Occurrence of foliar fungal diseases and their effects on yield of selected sunflower (*Helianthus annuus* L.) varieties in Abuja, Nigeria

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Abstract

This study was undertaken to assess the incidence and severity of fungal diseases of five sunflower varieties (SAMSUN1, SAMSUN2, SAMSUN3, SAMSUN4 and a Local variety) in 2021 and 2022 cropping seasons in Abuja, Nigeria. The field experiment was laid out in a randomized complete block design with three replications. Alternaria blight, Septoria leaf spot, and Phoma blight were observed on tested sunflower varieties. Disease incidence and severity varied among the varieties. In the first cropping season, the difference between the incidence of Septoria leaf spot in SAMSUN1 and SAMSUN4 (38% and 51%, respectively) was significant ($P \leq 0.05$) 35 days after sowing (DAS). In the second season, the difference in the incidence of Alternaria blight on SAMSUN1 and SAMSUN3 was significant at 35 DAS. In both the cropping seasons, there was no significant difference in the incidence of Phoma blight among the varieties at 49 DAS. The difference in the incidence of Alternaria blight between SAMSUN4 and the Local variety was significant. At 49 DAS, there was no significant difference in the disease severity of Alternaria blight and Phoma blight among the varieties in both cropping seasons. The difference between the highest yield in SAMSUN4 (2.89 tons ha^{-1}) and the lowest yield in SAMSUN1 (1.98 tons ha^{-1}) was significant in the first year. Screenhouse pathogenicity test confirmed that the diseases were present in all five varieties. Findings from this study could serve as a basis for fungal disease management strategies and for improving sunflower productivity in Nigeria.

Keywords: Alternaria, Foliar diseases, Incidence, Pathogenicity test, Phoma blight, Sunflower.

Introduction

Sunflower (*Helianthus annuus* L.) is a versatile crop globally with diverse applications, owing to its various varieties and distinct medicinal properties. Sunflower seeds contain over 40% good edible oil and 23% proteins and are rich in unsaturated fats, crude protein, fiber and essential nutrients like vitamin E, selenium, copper, zinc and B-complex vitamin (Weiss, 2000; Gonzalez-Matute *et al.,* 2002). Europe and America dominate the global sunflower production, accounting for 70 to 80% of the world's total production (Harter *et al*., 2004; Damodaran and Hegde, 2007). As reported by FAO, the global yield of sunflower in 2020 was 1.25 tons ha^{-1} (FAOSTAT 2021), while Nigeria has an average yield of 0.8 tons ha^{-1} (NAERLS, 2019). Sunflower is widely cultivated in South Africa, while large fields of hybrid sunflower farms are common in Ghana, Cote d'Ivoire and Mali in West Africa (Ndor *et al.,* 2019). Sunflower grows in all parts of Nigeria, in well-drained soils, but it performs better and yields more oil in temperate zones (Chattopadhyay *et al.,* 2016).

Sunflower is one of the major edible oilseed crop grown globally (Darvishzadeh and Saraffi, 2007). In Nigeria, four known varieties of sunflower have been developed by the Institute for Agricultural Research, Ahmadu Bello University, Zaria with different characteristics adapted to the Savannah agro-ecological zone. As is common with other crops, sunflower is not exempted from the attack of diseases; the commonest of which are fungal diseases that potentially reduce its economic value; causing significant yield loss and reduced oil quality of seeds. Common sunflower diseases in Nigeria are Sclerotina stalk rot, charcol rot, Alternaria leaf blight, Downy mildew and Phoma blight (Daramola *et al.,* 2019). Alternaria blight is an important fungal disease affecting sunflower in Nigeria (Alao *et al.,* 2014). Alternaria leaf blight caused by *Alternaria helianthi* stands out among these diseases with widespread occurrence, distribution and importance wherever the crop is grown, with yield loss ranging from 27.5–78.5% depending on the crop variety, soil fertility, time of infection and weather factors (Kaya *et al*., 2007; Alao *et al.,* 2014). Environmental conditions such as temperature, relative humidity, light variations, and nutrition have a significant impact on pathogen infection, symptom expression, proliferation, and survival, which in turn affect the yield response of host plants (Shenge *et al*., 2018). To successfully cultivate sunflowers and get good yields, healthy seeds are necessary, however, associated fungi and other pathogens could play a

role in seed deterioration (Biemond *et al*., 2012). Due to climatic variations and the continuous deteriorating effects of global warming, diseases that were otherwise not reported or prevalent in certain regions may begin to emerge as conditions become more favorable for disease proliferation (Shenge *et al*., 2018). Information on disease thresholds for commercial production of sunflower is lacking in Nigeria. The potential of sunflower as a high-value crop in Nigeria is huge, however, there is a wide information gap on the impact of diseases on commercial sunflower production in Nigeria. The objectives of the study were to determine the occurrence of fungal diseases affecting sunflower varieties in Abuja and the effect of the diseases on yield.

Materials and Methods

Experimental site, design and source of planting materials

The experiment was conducted at the University of Abuja Teaching and Research farm during the 2021 and 2022 wet seasons (July to October) to evaluate the natural incidence and severity of fungal diseases of sunflower. The following sunflower varieties: SAMSUN1 SAMSUN2 SAMSUN3 SAMSUN4 and a local variety from Abuja (Abuja Local) were planted on a field 18.5 × 12.75 m^2 with plot sizes of 2.1 × 2.25 m^2, with inter row and intra row spacings of 75 cm and 3 0 cm, respectively.

The first four sunflower varieties were obtained from IAR, ABU Zaria and the fifth variety from the local market in Abuja. All the varieties were planted on the Teaching and Research farm at the University of Abuja, Nigeria in the wet seasons (July to October) of 2021 and 2022. The experiment was laid out in a randomized complete block design and replicated thrice.

Agronomic practices and data collection

Standard agronomic practices were carried out and data regarding disease incidence and severity were collected at 35, 49 and 63 days after sowing (DAS). Disease incidence was determined as the percentage of the ratio of diseased plants in a plot to the total number of examined plants. Disease incidence (DI) and disease severity (DS) were determined using the formula shown below:

$$\text{DI (\%)} = \frac{\text{No. of diseased plants}}{\text{No. of plants examined}} \times 100$$

$$\text{DS (\%)} = \frac{\text{Sum of individual plant ratings}}{\text{No. of plants assessed} \times \text{maximum score}} \times 100$$

Disease severity for Alternaria blight was scored on a 5-point rating scale modified by Anjorin *et al*. (2013). Disease severity for Septoria leaf spot and Phoma blight were also scored on a 5-point rating system modified by Hilderbrandt *et al.* (1996). Diseases were assessed at 35 DAS and 49 DAS for Alternaria blight and Septoria leaf spot, Phoma blight disease was assessed at 49 DAS and 63 DAS, because at 35 DAS the disease symptoms had not manifested. Screenhouse studies were conducted to assess the reaction of sunflower varieties to Alternaria leaf blight, Septoria leaf spot and Phoma blight diseases. Plants were inoculated at 42 DAS and assessed 7 days post-inoculation for disease symptoms and disease severity scores were recorded for each disease.

Pathogenicity tests

Following procedures described by Kgatle *et al*. (2018), diseased sunflower leaves with symptoms typical of Alternaria blight and Septoria leaf spot were collected and placed in individual paper bags to prevent rapid desiccation, and transported to the laboratory in an ice box for further processing and analyses (Fig. 1).

The samples were cut into 5 mm^2 segments with a sterile scalpel blade. and disinfected in a 1.5% sodium hypochlorite solution for 3 min and rinsed in sterile distilled water for a minute. The leaf pieces were plated on potato dextrose agar (PDA) and incubated at 25 °C under 12 h alternating cycles of light and darkness for 3 days. The Alternaria and Septoria cultures were further sub-cultured on PDA media, as described above, to obtain pure cultures. Morphological identification was carried out based on method by (Simmons, 2007).

The isolates were cultured on PDA for 7 days at 25 °C and alternated in a 12-hour cycle of light and darkness, and morphologically identified under a Zeiss Stereomicroscope (Fig. 2). The same procedure was repeated for the Septoria and Phoma species. For *Alternaria* and *Septoria* species, spore suspensions were prepared from 2-week-old isolates and adjusted to a concentration of 4 × 10^5 spores mL^{-1} for inoculation of the sunflower plants.

Pathogenicity tests

Using the method described by Indawan (2016), 1.5% sodium hypochlorite solution was used to sterilize sunflower seeds for 3 min and rinsed in sterile water three times. In the green house, one seed per pot was sown in 15 cm wide plastic pots containing sterile soil, arranged in a randomized block design with three replicates. The prepared conidial spore suspension was used to inoculate 6 weeks old sunflower plants by spraying the leaves until run-off using the aerosol method. Plants sprayed with sterile distilled water served as control and covered with polyethene bags for 48 h to maintain a high relative humidity (>95%). After 7 days, plants were evaluated for expression of Alternaria blight symptoms (Fig. 3). The disease was scored using the scale modified by Anjorin *et al*. (2013).

Pathogenicity test for Phoma blight of sunflower

Stem fragments expressing Phoma blight symptoms were cut into 1 cm^2 pieces and sterilized in 70% ethanol for 10 s, 3% sodium hypochlorite solution for 10 min, rinsed in sterile distilled water for 3 min and dried with sterilized filter paper. Tissues were plated on Petri dishes containing PDA and incubated at 25 °C in the dark. Isolates were sub cultured on PDA at 25 °C and incubated for 7 days for germination of conidia. To determine conidia germination, a suspension of 20 mL was placed on a concave glass slide and transferred into a microchamber maintained at 100% humidity and covered. Morphological characteristics of mycelia, pycnidia, and conidia were observed under the microscope as shown in Fig. 2 (Roustaee *et al*., 2000).

In the greenhouse, seven days old seedlings arranged in a randomized block design were inoculated by applying the prepared inoculum to the cotyledons or stems using a dropper while sterile distilled water was applied to the control group. Afterwards, plants were covered with polyethene bags for 48 h to maintain high relative humidity (>95%) and promote pathogen development. The inoculated stems were observed for typical symptoms after 2 weeks (Fig. 3). Disease severity for Leaf spot and Phoma blight were also scored on a 5-point rating system modified from Hilderbrandt *et al*. (1996).

Data analyses

Records on disease incidence, severity, yield and screen house for all the varieties evaluated were taken for both seasons and all the data were analyzed using the analysis of variance and SPSS (2021) software package. Means were separated using the Duncan Multiple Range Test at ($P \leq 0.05$).

Results

In determining the occurrence of fungal diseases of sunflower on the field, Alternaria blight, Septoria leaf spot and Phoma blight were identified on the sunflower fields (Fig. 1). In the first season, at 35 days after sowing, all the varieties exhibited similar levels of incidence of Alternaria leaf blight with no significant differences ($P \leq 0.05$) as shown in Table 1. However, at 49 DAS, the difference between SAMSUN4 and the Local Variety was significant, while there was no significant difference between the other varieties. In the case of Leaf spot at 35 DAS, SAMSUN1had the lowest incidence while SAMSUN2 and SAMSUN$ had the highest incidence. The difference between the lowest incidence and highest incidence was significant. At 49 DAS, SAMSUN1 had the lowest incidence, while SAMSUN3 and SAMSUN4 had the highest, showing significant differences. For Phoma blight at 49 DAS, there are no significant differences in incidence among all varieties. At 63 DAS, the local variety was significantly different from the other varieties.

Alternaria leaf blight showed the Local Variety with the lowest disease severity while SAMSUN4 had the highest severity. The difference between the lowest and the highest severity was significant ($P \leq 0.05$) but the difference between the other varieties was not significant. At 49 DAS, the local variety with the lowest severity was significantly different from the other varieties. In case of leaf spot at 35 DAS, Local Variety with the lowest severity was significantly different from SAMSUN4, which had the highest severity. The difference between the other varieties was not significant. At 49 DAS, the Local Variety showed the highest severity, which was significantly different from other varieties. For Phoma blight at 49 DAS, there was no significant differences in severity among all the varieties. However, at 63 DAS, SAMSUN3 and SAMSUN4 exhibited a significantly higher severity compared to other varieties (Table 2).

In the second year, the incidence of Alternaria leaf blight at 35 DAS showed SAMSUN3 with a significantly higher incidence than SAMSUN1 while other varieties were not significantly different (P = 0.05). At 49 DAS, SAMSUN2 and SAMSUN3 showed significantly higher incidence compared to SAMSUN1 and the Local Variety. With leaf spot, at 35 DAS, there was no significant difference in incidence among the varieties. At 49 DAS, SAMSUN3 and SAMSUN4 showed significantly higher incidence compared to SAMSUN1, while the other varieties were not significantly different. For Phoma blight (PB), there was no significant differences in incidence between all varieties at 49 DAS and 63 DAS (Table 3).

The disease severity of Alternaria blight at 35 DAS had the Local Variety with the lowest severity, showing significant differences compared to SAMSUN1, SAMSUN2 and SAMSUN3. At 49 DAS, there was no significant differences in severity among the varieties at ($P \leq 0.05$). Leaf Spot (LS) at 35 DAS, had the Local Variety and SAMSUN1 with the lowest severities, which was significantly different from the other varieties. At 49 DAS, SAMSUN2 had the lowest severity, significantly different from SAMSUN1 and SAMSUN3 while the other varieties were not significantly different at $P \leq 0.05$. Phoma blight at 49 DAS, showed the Local Variety with significantly lower severity compared to SAMSUN1 and SAMSUN3 and no significant difference between the other varieties. At 63 DAS, SAMSUN2 showed significantly higher severity compared to SAMSUN1 and the Local Variety. The difference among the other varieties was not significant (Table 4).

Yield record in the first year ranged from 0.98 to 1.89 tons ha^{-1}. SAMSUN4 had the highest yield and was significantly different from SAMSUN1, which had the lowest yield. The other varieties *viz.*

SAMSUN2, SAMSUN3 and the Local Variety showed intermediate yields, with SAMSUN2 and the Local Variety having yields that were not significantly different from each other but significantly higher than SAMSUN1 (Fig. 4).

In the second year, yields ranged from 1.08 to 1.82 tons ha^{-1}. The Local Variety had the highest yield, significantly different from SAMSUN2 and SAMSUN1, which had the lowest yield. SAMSUN4 also showed a significantly higher yield compared to SAMSUN1 but was not significantly different from SAMSUN3 and the Local Variety. The standard error for both years is 0.18 tons ha^{-1}, indicating the variability of the data, with lower values suggesting more reliable measurements (Fig. 4).

In the screenhouse studies, the reaction of sunflower varieties to Alternaria leaf blight, Septoria leaf spot and Phoma blight diseases showed that the difference between the severities for Alternaria leaf blight was not significant for SAMSUN 2, SAMSUN 3, SAMSUN 4, and Local Variety but SAMSUN1 was significantly different from the rest at $P \leq 0.05$ (Table 5). The difference between the disease severity of SAMSUN1 and SAMSUN 2 was significant at $P \leq 0.05$, whereas the difference between SAMSUN 3, SAMSUN 4 and Local Variety was not significant at $P \leq 0.05$. For Phoma blight, there was no significant difference in the disease severity among the varieties (Table 5 and 6).

Discussion

Results of this study indicated that Alternaria blight, Septoria leaf spot, and Phoma black stem diseases occurred in all varieties. This incidence of Alternaria blight agrees with the report of Alao *et al.* (2014), which states that Alternaria blight is among the dominant diseases associated with sunflower seeds in Nigeria. In addition, while Kgatle *et al*. (2018) reported that Alternaria blight can significantly reduce sunflower yields in all growing regions, the nutritional quality of sunflower seeds can also be affected by this disease, as reported by Oyewole *et al*. (2017) where the protein and oil contents of infected seeds were lower than expected, this could negatively affect the value of the crop. Akash *et al*. (2019) reported that Alternaria blight is a potential and destructive disease in India, Australia, and other African countries.

Septoria leaf spot was observed on mature lower sunflower leaves. However, the incidence and severity of this disease in both years were minimal compared with Alternaria leaf blight. This agreed with the findings of Ramusi and Flett (2014) who reported that Septoria leaf spot does not significantly damage sunflower plants, as the lower leaves on mature plants are mainly affected. However, if not correctly managed, severe infections could lead to defoliation, negatively impacting yield.

Disease incidence of Phoma blight was higher during the late growth stages of sunflower. This agreed with the report by Bryan *et al*. (2019). Reports by OECD 2006 proposed the occurrence of Phoma blight disease in sunflowers in African countries and other parts of the world, except China. Interestingly, a few years later, the disease, was first reported by Chen *et al*. (2008), which became a concern in China and was included in its quarantine pest list by 2010. Harveson *et al*. (2016) also reported that infection of Phoma blight may be disregarded because the lesions are often superficial with minimal movement into the pith of sunflower stems. Notably, infections in early growth stages could reduce yield loss by 10 to 30% (Velasquez and Formento, 2003). This implies that severe infections may lead to substantial yield loss if ignored; hence, there is a need to implement management strategies to ensure increased yield (Bryan *et al*., 2019).

Generally, there were significant differences in disease incidence among the sunflower varieties. The Local variety generally showed lower disease incidence, especially for Phoma blight at 63 DAS. With disease severity, the Local variety generally showed lower disease severity for leaf blight and leaf spot. These differences in performance are crucial for selecting the most resistant varieties to improve sunflowers during breeding. The variation in the severity of these diseases might be due to factors such as weather conditions, crop variety, and management practices. The performance of varieties in terms of yields showed that the local variety performed better than the improved varieties. This corresponds with the reports of Kaya *et al*. (2007), where yield losses attributed to these diseases ranged from 24% to as high as 78.5 % depending on the crop variety, soil fertility, time of infection and weather factors.

Screen house studies showed that all the varieties manifested the diseases on the field, with the least severity on Phoma blight. These findings align with previous works and provide valuable insights into the incidence and severity of the diseases across different sunflower varieties. They could also serve as a reference for breeding programs to enhance disease resistance in sunflower varieties.

Conclusion

This study showed that Alternaria blight, Septoria leaf spot and Phoma blight diseases were observed on sunflower in the FCT, Abuja. Alternaria blight was the most severe, while Phoma blight was mild. The Local variety performed better having the least severities for all the three diseases and better yield in the two seasons. The findings from this study heighten our understanding of the impact of foliar diseases on different sunflower varieties, offering practical implications for farmers seeking to select varieties with improved resistance to the disease. The occurrence of these diseases indicated the need for effective disease management strategies such as integrated disease management, including

the use of high disease-resistant varieties, crop rotation, use of fungicides and good field hygiene for better sunflower performance.

Novelty statement

There is a huge potential of sunflower as a high-value crop in Nigeria. However, there exists a wide information gap on the impact of diseases on commercial sunflower production in Nigeria. The present study was, therefore, carried out to explore different diseases associated with sunflower and response of different sunflower varieties to the fungal pathogens.

Contribution of authors

ROE: Investigation, data collection, funding, writing original draft, writing- review and editing. TSA: Conceptualization, resources, formal analysis, validation, supervision, review and editing. SWA and BCA: Co-supervision, review and editing.

Conflict of interests

Authors declare no conflict of interest.

Table 1: Incidence of Alternaria leaf blight, Septoria leaf spot and Phoma blight in five sunflower varieties in 2021.

Variety	Alternaria Leaf Blight		Septoria Leaf Spot		Phoma Blight	
	35 DAS	49 DAS	35 DAS	49 DAS	49 DAS	63 DAS
SAMSUN1	32.00^{a}	24.33^{ab}	37.67^{a}	45.67^{a}	20.67^{a}	28.00^{b}
SAMSUN2	26.33^{a}	20.00^{ab}	49.67^{b}	52.00^{ab}	20.33^{a}	24.33^{b}
SAMSUN3	27.33^{a}	22.00^{ab}	44.33^{ab}	57.33^{b}	17.67^{a}	27.67^{b}
SAMSUN4	24.33^{a}	26.67^{b}	50.67^{b}	55.00^{b}	20.00^{a}	27.00^{b}
LOCAL VARIETY	20.00^{a}	17.00^{a}	45.00^{ab}	49.67^{ab}	18.00^{a}	16.67^{a}
±SE	4.53	2.499	2.64	2.62	2.16	2.30

Means followed by the same letters within a column are not significantly different as determined by Duncan Multiple Range Test at $P \leq 0.05$.

Table 2: Severity of Alternaria leaf blight, Septoria leaf spot and Phoma blight in five sunflower varieties in 2021.

Variety	Alternaria leaf blight		Septoria leaf spot		Phoma blight	
	35 DAS	49 DAS	35 DAS	49 DAS	49 DAS	63 DAS
SAMSUN1	38.67^{ab}	41.00^{b}	25.33^{ab}	34.33^{a}	34.33^{a}	36.00^{a}
SAMSUN2	39.33^{ab}	42.00^{b}	29.33^{ab}	32.00^{a}	32.00^{a}	37.67^{a}
SAMSUN3	44.67^{b}	51.33^{b}	29.33^{ab}	31.33^{a}	31.33^{a}	51.67^{b}
SAMSUN4	48.00^{b}	48.67^{b}	35.67^{c}	34.00^{a}	34.00^{a}	55.00^{b}
LOCAL VARIETY	30.67^{a}	26.00^{a}	23.33^{a}	41.00^{b}	31.00^{a}	35.00^{a}
SE±	2.89	3.62	1.49	1.98	2.88	2.28

Means followed by the same letters within a column are not significantly different as determined by Duncan Multiple Range Test at $P \leq 0.05$.

Table 3: Incidence of Alternaria leaf blight, Septoria leaf spot and Phoma blight in five Sunflower Varieties in 2022.

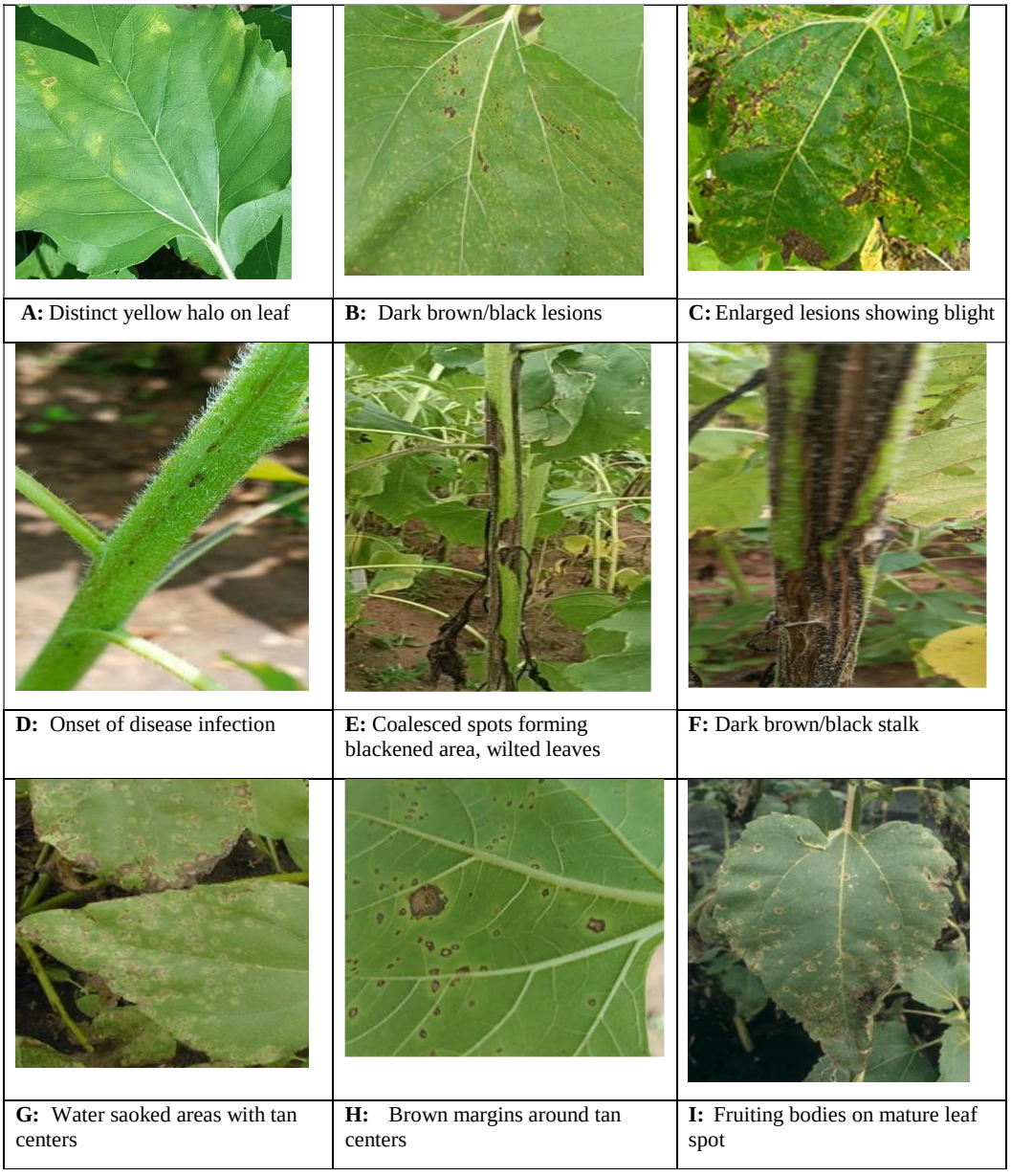
Variety	Alternaria leaf blight		Septoria leaf spot		Phoma blight	
	35 DAS	49 DAS	35 DAS	49 DAS	49 DAS	63 DAS
SAMSUN1	37.00^{a}	46.33^{a}	44.67^{a}	46.00^{a}	11.67^{a}	16.00^{a}
SAMSUN2	42.00^{ab}	59.67^{c}	54.33^{a}	57.00^{ab}	15.33^{a}	18.33^{a}
SAMSUN3	48.33^{b}	59.00^{c}	51.67^{a}	60.00^{b}	14.33^{a}	17.67^{a}
SAMSUN4	42.67^{ab}	54.33^{ab}	53.00^{a}	58.67^{b}	15.33^{a}	16.33^{a}
LOCAL VARIETY	40.67^{ab}	49.00^{a}	54.33^{a}	51.67^{ab}	12.33^{a}	14.33^{a}
SE±	3.04	2.19	3.98	3.43	1.67	1.70

Means followed by the same letters within a column are not significantly different as determined by Duncan Multiple Range Test at $P \leq 0.05$.

Table 4: Severity of Alternaria leaf blight, Septoria leaf spot and Phoma blight in five sunflower varieties in 2022.

Variety	Alternaria leaf blight		Septoria leaf spot		Phoma blight	
	35 DAS	49 DAS	35 DAS	49 DAS	49 DAS	63 DAS
SAMSUN1	40.33^{b}	44.33^{a}	28.00^{a}	37.33^{b}	32.67^{b}	38.33^{b}
SAMSUN2	40.67^{b}	46.33^{a}	28.67^{ab}	28.00^{a}	31.00^{ab}	32.00^{a}
SAMSUN3	41.00^{b}	49.00^{a}	32.00^{b}	46.^{00ab}	32.67^{b}	35.00^{ab}
SAMSUN4	37.33^{ab}	48.00^{a}	32.67^{c}	42.33^{ab}	31.00^{ab}	36.67^{ab}
LOCAL VARIETY	32.00^{a}	39.67^{a}	26.67^{a}	44.00^{ab}	24.33^{a}	32.67^{ab}
SE±	2.10	3.40	1.16	2.45	2.24	1.73

Means followed by the same letters within a column are not significantly different as determined by Duncan Multiple Range Test at $P \leq 0.05$.



A: Distinct yellow halo on leaf | **B:** Dark brown/black lesions | **C:** Enlarged lesions showing blight

D: Onset of disease infection | **E:** Coalesced spots forming blackened area, wilted leaves | **F:** Dark brown/black stalk

G: Water saoked areas with tan centers | **H:** Brown margins around tan centers | **I:** Fruiting bodies on mature leaf spot

Fig. 1: Symptoms of Alternaria leaf blight, Septoria leaf spot and Phoma blight of sunflower in the field. **A-C:** Stages of disease development for Alternaria leaf blight of sunflower. **D-F:** Stages of disease development for Phoma blight of sunflower. **G-I:** Stages of disease development for Septoria leaf spot of sunflower.

Table 5: Severity of Alternaria leaf blight, Septoria leaf spot and Phoma blight in five sunflower varieties under screen house inoculation.

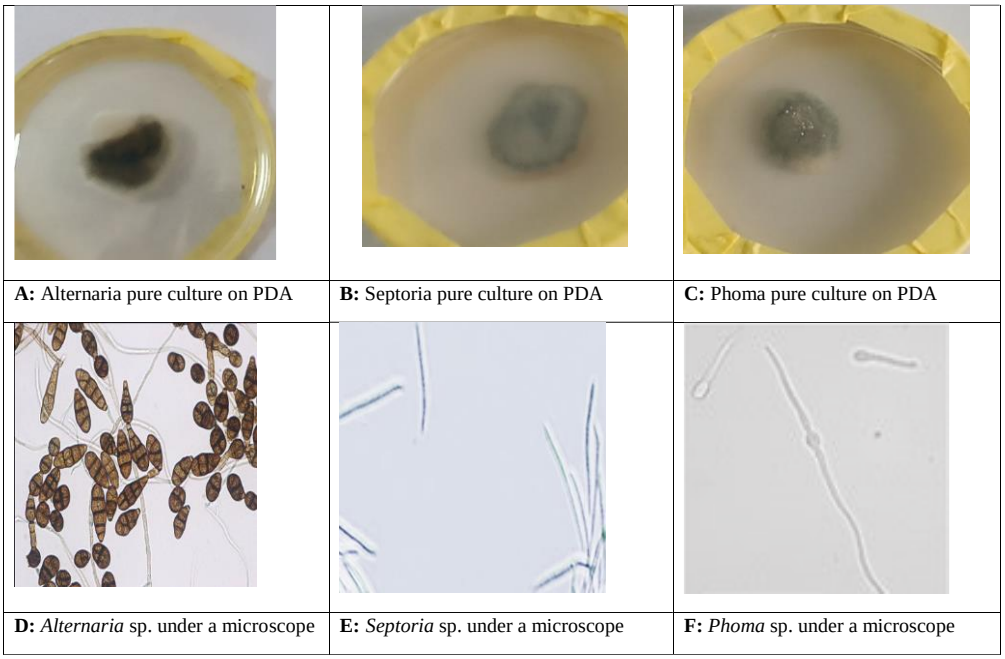
Variety	Alternaria leaf blight	Septoria leaf spot	Phoma blight
SAMSUN1	50.66[a]	39.00[b]	33.78[b]
SAMSUN 2	39.98[b]	46.31[c]	30.00[b]
SAMSUN 3	40.09[b]	42.22[bc]	34.76[b]
SAMSUN 4	43.71[b]	42.67[bc]	30.56[b]
Local Variety	35.81[b]	43.56[bc]	29.18[b]
Control	16.23[b]	22.28[a]	19.17[a]
±SE	3.236	2.136	1.546

Means followed by the different letters within a column are significantly different ($P \leq 0.05$) as determined by Duncan Multiple Range Test.

Table 6: Severity of Alternaria leaf blight, Septoria leaf spot, and Phoma blight on different sunflower varieties under screenhouse inoculation and disease interaction.

Variety	Severity
SAMSUN 1	41.99[b]
SAMSUN 2	38.77[b]
SAMSUN 3	41.69[b]
SAMSUN 4	38.98[b]
Local variety	36.18[b]
Control	19.22[a]
Disease interaction	
Alternaria Blight	39.08[b]
Phoma Blight	29.57[a]
Septoria Leaf Spot	39.77[b]
Interaction	36.14

For each gategoty, means followed by the different letters within a column are significantly different ($P \leq 0.05$) as determined by Duncan Multiple Range Test.



A: Alternaria pure culture on PDA | **B:** Septoria pure culture on PDA | **C:** Phoma pure culture on PDA

D: *Alternaria* sp. under a microscope | **E:** *Septoria* sp. under a microscope | **F:** *Phoma* sp. under a microscope

Fig. 2: Pure cultures on potato dextrose agar (**A-C**), and microscopic views of mycelia of *Alternaria*, *Septoria* and *Phoma* species (**D-F**).

A: Alternaria blight **B:** Septoria leaf spot **C:** Phoma blight

Fig. 3: Disease symptoms on sunflower leaves after seven days of inoculation.

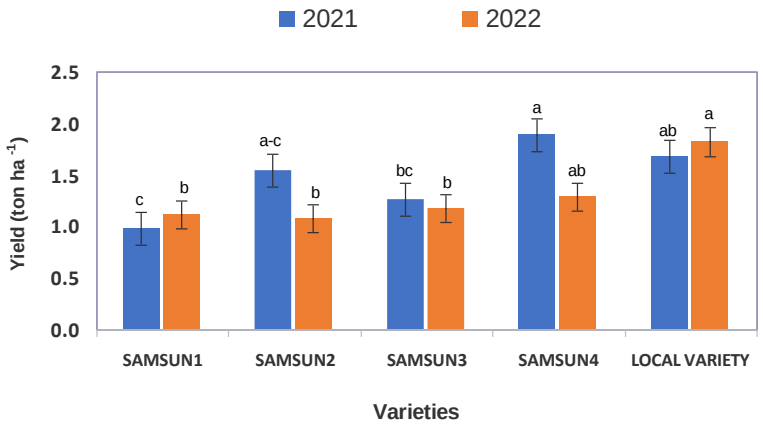


Fig. 4: Yield of five sunflower varieties (tons ha^{-1}) in 2021 and 2022. Values with different letters (in each year) show significant difference ($P \leq 0.05$).

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