Sustainable Pest Control Against Fall Armyworm Constrained By Limited Knowledge And Skills Of Maize Farmers: A Case Study In Central Sulawesi, Indonesia

Shahabuddin Saleh
Plant Pests and Diseases Department, Faculty of Agriculture Tadulako University
Palu, Indonesia
shahabsaleh@gmail.com

Mohammad Yunus
Plant Pests and Diseases Department, Faculty of Agriculture Tadulako University
Palu, Indonesia
mohyunus125@gmail.com

Dewi Nur Asih
Agribusiness Department,Faculty of Agriculture Tadulako University
Palu, Indonesia
dewi.nurasih5@gmail.com

Sulaeman Sulaeman
Agribusiness Department, Faculty of Agriculture Tadulako University
Palu, Indonesia
sulaemanjie6976@gmail.com

Siti Yuliaty Chansa
Agribusiness Department, Faculty of Agriculture Tadulako University
Palu, Indonesia
ulliechansa@gmail.com

I Gede Laksana Wibawa
Agribusiness Department, Faculty of Agriculture Tadulako University
Palu, Indonesia
gedewibowo30@gmail.com

Assa Natasyah
Student of Plant Pests and Diseases Department, Faculty of Agriculture Tadulako University
Palu, Indonesia
assanatasyah1702@gmail.com

***Abstract* - Maize is one of the priority agricultural commodities developed in Central Sulawesi. One of the obstacles that need to be addressed for this purpose is pest infestations, mainly fall armyworm (FAW), *Spodoptera frugiderda* (J.E. Smith), a new pest in Indonesia. The success of pest control is influenced, among others, by farmers' knowledge of this invasive pest and their control techniques. This study aims to analyze the behavior of farmers in controlling FAW and other maize pests and its relationship with their knowledge and attitude. Eighty farmers in Sigi Regency, Central Sulawesi were selected as respondents using a purposive sampling technique. The selected farmers represent four villages in Sigi Biromaru sub-district and farmer groups in each of these villages. The results showed that all respondents admitted that FAW was the most dominant and destructive pest that infested their maize crops. For pest control, all farmers only use chemical control even though they know the negative impact of chemical insecticides. Although farmers' knowledge and attitude positively correlated there is no correlation between both factors on farmers' behavior in FAW management. The willingness of farmers to implement sustainable pest control is constrained by the limited knowledge and skills of farmers in environmentally friendly pest control techniques.**

Keywords- Spodoptera frugiderda, maize, farmer knowledge and behavior, pest control

1. INTRODUCTION

Maize (*Zea mays*) is an important food crop in Indonesia besides rice. However, maize productivity in Central Sulawesi is still low. In 2020 the average productivity is 41.4 q. ha^{-1}, lower than the national maize productivity which reached 52.9 q. ha^{-1}[1]. Pest infestation is one of the main causes of declining maize productivity. There are more than 86% of maize households in Central Sulawesi experienced pest attacks including the infestation of Fall armyworm that increased their attack area from 448 ha (crop failure 1 ha) in 2019 to 902 ha (crop failure 9 ha) in 2020 [1,2]. Fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) is an invasive pest that has become a new major pest on maize in Indonesia and has been attacking about 13,379 Ha (crop failure 60 ha) in 2020[2].

Crop losses due to insect pests can be prevented, or reduced, by implementing effective crop protection technique, which mainly depend on the extent of farmer knowledge and behavior towards pests, control methods, availability and effectiveness of the protection methods used [3]. Therefore, it is important to understand what farmers know about

N. Edy et al. (eds.), *Proceedings of the 2nd International Interdisciplinary Conference on Environmental Sciences and Sustainable Developments 2022 Environment and Sustainable Development (IICESSD-ESD 2022)*, Advances in Biological Sciences Research 36,
https://doi.org/10.2991/978-94-6463-334-4_28

insect pests, their perceptions of yield losses due to these pests, the control methods used, and perceptions about the effectiveness of the control methods they choose to implement [4].

Chemical control is the most widely used for pest control in Indonesia [5]. Although those chemicals have several adverse impacts on humans, the environment and natural enemies of pests [6,7]. Therefore, the farmers need to adopt and use more sustainable pest control as implemented by maize farmers in others countries [8,9]. However, farmer adoption to technology depend on several factors including farmers and technology characteristic itself [10]. Accordingly, it is necessary to study the farmer's behavior in managing FAW and how it is related to their knowledge and attitudes.

II. MATERIALS AND METHODS

This research was carried out in Sigi Biromaru District, Sigi Regency, one of the centers of maize cultivation in Central Sulawesi. The research was conducted from April to October 2022. A total of 80 farmers were selected as respondents using a purposive sampling technique. The selected respondents represent four villages in Sigi Biromaru sub-district and farmer groups in each of these villages.

A. Research Instruments

The research instrument used to measure the knowledge, attitudes, and behavior of farmers is a questionnaire in open and closed format question. The questionnaire is in the form of a list of questions about; (1) farmer knowledge, (2) farmer attitude, and (4) farmer behavior related to FAW characteristics and control techniques used. We defined farmer knowledge as what farmers know about FAW. Respondents were asked about their knowledge by showing photos of FAW at different stages including the characteristics of the attack and the damage it caused. They were also asked about the control techniques they implemented. Instruments about the level of knowledge in the form of questions with two alternative choices: true (score = 1) and false (score = 2). The attitude of farmers in controlling FAW is the tendency of farmers to make decisions in controlling FAW pests while farmer behavior is a conscious and planned control action taken by farmers to control FAW and other corn pests. Farmer's attitudes and behavior was measured using three alternative answers: Agree (Score = 3), Doubtful (Score = 2), and Disagree (Score = 1). The questionnaire used previously had been tested for validity and reliability on 20 farmers at the research site. From a total of 31 questions, there were 24 "Valid" questions and 7 "Invalid" questions. The results of the instrument reliability test show that the instrument is reliable with the Cronbach's Alpha value of each variable being 0.633 (knowledge), 0.670 (attitude), and 0.66 (behavior). Therefore, the questionnaire used is reliable and can be reused to measure the same object even at different times and with respondents [11]. In addition to interviews with farmers, was also observed the existence and infestation of FAW on farmers' maize crops.

B. Data analysis

The research data are presented descriptively to provide complete information about the results of research related to the three variables observed. In addition, the Rank-Spearman correlation analysis was used to analyze the strength of the relationship between the independent variable (farmers' knowledge and perception of FAW pest control) and the dependent variable (farmers' behavior in managing FAW pests). Data analysis was performed using SPSS version 22 software.

III. RESULTS AND DISCUSSION

A. Farmer Characteristics

Farmers as the respondents in this study had varied characteristics (Table 1).

Table 1. Characteristics of farmers

No	Variables	Description	Number of farmers	Percentage
1	Age (years)	< 30	2	2.5
		30 - 50	48	60.0
		> 50	30	37.5
2	Education	Primary school	26	32.5
		Junior High School	12	15.0
		Senior High School	35	43.8
		University	7	8.7
3	Land ownership	Own land	24	45.0
		Cultivator	36	55.0
4	Area planted with maize (ha)	0.5	12	25.0
		1	18	31.3
		>1	30	43.8

Most farmers are aged 30-50 years (60%) or are still in productive age with the education level dominated by Senior High School (44%). They are dominated by smallholder farmers (55%). Only 44 % of farmers grow corn in an area of more than 1

ha, other farmers grow corn in an area of between 0.5 and 1 ha. The level of education of farmers in the research location, which is majority up to Senior High School level. This is point to a relatively high literacy level among maize farmers in study area. The education level of farmers in the study area is quite different from the results of studies in other locations which report that the majority of farmers' education is elementary school graduates [12,13]. With a fairly high level of education of farmers, it is hoped that farmers can implement good agricultural practices, regardless of whether they become farmers because of their conscious choice or because of economic limitations to continue their education to the university level. The previous study attained that the education level of smallholder farmers positively correlates with their rate of technology adoption [14]. Therefore, efforts are needed to increase the interest of the educated young generation in agriculture, including by involving the younger generation in the agricultural community [12].

B. Farmer's knowledge about FAW

The survey results showed that all farmers knew and acknowledged that their corn crops were attacked by FAW and this pest was the most dominant and destructor pest in their maize fields. This is in line with our field observation were characteristics of FAW infestation and FAW larvae is detected at the farmers' maize field (Fig.1). The morphological character of FAW as shown at Figure in accordance with [15]. The presence of FAW at the study area needs to be watched out for because until 2020 the attack area of FAW has reached 902 ha (crop failure 9 ha) in Central Sulawesi and 13,379 ha (crop failure 60 ha) at the national level [2]. This shows that FAW could be a serious threat to national food security.

Fig.1. Observation of *S.frugiperda* infestation (a) and it symptoms (b) at farmer's maize field. Adult larvae of FAW collected from maize crops (c) and its characteristic marks as indicated by four large spots arranged in a square on the upper surface on the eighth abdominal segment and a white inverted "Y" mark on the head.

Apart from FAW, there are several other pests that attack maize crops in our study area (Table 2).

Table 2. Mayor pest at the farmers' maize field

No	The most dominant and destructor pest	Number of respondents at the villages*				Total (Percentage)
		Sd 1	Sd 2	Sd3	Sd 4	
1	*S. frugiperda* (J.E.Smith)	22	20	16	22	80 (100)
2	*Stenocranus pacificus* Kirkaldy	21	17	16	19	73 (91.3)
3	*Helicoverpa armigera* Hubner	20	17	15	17	69 (86.3)
4	*Ostrinia furnacalis* Guenee	16	17	14	13	60 (75,0)
5	*Atherigona exigua* Stein	3	7	8	8	26 (32.5)
6	*Agrotis ipsilon* Hufnagel	5	9	7	7	28 (35.0)

* Sd = Sidondo

Of the six species of pests that attack farmers' maize plants, there are four species of pests that dominate, namely: FAW, corn planthopper, corn earworm, and Asian corn born. Infestation of corn planthopper, *S. pacificus* in Central Sulawesi besides FAW, have to be cautious farmers because both invasive pests have become important maize pests in other regions of Indonesia, particularly in West Sumatra [16].

C. Knowledge and attitudes of farmers in controlling FAW

All of the respondents use chemical insecticides as the first option against FAW and other maize pests. This is because they believe that this is an effective

way to control them. However, they are aware that chemical insecticides have a negative impact on the environment and may increase pest resistance (Table 3).

Table 3. Farmers' knowledge about management of FAW and another maize pest

No	Indicators	Numbers of farmers		
		Agree	Doubtful	Not Agree
1	Chemical control is a first option for pest control	80	0	0
2	Pesticides are effective for pest control	72	6	2
3	Pesticides has harmful effect on environment and human	76	1	2
4	Intensive use of pesticides induced a pest resistance	50	15	15

There are 12 types of insecticides used by farmers. Insecticides with the active ingredient chlorantraniliprole are the most widely used by farmers (Table 4).

Table 4. Types of pesticides used by farmers against FAW and other maize pests

No	Pesticide name	Active ingredient	Total number (Percentage)
1	Prevathon 50 SC	Chlorantraniliprole	45 (56.3)
2	Laser 480 SC	Permethrin	3 (3.8)
3	Sidatan 410 SL	Dimehipo	5 (6.3)
4	Meurtieur 30 EC	Emamectin benzoat	2 (2.5)
5	Dangke 40 WP	Methomyl	10 (12.5)
6	Sidamethrin 50 EC	Cypermethrin	4 (5)
7	Decis 25 EC	Deltamethrin	1 (1.3)
8	Spontan 400 SL	Dimehipo	1 (1.3)
9	Fostin 610 EC	Chlorpyrifos	2 (2.5)
10	Regent 50 SC	Fipronil	3 (3.8)
11	Vayego 200 SC	Tetraniliprole	1 (1.3)
12	Fenite 150 OD	Emamektin benzoat and Iufenuron	3
Total number of farmers (Percentage)			80 (100)

Although claimed to be nontoxic to humans, cases of poisoning and serious cardiac arrest due to exposure to chlorantraniliprole have been reported in India [17]. Therefore, farmers need to get information about the negative impact of using insecticides and some more sustainable pest control as alternative solutions. All of the farmers interviewed use chemical control as the only pest control implemented. In the application of those chemicals, some farmers mixed different types of pesticides (Table 5). They assumed that it will increase the pesticide efficacy. Interestingly, almost all of the farmers have the willingness to use a more sustainable technique control.

The high dependence on chemical insecticides by farmers is not only found by studies. Although they are increasingly expensive and have harmful effects on the environment and human health, the use of chemical pesticides by farmers in various agricultural countries continues to increase [6].

Table 5. Farmer attitudes and behavior on FAW management

No.	Attitude and behavior	Farmers number	Percentage
1	Only use chemical control	80	100
2	Mixed different type of pesticides at the time of application	23	28.8
3	Using safety tolls and procedure when application of pesticides such us: masker, glove, and shoes	75	93.7
4	Willingness to use a more sustainable technique control such us botanical pesticides or biological control agents	60	75.0

The use of pesticides in Indonesia has increased significantly in the last decade and more than 4000 brands of pesticides are allowed to circulate in this country [18].

D. The obstacles to farmers implementing a sustainable pest control

When asked the reason why farmers have not implemented a more sustainable pest control compared with chemical control, the majority of the farmers admitted that they have limited knowledge of other control techniques (38.8 %) or don't know how to make natural pesticides (41.3%), or the difficulty of obtaining them (20.0%) (Fig. 2).

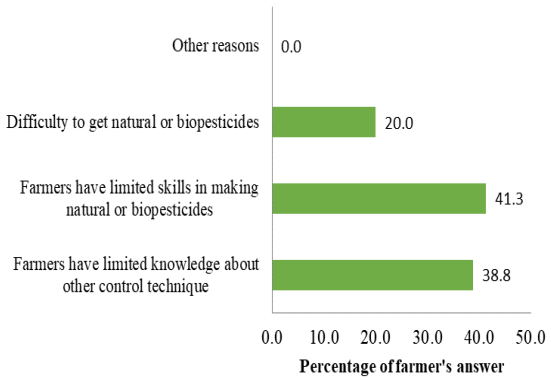

Fig. 2. The farmer's reason for not implementing sustainable pest control

What is interesting is the attitude of farmers towards alternative corn pest control that is more environmentally friendly, such as botanical pesticides or biopesticides (Table 5). Majority of the farmers are interested in implementing those pest control. This shows that in general farmers have an

awareness of the detrimental effect of pesticides so they intend to use control techniques other than pesticides but are constrained by several things, particularly their knowledge and skills in making and formulating natural pesticides as described in Fig. 2. This highlights the importance of strengthening farmers' knowledge and skills about sustainable control techniques that do not depend on chemical pesticides. The pest management technology offered must of course take into account the character of the technology. Relative advantages, compatibility, simplicity, and trial ability are important to be considered in introducing technology to farmers [19]. Those technology characteristics together with farmer and farm characteristics, as well as finance and institutional factors influence the successful adoption of technology by smallholder farmers [10].

In Zambia, chemical control is also the most common method implemented by farmers against FAW. Increased use of pesticides to manage fall armyworm poses health and environmental risks, besides the high cost for farmers and governments. Research into cultural and indigenous practices used by farmers will offer opportunities for alternative and sustainable management practices (Kansiime *et al*. 2019) [20]. One of the sustainable control against FAW that could be introduced to the farmers is Push-Pull Strategy that widely implemented by farmers in Africa because significantly decreased FAW infestation, increased maize yields, and claimed to be adaptive to climate change [8,9]. This pest management strategy is in line with the Law of the R.I. No. 22 of 2019 on the Sustainable Agriculture Cultivation System that emphasizes the implementation of integrated management and considers the climate change effect against crop pests [21].

E. The relationship between knowledge, attitudes and behavior of farmers in controlling FAW

The results of the correlation analysis did not detect a correlation between the farmers' behavior on FAW management and their knowledge ($r = 0.11$) as well as attitudes ($r=0.02$). However, there is a significant correlation between farmers' knowledge and attitudes ($r = 0.56$, $p = 0{,}002$). This result showed that farmers are in a paradoxical situation. They know that chemical pesticides have negative impacts on humans and the environment, including triggering pest resistance but in fact, they only use chemical control to deal with maize pests. According to Wilson & Tisdell (2001)[6], the paradoxical condition between the knowledge and behavior of farmers who depend on chemical control occurs because farmers have long been trapped and locked in an unsustainable pest control system when they have started to adopt chemical control. They are reluctant to switch to more environmentally friendly control techniques because of the high initial cost of switching to a more sustainable system and it needs the involvement of all parties, not only farmers, to act simultaneously in the transition process to avoid losses [11].

IV. CONCLUSION

The study showed that all farmers know and admitted that FAW was the most dominant pest that infested their maize crops and may reduce the maize yields significantly. Nevertheless, all farmers only use chemical control against maize pests even though they know the negative impact of chemical pesticides. The willingness to implement a sustainable pest control of FAW by farmers is constrained by the limited knowledge and skills. Therefore, training programs, with easy-to-understand formats, were needed to enhance farmers' knowledge and skills in sustainable control of FAW and other pests.

ACKNOWLEDGMENT

This study was funded by Penelitian Unggulan Grant of Tadulako University through DIPA Pascasarjana in 2022. The authors are grateful to the students and farmers that contributed to the survey activity.

REFERENCES

[1] Directorate of Food Crops, Horticulture, and Estate Crops Statistics (DFCHECS), "The 2020 Analysis of Maize and Soybean Productivity in Indonesia (The Results of Crop Cutting Survey)," BPS-Statistics Indonesia. 110 pp. (2021)

[2] M. Subehi, A. Abdurachman and L. Hasanah, "Statistics of Climate, Crop Pest and Climate Change Impact 2017-2020," Center for Agricultural Data and Information System Secretariate General - Ministry of Agriculture. 271 pp. (2020)

[3] H. Segura, J. Barrera, H. Morales and A. Nazar, "Farmers' perceptions, knowledge, and management of coffee pests and diseases and their natural enemies in Chiapas," Mexico. J Econ Entomol, vol. 97, pp.1491–1499 (2004).

[4] L.J. McLeod, D.W. Hine, P.M. Please, and A.B. Driver, "Applying behavioral theories to invasive animal management: towards an integrated framework," J Environ Manage, vol.161, pp.63–71 (2015).

[5] J. Mariyono, A. Kuntariningsih, and T. Kompas, "Pesticide use in Indonesian vegetable farming and its determinants,". Manag. Environ. Qual. Int. J., vol. 29 (2), pp.305–323 (2018).

[6] C. Wilson and C. Tisdell, "Why farmers continue to use pesticides despite environmental,

health and sustainability costs," Ecological Economics, vol. 39, pp.449–462 (2001).
[7] Md. W. Aktar, D. Sengupta, and A. Chowdhury, "Impact of pesticides use in agriculture: their benefits and hazards,". Interdisc Toxicol, vol. 2(1), pp.1–12 (2009).
[8] Z.R. Khan, J.O. Pittchar, C.A.O. Midega, and J.A. Pickett, "Push-pull farming system controls Fall Armyworm: Lessons from Africa," Outlooks Pest Manag, vol.29, pp.220–224 (2018).
[9] C.A.O Midega, J.O. Pittchar, J.A.Pickett, G.W. Hailu, Z.R. Khan, "A climate-adapted push-pull system effectively controls Fall Armyworm, *Spodoptera frugiperda* (J E Smith), in maize in East Africa," Crop Protect, vol.105, pp.10–15 (2018).
[10] O.A. Fadeyi, A. Ariyawardana, and A.A. Aziz, "Factors influencing technology adoption among smallholder farmers: a systematic review in Africa," Journal of Agriculture and Rural Development in the Tropics and Subtropics, vol.123 (1), pp.13-30 (2022).
[11] O.A. Bolarinwa, "Principles and methods of validity and reliability testing of questionnaires used in social and health science researches," Niger Postgrad Med J, vol. 22, pp.195-201 (2015).
[12] Harniati and O. Anwarudin, "The Interest and Action of Young Agricultural Entrepreneur on Agribusiness in Cianjur Regency, West Java," Jurnal Penyuluhan, vol.14(2), pp.189-198 (2018).
[13] O. Anwarudin, Sumardjo, A. Satria, and A Fatchiya, "A Review on Farmer Regeneration and Its Determining Factors in Indonesia," International Journal of Progressive Sciences and Technologies (IJPSAT), vol.10(2), pp.218-230 (2018).
[14] O. Oyinbo, J. Chamberlin, B. Vanlauwe, L. Vranken, Y.A. Kamara, P. Craufurd, and M. Maertens, "Farmers' preferences for high-input agriculture supported by site-specific extension services: Evidence from a choice experiment in Nigeria," Agricultural Systems, vol.173, pp.12-26 (2019).
[15] C. Sharanabasappa, M. Kalleshwaraswamy, M.S. Maruthi, and H.B Pavithra, "Biology of invasive fall army worm *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on maize," Indian Journal of Entomology, vol.80(3), pp.540-543 (2018).
[16] N. Nelly, H. Hamid, E.C. Lina, Yunisman, and Mysyahrawati, "*Stenocranus pacificus* (Hemiptera: Delphacidae) and *Spodoptera frugiperda* (Noctuidae; Lepidoptera) are important pests on maize mix-cropped with oil palm in West Sumatra," IOP Conf. Ser.: Earth Environ. Sci. vol. (974) 012004 (2022).
17] A.K. Mishra, V.K. Chandiraseharan, N. Jose, and T.D. Sudarsanam, "Chlorantraniliprole: An unusual insecticide poisoning in humans," Indian J Crit Care Med, vol.20(12), pp.742-744 (2016).
[18] V. Darwis, M. Mardiharini, I.S. Anugrah, Istriningsih, and Dadang, "Pesticides Industry in Indonesia," in Pesticides in Indonesia: Industry, Supply Chain and Use, E. Jamal, Dadang, and M. Sarwani (Eds.),. IPB Press, Bogor (2020).
[19] E.M. Rogers, Diffusion of innovations (5th ed.), New York: Free Press. 576 pp. (2003).
[20] M.K. Kansiime, I. Mugambi, I. Rwomushana, W. Nunda, J. Lamontagne-Godwin, H. Rware, H., A.N. Phiri, G. Chipabika, M. Ndlovud, and R. Daya, "Farmer perception of fall armyworm (*Spodoptera frugiderda* J.E. Smith) and farm-level management practices in Zambia," Pest Manag Sci, vol. 75, pp.2840–2850 (2019).
[21] Law of the R.I. No. 22 of 2019 on the Sustainable Agriculture Cultivation System. https://jdih.setneg.go.id/. Accessed 9 November (2022).