Evaluation of sesame genotypes for seed yield and bacterial blight (*Xanthomonas campestris pv. sesami*) disease resistance in optimum moisture areas of Western Tigray, Ethiopia

Werens Negash Golla\(^1\), Assefa Abadi Kebede\(^1\) and Yirga Belay Kindeya\(^1\)

**Abstract:** Ethiopia is one of the major producers of sesame in sub-Saharan Africa, and Ethiopian sesame particularly the whitish Humera type is among the highest quality in the world. However, the yield is lower than some of the producing countries due to many factors including low yielding varieties and bacterial blight disease severities. This study was conducted with the objective of evaluating sesame genotypes for yield and bacterial blight disease resistance during 2017/18 –2018/19 main cropping seasons at Dansha, Ethiopia. Sixteen sesame genotypes were evaluated with one local variety in randomized complete block design (RCBD) with three replications under hot spot area for bacterial blight disease infection. There was significant (P < 0.05) difference among the genotypes for yield, yield-related traits and bacterial blight disease severity. Higher seed yield was recorded in genotype WARC-063 (716.2 kg) with a mean yield advantage of 24.3% over the standard check Humera-1 whereas the lowest seed yield was

---

**ABOUT THE AUTHORS**

Werens Negash Golla (Mr) is a researcher in Tigray Agricultural Research Institute, Humera Agricultural Research Center. He has MSc in plant pathology from Mekelle University, Ethiopia. His research interest focuses on plant pathology, plant breeding, agronomy and agricultural economics.

Assefa Abadi Kebede (Mr) is a researcher in Tigray Agricultural Research Institute, Humera Agricultural Research Center. He has MSc in plant pathology from Mekelle University, Ethiopia. His research interest focuses on plant pathology, plant breeding and agricultural entomology.

Yirga Belay Kindeya (Mr) is a researcher in Tigray Agricultural Research Institute, Humera Agricultural Research Center. He has MSc in plant breeding from Harmaya University, Ethiopia. His research interest focuses on plant breeding and plant pathology.

The team research engaged on evaluation and development of sesame varieties for the optimum and moisture stress areas on collection of sesame germplasms, study of biotic and abiotic factors to enhance sesame productivity.

---

**PUBLIC INTEREST STATEMENT**

Sesame, an erect herbaceous annual plant in the genus *Sesamum*, locally called “Selit” or “Simsim,” is one of the major economically important oil crops in Ethiopia. The crop is either single-stemmed or branched growth habits and indeterminate and determinate growth characteristics. Ethiopia is one of the popular sesame producers in the world and the seed produced in low lands of Western Tigray, Ethiopia is highly competent in the world market by its desirable qualities in terms of color, taste and aroma. It is used as main cash crop which earns millions of dollars and as a source of rural employment and ensuring food security.

However, its production is constrained by different factors. Diseases like bacterial blight and existing low yielding sesame varieties cultivated by farmers are among the main problems. Development of high yielding and disease resistance/tolerance genotypes of sesame is crucial to boost sesame production and productivity.
recorded in WARK-081 (354.0 kg/ha). In response to disease reaction, four genotypes (WARC-063, WARK-074, Gonder-1, and Gida-Ayana) were resistant against bacterial blight and had higher grain yield than the rest of genotypes. From the study result, it could be concluded that genotype WARC-063, WARK-074, Gonder-1 and Gida-Ayana were both high yielding and resistant to bacterial blight disease and could be cultivated for seed yield in areas with bacterial blight disease problems. They could also be used in sesame breeding programs for further improvement.

Subjects: Agriculture & Environmental Sciences; Soil Sciences; Microbiology; Mycology; Biology; Epidemiology

Keywords: sesame; genotypes; bacterial blight; optimum moisture; yield; resistance

1. Introduction

Sesame (Sesamum indicum L.) otherwise known as Sesamum, member of the family Pedaliaceae, is one of the world’s oldest oilseed crop grown mainly for its high oil content of the seeds that contain approximately 52–57% oil and 25% protein content (Khan et al., 2009; Umar et al., 2010). Even though there have been contradictions on the origin of sesame, east Africa and India are considered as early origins for sesame and in Ethiopia sesame is found both as cultivated and wild types (Zerihun, 2012). Areas with annual rainfall of 625–1100 mm and temperature of >27°C are the most conducive for sesame production. The crop is tolerant to drought, but not to waterlogging and excessive rainfall and it is well adapted to a wide range of soils; however, it requires deep, well-drained, fertile sandy loams (Geremew et al., 2012). Ethiopia is one of the popular sesame producers in the world and the seed produced in western Tigray (Humera type) is highly competent in the world market by its desirable qualities in terms of color, taste and aroma (Taghouti et al., 2017). The major sesame producing regions in Ethiopia are situated in the low land of northwest and southwest, being northwestern regions have comparatively the highest yield per hectare (Wijnands et al., 2007).

Sesame is used as one of the main cash crops and the second export commodity, next to coffee in Ethiopia, and plays a significant role as the source of rural employment and ensuring food security of millions of people (Abebe, 2016). Despite the importance of sesame at national and regional level, its productivity is constrained due to inappropriate agronomic practices, low yield of existing varieties, weather uncertainties, lack of non-shattering, waterlogged and disease and insect resistant variety. Bacterial blight (Xanthomonas campestris pv. sesami) disease is among the major diseases of sesame which becomes the major threat in the study area and it is reported that yield losses due to bacterial blight disease on susceptible variety was up to 34.28% in Western Tigray, Northern Ethiopia (Golla et al., 2019). The disease is manifested by dark brown water-soaked spots, which later coalesce and form foliage blight and lead to defoliation (Bashir et al., 2007).

Sesame productivity is up to 1000–1200 kg/ha under optimum agronomic cultivation (Ali et al., 1997) and use of high yielder and resistant variety in optimum moisture areas is widely recognized as the safest, most economical and most effective method for increasing seed yield where bacterial blight disease is prevalent. However, the productivity of the available released sesame varieties so far is lower than some of the producing countries. In moisture stress areas of Western Tigray (Humera), Northern Ethiopia, different genotypes of sesame were evaluated to identify high-yielding with desirable agronomic traits in different growing seasons (Baraki & Berhe, 2019). However, there is limited study on the evaluation of sesame genotypes for high yielder and resistance/tolerance to bacterial blight disease in optimum moisture areas of western Tigray, Ethiopia. Under these circumstances, there is a need to exploit genetically host resistance and high yielder in the existing sesame commercial varieties and genotypes for optimum moisture areas of western Tigray, Ethiopia. Therefore, development of high yielding and disease resistance/tolerance genotypes/varieties of sesame are crucial to boost sesame production in a sustainable way in Western Tigray. Thus, the present study is designed to evaluate different sesame genotypes...
for high yielding and disease resistance against bacterial blight at field conditions in optimum moisture areas of Western Tigray, Ethiopia.

2. Materials and methods

2.1. Description of experimental site
The experiment was conducted at optimum moisture areas (Dansha) in naturally hot spot areas for bacterial blight disease. The study was conducted during (June–November) for two consecutive years in 2017/18 and 2018/19 cropping seasons. The site is located at geographical coordinates of 13° 38’ 306” North latitude and 36° 52’ 84.1” East longitude. The altitude and mean annual temperature of this experimental site was 747 m above the sea level (masl) and 28.7°C, respectively. The area receives an average annual rainfall of about 888.4 mm and the rainy months extend from June to September. The dominant soil in the district is luvisols and vertisols or soils with vertic properties (Ethiopian Agricultural and Research Organization (EARO), 2002).

2.2. Experimental materials and treatments
A total of 70 genotypes were evaluated during 2016/17 main cropping season in the optimum moisture areas (Dansha) of Western Tigray. Out of the tested genotypes, 17 sesame genotypes were selected to evaluate for yield and bacterial blight disease resistance in natural hot spot area at Dansha for two consecutive years in 2017/18 and 2018/19 cropping seasons as described in Table 1. The criteria for selection of 17 genotypes out of 70 genotypes were based on the reaction to the disease and seed yield. These resistant and high yielder genotypes were selected and evaluated during the 2 years, while the rest of genotypes were preserved for other purposes.

2.3. Experimental design and management
The experiment was laid out in RCBD with three replications. Each treatment was randomly assigned into a plot area of 10 m² (5 m row length and 2 m width), which consisted of five rows of sesame. The spacing between blocks and plots was 2 m and 1 m, respectively. The spacing between plants and rows was 10 cm and 40 cm, respectively. Seeds were sown on three times plowed plots of land. Each experimental plot was applied with the same rate of P₂O₅ (100 kg/ha) and Urea (50 kg/ha) fertilizers. All P₂O₅ and half of the Urea (N) fertilizer were applied during planting and the rest split of Urea was applied 45 days after planting. Other recommended agricultural practices were applied at the proper time for all experimental plots uniformly.

2.4. Data collected
Bacterial blight disease severity data were recorded on seven randomly selected and marked (pre-tagged) plants from the middle rows of each plot. The disease severity of bacterial blight was recorded at 86 days after planting using the scale of Sarwar and Haq (2006) where 0 = 0%, 1 = 0.1–5%, 2 = 5.1–10%, 3 = 10.1–20%, 4 = 20.1–50%, 5 = 50.1–70%, 6 = >70% with a response of immune, highly resistant, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible, respectively. The severity grades were converted to percentage severity index (PSI) according to the formula by Wheeler (1969) for analysis.

\[
\text{PSI}(\%) = \left( \frac{\sum (\text{number of plants in each grade} \times \text{disease grade})}{\text{total number of plants assessed} \times \text{highest disease grade}} \right) \times 100
\]

Agronomic data were also recorded from the central rows of each plot:

1. Number of fertile capsules per plant (NFCPP): The mean number of capsules obtained from 10 pre-tagged plants at harvest.
2. Number of seeds per capsule (NSPC): The mean number of seeds per capsule was obtained from 10 randomly taken plants at harvest by taking three capsules per plant.
3. Thousand Seed Weight (TSW): weight in grams of 1000 randomly chosen seeds.
4. Seed yield (kg/ha): the total seed yield (kg/ha) harvested from the net plot area.
2.5. Statistical data analysis
Analysis of variance (ANOVA) for number of capsules/plant, thousand seed weight, seed yield and PSI was carried out using GenStat-18 statistical package. Duncan’s Multiple Range Test (DMRT) was used for mean comparison among treatment means at 5% and 1% probability level.

3. Results and discussion
During the two consecutive cropping seasons, data were collected and analyzed separately to see the yield and diseases reaction across years. However, there were no significant differences (p < 0.05) between the two seasons so that the two seasons data were combined and analyzed together.

3.1. Yield and yield components
There were significant differences (p < 0.05) among the varieties in yield and yield-related components. The average yield of the sesame genotypes ranges from 716.2 kg/ha to 402.7 kg/ha (Table 2). The maximum seed yield (716.2 kg/ha) was obtained from genotype WARK-063 and the lowest seed yield (402.7 kg/ha) was recorded from the local variety (Hirhr). The genotype WARK-063 recorded a mean yield advantages of 24.32% and 43.77% compared with the standard check (Humera-1) and local variety, respectively. In addition, the yield obtained from the present genotype WARC-063 was higher in comparison with the regional and national average yield of 607 kg/ha and 686 kg/ha, respectively (Central Statistical Agency (CSA) of Ethiopia, 2019). Genotype WARK-063 and varieties Gida-Ayana and Gonder-1 were the best for several agronomic characteristics (Table 2).

The variation in yield and yield components among the tested varieties and genotypes was attributed to their genetic potential for yield and disease resistance. The present variety (standard check) was released as a tolerant variety for bacterial blight disease in the study area. However, its yield becomes getting low. This might be due to yield deterioration through time and susceptibleness of the variety to the pathogen. Tolerant genotypes are superior in agronomic performance and possess desirable characteristics including high thousand seed weight, number of seed per capsule,

Table 1. Description of sesame varieties and genotypes used for the study

| S/no | Genotype   | Status       | Seed color | Source of seed |
|------|------------|--------------|------------|----------------|
| 1    | WARK-059   | Advanced line| White      | WARC           |
| 2    | WARK-068   | Advanced line| White      | WARC           |
| 3    | WARK-063   | Advanced line| White      | WARC           |
| 4    | WARK-070   | Advanced line| White      | WARC           |
| 5    | WARK-074   | Advanced line| White      | WARC           |
| 6    | WARK-082   | Advanced line| White      | WARC           |
| 7    | WARK-081   | Advanced line| White      | WARC           |
| 8    | WARK-084   | Advanced line| White      | WARC           |
| 9    | WARK-092   | Advanced line| White      | WARC           |
| 10   | WARK-093   | Advanced line| White      | WARC           |
| 11   | WARK-100   | Advanced line| White      | WARC           |
| 12   | WARK-103   | Advanced line| White      | WARC           |
| 13   | ACC-202-374| Advanced line| White      | WARC           |
| 14   | Gida-Ayana | Released in year 2018 | White      | ASARC |
| 15   | Gonder-1   | Released in year 2016 | White      | GARC |
| 16   | Humera-1   | Released in year 2011 | White      | HUARC |
| 17   | Hirhr (local) | Farmers seed (local) | White      | HuARC |

WARC, HUARC, ASARC and GARC: Werer, Humera, Assosa and Gonder agricultural research center, respectively.

Golla et al., Cogent Food & Agriculture (2020), 6: 1771114
https://doi.org/10.1080/23311932.2020.1771114
and seed yield which are important in breeding program to develop resistant sesame cultivars to bacterial blight. The current finding is in conformity with the finding of Min and Toyota (2019) who reported that sesame yield reduction (5%) was caused by the symptom of bacterial leaf spot disease. Houshyarfard and Padasht Dahkai (2018) also reported that yield and yield components of peanut genotypes were affected by cercospora leaf spot disease and the authors justified that with increasing severity of early and late leaf spot diseases, there was a decrease in pod yield and yield components. In addition, Vajavat and Chakravarti (1977) and Shukla et al., (1972) reported that 60% and 20% losses due to blight disease under field conditions in Turkey and from Jalapur area in Madhya Pradesh, respectively. Moreover, up to complete yield loss under rainy and humid areas of the Sudan and Ethiopia (Eshetu et al., 1996; Osman, 1985).

CPP: capsules per plant; SPC: seed per capsule; TSW: thousand seed weight; LSD: least significant difference; CV (%): Coefficient of variation. Means with the same letters in the column are not significantly different at 5% probability level.

### 3.2. Reactions of sesame genotypes against bacterial blight disease

There were significant differences (p < 0.05) among the genotypes for percent bacterial blight severity index. Evaluation of the sesame genotypes done at Dansha revealed that among the 17 tested sesame genotypes, none was found immune and highly resistant, but 4 genotypes and varieties were resistant (5.1–10% PSI) and also four genotypes were moderately resistant (10.1–20% PSI), while nine genotypes were moderately susceptible (21.1–50% PSI), and represented by 23.53%, 23.53%, and 52.94% of genotypes, respectively (Figure 1). This implies that more than 50% of the tested sesame genotypes against bacterial blight disease were under moderate susceptible group.
Lowest PSI (%) was recorded in WARK-063, Gida-Ayana, ACC-202-374 and Gonder-1, that is 9.3%, 9.3%, 9.8% and 9.8%, respectively, while maximum percentage of severity index was recorded in, Hirhr and Humera-1, that was, 39.15%, 34.9% (Table 3). The variation for resistance level of the tested genotypes could be due to the different genetic resistance to bacterial blight disease infection. The result is in line with Golla et al. (2019) who found that sesame varieties differed in resistance level tested under bacterial blight disease pressure in Dansha (Kebabo), Western Tigray, Northern Ethiopia. Naqvi et al. (2012) similarly reported that sesame germplasms showed different levels of resistance to the disease with no completely resistant level tested at Faisalabad, Pakistan under natural conditions. In addition, Asad et al. (2004) were found different degrees of resistance under natural field conditions tested against bacterial blight disease from the 29 sesame entries conducted at National Agriculture Research Centre (NARC), Islamabad, Pakistan.

It could also be due to the production of some defense mechanism protein receptors, phytoalexins, Jasmonic acid/salicylic acid of the resistant genotypes after the injection of bacterial effectors. In addition, it might be due to inducing the effector-triggered immunity usually associated with programmed cell death at sites of infection, termed the hypersensitive response and the production of reactive oxygen species in the resistant and moderately resistant sesame genotypes. The inheritance mechanisms of such defense in bacterial pathogen were reported by Leach et al. (2014), host receptors detect pathogen-associated molecular patterns, the bacterial flagellin which weakens the immunity of the pathogen by production of reactive oxygen species, increases in intracellular calcium concentration, callose deposition in cell wall and antimicrobial compounds called phytoalexins.

3.3. Correlation between studied traits
The results showed that significant and positive correlations were found between seed yield and capsules per plant, seed per capsule and thousand seed weight. The implications of positive and significant associations of the different traits with seed yield might indicate the significance of number of capsules for determining the final seed yield of sesame. However, the yield and yield-related traits were negatively and significantly associated with bacterial blight disease severity expressed as PSI. This might indicate bacterial blight disease plays a vital role in reduction of sesame yield (Table 4). The result was in agreement with Lakew et al., (2018) who reported that there is a positive and negative relationship between the number of capsules per plant (r = 0.78) and thousand seed weight (r = −0.50) with grain yield, respectively. Negative and highly significant correlations between capsules per plant and seed per capsule with PSI, respectively, were obtained. In addition, Zebire and Tadesse (2018) reported that pod per plant and seed per pod were correlated positively with yield (kg/ha) whereas negatively correlated and non-significant with disease severity (%) in faba bean varieties.
4. Conclusion

The screening of superior sesame genotypes was conducted in areas of high bacterial blight disease infection under field conditions. The study revealed that significant variations were found across the sesame genotypes for all the traits measured. The highest seed yield was recorded from genotype WARK-063 followed by WARK-074. However, genotype WARK-081 and the local variety Hirhr were produced lower seed yields. Out of the 17 sesame genotypes tested, 4 genotypes were resistant (R), 4 also were moderately resistant (MR), and 9 genotypes were moderately susceptible (MS) against bacterial blight diseases. From the study result, it could be concluded that genotype WARC-063, WARK-074, Gonder-1 and Gida-Ayana were high yielding and resistant to bacterial blight disease and could be cultivated for seed yield in areas with bacterial blight disease problems. They could also be used in sesame breeding programs for further improvement.

Table 3. Bacterial blight disease severity index (%) on sesame genotypes evaluated at optimum moisture areas (Dansha) of Western Tigray, Northern Ethiopia

| S/no | Genotype        | PSI value | Disease reaction |
|------|-----------------|-----------|------------------|
| 1    | WARK-059        | 17.2d     | MR               |
| 2    | WARK-068        | 34.4a     | MS               |
| 3    | WARC-063        | 9.3e      | R                |
| 4    | WARK-070        | 17.7d     | MR               |
| 5    | WARK-074        | 17.7d     | MR               |
| 6    | WARK-082        | 32.0d     | MS               |
| 7    | WARK-081        | 24.3d     | MS               |
| 8    | WARK-084        | 17.5d     | MR               |
| 9    | WARK-092        | 33.1d     | MS               |
| 10   | WARK-093        | 32.5d     | MS               |
| 11   | WARK-100        | 25.9d     | MS               |
| 12   | WARK-103        | 35.7e     | MS               |
| 13   | ACC-202-374     | 9.8e      | R                |
| 14   | Gida-Ayana      | 9.3e      | R                |
| 15   | Gonder-1        | 9.8e      | R                |
| 16   | Humera-1 (standard check) | 34.9e   | MS               |
| 17   | Hirhr (local check) | 39.15a | MS               |
|      | LSD (5%)        | 6.632     |                  |
|      | CV (%)          | 16.9      |                  |

PSI: percentage severity index; R: resistant; MR: moderately resistant; MS: moderately susceptible; LSD: least significant difference; CV (%): Coefficient of variation. Means followed with the same letters are not significantly different at 5% level of significance.

Table 4. Simple correlation coefficients among yield and yield components and percent severity index (PSI) of sesame genotypes evaluated at optimum moisture areas (Dansha) of Western Tigray, Northern Ethiopia

| Parameter | CPP  | SPC  | TSW  | Yield (kg/ha) | PSI  |
|-----------|------|------|------|---------------|------|
| CPP       | -    | -    | -    | -             | -    |
| SPC       | -0.29* | -    | -    | -             | -    |
| TSW       | -0.13** | -0.25** | -    | -             | -    |
| Yield     | 0.51** | 0.48** | 0.19** | -             | -    |
| PSI       | -0.45** | -0.38** | -0.17** | -0.29* | -    |

**and *; refers to mean square values highly significant at p < 0.01 and significant at p < 0.05, respectively; ns: means not significant at p < 0.05.
Acknowledgements
The authors thank the Humera Agricultural Research Center (HuARC) for the financial support, and crop case team members for their excellent assistance during the research work.

Funding
The authors did not receive any direct funding for this research.

Competing interests
The authors declare no competing interests.

Author details
Weres Negash Golla
E-mail: weresgolliano19@gmail.com
ORCID ID: http://orcid.org/0000-0002-1212-4145

Assefa Abadi Kebede
E-mail: asse2008ec@gmail.com
Yirga Belay Kidneya
E-mail: yirgabelay66@gmail.com

1 Tigray Agricultural Research Institute, Humera
Agricultural Research Center, P.O. Box 62, Humera, Tigray, Ethiopia.

Citation information
Cite this article as: Evaluation of sesame genotypes for seed yield and bacterial blight (Xanthomonas campestris pv. sesami) disease resistance in optimum moisture areas of Western Tigray, Ethiopia, Weres Negash Golla, Assefa Abadi Kebede & Yirga Belay Kidneya, Cogent Food & Agriculture (2020), 6: 1771114.

References
Abebe, N. T. (2016). Review of sesame value chain in Ethiopia. International Journal of African and Asian Studies, 19, 36–47. https://doi.org/10.1080/23311932.2019/1705741
Ali, M. H., Ullah, M. J., Bhiyani, M. S. V., & Amin, A. K. M. R. (1997). Effect of nitrogen and phosphorus on the yield attributes and yield of sesame (Sesamum indicum L.). Bangladesh Journal of Agricultural Sciences, 24(1), 27–32.
Asad, S., Fouzia, S., Mirza, M. Y., Akhtar, M. A., & Ali, N. (2004). Screening of sesame lines against bacterial leaf blight under natural field conditions. Pakistan Journal of Phytopathology, 16, 31–32.
Baraki, F., & Berhe, M. (2019). Evaluating performance of sesame (Sesamum indicum L.) genotypes in different growing seasons in northern Ethiopia. International Journal of Agronomy, 2019, 1–7. https://doi.org/10.1155/2019/7804621
Bashir, S., Ul-Haque, M. I., Mukhtar, T., Irshad, G., & Hussain, M. A. (2007). Pathogenic variation in Pseudomonas syringae and Xanthomonas campestris pv. Sesami associated with blight of sesame. Pakistan Journal of Botany, 39(3), 939–943.
Central Statistical Agency (CSA) of Ethiopia. (2019). Agricultural sample survey 2018/19 (2011 E.C.) report on area and production of major crops for private peasant holdings, Meher season, volume I. http://www.csa.gov.et/survey-report/category/373-eth-ggs-2018.
Eshetu, W., Korbko, A. P., Chumaeobakaya, A. A., & Dilbo, C. (1996). Bacteria leaf spot and stem maceration of sesame (Sesamum indicum L.) in some area of Ethiopia. Sesame and Safflower Newsletter, 2, 11–14.
Ethiopian Agricultural and Research Organization (EARO). (2002). An assessment of the agricultural production base, technological packages and innovation and intervention strategies for commercial farmers in Kafka-Humera Woreda of Tigray Regional State.
Geremew, T., Adugna, W., Muez, B., & Hogas, T. (2012). Sesame production manual. EIAAR and embassy of the Kingdom of the Netherlands. Ethiopia, 1–34.
Golla, W. N., Ayimut, K. M., & Abay, D. G. (2019). Evaluation of sesame (Sesamum indicum L.) varieties for seed yield and yield components under bacterial blight (Xanthomonas campestris pv. sesami) disease pressure in Western Tigray, Ethiopia. Plant Pathology and Microbiology, 2016, 1–5. doi: 10.35248/2157-7471.19.10.485
Houshyarofard, M., & Padash Dohkai, M. T. (2018). Evaluation of peanut genotypes for resistance to Cercospora leaf spot diseases in Iran. Journal of Crop Protection, 7(4), 437–446.
Khan, M. H. A., Sultan, S. A., Islam, M. N., & Hasanuzzaman, M. (2009). Yield and yield contributing characters of sesame as affected by different management practices. American-Eurasian Journal of Scientific Research, 4(3), 195–197. http://www.idosi.org/ajesi/v4i3/019.pdf
Lako, S., Ayalew, D., Assefa, F., & Tejada Moral, M. (2018). Optimum inter-row spacing and seeding rate of sesame for harnessing the maximum productivity potential in the dry land area of Abergelle District, Northeast Ethiopia. Cogent Food & Agriculture, 4(1), 1–16. https://doi.org/10.1080/23311932.2018.1485471
Leach, J. E., Leung, H., & Tisserat, N. A. (2016). Plant disease and resistance. In N. K. Van Allen (Ed.), Encyclopedia of agriculture and food systems (Vol. 4, pp. 360–374). Elsevier.
Min, Y. Y., & Toyota, K. (2019). Occurrence of different kinds of diseases in sesame cultivation in Myanmar and their impact to Sesame yield. Journal of Experimental Agriculture International, 38(4) 1–9. https://doi.org/10.9734/jeai/2019/v38i430309
Naqvi, S. F. M., Inam-ul-Haq, M. I., Tahir, & Mughal, S. M. (2012). Screening of sesame germplasm for resistance against the bacterial blight caused by Xanthomonas campestris pv. sesami. Pakistan Journal of Agricultural Sciences, 49(2), 131–134.
Osman, H. E. (1985). New sesame varieties for the sudan cenral rain lands. Sesame and Safflower Newsletter, 1, 34–35.
Sarwar, G., & Haq, M. A. (2006). Evaluation of sesame germplasm for genetic parameters and disease resistance. Journal of Agricultural Research, 44(2), 89–96.
Shukla, B. N., Chand, J. N., & Kulkarni, S. N. (1972). Changes in sugar content of sesame leaves infected with Xanthomonas sesami. Indian Phytopathology, Nature (London), 213(5078), 813.
Toghetti, M., Naserollah, N., Gaboun, F., & Rochdi, A. (2017). Multi-environment assessment of the impact of genetic improvement on agronomic performance and on grain quality traits in Moroccan durum wheat varieties of 1949 to 2017. Global Journal of Plant Breeding and Genetics, 4(7), 394–404.
Umur, H. S., Okoye, C. U., & Momman, B. D. (2010). Resource use efficiency in sesame (Sesamum indicum L.) production under organic and inorganic fertilizers applications in Keana Local Government Area, Nasarawa State, Nigeria. Research Journal of Agriculture and Biological Sciences, 6(4), 466–471.
Vajjat, R., & Chakravarti, B. P. (1977). Yield losses due to bacterial leaf spot of Sesamum orientale in
Rajasthan (India). *Indian Journal of Mycology and Plant Pathology*, 7(1), 97.

Wheeler, B. E. J. (1969). *An Introduction to Plant Diseases*. Wiley and Sons.

Wijnands, J., Biersteker, J., & Hiel, R. (2007). Oil seed business opportunities in Ethiopia. Ministry of Agriculture, Nature and food quality.

Zebré, D. A., & Tadesse, K. A. (2018). Evaluation of faba bean (Vicia faba L.) varieties for yield and reaction to chocolate spot disease at Chencha. *Southern Ethiopia. African Journal of Plant Science*, 12(8), 155–163. [https://doi.org/10.5897/AJPS2017.3557](https://doi.org/10.5897/AJPS2017.3557)

Zerihun, J. (2012). Sesame (Sesame indicum L.) crop production in Ethiopia: Trends, challenges and future prospects. *Science, Technology and Arts Research Journal*, 1(3), 01–07. [https://www.ajol.info/index.php/star/article/view/98793](https://www.ajol.info/index.php/star/article/view/98793)