crop—either of the same or a different family can divert pest attack away from the main crop, thereby reducing pesticide use, conserving natural enemies, improving crop quality, and promoting soil health. Similarly, insect traps serve both for population monitoring and for direct suppression. These traps may employ visual (colour, light), chemical (pheromones, attractants), or food-based lures and are designed to be safe for non-target organisms and free from food residue concerns (Kronkright, 1991). Typical traps consist of a transparent cover to admit light for insect orientation, a deflector plate to prevent escape, and a coloured sticky base to capture adults. Chu and Henneberry (1998) recommended the installation of one light trap per five acres for effective monitoring and reduction of aphid populations.

In light of these considerations, the present study was undertaken to develop and evaluate eco-friendly management strategies for *P. nigronevosa*, the principal vector of BBTV, with a specific focus on identifying resistant cultivars, evaluating trap efficiency, and integrating effective components into a sustainable IPM framework.

## MATERIALS AND METHODS

### Installation of pheromone traps at different heights

This experiment was conducted at a private banana farm near Thatta District, Sindh, where the ‘Bombay’ cultivar was grown on a five-acre plantation with plants ranging from 0.8 m to 4 m in height. Pheromone traps were installed at four different heights in August 2017 to determine the most effective level for attracting *Pentalonia nigronervosa* adults. The methodology followed Alplzar et al. (1999), with following treatments such as  $T_1$  = Trap installed on ground surface,  $T_2$  = Trap at 1 m height,  $T_3$  = Trap at 2 m height,  $T_4$  = Trap at 3 m height, and  $T_5$  = Control (no trap).

Aphid populations captured in each treatment were monitored weekly for four consecutive weeks (August–September 2017). After each observation, traps were replaced with fresh units to maintain uniform lure potency. The number of aphids caught per trap was recorded, and mean values were calculated for each height.

### Use of botanical extracts against *P. nigronervosa*

Field trials were conducted during December 2018 at Syed Fakhar Abbas Shah and Dr. Azam Zardari farms, Shaheed Benazirabad District, to evaluate the efficacy of four plant extracts—neem oil (*Azadirachta indica*), tobacco (*Nicotiana tabacum*) solution, neem leaf powder, and eucalyptus (*Eucalyptus globulus*) extract against *P. nigronervosa* on ‘G-9’, ‘Dhaka’, and ‘Basrai’ banana cultivars.

### Preparation of botanical extracts

Extracts were prepared following the method of Bahar et al. (2007).

**Tobacco extract:** 1 kg of tobacco leaves was soaked overnight in 10 L of water, and the solution was filtered

through muslin cloth.

**Neem and eucalyptus extracts:** 5 kg of fresh leaves of each plant were boiled in 10 L of water for 30 min at approximately 200 °C, cooled, and filtered.

Each extract was prepared separately for each replication, and 1 L of solution was applied per treatment.

### Experimental design and application

The trial was laid out in a Randomized Complete Block Design (RCBD) with five treatments (four botanical extracts + control) and four replications (plot size = 8 × 7 m = 56 m<sup>2</sup>). Control plots remained unsprayed. Five banana plants per replication were randomly tagged for observations. Sprays were applied when aphid populations reached an observable density.

Aphid counts were taken 1 day before treatment (pre-spray) and at 3 and 6 days after spraying (post-spray). Counts were recorded from the top, middle, and bottom leaves of each plant, and the mean number of aphids per plant was calculated for each treatment and sampling date.

### Population management of *P. nigronevosa* using trap combinations

To evaluate the effectiveness of different trapping systems, a separate field experiment was conducted using combinations of color traps, pheromone traps, and botanical extracts. Treatments were carried out T<sub>1</sub> = *Cynodon dactylon* extract, T<sub>2</sub> = Color traps, T<sub>3</sub> = Pheromone traps (Iridoid-based), T<sub>4</sub> = Combined traps (*C. dactylon* extract + color + pheromone), and T<sub>5</sub> = Control. Aphid populations were monitored weekly for four weeks following the procedures of Alplzar et al. (1999).

### Preparation of color traps

Color traps were prepared following Elango et al. (2017). Laminated plastic sheets (0.3 × 0.2 m) in three colors, yellow, orange, and red, were coated with a thin layer of commercial grease to serve as an adhesive surface. The traps were mounted on wooden stakes at uniform spacing within the banana field. After one week of exposure, the grease and adhered insects were removed, allowing the traps to be reused cost-effectively.

### Preparation of *Cynodon dactylon* extract

The extract of *C. dactylon* (Durva grass) was prepared according to Rahman (2014). The aerial parts of the plant were separated from roots, cleaned, air-dried in shade, and ground into fine powder. Fifty grams of powder were soaked in 400 mL of methanol and placed in a shaking incubator at 25 °C and 50 rpm for 48 h. The mixture was filtered through Whatman No. 1 filter paper, and the filtrate was evaporated to dryness at room temperature. The crude extract was stored at 4 °C until use.

### Data analysis

All experimental data were subjected to statistical analysis using Statistix 8.1 (Analytical Software, 2005). Mean values ± standard error (SE) were computed for each treatment. The effects of treatments were analyzed through Analysis of Variance (ANOVA), and significant differences among means were separated using the Least Significant Difference (LSD) test at the 5% probability level, following the procedures of Gomez and Gomez (1984). Percentage reduction in aphid populations was calculated using Abbott's formula (Fleming & Ratnakaran, 1985). Graphical representations were prepared in Microsoft Excel 2019 for visualization of treatment performance.

## RESULTS

### Effect of Pheromone Trap Height on the Population of *P. nigronevosa*

An experiment with four replications was conducted to determine the effect of pheromone trap height on the population density of *P. nigronevosa* in banana plantations. Data were analyzed through analysis of variance (ANOVA), and mean separations were performed using the Least Significant Difference (LSD) test at the 5% probability level. As shown in Table 1, during the first week of November, the mean numbers of aphids per trap were 39.25, 37.75, 45.25, and 39.00 when pheromone traps were installed on the ground surface (T<sub>1</sub>), at 1 m (T<sub>2</sub>), 2 m (T<sub>3</sub>), and 3 m (T<sub>4</sub>) heights, respectively, compared with 39.88 aphids per trap in the control (T<sub>5</sub>). In the second week, aphid populations declined slightly to 34.75, 32.25, 40.00, and 34.00 aphids per trap at T<sub>1</sub>–T<sub>4</sub>, while the control remained higher (43.36 aphids per trap). A significant reduction (P < 0.05) in aphid numbers was observed during the third week, with mean values of 32.50, 28.25, 21.75, and 26.50 aphids per trap for T<sub>1</sub>–T<sub>4</sub>, respectively, as compared to 44.46 aphids per trap in the control. By the fourth week, aphid abundance was markedly reduced (P < 0.05) to 13.50, 17.25, 9.50, and 17.25 aphids per trap at the respective heights, whereas the control still recorded 43.16 aphids per trap. Overall, traps installed at 2 m height (T<sub>3</sub>) consistently achieved the greatest reduction in aphid numbers throughout the four weeks, indicating this height as the most effective for capturing adult *P. nigronevosa*.

The reduction percentages further confirmed this trend (Table 1). Minimal reductions were observed during the second week (7.79%, 4.77%, 3.28%, and 4.44% for T<sub>1</sub>–T<sub>4</sub>, respectively), but the decline became pronounced by the third week (16.87%, 25.07%, 51.76%, and 31.22%) and peaked during the fourth week (64.79%, 52.81%, 78.88%, and 55.16%, respectively). The highest suppression (78.88%) was obtained from traps positioned at 2 m height (T<sub>3</sub>), which differed significantly ( $P < 0.05$ ) from all other treatments.

Table 1. Effect of pheromone traps on aphid population in banana plantation at different heights.

Weeks	Reduction in number and percentage of aphids by pheromone installation					LSD SE±
	T1	T2	T3	T4	T5	
<b>Average number per plant</b>						
1 <sup>st</sup>	39.25 <sup>bc</sup>	37.75 <sup>cd</sup>	45.25 <sup>a</sup>	39.00 <sup>c</sup>	39.88 <sup>bc</sup>	5.89 ±2.92
2 <sup>nd</sup>	34.75 <sup>a</sup>	32.25 <sup>a-c</sup>	40.00 <sup>ab</sup>	34.00 <sup>a-c</sup>	43.36 <sup>ab</sup>	
3 <sup>rd</sup>	32.50 <sup>de</sup>	28.25 <sup>ef</sup>	21.75 <sup>gh</sup>	26.50 <sup>g</sup>	44.46 <sup>ab</sup>	
4 <sup>th</sup>	13.50 <sup>j</sup>	17.25 <sup>hi</sup>	9.50 <sup>j</sup>	17.25 <sup>hi</sup>	43.16 <sup>ab</sup>	
<b>Reduction percent</b>						
1 <sup>st</sup>	0.00	0.00	0.00	0.00	0.00	8.98 ± 4.41
2 <sup>nd</sup>	7.79 <sup>t</sup>	4.77 <sup>t</sup>	3.28 <sup>t</sup>	4.44 <sup>t</sup>		
3 <sup>rd</sup>	16.87 <sup>e</sup>	25.07 <sup>de</sup>	51.76 <sup>c</sup>	31.22 <sup>d</sup>		
4 <sup>th</sup>	64.79 <sup>d</sup>	52.81 <sup>c</sup>	78.88 <sup>a</sup>	55.16 <sup>c</sup>		

Letters showed the significance difference Treatments:

T1 = Pheromone traps installed on the ground surface

T2 = Pheromone traps installed at height of 1m

T3 = Pheromone traps installed at height of 2m

T4 = Pheromone traps installed at height of 3m

T5= Control

### Repellent Action of Botanical Pesticides Against *Pentalonia nigronervosa*

A field experiment was conducted to evaluate the repellent and insecticidal activity of various botanical extracts on *P. nigronervosa* populations infesting banana plants. The comparative efficacy of neem oil, tobacco solution, neem powder, and eucalyptus extract was assessed against an untreated control. The results are summarized in Table 2. Before the application of treatments, the average aphid population was approximately 45 aphids per plant across all plots. At three days after treatment (3 DAT), aphid populations declined markedly to 24.58, 18.67, 22.50, and 26.67 aphids per plant in plots treated with neem oil (T<sub>1</sub>), tobacco solution (T<sub>2</sub>), neem powder (T<sub>3</sub>), and eucalyptus extract (T<sub>4</sub>), respectively, compared with 47.67 aphids per plant in the untreated control (T<sub>5</sub>). Among treatments, the tobacco solution (T<sub>2</sub>) produced the most pronounced reduction ( $P < 0.05$ ), although differences among T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub> were statistically non-significant at this interval. By six days after treatment (6 DAT), aphid populations further declined to 14.83, 12.58, 17.25, and 18.83 aphids per plant for T<sub>1</sub>–T<sub>4</sub>, respectively, while the control exhibited 49.67 aphids per plant. Again, the tobacco solution achieved the greatest suppression, significantly outperforming the eucalyptus treatment ( $P < 0.05$ ), though its effect remained statistically comparable to neem oil and neem powder. The corresponding reduction percentages indicated that after 3 DAT, tobacco solution (57.14%) resulted in greater population reduction than neem oil (44.65%) and eucalyptus (39.65%) and was statistically similar to neem powder (48.95%). After 6 DAT, the reduction rate reached 70.90% with tobacco solution, followed by neem oil (66.45%), neem powder (59.89%), and eucalyptus (56.66%). Overall, these findings demonstrate that tobacco extract (T<sub>2</sub>) exhibited the highest efficacy and sustained repellence against *P. nigronervosa* under field conditions, achieving the greatest and most consistent population reduction among all botanical treatments tested.

### Effect of Botanical Pesticides on the Population of *P. nigronervosa*

The results illustrated in Figure 1 show the treatment-wise variation in aphid populations following the application of botanical pesticides. A significant reduction ( $P < 0.05$ ) in *P. nigronervosa* abundance was recorded in all treated plots compared with the untreated control. Among the treatments, the tobacco solution (T<sub>2</sub>) suppressed aphid populations most effectively, with a mean of 25.64 aphids per plant, followed by neem oil (T<sub>1</sub>; 28.36 aphids/plant), neem powder (T<sub>3</sub>; 30.39 aphids/plant), and eucalyptus extract (T<sub>4</sub>; 30.39 aphids/plant), whereas the control (T<sub>5</sub>) recorded the highest infestation (45.67 aphids/plant). Similarly, the percentage reduction in aphid populations (Figure 2) revealed that tobacco solution achieved the greatest suppression (64.02%) compared with neem oil (55.55%), neem powder

(54.42%), and eucalyptus (48.16%). The difference between neem oil and neem powder was statistically non-significant ( $P > 0.05$ ). These results confirm that tobacco extract ( $T_2$ ) exhibited superior repellence and toxicity against *P. nigronevosa*, followed closely by neem oil, both of which represent promising eco-friendly alternatives for banana aphid management.

Table 2. Effect of various botanical pesticides against *P. nigronevosa*

Treatments	Reduction in aphid population after application of botanical pesticides (%)				
	Before treatment	After 3days	After 6days	After 3days	After 6days
	Average number per plant			Reduction percent	
T1	45.07a	24.58bc	14.83ef	44.65ef	66.45ab
T2	45.67a	18.67de	12.58f	57.14cd	70.90a
T3	45.46a	22.50bcd	17.25def	48.95de	59.89bc
T4	45.37a	26.67b	18.83cde	39.65f	56.66cd
T5	45.44a	47.67a	49.67a	-	-
LSD		5.9072±		8.4667±	
SE±		2.9888		4.2501	

Treatments:

T1 = Neem oil

T2 = Tobacco solution

T3 = Neem powder (Solution)

T4 = Eucalyptus (solution)

T5 = control (untreated)

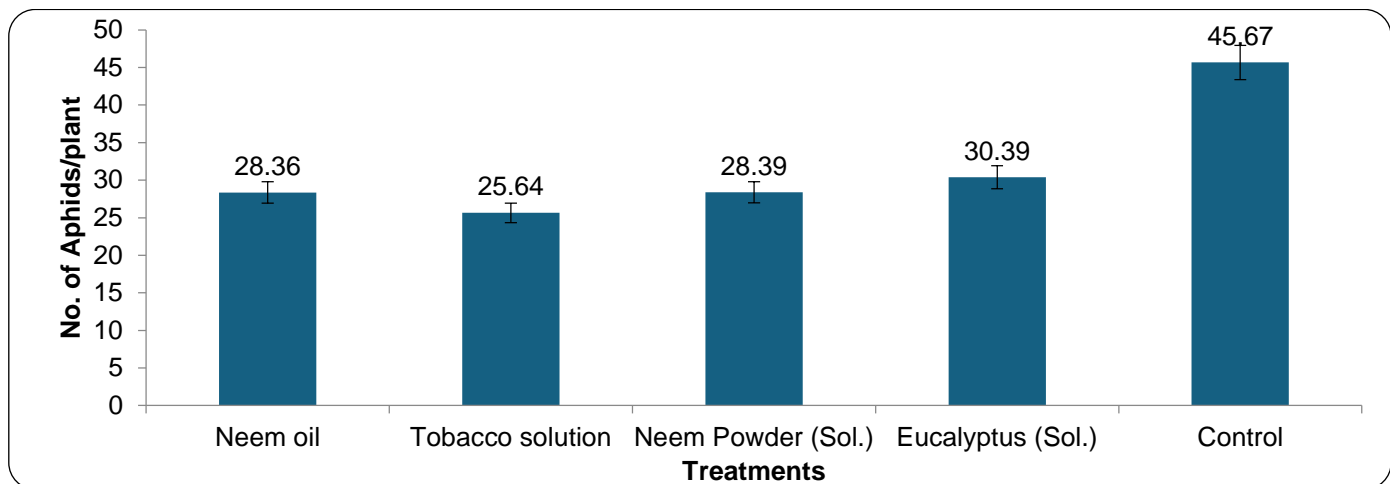


Figure 1. Effect of various botanical pesticides on the population of aphid.

### Management of *Pentalonia nigronevosa* Through Different Traps under Field Conditions

A field experiment was conducted to evaluate the effectiveness of different trapping methods *Cynodon dactylon* extract, color traps, pheromone traps, and a combination of all three on the population dynamics of *P. nigronevosa* in banana plantations. The results are presented in Table 3. In the treatment using *C. dactylon* extract ( $T_1$ ), the mean aphid population decreased progressively from 39.75 aphids per plant in the first week of November to 37.50, 26.50, and 15.25 aphids per plant in the second, third, and fourth weeks, respectively. A similar downward trend was observed in plots treated with color traps ( $T_2$ ), where aphid numbers declined from 38.50 in the first week to 33.50, 31.75, and 12.75 aphids per plant by the fourth week. In plots with pheromone traps ( $T_3$ ), the aphid population was reduced from 38.50 aphids per plant in the first week to 36.00, 26.00, and 16.25 aphids per plant in the subsequent weeks. However, the most substantial suppression occurred in plots treated with the combined system ( $T_4$ : color traps + *C. dactylon* extract + pheromone traps), where the aphid population decreased sharply from 44.00 aphids per plant in the first week to 41.75, 21.00, and 8.50 aphids per plant by the fourth week. Throughout the experimental period, the combined treatment ( $T_4$ ) consistently recorded the lowest aphid population and produced a significantly greater ( $P < 0.05$ ) reduction compared with individual trap treatments and the control. The percentage reduction in

aphid population followed a similar pattern (Table 3). Minimal reductions were recorded in the second week (5.51%, 12.72%, 6.45%, and 5.10% for T<sub>1</sub>–T<sub>4</sub>, respectively). However, reductions became substantial by the third and fourth weeks, reaching 32.94% and 60.69% (T<sub>1</sub>), 17.29% and 66.08% (T<sub>2</sub>), 31.59% and 57.32% (T<sub>3</sub>), and 52.09% and 80.51% (T<sub>4</sub>), respectively. Among all treatments, the combination of color traps, pheromone traps, and *C. dactylon* extract (T<sub>4</sub>) achieved the highest aphid suppression (80.51%) during the fourth week, demonstrating a strong synergistic effect under field conditions.

Table 3. Effect of different traps on *P. nigronervosa* under field conditions.

Weeks	Reduction in number and percent of aphids through traps application					LSD SE±
	T1	T2	T3	T4	T5	
<b>Average number per plant</b>						4.9827± 2.47
1 <sup>st</sup>	39.75a-c	38.50bc	38.50bc	44a	38.44bc	
2 <sup>nd</sup>	37.50bc	33.50de	36.00c-e	41.75ab	41.26ab	
3 <sup>rd</sup>	26.50f	31.75e	26.00f	21.00g	45.12a	
4 <sup>th</sup>	15.25h	12.75hi	16.25gh	8.50i	47.01a	
<b>Reduction percent</b>						10.747±5.28
1 <sup>st</sup>	0.00	0.00	0.00	0.00	0.00	
2 <sup>nd</sup>	5.51f	12.72ef	6.45f	5.10f	5.10f	
3 <sup>rd</sup>	32.94d	17.29e	31.59d	52.09c	52.09c	
4 <sup>th</sup>	60.69bc	66.08b	57.32bc	80.51a	80.51a	

Treatments:

T1= Extract of *C. dactylon*

T2= Color traps

T3= Pheromone traps

T4= Color traps + Extract of *C. dactylon* + Pheromone traps

T5= Control

## DISCUSSION

Banana (*Musa paradisiaca* L.) is one of the most economically and culturally valuable fruit crops in the lower region of Sindh Province, particularly in the districts of Thatta, Hyderabad, and Shaheed Benazirabad, where banana cultivation predominates. Among the major constraints on banana production, Banana bunchy top disease (BBTD), caused by the Banana bunchy top virus (BBTV) and transmitted by the banana aphid *Pentalonia nigronervosa* Coquerel, is considered the most devastating viral disease worldwide. Newly infected plants typically fail to produce fruit, and fruits from later-infected plants are often unmarketable (Cerruti et al., 2011). In the present study, surveys conducted across Thatta, Hyderabad, and Shaheed Benazirabad confirmed the widespread presence of *P. nigronervosa* and the incidence of BBTV in commercial banana plantations. A series of eco-friendly management trials was subsequently undertaken to identify effective non-chemical strategies for controlling the aphid population under field conditions.

Results from pheromone trap trials demonstrated a significant influence of trap height on aphid catch efficiency. Aphid populations decreased progressively over four weeks, with the most pronounced reduction recorded in traps installed at 2 m height (T<sub>3</sub>), where mean populations declined from 45.25 to 9.50 aphids per plant. This position resulted in an overall reduction of 78.88% by the fourth week, significantly higher ( $P < 0.05$ ) than other trap heights. These findings are consistent with those of Dahlquist (2008), who reported that pheromone-based trapping significantly reduced pest damage in banana plantations, lowering total corm damage by 33% compared with 42% in untreated plots. The improved efficacy at 2 m height likely reflects optimal alignment with the flight path and activity zone of alate aphids, thereby enhancing trap interception efficiency.

Growers in Sindh typically rely on synthetic insecticides for aphid management, which, although initially effective, often lead to secondary pest resurgence, resistance development, and environmental contamination (Bahar et al., 2007). Consequently, there is increasing interest in safer, plant-derived alternatives for sustainable pest suppression (Pedigo, 2002).

In the present study, botanical pesticides such as neem oil, neem powder, tobacco extract, and eucalyptus extract were evaluated for their insecticidal and repellent effects against *P. nigronervosa*. Among these, the tobacco extract (T<sub>2</sub>) demonstrated superior performance, reducing aphid populations from 45.67 to 18.67 aphids per plant at three

days after treatment (3 DAT) and further to 12.58 aphids per plant at six days after treatment (6 DAT), corresponding to an overall reduction of 70.9%. This effect was significantly greater ( $P < 0.05$ ) than eucalyptus extract and comparable to neem oil and neem powder. These results are supported by Bahar et al. (2007), who reported that tobacco leaf extract achieved 74–90% mortality of aphids under varying experimental conditions. Neem-based extracts were also effective, while garlic and eucalyptus exhibited moderate effects. The relatively rapid degradation of botanical compounds under field conditions (due to sunlight, moisture, and microbial activity) ensures environmental safety but may necessitate repeated applications to sustain control (Pedigo, 2002). Overall, tobacco extract proved the most effective among the tested botanicals, likely due to the presence of alkaloids such as nicotine, which act as neurotoxins, disrupting the aphid's feeding and nervous systems.

The integration of physical and botanical control measures further enhanced management efficiency. The combination of colour traps, pheromone traps, and *Cynodon dactylon* extract ( $T_4$ ) achieved the highest overall reduction in aphid population (80.51%) by the fourth week, surpassing the effects of individual trap types. This indicates a synergistic interaction between visual, olfactory, and repellent cues, which together improves aphid interception and deterrence. Such multi-tactic approaches are fundamental components of Integrated Pest Management (IPM) systems and offer a practical framework for sustainable aphid suppression. Collectively, these results demonstrate that the strategic integration of pheromone traps, botanical sprays, and biological cues can significantly reduce banana aphid populations, minimizing the need for chemical insecticides and supporting environmentally sustainable pest management.

## CONCLUSION

The findings of this study confirm that the installation of pheromone traps at 2 m height is the most effective physical strategy for controlling *P. nigronevosa* in banana plantations. Among botanical treatments, tobacco extract demonstrated the greatest reduction in aphid population. Integration of eco-friendly tactics within an IPM framework comprising pheromone and color traps, *C. dactylon* extract, and targeted botanical sprays resulted in substantial aphid suppression, improved banana yield, and higher economic returns compared with conventional chemical management.

## RECOMMENDATIONS

Based on the outcomes of this study, the following recommendations are proposed:

### Adoption of Eco-Friendly IPM Practices:

Farmers should incorporate pheromone traps at 2 m height and deploy colour traps combined with *C. dactylon* extract for continuous aphid monitoring and suppression.

### Use of Botanical Pesticides:

Tobacco extract is recommended as a natural and effective botanical pesticide for reducing banana aphid populations without leaving chemical residues.

### Need-Based Chemical Intervention:

In cases of severe infestation exceeding economic threshold levels, selective insecticides such as Coragen may be used judiciously within the IPM framework.

### Extension and Training:

Grower education on trap installation, extract preparation, and ecological pest management should be prioritized to promote sustainable banana production in Sindh Province and similar agro-ecological regions.

## AUTHOR CONTRIBUTIONS

Conceptualization, S.A.B. and A.G.L.; methodology, S.A.B., A.G.L., and T.S.S.; formal analysis, S.A.B., A.G.L., and T.S.S.; investigation, S.A.B. and A.G.L.; resources, S.A.B., A.G.L., T.S.S., and M.A.K.; data curation, S.A.B. and A.G.L.; writing—original draft preparation, S.A.B., A.G.L., and T.S.S.; writing—review and editing, S.A.B., A.G.L., T.S.S., and M.A.K.; visualization, A.G.L., T.S.S., and M.A.K.; supervision, A.G.L.; project administration, A.G.L.; funding acquisition, S.A.B. and A.G.L.

## COMPETING OF INTEREST

The authors declare no competing interests.

## REFERENCES

- Alplzar, D., Fallas, M., Oelschlager, A. C., Gonzalez, L., & Jayaraman, S. 1999. Pheromone based mass trapping of the banana weevil, *Cosmopolites sordidus* (Germar) and the West Indian sugarcane weevil *Metamasius hemipterus* L. (Coleoptera: Curculionidae) in plantain and banana. International Proceedings XIII ACORBAT Meeting, 23-27 November 1998, pp. 515-38. Guayaquil, Ecuador.
- Bahar, H., Islam, A., Mannan A., & Uddin, J. 2007. Effectiveness of Some Botanical Extracts on Bean Aphids Attacking Yard-Long Beans. *Journal of Entomology*, 4 (2), 136-142
- BPIA, 2011. Biopesticide Industry Alliance. Biochemical Biopesticides: Plant Extracts. <http://www.biopesticideindustryalliance.org/biochemicalplant.php>
- Bush, E. 2001. Thresholds for Plant-Disease Management. Pages 114-127 in: Economic Thresholds for integrated Pest Management. L.G. Higley and L.P. Pedigo, eds, University of Nebraska Press, Lincoln, NE. *P. Pentagonia*, 1-6
- Cerruti, R.R.H., Wang, K.H., Pradhan, N.C., Manandhar, R., Wright M.G., & Vorsino, A. 2011. Population distribution and density of *Pentalonia nigronervosa* (Hemiptera: Aphididae) within banana Mats: Influence of Plant Age and Height on Sampling and Management. *Journal of Economic Entomology*, 104(3), 947-955
- Elango, K., Sridharan, S., Saravanan, P.A., & Balakrishnan, S. 2017. Relative Performance of Different Colour Laden Sticky Traps on the Attraction of Sucking Pests in Pomegranate. *International Journal of Current Microbiology and Applied Sciences*, 6(11), 2997-3004
- Evans, G.A., & Polaszek, A. 1998. The *Encarsia cubensis* species-group (Hymenoptera: Aphelinidae). *Proceedings of the Entomological Society of Washington*, 100, 222-233
- Footitt, M.P., & Miller, R.H. 2010. The identity of *Pentalonia nigronervosa* Coquerel and *Pentalonia caladii* van der Goot (Hemiptera: Aphididae) based on molecular and morphometric analysis, *Zootaxa*, 2358(1), 23-38
- Gomez, K.A., & Gomez, A.A. 1984. Statistical procedures for agricultural research. An International Rice Research Institute Book. United State of America.
- Kogan, M. 1998. Integrated Pest Management: Historical Perspectives and Contemporary Developments. *Annual Review of Entomology*, 43, 234-270
- Krishna, V.V., Byju, N.G., & Tamizheniyan, S. 2003. Integrated Pest Management in Indian Agriculture: A Developing Economy Perspective, Radcliffe's IPM World Textbook, P *Pentalonia*, 45
- Memon I.N., Wagan, H., & Noonari, S. 2016. Economic analysis of banana production under contract farming in Sindh Pakistan. *Journal of Marketing and Consumer Research*, 21, 14-21
- Pedigo, L., & *Pentalonia*, 2002. Entomology and pest management. Princeton and Hall Incorporation, London.
- Rahman, S. 2014. *Cynodon dactylon*: Antimicrobial potential of crude extract as valuable medicinal plant. Dissertation Submitted to Brac University. Dhaka, India, 16-18
- Singh, A.K., & Kumar, M. 2003. Efficacy and economics of neem-based products against cotton jassid, *Amrasca biguttulla biguttulla* Dist. in okra. *Crop Research (Hisar)*, 26(2), 271-274
- Solangi, B.K., Hong, L.W., Mastoi M.I., & Pirzada, A.A. 2010. Population dynamics of natural enemies on different varieties of cotton. *Malaysian Journal of University Putra Malaysia*.
- Waterhouse, D.F. 1989. Chapter 6. *Pentalonia nigronervosa* Coquerel. 42-49 In *Biological Control: Pacific Prospects*. D. F. Waterhouse & K. R. Norris, Ed. Inkata Press: Melbourne, 454