Original Research Article

Occurrence of different kinds of diseases in sesame cultivation in Myanmar and their impact to sesame yield

ABSTRACT

We surveyed diseases of sesame in 10 farmers' fields at Nay Pyi Taw, Myanmar and did interviews25 farmers for the occurrence of diseases and its impact on yield in Magway, the major sesame growing areain Myanmar. We found phyllody, charcoal rot (root and stem rot), Alternaria leaf blight, powdery mildew, and leaf curl, based on on-site symptoms and their microscopic observation in Nay Pyi Taw. The disease incidence ranged from 5% to 30% in phyllody, from 10% to 30% in charcoal rot (root and stem rot) and 10% to 40% in Alternaria blight, while leaf curl and powdery mildew were not observed abundantly. According to interviews conducted in Magway, 60% of the farmers suffered from phyllody disease symptoms, 80% from charcoal rot, 48% from Cercospora, 28% bacterial leaf spot and 24% diseases with the symptoms of leaf roll. Most farmers (84%) noticed combinations of diseases symptoms either phyllody or charcoal rot/black and stem rot or Cercospora leaf spot and/or bacterial leaf spot. Yield losses ranged from 10 to 50% by phyllody, from 15 to 100% by charcoal rot (root and stem rot) and from 0 to 50% by leaf spots. Other abnormal symptoms such as discoloring of root, seedling death and leaf yellowing were also observed. There were no significance relations between the actual yield and yield losses estimated by each disease. A half of farmers (54%) burnt the crop residues after harvest, while 45% directly buried them in their fields including disease infected plant parts in the soil. Although there was no difference in sesame yield between these two practices, the average yield was higher by 15% in farmers with the burnt practice. Only a few farmers applied fungicides. Potential constraints to cause yield reduction and necessary actions to increase sesame yield are discussed.

Keywords: Alternaria*, charcoal rot, control measures, disease incidence, phyllody, yield loss,*

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is the major oilseed crop in Myanmar for both export and domestic consumption. Myanmar stands the second largest producers of sesame in the world [1]. Sesame is cultivated two times a year: May to August as the monsoon crop and September or October to December as the cool season cultivation. The total sesame sown area in 2017-2018 was 1.6 million ha, in which 829,000 ton of sesame was produced with the yield of 0.54 t ha^{-1} [2]. The sesame yield in Myanmar is low compared with that in other major sesame producing countries such as 1.41 t ha^{-1} in Chia, 0.90 t ha^{-1} in Bangaladesh, and0.78 t ha^{-1} in Ethiopia [1]. In Myanmar, 80% of the sown area is within the central dry zone, which comprises parts of Mandalay, Sagaing and Magway regions and makes up the major growing area for oilseed crops.

Sesame is damaged by a number of fungal, bacterial and viral diseases, such as *Cercospora sesami*, *Cylindrosporium sesami*, *Alternaria seasami*, *Pseudomonas sesami*, *Macrophomina phaseoli*, *Phytophthora parasitica*,*Oidium* spp., *Erysiphecirhoracearum*, *Phytophthoranicotianae* var. *sesame* and *Helminthosporiumsesamiare*[3]. Considerable yield losses due to diseases have been reported; yield losses of 45% by the powdery mildew, *Luveillutataurica*, 55%-90% by phyllody disease caused by phytoplasma [4,5], 5-100% by *M. phasiolina*, 22-53% by Cercopspora leaf spot [6]. A disease

complex of powdery mildew with dry root rot disease, which is caused by the fungi *Macrophomina* and *Oidium*, results in low productivity of sesame in India [7].

In Myanmar, different symptoms in sesame cultivation have been reported by the Department of Plant Pathology, Yezin Agricultural University: phyllody disease, virescence, yellowing floral sterility and stem proliferation in infected plants, Alternaria leaf blight, dark brown rounded to irregular lesions on leaves, powdery mildew, dirty white powder. However, in-depth investigations have not been undertaken in Myanmar until now and there is no sufficient information on the major threat of sesame cultivation, making it difficult to develop suitable disease control measures. Available information in Myanmar is only the studies by ~~Win et al.~~ [8] who worked on phyllody disease and by ~~Wai et al. (2007)~~[9] who did varietal screening against charcoal rot disease caused by *M. phaseolina*.

In order to manage diseases in the field, it is necessary to know the incidence and distribution of each sesame disease and their impact on production. In Myanmar, sesame ~~has been~~is cultivated by small holders' farmers with minimum inputs. Therefore, expanding knowledge of sesame diseases to local farmers is very important for the development of effective disease control tactics in sustainable agriculture. The aims of this study were to observe the prevalence of sesame diseases and evaluate its control practices by small holder~~s~~ famers. In this study, we firstly identified different diseases through microscopic examination of specimens collected from sesame fields in Nay Pyi Taw and then evaluated their incidence. Then, we interviewed on disease occurrence, impact on sesame yield and managements practiced ~~with~~ by small holder's farmers in Magway regions, one of the major sesame growing areas.

Comment [Hi1]: Consider fragmenting this sentence because it is too long.

Comment [Hi2]: Revise grammar.

2. MATERIALS AND METHODS

2.1 Disease Specimen Collection

Specimen~~s~~ were collected from four different sesame fields at the flowering time of sesame, in the middle of June~~,~~ 2016 in Yezin, Pyinmana located in Nay Pyi Taw areas. The appearance of aboveground disease symptoms which were likely to be charcoal rot, Alternaria blight, powdery mildew, phyllody and leaf curl was carefully observed and recorded in each field with photographs of the disease symptoms. Then, the specimens collected were put into a plastic bag and taken to the laboratory for microscopic examination ~~and brought to the laboratory~~.

2.1.1 Microscopic Examination

Microscopic examination was done in the laboratory of Plant Pathology~~,~~ atYezin Agricultural University. Specimen~~s~~ were collected from symptoms on the fresh leaf specimens with dark brown color round to irregular zonate lesions, dirty white powdery substance on leaves and black dots on stems and carefully checked for the presence of spores and spore fruiting body of pathogens under low and ~~high power~~high-power objective lens (10x and 40x) [10].

For charcoal rot disease, firstly the bark of diseased stems of sesame was peeled off and placed onto a drop of sterilized water on a slide and checked under microscope. For mycelium observation, a drop of sterilized water was placed on a clean glass slide and the bark of diseased stems of sesame was peeled off and cut into small pieces and surface sterilized with 95% ethyl alcohol for 30 seconds and transferred into 10% sodium ~~hypochloride~~hypochlorite for ~~1~~ oneminute. Then, the specimen~~s~~ were washed into sterilized water for ~~3~~ threetimes and finally the pieces were dried and transferred onto water agar and incubate~~d~~ at room temperature. After ~~3~~ threedays of incubation, the mycelium formation of *Macrophomina phaseolina* name was confirmed.

For Alternaria leaf blight, a drop of sterilized water was placed on a clean glass slide. A small amount of fungal spores taken from the dark brown irregular lesions on the leaves was placed into a drop of water drop and covered with a cover slip. Morphological characteristics of conidia and conidiophores of the causal organism were checked and then identified.

For powdery mildew, a drop of sterilized water was placed on a clean glass slide. Three to five pieces of thin cross section leaves collected from plant parts showing dirty whitish fungal patches ~~symptoms~~ were cut with sterilized razor blade and put in a water drop on the slide and covered with a cover slip. Shape, color, spore size of conidia and conidiophore~~s~~ were observed under the microscope.

2.1.2 Occurrence of Sesame Diseases in Nay Pyi Taw

A ~~Total~~ total ~~10~~ tensesame fields were surveyed for the occurrence of phyllody, charcoal rot, Alternaria leaf blight in northern part of Nay Pyi Taw area in 2016. Out of ~~10~~ tenfields, ~~4~~ fourfields from Pyinmanar, ~~3~~ threefrom Pobbathri and ~~3~~ threefrom Zeyathiri township were selected. Aboveground symptoms, in particular appearance of each disease were

carefully checked across the field using the diagonal method~~(diagonal)~~ of sampling. For each disease, plants were randomly checked across the field from 7m apart (14 x14 cm row spacing) and recorded the percentage of infested plants based on the visual examination. Disease incidence was calculated on the basis of percent plant infected in total plant populations. Symptoms of charcoal rot/root and stem rot disease; black dots on the stems, Alternaria leaf blight, powdery mildew, phyllody, leaf curl were ~~found out~~observed in several sesame fields as shown in plates~~(~~1, 2, 3 and 4~~)~~. Except for phyllody and leaf curl disease, microscopic examination of above ground symptoms of charcoal rot/root and stem rot, Alternaria blight and powdery mildews were checked using leaves and stems ~~samples.The~~samples. The presence of pathogen spores: pycnidia and pycnidiospores of *M. phaseolina* on the bark of sesame stems (Plate 1), Alternaria spore when fungal spores were taken from black color lesions on leaves (Plate 2) and pathogens of *Oidium* with hyaline barrel shaped spore after making cross section of white powdery mildews appearance on sesame leaves (Plate 3) were observed.

Comment [Hi3]: Revise grammar. This sentence does not read well.

Comment [Hi4]: Not clear what you mean? Did you check for the symptoms on the leaves. You may need to rephrase that part to make the procedure clearer.

2.2 Evaluation of Awareness of Sesame Diseases and Control Measures by Smallholder Farmers in Magway

Formatted: Indent: Left: 0", Hanging: 0.5"

The large proportion of farmers is engaged in sesame production throughout the year in Magway Township. Photographs were prepared for typical disease symptoms of ~~Charcoal~~Charcoal rot, phyllody, Alternaria leaf blight, leaf curl, Cercospora leaf spot and bacterial leaf spot with their causal agents. Using the photographs, a disease ~~questionaries~~[1] survey was conducted using questionnaires in three villages in Magway Township ~~in~~ duringthe harvesting period in~~,~~ August~~,~~ 2016. A total of 25 farmers were surveyed ~~Survey was done in a total of 25 farmers~~ on their knowledge of sesame diseases. If the disease symptoms were noticed in their fields, effect on sesame yield and control measures were interviewed. Additional information on farm experience, cultivation practices, inputs and constraints on sesame production and management practices was also collected.

Comment [Hi5]: Not clear what you are trying to say, revise grammar.

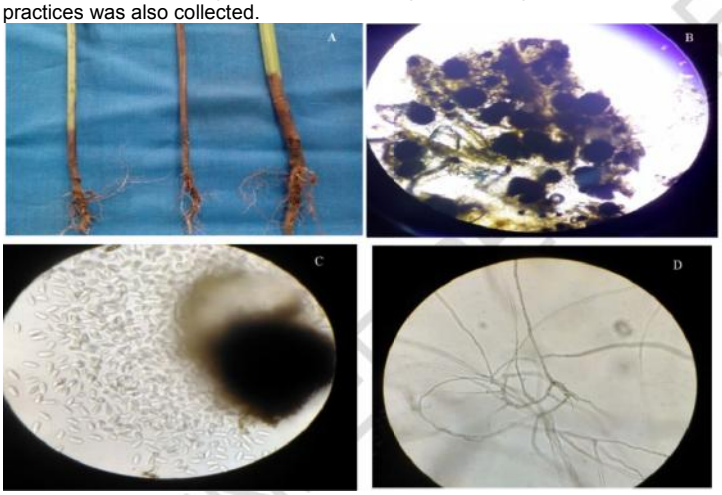

Plate 1. (A) Elongated brownish dark lesions on stem, (B) ~~Pycinidia~~Pycnidia formation on bark of sesame stem, (C) ~~Pycinidia~~Pycnidia and pycnidiospores of ~~*Macrophomina*~~*M.phaseolina* (40x), (D) Hypha of *Rhizoctonia bataticola* (40x).

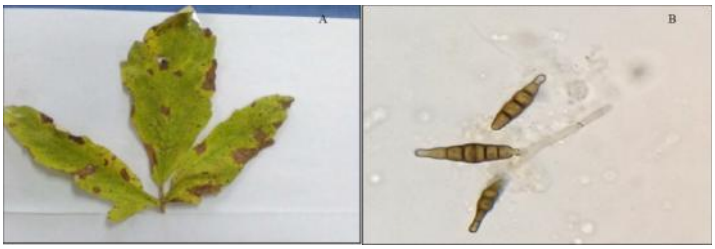

Plate 2. (A) Dark brown irregular lesions with concentric ring on sesame leaves, (B) Conidia of ~~*Alternaria*~~ *A.sesami* taken from dark brown lesions leaves (40x)

3. RESULTS

3.1 Occurrence of Sesame Diseases and Its Incidence in Nay Pyi Taw

Disease symptoms of phyllody, charcoal rot and Alternaria blight were most frequently observed in all survey fields. The disease incidence (DI) % of phyllody, charcoal rot (stem rot), and Alternaria blight ranged from 5%-30%, 10%-30% and 10%-40%, respectively (Table 1). Symptoms of leaf curl, powdery mildew ~~was~~ ~~were~~not abundantly observed in Nay Pyi Taw area and their incidence~~s~~were not assessed.

Comment [Hi6]: There is a 5 in that Table 1 in the column for Alternaria blight.

Plate 3. (A) Dirty white podwery on sesame, (B) Condia and condiophores of *Oidium* spp. (40x) after cross section of leaves with dirty white spot

Plate 4. Transformation of flora parts into green leafy structure

Table 1. Occurrence of sesame diseases and their incidence (%) in Nay Pyi Taw area

Field No.	Phyllody disease	Black stem rot	Alternaria leaf blight
1	0	20	10
2	20	15	30
3	10	10	20
4	5	25	15
5	10	30	5
6	20	25	20
7	30	15	30
8	20	10	40
9	10	20	30
10	15	30	25
Avg.	14	20	22.5

3.2 Observation of sesame diseases and control measures by smallholder farmers in Magway region

3.2.1 Cultivation Practice and Cropping Pattern

In Magway region, sesame has been rotated with pulses for more than 20 years and is the major income source for small scale farmers. It is grown as a single crop or intercropped with pigeon pea. Most of the farmers used sources of sesame seeds from their local market while others purchased seeds from the Department of Agriculture (DoA) in Magway township. Cowdung manure and basal fertilizers were applied during land preparation. Insecticides to control for leaf roll were sprayed within 15-45 days after sowing if necessary. Although the recommended rate of balanced fertilizers was 125 kg urea (58 kg N) ha^{-1}, 125 kg triple super phosphate (23.5 kg P) ha^{-1} and 62 kg potash (32.5 kg K) ha^{-1} for sesame production, the practical application rates varied among the farmers.

It was noticed that 84% of the farmers (21 out of 25) cultivated sesame alone in the monsoon cultivation and 16% of farmers did sesame with pigeon pea or other kinds of pulses. Black sesame (Sinyadar 13) was the most popular variety with yields of 245-735 kg ha^{-1}.

3.3 Incidence of Sesame Diseases and Yield Loss

Sixty percentMore than a half the of farmers interviewed ((60%, 15 out of 25) suffered phyllody disease symptoms in their fields, 80% suffered from charcoal rot, 48% from Cercospora, 28% from bacterial leaf spot and 24% from diseases with the symptoms of leaf roll (Fig. 1). Most farmers (84%) answered confirmed simultaneous presence of that their sesame fields suffered combinations of disease symptoms either phyllody or charcoal rot/black and stem rot or Cercospora leaf spot and/or bacterial leaf spot (Fig. 2). All disease symptoms were apparently noticed by farmers 30 days onwards after sowing. In case of phyllody, yield losses ranged from 10-50%, while stem rot symptoms brought yield losses ranging from 15 to 100% and little yield reduction to up 50% yield losses were observed by the symptoms of leaf spots.

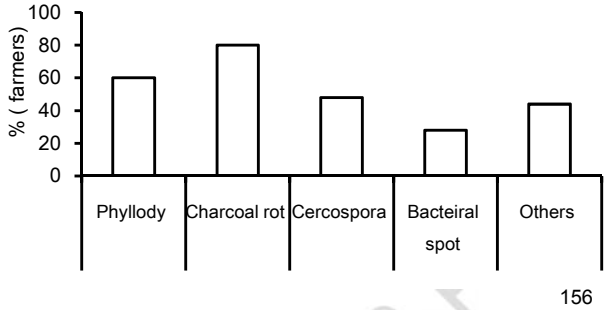

Fig. 1. Percentage of farmers suffering from sesame diseases
Results of interviewing with a total of 25farmers in Magway

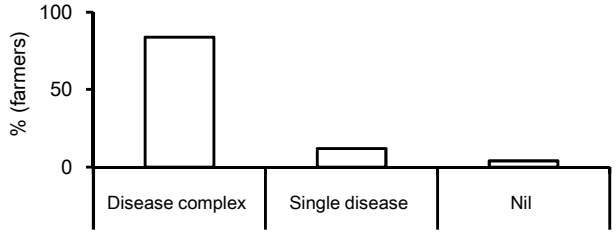

Fig. 2. Ratio (%) of farmers (total 25) who suffered from sesame diseases complex

No one answered that they noticed the symptoms appearance of powdery mildew and Alternaria leaf blight on their sesame. Instead, some farmers additionally informed their experiences in the occurrence of abnormal symptoms showing root red and seedling death, root rot, and leaf yellowing around 20 to 40 days after sowing and which seemed to reduce sesame yield by 10 to 40% if these symptoms were observed in their fields. No significance significantrelation correlationwas found between the actual yield and yield loss estimated for each disease:phyllody, charcoal rot, Cercospora, bacterial leaf spot and other diseases answered that were reportedby famers in Magway (Fig. 3a,b,c,d,e).

Comment [Hi7]: Should not this be part of the discussion. It is expected that you present results of the survey that was carried out in this Section on Results.

Comment [Hi8]: Where are the results. You did not make reference to ant Table or Figure.

Comment [Hi9]: Please rephrase and try not to use the words suffered disease symptoms.Organisms do not suffer symptoms. Symptoms show the presence of a disease.

Comment [Hi10]: Please refer the reader to results that are presented in this section. Where are the figures presented.

Comment [Hi11]: Revise grammar

Comment [Hi12]: Please rephrase, this sentence does not read well and as such is difficult to understand.

Comment [Hi13]: You need to present the p-values and correlation coefficient for you to substantiate this claim. How did you conlude that there were not significant corellations

3.4 ~~ActionsTaken for Sesame Diseases by Farmers in Magway Region and Control Measures~~Strategies used to manage sesame diseases by smallholder farmers in Magway Region

In survey areas, 54% of farmers burned sesame crop residues while 45% farmers directly buried them in the soil including disease infected plant parts. Although there was no difference in sesame yield between these two practices, the average yield was higher by 15% in farmers with the burnt practice. Only a few farmers applied fungicides such as carbendazim for charcoal rot/black rot of stem and ~~amidachloroit~~imidacloprid for phyllody diseases to the field.

4. DISCUSSION

The present study revealed that sesame cultivation in Nay Pyi Taw and Magway, Myanmar was ~~damaged~~ adversely affected or reduced ~~from~~ by mixtures of ~~various fungal, bacterial and viral~~ diseases that are caused by *Candidatus Phytoplasma*,*Macrophomina*, *Alternaria*, *Oidium*, *Cercospora* and *Xanthomonas* etc. Among the diseases, phyllody and charcoal rot diseases were prominent in both areas. Farmers noticed most of the disease symptoms ~~around~~ at leastone month after sowing. According to ~~Gupta et al.~~ [6], sesame phyllody disease caused by *Phytoplasma*can be prevalent throughout the year and is transmitted by the insect vector (*Orosius albicinctus*). Although their study did not mention disease incidence and yield losses, the present study showed disease incidence of phyllody ranging from 5-30% and yield losses by up to 50% in Magway.

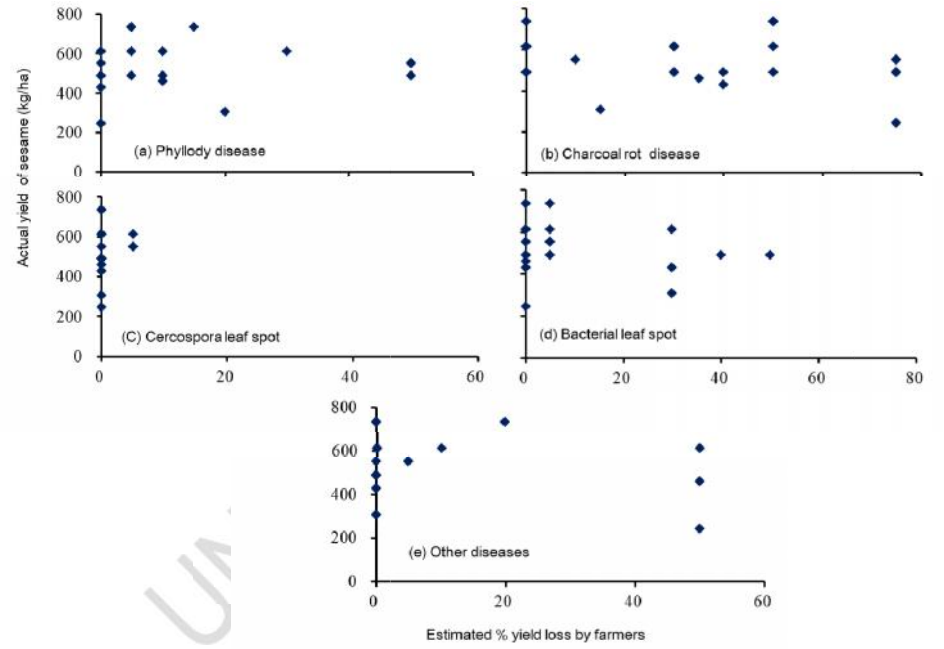

Fig. 3. Estimated yield loss due to (a) Phyllody, (b) Charcoal rot, (c)Cercospora leaf spot, (d) Bacterial leaf ~~spot, (~~spot, (e)~~Other~~other diseases reported by farmers and their actual sesame yield in Magway

In general, root rot caused by *M. phaseolina* is the most devastating disease in many ~~growing~~ sesame producing countriessuch as India and Pakistan [11,12,13].~~Murugesan et al.~~ [14] reported that 1% increase in the incidence of *M. phaseolina*reduced seed yield by 1.8 kg ha^{-1}. In this study, 30% of disease incidence was recorded by charcoal rot disease and almost all the farmers experienced ~~in a~~yield reduction up to 50% to 100% when they noticed charcoal rot symptoms in their fields, indicating that the disease incidence of *M. phaseolina* and its yield losses would be the largest in sesame cultivation.

Comment [Hi14]: You did not present the results that you are describing here.

Comment [Hi15]: But these results were just described but not presented in the result section.

Comment [Hi16]: I did not see where the results are presented.

Comment [Hi17]: Rephrase the title of this figure, it should indicate that you are presenting results for relationship or correlations between Estimated yield loss and actual yield loss due to the diseases whose results are shown in the figure.

Comment [Hi18]: Results not presented

We did not identify the actual disease incidence and severity of each disease in farmer fields in Magway, instead, we asked farmers for their yield and knowledge on sesame diseases. Most of the farmers in Myanmar are living in rural areas and outskirts and thus understanding of their perceptions and knowledge on constraints of sesame production are very important to analyze the impact of diseases on sesame yield and efficiency of their control measures. However, it was difficult to conclude that estimation of yield loss caused by each disease was directly related with their actual yield in this study, because there were no significant relations between actual sesame yield and yield losses caused by each ~~disease .~~disease.

Low yields have been attributed to several factors, e.g. variety, agronomic practices, soil salinity, poor drainage, poor planting methods (broadcasting), weeds, diseases and insect pests [4,15]. One or several of these reasons could probably affect low yields in Myanmar. Most of the famers seemed to lack ~~in~~ the knowledge on the proper use of fertilizers throughout the crop growing season. Recently, the presence of pigeon pea cyst nematode *Heterodera cajani* has been confirmed in sesame cultivated fields in Magway (unpublished data). Therefore, improper fertilization and/or the nematode might cause damage and thus yield reduction. Further investigation of densities of cyst nematodes in sesame cultivated fields relation to yield is now under planning.

Although farmers noticed abnormal symptoms, sometimes seriously ones, in their fields, most farmers did not take an action. This is because farmers did not either pay attention to diseases or know effective control measures. At present, chemical fungicides are the first choice for farmers to combat diseases because of their easy ~~aplicability~~applicability and immediate therapy [7]. In the present study, farmers did not clearly recognize the name of chemicals even though they used them. Fungicides still play a vital role in the control of the disease due to the ~~lacks~~lacks of ~~a high quality~~certified disease free~~of~~seeds~~of and~~sesame and proper sanitation in their fields.

4. CONCLUSION AND RECOMMENDATION

Based on the microscopic examination of symptoms appearance, diseases of charcoal rot, Alternaria blight, powdery mildew and their causal agents were detected. Limited knowledge on sesame diseases was noticed among farmers except on charcoal rot disease (locally called 'Yoeme'). There is a need for more studies on crop loss assessment by individual diseases in Myanmar. The use of chemical fungicide is the only way control to practice so far. The interest of farmers in managing infested crop residues and enough knowledge on proper application of using fungicides are lacking. Therefore, proper trainings or extension service for sesame diseases and awareness of fungicide use should be provided to smallholder sesame producers. ~~those rural areas by various organizations.~~ The research attention to developing holistic disease control measures (use of the resistant variety, biocontrol agents, and proper cultural practices) for the improvement of sesame yield qualitatively and quantitatively should be investigated as of its being a vital role in earning foreign income.

Comment [Hi19]: Revise grammar.

Comment [Hi20]: Revise grammar

Comment [Hi21]: Not clear

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAOSTAT (2017) http://www.fao.org/faostat/en/#data/QC
2. MOALI. Myanmar Agriculture in Brief. Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, Myanmar.2018.
3. Weiss EA. 2000.Oilseed Crops. 2nd edition. Blackwell Science, UK.
4. Egonyu JP, Kyamanywa S, Anyanga W, SSekabembe CK. Review of pests and diseases of sesame in Uganda. African Crop Conference Proceedings. ~~2005;7:1411~~2005; 7:1411-1416.
5. Gopal K, Jagadeswar R, Prasad G. Evaluation of sesame (*Sesamum indicum*) genotypes for their reaction to powdery mildew and phyllody diseases. Plant Disease Research. 2005;20(2):126-130.
6. Gupta KN, Naik, KRR, Bisen R. Status of sesame diseases and their integrated management using indigenous practices. International Journal of Chemical Studies. 2018;6(2):1945-1952.

7. Jealakshmi C, Rettinassababady C, Nema S. Integrated management of sesame diseases. Journal of Biopesticides.2003;691:68-70.
8. Win NKK, Back C-G, Jung H-Y.Phyllody phytoplasma infecting sesame (*Sesamum indicum*) in Myanmar. Tropical Plant Pathology. 2010;35(5):310-313.DOI: 10.1590/S1982-56762010000500006
9. Wai KPP. Pycnidium formation in vitro of *Macrophomina phaseolina* (*Rhizoctonia bataticola*), causal agent of stem and root rot of sesame (*Sesame indicum* L.), and reaction of some sesame varieties to the disease. Thesis, Plant Pathology Department, Yezin Agricultural University. 2007.
10. Yu KH. Methods in plant pathology and integrated disease management. Lecture book, Department of Plant Pathology, Yezin Agricultural University, Myanmar. 2013.
11. Choudhary CS, Arun A, Prasad SM. Management of stem and root rot of sesame. International Journal of Agricultural Sciences. 2014;10(2):755-760.
12. Meena B, Indiragandhi P, Ushakumari R. Screening of sesame (*Sesamum indicum* L.) germplasm against major diseases. Journal of Pharmacognosy and Phytochemistry. 2018;7(1S):1466-1468.
13. Bedawy IMA, Moharm MHA. Reaction and performance of some sesame genotypes for resistance to *Macrohpomina phaseolina*, the incitant of charcoal rot disease. Alexandria Science Exchange Journal. 2019;40(1):12-18.
14. Murugesan M, Shanmugam MM, Menon PP, Arokiaraj A, Dhamu, KP and Kochubabu M. Statistical assessment of yield loss of sesamum due to insect pests and diseases. Madras Agricultural Journal.1978;65:290-295.
15. El-Bramawy MASA, Abd Al-Wahid OA. Evaluation of resistance of selected sesame (*Sesamum indicum*) genotypes to Fusarium wilt disease caused by *Fusarium oxysporum* f. sp. *sesami*. Tunisian Journal of Plant Protection. 2009;4(1):29–39.