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RESEARCH ARTICLE

ASSESSMENT OF INFESTATION OF *SPODOPTERA FRUGIPERDA* (J.E. SMITH) ON MAIZE AND ITS IMPLEMENTED MANAGEMENT PRACTICES WITH THEIR EFFICACY IN KAILALI, NEPAL

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ABSTRACT

Fall armyworm has been recently introduced to Nepal. In a very less time, the invasive pest has rapidly spread throughout the country causing 21% of yield loss in the total production of maize. It has the potential to attack all the crop stages of maize. If the effect of fall armyworm is neglected, it can result in the loss of 53% in the total production threatening food security and living of millions of farming households. Keeping the fact in mind, two blocks from the Tikapur Municipality of Kailali district, Nepal were surveyed to understand the infestation status of FAW in maize, farmer's perception, implemented management practices at the local level for its control, and its efficacy. Lack of knowledge regarding the identification and control measures has led to more than 50% of the household being infected by FAW. The average yield loss has reached 129.058 kg/ha in block 10 and 93.052 kg/ha in block 24. The average percentage of infestation has drooped to only 4.15% when all the measure of management was applied in an integrated way. Our study concluded that there is a pivotal need for extension knowledge to farmers on the identification of the pest, its life cycle, effective management practices, and tie for its implementation.

KEYWORDS

Fall armyworm, infestation, maize, control measures, farmers.

1. INTRODUCTION

Fall armyworm (FAW), *Spodoptera frugiperda* (Lepidoptera: Noctuidae), is a devastating pest of cereal crops native to the western hemisphere - especially tropical and subtropical regions of America (FAO, 2017; CABI, 2017; Smith, 2017; Capinera J., 2001). It is highly polyphagous in nature which feeds on 186 plant species from 42 families (Hoy, 2013; Early et al., 2018). However, corn and rice are the major hosts (Hoy, 2013). On the other hand, revealed that there are 353 fall armyworm larval host plants species belonging to 76 plant families with the greatest number of hosts texa in the family Poaceae (106 texa), followed by Asteraceae and Fabaceae (31 texa) each (Montezano et al., 2018). It is called fall armyworm because it does not reach the more northerly regions until late in the summer or early in the fall (Luginbill, 1990). This pest is a strong flier with migratory and localized dispersal habit and can fly up to 500km before oviposition (Prasanna et al., 2018). Restriction fragment length polymorphism (RFLP) analysis of generic DNA identified two groups generally consistent with the R-strain (Rice strain), which is most consistently found in millet and grass species associated with Pasture habitats, and C-strain (corn strain), which prefers maize and sorghum (Lu et al., 1992).

Recognizing FAW is the first step for management. A study reported that the face of matured larva is marked with inverted 'Y', epidermis is rough or granular in texture and the egg is of fine shaped with flattened base measuring 0.4mm in diameter and 0.3mm in height (Prasanna et al., 2018). According to a study, the four black dots arranged in a square on the back of the last abdominal segment are also distinctive to FAW larvae (CABI, 2017). Spines bearing dark colored elevated spots occur dorsally on the body (CABI, 2017). Luginbill reveals that adults are active during hot and humid evening favoring night for oviposition (Luginbill, 1928). Studying about the life cycle of FAW, it completes its life cycle in 30 days in summer, 60 and 80 to 90 days during spring and winter respectively with the absence of diapause (Capinera, 2002). Luginbill has mentioned that moth deposits eggs in a mass of two or three layers, or decks or in heaps; all the eggs from a fertilized female are fertile, covered by scales and hatch (Luginbill, 1928).

Capinera also agreed to the furry or moldy appearance of egg due to a layer of greyish scales between the eggs and over the egg mass (Capinera, 2002). Total egg production (per female) counts to an average of 1500 with 100 to 200 eggs per mass (Capinera, 2002). Egg stage lasts for two to three days in summer (Capinera, 2002). The activity of larva can be observed in the early morning and in the late evening (Luginbill, 1928). After having own shells as their first meal, larva begins to scatter in all directions in search of food (Luginbill, 1928). Capinera has talked about six instars of larva. 1st instar is greenish with a black head (Capinera, 2002). Head turned orangish in 2nd instar. Dorsal surface of the body becomes

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brownish and lateral white lines begin to form in 3rd instar. Whereas the head is reddish-brown, moulted with white in 4th to 6th instar. Also, the brownish body bears white subdorsal and lateral lines (Capinera, 2002). Larva stage lasts for 14 days in summer and 30 days in winter (Capinera, 2002).

Similarly, found out the mean development time to be 3.3, 1.7, 1.5, 1.5, 2.0 and 3.7 days for instars 1 to 6 respectively when the larvae were reared at 25 °C (Pitre and Hogg, 1983). Soil is the preferred medium for pupation from depth of 1 to 3 inches (Luginbill, 1928). Cocoon is formed by tying soil particles with silk (Luginbill, 1928). Capinera revealed that leaf debris and other materials may be used by larva to form cocoon on the soil surface when the soil is too hard (Capinera, 2002). Pupa is about 14 to 18 mm in length, about 4.5 mm in width and reddish-brown in color (Capinera, 2002). Depending on the temperature, the pupa turns into an adult in 8 to 9 days in summer and 20 to 30 days in winter (Capinera, 2002). Adult stage lasts for about 10 days, with a range of about 7 to 21 days (Capinera, 2002). The dark grey color makes them unremarkable in surroundings (Luginbill, 1928).

In maize, FAW attacks all crop stages from seedling emergence through to ear development (Sisay et al., 2019 b). The first study, based on surveys estimated that FAW had the potential to cause maize yield losses ranging from 8.3 to 20.6 million tons per annum (21-53% of production), if left uncontrolled (Abrahams, et al., 2017; Day et al., 2017). Recent estimates by Centre for Agriculture and Biosciences International (CABI) in 12 maize producing countries showed that without control FAW can cause maize yield losses ranging from 4.1 to 17.7 million tonnes per year which is equivalent to an estimated loss between US $1088 and US $4661 million annually (Rwomushana et al., 2018). Yield losses were recorded the highest in Argentina (72%), and it was 34% in Brazil, threatening the food and nutrition security and livelihood of millions of farming households (Murua et al., 2006; Cruz et al., 1999). It is rapidly spreading across Africa, currently affecting 44 countries (Rwomushana et al., 2018). A study reported its infestation in Yemen and Karnataka state of India by July 2018 (Ganiger et al., 2018). Furthermore, it was confirmed in five Asian countries including China by 2019 (FAO, 2018).

In Nepal, the *Spodoptera frugiperda* has been recorded for the first time on maize form Nawalpur district (N 27° 42' 16.67", E 84° 22' 50.61") on 9th May 2019 (Bajracharya et al., 2019). The samples collected from Nawalparasi district were sent for the molecular identification to National Bureau of Agricultural Insect Resources (NABIR), Bangaluru, India on 20th July 2019, which confirmed to be *Spodoptera frugiperda* on 9th of August 2019 (MOALD, 2019). Fall armyworm has spread across 58 districts of Nepal so far, causing yield loss of 21% of the total maize production of the country (Online Khabar, 2020). Maize is the second most important crop after rice in terms of area and production in Nepal (KC et al., 2015). A total maize production and yield have been reported 2,713,635 tons and 2.84 t/ha in Nepal and 18,334 tonnes and 2.87 t/ha respectively in Kailali (MoALD, 2020). A study reported that maize demand has been constantly growing by about 5% annually in the last decade (Sapkota and Pokhrel, 2010). Among cereals, it contributes about 26.8% of the total feed requirement (Sapkota and Pokhrel, 2010). As we know Maize is the second most important crop and is preferred by the C-strain FAW, in this regard this invasive pest is paving its way for threatening food security and livelihood of the people especially living in the mid-hills and high hills of Nepal. This research survey is carried with an aim to understand infestation status of FAW in maize, farmer's perception, implemented management practices at the local level for its control and its efficacy in Tikapur municipality of Kailali district.

2. Material and Methods

2.1 Study site

The survey was conducted in Kailali district of Sudurpaschim province of Nepal. Ward no. 1 of Tikapur municipality was selected as a study area. Two blocks namely, block no 10 and block no 24 from ward no. 1 were randomly selected.

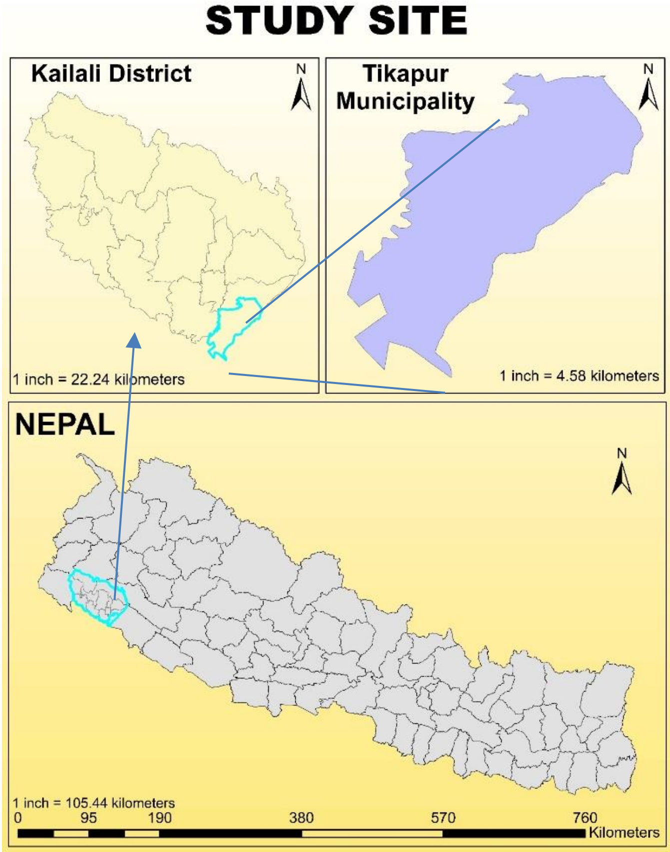

Figure 1: Map of Study Area

2.2 Sampling design and analysis

25 households of maize growing farmers from each block were chosen by random sampling technique and scheduled interviews were carried out in each selected household. The study was conducted during July to August, 2020. In both blocks, surveys covered growing period of maize from 35 to 65 days after sowing (DAS). In each surveyed farm, an area of 3m × 3m was randomly selected and total numbers of plants and damaged plants were counted (Sisay et al., 2019 a).

Then, percentage field infestation was calculated as follows:

% Field infested = (Number of FAW infested fields)/ (total number of field surveyed) × 100

Percentage plant infestation was calculated as follows:

% plant infestation = (Number of FAW infested plants)/ (Total number of plants observed) × 100

Yield loss was calculated as follows:

Yield loss (kg/ha) = Yield before FAW infestation (kg/ha) − Yield after FAW infestation (kg/ha)

Data analysis was done by using Microsoft Excel (MS Excel). Independent 't test' was computed to test whether the average of different variables between two blocks are significantly different or not. Chi square test was computed to examine whether there is significant relation between different variables and adoption status of management practices.

3. Results

3.1 Socioeconomic characteristics of household head

Table 1 gives the summary of the demographic and socio-economic characteristics of household head. The average age is found to be 47.46 years old for block no.10 and 54.92 years old for block no.24. The average age for block no 10 is found to be significantly different with that of Block no 24 at 1% significance level. The average family size is 4.92 (block no.10) and 4.8 (block no.24). In both blocks the majority of household head are male. More than half of the household head were found without secondary level of education in both blocks. Majority of the household head were found to be engaged in off farm activities in both blocks. Very less households have access to credit with an average of 0.16 in block 10 and 0.28 in block 24. Household size is about 0.12 ha for block 10 and 0.0847 ha for block 24 with maize area of 0.04 ha and 0.02 ha in Block no 10 and 24 respectively. The average total land size and maize area of block no 10 are found to be significantly different with that of block no 24 at 1% significance level. Random planting is less practiced in both blocks. Sequential cropping is more practiced over crop rotation and mono-cropping in both blocks with an average of 0.49 and 0.51 in block 10 and block 24 respectively. In case of cropping pattern, sole cropping and mixed cropping were found in majority in both blocks. Both the blocks are dominated by Brahmin community followed by Chhetri, Janajati and Dalits.

Table 1: Demographic and Socio-economic characteristics of household head

Variable	Block No.10 (n=25)		Block no.24 (n=25)		T test value
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	
Age (years)	47.76	7.48	54.92	11.01	2.69 ***
Family size	4.92	1.07	4.8	1.29	0.358
Gender (male = 1, female = 0)	0.8	0.4	0.68	0.47	0.97
Education (secondary = 1, otherwise = 0)	0.44	0.5	0.36	0.49	0.57
Off farm activity (yes = 1, no = 0)	0.72	0.45	0.64	0.49	0.601
Credit access (yes = 1, no = 0)	0.16	0.37	0.28	0.46	1.016
Household size (ha)	0.12	0.04	0.0847	0.034	3.36***
Maize area (ha)	0.04	0.025	0.02	0.014	3.49***
Planting method (Random = 1, otherwise = 0)	0.33	0.066	0.41	0.49	0.81
Cropping System					
a. (Mono cropping = 1, otherwise = 0)	0.32	0.064	0.37	0.71	0.351
b. (Sequential Cropping = 1, otherwise = 0)	0.49	0.098	0.51	0.52	0.19
c. (Crop Rotation = 1, otherwise = 0)	0.43	0.086	0.48	0.6	0.412
Cropping pattern					
a. (Sole cropping = 1, otherwise = 0)	0.45	0.09	0.49	0.63	0.314
b. (Inter Cropping with legumes = 1, otherwise = 0)	0.27	0.054	0.33	0.32	0.924
c. (Mixed Cropping =1, otherwise = 0)	0.5	0.1	0.48	0.02	0.98
Days after sowing	60.48	2.58	61.32	2.35	1.203

Note: *** indicates 1% level of significance.

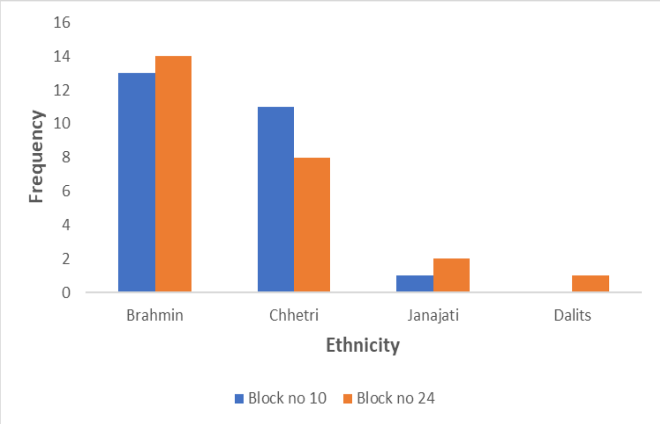

Figure 2: Ethnicity of Block 10 and 24 of Tikapur Municipality, Kailali

3.2 Infestation status, implemented management practices and Constraints in controlling FAW

Field infestation, implemented management practices and problems facing in controlling FAW are presented in table 2. Field infestation was seen in more than half of the household surveyed in both villages. It was 60% in block no 10 and 52% in block no 24. Among household infested with FAW, most of them adopted management practices. But those household where infestation is not yet seen has not adopted any preventive measures against FAW. Among implemented management practices most of them had adopted cultural method (40% in block 10 and 36% in block 24) of pest management followed by the use of locally available materials toxic to FAW (24% in block 10 and 16% in block 24) and chemical (16% in block 10 and 8% in block 24). Very few households were found to receive extension facilities about FAW and its control measures. It was 12% in block 10 and 8% in block 24. According to our study the main problem faced by farmers in controlling FAW was lack of sufficient knowledge about FAW. It was 32% in block 10 and 36% in block 24. As this is the problem of those households infested with FAW the percentage of this problem was 53.33% in block 10 and 69.23% in block 24 among FAW infested household.

Table 2: Farmer's knowledge and perception on FAW

Variable	Block No.10 (n=25)	Block No.24 (n=25)
Field infestation	15 (60.0%)	13 (52.0%)
Adopters of management practices	12 (48%)	9 (36%)
A. Male adaptors	9 (36%)	7 (28%)
B. Female adopters	3 (12%)	2 (8%)
Implemented management practices		
1.Cultural	10 (40%)	8 (32%)
A. Handpicking of egg masses and larva	6 (24%)	4 (16%)
B. Frequent weeding	2 (8%)	1 (4%)
C. Early planting	0 (0%)	1 (4%)
D. Crop Rotation	2 (8%)	2 (8%)
2. Chemical	4 (8%)	2 (8%)
3. Locally available materials toxic to FAW	6 (24%)	4 (16%)
A. Ash	4 (16%)	3(12%)
B. Neem products	1 (4%)	0 (0%)
C. Lime	1 (4%)	1 (4%)
Receiving Extension facilities on FAW	3 (12%)	2 (8%)
Problems facing in controlling FAW		
A. Lack of enough budget	1 (4%)	3 (12%)
B. Lack of sufficient knowledge on controlling FAW	8 (32%)	9 (36%)
C. Unavailability of pesticides in time	3 (12%)	1 (4%)

Note: Figure in parenthesis () indicates percentage.

3.3 Adoption status of management practices

Table 3 describes the adoption of management practices among different socioeconomic characteristics. Chi square value is calculated. No significant relation was observed in case of sex, education and age of the household head with adoption status in both the blocks.

Table 3: Adoption status of management practices among different socioeconomic characteristics

Variables	Block No.10 (n =25)			Block No.24 (n =25)		
	Adopters	**Non adopters**	**Chi square value**	**Adopters**	**Non adopters**	**Chi square value**
Sex			0.01			0.115
A. Male	9	11		7	10	
B. Female	3	2		2	6	
Education			4.116			0.973
A. Illiterate	2	7		3	9	
B. Primary	3	2		2	2	
C. Secondary	6	1		4	3	
D. Higher secondary	1	3		0	2	
Age			0.431			0.423
A. Below 34 Years	1	2		2	1	
B. 40 to 60 years	10	10		4	10	
C. Above 60 years	1	1		3	5	

Note: * indicates 10% level of significance.

3.4 Infestation and yield loss perceived by farmers due to FAW in maize

Average percentage infestation and yield loss in maize were found to be greater in block 10 than that of block 24. Table 4 shows average percentage infestation and yield loss of both villages. Average percentage plant infestation was 11.372% in block 10 with standard deviation of 4.328 and it was found to be 8.913% in block 24 with standard deviation of 2.473. Average yield loss in block 10 was found to be 129.058 kg/ha and that was 93.052 kg/ha in block 24.

Table 4: Assessment of infestation and yield loss

Variable	Block No.10		Block No.24	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
% infestation	11.372	4.328	8.913	2.473
Yield loss (kg/ha)	129.058	58.997	93.052	27.733

3.5 Efficacy of different management practices against FAW implemented by farmers

The efficacy of different implemented management practices in both villages is shown in table 5. These management practices are ranked according to their efficacy to control FAW infestation. The management practice which results minimum plant infestation is ranked as first and vice versa. Those households which do not adopt any management practices have highest infestation (18.17%). Among management practices cultural method is the least effective with average percentage infestation of 13.15%. Use of locally available materials toxic to FAW seems to be more effective than the cultural method with average percentage infestation of 8.27%. Table 5 reveals that a combination of two or more management practices control FAW better than individual practice. Use of all three management practices that are chemical, cultural and locally available materials are found to be the most effective in controlling FAW with an average percentage infestation of only 4.15%.

Table 5: Assessment of the efficacy of implemented management practices against FAW

Implemented management practices	Average Percentage plant infestation	Rank (Efficacy)
No adoption of management practices	18.17	VIII
Cultural method	13.15	VII
Chemical pesticides	6.85	IV
Locally available materials toxic to FAW	8.27	VI
Cultural + chemical	6.25	III
Cultural + locally available materials toxic to FAW	7.34	V
Chemical + locally available materials toxic to FAW	4.93	II
Cultural + chemical + locally available materials toxic to FAW	4.15	I

4. Discussion

Majority of the household surveyed were patriarchal and joint family. This finding of our study is in consistent with that of CBS. Their farming system was subsistence type so involved in nonagricultural works for generating income. Lack of any facilities of subsidies from government was the reason behind practicing subsistence farming. The problem of land fragmentation was prevalent there that hindered them from adopting modern methods of cultivation. Most of them were found to give continuation to the traditional methods of cropping systems and cropping patterns. This revealed that they are unaware of the advantages of crop rotation and intercropping. Lack of agricultural knowledge and extension services were the main reasons behind these problems.

Though the percentage of plant infestation seems to be less, it is necessary to apply control measures. Fernandez also recommended to apply appropriate management practices on maize if 5% of the seedlings are cut or 20% of whorls of small plants are damaged by FAW (Fernandez, 2002). Most of the farmers failed to recognize FAW and thus they were unable to adopt appropriate management practices. Very few farmers were familiar with the larval stage of FAW. Koffi also reported that maize producers in Ghana were familiar with the larval stage of FAW due to its visible injuries in maize plant (Koffi, 2020). Implementation of management practices was found to be greater in Block no 10 than that of Block no 24 due to higher literacy rate in Block no 10. Greater number of male farmers had adopted management practices as they had greater access to agricultural extension services and also had higher literacy rate than women. A group researchers also reported that most of the Nepalese women especially of rural part of the country are illiterate and limited in agricultural and household activities (Bhandari et al., 2015).

Most of the household surveyed were of smallholder farmers owing less than a hectare of land. Nearly half of the Nepalese farmers had less than 0.5 hectare of land (CBS, 2011). Due to small land size, agriculture mechanization was restricted and hence, they were not able to adopt commercialization in agriculture. Most of them used cultural method of pest management. CABI also reported that smallholders' farmers practice handpicking, destroying egg masses and larvae and putting sand mixed with lime or ash in the whorl of infested maize to kill the larvae (CABI, 2017). Early planting helps to create asynchrony between the pest and critical crop growth stages. Intercropping of maize with leguminous crops results in a significantly lower FAW infestation, compared with mono-cropping (Hailu et al., 2018). Similarly, crop rotation helps to break the continuous life cycle of the pest. FAO reported that crop rotation of maize with non host crops such as bean, sunflower helps to reduce infestation of FAW (FAO, 2018). There are many other cultural methods of pest management including deep ploughing, increasing ground cover, grown of maize hybrids with tight husk cover will reduce ear damage by FAW (Firake et al., 2019). But they were found to use very few options of cultural pest management because of lack of sufficient knowledge about FAW and its control measures. Very few farmers used to go with the chemical method of pest management.

This finding of our study is in consistent with the research conducted in

Africa (Abate et al., 2000). It might be due to less percentage of plant infestation and/or may be due to unavailability of pesticide in time. Farmers of Block no 10 had easy access to the market so that they were found to use chemical pesticides more than that of Block no 24. Some of the farmers in both villages used locally available materials toxic to FAW for its control such as sand, lime powder and neem products. They used to apply ash and lime powder by dusting and neem oil by spraying into the infested plants. A Group Researchers reveals that neem seed powder is efficient in killing FAW larvae causing over 70% of mortality (Maredia et al., 1992). Such products can be made easily in house and are somehow effective in controlling pest so many of them are interested towards these products. Schmutterer revealed that because of availability and affordability many botanical pesticides have been used in developing countries for centuries (Schmutterer, 1985). But they were unaware of the appropriate dose, method and time for application. Some of the farmers showed finance as a major problem in controlling FAW. These farmers had very less land area as compared to others and are illiterate. The male from such household used to go to India to live from hand to mouth. They are even unable to afford pesticides and also have no idea to control the pest. This lacking of knowledge can be linked with lack of facilities of extension services. Nevertheless, among overall farmers, lack of sufficient knowledge about FAW and its control measures was the major problem.

According to our study, the infestation of FAW is in increasing rate in both villages but a bit more in Block no 10. This increasing rate of FAW incidence is due to lack of any preventive measures, seeds from unauthorized sources and careless by the farmers especially of small land size. They are not aware that this invasive pest will cause a serious threat to food security in nearby future. Percentage plant infestation seems to be more in Block no 10 though there were more numbers of adopters than in block no 24. This was due to the fact that the percentage field infestation was more in Block no 10. Due to this very reason, they were seriously concerned about infestation and most of the farmers had adopted some of the management practices but they were not so effective. The yield loss reported was about 4% of the average yield of the region. A study reported yield loss of 11.57% on maize from a study conducted in the eastern Zimbabwe (Baudron et al., 2019). The less yield loss in our case is due to the fact that the pest has recently been introduced in the region.

Our study revealed that the implementation of more than one method of management practices results in effective control of FAW. This emphasizes on Integrated Pest Management (IPM). FAO states that Integrated Pest Control is a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury (FAO, 1975). It includes cultural, physical, chemical, biological and mechanical methods. But they were found to use only a few of these methods. This is due to lack of knowledge and extension facilities. Most of the farmers were not aware about IPM. Nonetheless, they consciously or unconsciously implemented more than one method of pest management.

5. Conclusion

Majority of the farmers surveyed were infested with FAW, nonetheless the infestation is not so severe yet. The pest is in the state of rapid and substantial expansion in the region. Though the farmers have implemented some of the management practices, the result is not so satisfactory. Those farmers who implemented different management practices in an integrated way are able to control pest effectively. They are able to do so because the pest has recently been introduced in the region and the infestation is not so severe. But when it spreads thoroughly across the region their present management methods will not be as effective as they are at present. Most of the farmers are unknown about this new invasive pest due to which they cannot adopt appropriate management practices. They are deprived of agricultural extension services. Most of them are practicing traditional system of cultivation. Mechanization and scientific production technologies are lacking in the region. At present, as the infestation rate is low in maize field, farmers are ignoring this pest. If this situation continues, this invasive pest will cause considerable yield loss threatening the livelihood of the maize growing farmers.

So, it is a high time to adopt effective management strategies for its control to prevent further expansion. We can learn from other countries where it has been a serious threat and their management strategies to tackle it. There is an urgent need to spread awareness among farmers about the identification of the pest, its life cycle, effective management practices and time for their implementation. Extension services should be provided at the grassroots level. Pesticides and other necessary tools used in pest control should be made available in time. The government should recognize those farmers who cannot adopt management practices due to their poor economic condition and subsidy should be provided for such needy farmers. Effective regulation of plant quarantine check post should be done at Nepal India border to prevent import of infested planting materials. Focuses should be given towards Integrated Pest Management (IPM) for sustainable management which is cost-effective and environmentally safer. At the same time, resistant varieties against FAW should be developed.

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