Research Article:

LABORATORY AND FIELD SCREENING OF MAIZE VARIETIES AGAINST FALL ARMYWORM, *Spodoptera frugiperda* (J. E. Smith, 1797) (LEPIDOPTERA: NOCTUIDAE), AT GORKHA, NEPAL

Chiran Adhikari[a*], Sundar Tiwari[a], Resham Bahadur Thapa[a], Saraswati Neupane[b] and Sheela Devi Sharma[b]

[a]Faculty of Agriculture, Agriculture and Forestry University, Rampur, Chitwan, Nepal

[b]Nepal Agricultural Research Council, Rampur, Chitwan, Nepal

*Corresponding author: cadhikari@afu.edu.np

Received date: 31 July 2024, Accepted date: 12 September 2024

DOI: https://doi.org/10.3126/jafu.v6i1.78160

ABSTRACT

There are several production constraints in maize cultivation in Nepal, and fall armyworm (*Spodoptera frugiperda* J. E. Smith, 1797) is considered one. Fall armyworm (FAW) is an invasive, polyphagous, and voracious agricultural pest in maize crops. The current study aimed to understand the host plant selection behavior of the fall armyworm on different popular maize varieties in lab and field conditions. The lab experiment (choice test) was conducted at the Department of Entomology, AFU, in June 2022. Cohorts of fifteen third-instar larvae were used for laboratory bioassay in a Completely Randomized Design (CRD) with ten replications. Ten different maize varieties (7 open-pollinated varieties and 3 hybrids) represent treatments at both conditions, which are popular and recommended in Nepal. The number of larvae settled on each maize variety was counted at 1 hour, 4 hours, 12 hours, and 24 hours after larvae were released. The results showed that the selection of maize genotype by fall armyworm larvae was initially random. However, at the end of the experiment, there was a significant difference in the settlement of FAW larvae among the varieties. The larvae settled on different maize genotypes of their preference. Rampur Hybrid- 12 was least preferred whereas Posilo Makai-1, Rampur Composite, Arun- 4, and Manakamana- 7 were more preferred by FAW. The field experiment was conducted in 2022 in Gorkha, Nepal. The experiment was carried out in Randomized Complete Block Design (RCBD) with ten treatments, which were replicated three times. The data were collected at every 10-day interval after 20DAS (V4 stage). Based on the percent plant infestation with live larvae and the intensity of foliar damage, Rampur Hybrid- 12, Deuti, and Manakamana- 3 were comparatively less attracted toward FAW. In contrast to that, Manakamana- 7, Rampur Hybrid- 16, Rampur Composite, Arun-4, and Arun- 2 were found to be more prone to fall armyworm attacks. Not all varieties are equally susceptible to FAW damage. These findings have important implications for understanding the range of preference by FAW on different maize varieties.

Key words: Cohorts, DAS, instar, preference test, tolerance

INTRODUCTION

In Nepal, maize (*Zea mays*) is the second most important crop among cereals in terms of area (9,85,565 ha) and production (31,06,397 Mt) with 3.15 t/ha productivity after rice, which shares almost 29% of the total area and 27% of the total production of cereal crops in 2021/22 (MoALD, 2023). Maize production is affected by insect pests and diseases with major loss of fall armyworm (Ranum et al., 2014). Fall armyworm (*Spodoptera frugiperda*) is a polyphagous and more devastating agricultural pest but prefers maize and sweetcorn (Montezano et al., 2018; Sparks, 1979). In Nepal, this pest was first noticed in Gaidakot, Nawalpur district, on the 9th

of May 2019 (Bajracharya et al., 2019). Now, this pest has spread to more than 72 districts of Nepal with a loss of 20-35% (PQPMC, 2019). The larval stage of this species feeds on growing maize leaves, forming elongated papery windows and moving to whorl with moist sawdust-like frass near the funnel and upper leaves (CABI, 2017). This pest has unique morphological features in larval and adult stages, as the larva contains a white inverted 'Y' on the head, distinct black spots on the body, and four "dots" that form a rectangular shape on the eighth abdominal segment of the larval abdomen (Kalleshwaraswamy et al., 2018). This has a wider host range and prefers many categories of crops. Some crops/hosts are more favored, and some are the least preferred. Such a preference ability of FAW in the different hosts is influenced by chemical (Olfactory or gustatory) or physical (tactile or visual) stimuli (Shelton & Badenes-Perez, 2006). An understanding of the host preference of fall armyworm larvae helps to develop a non-chemical pest management strategy. These strategies can be employed to develop tolerance varieties of maize against fall armyworms.

Pesticidal management is the common practice of FAW management in Nepal (GC et al., 2019), but such pesticides increase the resistance to the FAW population (Yu, 1991) they have deleterious effects on humans and the environment (Lewis et al., 2016). The use of sole synthetic insecticides is undesirable in the integrated pest management (IPM) program (Day et al., 2017). A reliable, durable, safe, environmentally friendly, and cost-effective breeding strategy involving native host plant resistance (HPR) offers a potential control measure among all pest management programs against FAW and other insect attacks in crops (Sharma & Ortiz, 2002). Resistant maize cultivars play an important role in minimizing the use of pesticides, helping in reconstructing natural balance, and aiding in the movement of bio-control agents (Anuradha, 2012; Hafeez & Zia, 2009; Jindal & Hari, 2008; Vishvendra et al., 2017). Varieties and cultivars with a high ability to resist and tolerate insect-pest prevalence can play a major role in maize breeding programs and the economic value of various pest management measures (Anuradha, 2012; Yonow et al., 2017). Therefore, the main aim of these experiments was to study the host preferences of FAW larvae by screening maize varieties.

MATERIALS AND METHODS

Laboratory Experiment

Preparation of maize cultivars for choice study

The experiment was carried out in the Entomology Laboratory of Agriculture and Forestry University, Rampur, Chitwan, Nepal (27.650407^0 N, 84.350143^0 E, and 228 masl) in June 2022. Ten different released maize varieties (Table 1) were collected from the National Maize Research Programme (NMRP), Rampur, Chitwan, for the preference study (choice test). The plants were grown in pots (25 cm diameter × 30 cm height), which were filled with a soil mix of 4 kg (The composition of black soil, compost, and sand at a proportion of 2:1:1) and watered at three-day intervals. Five seeds of each variety were placed in each pot for regular obtain of fresh leaves for the choice study. Pots were placed in the open corridor at the Department of Entomology. There was one pot for a single variety, so there were altogether ten pots for growing ten different maize varieties.

Colony management

The fall armyworm eggs were collected along with the maize leaves from a nearby pesticide-free maize field and placed in normal aerated polythene bags, which were taken to the Entomology Laboratory. Egg masses were then kept in the white transparent plastic box (19.00 cm × 12.50 cm × 7.50 cm) and placed inside the bug dorm (24.5 × 24.5 × 24.5 cm). After the hatching of eggs, fresh maize chopped leaves (Variety: Rajkumar) were continuously supplied to larvae. Similarly, each day, leaves with fall armyworm larvae were transferred to another new box (size same as above) and gently brushed with a fine hair brush. A similar process was continued until the emergence of third-stage larvae (cohorts). The third instar stage is larger than the second instar stage, with a body length ranging from 5.1 – 7.8 mm and a head capsule width ranging from 1.0 – 1.3 mm (n=140). The dorsal surface of the body is brownish-green with the appearance of white lines extending along the body (Kasige et al., 2022). Before the commencement of the laboratory experiment, larvae were kept at starvation for 24 hours.

Table 1. Different maize varieties used in the fall armyworm choice test

Name of maize variety	Certification year B.S.(A.D.)	Days to maturity	Recommended geographical location	Hybrid/ OPV
Rampur Composite	2032 (1975)	110-115	Terai, Inner Terai & mid hills	OPV
Arun-2	2039(1981)	80-90	Terai, inner terai & foot hill (<1000m)	OPV
Rampur Hybrid-12	2078(2022)	160-165(winter) 120-150(spring)	Terai & inner terai foot hills (<700masl)	Hybrid
Manakamana-3	2059(2002)	142	Mid hill of E, C & W Development Region (1000-1700 masl)	OPV
Arun-4	2072(2015)	113-115	Eastern terai, inner terai & mid hills of mid-western region	OPV
Rampur Hybrid-14	2078(2022)	155-170(winter) 120-145(spring)	Terai & inner terai foot hills (<1000masl)	Hybrid
Rampur Hybrid-16	2078(2022)	160-175(winter) 125-150(spring)	Terai & inner terai foot hills (<1000masl)	Hybrid
Manakamana-7	2074(2018)	158	Mid hills (700-1600 masl)	OPV
Posilo Makai-1	2065(2008)	145-155	E-W mid hill below 1600 masl	OPV
Deuti	2063(2006)	130-135	Mid-hills	OPV

(MoALD, 2023)

Host preference (choice test) study

Maize leaves of ten different varieties were collected from potted plants of age 25 days with 4 to 6 fully developed leaves separately and made pieces of equal length of 10 cm with the help of sterilized scissors. Three leaf pieces of each variety were taken and placed at the bottom of the round plastic bucket (15 cm diameter × 10 cm height) equidistant from the center of the bucket around the perimeter. Freshly cut leaves were used for feeding the worms each day. Cohorts of third-instar larvae were used for laboratory experiments. Fifteen 3rd instar larvae were released at the center of each round bucket and covered by transparent muslin cloth from the top to prevent escape. The laboratory experiment was carried out in a Completely Randomized Design (CRD) with ten treatments which were replicated ten times. The numbers of larval settlements on each maize cultivar were observed in 1 hour, 4 hours, 12 hours, and 24 hours of experiment setup.

Field Experiment

A field experiment was set up in the Gorkha district of Nepal (28.050691^0 N, 84.485242^0 E, and 448 masl) in March- July 2022. The soil type of the field was clay loam and received an average annual rainfall of 1491.5 mm. This location was situated under mid-hill conditions having sub-tropical to temperate climates. Ten different cultivars of maize (Table 1) were selected for study. The plot size for each maize cultivar was $4x3m^2$, having 4 rows with 20 plants in each row, and this was replicated three times using Completely Random Block Design (RCBD). Row-to-row and plant-to-plant distance was 75X20 cm^2. The normal agricultural practices, such as planting, weeding, and fertilizer application, were done as per the recommendation by NMRP, Rampur, Chitwan, Nepal. Data were collected from the middle two rows of all the plots. The FAW infestations as well as the FAW population, were assessed from maize planting to harvesting. The first observation was initiated when the crop coincided with the 21-day-old (V4 stage). Observations were made on the number of total plant stands, number of infected plants, and number of live larvae. The presence or absence of foliar damage on the upper four leaves and whorl were recorded. The data was collected every 10-day interval after 21DAS.

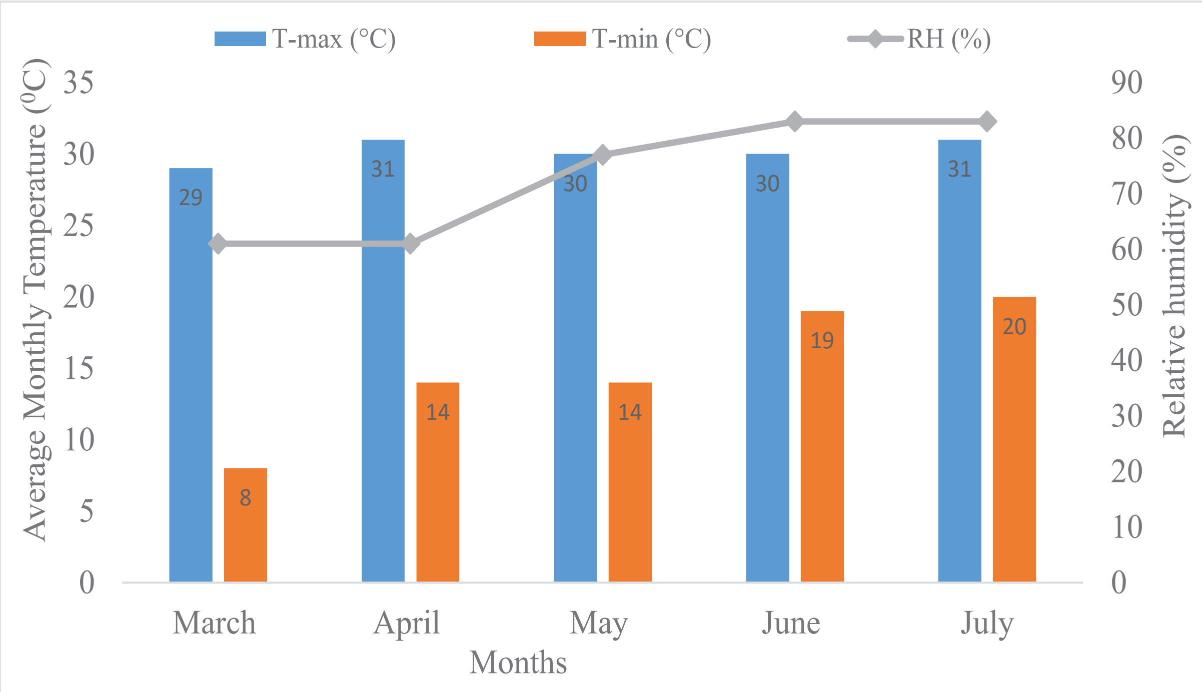

Fig. 1. Meteorological data during the experimental period

Statistical analysis

The collected data were tabulated and maintained in the Excel sheet and were transformed to square-root transformation. Analysis of variance (ANOVA) was used for the data analysis using the Rstudio (4.1.3 version), and multiple comparisons among the treatments were done by using the Least Significant Difference (LSD) test at 5% and 1% level of significance (Gomez & Gomez, 1984).

RESULTS AND DISCUSSION

Laboratory Evaluation

Larvae settlement of fall armyworm on 1 hrs ($F_{df\,(9,90)}$ = 1.99; $p<0.05$), 12 hrs ($F_{df\,(9,90)}$ = 6.51, $p<0.001$) and 24 hrs ($F_{df\,(9,90)}$ = 40.38, $p<0.001$) were significantly different among the varieties but there is no significant result on 4hrs ($F_{df\,(9,90)}$ = 1.59, $p>0.05$) of larval settlement.

Larva settlement at 1 hour of release

On 1hour of fall armyworm larva released, the highest mean number of larvae were settled in Posilo Makai (1.367± 0.18), which was statistically at par with Rampur Composite (1.304± 0.67), Manakamana-3 (1.264± 0.34), Arun-2 (1.205± 0.40), Manakamana-7 (1.095± 0.47) and

Arun-4 (1.021± 0.42). The lowest mean number of larvae was recorded in Rampur Hybrid-14 (0.898± 0.32), Deuti (0.898± 0.32), Rampur Hybrid-12 (0.950± 0.33), and Rampur Hybrid-16 (0.950± 0.33), which were not significantly different from each other (Table 2). The selection of resistant varieties and genetically modified seeds plays a vital role in controlling fall armyworms (Burtet et al., 2017).

Larva settlement at 4 hours of release

The data taken on 4 hours of larvae released exhibited non-significant differences ($p>0.05$) in settlement among the treatments.

Larva settlement at 12 hours of release

However, in 12 hours, the preference of fall armyworm larvae was greatest in Rampur Composite (1.716± 0.25) and Posilo Makai-1(1.610± 0.09) as compared to other varieties. The lowest number of larvae was recorded in Rampur Hybrid-16 (1.018± 0.27), Deuti (1.053± 0.32), Rampur Hybrid-12 (1.105± 0.30), and Rampur Hybrid-14 (1.105± 0.30) and were statistically on par with each other.

Larva settlement at 24 hours of release

After 24 hours of larva release, the maximum number of larvae was recorded in Posilo Makai-1 (1.892± 0.15), which was not significantly different from Rampur Composite (1.838± 0.16), Arun-4 (1.809± 0.18), Manakamana-7 (1.755± 0.15), and Arun-2 (1.697± 0.15). But significantly lower numbers of larvae were settled in Rampur Hybrid-12 (0.862± 0.25), which was statistically on par with Rampur Hybrid-14, Rampur Hybrid-16, and Deuti (0.966± 0.27) (Table 2). In our study, the order of preferences by fall armyworm was as follows: Posilo Makai-1> Rampur Composite> Arun-4> Manakamana-7> Arun-2> Manakamana-3> Deuti> Rampur Hybrid-16> Rampur Hybrid-14> Rampur Hybrid-12. According to the annual report of NMRP, Rampur, Chitwan, Nepal (2021), classification of maize genotypes against fall armyworm based on leaf damage rating (1-9 scale) were; highly susceptible (>7-9) = Arun-6; moderately susceptible (>6-7) = Posilo Makai-1, Rampur Composite, Arun-2, Arun-4, Manakamana-7; least susceptible (1-5) = Manakamana-3, Deuti and Rampur Hybrid lines. Our result was per the NMRP (2021) annual report, which explains that Posilo Makai-1 and Rampur Composite were the most preferred varieties by FAW. Arun-2, Arun-4, and Manakamana-7 were the medium preferred genotypes, whereas Manakamana-3, Deuti, and the Rampur Hybrid series (i.e., RH-12, RH-14, and RH-16) were categorized as the low preferred maize varieties by FAW among the tested ones. In the case of hybrid varieties, Lackisha Navin et al. (2021) agreed that nutritional and secondary metabolite variations among the maize hybrids influence the feeding preference of the fall armyworm.

Table 2. Third instar larva settlement on leaves of different maize varieties in different time intervals under laboratory conditions, Chitwan, Nepal.

Maize varieties	Mean (± SE) number of larvae settlement			
	1hrs	4hrs	12hrs	24hrs
Rampur Composite	1.304± 0.667^{ab}	1.331±0.505	1.716±0.253^{a}	1.838±0.156^{a}
Arun-2	1.205±0.404^{ab}	1.334±0.496	1.416±0.326^{bc}	1.697±0.150^{a}
Rampur Hybrid -12	0.950±0.330^{b}	1.244±0.240	1.105±0.296^{de}	0.862±0.250^{c}
Manakamana- 3	1.264±0.338^{ab}	1.296±0.150	1.280±0.262^{cde}	1.244±0.240^{b}
Arun- 4	1.021±0.418^{ab}	1.311±0.448	1.470±0.394^{abc}	1.809±0.175^{a}
Rampur Hybrid -14	0.898±0.322^{b}	1.105±0.296	1.105±0.296^{de}	0.966±0.273^{c}
Manakamana- 7	1.095±0.472^{ab}	1.237±0.549	1.364±0.394^{bcd}	1.755±0.150^{a}
Posilo Makai- 1	1.367±0.184^{a}	1.457±0.293	1.610±0.092^{ab}	1.892±0.151^{a}
Rampur Hybrid- 16	0.950±0.330^{b}	0.950±0.330	1.018±0.267^{e}	0.966±0.273^{c}
Deuti	0.898±0.322^{b}	1.037±0.371	1.053±0.317^{e}	0.966±0.273^{c}
Grand mean	1.095	1.230	1.314	1.40
p-value	<0.05*	ns	<0.001***	<0.001***
LSD (5%)	0.353	0.345	0.267	0.192
CV%	36.297	31.522	22.892	15.425
SEm (±)	0.056	0.049	0.077	0.137

LSD denotes the least significant difference, CV denotes the coefficient of variation, SEm denotes the standard error of mean, and means in columns separated by the same letters are not statistically different by LSD at P≤ 0.05; the value after ± indicates standard error.

Field Evaluation

There was a significant difference in the percentage of plant infestation among the tested crop varieties. Leaf damage inflicted by FAW larvae was significantly different among tested crop varieties in 21, 31, 41, and 51 days after sowing (DAS). Based on damage symptoms on the whorl and upper four leaves, Rampur Hybrid -12 and Manakamana -3 were found consistently superior compared to other varieties (Table 3). The data recorded of *S. frugiperda* on 21 days after sowing revealed significant differences among the treatments, with the percentage damage ranging between 3.42% to 5.60%. The Rampur Hybrid- 12 has outperformed among the rest of the varieties with 3.42% plant infestation, followed by Manakamana- 3, Deuti, Posilo Makai-1, and Rampur Hybrid- 14 with 3.75%, 3.96%, 3.99%, and 4.11% plant infestation, respectively and were at par with each other. Among tested varieties, Arun- 2 (4.63%), Arun-4 (4.71%), Rampur Composite (5.15%), Rampur Hybrid- 16 (5.40%), and Manakamana- 7 (5.60%) were the preferred ones by FAW, which were statistically at par with each other.

The data observed on 31 days after sowing exhibited significant differences among the varieties. The lowest infestation was recorded on Rampur Hybrid- 12 (3.50%), and it was followed by other varieties, viz., Deuti (4.02%) and Manakamana- 3 (4.09%), and they were found at par with each other. However, significantly highest damage percentage was recorded on Manakamana- 7 with 5.58% followed by Rampur Hybrid- 16 (5.41%), Rampur Composite (5.29%), Arun- 4 (4.92%), Arun- 2 (4.82%), Posilo Makai- 1 (4.56%) and Rampur Hybrid- 14 (4.29%), respectively and were found statistically at par with each other.

The data recorded of *S. frugiperda* on 41 days after sowing elucidated significant differences among the varieties. Rampur Hybrid- 12 recorded minimum leaf damage (3.19%) and it was found to be significantly superior to Deuti (3.39%), Manakamana- 3 (3.49%), Posilo Makai- 1 (3.69%), Rampur Hybrid- 14 (3.91%) and Arun- 2 (4.21%) and were statistically at par with each other. In Manakamana- 7, higher leaf damage of 5.25% was noticed, which was followed by Rampur Hybrid- 16, Rampur Composite, and Arun- 4 with 4.91%, 4.85%, and 4.46% plant infestation, respectively, and were statistically similar with each other.

The data recorded of *S. frugiperda* on 51 days after sowing illustrated significant differences among the tested varieties, with the minimum crop damage percent recorded on Rampur Hybrid-12 (2.36%), which was statistically at par with Deuti (2.76%) and Manakamana- 3 (2.76%). Medium preference of FAW was observed on Rampur Hybrid- 14, Posilo Makai- 1, and Arun-2 with percentage plant infestation of 3.25%, 3.40%, and 3.62%, respectively. However, the significantly highest FAW damage percentage in maize plants was observed in Manakamana- 7 with 4.67%, followed by Rampur Hybrid- 16 (4.22%), Rampur Composite (4.11%), and Arun-4 (4.06%) and were found at par with each other (Table 3).

Table 3. Plant Infestation Percentage on Maize by Fall armyworm Larvae in Gorkha, 2022

Crop Varieties	Plant Infestation %			
	21 DAS	31 DAS	41 DAS	51 DAS
Rampur Composite	5.15 (26.00)^{ab}	5.29 (28.07)^{ab}	4.85 (23.17)^{ab}	4.11 (16.52)^{abc}
Arun-2	4.63 (20.93)^{bcd}	4.82 (23.21)^{abcd}	4.21 (17.31)^{bcd}	3.62 (12.74)^{bcd}
Rampur Hybrid (RH) -12	3.42 (11.21)^{e}	3.50 (12.25)^{e}	3.19 (9.71)^{e}	2.36 (5.09)^{f}
Manakamana-3	3.75 (13.58)^{e}	4.09 (16.81)^{de}	3.49 (11.78)^{de}	2.76 (7.19)^{ef}
Arun-4	4.71 (21.74)^{bc}	4.92 (24.25)^{abc}	4.46 (19.40)^{abc}	4.06 (16.12)^{abc}
Rampur Hybrid (RH) -14	4.11 (16.44)^{cde}	4.29 (18.59)^{cd}	3.91 (15.65)^{cde}	3.25 (10.43)^{de}
Rampur Hybrid (RH) -16	5.40 (28.80)^{a}	5.41 (29.55)^{a}	4.91 (23.73)^{ab}	4.22 (17.55)^{ab}
Manakamana-7	5.60 (31.30)^{a}	5.58 (31.41)^{a}	5.25 (27.10)^{a}	4.67 (21.40)^{a}
Posilo Makai -1	3.99 (15.64)^{de}	4.56 (21.20)^{bcd}	3.69 (13.35)^{cde}	3.40 (11.16)^{cde}
Deuti	3.96 (15.21)^{de}	4.02 (16.17)^{de}	3.39 (11.01)^{de}	2.76 (7.16)^{ef}
Grand mean	4.47	4.65	4.13	3.52
SEm	0.23	0.21	0.23	0.24
LSD	0.66	0.73	0.80	0.72
CV	8.54	9.13	11.31	11.95
p-value	*** (<0.001)	*** (<0.001)	*** (<0.001)	*** (<0.001)
F-value	11.24	7.67	6.98	9.54

CV: Coefficient of Variation; LSD: Least Significant Difference; SEm: Standard Error of Mean; ***: Significance at < 0.1% (p<0.001); **: Significance at 1% (p<0.001); *: Significance at 5% (p<0.05); DAS: Day After Sowing; Mean values in columns separated by the same letters are not statistically different by LSD at P≤ 0.05; Fig. in parenthesis indicate original values.

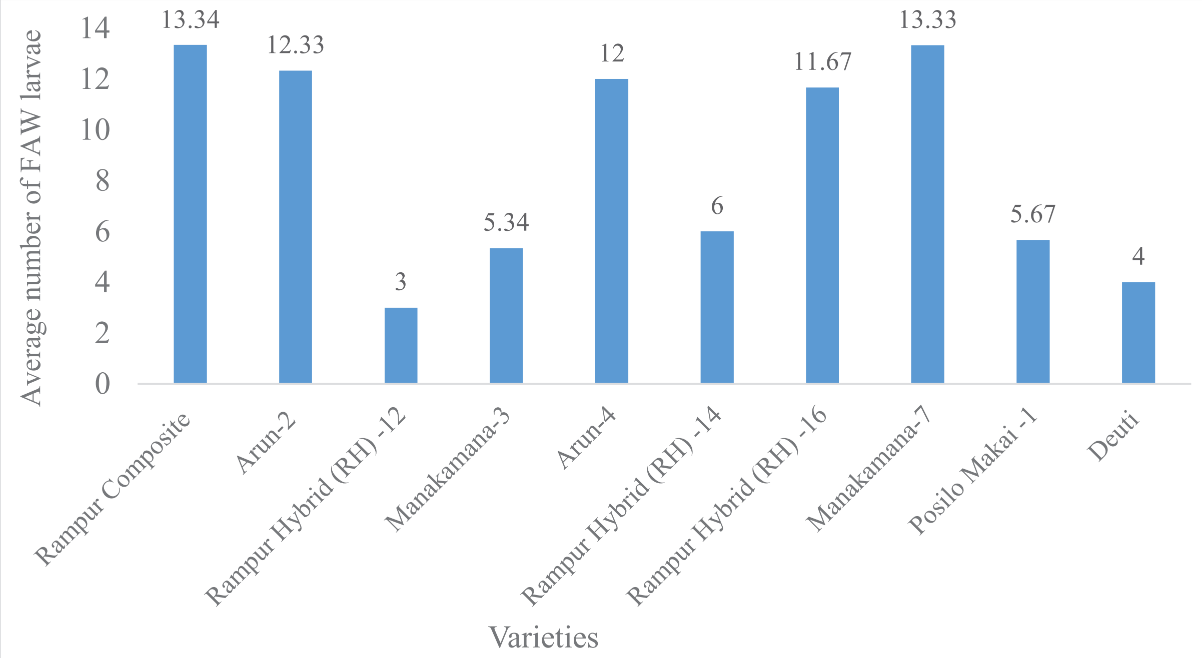

Fig. 2. Average number of fall armyworm (FAW) larvae on various maize varieties in Gorkha, 2022

Based on the percent plant infestation with live larvae and the intensity of foliar damage, Rampur Hybrid- 12 was least preferred by fall armyworm, followed by Deuti and Manakamana-3. Whereas, Manakamana- 7, Rampur Hybrid- 16, Rampur Composite, Arun- 4, and Arun-2 were more preferred among the tested varieties. The annual report of NMRP (2021) also explained a similar finding. According to them, out of 38 tested varieties, none of the genotypes were found resistant/tolerant against fall armyworms in this study period. However, Arun-3, EEYC-1, SPPTLYQ-A, CORRALJOS002SIYQ, Mankamana-3, Rampur-4, Deuti, BGBYPOP, 05SAVDI, R-POP-2, KSYNF10, S0128, Rampur hybrid-10, and CAH 1715 were found to be less susceptible to the fall armyworm. Rampur Hybrids have more hairs on leaves and stems, so it may be one reason to be tolerant against FAW (Tiwari, 2022). Physical characteristics of host plants, such as trichomes, wax amount, thickness and toughness of leaves, and secondary toxic metabolites can influence host-plant selection behavior (Gatehouse, 2002). The density of trichomes plays a crucial role in plant resistance and influences chewing damage by *S. frugiperda* (Moya-Raygoza, 2016). Among the hybrid lines, Rampur Hybrid-12 has a tight husk covering and has small hairs on leaves, stems, and cob during the research observation, which may be one reason for FAW tolerance. The cultivation of maize hybrids with tight husks is found to be effective in reducing FAW damage (Firake et al., 2019). Rampur Hybrid-12 is a heat-stress-tolerant and FAW-tolerant hybrid variety, as explained by NMRP (2021), which was also observed in our study. Hybrid had lower leaf damage percentage and scorings as compared to other lines as given by Asare et al. (2023), which is somehow similar to our findings. Among the various cultivars of maize crop, FAW preference may differ, and this is influenced by cuticular lipids (Yang, 1993a), the presence of wax materials on the leaf surface (Yang et al., 1993b), and antifeedants or anti-repellents may also affect the preference level. Maize varieties and cultivars with a high ability to resist and tolerate insect-pest prevalence can play a major role in maize breeding programs and the economic value of various pest management measures (Anuradha, 2012; Yonow et al., 2017).

CONCLUSION

Currently, the control of fall armyworm has been dominated by the use of chemical insecticides, with their adverse effects on the environment, human health, and natural enemies, as well as the cost implications. The findings of this study are important for understanding the host preferences of FAW to create and design sustainable management options. The outcome of this research offers a safe, reliable, environmentally friendly, durable, and cost-effective approach to controlling the fall armyworm. The main objective is to provide practical recommendations to the farmers to select the more tolerant variety of maize against fall armyworm to increase maize yield. Tolerant maize varieties play an important role in minimizing the use of pesticides. Results showed that the preferential association of fall armyworm was not the same for all tested maize varieties. Some are more preferred, and some are least preferred. None of the maize genotypes were found to be completely resistant to fall armyworm. Based on our results, Rampur Composite, Arun-2, Arun-4, Rampur Hybrid- 16, and Manakamana-7 were the more preferred genotypes, whereas Posilo Makai-1 and Rampur Hybrid- 14 were medium preferred. However, among the hybrid lines, Rampur Hybrid -12 and among the OPV, Manakamana-3 and Deuti were less preferred genotypes by the fall armyworm. The selection of tolerance varieties against FAW is a sustainable strategy for pest management. These research findings are useful to maize-growing farmers for the selection of suitable varieties that are least preferred by FAW. However, these findings only provide a basic idea of the varietal selection of fall armyworm among tested varieties, but testing of such genotypes in a wider group of plant species and on a wider field areas considering growth and development parameters, oviposition preferences, etc., is suggested for more realistic results.

ACKNOWLEDGEMENTS

The authors are very grateful to the Directorate of Research and Extension (DOREX) of Agriculture and Forestry University, Department of Entomology/AFU and the National Maize Research Program (NMRP), Nepal Agricultural Research Council (NARC), Rampur, Chitwan, Nepal for the financial and technical supports during the study period.

REFERENCES

Anuradha, M. (2012). Maize inbred lines screening for resistance against *Chilo partellus*. *International Journal of Plant Protection*, *5*(2), 290- 293.

Asare, S., Kena, A., Amoah, S., Annor, B., Osekre, E. A., & Akromah, R. (2023). Screening of maize inbred lines and evaluation of hybrids for their resistance to fall armyworm. *Plant Stress*, *8*, 100148.

Bajracharya, A. S. R., Bhat, B., Sharma, P., Shashank, P. R., Meshram, N. M., & Hashmi, T. R. (2019). First record of fall armyworm *Spodoptera frugiperda* (J. E. Smith) from Nepal. *Indian Journal of Entomology, 81*(4), 635-639.

Burtet, L. M., Bernardi, O., Melo, A. A., Pes, M. P., Strahl, T. T., & Guedes, J. V. (2017). Managing fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), with Bt maize and insecticides in southern Brazil. *Pest Management Science*, *73*(12), 2569-2577.

CABI, (2017). *Spodoptera frugiperda* (Fall armyworm). CABI, Wallingford, UK. Available online: https://www.cabi.org/isc/datasheet/29810.

Day, R., Abrahams, P., Bateman, M., Beale, T., Clottey, V., Cock, M., & Witt, A. (2017). Fall armyworm: impacts and implications for Africa. *Outlooks on Pest Management*, *28*(5), 196-201.

Firake, D., Behere, G., Babu, S., & Prakash, N. (2019). *Fall Armyworm: Diagnosis and Management. An Extension Pocket Book.* Umiam-793, 103.

Gatehouse, J. A. (2002). Plant resistance towards insect herbivores: a dynamic interaction. *New*

Phytologist, *156*(2), 145-169.

GC, Y., Dhungel, S., Ghimire, K., Devkota, S. and GC, A. (2019). Fall armyworm: global status and potential threats for Nepal. *Journal of Agriculture and Environment*, *20*, 10 20.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical Procedures for Agricultural Research*. John Wiley & Sons. 1-95p.

Hafeez, F., & Zia, K. (2009). Relative resistance of different maize varieties against insect complex harboring crop ecology. *Agricultural Society of Science*, *5*, 52-54.

Hardke, J. T., Lorenz, G. M. III. & Leonard, B. R. (2015). Fall armyworm (Lepidoptera: Noctuidae) ecology in southeastern cotton. *Journal of Integrated Pest Management*, *6*: 1-8.

Jindal, J., & Hari, N. S. (2008). Studies on components of resistance in maize genotypes to *Chilo partellus* (Swinhoe). *Indian Journal of Entomology*, *70*(4), 314- 318.

Kalleshwaraswamy, C., Maruthi, M., & Pavithra, H. (2018). Biology of invasive fall armyworm *Spodoptera frugiperda* (J E Smith)(Lepidoptera: Noctuidae) on maize. *Indian Journal of Entomology, 80*(3), 540-543.

Kasige, R. H., Dangalle, C. D., Pallewatta, N., & Perera, M. T. M. D. R. (2022). Laboratory studies of larval cannibalism in same-age conspecifics of fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera, Noctuidea) in maize. *Tropical Agricultural Research and Extension*, *25*(1).

Kumela, T., Simiyu, J., Sisay, B., Likhayo, P., Mendesil, E., Gohole, L., & Tefera, T. (2019). Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya. *International Journal of Pest Management*, *65*(1), 1-9.

Lackisha Navin, A., Saminathan, V. R., & Sheeba Joyce Roseleen, S. (2021). Host plant resistance in maize hybrids to fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) (J. E. Smith). *The Pharma Innovation Journal*, *10*(10), 2366-2371.

Lewis, S. E., Silburn, D. M., Kookana, R. S., & Shaw, M. (2016). Pesticide behavior, fate, and effects in the tropics: an overview of the current state of knowledge. *Journal of Agricultural and Food Chemistry*, *64*(20), 3917-3924.

MoALD. (2019). *Protocol for Integrated Pest Management of FAW, Spodoptera frugiperda in Nepal.* PQPMC, NARC, IDE, CIMMYT. 17p. http://www.npponepal.gov.np/ download file/IPM_Protocol_ Final_1603000843.pdf.

MoALD. (2023). *Statistical information on Nepalese agriculture 2021/22*. Kathmandu: Ministry of Agriculture, Land Management and Cooperatives.

Montezano, D. G., Specht, A., Sosa-Gomez, D. R., Roque-Specht, V. F., Sosa-Silva, J. C., Paula- Moraes, S. V., Peterson, J. A., & Hunt, T. E. (2018). Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. *African Entomology*, *26*(2), 286-300.

Moya-Raygoza, G. (2016). Early development of leaf trichomes is associated with decreased damage in teosinte, compared with maize, by *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Annals of the Entomological Society of America*, *109*(5), 737-743.

NMRP, (2021). *Annual Report 2077/78 (2020/21)*. National Maize Research Program, NARC, Rampur, Chitwan, Nepal.

Plant Quarantine and Pesticide Management Centre. (2019). *American Fall Armyworm and Its Management [Fact Sheet]*. Government of Nepal, Ministry of Agriculture and Livestock Development. http://www.npponepal.gov.np/downloadsdetail/13/2019/62421561.

Ranum, P., Pena-Rosas, J. P., & Garcia-Casal, M. N. (2014). Global maize production, utilization, and consumption. *Annals of the New York Academy of Sciences*, *1312*(1), 105 112. https://doi.org/10.1111/nyas.12396

Sharma, H. & Ortiz, R. (2002). Host Plant Resistance to Insects: an eco-friendly approach for pest management and environment conservation. *Journal of Environmental Biology, 2*, 111-135.

Shelton, A. M., & Badenes-Perez, F. R. (2006). Concepts and applications of trap cropping in pest management. *Annual Review of Entomology*, *51(1)*, 285-308.

Sparks, A. N. (1979). A review of the biology of the fall armyworm. *Florida Entomologist*, *62*: 82-87.

Tiwari, S. (2022). Host plant preference by the fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Noctuidae: Lepidoptera) on the range of potential host plant species. *Journal of Agriculture and Forestry University*, *5(1)*, 25-33.

Vishvendra, D. V., Kumar, S., Kumar, R., & Vaibhav, V. (2017). Screening of maize cultivars against maize stem borer, *Chilo partellus* (Swinhoe), under natural field conditions. *International Journal of Current Microbiology and Applied Sciences, 6(10)*, 1414- 1418.

Yonow, T., Kriticos D. J., Ota, N., Berg, J. V. D., & Hutchison, W. D. (2017). The potential global distribution of *Chilo partellus*, including consideration of irrigation and cropping patterns. *Journal of Pest Science, 90*, 459-477.

Yang, G., Espelie, K. E., Wiseman, B. R., & Isenhour, D. J. (1993b). Effect of corn foliar cuticular lipids on the movement of fall armyworm (Lepidoptera: Noctuidae) neonate larvae. *Florida Entomologist*, *76(2)*, 302-316.

Yang, G., Wiseman, B. R., Isenhour, D. J., & Espelie, K. E. (1993a). Chemical and ultra-structural analysis of corn cuticular lipids and their effect on feeding by fall armyworm larvae. *Journal of Chemical Ecology*, *19(9)*, 2055-2074.

Yu, S. J. (1991). Insecticide resistance in the fall armyworm, *Spodoptera frugiperda* (J. E. Smith). *Pesticide Biochemistry and Physiology*, *39*(1), 84-91.