Research article

HOST PLANT PREFERENCE BY THE FALL ARMYWORM, *Spodoptera frugiperda* (J.E. SMITH) (LEPIDOPTERA: NOCTUIDAE) ON THE RANGE OF POTENTIAL HOST PLANT SPECIES

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ABSTRACT

Maize is the most important cereal crop after rice and wheat in Asia. Nowadays, maize production is threatened by one invasive pest, the fall armyworm (*Spodoptera frugiperda*) particularly in Africa and Asia, and threatens millions of poor people. Fall armyworm feeds a wide range of crops and non-crops including weeds, with over 353 plant species. But most frequently consumed crops are field corn, sweet corn, wheat, sorghum, sugarcane, Bermuda grass etc. Fall armyworm has six larval stages, the first three stages are less voracious compared to the latter stages. Larvae are very numerous and disperse in large numbers and behave like 'armyworm'. Insecticides are considered an important tool of FAW management as well as other lepidopteran maize pests. However, these practices are not sustainable and are linked to the environment, biodiversity and farmers' health. Alternative management strategies should be developed by understanding pest biology and ecology. Hence, a series of laboratory choice and paired-choice tests were conducted at Agriculture and Forestry University in May 2021 to evaluate the host plant preference by the fall armyworm. Potential host plants were *Zea mays* (maize cultivars - Rampur composite, Arun-2 and Rampur hybrid-10), Pennisetum *purpureus* (Napier), *Oryza sativa* (rice), *Sorghum bicolor* (Sorghum), *Fagopyrum esculentum* (Buckwheat), *Vigna unguiculata* (Cowpea) and *Glycine max* (Soybean). In choice tests, FAW preference was ranked as Rampur Composite > Sorghum > Rampur hybrid-10 > Arun-2 > Napier > Rice > Buckwheat > Cowpea > Soybean. Rampur composite and sorghum were the most preferred host plants, Rampur hybrid, Arun-2 and Napier were the medium preferred, rice was categorized as the low preferred and other host plants such as buckwheat, cowpea and soybean were the least preferred host plant of fall armyworm. In paired-choice tests, Rampur composite was more preferred than sorghum, but not significantly so. These research findings are useful to utilize in habitat manipulation strategies for fall armyworm management. Most preferred plant species can be deployed as trap crops and least preferred host plants can be used as repellent or push crops in a push-pull strategy. Such host plants in-and-around the main field can reduce the fall armyworm damage and reduce pesticide amount in main crops.

Keywords: Fall armyworm, agroecology, habitat management, trap crops, push -pull strategy

INTRODUCTION

Fall armyworm (FAW), *Spodoptera frugiperda* (J.E Smith) is a voracious polyphagous pest, native to North and South America. This pest is recently reported in the status of invasive in Africa in 2016 (Goergen et al., 2016) and in Asia in 2018 (Kalleshwaraswamy et al., 2018). This pest has been reported as an economic pest of many crops because it has the ability of high dispersal, wide host range and high fecundity (Kalleshwaraswamy et al., 2018). In just 12 maize-producing countries of Africa, this pest has caused a maize yield loss ranging from 8.3 to 20.6 M tonnes per annum, if not adopted any control measures and this value was estimated at between $2,481m and $6,187m (Day et al., 2017). Fall armyworm has also been reported in Nepal in May in Gaidakot of Nawalpur district (Bajracharya et al., 2019) and has invaded all maize-growing districts of Nepal (Bajracharya, Bhat & Sharma, 2020). The suitable climatic conditions in India and Nepal, and the availability of a wide range of hosts including the most preferred host maize, play a great role to establish this pest as an invasive status in Nepal (Gahatraj, Tiwari, Sharma & Kafle, 2020).

According to Montezano et al. (2018), FAW feeds more than 350 plant species. He reported that fall armyworm damages particularly the Poaceae. Asteraceae, and Fabaceae crops. The majority of cereal crops such as maize (*Zea mays* L.), paddy (*Oryza sativa* L.), sorghum (*Sorghum bicolor* (L.), Moench), wheat (*Triticum aestivum* L.), millet (*Eleusine coracana* Gaertn) etc. are belong to Poaceae family and all leguminous crops belong to Fabaceae family (Gahatraj et al., 2020). Peanut (*Arachis hypogea* L.) and Bermuda grass (*Cynodon dactylon* L., Pers.) are the other favourite hosts of FAW (Sparks, 1979). This wider host range indicates that the preference of FAW in various hosts can be differential. Some crops or hosts are more favoured hosts 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 (Badenes-Perez, Shelton, and Nault, 2004). An understanding of the host preference of fall armyworm larva helps to develop a non-chemical pest management strategy for fall armyworm. These strategies can be employed to develop trap cropping and other agroecological pest management protocol such as the push-pull strategy (Harrison et al., 2019). Trap crops are the most preferred host of insect pests that help to attract the pest in certain trap cropping areas and protect the main crop from pest damage (Shelton & Badenes-Perez, 2006; Hokkanen, 1991; Tiwari et al., 2019). Similarly, the push-pull strategy is one of the most suitable methods of pest management for the maize stem borer in Africa (Khan & Pickett, 2004; Khan et al., 2008) and being employed for fall armyworm management in some parts of the world (Guera et al., 2021; Hailu et al., 2018). Most suitable host can be used as a pull crop "trap crop' and repellent crop or the least preference crop can be used as a push or 'repellent crop'. Sometimes, the deployment of flowering push or pull crops can share the shelter, nectar, alternative food or pollen to the pest's natural enemies (González-Chang et al., 2019) and improve conservation biological control (Tiwari, Sharma & Wratten, 2020). Hence, this host preference study supports understanding the pest's biology and ecology as well as helps to screen or rank the potential trap or repellent crops. This information's are useful to develop an integrated pest management protocol for various categories of pests including fall armyworm.

MATERIALS AND METHODS

Host plant preparation and fall armyworm colony management

Potential fall armyworm host plants seeds were collected from agrovets (Sahayogi Agrovet, Narayanghat) and National Maize Research Programme (NMRP), Rampur (Table 1). Napier leaf was collected from National Cow Research Programme, Rampur. Seeds of each host plant were grown in a plastic bucket (25 cm diameter x 30 cm height) in the open corridor at the Department of Entomology of Agriculture and Forestry University (www.afu.edu.np) and sown in a plastic bucket (25 cm diameter x30 cm height). There were altogether fifteen plastic buckets (25 cm diameter x 30 cm height) and each bucket was filled with garden topsoil (loamy soil and sand mixture).) Collected from the nearby mango orchard (27^0 39.1020' N, 84^0 21.1710 E and 128 masl) and seeds were sown on 3 May 2021.

Similarly, the fall armyworm colony was maintained for the regular supply of third stages larva for the host preference study. Egg masses with pieces of maize leaves were collected from the pesticide-free maize field from the agronomy farm (27^0 38.8290' N, 84^0 20.9880 E and 119 masl) and reared in Petri dishes (10 cm diameter) feeding maize leaves (Rampur Composite). The moistened filter paper was placed on the bottom of each Petri dish. After hatching the egg masses, soft maize leaves were provided as food materials and transferred to another plastic bucket (26 cm diameter and 20 cm height). Similarly, each day leaves with fall armyworm larvae were transferred to other new buckets (size same as above) and gently brushed with a fine hair brush. A similar process was continued until the emergence of third stages larvae. The insect rearing room temperature, humidity and photoperiod were 27^0c 80.5% and 16:8 hr L:D (Light: Day), respectively.

Table 1. Host plant species used in fall armyworm choice test

Scientific name	Common name	Family	Cultivars
Zea mays L.	Maize	Poaceae	Rampur Composite
Zea mays L.	Maize	Poaceae	Arun-2
Zea mays L.	Maize	Poaceae	Rampur hybrid-10 F1
Pennisetum purpureus (Schumach.) Morrone	Napier	Poaceae	Hatti Ghas -1
Oryza sativa L.	Rice	Poaceae	Chaite -2
Sorghum bicolor (L.) Moench	Sorghum	Poaceae	Local
Fagopyrum esculentum Moench	Buckwheat	Polygonaceae	Mitho Fapar -1
Vigna unguiculata (L.) Walp.	Cowpea	Fabaceae	Prakash
Glycine max (L.) Merr.	Soybean	Fabaceae	Hardi

Choice test

Leaves pieces of each host plant (25 days-old seedlings and size-10 cm length) were taken and placed at the rate of three pieces for each host plant species (size of 10 cm length) at the bottom of the circular plastic bucket (15 cm diameter x 10 cm height). Equal distance for each host plant leaves was maintained in the perimeter of each circular bucket and fifteen third stages FAW larva were released at the centre of the bucket (15 cm diameter x 10 cm height) and covered by transparent muslin cloth from the top to prevent from escape. There were three replications for each host plant.

Paired-choice test

Two potential host plants selected from the choice tests were evaluated in the paired-choice test. Rampur composite was compared with sorghum. Leaves pieces of Rampur composite (10 cm length) and sorghum leaves (10 cm length) were placed at an equal distance at the bottom of the circular plastic bucket. There were three replications for each host plant. Third-stages ten FAW larva were released at the centre of the bucket (15 cm diameter x 10 cm height) and covered by transparent muslin cloth from the top to prevent from escaping. The number of FAW larva settled in both plants was counted at 12 h, 24h and 48 h.

Data observations and analysis

First settlement time of FAW was recorded in choice tests. Larval settlement in 2h, 4h, 8h, 16h, 24h and 48 hours were also recorded. In paired-choice tests, larval settlement numbers were recorded in 12h, 24h and 48 h. Similarly, data were transformed to square-root transformation to get the average larva settled over 48 hours (Figure 1). Analysis of variance (ANOVA) was used for the data analysis using the GenStat statistical package (GenStat Discovery Edition 4, VSN International Ltd (Rothamstead Experimental Station, United Kingdom), to observe the effect of host species on the first settling time (mins), the number of FAW larva recorded on each plant species over time. In paired-plant species, plant species were statistically compared using a paired sample t-test in 12h, 24h and 48h ($p < 0.05$) ($n = 5$).

RESULTS AND DISCUSSION

There was a significant effect of host plant species on the settlement of fall armyworm larva ($p < 0.001$). Fall armyworm larva was quickly settled in three maize cultivars which were not significantly different to the Napier, rice and sorghum, but significantly settled earlier compared to buckwheat, cowpea and soybean. Time to the first settlement in maize cultivars were almost 2 times earlier ($\bar{x} = 11.0$ min) than buckwheat, cowpea, and soybean (> 26.0 min). Time to the first settlement in buckwheat and cowpea was significantly similar (Table 1). Similar results were found by Nagoshi and Meagher (2008) and reported that FAW has a preferential association to the large grasses such as corn and sorghum as well as rice and Bermuda grass. Sparks et al., (1979) in their study revealed that maize, peanut, sorghum and Bermuda grass are the most favoured host of FAW.

Table 2. Mean time required for the first settlement by fall armyworm larva in a choice tests

Host plant species	First settlement (Min)
Rampur Composite	11 ± 2.08 a
Arun-2	11 ± 1.53 a
Rampur Hybrid-10	12 ± 2.31 a
Napier	21 ± 3.00 ab
Rice	19.67 ± 4.18 ab
Sorghum	13 ± 0.58 a
Buckwheat	26.67 ± 7.69 c
Cowpea	31 ± 4.93 c
Soybean	46 ± 7.02 d
Grand mean	21.3 ± 4.38
CV (%)	11.50
LSD (%)	13.14
P value	< 0.001
Level of significance	***

LSD denotes the least significant difference, CV denotes coefficient of variation, and means within the same column with no letter's common are significantly different (Fisher's unprotected LSD; p< 0.05) (n =3)

Table 3. Mean number of fall armyworm larva recorded in the various plant hosts over eight hours in choice tests.

Host plant species	2h	4h	8h
Rampur Composite	2.67 ± 0.58 cd	3.33 ± 0.33 d	3.33 ± 0.33 d
Arun-2	1.33 ± 0.67 ab	2.33 ± 0.33 cd	2.67 ± 0.67 cd
Rampur Hybrid-10	3.00 ± 0.33 d	1.67 ± 0.67 bc	2.67 ± 0.33 cd
Napier	2.00 ± 0.00 bc	2.00 ± 0.00 bc	2.00 ± 0.00 bc
Rice	1.00 ± 0.33 a	1.00 ± 0.00 ab	1.00 ± 0.00 ab
Sorghum	2.67 ± 0.33 cd	2.33 ± 0.67 cd	2.33 ± 0.67 cd
Buckwheat	1.00 ± 0.67 a	1.33 ± 0.33 bc	0.00 ± 0.00 a
Cowpea	0.67 ± 0.00 a	1.00 ± 0.00 ab	0.00 ± 0.00 a
Soybean	0.67 ± 0.33 a	0.00 ± 0.00 a	1.00 ± 0.00 ab
Grand mean	1.67 ± 0.33	1.67 ± 0.39	1.67 ± 0.37
CV (%)	0.00	0.00	0.00
LSD (%)	0.999	1.172	1.117
P value	< 0.001	0.001	< 0.001
Level of significance	***	**	***

LSD denotes least significant difference, CV denotes coefficient of variation, means within the same column with no letter's common are significantly different (Fisher's unprotected LSD; p< 0.05) (n =3)

Fall armyworm larva settled in 2h, 4h and 8h were significantly different ($p< 0.001$). In 2h of FAW larva released, significant number of FAW larva were settled in Rampur hybrid-10 ($\bar{x} = 3.0$) which was not significantly different to the Rampur composite ($\bar{x} = 2.67$) and sorghum ($\bar{x} = 2.672.67$), but significantly lower numbers of larva were settled in other host plant species. But after 4 h and 8 h of larva released, the maximum number of larvae were settled in Rampur composite in both 4h and 8h which was not significantly different than Arun-2 and sorghum, but not significantly different than other host plants in 4h and 8h except in Rampur hybrid-10 in 8h. Number of larval settlements in Rampur hybrid-10, Napier and sorghum were significantly similar in 4 h. Similarly, the number of FAW larva settlements in Arun-2, Rampur hybrid-10, and sorghum were not significantly different (Table 2).

Similarly, larval settlement over 48h varied significantly between host plant species ($p < 0.001$). The number of larva settlements in Rampur hybrid-10 was significantly higher than in other host plant species. However, there was no significant difference between Rampur composite, Arun-2, Napier, rice and sorghum in 16h. Similarly, there were no significant differences in cowpea, soybean and buckwheat in 16h. In 24h of larva released, maximum number of larvae were recorded in sorghum ($\overline{x}$ = 3.67) which was significantly higher than the other host plants. There was no significant difference in the larval settlement between Rampur composite, Arun-2 and Napier. Similarly, Rampur hybrid-10, rice and cowpea were not significantly different for larval settlement. In 48h of larva released, a significant number of FAW larva were counted in Rampur composite ($\overline{x}$ = 3.33) which was not significantly different to the Arun-2 ($\overline{x}$ = 2.67), but significantly different to the other host plant species. Arun-2, Rampur hybrid-10, Napier and sorghum were not significantly different. Buckwheat, cowpea and soybean were not significantly different (Table 3).

Table 4. Mean number of fall armyworm larva recorded in the various host over forty-eight hours in choice tests.

Host plant species	16h	24h	48h
Rampur Composite	2.00 ± 0.00 b	2.67 ± 0.33 e	3.33 ± 0.33 e
Arun-2	2.00 ± 0.00 b	2.67 ± 0.33 e	2.67 ± 0.33 de
Rampur Hybrid-10	3.00 ± 0.00 c	1.33 ± 0.33 cd	2.33 ± 0.33 d
Napier	2.00 ± 0.00 b	2.00 ± 0.00 de	2.00 ± 0.00 cd
Rice	2.00 ± 0.00 b	1.00 ± 0.00 c	1.33 ± 0.33 bc
Sorghum	2.00 ± 0.00 b	3.67 ± 0.67 f	2.33 ± 0.33 d
Buckwheat	1.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Cowpea	0.00 ± 0.00 a	1.00 ± 0.00 c	0.67 ± 0.33 ab
Soybean	0.67 ± 0.33 a	0.67 ± 0.33 ab	0.33 ± 7.02 a
Grand mean	1.630 ± 0.11	1.67 ± 0.33	1.67 ± 0.31
CV (%)	3.90	0.00	0.00
LSD (%)	0.333	0.999	0.935
P value	< 0.001	< 0.001	< 0.001
Level of significance	***	***	***

LSD denotes the least significant difference, CV denotes coefficient of variation, means within the same column with no letter's common are significantly different (Fisher's unprotected LSD; $p< 0.05$) (n =3)

The number of FAW larva counted over 48h varied significantly between host plant species ($p< 0.001$). Larval settlement in Rampur composite was significantly higher ($\overline{x}$ = 1.78) which was significantly different to other host plant species except for sorghum ($\overline{x}$ = 1.56) (Figure 1). Arun-2, Rampur hybrid-10 and Napier were not significantly different, but significantly different to Rampur composite, rice, buckwheat, cowpea and soybean, respectively. The lowest number of larvae was recorded in buckwheat ($\overline{x}$ = 0.77), cowpea ($\overline{x}$ = 0.74) and soybean ($\overline{x}$ = 0.73), which were not significantly different from each other.

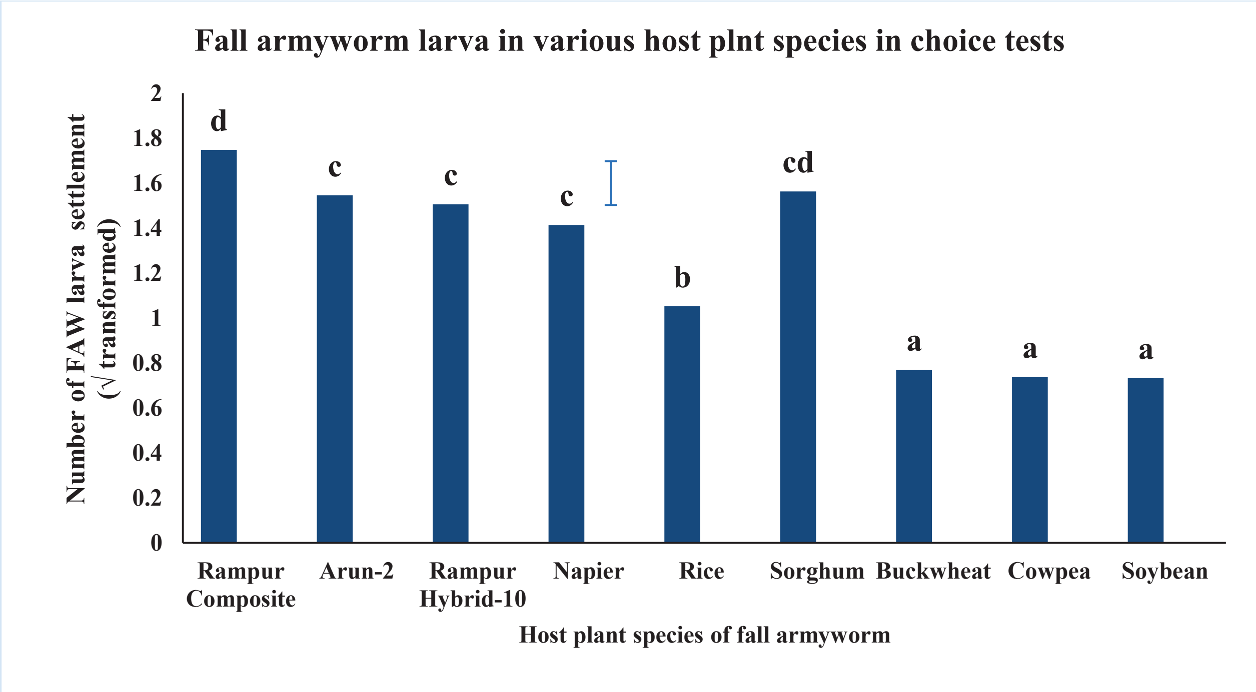

Figure 1. Mean numbers (√ transformed) of fall armyworm larva recorded in nine plant species over 48h.

The vertical bar is the least significant difference, LSD (5%). Means with no letters in common are significantly different (Fisher's unprotected LSD; $p < 0.05$) ($n = 3$).

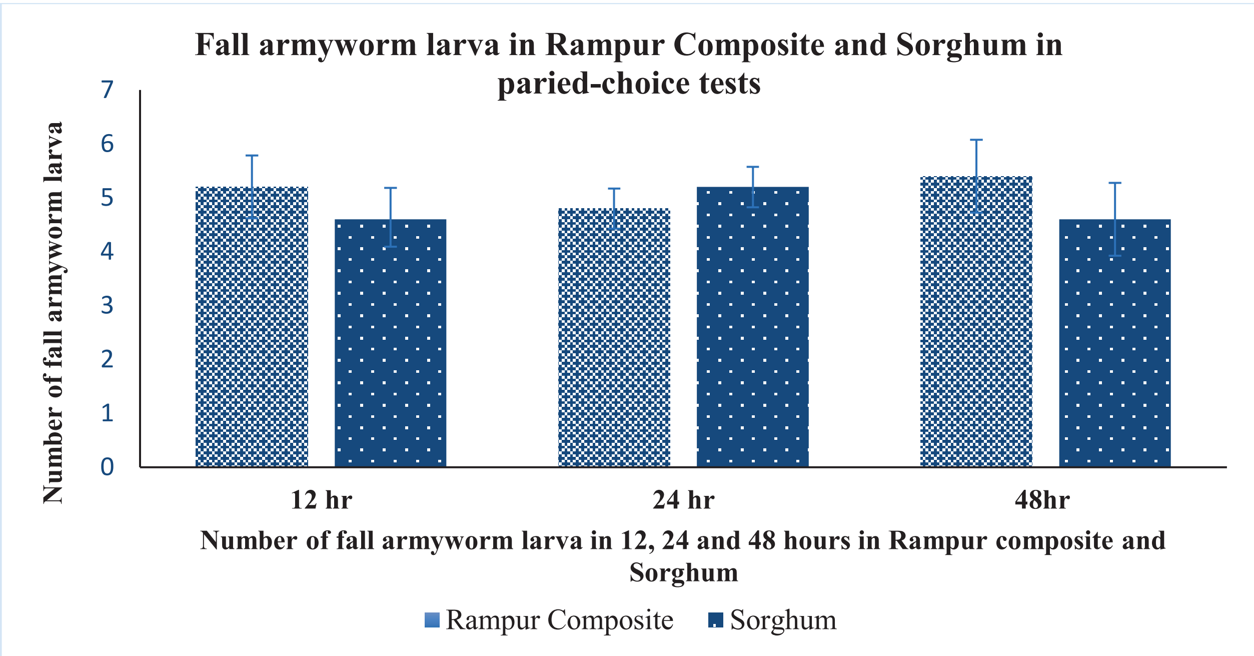

Figure 2. Mean numbers (√ transformed) of fall armyworm larva recorded in a paired-choice experiment between Rampur composite and Sorghum in 12 h, 24 h and 48 h. The vertical bar is the standard error bar. Within each pair, plant species were statistically compared using a paired sample t-test ($p < 0.05$) ($n = 5$).

In paired-choice experiments, there were no significant differences between the two host plant species by the fall armyworm larva. This indicates that the same preferences have been recorded over 48 hours.

However, in 12h and 48h, preference of fall armyworm larvae was greatest in Rampur composite compared to sorghum. But in 24h, sorghum was more preferred by FAW compared to Rampur composite.

Maize and sorghum are the two potential host plants of fall armyworms (Harrison et al., 2019). Assefa and Ayalew (2019) reported that FAW causes significant damage to several economically important cultivated grasses including maize, rice, sorghum and sugarcane, vegetables and cotton crops. In the case of hybrid varieties, Lackisha Navin, Saminathan, and Sheeba Joyce Roseleen (2021) agreed that nutritional and secondary metabolite variations among the maize hybrids influence the feeding preference of fall armyworm. Their preference for particular host plants depends on the FAW strains, there are two types of strains, the first strains primarily damage corn, sorghum, cotton and other strains that damage rice, Burmuda grass etc (Virginia Co-operative Extension, 2009). Their preference depends on the crop family, Poaceae family crops are the most preferred crop followed by Fabaceae, Solanaceae, Asteraceae, Rosaceae etc. (Casmuz et al., 2010). In this study, the order of preferences were as Rampur Composite> Sorghum > Rampur hybrid-10 > Arun-2 > Napier > Rice> Buckwheat > Cowpea > Soybean. Rampur composite and sorghum were the most preferred host plants, Rampur hybrid, Arun-2 and Napier were the medium preferred host plant, rice was categorized as the low preferred host plant and other host plants such as buckwheat, cowpea and soybean were the least preferred host of fall armyworm.

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). Even in various cultivars of maize crop, FAW preference may differ and this is influenced by cuticular lipids (Yang, 1993a), presence of wax materials on the leaf surface (Yang, 1993b), antifeedants or anti-repellents may also affect the preference level

In integrated pest management, most preferred host plants such as Rampur composite and sorghum can be planted as a potential trap crop to protect crops other than the maize. Sorghum can be deployed in maize plants to distribute their infestation in sorghum that can protect maize plants. These different preferential associations of host plants can also be deployed as push-pull crops in the push-pull strategy as suggested by Khan et al. (2008). Similarly, most preference host plants can be used for the mass production of fall armyworm larva and used in the laboratory bioassay as well as other scientific studies such as biology and ecology etc. Deployment of sorghum as well as Napier in maize field not only distributes fall armyworm larva in a maize field and protects main crops, but also such plant can be used in livestock feeding materials. These findings only provide a basic idea of host plant selection of fall armyworm but testing of such host plants in a wider group of plant species considering growth and development parameters oviposition preferences etc. are suggested for more realistic results.

CONCLUSION

Fall armyworm is the most devastating pest of maize including other plant species. This pest was first noticed in Africa in 2016, in India in 2018 and in Nepal in 2019. Economic losses caused by this pest threaten the livelihoods of millions of poor farmers. Maize, wheat, cotton, sorghum, sweet corn, and Bermuda grass are the major crops damaged by the fall armyworm. Pesticidal management practices are the common method of pest management in the world including in Nepal. But these practices are not sustainable and ecofriendly. Hence, integrated management practices such as cultural, mechanical, physical, biological and chemical are suggested as integrated approaches to FAW management. Agro-ecological practices such as trap cropping, use of resistant varieties, push-pull management, augmentation and conservation of biological control agents are the sustainable strategies for pest management. In this study, host plant selection of fall armyworms in a wide range of host plant species were tested. Results showed that the preferential association of fall armyworm was not the same for all tested host plants. Some are more preferred and some are least preferred. The preference of host plants by herbivores is generally influenced by the physical cues and chemical cues of the host plant. In integrated pest management, most preferred plants such as Rampur composite and sorghum can be used as trap crops or pull crops in a push-pull strategy. Napier and other two maize varieties such as Arun-2 and Rampur hybrid-10 are medium preferred plant species. Whereas leguminous crops such as cowpea and soybean are the least preferred host plants. Such leguminous plants can be integrated into a maize field to repel or push the fall armyworm away from the main crops. This study also suggests that while sowing maize crops in the field, the potential alternate host of FAW around the field should be identified and cleared to reduce FAW outbreaks.

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