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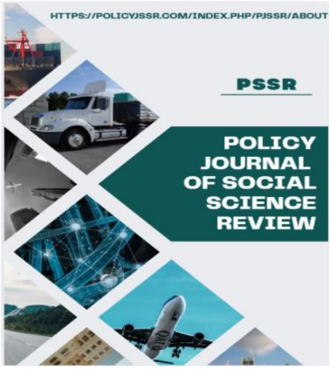

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POPULATION DYNAMICS AND INFESTATION PATTERNS OF MAJOR INSECT PESTS OF MAIZE IN RELATION TO ABIOTIC FACTORS

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ABSTRACT

Maize is a strategic cereal crop, but its productivity is reduced by recurring infestations of stem borers, fall armyworm and aphids. A field study was conducted at the Hazara Agriculture Research Station, Haripur, during the kharif season of 2024 to document the seasonal occurrence of Chilo partellus, Spodoptera frugiperda and Rhopalosiphum maidis and to examine their relationships with weather variables and selected natural enemies. Weekly observations were taken from crop establishment until maturity from replicated maize plots. Stem borer and fall armyworm damage were recorded as percentage damaged or infested plants, whereas aphids were counted as individuals per leaf. Weather variables included maximum and minimum temperature, morning and evening relative humidity, sunshine hours and rainfall. Stem borer appeared during the 29th standard meteorological week and reached a peak of 27.5% damaged plants during the 31st week. Fall armyworm also initiated during the 29th week and reached the highest infestation of 45.0% during the 31st week. Maize aphid appeared later, during the 33rd week, and peaked at 5.61 aphids per leaf during the 37th week. Minimum temperature and sunshine hours were positively associated with stem borer and fall armyworm incidence, while maximum temperature was positively associated with fall armyworm. Rainfall was negatively associated with aphid abundance. Aphid abundance increased together with spiders and ladybird beetles, while carabid larvae followed fall armyworm occurrence. These results show that pest pressure in Haripur maize is highly seasonal and weather sensitive. Timely scouting around the 29th to 37th standard meteorological weeks can support location-specific integrated pest management decisions.

Keywords: Zea mays; Chilo partellus; Spodoptera frugiperda; Rhopalosiphum maidis; weather factors; natural enemies; IPM

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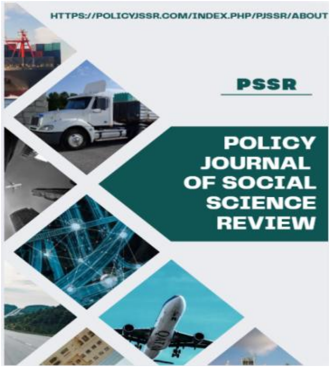

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1. Introduction

Maize (Zea mays L.) is one of the three dominant global cereals, together with wheat and rice, and it contributes directly to food, feed and industrial raw material systems. FAOSTAT production records show the continuing global importance of these cereals, while regional production systems in Pakistan remain exposed to biotic stress under rainfed and irrigated ecologies (FAO, 2025). In the Hazara region of Khyber Pakhtunkhwa, maize is widely grown during the kharif season and is vulnerable to early vegetative and reproductive-stage insect attack. The local pest complex includes borers, armyworms, aphids and defoliators, with field surveys in nearby Mansehra confirming the presence of diverse maize-associated insect fauna (Khan et al., 2022).

The spotted stem borer, Chilo partellus, is one of the most damaging lepidopteran pests of maize and other cereals in South Asia and Africa. Larvae injure leaves, bore into stems, produce dead hearts and reduce the transport of assimilates to developing ears. Earlier work on cereal stem borers has shown that population development is strongly conditioned by host stage, temperature, natural enemies and the synchrony between crop growth and larval feeding windows (Kfir et al., 2002). In the upper Himalayan region, C. partellus catches and infestation have been reported to vary strongly across meteorological weeks, indicating that local weather is central to outbreak prediction (Ahad et al., 2008).

Fall armyworm, Spodoptera frugiperda, has become an additional threat to maize systems because of its migratory ability, broad host range and high reproductive potential. The pest was reported as an invasive species in West and Central Africa in 2016 (Goergen et al., 2016), and subsequent risk modelling suggested that many tropical and subtropical maize-growing regions are climatically suitable for establishment or recurrent invasion (Early et al., 2018). Reviews and impact assessments show that unmanaged fall armyworm infestations can cause substantial yield losses, although damage varies with crop stage, larval density, agronomic conditions and management timing (Day et al., 2017; Overton et al., 2021).

Maize aphid, Rhopalosiphum maidis, is generally considered a sucking pest but can become economically relevant when colonies develop rapidly on leaves, whorls and tassels. Aphid outbreaks are shaped by temperature, humidity, rainfall, plant nutritional condition and predation pressure. Insect responses to weather are biologically plausible because temperature affects development rate and survival, while rainfall can either create favorable crop microclimates or physically dislodge soft-bodied insects such as aphids (Bale et

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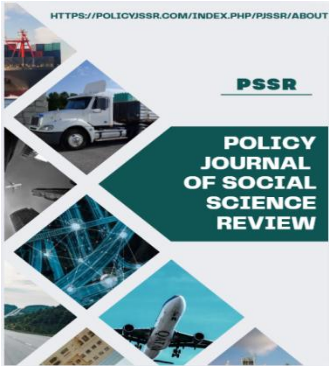

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al., 2002). Understanding these relationships is especially important under changing climate patterns, where pest phenology may shift and conventional calendar-based sprays become less reliable.

Integrated pest management in maize requires decisions based on local surveillance rather than routine pesticide use. Economic thresholds, timely scouting and conservation of predators are core principles of IPM (Pedigo et al., 1986). Habitat-based biological control research also demonstrates that spiders, ladybird beetles, carabids and other natural enemies can suppress pest populations when pesticide disturbance is minimized (Landis et al., 2000; Bianchi et al., 2006). Fall armyworm management guides similarly stress field monitoring, crop hygiene, biological control and careful insecticide selection (Prasanna et al., 2018; Hruska, 2019; Harrison et al., 2019; Tepa-Yotto et al., 2022).

Despite general knowledge on maize pests, location-specific pest calendars are still limited for Haripur. The present study was therefore conducted to determine the seasonal dynamics of C. partellus, S. frugiperda and R. maidis at the Hazara Agriculture Research Station and to relate pest incidence to abiotic weather variables and natural enemies. The objective was to generate practical baseline information for early warning, scouting schedules and IPM recommendations for maize growers in the Hazara agro-ecological zone.

2. Materials and methods

The field experiment was conducted during the 2024 *kharif* season at the Hazara Agriculture Research Station in Haripur, Pakistan (33.99°N, 72.93°E; 520 m a.s.l.), a subtropical region with monsoon rains from July to August. Maize variety Islamabad was sown in 10 m × 8 m plots with 75 cm row and 20 cm plant spacing, using standard agronomic practices and fertilizer at 120:80:60 kg ha^{-1} N:P_2O_5 :K_2O. Arranged in a randomized complete block design with three replications and no insecticidal treatment to observe natural pest dynamics, the study monitored pests and natural enemies weekly from emergence to maturity by randomly selecting twenty plants per plot to assess *Chilo partellus* (dead hearts, tunneling, shot holes, exit holes) and *Spodoptera frugiperda* (egg masses, larvae, leaf damage), while *Rhopalosiphum maidis* was counted on ten plants per plot, and natural enemies like spiders, ladybird beetles, and carabid larvae were recorded per plant. Daily weather data (max/min temperature, morning/evening relative humidity, sunshine hours, rainfall) from the station were summarized weekly, and Pearson correlations were computed to relate pest incidence to abiotic factors and natural enemy populations, with significance at p ≤

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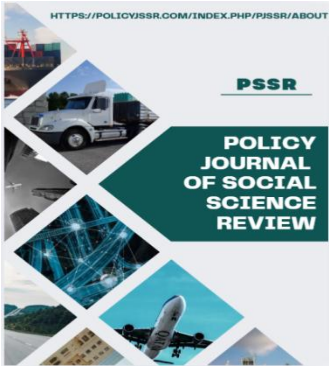

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0.05 and p ≤ 0.01, while emphasizing that percent data from single-season observations require cautious interpretation and multi-year validation before predictive modeling.

3. Results

3.1 Seasonal incidence of maize stem borer

Stem borer damage began during the 29th standard meteorological week with 7.5% damaged plants. Damage increased sharply over the next two weeks and reached the seasonal maximum of 27.5% damaged plants during the 31st week. After this peak, infestation declined gradually from 25.0% in the 32nd week to 10.0% in the 38th week. This trend indicates that the early vegetative stage was the most vulnerable period for stem borer injury under Haripur conditions.

Table 1

Weekly population trend of maize stem borer (Chilo partellus)

SMW	% damaged plants	Mean +/- SE
29	7.5	7.5 +/- 0.8
30	18.5	18.5 +/- 1.2
31	27.5	27.5 +/- 1.5
32	25.0	25.0 +/- 1.3
33	22.5	22.5 +/- 1.1
34	20.0	20.0 +/- 1.0
35	17.5	17.5 +/- 0.9
36	15.0	15.0 +/- 0.8
37	12.5	12.5 +/- 0.7
38	10.0	10.0 +/- 0.6

Note. SMW = standard meteorological week.

3.2 Seasonal incidence of fall armyworm

Fall armyworm infestation appeared in the 29th standard meteorological week at 15.0% infested plants. Infestation increased rapidly and reached 45.0% during the 31st week. The population remained high during the 32nd and 33rd weeks, with 42.5% and 38.5% infestation, respectively, before declining to 15.0% by the 38th week. The fall armyworm peak coincided with the stem borer peak, showing that early to mid-vegetative maize required the most intensive scouting.

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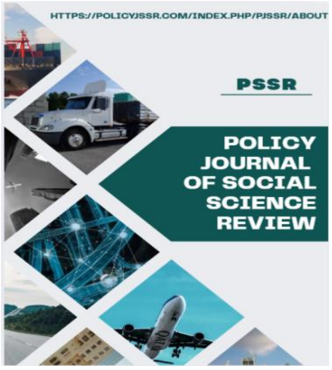

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Table 2

Weekly population trend of fall armyworm (Spodoptera frugiperda)

SMW	% infestation	Mean +/- SE
29	15.0	15.0 +/- 1.0
30	32.5	32.5 +/- 1.4
31	45.0	45.0 +/- 1.6
32	42.5	42.5 +/- 1.5
33	38.5	38.5 +/- 1.3
34	35.0	35.0 +/- 1.2
35	25.0	25.0 +/- 1.1
36	20.0	20.0 +/- 1.0
37	17.5	17.5 +/- 0.9
38	15.0	15.0 +/- 0.8

Note. Values indicate plants showing typical fall armyworm damage symptoms.

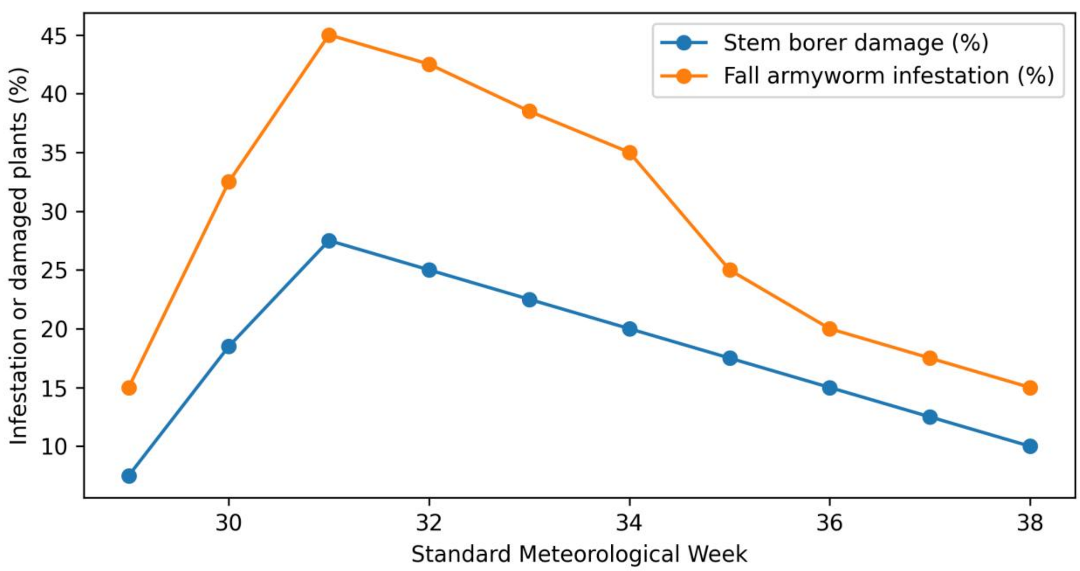

Figure 1. Seasonal infestation trends of maize stem borer and fall armyworm at HARS, Haripur during kharif 2024.

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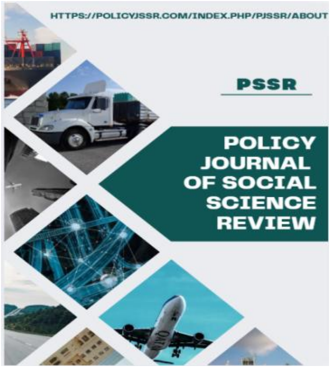

3.3 Seasonal abundance of maize aphid

Aphid incidence was detected later than the lepidopteran pests. The population was first recorded during the 33rd standard meteorological week at 2.80 aphids per leaf. Aphid numbers rose steadily and reached a maximum of 5.61 aphids per leaf during the 37th week. A gradual decline was then recorded, with the population falling to 3.20 aphids per leaf by the 40th week. The delayed aphid peak suggests that aphid scouting should be emphasized during later vegetative and reproductive crop stages.

Table 3. Weekly population trend of maize aphid (Rhopalosiphum maidis)

SMW	Aphids per leaf	Mean +/- SE
33	2.80	2.80 +/- 0.3
34	3.50	3.50 +/- 0.4
35	4.20	4.20 +/- 0.5
36	5.10	5.10 +/- 0.5
37	5.61	5.61 +/- 0.6
38	5.00	5.00 +/- 0.5
39	4.30	4.30 +/- 0.4
40	3.20	3.20 +/- 0.3

Note. Aphid values are expressed as mean number per leaf.

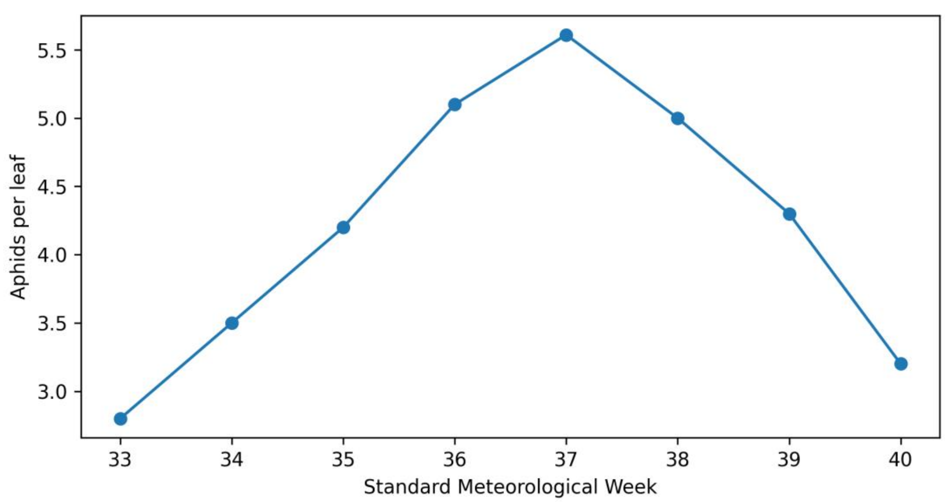

Figure 2. Seasonal population dynamics of maize aphid at HARS, Haripur during kharif 2024.

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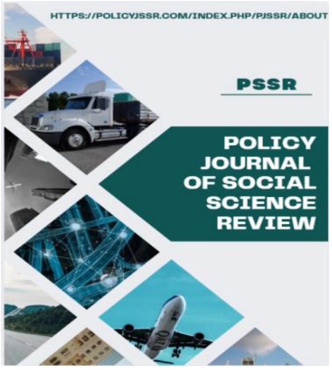

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3.4 Natural enemy occurrence

Natural enemies were present throughout the observation period but their peaks differed among groups. Spiders reached the highest recorded density of 0.85 per plant during the 38th week. Ladybird beetles reached 1.00 per plant during the same week, coinciding with the late aphid peak. Carabid larvae reached 0.25 per plant during the 32nd week, one week after the fall armyworm peak. The timing of these peaks indicates a numerical response of predators to prey availability.

Table 4

Peak occurrence of major natural enemies in maize

Natural enemy	Peak population	Peak SMW	Associated pest
Spiders	0.85 per plant	38	Aphids
Ladybird beetles	1.00 per plant	38	Aphids
Carabid larvae	0.25 per plant	32	Fall armyworm

Note. These peak values summarize the highest weekly abundance observed during the season.

3.5 Relationship between pests and weather variables

Correlation analysis showed distinct weather responses among pest species. Stem borer was positively and significantly associated with minimum temperature, morning relative humidity and sunshine hours. Fall armyworm was positively associated with maximum temperature, minimum temperature, evening relative humidity, sunshine hours and rainfall. Aphid abundance was positively associated with minimum temperature and morning relative humidity, but negatively associated with maximum temperature and rainfall. The negative rainfall association for aphids suggests that rainfall may suppress colonies through direct wash-off or unfavorable leaf-surface conditions.

Table 5

Correlation coefficients between maize pests and weather parameters

Weather parameter	Stem borer r	Fall armyworm r	Aphid r
Maximum temperature	-0.62 NS	0.69*	-0.64*
Minimum temperature	0.68*	0.58*	0.74*
Morning RH	0.56*	0.42 NS	0.62*
Evening RH	0.45 NS	0.51*	0.48 NS
Sunshine hours	0.71*	0.65*	0.32 NS
Total rainfall	0.23 NS	0.61*	-0.58*

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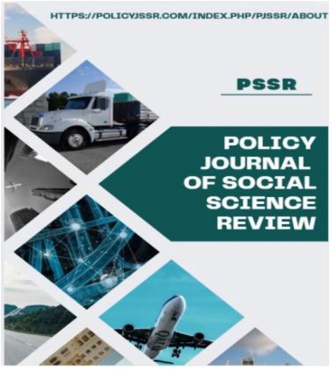

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*Note. * = significant at p <= 0.05; NS = non-significant.*

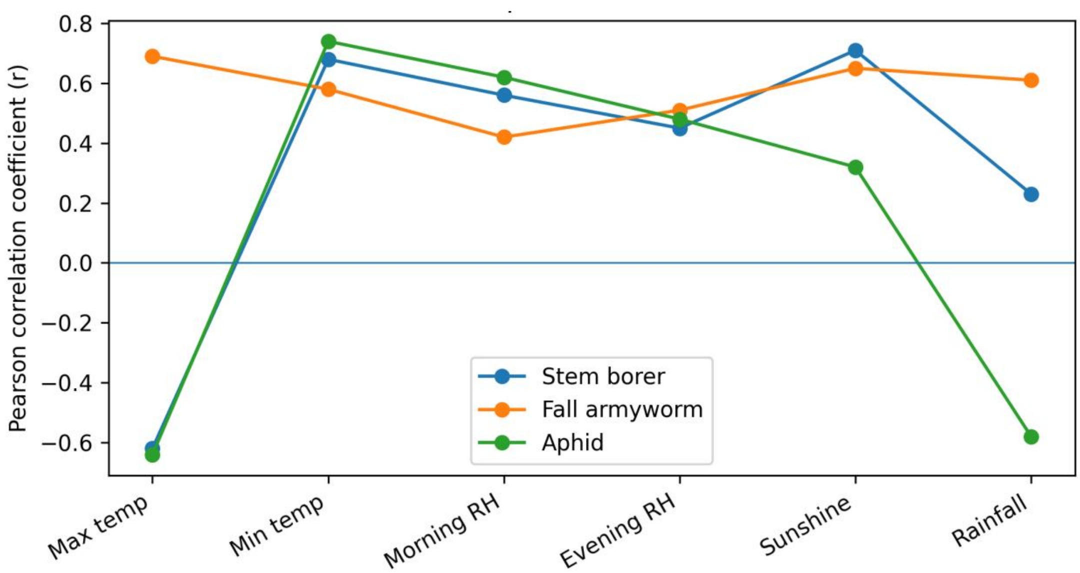

Figure 3. Comparative correlation pattern between pest incidence and abiotic factors.

3.6 Relationship between pests and natural enemies

Aphid population showed a highly positive relationship with spiders and ladybird beetles, and fall armyworm showed a positive relationship with carabid larvae. The predator peaks lagged slightly behind pest peaks, which is expected in field systems where natural enemies respond numerically after prey populations increase. These results support the conservation of generalist and specialist predators as part of local maize IPM.

4. Discussion

The pest calendar recorded in this study demonstrates that maize pest risk at Haripur is not uniform across the season. Stem borer and fall armyworm both appeared early and reached maximum levels in the 31st standard meteorological week. This early concentration of lepidopteran injury is consistent with the biology of stem borers and fall armyworm, whose larvae exploit young plants and whorl tissues. Similar week-based population variation has been reported for maize stem borer in the upper Himalayas (Ahad et al., 2008), and the documented diversity of maize pests in Mansehra supports the need for district-level surveillance in the Hazara region (Khan et al., 2022).

Fall armyworm infestation was higher than stem borer infestation during most

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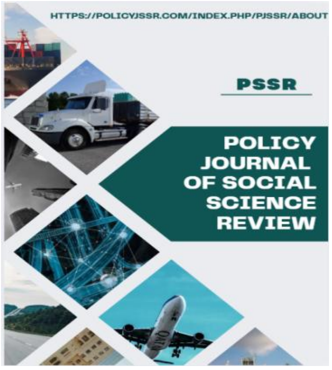

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overlapping weeks, which reflects the aggressive whorl-feeding behavior and rapid population build-up of S. frugiperda. The invasive status, broad host use and strong dispersal capacity of fall armyworm have been emphasized by Goergen et al. (2016), Montezano et al. (2018) and Kenis et al. (2023). In practical terms, the 45.0% peak observed during the 31st week indicates that maize growers should not wait until visible injury spreads across the field before starting scouting. Field inspection should begin soon after establishment, and management decisions should be based on larval stage and plant injury rather than calendar sprays alone.

The weather associations support the use of meteorological information as an early warning tool. Minimum temperature and sunshine hours were positively related to stem borer and fall armyworm, indicating favorable development and feeding conditions during warm, bright weeks. The positive association between maximum temperature and fall armyworm is consistent with the general thermal sensitivity of insect development, although very high temperatures may become inhibitory at upper thresholds. Climate-based forecasting studies have shown that fall armyworm establishment and seasonal pressure are strongly linked to environmental suitability (Early et al., 2018; Bale et al., 2002).

Aphid dynamics differed from the lepidopteran pests. Aphid population appeared later and peaked during the 37th week, when plant canopy structure and microclimate likely became more favorable for colony development. Rainfall showed a significant negative association with aphids, which is biologically plausible because rain can dislodge aphids and reduce colony survival. In contrast, morning relative humidity and minimum temperature favored aphid presence. These relationships mean that aphid risk in Haripur maize should be monitored during humid late-season periods, especially after dry intervals that allow colonies to establish.

The natural enemy pattern strengthens the case for conservation biological control. Spiders and ladybird beetles peaked alongside aphids, whereas carabid larvae increased around the fall armyworm peak. Natural enemy conservation is a core part of IPM because generalist predators can reduce pest population growth and delay the need for insecticide intervention (Landis et al., 2000; Bianchi et al., 2006). However, predator abundance alone does not prove complete biological control. Predator-prey correlations may also reflect predators aggregating where prey are abundant. Therefore, future studies should include exclusion cages or predator manipulation to quantify actual suppression.

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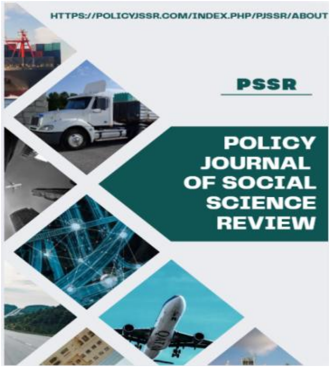

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The results have immediate management implications. The 29th to 32nd weeks should be considered the critical scouting period for stem borer and fall armyworm, while the 33rd to 38th weeks should receive greater attention for aphids and their natural enemies. Economic threshold theory shows that intervention should occur before injury exceeds the economic injury level, not after field-wide damage is already visible (Pedigo et al., 1986). For fall armyworm, the literature also supports combining field monitoring, cultural practices, biological control, resistant germplasm where available and cautious use of selective insecticides (Prasanna et al., 2018; Hruska, 2019; Harrison et al., 2019; Tepa-Yotto et al., 2022).

A limitation of the present manuscript is that it reports one season from one research station. Weather-pest associations from a single season can be useful for local planning but should not be treated as final prediction equations. Multi-year datasets are required to separate stable ecological relationships from season-specific coincidences. Still, the study provides a baseline pest calendar for Haripur and identifies practical scouting windows that can be tested in farmer fields.

5. Conclusion

Major maize pests at HARS, Haripur showed clear seasonal patterns during kharif 2024. Stem borer and fall armyworm appeared during the 29th standard meteorological week and peaked during the 31st week, while maize aphid appeared during the 33rd week and peaked during the 37th week. Minimum temperature and sunshine hours favored stem borer and fall armyworm, maximum temperature favored fall armyworm, and rainfall suppressed aphid population. Predator occurrence followed pest abundance, especially aphids with spiders and ladybird beetles. The study supports a weather-informed IPM calendar in which early-season scouting targets stem borer and fall armyworm, while late-season scouting targets aphids and predator conservation. Multi-year validation is recommended before converting these associations into formal predictive models.

Declarations

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Conflict of interest: The author declares no conflict of interest.

Ethics statement: This study involved field observations and agronomic trials only; therefore, human or animal ethics approval was not applicable.

Data availability: The numerical data used for tables and figures are presented within

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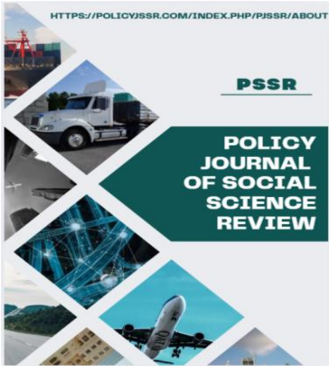

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the manuscript. Additional raw field sheets should be retained by the author for journal review, if requested.

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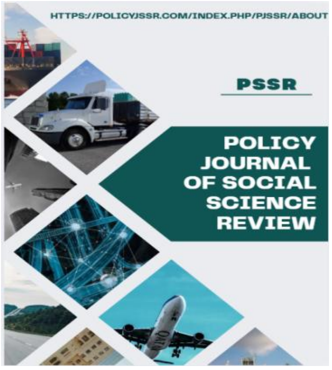

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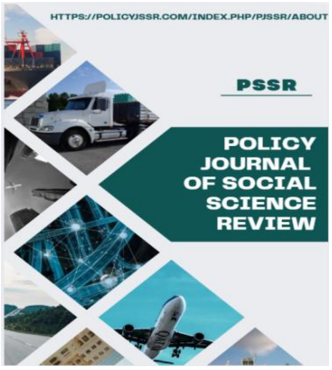

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