



Research Article

Efficacy of Physical, Botanical and Chemical Interventions Against the Shoot and Fruit Borer and Their Impact on Marketable Yield of Litchi (*Litchi chinensis* Sonn.) in Northern BangladeshMd. Helal Uddin^{1,2}, Md. Habibur Rahman¹, Md Asaduzzaman¹ and Md. Mohasin Hussain Khan^{1✉}¹Department of Entomology, Faculty of Agriculture, Patuakhali Science and Technology University, Dumki, Patuakhali-8660, Bangladesh.²Department of Agricultural Studies, Adorsho Mohila College, Pabna, Bangladesh.

ARTICLE INFO

ABSTRACT

Article history

Received: 08 August 2026

Accepted: 24 September 2026

Published: 30 September 2026

Keywords

Conopomorpha sinensis;
litchi shoot and fruit borer;
marketable yield;
integrated pest management
(IPM).

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Litchi shoot and fruit borer (*Conopomorpha sinensis*) a key constraint to litchi production, is a factor that reduces the fruit quality and marketable yield. The present study compared the effectiveness of physical, botanical, organic, biopesticide and chemical control methods of litchi shoot and fruit borer and their impact on yield. The experiment was done in a commercial 'Bombay' litchi orchard at Ishwardi, Pabna, Bangladesh during March to September 2025 with Randomized Complete Block Design (RCBD) having nine treatments and three replications. Chlorantraniliprole (T₈) proved to be the most effective against shoot borer with the lowest infestation rate of 2.67% and 88.24% reduction compared with the untreated control 22.67%. Fruit-Cluster bagging (T₁) and chlorantraniliprole (T₈) both reduced fruit-borer infestations to 3.00%, respectively, whereas the infestation was 28.33% in the control, resulting in 89.45% and 89.41% reduction, respectively. T₁ had the lowest infestation (2.67%) and reduction (91.30%) at harvest time and was followed by T₈ (3.00%, 90.22%) while the control had an infestation of 30.67%. Chlorantraniliprole also yielded more marketable yields (4.20 ± 0.11 t ha⁻¹) which was a 103.46% higher than the untreated control (2.07 ± 0.05 t ha⁻¹); neem oil yielded the highest number of fruits (1936.33 fruits tree⁻¹) and the highest gross yields (43.70 kg tree⁻¹). In general, chlorantraniliprole and fruit-cluster bagging were the most effective methods of controlling borer damage, and chlorantraniliprole led to the highest increase in marketable fruit. The results can contribute for a phenology-based IPM programme towards sustainable litchi production in Bangladesh with a combination of selective insecticide along with physical and botanical methods.

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Introduction

Litchi or lychee (*Litchi chinensis* Sonn.) is a very unusual crop of high value, reputed to have been introduced between southern China and northern Viet Nam, and now grown in South and Southeast Asian countries, Australia, Africa and America (Menzel, 2002; Menzel and Waite, 2005). It is a well liked consumer variety with a relatively high willingness to pay, due to its bright red colour, translucent aril and strong aromatic odor (Septembre-Malaterre et al., 2016; Zhao et al., 2020), while the aril is a valuable source of vitamin C, sugars and phenolic compounds. The mature litchi orchard is a big contributor to the annual cash income of small holder and medium orchard farmers in a short marketing season and also provides seasonal jobs

during the periods of pruning, spraying, bagging, harvesting and grading (Menzel, 2002). Regardless of this, however, the productivity of most orchards in many production areas is also low compared to their biological potential because of irregular bearing, heat and moisture stress, fruit cracking and most importantly damage from insect pests.

In all its growth stages, litchi supports a varied arthropod complex, with the fruit and shoot borer *Conopomorpha sinensis* being one of the most economically damaging agent as it develops inside of the plant, boring tender shoots during flowering and developing fruit and harvest (Waite and Hwang, 2002; Menzel and Waite, 2005). Because the larvae feed inside plant tissues, they become difficult to reach after

Cite This Article

Uddin, M.H., Rahman, M.H., Asaduzzaman, M., and Khan, M.M.H. 2026. Efficacy of Physical, Botanical and Chemical Interventions Against the Shoot and Fruit Borer and Their Impact on Marketable Yield of Litchi (*Litchi chinensis* Sonn.) in Northern Bangladesh. *Journal of Bangladesh Agricultural University*, 24(3): 258-265. <https://doi.org/10.3329/jbau.v24i3.93897>

entry, and dense canopies can further limit insecticide penetration as fruits develop (Schulte et al., 2007). Matching the tactic to the vulnerable, externally exposed stage of the pest (the egg and newly hatched larva prior to the beginning of tunnelling) thus depends more on the timing than a fixed spray date (Schulte et al., 2007; Choudhary et al., 2026).

Shoot and fruit borers are major threats in litchi orchards of Bangladesh causing yield loss and poor fruit quality along with uncontrolled use of pesticides (Ahad et al., 2010; Azad, 2025; Taher et al., 2023). These orchards are usually spray-maintained with broad-spectrum insecticides, which may not be timed with a high degree of precision and may result in higher levels of insecticide residues, risk to pollinators and risk of insecticide resistance, but also do not always lead to an increase in marketable production. The efficacy of systemic and translaminar insecticides, diamide chemistries and physical exclusion methods by bagging have been shown to work to some extent against fruit and shoot borers of litchi in previous trials but their relative efficacy has not been compared under the same field conditions, across phenological stages in a commercial orchard in Bangladesh.

The present work was therefore designed to evaluate nine treatments, namely, non-chemical (organic, botanical, biopesticide and conventional chemical) treatments against litchi shoot and fruit borer at different growth stages (flowering, fruiting and harvesting) and also to relate the suppression of the borers directly to the fruit retention and marketable yield of litchi. The specific objectives were (i) to compare the efficacy of nine treatments for shoot and fruit-borer infestation at the stage of their maximum activity, and (ii) to estimate the reduction of borer infestation due to each treatment which helps to

identify the suitable treatment combination and time for implementing them in the northern Bangladeshi litchi belt as a basis for a phenology-based IPM programme.

Materials and Methods

Experimental site, period and plant material

The field experiment was conducted in a farmers' commercial litchi orchard of Ishwardi Upazila, Pabna District, in north-western, Bangladesh from March to September 2025 during the flowering, fruiting and harvesting stage of litchi. Bombay litchi (*Litchi chinensis* Sonn.) was used as the test cultivar. Canopy volume and intensity of bearing and management history were used to select 27 trees of similar age to be tagged (excluding trees with severe mechanical damage, dieback, and abnormal bearing). All trees underwent the same routine orchard management (irrigation, pruning and removal of dead twigs) except for the different inputs of pest management that were applied, which would allow the differences in results to be attributed to the pest management rather than to unequal orchard management.

Experimental design and treatments

The trial design was a randomised complete block (RCBD) of nine treatments replicated three times ($3 \times 9 = 27$ experimental trees, one per treatment per block) and treatment positions were randomised separately per block according to the statistical principles of Gomez and Gomez (1984). The treatments included a physical/non-chemical treatment (fruit-cluster bagging), a botanical insecticide (neem oil), and five responses of conventional or insecticide-derived insecticides: avermectin, neonicotinoid, spinosyn and diamide.

Table 1. Treatments evaluated against litchi shoot and fruit borer

Code	Treatment and dose	Category	Mode, timing and frequency of application
T ₁	Fruit-cluster bagging	Physical / non-chemical	Healthy fruit clusters were enclosed in protective paper bags (approximately 30 × 20 cm) within 10 days after natural fruit set. The open end of each bag was securely tied around the basal portion of the panicle without injuring the fruits. Sufficient space was maintained for fruit development and ventilation, and the bags remained in place until harvest.
T ₂	FYM 30 kg + poultry manure 10 kg + vermicompost 5 kg + neem cake 3 kg tree ⁻¹	Organic amendment	All components were thoroughly mixed and applied uniformly to the tree basin, followed by light incorporation into the surface soil and irrigation. The amendment was applied once before the active flowering/fruiting period.
T ₃	Neem oil, 4 mL L ⁻¹ water	Botanical / biopesticide	Applied as a full-canopy spray before flowering, ensuring uniform coverage of tender shoots and foliage. A follow-up spray may be stated after fruit set only if this was actually done in the field.
T ₄	Emamectin benzoate	Chemical	Applied as a full-canopy spray, thoroughly wetting shoots,

	5% SG, 0.4 g L ⁻¹ water	(avermectin)	foliage and developing fruit clusters. Where this matches the field record, state three applications at 10-day intervals beginning at early fruit development.
T ₅	Imidacloprid 17.8 SL, 0.5–0.7 mL L ⁻¹ water	Chemical (neonicotinoid)	Applied as a full-canopy spray at 15-day intervals, targeting active shoot growth and early pest infestation.
T ₆	Spinosad, 0.25 mL L ⁻¹ water	Biopesticide-derived (spinosyn)	Applied as a full-canopy spray. If consistent with the field procedure, report three applications at 10-day intervals, beginning during early fruit development.
T ₇	Flubendiamide 39.35 SC, 0.30 mL L ⁻¹ water	Chemical (diamide)	Applied as a full-canopy spray. If consistent with the actual experiment, report three applications at 10-day intervals, beginning when fruits reached approximately the pea-size stage.
T ₈	Chlorantraniliprole 18.5 SC, 0.40 mL L ⁻¹ water	Chemical (diamide)	Applied as a full-canopy spray. If consistent with the field procedure, report three applications at 10-day intervals, beginning at approximately the pea-size fruit stage.
T ₉	Untreated control	Control	No insecticide, botanical product, organic pest-management treatment or fruit bagging was applied. Trees received only routine non-pesticidal orchard management, including irrigation, pruning and removal of dead twigs.

Pest sampling and assessment

Sampling was done according to the modified methods developed by Ahad et al. (2010), Schulte et al. (2007) and Kumar et al. (2014) separately for the litchi shoot borer and litchi fruit borer (*Conopomorpha sinensis*) at the stage(s) when they are agronomically active. To minimize directional bias, sampling units were taken

from all four cardinal directions and from the inner and outer canopy locations within each tree. A unit was considered infested if it had one or more live pests or one or more characteristic new injury symptom (Table 2).

Table 2. Pest-wise sampling unit, sample size and infestation criterion

Pest	Crop stage	Sampling unit	Sample size tree ⁻¹	Infestation criterion
Shoot and Fruit borer	Flowering	Tender shoot	50 shoots	Entry hole, frass, tunnelling or wilted/dried shoot
	Fruiting / harvesting	Fruit	100 fruits	Entry hole, frass, larva/gallery or internal feeding

For each tree and stage, healthy units, infestation (%) and reduction over the untreated control were derived from the primary counts as: Healthy units = Total observed – Infested units; Infestation (%) = (Infested units / Total observed) × 100; and Reduction over control (%) = [(C – T) / C] × 100, where C and T are the mean infestation of the control and of a treatment at the same crop stage, following the principle of Abbott (1925).

Yield and yield-contributing parameters

For each experimental tree, total fruits, fruit drop, mean fruit weight, fruit-borer damage at harvest and marketable fruits were recorded. Gross yield (kg tree⁻¹) was calculated from total fruits × mean fruit weight, whereas marketable yield was calculated from marketable fruits × mean fruit weight. Yield (t ha⁻¹) was estimated assuming 100 trees ha⁻¹. Yield increase over control (%) was calculated as [(Yt – Yc)/Yc] × 100, where

Yt and Yc represent treatment and untreated-control marketable yields, respectively. The same nine treatments were evaluated, with emphasis here on their effects on shoot- and fruit-borer infestation.

Statistical analysis

Tree-level data were analysed using a randomised complete block design (RCBD) with separate ANOVA for each pest, crop stage, response variable and yield-contributing character following the model $Y_{ij} = \mu + T_i + B_j + e_{ij}$. Percentage data were arcsine square-root transformed, and count data as $\sqrt{x + 0.5}$, while means ± SE (three replications) are presented in original units. Treatment means were compared using Fisher's protected LSD at $p = 0.05$. Significance was denoted as ** ($p < 0.01$), * ($p < 0.05$) and NS ($p \geq 0.05$). CV (%) was calculated from the error mean square following Gomez and Gomez (1984).

Results

Litchi shoot borer (*Conopomorpha sinensis*)

At the flowering stage, chlorantraniliprole (T_8) suppressed shoot-borer infestation the best, with 48.67 healthy shoots per 50 and 2.67% infestation (88.24% reduction compared with the control), followed closely by flubendiamide (T_7 , 4.00%, 82.35% reduction) and emamectin benzoate (T_4 , 5.33%, 76.47% reduction) (Table 3). The organic amendment (T_2 , 15.33%

infestation) and neem oil (T_3 , 10.67% infestation) were comparatively less effective and these are products that are either contact or ingestion based products that act on the larvae which are concealed and living on the inside once they have entered the shoot. The highest infestation (22.67%) was observed in the untreated control.

Table 3. Effect of treatments on litchi shoot borer infestation at the flowering stage.

Treatment	Healthy shoots/50	Infested shoots/50	Infestation (%)	Reduction over control (%)
T_1	41.33 $\pm$ 0.67 e	8.67 $\pm$ 0.67 b	17.33 $\pm$ 1.33 b	23.53
T_2	42.33 $\pm$ 0.33 e	7.67 $\pm$ 0.33 b	15.33 $\pm$ 0.67 b	32.35
T_3	44.67 $\pm$ 0.33 d	5.33 $\pm$ 0.33 c	10.67 $\pm$ 0.67 c	52.94
T_4	47.33 $\pm$ 0.33 bc	2.67 $\pm$ 0.33 de	5.33 $\pm$ 0.67 de	76.47
T_5	43.67 $\pm$ 0.33 d	6.33 $\pm$ 0.33 c	12.67 $\pm$ 0.67 c	44.12
T_6	46.67 $\pm$ 0.33 c	3.33 $\pm$ 0.33 d	6.67 $\pm$ 0.67 d	70.59
T_7	48.00 $\pm$ 0.58 ab	2.00 $\pm$ 0.58 ef	4.00 $\pm$ 1.15 ef	82.35
T_8	48.67 $\pm$ 0.33 a	1.33 $\pm$ 0.33 f	2.67 $\pm$ 0.67 f	88.24
T_9	38.67 $\pm$ 0.33 f	11.33 $\pm$ 0.33 a	22.67 $\pm$ 0.67 a	—
CV (%)	1.49	12.26	12.26	—
LSD (0.05)	1.148	1.148	2.296	—
Significance	**	**	**	—

T_1 = fruit-cluster bagging; T_2 = organic amendment (FYM + poultry manure + vermicompost + neem cake); T_3 = neem oil 4 mL L⁻¹; T_4 = emamectin benzoate 5% SG 0.4 g L⁻¹; T_5 = imidacloprid 17.8 SL 0.5–0.7 mL L⁻¹; T_6 = spinosad 0.25 mL L⁻¹; T_7 = flubendiamide 39.35 SC 0.30 mL L⁻¹; T_8 = chlorantraniliprole 18.5 SC 0.40 mL L⁻¹; T_9 = untreated control. Means followed by the same letter within a column do not differ significantly (Fisher's protected LSD, $p = 0.05$). ** $p < 0.01$.

Litchi fruit borer (*Conopomorpha sinensis*)

Bagging (T_1) and chlorantraniliprole (T_8) provided the highest protection (fruit damage was limited to 3.00% or 89.4–89.5% reduction) and were statistically equivalent at the fruiting stage followed by flubendiamide (T_7 , 4.33%, 84.71% reduction) and emamectin benzoate (T_4 , 5.00%, 82.35% reduction) (Table 4). This ranking was preserved at harvest as T_1 resulted in the lowest amount of damage overall

(2.67%, 91.30% reduction), which was not significantly different from T_8 (3.00%, 90.22% reduction) with T_7 and T_4 the next most effective treatments (Table 5). Neem oil (T_3) and the organic amendment (T_2) gave slightly less but significant protection compared to the untreated control whose infestation at fruiting and harvesting were 28.33% and 30.67% respectively.

Table 4. Effect of treatments on litchi fruit borer infestation at the fruiting stage.

Treatment	Healthy fruits/100	Infested fruits/100	Infestation (%)	Reduction over control (%)
T_1	97.00 $\pm$ 0.00 a	3.00 $\pm$ 0.00 g	3.00 $\pm$ 0.00 g	89.45
T_2	82.00 $\pm$ 0.58 f	18.00 $\pm$ 0.58 b	18.00 $\pm$ 0.58 b	36.47
T_3	90.33 $\pm$ 0.33 d	9.67 $\pm$ 0.33 d	9.67 $\pm$ 0.33 d	65.88
T_4	95.00 $\pm$ 0.58 b	5.00 $\pm$ 0.58 f	5.00 $\pm$ 0.58 f	82.35

Treatment	Healthy fruits/100	Infested fruits/100	Infestation (%)	Reduction over control (%)
T ₅	87.00 ± 0.00 e	13.00 ± 0.00 c	13.00 ± 0.00 c	54.12
T ₆	93.33 ± 0.33 c	6.67 ± 0.33 e	6.67 ± 0.33 e	76.47
T ₇	95.67 ± 0.33 b	4.33 ± 0.33 f	4.33 ± 0.33 f	84.71
T ₈	97.00 ± 0.00 a	3.00 ± 0.00 g	3.00 ± 0.00 g	89.41
T ₉	71.67 ± 0.33 g	28.33 ± 0.33 a	28.33 ± 0.33 a	—
CV (%)	0.68	6.06	6.06	—
LSD (0.05)	1.06	1.06	1.06	—
Significance	**	**	**	—

Table 5. Effect of treatments on litchi fruit borer infestation at the harvesting stage.

Treatment	Healthy fruits/100	Infested fruits/100	Infestation (%)	Reduction over control (%)
T ₁	97.33 ± 0.33 a	2.67 ± 0.33 g	2.67 ± 0.33 g	91.30
T ₂	81.33 ± 0.88 f	18.67 ± 0.88 b	18.67 ± 0.88 b	39.13
T ₃	89.00 ± 0.58 d	11.00 ± 0.58 d	11.00 ± 0.58 d	64.13
T ₄	94.67 ± 0.88 b	5.33 ± 0.88 f	5.33 ± 0.88 f	82.61
T ₅	86.00 ± 0.00 e	14.00 ± 0.00 c	14.00 ± 0.00 c	54.35
T ₆	93.33 ± 0.33 c	6.67 ± 0.33 e	6.67 ± 0.33 e	78.26
T ₇	95.33 ± 0.33 b	4.67 ± 0.33 f	4.67 ± 0.33 f	84.78
T ₈	97.00 ± 0.58 a	3.00 ± 0.58 g	3.00 ± 0.58 g	90.22
T ₉	69.33 ± 0.33 g	30.67 ± 0.33 a	30.67 ± 0.33 a	—
CV (%)	0.83	6.91	6.91	—
LSD (0.05)	1.285	1.285	1.285	—
Significance	**	**	**	—

T₁ = fruit-cluster bagging; T₂ = organic amendment (FYM + poultry manure + vermicompost + neem cake); T₃ = neem oil 4 mL L⁻¹; T₄ = emamectin benzoate 5% SG 0.4 g L⁻¹; T₅ = imidacloprid 17.8 SL 0.5–0.7 mL L⁻¹; T₆ = spinosad 0.25 mL L⁻¹; T₇ = flubendiamide 39.35 SC 0.30 mL L⁻¹; T₈ = chlorantraniliprole 18.5 SC 0.40 mL L⁻¹; T₉ = untreated control. Means followed by the same letter within a column do not differ significantly (Fisher's protected LSD, *p* = 0.05). ** *p* < 0.01.

Yield and yield-contributing characters

The yield and yield contributing attributes of litchi were significantly affected by the treatments (Table 6). The highest number of total fruits per tree was recorded in T₃ (neem oil) with 1936.33 ± 48.75 fruits, which was statistically similar to T₇ (1924.67 ± 48.75) and T₈ (1912.67 ± 48.34). However, T₈ (chlorantraniliprole) produced the highest number of marketable fruits per tree (1855.29 ± 48.18), followed by T₇ (1834.79 ± 46.91) and T₁ (1805.47 ± 9.17). The highest individual fruit weight was also observed in T₈ (22.66 ± 0.14 g), which was statistically similar to T₃ (22.61 ± 0.17 g), T₁ (22.59 ± 0.05 g), and T₇ (22.57 ± 0.17 g). Treatments T₃, T₇, and T₈ (43.70 ± 1.47 kg/tree, 43.45 ± 1.41 kg/tree, and 43.34

± 1.30 kg/tree, respectively) were found to be in the same statistical group for gross yield. The untreated control (T₉) exhibited the smallest results as far as the number of fruits, marketable fruits, fruit weight and gross yield were concerned.

Regarding marketable yield, T₈ showed the best performance with 42.04 ± 1.12 kg/tree and 4.20 ± 0.11 t/ha, followed by T₇ with 41.41 ± 1.10 kg/tree and 4.14 ± 0.11 t/ha. The comparatively high marketable yield of 40.79 kg/tree and 4.08 t/ha by T₁ was also found. The highest yield increase over the untreated control was obtained from T₈ (103.46%), followed by T₇ (100.41%), T₁ (97.38%), and T₃ (88.57%). In contrast, T₉ yielded 20.66 ± 0.46 kg/tree and 2.07 ± 0.05 t/ha of marketable trees, respectively, indicating the significant yields that

could be gained by the treatments applied. In general, chlorantraniliprole (T_8) was the most effective treatment for the marketable fruit production and marketable yield with neem oil (T_3) having the highest

total fruit number and gross yield. Treatment effects were significant ($p < 0.01$) for the measured yield and yield contributing traits.

Table 6. Effect of treatments on yield and yield-contributing characters of litchi.

Treatments	Total fruits/tree	Marketable fruits/tree†	Fruit wt. (g)	Gross yield (kg/tree)	Mkt. yield (kg/tree)†	Yield (t/ha)†	Increase over control (%)
T1	1855.00 ± 7.02 b	1805.47 ± 9.17 ab	22.59 ± 0.05 a	42.57 ± 0.19 b	40.79 ± 0.23 abc	4.08 ± 0.02 abc	97.38
T2	1786.33 ± 31.25 c	1452.82 ± 29.88 e	22.17 ± 0.24 c	39.62 ± 1.12 c	32.21 ± 0.75 e	3.22 ± 0.07 e	55.88
T3	1936.33 ± 48.75 a	1723.33 ± 44.82 bc	22.61 ± 0.17 a	43.70 ± 1.47 a	38.96 ± 1.05 bc	3.90 ± 0.11 bc	88.57
T4	1710.67 ± 42.67 d	1619.49 ± 43.11 cd	22.04 ± 0.04 d	37.70 ± 0.87 de	35.69 ± 0.95 d	3.57 ± 0.10 d	72.74
T5	1783.67 ± 51.74 c	1533.96 ± 44.50 de	21.85 ± 0.20 e	38.99 ± 1.38 d	33.52 ± 1.02 de	3.35 ± 0.10 de	62.21
T6	1847.00 ± 7.02 b	1723.81 ± 8.95 bc	22.29 ± 0.05 b	41.17 ± 0.18 b	38.42 ± 0.22 c	3.84 ± 0.02 c	85.95
T7	1924.67 ± 48.75 a	1834.79 ± 46.91 a	22.57 ± 0.17 a	43.45 ± 1.41 a	41.41 ± 1.10 ab	4.14 ± 0.11 ab	100.41
T8	1912.67 ± 48.34 a	1855.29 ± 48.18 a	22.66 ± 0.14 a	43.34 ± 1.30 a	42.04 ± 1.12 a	4.20 ± 0.11 a	103.46
T9	1424.67 ± 30.34 e	987.72 ± 21.55 f	20.92 ± 0.07 f	29.81 ± 0.73 f	20.66 ± 0.46 f	2.07 ± 0.05 f	—
CV (%)	2.19	3.90	0.78	2.59	4.06	4.06	—
LSD (0.05)	66.09	108.97	0.299	1.724	2.529	0.253	—
Significance	**	**	**	**	**	**	—

T_1 = fruit-cluster bagging; T_2 = organic amendment (FYM + poultry manure + vermicompost + neem cake); T_3 = neem oil 4 mL L⁻¹; T_4 = emamectin benzoate 5% SG 0.4 g L⁻¹; T_5 = imidacloprid 17.8 SL 0.5–0.7 mL L⁻¹; T_6 = spinosad 0.25 mL L⁻¹; T_7 = flubendiamide 39.35 SC 0.30 mL L⁻¹; T_8 = chlorantraniliprole 18.5 SC 0.40 mL L⁻¹; T_9 = untreated control. Means followed by the same letter within a column do not differ significantly (Fisher's protected LSD, $p = 0.05$). ** $p < 0.01$.

Discussion

Application of the diamide insecticide and fruit exclusion through bagging timed according to phenology of the litchi crop correlated very well with litchi yield increases. The most effective treatment at each of these stages varied, suggesting that a programme based on the stages rather than a calendar would be more beneficial than a single treatment.

Shoot borer management

The diamide insecticides chlorantraniliprole (T_8) and flubendiamide (T_7) were most effective against shoot borer, similar to the two year field trials conducted by Upadhyay et al. (2020) concluded that these two insecticides were the most effective against *Conopomorpha sinensis* and recommended them for use from the onset of fruit set. This difference can be attributed to difference in feeding mode between the larvae of shoot-borers and the organic amendment and diamide insecticides. Diamide insecticides act on the

ryanodine receptor and are effective after some internal feeding of the larva has begun whereas the

internal feeding habit of shoot-borers makes them less readily available to contact and ingestion products.

Fruit borer management

Bagging (T_1) and chlorantraniliprole (T_8) gave the same high level of protection of fruit at harvest. The good and consistent performance of bagging agrees with Taher et al. (2022) who found that litchi bunch bagging achieved over 95% pest free fruits and the efficacy was sustained till the harvest and Debnath and Mitra (2008) showed that panicle bagging also controlled the fruit maturity and fruit quality improvement. Likewise, Taher et al. (2023) found that paper bagging and effective insecticides resulted in higher fresh-fruit recovery compared to the control; and Kumar et al. (2026) reported 10–35% yield increase due to bunch bagging at the right time in different litchi growing areas of India. The high efficacy of the diamide insecticides here,

supports the findings of Upadhyay et al. (2020) and indicates that chlorantraniliprole or flubendiamide can be an effective chemical alternative in similar efficacy against fruit borer where, bagging labour is limiting.

Yield response and its practical implications

The present study revealed that the treatment T₈ (chlorantraniliprole) significantly improved marketable yield of litchi with 4.20 t/ha which is 103.46% higher than the control T₉ (without treatment) while T₃ (neem oil) produced the highest fruit count and gross yield. The superior performance of chlorantraniliprole may be explained by its ability to control litchi fruit and shoot borer (*Conopomorpha sinensis*) which resulted in less fruit damage and higher percentage of marketable fruits. It agrees with the results of Upadhyay et al., (2020), who found that chlorantraniliprole and flubendiamide was the most effective insecticide against *C. sinensis* in litchi and can significantly mitigate the losses caused by the pest. Likewise, the use of effective borer control for fruit yield and quality of litchi was evidenced by Schulte et al. (2007) who showed that treatments with spinosad and imidacloprid, both chemical and biologically derived, could help to reduce fruit infestation of *C. sinensis* in litchi orchards. The relative efficiency of neem oil and fruit-cluster bagging reported in the present experiment is also similar to the findings of Taher et al. (2023) who noted that in their experiment, neem oil decreased fruit-borer infestation of litchi by 78.73% and paper bagging resulted in 100% protection with a higher percentage of fresh fruits than the untreated control. Thus it can be concluded that application of selective insecticide and/or adopting sustainable approach for suppression of fruit-borer damage can significantly contribute to better marketable litchi production.

Conclusion

The present study confirmed that the phenological approach of management could significantly decrease the incidence of shoot and fruit borer and enhance marketable yield of litchi in field environment of the northern parts of Bangladesh. Chlorantraniliprole (T₈) was the most effective treatment against shoot borer with 88.24% reduction in infestation, whereas fruit-cluster bagging (T₁) and chlorantraniliprole (T₈) were the most effective treatments during the fruiting and harvesting stages against fruit borer. Fruit infestation was lowest in T₁ (2.67%) and T₈ (3.00%) at harvest, suggesting that both physical exclusion and selective use of insecticides can be effective in suppressing borers. In terms of yield productivity, the highest marketable yield (4.20 t/ha) and yield increase over the untreated control (103.46%) was observed by T₈, while the highest number of fruits and gross yield was

observed by neem oil (T₃). The overall conclusions indicate that integration of chlorantraniliprole, flubendiamide, fruit-cluster bagging and other effective non-chemical control measures can be done based on the crop phenology with the aim of reducing the reliance on indiscriminate pesticide use and reducing the damage of fruits to enhance the marketable production of litchi. Thus, an integrated pest management (IPM) approach based on litchi phenology which takes into account the use of selective insecticides along with physical and botanical methods could be a feasible and sustainable solution for litchi shoot and fruit borer management in the main litchi producing zones of Bangladesh.

Acknowledgements

The authors are grateful to Director, Research and Training Centre (RTC), Patuakhali Science and Technology University for providing financial assistance during the study.

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