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RESEARCH ARTICLE

Incidence pattern of pod borer complex on different red gram cultivars in relation to various weather factors in the Terai agro-ecological zone of West Bengal

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Abstract

A study, conducted in the Instructional Farm of Uttar Banga Krishi Viswavidyalaya (UBKV) during 2023-24 and 2024-25, unveils valuable insights about the seasonal occurrence pattern of pod borer complex on different red gram cultivars and identifies the most promising cultivar under the Terai agro-climatic situation of West Bengal. The study reported 5 species of pod borers, namely *Maruca vitrata* (Fabricius) , *Exelastis atomosa* (Walsingham), *Lampides boeticus (Linnaeus)*, *Melanagromyza obtusa* (Malloch) and *Apion clavipes* Gerstäcker, infesting the red gram plants in this region. Of them, the population was lowest for *M. vitrata* (6.31 larvae/plant) and highest for *L. boeticus* (10.93 larvae/plant). Among the red gram cultivars screened, Pusa Arhar-16 had faced the highest pod borer incidence with 24.43 larvae/plant, whereas the cultivar Upas-120 faced the least incidence with 16.93 larvae/plant. In both seasons, the sampled pod borer complexes were characterized by less dominance and greater evenness. The seasonal incidence pattern suggested the 48th–49th standard meteorological week (SMW), the 50th–51st SMW and the 4th–6th SMW as the most critical periods of pod borer incidence in early-, mid- and late-maturity cultivars respectively. The incidence was initiated by *M. vitrata* for all the cultivars, followed by *E. atomosa* and *L. boeticus*, while *M. obtusa* and *A. clavipes* arrived later in the season. Different weather factors were noted to have significant influences on the seasonal occurrence of these pests. Among the 7 cultivars, Upas-120 was recorded with significantly ($p < 0.001$) greater yield (85.04 g/m^2), whereas yield was lowest for Pusa Arhar-16 (58.22 g/m^2), suggesting Upas-120 as the most promising cultivar for this region.

Keywords: *Cajanus cajan*; correlation; diversity; pigeon pea; seasonal occurrence; yield

Introduction

Red gram (*Cajanus cajan* (L.) Millsp.) is an important perennial pulse crop that belongs to the family Leguminosae or Fabaceae. This crop is also known as pigeon pea, arhar, tur, adhaki, etc. to the people from different parts of India (1). Red gram is usually grown in the tropical and subtropical countries of the world and is well suited for rainfed agriculture because of its deep taproot system, drought tolerance potential, heat tolerance capability, ability to withstand poor soil fertility and fast-growing habit (2). Being a legume crop, red gram possesses an immense ability to nourish the soil through symbiotic nitrogen fixation and can assimilate 40 kg more soil nitrogen per hectare than other legume crops (3). The demand for red gram in India is increasing day by day due to its ability to provide high-quality protein and become one of the major protein diets for the vegetarian population of the country (4). Red gram seeds contain about 20–22 % protein, 65 % carbohydrate, 1.2 % fat and 3.8 % ash, providing about 335 cal energy per 100 g (1, 5). Red gram is the 5th most important legume crop in the world and holds 2nd rank in terms of production and area coverage in India, after chickpea (5). India is the world leader in red gram production, accounting for more than 90 % of the global red gram production and area (6), with an impressive production of 4.32 million tons cultivated over an area of 5.2 million hectares in 2021, with a productivity of 825 kg/hectare (7). In India, red gram is mostly cultivated in states like Maharashtra, Madhya Pradesh, Karnataka, Gujarat, Andra Pradesh, etc. (5). To some extent, red gram is also cultivated in the northern districts of West Bengal, contributing to the socio-economic status of the rural people of the region.

Even after being such an important crop, the production of red gram is seriously threatened by a variety of insect pests both in the field (at different phases of crop growth) and in storage conditions. This group of insect pests includes different pod borers, pod fly, stem fly, leaf miner, bean weevil, defoliators, sucking pests, including aphids, white fly, leaf hoppers and thrips, as well as stored grain pests like bruchids, causing extensive yield loss worldwide (8). This list comprises more than 250 insect pests and the damage caused by different pod-feeding insects results in major reduction in grain yield (9). The yield losses due to the pod borer complex ranging from 48.75–58.75 % (10). Among different species of pod feeding insects, *Melanagromyza obtusa* (Malloch) contributed the highest (36.94 %), followed by *Clavigrella gibbosa* (Spinola) (20.37 %), *Lampides boeticus* (Linnaeus) (15.43 %), *Exelastis atomosa* (Walsinghum) (14.03 %) and *Helicoverpa armigera* (Hübner) (12.93 %) (11). However, such damage highly depends on the time of pest appearance, its population fluctuations, rate of infestation, etc. and also greatly varies from variety to variety (12). Hence, proper monitoring of population dynamics of these insect pests is of utmost importance in order to initiate timely control measures and is very crucial to develop proper integrated pest management strategies (13). In addition, different weather factors have a significant influence on the population build-up and suppression of these insect pests. Keeping this in view, the study has been performed to assess the diversity, population dynamics and impact of weather parameters on the seasonal incidence of the pod borer complex in different red gram cultivars in the Terai agro-climatic zone of West Bengal.

Materials and Methods

Study area

The experiment was conducted in the Instructional Farm of Uttar Banga Krishi Viswavidyalaya (UBKV), Pundibari, West Bengal, India, during the study periods of 2023-24 and 2024-25. This study region has a per-humid climate, with a temperature range from 10–38 °C and an annual average rainfall of more than 3000 mm which occurs mostly from June to September due to the southwest monsoon. Thereafter, from December to February, a brief winter prevails with lower sunlight intensity and little or no rainfall. These winter months are an optimum timeframe for flowering and fruiting of red gram in this region.

Field study

Screening test was performed on 7 red gram cultivars with varying maturity periods. These include 3 mid-maturing cultivars, namely Birsa Arhar-1 (V1), Birsa Arhar-2 (V2) and Upas-120 (V3); 1 early maturing cultivar, namely Pusa Arhar-16 (V4); and 3 late maturing cultivars, namely Sonali (V5), Roshani (V6) and Raiganj Local (V7). Among them, Raiganj Local is an indigenous cultivar, whereas others are released cultivars. Planting was done in 5 m × 5 m experimental plots (3 plots/replications for each cultivar) with a spacing of 30 cm × 100 cm in the 4th week of April, i.e., during the 18th standard meteorological week (SMW), in both study years. In the experimental plots, crops were cultivated following the standard agronomic practices, except for plant protection measures (14).

To observe the diversity of pod borers in the red gram cultivars, insect pests were collected by using different collection methods like active searching and net sweeping (15). Thereafter, the seasonal incidence pattern of different insect pests was recorded for all 7 cultivars at weekly intervals, starting from the first incidence of each pest until it completely disappeared from the field. The larval populations of bean pod borer, plume moth and blue butterfly were counted from 5 randomly selected plants from each replication (16, 17). Pod fly maggot and pod weevil grub populations were counted from 100 randomly plucked pods (20 pods from each of 5 plants) in each replication. The pods were split opened and examined to count the number of maggots and grubs (18). For yield assessment, 5 random 1 m^2 areas were selected from each replication and the grain yield from those areas was determined and expressed as g/m^2.

Diversity indices

Based on the cumulative population of different insect pests, the following ecological indices for species diversity, richness, evenness and dominance were computed for each cultivar during both seasons (Table 1).

Specimen identification

The collected immature stages of different pod-boring insects were brought to the laboratory and reared for adult emergence. The adults were pinned, dried and identified under a ZEISS Stemi 508 stereo-zoom microscope equipped with a 16 mp CMOS camera, using appropriate identification keys (23). Later, the specimens were sent to the Zoological Survey of India (ZSI), Kolkata, for confirmation of their identity.

Recording of weather data

Daily weather data such as maximum temperature (T_{max}), minimum temperature (T_{min}), maximum relative humidity (RH_{max}), minimum relative humidity (RH_{min}), rainfall, bright sunshine hours (BSH) and evaporation (EVP) were recorded from the Meteorological Unit of UBKV, located within 500 m from the observational fields. From these weather data, the average daily temperature (T_{avg}), temperature difference (T_{diff}), average daily relative humidity (RH_{avg}) and relative humidity difference (RH_{diff}) were computed.

Statistical analysis

Pearson correlation and regression analyses were performed to find out the impact of different weather parameters on the incidence of different insect pests. Two-factor factorial randomized block design, followed by Duncan's New Multiple Range Test (DNMRT) at α = 0.05, was performed to analyse the yield of different cultivars during both seasons. Statistical analyses were performed using the R statistical software version 4.4.1 (24) and the chord diagram was constructed

Table 1. Different ecological indices used in the study

Indices	Equation	Notes	Reference
Shannon diversity index (H')	$-\sum_{i}^{n} p_i \ln p_i$	p_i = proportion of species in a community (n_i/N)	(19)
Margalef richness index (D')	$\frac{S-1}{\ln N}$	S = total number of species N = total number of individuals	(20)
Pielou evenness index (J')	$\frac{H'}{\ln S}$	H' = Shannon's index S = total number of species	(21)
Simpson dominance index (D)	$\sum {p_i}^2$	p_i = proportion of species in a community (n_i/N)	(22)

using the Origin® software.

Results and Discussion

Diversity and abundance of different pod borers in red gram cultivars

The study has reported 5 species of pod borers infesting the red gram cultivars in this region (Table 2). The diversity included 3 lepidopteran (i.e., bean pod borer, plume moth and blue butterfly), 1 coleopteran (i.e., pod weevil) and 1 dipteran (i.e., pod fly) pest (Fig. 1). There was documentation of 64 species of insect pests infesting red gram in northeast India, with 11 species constituting the pod borer complex (25). Although, from our study region, we have identified only 5 pod borers of red gram, all of which are potential key pests to this crop (1, 25). Regular occurrences of these pod borers on red gram were also reported by other researchers around India (15, 26, 27).

The chord network linking the yearly population of different pod borers with their population on different red gram cultivars, suggested almost similar incidence of pod borers in both the study years (Fig. 2). In the pod borer community, the population was lowest for bean pod borer (i.e., 6.31 larvae/plant throughout the season) and highest for blue butterflies (i.e., 10.93 larvae/plant throughout the season). The cumulative incidence of pod borers (Fig. 3) suggested that the cultivars Pusa Arhar-16 and Raiganj Local were more susceptible to pod borer incidence in both seasons, whereas the cultivar Upas-120 faced less pod borer incidence as compared to the others. In a study it was found that Pusa Arhar-16 has a higher amount of protein and amino acid content, which is much higher than that of Upas-120 (28). As protein content has a positive influence on red gram insect pest incidence, hence elucidating the susceptibility of Pusa Arhar-16 (29).

As presented in Table 3, the cumulative ecological indices were almost similar during both the study seasons, with slightly higher values recorded during the 2024-25 season (i.e., H'=1.596, D'=0.799 and J'=0.991) than the 2023-24 season (i.e., H'=1.589, D'=0.791 and J'=0.988). The highest Shannon diversity index (H') value for the cultivar Pusa Arhar-16 during both seasons (i.e., 1.606 and 1.605 during 2023-24 and 2024-25, respectively) also indicated a greater incidence of pests on this cultivar than others. On the other hand, Upas-120 was characterized by the highest Margalef richness values during both seasons (i.e., 1.402 and 1.426 during 2023-24 and 2024-25 respectively). Furthermore, in all cases, the Pielou evenness index had higher values tending towards 1 and the Simpson dominance index had lower values tending towards 0, highlighting less dominance and greater evenness in the sampled pod borer

Table 2. List of pod borers identified infesting red gram pods during the 2023-24 and 2024-25 study period

Sl. No.	Common name	Scientific name	Family	Order
1.	Bean pod borer	*Maruca vitrata* (Fabricius, 1787)	Crambidae	Lepidoptera
2.	Plume moth	*Exelastis atomosa* (Walsinghum, 1885)	Pterophoridae	Lepidoptera
3.	Blue butterfly	*Lampides boeticus* (Linnaeus, 1767)	Lycaenidae	Lepidoptera
4.	Podfly	*Melanagromyza obtusa* (Malloch, 1914)	Agromyzidae	Diptera
5.	Pod weevil	*Apion clavipes* Gerstaecker, 1856	Apionidae	Coleoptera

Table 3. Ecological indices for pod borer complexes observed on different red gram cultivars during 2023-24 and 2024-25

Cultivars	Season-wise ecological indices[a]							
	2023-2024				2024-2025			
	H'	D'	J'	D	H'	D'	J'	D
Birsa Arhar-1	1.596	1.284	0.992	0.205	1.601	1.319	0.995	0.203
Birsa Arhar-2	1.588	1.297	0.987	0.209	1.596	1.331	0.992	0.205
Upas-120	1.591	1.402	0.988	0.208	1.597	1.426	0.992	0.205
Pusa Arhar-16	1.606	1.253	0.998	0.202	1.605	1.250	0.998	0.202
Sonali	1.555	1.302	0.966	0.221	1.562	1.298	0.970	0.217
Roshani	1.575	1.265	0.979	0.213	1.581	1.287	0.982	0.210
Raiganj Local	1.586	1.230	0.986	0.209	1.593	1.277	0.990	0.207
Cumulative	1.589	0.791	0.988	0.208	1.596	0.799	0.991	0.205

[a]H': Shannon diversity index; D': Margalef richness index; J': Pielou evenness index; D: Simpson dominance index.

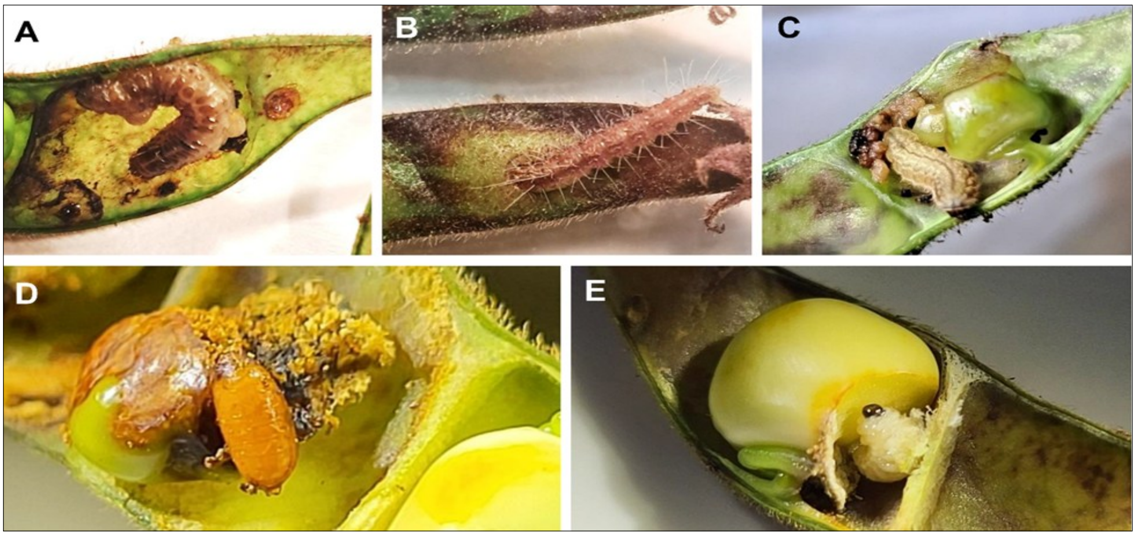

Fig. 1. Pod damage caused by the pod borer complex. (A) *Maruca vitrata*; (B) *Exelastis atomosa*; (C) *Lampides boeticus*; (D) *Melanagromyza obtusa*; (E) *Apion clavipes*.

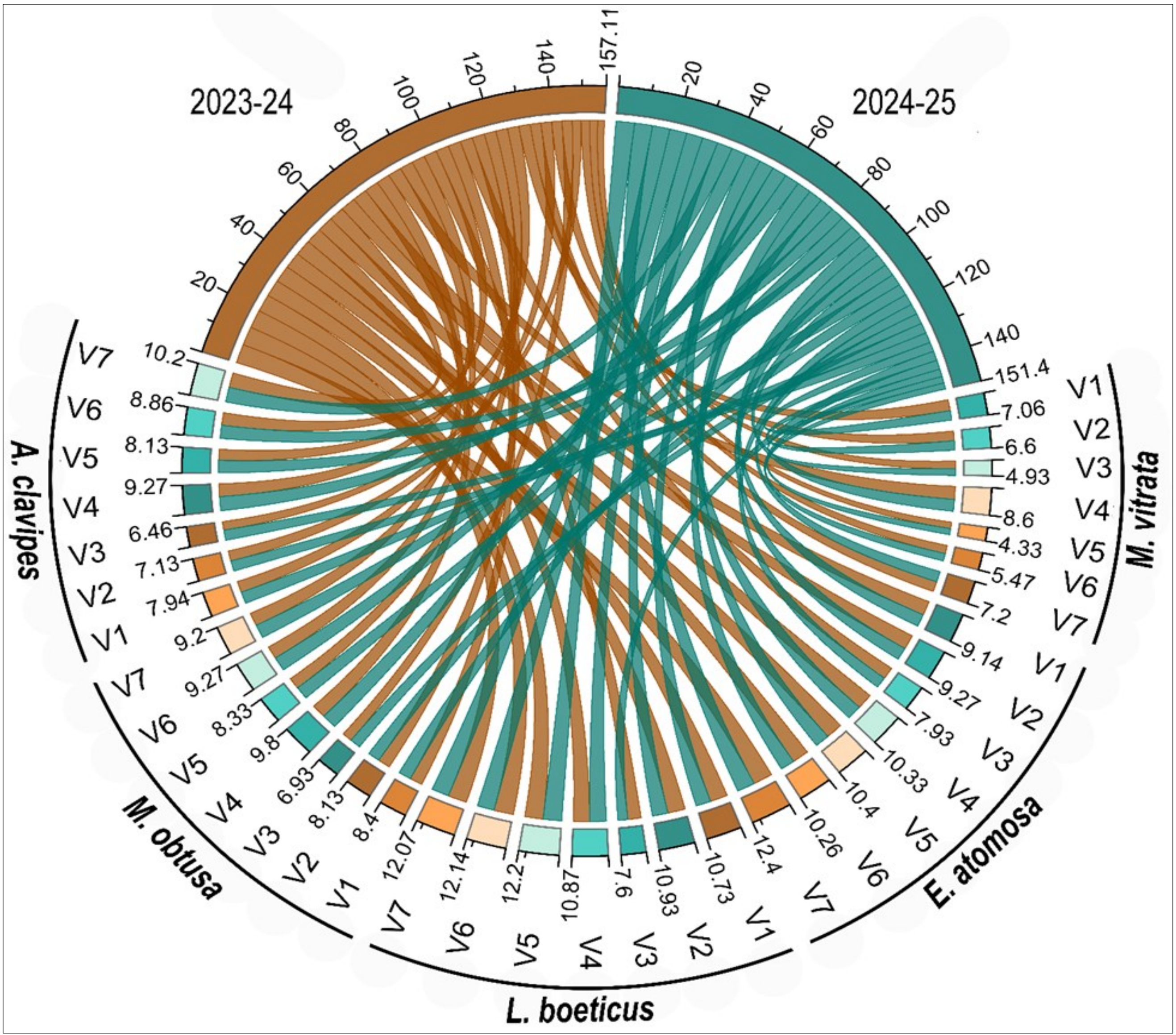

Fig. 2. Chord network representing the connection (links) between the 2023-24 and 2024-25 yearly populations (start nodes) of different pod borers with their population on different red gram cultivars (end nodes).

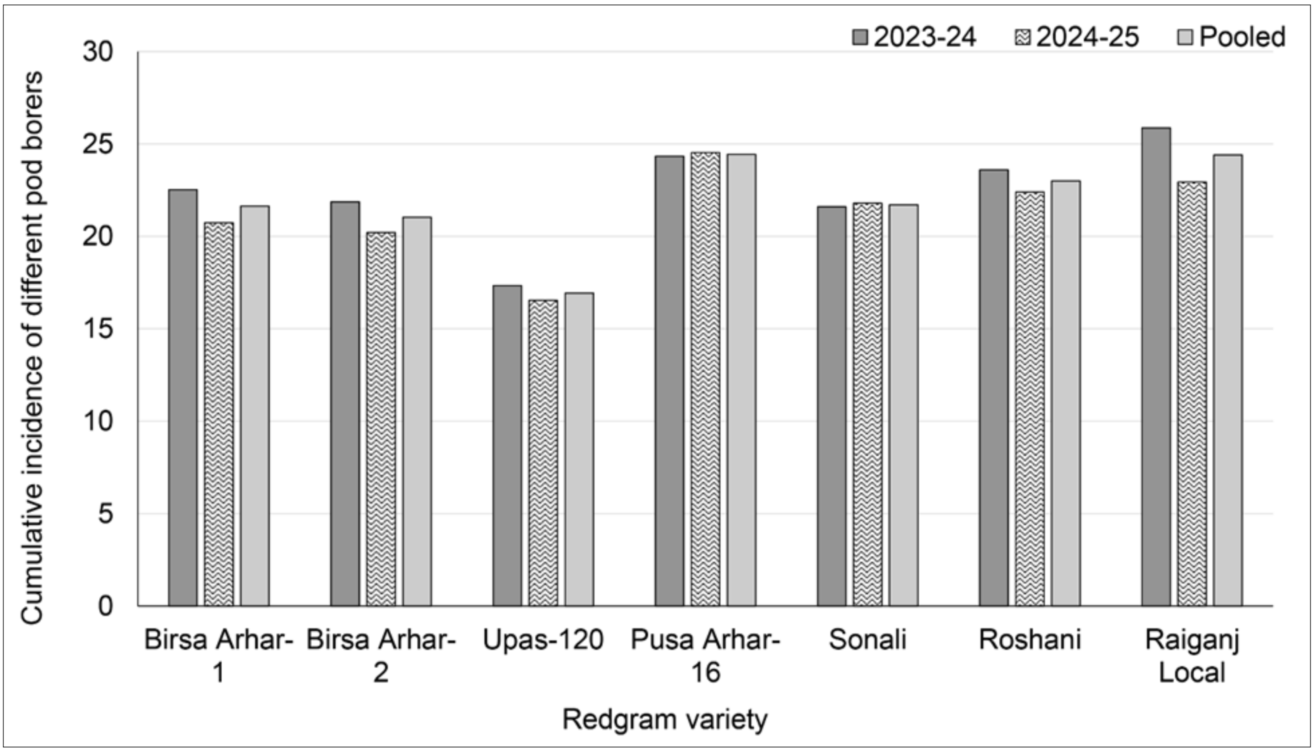

Fig. 3. Cumulative incidence of pod borer complex on different red gram cultivars during the study periods.

complexes (30).

Seasonal occurrence of pod borer complex in different red gram cultivars

In our study, we noted considerable variation in the seasonal occurrence of different pod borers in different red gram cultivars based on their maturity period. As the flowering time of different red gram cultivars were almost similar in both seasons, the occurrence period of the pod borer complex on the cultivars was almost similar in both seasons. In Pusa Arhar-16, which is an early maturing cultivar, pod borer incidence began on the 41st SMW (i.e., mid-October) during both study seasons and ended during the 52nd SMW (i.e., end of December), with the highest population build-up on the 48th-49th SMW. For mid-maturity cultivars, the incidence started on the 43rd SMW (i.e. end of October) and continued up to the 1st SMW of the next year (i.e., 1st week of January), with peak incidence on the 50th–51st SMW. In contrast, for late maturity cultivars, incidence started on the 47th–49th SMW (i.e., end of November to early December) and continued up to the 6th–8th SMW of the next year (i.e., mid- to end-February) and faced peak pod borer incidence during the 4th–6th SMW (Fig. 4, 5). In West Bengal, red gram flowering and fruiting usually take place from November to February, which corresponds to the typical period of pod borer incidence in our study (31).

However, the succession of different pod borers followed an almost similar trend for all the cultivars during both the study years. The incidence was initiated with bean pod borer early in the season for all the cultivars, followed by blue butterfly and plume moth, whereas pod fly and pod weevil arrived later in the season. This succession correlates with the time of flowering and pod formation in the red gram cultivars. Usually, bean pod borer, plume moth and blue butterfly occur in the red gram field during flowering and remain until the crop matures (32). In contrast, pod fly and pod weevil tend to infest the crop later in the season, after pod formation (27). In our study, the bean pod borer had a higher population during the early period of pod borer incidence, whereas pod fly tended to dominate the pod borer community at the later period of incidence, specifically after pod formation. This enumerates the period-specific dominance of different pod borer species. Such an occurrence of *M. vitrata* early in the season and a greater dominance by *M. obtusa* later in the season was also reported by other researchers (26, 33). Another interesting fact is that although in the case of the early and mid-maturing cultivars, bean pod borer remains in the field until harvesting, whereas for late-maturity cultivars, this pest disappeared from the field prior to harvesting. Our data on the seasonal incidence of different pod borers on red gram are almost in corroboration with the findings of other researchers from other parts of the country (33-36). However, certain deviations from earlier reports may be attributed to variation in location, prevailing weather, topography, cultivar differences, etc.

Effect weather factors on the seasonal occurrence of pod borers in red gram

The pattern of seasonal occurrence of an insect pest in a region is defined by the prevailing weather conditions of that region (37). Our study has also recorded the influence of various weather parameters on the seasonal occurrence of different pod borers on red gram. For instance, our correlation study suggested a significantly negative impact of temperature (T_{max}, T_{min} and T_{avg}), evaporation and rainfall on the seasonal occurrence of different pod borers of red gram (Fig. 6). In contrast, RH_{diff}, T_{diff} and BSH are the factors that had a significantly positive influence on their occurrence. This trend in the effect of various weather factors was almost similar for all the pod borers. Moreover, the stepwise regression analysis revealed a 17.8 % contribution (R^2= 0.178, p > 0.05, N=140 number of observations) of the weather parameters to the cumulative pod borer incidence (Table 4). T_{min}, RH_{min} and BSH were the factors that had a significant influence on their incidence. Among them, T_{min} had a negative impact (3.8 % influence), whereas RH_{min} and BSH had a positive impact (0.8 % and 4.2 % influence respectively) on the pod borer occurrence. However, while these factors had statistically significant role, a large portion of the population dynamics is also driven by other, unmeasured factors, like natural enemies, edaphic factors, etc.

As stated above, in this agro-ecological region, red gram flowering and fruiting take place from November to February, when lower temperatures prevail (31). These flowering and fruiting stages are the most appropriate time for infestation by the pod borer complex (38, 39), justifying the observed negative correlation of temperature with their incidence (38, 39). Likewise, as the study was conducted during the winter period, the occurrence of rainfall was very low. Still, rainfall had a significant negative impact on pod borer incidence, which might be due to its ability to cause a catastrophic decrease in insect populations (40). Our data on the influence of different weather parameters on the incidence of different insect pests of pigeon pea are almost in corroboration with the findings of other researchers from different parts of the country (16, 33, 34, 41-43). However, certain variations in our data from the aforesaid variations may be attributed to regional differences in environmental condition.

Yield assessment of different red gram cultivars

Our study has documented a significant (p < 0.001) variation in yield attributes of different red gram cultivars (Table 5). However, the mean yield was at par during both seasons. Among the red gram cultivars, Upas-120 recorded the highest yield (i.e., 85.04 g/m^2). This variety is characterized by a higher number of branches and pods per plant, which coupled with low insect pest incidence, might have contributed to the greater yield (44). On the other hand, the yield was significantly the lowest for Pusa Arhar-16 (i.e., 58.22 g/m^2). This situation directly reflects the effect of pod borer incidence on red gram yield. In addition to that, early-maturity of this cultivar can also lead to its lower yield. However, Pusa Arhar-16 can achieve a yield around 20 q/ha, which was greatly compromised due to insect pest incidence in our study (45). In contrast, Raiganj Local, which was the second most infested cultivar in our study, exhibited a significantly higher yield (i.e., 77.49 g/m^2) which was at par with the yield of Birsa Arhar-2 (i.e., 75.19 g/m^2), showcasing its ability to withstand insect

Table 4. Stepwise multiple regression between the cumulative incidence of pod borers and weather parameters from pooled data

Variable	Regression coefficient	Standard error	t value	Pr > |t|	R^2	Adj. R^2	Root MSE	F value	Pr > F
Intercept	0.063	0.136	0.46	0.643	0.178	0.169	0.281	19.90	< 0.0001
T_{min} (°C)	-0.038	0.005	-7.21	< 0.0001					
RH_{min} (%)	0.008	0.002	3.47	0.0006					
BSH (hr/day)	0.042	0.008	4.89	< 0.0001					

Table 5. Yield (in g/m^2) of different red gram varieties during 2023-24 and 2024-25 using two-factor factorial ANOVA and DNMRT post-hoc test at α = 0.05

Year	Cultivars[a]							Mean
	Birsa Arhar-1	Birsa Arhar-2	Upas-120	Pusa Arhar-16	Sonali	Roshani	Raiganj Local	
2023-24	68.90	76.69	87.55	57.16	70.75	65.68	76.10	71.83[a]
2024-25	71.22	73.69	81.53	59.29	67.20	69.81	78.87	71.80[a]
Mean	70.06[c]	75.19[b]	85.04[a]	58.22[d]	68.97[c]	67.75[c]	77.49[b]	

ANOVA

Source	Df	Sum of square	Mean sum of square	F value	Pr(>F)
Replication	2	2.20	1.10	0.08	0.93
Year	1	0.00	0.00	0.00	0.98
Variety	6	2585.00	430.80	30.22	< 0.001
Year × Variety	6	9.60	1.60	0.11	0.99
Error	26	370.70	14.30		

[a]Means suffixed with different letters are significantly different.

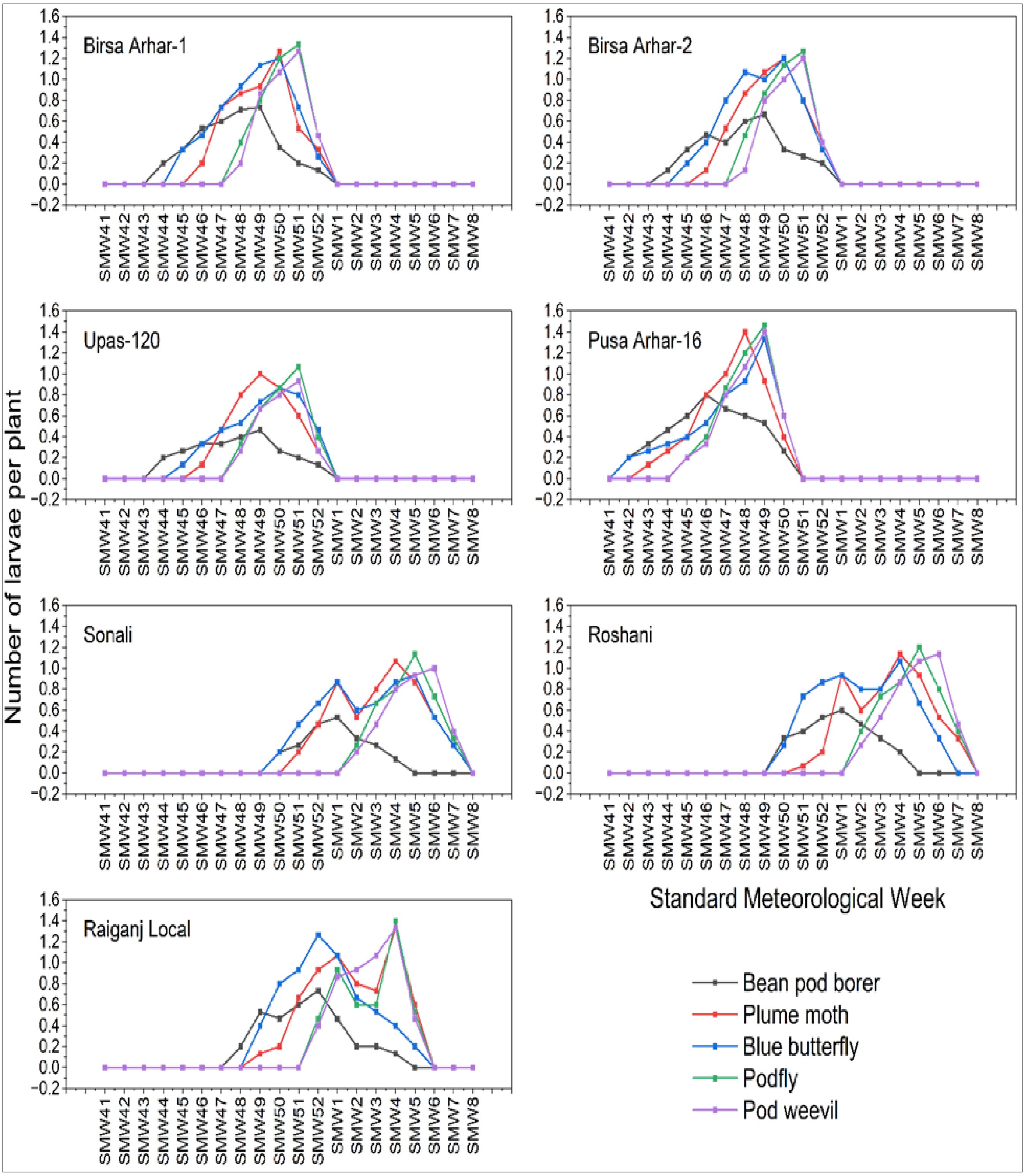

Fig. 4. Population dynamics of different pod borers on different red gram cultivars during 2023-2024.

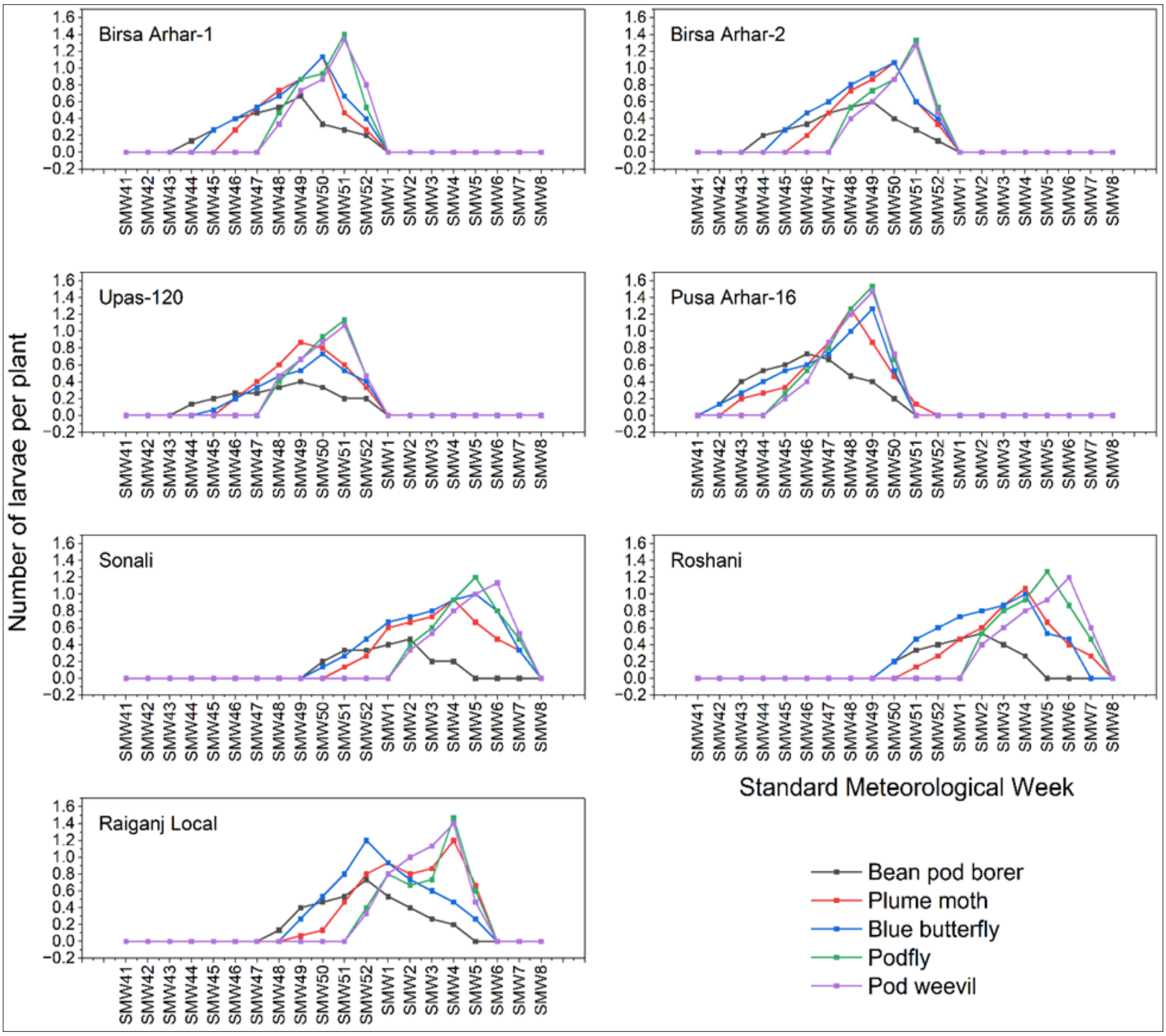

Fig. 5. Population dynamics of different pod borers on different red gram cultivars during 2024-2025.

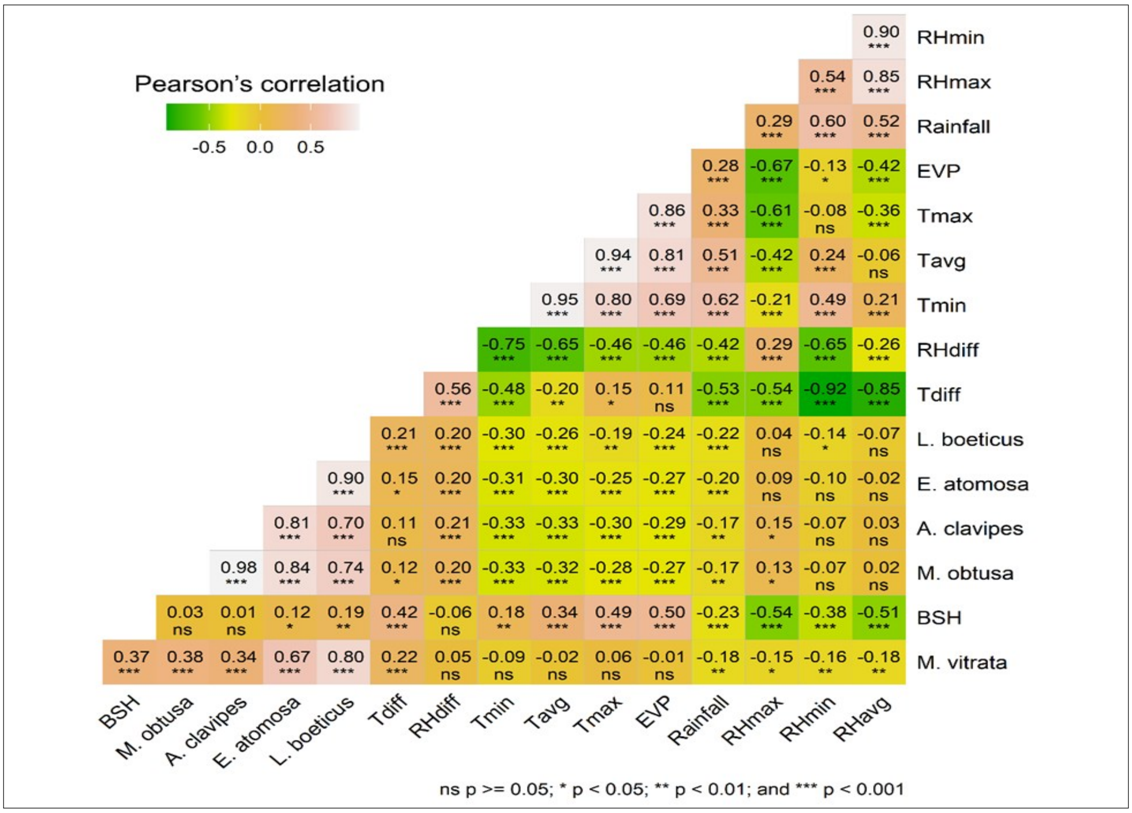

Fig. 6. Pearson's correlation of different weather parameters with the population of different pod borers from pooled data of two seasons.

pest incidence. Raiganj Local is an indigenous cultivar of this region and is highly adapted to the local climatic conditions, which may justify its resilience against pod borer incidence.

Conclusion

Knowledge on the seasonal occurrence of insect pests in an agro-climatic region is of utmost importance for developing an appropriate pest management schedule for that particular situation. On the other hand, varietal screening is essential to identify the most suitable variety that can provide higher yields with minimized insect pest incidence. Our study combined these two aspects, providing valuable insights into the seasonal occurrence of the pod borer complex on different red gram cultivars under the Terai agro-climatic zone of West Bengal. Our study suggests that Upas-120 could be the most promising cultivar of red gram in the region under consideration, as it not only faced a reduced insect pest incidence but also provided a greater yield under this situation. In addition to Upas-120, the Raiganj Local cultivar could also be a suitable variety for this region because of its ability to produce satisfactory yields despite experiencing higher pest incidence. Being an indigenous cultivar, Raiganj Local can acclimatize well to the area conditions and may be readily accepted by the local farmers. Furthermore, its resilience to local pests and diseases makes it a promising option for sustainable agriculture practices. By adopting Raiganj Local, farmers may not only enhance their productivity but also contribute to the preservation of biodiversity in their farming systems. Moreover, our study also indicates variation in the incidence pattern of different insect pests in different red gram cultivars. However, all the cultivars were highly prone to pod borer incidence during flowering and pod formation stages, showcasing the optimal time period for the initiation of pest management approaches.

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Authors' contributions

SKS[1] carried out the field observation. RN assisted in the field observation and identification of specimens. BK supplied the seed materials required for the study. NC conceived and designed the study and wrote the manuscript. JG supervised the study and supplied the materials required. AG performed the statistical analyses. SKS[2] supervised the study. SS wrote the manuscript, performed the data analyses, data visualization and revised the manuscript. All authors read and approved the final manuscript [SKS[1] stands for Subham Kumar Sarkar and SKS[2] for Sabita Kumar Senapati].

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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