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RESEARCH ARTICLE

SCREENING OF ETHIOPIAN FABA BEAN (*VICIA FABA* L.) ACCESSIONS FOR RESISTANCE AND YIELD PARAMETERS AGAINST FABA BEAN GALL DISEASE (*OLPIDIUM VICIAE*) UNDER FIELD CONDITIONS

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ABSTRACT: Faba bean (*Vicia faba* L.) has been produced for centuries in Ethiopia and provides protein supplements to the diet of rural households. It is recently threatened by a new emerging gall disease caused by the fungal pathogen *Olpidium viciae* Kusano. The purpose of this study was to screen faba bean accessions with high yield potential for resistance against gall disease under rain-fed field conditions. A local check and 180 accessions were screened following standardized procedures. The seeds were sown in a randomized complete block design with three replications during the 2017–2019 cropping seasons. SPSS statistical software version 20 was used to calculate the disease severity index (DSI), an area under disease progress curve. Significant ($p \leq 0.05$) positive correlation was recorded between the disease severity and altitude ($r = 0.27$), precipitation ($r = 0.37$). Though no accessions were found resistant, 87.18% were identified as moderately resistant (DSI: 16.50–39.45%) to the test pathogen. In a combined mean analysis over districts, the lowest DSI was recorded for FB-Obse (DSI=16.50%), FB-Hachalu (DSI = 17.83%), FB-26872 (DSI = 18.84%), FB-26873 (DSI = 9.61%), and FB-28107 (DSI = 19.85%) accessions. Similarly, they exhibited various levels of yield potentials. The highest DSI rate (74.88–100%) was recorded between 38–77 days after crop emergence. The average minimum infection rate was recorded ($r = 0.003$) for FB-26873 variety at Sululta with a coefficient of determination of 79.00%. Crops with the lowest DSI exhibited the uppermost yield parameters. Hence, faba bean accessions with the maximum yield and moderate resistance to gall disease were recommended to be used for production.

Key words/phrases: Disease severity index, Faba bean, Gall disease, Resistant, Yield parameter.

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INTRODUCTION

Faba bean (*Vicia faba* L.) is an important pulse crop cultivated in the world for food and fodder (Singh *et al*., 2013). Ethiopia is the main faba bean diversity centre next to China (Behailu Mulugeta *et al*., 2018). Faba bean is mostly grown by farmers in the highlands of Ethiopia (1,800–3,000 m.a.s.l) receiving annual rainfall of 700–1,000 mm (Teklay Abebe *et al*., 2018). It has an important place in the Ethiopian national diet and is used to make various traditional dishes for its high protein content (Endalkachew Fekadu *et al*., 2018; Etemadi *et al*., 2019).

Despite its wide ecological and economic benefits, the average actual yield (2.1 tons per hectare) of faba bean is far below its potential 4.4 tons per hectare (Wondafrash Mulugeta *et al*., 2019). The low crop yield is attributed to different biotic and abiotic factors (Alireza *et al*., 2021). Among biotic factors, fungal disease such as chocolate spot (caused by *Botrytis fabae* Sardiña), rust (caused by *Uromyces viciae-fabae* (Pers.) J. Schröt.), downy mildew (caused by *Peronospora viciae* (Berk.) Casp.), and black root rot (caused by *Fusarium solani* (Mart.) Sacc.) are the most common widespread and destructive among faba bean yield-limiting fungal diseases (Teklay Abebe *et al*., 2014). Similarly, faba bean productivity is significantly influenced by its genotype (Sheikh *et al*., 2015).

In recent years, in addition to the previous common diseases, the crop is threatened by the new emerging faba bean gall disease caused by *Olpidium viciae* Kusano. The gall disease was widely disseminated in the high altitudes (above 2,400 m a.s.l.) of faba bean growing areas within a few years since 2010 (Teklay Abebe *et al*., 2018). The disease becomes the most devastating and causes up to 100% crop loss in many highland areas of the country (Bogale Nigir *et al.*, 2017).

Although farmers use different management options such as good soil drainage, use of disease-free seeds, fungicide spray, and crop rotation, none of these were able to control gall disease adequately under field conditions (Teklay Abebe *et al*., 2018). Fungicides have negative effects on public health and environmental balance (Singh *et al.*, 2013). Hence, it needs more attention to find non-hazardous solutions to manage the disease and sustain the productivity of the crop.

In Ethiopia, it is clearly observed that there is no sound gall disease control measure identified yet. Screening of faba bean accessions being resistant to gall disease and having higher productivity potential could be the most sustainable management options. The cultivation of resistant crop varieties

eliminates the crop losses caused by disease (Soler *et al*., 2021; Su *et al*., 2021) and reducing costs related to fungicide applications, and increases crop productivity (Pornthip and Prakit, 2021). The hazard of pollution of the environment with toxic chemical compounds can also be avoided (Teklay Abebe *et al.*, 2014).

As a result of efforts made through national and regional faba bean improvement programs of Ethiopia, many faba bean varieties were released at different times. There are only a few studies about the evaluation of resistance of faba bean varieties against gall diseases in Ethiopia. Therefore, the objective of this study was to evaluate and identify nationally available faba bean accessions for high yield and better resistance to faba bean gall diseases after natural infection at the most faba bean gall disease hot spot areas under rain-fed field conditions.

MATERIALS AND METHODS

Description of the study sites

The study was conducted at Angolelana Tera, Sululta, and Midakegn districts on farmers' fields during the main cropping seasons (June-August) of the year 2017–2019. These study sites are considered the hotspot areas for faba bean gall disease since its occurrence in Ethiopia (Bitew Beyene and Tigabie Abiro, 2016). Angolelana Tera is located in North Shoa zone of the Amhara National Regional State, and 110 km North East of the capital city, Addis Ababa. It is found at the longitude of 39° 27' 0" E and latitude of 9° 33' 0" N. The altitude of the specific study site is 2,774 m.a.s.l. with brown soil colour and plane topography.

Both Sululta and Midakegn districts are located in the Oromia National Regional State. Sululta district is located in North Shoa zone at about 23 km to the North of Addis Ababa. It is found at longitude 38° 43' 59.99" E and latitude 9° 10' 59.99" N, and an altitude of the specific study site is 2,610 m.a.s.l., whereas Midakegn district is located in West Shoa zone at about 170 km to the West of Addis Ababa, Ethiopia. It is found at longitude 37° 28' 94" E, latitude 9° 08' 61" N and altitude 2520 m.a.s.l. Soil types of all the research sites are vertisols.

In the 2017 cropping season, the monthly mean precipitation for June–August was 284.40 mm, 273.90 mm, and 231 mm at Angolelana Tera, Sululta, and Midakegn districts, respectively. Whereas the average daily minimum mean temperature (14.60°C) was recorded at Midakegn district. Similarly, in the 2018 cropping season, the maximum monthly mean

precipitation (358.20 mm) was recorded at Angolelana Tera district. During this period the average temperature at all sites was between 15.40–15.50°C. Likewise, in the 2019 cropping season, the maximum precipitation was recorded at Angolelana Tera (274.50 mm) followed by Midakegn district (272.7 mm), whereas the minimum average daily temperature was recorded at Angolelana Tera district (14.90°C) (Table 1).

Table 1. Climate data of the month June to August during 2017–2019 cropping seasons.

Districts and cropping seasons	Precipitation (mm)	Daily temperature (°C)		
		Minimum	Maximum	Average
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Angolelana Tera district				
2017	284.40 ± 90.40	8.60 ± 1.10	21.20 ± 0.90	14.90 ± 0.20
2018	358.20 ± 50.10	9.30 ± 0.90	21.50 ± 0.50	15.40 ± 0.70
2019	274.50 ± 64.90	8.60 ± 0.60	21.30 ± 0.90	14.90 ± 0.50
Average	295.70 ± 78.90	8.80 ± 0.80	21.30 ± 0.70	15.10 ± 0.50
Sululta district				
2017	273.90 ± 91.30	9.60 ± 0.90	22.50 ± 0.90	16.10 ± 0.10
2018	349.10 ± 53.20	9.20 ± 0.60	21.90 ± 0.10	15.50 ± 0.30
2019	206.90 ± 86.40	9.00 ± 0.10	22.10 ± 0.60	15.60 ± 0.30
Average	276.70 ± 91.90	9.30 ± 0.70	22.20 ± 0.60	15.70 ± 0.30
Midakegn district				
2017	231.00 ± 75.50	10.00 ± 1.20	19.30 ± 0.60	14.60 ± 1.00
2018	277.70 ± 31.50	9.70 ± 0.20	21.10 ± 0.30	15.40 ± 0.20
2019	272.70 ± 58.50	9.90 ± 0.70	21.20 ± 0.70	15.50 ± 0.20
Average	240.90 ± 55.70	9.90 ± 0.20	19.80 ± 1.60	15.90 ± 1.20

Source: EMA, 2019

Collection of faba bean accessions and screening procedures

A total of 180 faba bean accessions were collected from the Ethiopian Biodiversity Institute (EBI), and Holota Agricultural Research Centre (HARC). The screening processes of faba bean accessions against gall diseases were conducted for three consecutive cropping seasons from 2017 to 2019 under natural infection in rain-fed field conditions. The faba bean germplasm were sown in June (main rainy season) for all years. In the 2017 cropping season, all the collected accessions were sown in the farmers' fields at each experimental site and those best adapted to the study locations (30 from EBI and eight from HARC collection) were selected for additional screening in the 2018 cropping season. Based on the results of the 2017 and 2018 cropping season, a local check and 14 faba bean accessions with moderate resistance against gall diseases and potential yield parameters were selected and planted for further evaluation in the 2019 cropping season.

Experimental design and field management

Farmland previously sown with faba bean was prepared with assistance from the farm field owners (farmers) for the three cropping seasons (2017–2019) at each experimental site. In all cropping seasons, the faba bean accessions were arranged in Randomized Complete Block Design (RCBD) with three replications. In 2017, a total of 180 faba bean accessions were sown on a 500 m^2 (25 m length x 20 m width) experimental field area which was divided into ten blocks. Each block consisted of 24 plots. The faba bean accessions were evaluated for gall disease resistance and adaptation to the ecological zone of the study areas. Then, 38 faba bean accessions that showed better adaptation to the study area and tolerant to gall disease were screened for the 2018 cropping season. In 2018, a total of 200 m^2 (20 m length x 10 m width) experimental farm fields were prepared and divided into six blocks. Each block consisted of 16 plots. At the final experimental period (2019 cropping season) a total of 100 m^2 (10 m length x 10 m width) experimental field was divided into four blocks. Each block consisted of ten (10) plots. Each block was 40 cm far apart in all experimental periods. Similarly, each plot was arranged in 1 m^2 in area and divided into three rows. The spaces between rows were 40 cm. A total of 12 seeds were sown for each accession (4 seeds/row) on each plot. The distance between seeds was 10 cm. The local check was sown in every 10 test plots. The experimental field was plowed following the standard practices for faba bean production before sowing. Weeding and other agronomic practices were carried out at an appropriate time.

Data collection

Disease and crop data were recorded on plant basis to evaluate the performance of the experimental accessions in different time intervals. The disease data were recorded on the 60th day after the date of crop emergence. Percent disease incidence of faba bean gall diseases was assessed by counting the number of diseased plants per total number of plants inspected and expressed as a percentage of total plants. The gall disease severity index was recorded using a 0–9 scale following the methods described by Aghajani (2009). Six resistance levels were used in these experiments viz., highly resistant (healthy plant, grade = 0, DSI = 0–2%), resistant (1–15 % of the plant surface infected, grade = 1, DSI = 2.1–15%), moderately resistant (15.1–40% of the plant surface infected, grade = 3, DSI = 15.1–40 %), moderately susceptible (40.1–60 of the plant surface infected, grade = 5, DSI = 40.1–60%), susceptible (60.1–80% of the plant surface infected,

grade = 7, DSI = 60.1–80%), highly susceptible (>80% of plant surface infected, grade = 9, DSI = 80.1–100%). The DSI of each faba bean accession was calculated by the following formula (Aghajani, 2009).

$$DSI = \left(\frac{a + 3b + 5c + 7d + 9e}{9(a + b + c + d + e)}\right) x100$$

where, 9 = highest rating value, a = number of plants in class 1, b = number of plants in class 3, c = number of plants in class 5, d = number of plants in class 7, e = number of plants in class 9.

The Area Under the Disease Progress Curve (AUDPC) was calculated from DSI (Villegas-Fernandez *et al*., 2011) as follows;

$$AUDPC = \sum_{i=0}^{n} [0.5\ (yi + yi + 1)(ti + 1 - ti)]$$

Where y_i is disease severity at i^{th} assessment, t_i is a time of assessment and n is total assessments.

The crop was harvested 115 days after the date of crop emergence. The yield parameters (viz., pod/plant, seed/pod, and 100 seeds weight) of each faba bean variety were evaluated for each cropping season and experimental sites. Hundred seed weight was determined using a digital balance (Sartorius, Germany).

Data analysis

The data were analysed by one-way ANOVA implemented in SPSS statistical software version 20 to evaluate the presence of significant difference among faba bean accessions in response to gall disease. The AUDPC of the disease was analyzed from DSI. Means were compared using the least significant difference (LSD) at a 5% probability level ($p \leq 0.05$). The percentage of seed germination in the field was calculated by counting the number of seeds germinated per total number of seed sown and expressed as a percentage of total seeds (Bhagat *et al*., 2013).

RESULTS

Gall disease parameters

Gall disease intensity in 2017 and 2018 cropping seasons

The experiment results revealed that there was significant variation ($p< 0.05$) among the faba bean accessions against gall disease incidence and the disease severity index (DSI) in combined mean analysis over the experimental sites, and cropping seasons. FB-28104 accession was found to have the highest percent disease incidence with 94.22%. This was followed by a statistically non-significant ($p>0.05$) result of FB-212566 (93.39%) (Table 2).

The combined mean DSI of faba bean gall-forming diseases in 2017 and 2018 cropping seasons were between 15.60% and 61.50%. The highest and the lowest disease DSI were recorded on FB-26869 (61.50%) and FB-26872 (15.60%) accessions, respectively. There was significant variability ($p\leq 0.05$) in the resistance of faba bean accession against faba bean gall disease (Table 2). In this study, the average of two years' experiments indicated that among 38 accessions, and a local check, 34 (87.18%) were classified as moderately resistant (DSI: 15.60–39.45%), four (10.26%) were classified as moderately susceptible (DSI: 41.35–41.47%), and one (2.56%) was susceptible (FB-26869: DSI = 61.50%). However, no resistant accession was found against faba bean gall disease. Hence, fourteen faba bean accessions (viz., FB-26872, FB-Tumsa, FB-26873, FB-28107, FB-Obse, FB-Hachalu, FB-26883, FB-Numan, FB-28770, FB-26885, FB-COLL-0038, FB-26875, FB-26867, and FB-25280) those had shown better reactions among moderately resistant accessions were selected for further evaluation (Table 2).

Gall disease intensity during 2019 cropping season

The result presented in Table 3 indicated that the reaction of 14 faba bean accessions and a local check against faba bean gall disease was significantly varied ($p\leq0.05$) across districts. The lowest DSI was recorded on FB-Hachalu (6.67%) followed by FB-Obse (8.33%) at Sululta district than the remaining accessions. Similarly, the lowest mean DSI of gall disease was recorded on FB-Obse accession with 11.67%, and 16.33% at Midakegn, and Angolelana Tera districts, respectively. The highest DSI was recorded on local check at Angolelana Tera (DSI = 63.00%) and Sululta (DSI = 22.38%) districts, whereas the highest DSI recorded on FB-26885 (DSI = 46.67%) accession at Midakegn district (Table 3).

In the analysis of a combined mean average faba bean accessions, the lowest average DSI (13.11%) was recorded at Sululta, whereas the higher average DSI (38.76%) was recoded at Angolelana Tera than Midakegn district (DSI = 31.89%) (Table 3).

Table 2. Average faba bean gall diseases intensity of the three experimental sites during 2017 and 2018 cropping seasons of some faba bean accessions.

Faba bean accessions	2017 cropping season		2018 cropping season		Combined mean		Reaction
	Incidence (%) ± SD	Severity (%) ± SD	Incidence (%) ± SD	Severity (%) ± SD	Incidence (%) ± SD	Severity (%) ± SD	
FB-26872	88.83^{b} ± 3.00	16.83^{c} ± 0.35	50.79^{a} ± 42.07	14.36^{a} ± 4.90	69.08^{a} ± 26.90	15.60^{a} ± 1.74	MR
FB-Tumsa	80.00^{b} ± 11.27	20.15^{a} ± 10.56	52.47^{a} ± 40.73	13.17^{a} ± 1.52	66.24^{a} ± 19.46	16.66^{a} ± 9.94	MR
FB-26873	91.20^{b} ± 8.32	17.04^{c} ± 5.13	58.32^{c} ± 36.72	16.61^{a} ± 4.81	74.76^{b} ± 32.40	16.83^{a} ± 0.30	MR
FB-28107	97.17^{a} ± 12.10	21.08^{a} ± 1.25	60.31^{c}± 34.11	15.94^{a} ± 3.83	78.74^{b} ± 26.06	18.51^{a} ± 3.63	MR
FB-Obse	98.60^{a} ± 11.23	21.05^{a} ± 1.23	53.32^{a} ± 39.23	16.34^{a} ± 3.67	75.96^{b} ± 32.02	18.70^{a} ± 3.33	MR
FB-Hachalu	97.67^{a} ± 10.45	21.23^{a} ± 0.45	51.85^{a} ± 44.93	16.15^{a} ± 3.63	74.76^{b} ± 32.40	18.79^{a} ± 3.59	MR
FB-26883	91.14^{b} ± 21.25	18.21^{c} ± 3.56	60.35^{c} ± 32.80	20.87^{b} ± 11.77	75.75^{b} ± 21.77	19.54^{a} ± 1.88	MR
FB-Numan	90.17^{a} ± 10.25	21.54^{a} ± 2.53	59.45^{c} ± 33.94	16.46^{a} ± 3.96	74.81^{b} ± 21.72	19.00^{a} ± 3.59	MR
FB-28770	85.00^{b} ± 11.25	22.44^{a} ± 2.56	56.32^{c} ± 37.41	18.44^{a} ± 6.01	70.66^{a} ± 20.28	20.44^{a} ± 2.83	MR
FB-26885	98.83^{a} ± 12.45	21.75^{a} ± 4.05	57.42^{c} ± 36.58	20.92^{b} ± 6.67	78.13^{b} ± 29.28	21.33^{a} ± 0.59	MR
FB-COLL-0038	96.80^{a} ± 18.45	21.05^{a} ± 0.45	71.57^{b} ± 27.10	21.01^{b} ± 9.00	84.19^{c} ± 17.84	21.03^{a} ± 0.03	MR
FB-26875	95.20^{a} ± 9.20	21.60^{a} ± 0.76	64.66^{c} ± 31.15	21.09^{b} ± 9.09	79.93^{b} ± 21.60	21.34^{a} ± 0.36	MR
FB-26867	91.00^{b} ± 6.02	23.67^{b} ± 1.45	46.03^{d} ± 45.78	21.13^{b} ± 11.58	68.52^{a} ± 31.80	22.40^{a} ± 1.79	MR
FB-25280	95.00^{a} ± 0.98	17.83^{c} ± 2.47	53.73^{a} ± 43.53	28.24^{c} ± 27.72	74.36^{b} ± 29.18	23.04^{a} ± 7.36	MR
FB-25018	94.17^{a} ± 1.23	21.25^{a} ± 3.12	69.95^{b} ± 25.26	41.77^{d} ± 20.96	82.06^{c}± 17.13	31.51^{b} ± 14.51	MR
FB-26871	98.60^{a} ± 8.69	21.60^{a} ± 5.02	73.42^{b} ± 23.92	42.22^{d} ± 11.59	86.01^{c} ± 17.80	31.91^{b} ± 14.58	MR
FB-28112	86.33^{b} ± 12.24	22.67^{a} ± 0.25	64.73^{c} ± 31.49	42.92^{d} ± 12.75	75.53^{b} ± 15.28	32.80^{b} ± 14.32	MR
FB-212565	98.17^{a} ± 23.58	24.75^{b} ± 0.14	74.45^{b} ± 18.71	43.49^{d} ± 14.15	86.31^{c} ± 16.77	34.12^{b} ± 13.25	MR
FB-Dosha	99.00^{a} ±20.12	24.10^{b} ± 3.54	64.06^{c} ± 29.64	44.59^{d} ± 13.43	81.53^{c} ± 24.71	34.35^{b} ± 14.49	MR
FB-26870	98.33^{a} ± 10.25	22.67^{a} ± 0.25	76.82^{f} ± 29.80	47.46^{e} ± 14.78	87.58^{c} ± 15.21	35.07^{b} ± 17.53	MR
FB-26400	85.67^{b} ± 11.25	23.25^{a} ± 0.12	66.38^{b} ± 26.55	47.71^{e} ± 10.06	76.03^{b} ± 13.64	35.48^{b} ± 17.29	MR
FB-26864	97.85^{a} ± 12.25	23.36^{b} ± 12.45	71.29^{b} ± 25.45	47.86^{e} ± 12.51	84.57^{c} ± 18.78	35.61^{b} ± 17.32	MR
FB-26399	87.00^{b} ± 14.25	23.42^{b} ± 0.25	78.82^{f} ± 25.02	48.06^{e} ± 22.99	82.91^{c} ± 5.78	35.74^{b} ± 17.42	MR
FB-28113	90.60^{b} ± 11.22	23.60^{b} ± 1.25	77.96^{f} ± 19.69	48.17^{e} ± 13.50	84.28^{c} ± 8.94	35.88^{b} ± 17.37	MR
FB-Ashebeka	98.50^{a} ± 10.25	23.58^{b} ± 0.08	65.41^{b} ± 20.27	48.18^{e} ± 21.14	81.96^{c} ± 23.40	35.88^{b} ± 17.39	MR
FB-28109	96.67^{a} ± 7.25	23.58^{b} ± 2.14	66.55^{b} ± 26.26	48.20^{e} ± 14.24	81.61^{c} ± 21.30	35.89^{b} ± 17.41	MR
FB-26877	96.67^{a} ± 8.22	25.08^{b} ± 1.45	68.06^{b} ± 31.31	48.69^{e} ± 17.07	82.37^{c} ± 20.23	36.89^{b} ± 16.69	MR
FB-28105	96.67^{a} ± 7.23	23.00^{a} ± 2.78	69.07^{b} ± 31.94	49.58^{e} ± 20.50	82.87^{c} ± 19.52	36.29^{b} ± 18.80	MR
FB-26876	95.00^{a} ± 9.36	22.83^{a} ± 0.47	65.61^{b} ± 23.05	50.67^{e} ± 4.23	80.30^{c} ± 20.78	36.75^{b} ± 19.69	MR
FB-212566	98.75^{a} ± 8.45	25.50^{b} ± 0.45	88.03^{e} ± 16.61	50.30^{e} ± 19.47	93.39^{d} ± 7.58	37.90^{b} ± 17.54	MR

Faba bean accessions	2017 cropping season		2018 cropping season		Combined mean		Reaction
	Incidence (%) ± SD	Severity (%) ± SD	Incidence (%) ± SD	Severity (%) ± SD	Incidence (%) ± SD	Severity (%) ± SD	
FB-26887	98.50^{a} ± 10.45	24.58^{a} ± 0.98	71.46^{b} ± 37.54	51.30^{e}± 23.06	84.98^{c} ± 19.12	37.94^{b} ± 18.90	MR
FB-28103	96.33^{a} ± 16.56	22.17^{a} ± 6.07	86.04^{e} ± 22.64	55.62^{f} ± 27.66	91.19^{d} ± 7.28	38.90^{b} ± 23.66	MR
FB-25292	100.00^{a} ± 11.25	23.60^{b} ± 2.03	62.48^{c} ± 27.36	55.26^{f} ± 26.36	81.24^{c} ± 26.53	39.43^{b} ± 22.39	MR
FB-25022	96.00^{a} ± 15.47	23.60^{b} ± 5.04	87.70^{e} ± 18.87	55.30^{f} ± 13.63	91.85^{d} ± 5.87	39.45^{b} ± 22.42	MR
FB-Wayu	97.83^{a} ± 17.85	25.08^{b} ± 1.07	63.65^{c} ± 26.27	57.61^{f} ± 7.70	80.74^{c} ± 24.17	41.35^{c} ± 23.00	MS
FB-26881	96.67^{a} ± 19.52	24.67^{b} ± 2.09	60.90^{c} ± 22.20	57.80^{f} ± 4.52	78.78^{b} ± 25.30	41.23^{c} ± 23.42	MS
FB-28104	96.60^{a} ± 20.12	24.00^{b} ± 0.23	78.49^{f} ± 21.56	58.93^{f} ± 5.80	87.55^{c} ± 12.80	41.47^{c} ± 24.70	MS
Local check	98.19^{a} ± 32.56	42.43^{c} ± 12.54	71.42^{b} ± 27.79	44.05^{d} ± 20.43	84.81^{c} ± 18.93	43.50^{c} ± 13.88	MS
FB-26869	99.20^{a} ± 25.46	60.00^{d} ± 0.14	89.23^{e} ± 16.53	62.99^{f} ± 15.32	94.22^{d} ± 7.05	61.50^{d} ± 27.57	S
Mean	94.94^{a} ± 12.35	22.74^{a} ± 2.05	66.89^{b} ± 29.53	38.73^{d} ± 12.72	80.80^{c} ± 19.68	30.61^{b} ± 12.86	MR
CV %	12.00	12.00	44.15	32.84	24.36	42.01	
F-value	1.05	7.56	26.67	38.34	13.86	22.95	
LSD	0.39	0.00	0.0003	0.0002	0.1951	0.0001	

Means within a column followed by the same letter are not significantly different at p≥0.05

CV: Coefficient of Variation, MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible, SD: Standard Deviation

Table 3. Faba bean gall disease intensity on selected faba bean accessions during 2019 cropping season at different districts.

Faba bean accessions	Angolelana Tera district		Sululta district		Midakegn district	
	Incidence (%)	Severity (%)	Incidence (%)	Severity (%)	Incidence (%)	Severity (%)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
FB-Obse	40.42^{c*} ± 2.10	16.33^{a*} ± 13.28	31.02^{b**} ± 16.69	8.33^{a**} ± 3.33	55.33^{a*} ± 10.75	11.67^{a*} ± 2.89
FB-28770	29.03^{c*} ± 12.25	16.56^{a*} ± 21.47	25.00^{b*} ±3.30	11.67^{a*} ± 20.21	100.00^{d**} ± 0.00	45.00^{e**} ± 5.00
FB-28107	48.61^{a*}± 11.00	18.00^{a*} ± 19.40	9.78^{a**} ± 5.98	12.89^{a*} ±6.71	98.33^{d***} ± 31.79	36.67^{d**} ± 17.89
FB-Hachalu	41.30^{a*} ± 12.30	21.67^{b*} ± 10.69	23.17^{b**} ± 2.45	6.67^{a**} ± 7.66	74.89^{b***} ± 9.11	20.00^{b*} ± 18.03
FB-26875	44.72^{a*} ± 3.12	28.33^{b*} ± 4.71	32.09^{b*} ± 30.86	12.78^{a**}± 14.96	76.67^{b**} ± 20.55	33.33^{c*} ± 26.25
FB-26873	50.61^{a*} ± 1.03	30.00^{c*} ± 7.64	42.96^{c*} ± 6.80	17.22^{b**} ± 10.18	88.56^{c**} ± 19.82	28.33^{b*} ± 20.21
FB-26883	69.08^{b*} ± 15.23	31.83^{c*} ± 17.48	31.92^{b**} ± 16.56	15.55^{b**} ± 12.52	80.96^{c*} ± 22.90	40.00^{d***}± 17.32
FB-Numan	33.33^{c*} ± 18.02	31.00^{c*} ± 15.25	22.50^{b*} ± 3.39	12.22^{a**} ± 11.10	88.67^{c**} ± 19.63	39.00^{d*} ± 20.00
FB-26867	33.94^{c*} ± 1.23	34.17^{c**} ± 11.25	17.41^{a**} ± 5.95	11.11^{a*} ± 16.36	77.89^{b***} ± 38.30	15.00^{a*} ± 8.66
FB-Tumsa	49.62^{a*} ± 9.00	36.00^{c**} ± 29.18	35.19^{b**} ± 3.64	18.33^{b*} ± 16.10	73.33^{b***} ± 23.09	36.67^{d**} ± 11.55
FB-26885	43.18^{a*} ± 2.25	42.50^{d*} ± 3.89	36.11^{b*} ± 29.29	22.22^{b**} ± 28.70	100.00^{d**} ± 0.00	46.67^{e*} ± 15.28
FB-25280	74.44^{b*} ± 14.02	43.10^{d*} ± 6.11	66.67^{c*} ± 0.00	12.22^{a**} ± 14.58	93.33^{c**} ± 11.55	30.00^{c***} ± 26.46
FB-26872	52.22^{a*} ± 1.23	46.33^{d*} ± 32.72	14.81^{a**} ± 19.60	6.33^{a**} ± 7.77	85.57^{c***} ± 17.09	23.33^{b***} ± 11.55
FB- Coll-0038	35.56^{c*} ± 4.58	48.89^{d*} ± 27.10	29.17^{b*} ± 5.89	6.67^{a**} ± 6.02	81.56^{c**} ± 31.94	40.00^{d*} ± 20.00
Local check	43.33^{a*} ± 10.25	63.00^{e*} ± 1.89	25.59^{b**} ± 5.59	22.38^{b**} ± 22.38	82.78^{c***} ± 20.57	31.67^{c*} ± 14.43
Average	45.96^{a*} ± 12.52	38.76^{c*} ± 24.41	29.56^{b**}± 13.44	13.11^{a**} ± 5.20	83.86^{c***} ± 11.87	31.89^{c*} ± 58.80

Means within a column followed by the same letter are not significantly different at p≥0.05, Means across the district within a row followed by the same number of * are not significantly different at p≥0.05.

Combined mean analysis of gall disease intensity over the three cropping seasons

The interaction effect of faba bean accessions with districts and cropping season showed significant difference ($p \leq 0.05$) in gall disease incidence and severity. In combined mean analysis over year (2017–2019), the DSI of 14 accessions and local check was recorded between 16.50–41.8% (Table 4).

The lowest DSI was recorded on FB-Obse (DSI = 16.50%) followed by FB-Hachalu (DSI = 17.83%), FB-26872 (DSI = 18.84%), FB-26873 (DSI = 19.61%), and FB-28107 (DSI = 19.85%) over the three districts. The local check exhibited higher DSI (41.8%) than the remaining accessions (Table 4). For the reaction of the 14 accessions classified as moderately resistant, there was significant variation on their reaction level against gall disease. The combined mean analysis of DSI of gall disease over the faba bean accessions revealed that the average maximum DSI (26.3%) was recorded during 2019 cropping seasons followed by 2017 (DSI = 21.8%) and 2018 (DSI = 20.3%) (Table 4).

Combined gall disease severity over districts

Over the three cropping seasons, the highest DSI (31.58%) was recorded at Angolelana Tera followed by Midakegn (25.53%), and Sululta (13.29%) districts (Fig. 1). The lowest DSI was recorded on FB-Hachalu (9.51%), FB-Obse (9.72%), FB-26872 (9.77%), and FB-26873 (10.50%) at Sululta, whereas the lowest DSI was recorded on FB-Obse (15.20%), FB-Hachalu (18.55%), FB-26872 (20.22%), and FB-Tumsa (21.08%) at Midakegn district. Similarly, the lowest DSI was recorded on FB-Obse (18.17%), FB-26885 (24.58%), FB-Tumsa (25.46%), and FB-Numan (25.50%) at Angolelana Tera district (Fig. 1).

Table 4. Average gall disease intensity of selected faba bean accessions over experimental sites during three cropping seasons.

	2017 cropping season		2018 cropping season		2019 cropping season		Combined mean		
Faba bean accessions	**Incidence (%) ± SD**	**Severity (%) ± SD**	**Incidence (%) ± SD**	**Severity (%) ± SD**	**Incidence (%) ± SD**	**Severity (%) ± SD**	**Incidence (%) ± SD**	**Severity (%) ± SD**	**Reaction**
FB-Obse	$98.6^{a} \pm 11.2$	$21.1^{a} \pm 1.2$	$53.3^{c} \pm 39.2$	$16.3^{b} \pm 3.7$	$42.3^{e} \pm 12.3$	$12.1^{f} \pm 4.0$	$64.7^{g} \pm 29.9$	$16.5^{b} \pm 4.5$	MR
FB-Hachalu	$97.7^{a} \pm 10.5$	$21.2^{a} \pm 0.5$	$51.9^{c} \pm 44.9$	$16.2^{b} \pm 3.6$	$46.5^{e} \pm 26.2$	$16.1^{b} \pm 8.2$	$65.3^{g} \pm 28.1$	$17.8^{b} \pm 2.9$	MR
FB-26872	$88.8^{b} \pm 3.0$	$16.8^{b} \pm 0.4$	$50.8^{c} \pm 42.1$	$14.4^{b} \pm 4.9$	$50.9^{e} \pm 35.4$	$25.3^{g} \pm 20.1$	$63.5^{g} \pm 21.9$	$18.8^{b} \pm 5.8$	MR
FB-26873	$91.2^{b} \pm 8.3$	$17.0^{b} \pm 5.1$	$58.3^{d} \pm 36.7$	$16.6^{b} \pm 4.8$	$60.7^{d} \pm 24.4$	$25.2^{g} \pm 6.9$	$70.1^{e} \pm 18.3$	$19.6^{b} \pm 4.8$	MR
FB-28107	$97.2^{a} \pm 12.1$	$21.1^{a} \pm 1.3$	$60.3^{d} \pm 34.1$	$15.9^{b} \pm 3.8$	$52.2^{c} \pm 44.4$	$22.5^{a} \pm 12.5$	$69.9^{e} \pm 23.9$	$19.9^{b} \pm 3.5$	MR
FB-Tumsa	$80.0^{d} \pm 11.3$	$20.2^{a} \pm 1.6$	$52.5^{c} \pm 30.7$	$13.2^{b} \pm 1.0$	$52.7^{c} \pm 18.0$	$30.3^{d} \pm 1.4$	$61.7^{g} \pm 5.8$	$21.2^{a} \pm 2.6$	MR
FB-26867	$91.0^{b} \pm 4.0$	$23.7^{a} \pm 1.0$	$46.0^{a} \pm 25.8$	$21.1^{a} \pm 1.6$	$43.1^{a} \pm 21.3$	$20.1^{a} \pm 2.3$	$60.0^{g} \pm 6.9$	$21.6^{a} \pm 0.8$	MR
FB-Numan	$90.1^{b} \pm 1.3$	$21.5^{a} \pm 1.5$	$59.5^{d} \pm 23.9$	$16.5^{b} \pm 2.9$	$48.2^{b} \pm 25.5$	$27.4^{g} \pm 3.7$	$65.9^{g} \pm 1.7$	$21.8^{a} \pm 2.5$	MR
FB-28770	$85.0^{c} \pm 1.3$	$22.4^{a} \pm 1.6$	$56.3^{d} \pm 17.4$	$18.4^{c} \pm 2.0$	$51.3^{c} \pm 12.2$	$24.4^{g} \pm 7.9$	$64.2^{g} \pm 8.2$	$21.8^{a} \pm 1.0$	MR
FB-26875	$95.2^{a} \pm 7.2$	$21.6^{a} \pm 1.8$	$64.7^{e} \pm 11.2$	$21.1^{a} \pm 6.1$	$51.2^{c} \pm 12.9$	$24.8^{g} \pm 1.7$	$70.3^{e} \pm 2.6$	$22.5^{a} \pm 1.0$	MR
FB-26883	$91.1^{b} \pm 2.3$	$18.2^{b} \pm 1.6$	$60.3^{d} \pm 12.8$	$20.9^{a} \pm 1.8$	$60.7^{d} \pm 5.6$	$29.1^{d} \pm 2.4$	$70.7^{e} \pm 7.7$	$22.7^{a} \pm 3.7$	MR
FB-COLL-0038	$96.8^{a} \pm 8.5$	$21.1^{a} \pm 0.3$	$71.6^{f} \pm 7.1$	$21.0^{a} \pm 5.0$	$48.8^{b} \pm 8.6$	$31.9^{d} \pm 2.3$	$72.4^{e} \pm 4.0$	$24.6^{g} \pm 2.3$	MR
FB-25280	$95.0^{a} \pm 1.9$	$17.8^{b} \pm 1.5$	$53.7^{c} \pm 23.5$	$28.2^{d} \pm 7.7$	$78.6^{e} \pm 3.7$	$28.4^{d} \pm 5.5$	$75.6^{e} \pm 2.8$	$24.8^{g} \pm 4.1$	MR
FB-26885	$98.8^{a} \pm 12.5$	$21.8^{a} \pm 4.1$	$57.4^{d} \pm 36.6$	$20.9^{a} \pm 6.7$	$59.8^{d} \pm 35.0$	$37.1^{e} \pm 13.1$	$72.0^{e} \pm 23.3$	$26.6^{g} \pm 9.1$	MR
Local check	$98.2^{a} \pm 32.6$	$42.4^{e} \pm 12.5$	$71.4^{f} \pm 27.8$	$44.1^{e} \pm 20.4$	$50.6^{b} \pm 29.3$	$39.0^{e} \pm 21.3$	$73.4^{e} \pm 23.9$	$41.8^{e} \pm 2.6$	MS
Average	$92.9^{b} \pm 5.5$	$21.8^{a} \pm 6.0$	$57.9^{d} \pm 7.2$	$20.3^{a} \pm 7.6$	$53.1^{b} \pm 8.9$	$26.3^{g} \pm 7.1$	$67.9^{e} \pm 4.7$	$22.8^{a} \pm 5.8$	MR
CV (%)	5.92	27.62	12.46	37.19	16.77	27.04	6.84	25.91	MR
LSD	0.39	0	0.0003	0.0002	0.0008	0.0006	0.007	0.0025	MR

The same letter in the same column indicates absence of significant difference ($p>0.05$), SD = standard deviations, CV= Coefficient of Variation, LSD= Least Significant difference, MR = Moderately resistant, MS = Moderately susceptible

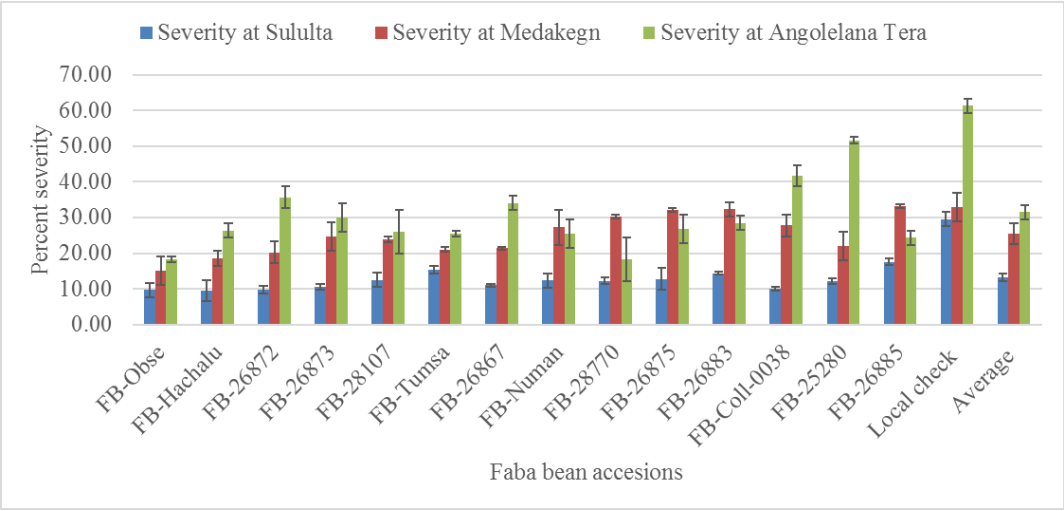

Fig.1. Gall disease severity on faba bean accessions at various localities.

Area Under Disease Progress Curve (AUDPC) and apparent infection rate

The date of gall disease incidence on faba bean accessions varied across the districts over the three cropping seasons (2017–2019) (Fig. 2). At Angolelana Tera, the gall disease incidence was observed between 15 and 38 days, whereas at Sululta district it was observed between 38 and 77 days after crop emergence. Higher DSI was recorded at Angolelana Tera (DSI = 13.68–47.29%) than the Sululta district throughout the cropping seasons. The fastest DSI rate (74.88–100%) was recorded between 38–77 days after emergence at both districts. At Angolelana Tera, and Sululta districts, a slow DSI rate (55.78–49.78%) was observed starting from 77 days, and become constant between 103–115 days after the crop emergence (Fig. 2). Similarly, higher AUDPC was recorded at Angolelana Tera (1616.97) than Sululta (1238.46) district with maximum infection rate (r = 0.02) and coefficient of determination (R^2 = 88%) (Table 5).

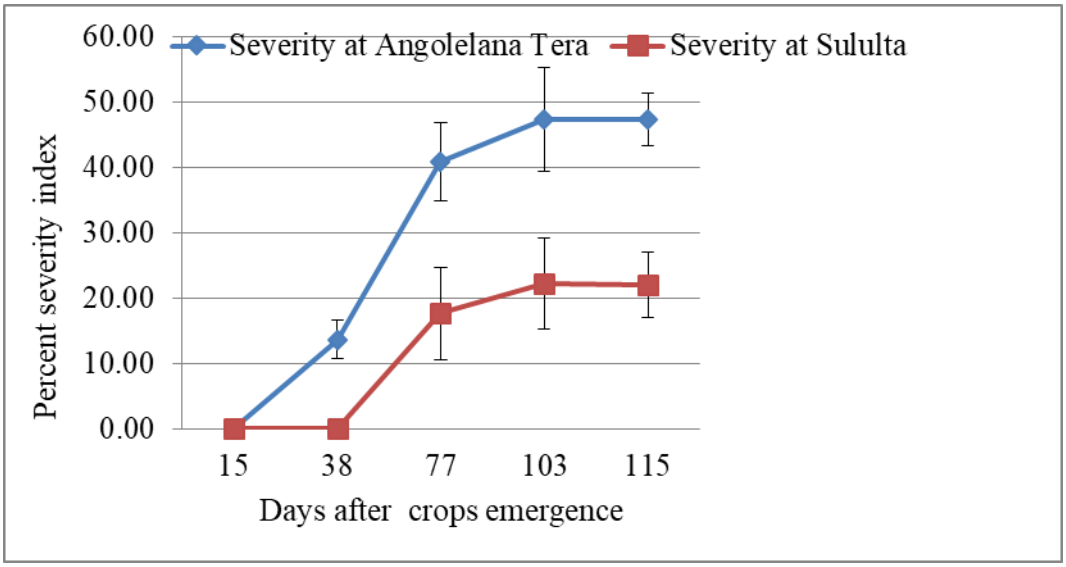

Fig. 2. Gall disease progress curve at Angolelana Tera and Sululta districts. Vertical line on the graphs indicates standard error.

Analysis of agronomic parameters versus gall disease intensity

Seed germination percentage of faba bean accessions over study sites

The maximum seed emergence percentage was recorded on FB-Obse at Sululta (98.26%) district. FB-Coll-0038 accession showed significantly higher field emergence efficiency than others at Midakegn (96.30%) district (Table 6). The percentage germination of seeds in the field at Angolelana Tera was significantly lower than at Sululta and Midakegn districts. There was no significant difference ($p \geq 0.05$) between Sululta and Midakegn districts in a combined mean average percentage germination of faba bean seeds. The highest combined faba bean accession mean average germination percentage was recorded at Sululta (90.99%) followed by Midakegn (85.00%), and Angolelana Tera (47.73%). The combined mean average germination analysis of faba bean accessions over the three districts revealed that the highest seed germination percentage was recorded on FB-26873 (79.85%), followed by FB-Obse (79.30%), and FB-Hachalu (79.09%) (Table 6).

Table 5. AUDPC and apparent infection rate of faba bean gall disease over three cropping seasons (2017–2019).

Faba bean accessions	Angolelana Tera district			Sululta district		
	Mean AUDPC	Apparent infection rate (r)	Coefficient of determination (R^2) (%)	Mean AUDPC	Apparent infection rate (r)	Coefficient of determination (R2) (%)
	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	
FB-Obse	815.50^{c*} ± 68.68	0.01^{a*} ± 0.1	92	523.89^{a**} ± 43.08	0.01^{b*} ± 0.6	83
FB-28770	763.50^{c*} ± 31.09	0.02^{a*} ± 0.5	82	1843.03^{d**} ± 13.05	0.01^{b**} ± 0.3	80
FB-28107	815.51^{c*} ± 43.90	0.01^{a*} ± 0.04	86	831.86^{c*} ± 49.04	0.01^{b*} ± 0.07	85
FB-Hachalu	1072.60^{a*} ± 54.08	0.01^{a*} ± 0.1	91	140.02^{b**} ± 50.07	0.01^{b*} ± 0.7	89
FB-26875	1373.25^{a*} ± 42.01	0.02^{a*} ± 0.1	89	1015.36^{c**} ± 13.03	0.01b* ± 0.8	81
FB-26873	1417.50^{a*} ± 10.04	0.01^{a*} ± 0.01	93	910.00^{c**} ± 63.99	0.003^{d*} ± 0.01	81
FB-26883	1581.01^{a*} ± 9.20	0.02^{a*} ±0.2	96	1115.10^{c**} ± 98.00	0.06^{c**} ± 0.2	86
FB-Numan	1620.75^{a*} ± 92.10	0.002^{b**} ± 0.10	48	1534.52^{d*} ± 42.03	0.02^{a*} ± 0.10	86
FB-26867	2128.75^{b*} ± 95.05	0.02^{a*} ± 0.01	94	548.03^{a**} ± 92.00	0.01^{b*} ± 0.12	83
FB-Tumsa	1746.00^{a*} ± 63.06	0.01^{a*} ± 0.11	92	1044.16^{c**} ± 51.20	0.01^{b**} ± 0.11	85
FB-26885	2004.05^{b*} ± 19 .03	0.02^{a*} ± 0.00	86	2135.10^{d*} ± 69.02	0.01^{b**} ± 0.01	81
FB-25280	2114.50^{b*} ± 13.57	0.02^{a*} ± 0.01	92	974.69^{c**} ± 87.02	0.01^{b**} ± 0.00	80
FB-26872	2173.00^{b*} ± 8.03	0.08^{a*} ± 0.10	86	682.50^{a**} ± 80.01	0.01^{b*} ± 0.11	80
FB- Coll-0038	2322.50^{b*} ± 81.03	0.04^{a*} ± 0.14	88	4262.50^{d**} ± 80.04	0.01^{b**} ± 0.21	82
Local check	2961.75^{b*} ± 94.41	0.02^{a*} ± 0.01	90	1015.36^{c**} ± 22.06	0.01^{b*} ± 0.18	80
Average	1616.97^{a*} ± 67.03	0.02^{a*} ± 0.11	88	1238.46^{c**} ± 78.05	0.01^{b**} ± 0.13	79

Similar letters within the same column indicate an absence of significant difference (P > 0.05), means across the district within a row followed by the same number of * are not significantly different at p>0.05, SD = standard deviation

Table 6. Seed germination of faba bean accessions at different districts.

Faba bean accessions	Angolelana Tera district	Sululta district	Midakegn district	Combined
	Germination (%)	Germination (%)	Germination (%)	Germination (%)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
FB-Obse	61.85^{a*} ± 2.08	98.26^{a***} ± 3.06	77.78^{c**} ± 22.22	79.30^{a**} ± 18.25
FB-28770	57.00^{a*} ± 1.73	77.04^{c**} ± 2.08	85.19^{b**} ± 12.83	73.08^{ab**} ± 14.51
FB-28107	44.44^{b*} ± 3.61	90.56^{b***} ± 1.00	85.19^{b***} ± 30.40	73.40^{ab**}± 25.22
FB-Hachalu	58.00^{a*} ± 2.08	94.07^{a***} ± 1.53	85.19^{b**} ± 6.42	79.09^{a**} ± 18.79
FB-26875	48.00^{b*} ± 0.00	94.07^{a***}± 4.04	81.48^{c**} ± 13.86	74.52^{ab**} ± 23.81
FB-26873	55.00^{a*} ± 1.53	91.96^{b***} ± 0.58	92.59^{a***} ± 6.42	79.85^{a**} ± 21.52
FB-26883	48.15^{b*} ± 0.71	94.78^{a***} ± 1.00	81.48^{c**} ± 6.42	74.80^{ab**} ± 24.02
FB-Numan	50.00^{b*} ± 2.12	97.67^{a***} ± 1.73	77.78^{c**} ± 29.40	75.15^{ab**} ± 23.94
FB-26867	48.15^{b*} ± 0.71	79.26^{c**} ± 3.51	88.89^{b**} ± 11.11	72.10^{b**} ± 21.29
FB-Tumsa	52.00^{b*} ± 1.73	97.67^{a***} ± 1.00	81.48^{c**} ± 12.83	77.05^{a**} ± 23.16
FB-26885	37.04^{c*} ± 4.24	93.85^{b***} ± 0.58	88.89^{b***} ± 11.11	73.26^{ab**} ± 31.47
FB-25280	38.00^{c*} ± 1.73	87.04^{b***} ± 2.89	81.48^{c***} ± 6.42	68.84^{c**} ± 26.85
FB-26872	45.00^{b*} ± 0.58	96.1b^{a***} ± 2.31	88.89^{b***} ± 11.11	76.66^{a**} ± 27.66
FB- Coll-0038	38.00^{c*} ± 1.73	87.04^{b***} ± 3.06	96.30^{a***} ± 6.42	73.78^{ab**} ± 31.33
Local check	35.00^{c*} ± 1.41	85.37^{b***} ± 1.53	88.89^{b***} ± 11.11	69.75^{b**} ± 30.15
Average	47.73^{b*} ± 1.02	90.99^{a***} ± 2.14	85.00^{b***} ± 0.89	74.71^{ab**} ± 23.44

Means within a column followed by the same letter are not significantly different at p≥0.05, Means across the district within a row followed by the same number of * are not significantly different at p≥0.05

Yield parameters

Analysis of yield parameters in 2018 cropping season

Faba bean gall disease significantly affected ($p<0.05$) yield parameters in various experimental sites. In 2018 cropping season, the highest number of pods per plant was obtained from FB-25280 (6.07 pods/plant) followed by FB-28770 (5.73 pods/plant) at Sululta and Angolelana Tera districts, respectively (Table 7). FB-26867 accession had produced maximum number of seeds per pod (3.00 seeds/pod) at Sululta districts. FB-26875 accession had exhibited highest number of seeds per pod (1.98 seeds/pod) among others at Angolelana Tera district. On another hand, FB-26872 produced maximum 100 seeds weight at Midakegn (97.97 g) and Sululta (90.87 g) districts. But, maximum 100 seeds weight was recorded on FB-Numan (72.53 g) at Angolelana Tera district. In a combined analysis over the faba bean accessions, the highest 100 seed weight was recorded at Midakegn (77.67 g) followed by Sululta (71.37 g) and Angolelana Tera (19.98 g) districts (Table 7).

Analysis of yield parameters in 2019 cropping season

The combined mean analysis of faba bean accessions at each experimental site revealed that significantly ($p<0.05$) higher pods per plant was recorded at Sululta (9.26 pods/plant) than Angolelana Tera (1.55 pods/plan) district. Similar patterns were followed in number of pods per plant and number of seeds per pod (Table 8). The highest number of pods per plant was recorded on FB-Numan both at Sululta (14.18 pods/plant) and Angolelana Tera (5.31 pods/plant) districts. The number of seeds per pod was not significantly different ($p>0.05$) among the tested accessions at Sululta district, while the maximum seeds per pod recorded on FB-26875 accession (11.02 seeds/pod) at Angolelana Tera district. The maximum 100 seeds weight was recorded on FB-Obse (78.69 g) at Sululta followed by FB-Hachalu (75 g), and FB-Tumsa (55.34 g) at Midakegn and Angolelana Tera districts, respectively (Table 8).

Table 7. Average yield parameters of some faba bean accessions at different experimental sites during 2018 cropping season.

Faba bean accessions	Field experimental sites						
	Angolelana Tera			Sululta			Midakegn
	Pod/ plant	Seed/pod	100 seed weight (g)	Pod/ plant	Seed/pod	100 seed weight (g)	100 seed weight (g)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
FB-Obse	2.12^{c} ± 0.12	0.30^{b} ± 0.01	54.14^{b} ± 11.36	1.85^{e} ± 0.12	2.00^{b} ± 0.69	86.31^{a} ± 10.25	90.81^{a} ± 10.23
FB-28770	5.73^{a} ± 0.21	1.72^{a} ± 0.23	20.44^{d} ± 8.06	3.00^{c} ± 0.23	1.63^{b} ± 0.78	65.33^{c} ± 11.36	70.06^{c} ± 12.95
FB-28107	1.89^{c} ± 0.54	0.74^{b} ± 0.21	34.44^{c} ± 8.34	2.63^{d} ± 0.45	2.11^{b} ±0.36	69.22^{c} ± 15.67	82.59^{b} ± 12.65
FB-Hachalu	3.82^{b} ± 1.20	1.80^{a} ± 0.43	36.60^{c} ± 9.36	1.80^{e} ± 0.69	2.73^{a} ± 0.56	71.25^{c} ± 13.96	84.31^{b} ± 15.60
FB-26875	4.07^{b} ± 2.00	1.98^{a} ± 0.56	20.68^{d} ± 5.89	4.20^{b} ± 0.47	1.41^{c} ± 0.45	82.73^{b} ± 16.58	80.73^{b} ± 8.96
FB-26873	1.76^{c} ± 0.01	1.34^{a} ± 0.53	14.39^{e} ± 4.23	3.02^{c} ± 0.25	1.77^{b} ± 0.98	80.13^{b} ± 17.6	79.04^{b} ± 11.84
FB-26883	5.59^{a} ± 1.30	0.68^{b} ± 0.12	17.67^{e} ± 3.78	3.64^{a} ± 0.23	1.66^{b} ± 0.74	66.95^{c} ± 5.98	72.80^{c} ± 7.98
FB-Numan	2.69^{c} ± 0.23	1.60^{a} ± 0.32	72.53^{a} ± 20.7	2.38^{d} ± 0.15	2.53^{a} ± 0.92	65.64^{c} ± 7.95	71.87^{c} ± 8.96
FB-26867	1.68^{c} ± 0.41	0.26^{b} ± 0.01	15.50^{e} ± 2.89	2.13^{d} ± 0.45	3.00^{a} ± 0.85	79.61^{b} ± 12.30	71.73^{c} ± 8.65
FB-Tumsa	4.14^{b} ± 1.52	1.53^{a} ± 0.23	36.18^{c} ± 21.36	1.70^{e} ± 0.18	2.77^{a} ± 0.45	70.00^{c} ± 12.65	88.85^{a} ± 4.68
FB-26885	2.27^{c} ± 0.21	1.89^{a} ± 0.25	64.90^{a} ± 11.58	3.28^{c} ± 0.14	1.90^{b} ± 0.35	56.16^{d} ± 14.60	73.12^{c} ± 5.67
FB-25280	0.00^{d} ± 0.00	0.00^{c} ± 0.00	0.00^{f} ± 0.00	6.07^{a} ± 0.16	1.91^{b} ± 0.36	70.27^{c} ± 10.90	72.88^{c} ± 10.95
FB-26872	3.95^{b} ± 1.23	1.67^{a} ± 0.24	20.43^{d} ± 10.30	4.00^{b} ± 0.47	1.44^{c} ± 0.47	90.87^{a} ± 9.25	97.97^{a} ± 9.96
FB-Coll-0038	4.63^{a} ± 1.24	1.87^{a} ± 0.96	35.49^{c} ± 11.45	2.74^{c} ± 0.16	2.25^{a} ± 0.49	68.76^{c} ± 7.98	71.74^{c} ± 10.63
Local check	1.82^{c} ± 0.01	1.83^{a} ± 0.78	20.76^{d} ± 4.65	2.00^{e} ± 0.89	2.30^{a} ± 0.48	47.36^{d} ± 6.89	56.48^{c} ± 5.68
Average	3.08^{b} ± 1.62	1.30^{a} ± 0.68	30.94^{c} ± 19.98	2.96^{c} ± 1.17	2.09^{b} ± 0.49	71.37^{c} ± 11.30	77.67^{b} ± 10.24

Means within a column followed by the same letter are not significantly different at 5% probability level, SD = standard deviation, FB = Faba Bean

Table 8. Average yield parameters of faba bean accessions at different experimental sites during 2019 cropping season.

Faba bean accessions	Angolelana Tera district			Sululta district			Midakegn district
	Pod/plant	Seeds/pod	100 seeds weight (g)	Pod/plant	Seeds/pod	100 seeds weight (g)	100 seeds weight (g)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
FB-Obse	$0.18^{c} \pm 0.01$	$0.72^{c} \pm 0.02$	$28.38^{b} \pm 0.04$	$7.85^{b} \pm 0.23$	$3.28^{a} \pm 0.25$	$78.69^{a} \pm 2.36$	$73.01^{a} \pm 5.63$
FB-28770	$0.05^{c} \pm 0.02$	$7.30^{a} \pm 0.01$	$9.56^{c} \pm 0.01$	$13.40^{a} \pm 1.23$	$2.71^{a} \pm 0.36$	$25.79^{c} \pm 2.45$	$17.94^{d} \pm 2.35$
FB-28107	$0.41^{c} \pm 0.03$	$2.72^{b} \pm 0.01$	$17.90^{b} \pm 0.04$	$13.39^{a} \pm 1.56$	$2.67^{a} \pm 0.12$	$58.12^{b} \pm 3.21$	$33.51^{c} \pm 2.54$
FB-Hachalu	$0.18^{c} \pm 0.01$	$2.20^{b} \pm 0.03$	$43.40^{a} \pm 0.23$	$5.68^{b} \pm 0.58$	$1.93^{a} \pm 0.47$	$71.39^{a} \pm 1.65$	$75.01^{a} \pm 5.68$
FB-26875	$4.09^{a} \pm 0.02$	$11.02^{a} \pm 0.02$	$9.32^{c} \pm 0.15$	$4.50^{b} \pm 0.24$	$3.11^{a} \pm 0.65$	$21.07^{c} \pm 2.34$	$27.27^{c} \pm 2.45$
FB-26873	$0.54^{c} \pm 0.03$	$0.20^{c} \pm 0.04$	$5.83^{c} \pm 0.12$	$10.84^{a} \pm 1.24$	$2.47^{a} \pm 0.47$	$62.03^{b} \pm 4.35$	$46.20^{b} \pm 3.65$
FB-26883	$0.41^{c} \pm 0.04$	$0.48^{c} \pm 0.01$	$16.71^{b} \pm 1.30$	$4.90^{b} \pm 0.45$	$3.12^{a} \pm 0.36$	$23.53^{c} \pm 2.35$	$49.20^{b} \pm 2.45$
FB-Numan	$5.31^{a} \pm 0.01$	$10.4^{a} \pm 0.06$	$41.01^{a} \pm 2.16$	$14.18^{a} \pm 2.69$	$1.39^{a} \pm 0.21$	$60.34^{b} \pm 2.64$	$66.13^{a} \pm 3.65$
FB-26867	$0.32^{c} \pm 0.04$	$0.32^{c} \pm 0.01$	$4.50^{d} \pm 0.69$	$10.57^{a} \pm 2.35$	$1.92^{a} \pm 0.84$	$50.33^{b} \pm 2.65$	$54.27^{b} \pm 4.56$
FB-Tumsa	$1.64^{b} \pm 0.06$	$2.51^{b} \pm 0.04$	$55.34^{a} \pm 2.63$	$6.56^{b} \pm 1.54$	$1.79^{a} \pm 0.65$	$31.08^{c} \pm 2.35$	$70.71^{a} \pm 4.65$
FB-26885	$4.95^{a} \pm 0.04$	$9.13^{a} \pm 0.08$	$37.60^{a} \pm 1.56$	$8.32^{b} \pm 0.85$	$2.40^{a} \pm 0.14$	$32.32^{c} \pm 2.45$	$6.88^{d} \pm 1.25$
FB-25280	$0.00^{d} \pm 0.00$	$0.00^{c} \pm 0.00$	$0.00^{d} \pm 0.00$	$11.53^{a} \pm 1.45$	$2.01^{a} \pm 0.90$	$23.65^{c} \pm 2.34$	$23.12^{c} \pm 2.35$
FB-26872	$1.09^{b} \pm 0.03$	$2.49^{b} \pm 0.05$	$7.97^{c} \pm 1.25$	$6.88^{b} \pm 0.24$	$2.48^{a} \pm 0.21$	$63.71^{b} \pm 2.68$	$47.01^{b} \pm 5.68$
FB- Coll-0038	$3.45^{a} \pm 0.01$	$3.91^{b} \pm 0.03$	$13.85^{c} \pm 2.03$	$9.92^{b} \pm 0.69$	$3.09^{a} \pm 0.47$	$34.16^{c} \pm 4.68$	$46.26^{b} \pm 6.35$
Local check	$0.60^{c} \pm 0.03$	$2.33^{b} \pm 0.01$	$7.82^{c} \pm 1.06$	$10.36^{a} \pm 2.56$	$1.98^{a} \pm 0.25$	$48.08^{b} \pm 4.52$	$39.52^{b} \pm 4.56$
Average	$1.55^{b} \pm 1.09$	$3.72^{b} \pm 0.83$	$19.95^{b} \pm 6.96$	$9.26^{b} \pm 3.16$	$2.42^{a} \pm 0.57$	$45.62^{b} \pm 13.60$	$45.07^{b} \pm 10.78$

Means within a column followed by the same letter are not significantly different at 5 % probability level, SD = standard deviation, FB = Faba Bean

Analysis of yield parameters during 2018–2019 cropping seasons

The interaction of faba bean accessions with gall disease significantly ($p< 0.05$) affected yield parameters over districts. The number of pods/plants was higher at Sululta (6.11 pods/plant) than Angolelana Tera (2.18 pods/plant) district. However, there was no significant difference ($p>0.05$) among the districts on the number of seeds/pods in a combined analysis of accessions (Table 9). Lower (5.73 g) 100 seeds weight was recorded at Angolelana Tera than other districts (Table 9).

Maximum pods per plant were recorded on FB-26875, and FB-Numan accessions at Angolelana Tera, and Sululta districts, respectively. There was no significant ($p>0.05$) difference recorded among evaluated accessions in many seeds per pod at Sululta district, while FB-Coll-0038 (2.67 seeds/pod), FB-Obse (2.64 seeds/pod), and FB-26867 (2.46 seeds/pod) ranked first to third for the number of seeds per pod. There was a significant difference ($p<0.05$) among accessions in 100 seeds weight at both districts. The maximum 100 seeds weight was recorded on FB-Obse (78.69 g) at Sululta followed by FB-Hachalu (75 g), and FB-Numan (12 g) at Midakegn and Angolelana Tera districts, respectively (Table 9).

In combined mean analysis over the cropping seasons (2018–2019), FB-Obse, FB-26872, FB-26873, and FB-Hachalu produced significantly ($p<0.05$) better 100 seeds weight than others with the value 82.50 g, 77.29 g, 71.08 g, and 71.32 g at Sululta, respectively. At Midakegn, FB-Obse (81.91 g), FB-Tumsa (79.78 g), FB-Hachalu (79.66 g), and FB-26872 (78.49 g) exhibited the highest 100 seeds weight, whereas FB-Numan (56.77 g), FB-26885 (51.25 g), FB-Tumsa (45.76 g), and FB-Obse (41.26 g) resulted in the highest 100 seeds weight among others at Angolelana Tera district. In general, an average maximum 100 seeds weight was harvested from Midakegn (61.41 g) followed by Sululta (58.50 g) and Angolelana Tera (25.44 g) districts (Table 9).

Table 9. Average yield parameters of faba bean accessions during 2018–2019 cropping seasons.

Faba bean accessions	Angolelana Tera district			Sululta district			Midakegn district
	Pod/plant	Seeds/pod	100 seeds weight (g)	Pod/plant	Seeds/pod	100 seeds weight (g)	100 seeds weight (g)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
FB-Obse	1.15c* ± 4.08	0.51b* ± 1.00	41.26a* ± 0.06	4.85a** ± 3.06	2.64a** ± 0.00	82.50d** ± 11.25	81.91d** ± 2.01
FB-28770	2.89b* ± 1.05	4.51a* ± 1.13	15.00a* ± 0.07	8.20b** ± 1.03	2.17a** ± 0.04	45.56b** ± 4.07	44.00b** ± 3.00
FB-28107	1.15c* ± 1.10	1.73c* ± 0.50	26.17a* ± 0.70	8.01b** ± 1.20	2.39a* ± 0.10	63.67a** ± 6.60	58.05a** ± 3.01
FB-Hachalu	2.00d* ± 0.01	2.00d* ± 0.10	40.00c* ± 0.40	3.74a** ± 2.19	2.33a** ± 0.80	71.32d** ± 6.02	79.66d** ± 3.00
FB-26875	4.08a* ± 1.33	6.50a* ± 2.29	15.00a* ± 0.67	4.35a* ± 0.11	2.26a** ± 0.26	51.90a** ± 19.07	54.00a** ± 3.07
FB-26873	1.15c* ± 3.01	0.77b* ± 1.12	10.11b* ± 0.14	6.93a** ± 2.12	2.12a** ± 0.54	71.08a** ± 7.01	62.62c** ± 1.00
FB-26883	3.00b* ± 3.01	0.58b* ± 0.06	17.19a* ± 0.70	4.27a** ± 2.09	2.39a** ± 0.05	45.24b** ± 3.03	61.00c*** ± 1.00
FB-Numan	4.00a* ± 2.80	6.00a* ± 0.15	56.77b* ± 0.18	8.28b** ± 0.71	1.96a** ± 0.12	62.99c** ± 14.15	69.00d** ± 2.00
FB-26867	1.00c* ± 3.07	0.29b* ± 1.06	10.00b* ± 1.09	6.35a** ± 3.15	2.46a** ± 0.19	64.97c** ± 10.25	63.00c** ± 1.00
FB-Tumsa	2.89b* ± 4.14	2.02c* ± 0.07	45.76a* ± 0.15	4.13a** ± 2.10	2.28a* ± 0.26	50.54a** ± 2.15	79.78d*** ± 3.00
FB-26885	3.61b* ± 1.03	5.51a* ± 2.22	51.25a* ± 1.12	5.80a** ± 3.34	2.15a** ± 0.10	44.24b** ± 1.40	40.00b** ± 1.00
FB-25280	0.00d* ± 0.00	0.00d* ± 0.00	0.00c* ± 0.00	8.80b** ± 3.06	1.96a** ± 0.08	46.96b** ± 0.07	48.00a** ± 2.00
FB-26872	2.52b* ± 1.01	2.08c* ± 0.50	14.20a* ± 0.20	5.44a** ± 3.50	1.96a* ± 0.29	77.29c** ± 24.20	72.49c** ± 1.02
FB- Coll-0038	4.04a* ± 2.50	2.89c* ± 1.06	24.67a* ± 0.00	6.33a* ± 2.14	2.67a* ± 0.29	51.46a** ± 6.15	59.00c** ± 4.00
Local check	1.21c* ± 1.12	2.08c* ± 0.11	14.29a* ± 0.19	6.18a** ± 4.12	2.14a* ± 0.27	47.72b** ± 9.32	48.00a** ± 2.00
Average	2.18b* ± 1.30	2.36c* ± 0.70	25.44a* ± 2.27	6.11a** ± 1.27	2.26a* ± 0.13	58.50a** ± 10.27	61.41c** ± 2.08

Means within a column followed by the same letter and means across the district within a row followed by the same number of * are not significantly different at 5%, SD = standard deviation, FB = Faba Bean

P-values of contrast analysis between different traits

The combined mean analysis over cropping seasons, and districts showed that there was significant difference ($p<0.05$) in disease severity and 100 seeds weight between local check and various faba bean accessions. Gall disease severity and faba bean yield parameters in FB-Obse accession showed no significant difference ($p>0.05$) from FB-26872 accession. Significant ($p = 0.003$) higher disease severity (DSI = 26.96%) was recorded during 2019 than others cropping seasons (Table 10). On the other hand, significant ($p<0.05$) higher seeds/pod (2.8 seeds) and 100 seeds weight (55.8 g) yield parameters were recorded in 2018 than 2019 cropping seasons over the three districts. Also, significant variations were recorded in gall disease severity and yield parameters among districts. The highest disease severity was recorded at Angolelana Tera (DSI = 29.26%) among Sululta and Midakegn districts. Maximum 100 seeds weight was recorded at Midakegn district (61.43 g) although it was not significantly different ($p = 0.445$) from Sululta district (Table 10).

Table 10. P-values of contrast analysis between different traits.

Contrast	DF	Severity	Pod/Plant	Seed/Pod	100 seeds weight
Between some faba bean accessions					
Local check vs FB-Obse	134	<0.001*	0.778	0.962	0.004*
FB-Obse vs FB-26872	134	>0.05	>0.05	>0.05	>0.05
FB-Obse vs FB-26885	134	0.007*	0.360	0.139	0.035*
FB-Obse vs FB-26867	134	0.164	0.820	1.000	0.041*
Between cropping seasons					
2017 vs 2018	134	0.437	NA	NA	NA
2017 vs 2019	134	0.023*	NA	NA	NA
2018 vs 2019	134	0.003*	0.044	0.397	0.621
Between districts					
Angolelana Tera vs Sululta	134	<0.001*	<0.001*	0.530	<0.001*
Angolelana Tera vs Midakegn	134	<0.001*	0.002*	0.185	<0.001*
Sululta vs Midakegn	134	<0.001*	<0.001*	0.483	0.445

DF = degrees of freedom; FB = faba bean; "*" = significant at 5%, NA = not analyzed

Correlation analysis between different traits

The Pearson's correlation coefficient showed that gall disease incidence has weak, positive and high significant ($p<0.05$) correlation with disease severity index ($r = 0.49$) (Table 11). Likewise, a weak, positive and significant correlation of seeds per pod with 100 seeds weight ($r = 0.06$) was observed. Similarly, positive and significant correlation of altitude ($r = 0.27$) and precipitation ($r = 0.37$) with gall disease severity was also observed. In contrary, pods per plant ($r = -0.05$), seeds per pod ($r = -0.03$), and 100 seeds weight ($r = -0.14$) was negatively correlated with gall disease

incidence. Also, pods per plant (r = −0.07), 100 seeds weight (r = −0.53), and temperature (r = −0.23) have significant negative correlation with gall disease severity index (Table 11).

Table 11. Correlation coefficients values of the pairs of different traits.

Traits code	Traits	T1	T2	T3	T4	T5	T6	T7	T8	T9
T1	FB-accession	1								
T2	Incidence	0.06*	1							
T3	Disease severity	0.12**	0.49**	1						
T4	Pods per plant	0.08**	-0.05ns	-0.07**	1					
T5	Seeds per pod	0.05*	-0.03ns	-0.02ns	0.08**	1				
T6	seeds weight	0.18**	-0.14**	-0.53**	0.04ns	0.06*	1			
T7	Altitude	0.01ns	0.49**	0.27**	0.31**	0.05ns	0.10**	1		
T8	Precipitation	0.01ns	0.64**	0.37**	0.28**	0.04ns	0.01**	0.94**	1	
T9	Temperature	-0.01ns	-0.43**	-0.23**	-0.31**	0.08**	0.10**	-0.99**	-0.89**	1

**: Correlation is significant at the 0.01 level (2-tailed)

*: Correlation is significant at the 0.05 level (2-tailed), ns: not significant, FB: Faba bean

Regression analysis

The simple linear regression analysis revealed that for each unit increase of an altitude resulted in a raise of gall disease incidence by 0.16% (Fig. 3A) and disease severity index by 0.09% (Fig. 3B). Based on the coefficient of determination value (R^2), the equation explained about 92% of the variation in disease incidence and 98% of the variation in gall disease severity index were due to altitude. Similarly, the estimated slope of the regression line obtained for gall disease incidence was 0.43. The estimate showed that for each unit increase in gall disease incidence, there was a raise in gall disease severity index by 0.43%. The equation explained about 88% of the variation in severity index due to disease incidence (Fig. 3C). Also, a unit increase of pods per plant resulted in an increase of seeds per pod by 0.47 seeds with 96% variations (Fig. 3E). On the contrary, for each unit increase in percent severity index of gall disease, there was a 100 seeds weight loss by 0.19 g. The regression equation explained about 99% variation in seed weight loss by disease severity (Fig. 3D). For each unit increase of percent severity index of gall disease there was pods loss by 0.045 pods (Fig. 3F).

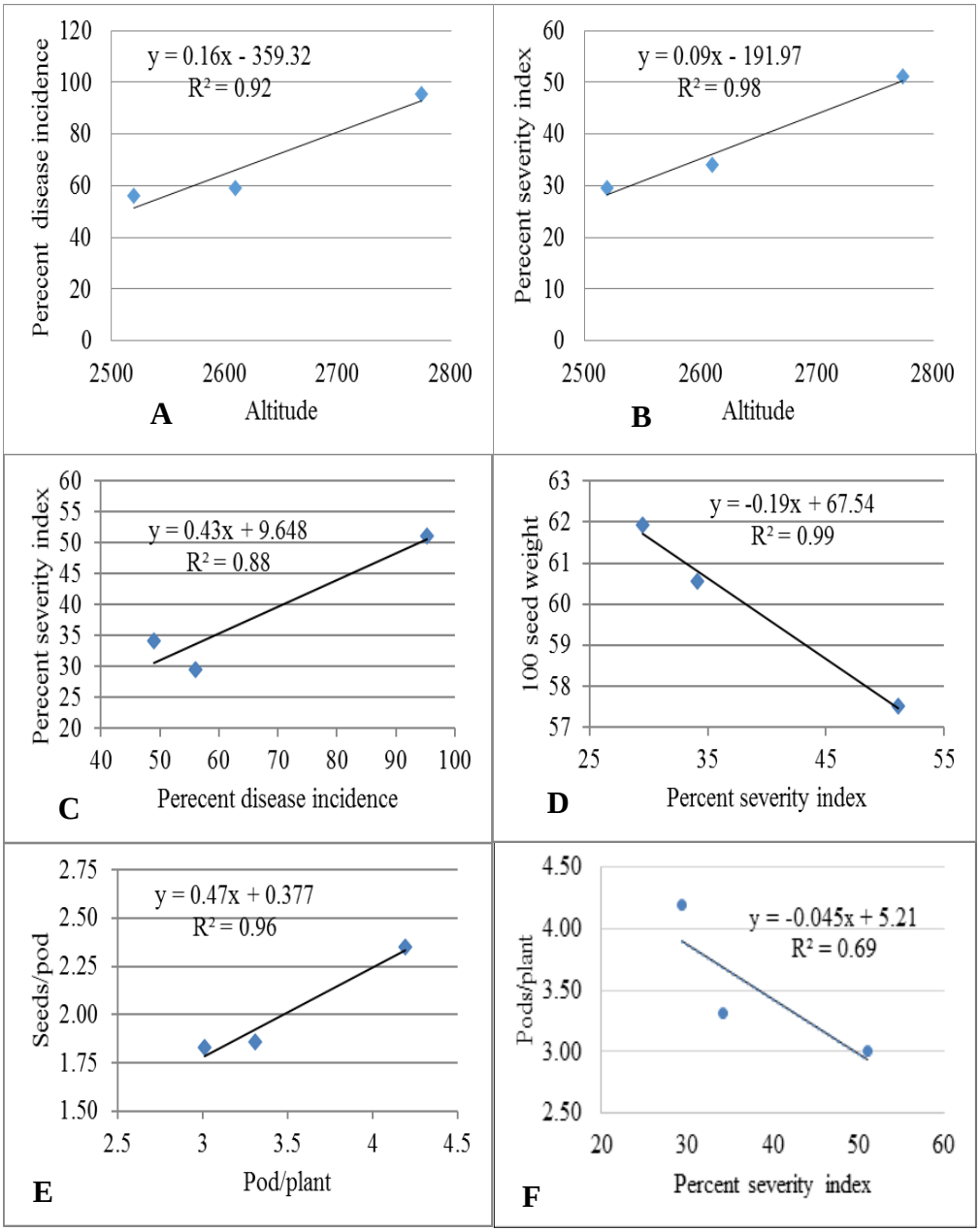

Fig. 3. Regression analysis: A. Altitude and percent disease incidence, B. Altitude and Percent severity index, C. Percent disease incidence and severity index, D. Percent severity index and 100 seeds weight, E. Pods/plant and seeds/pod, F. Percent severity index and pods/plant.

DISCUSSION

Identification of faba bean accessions resistant to gall disease with a high yield potential could guarantee the use of eco-friendly disease management options and cultivation productivity for faba bean farmers. Resistant accessions reside in high value among disease controlling methods, because it is certainly applied, requires few inputs and is economically profitable (Behailu Mulugeta *et al*., 2018). The gall disease was characterized by the formation of chlorotic galls which enlarges to light brown, circular, or elliptical rough spots on both sides of the leaves and stems (Teklay Abebe *et al*., 2014). The disease was observed soon after crop emergence on infested soil and faba bean residue plots. It is more destructive at the early growth stages of the plant, is spread by wind, rain, and weeding practices, and causes a high reduction of crop yield (Teklay Abebe *et al*., 2018).

Interestingly, we observed similar disease symptoms with the previous reports in our study (Teklay Abebe *et al*., 2014). However, the date of occurrence of gall disease after the crop emergence varied at different experimental sites and cropping seasons. The progress of the disease incidence gradually became severe at high altitude and average low temperature as the rain increases and reaches its maximum in the mid rainy season. These could be correlated with the climate of the experimental locations and cropping seasons. Pszczółkowska *et al*. (2020) reported that disease incidence and spread of pathogenic fungi were related to weather conditions and determined by the distribution pattern of precipitation and average temperature during the growing season. Besides, the distribution of gall disease has a linear relationship with the rise of altitude (Teklay Abebe *et al*., 2014).

In the present study, the absence of innate resistance was observed as no faba bean variety was found resistant to gall disease. However, FB-26872, FB-Tumsa, FB-26873, FB-28107, FB-Obse, FB-Hachalu, FB-26883, FB-Numan, FB-28770, FB-26885, FB-COLL-0038, FB-26875, FB-26867, and FB-25280 accessions had shown better reactions against gall disease. The reaction levels varied at different experimental locations and during main cropping seasons. They demonstrated better seed field germination percentage, lower disease severity, AUDPC, and apparent infection rate against gall disease causal agent *Olpidium viciae* compared with the rest of the accessions.

These results agree with Teklay Abebe *et al*. (2018), who reported that improved and local faba bean varieties were affected by faba bean gall

disease without any tolerance. According to Bogale Nigir *et al*. (2017), gall disease infected both local cultivars and improved varieties in Ethiopia; nevertheless, the intensities were higher on the local cultivars. This suggests that the difference in reaction levels and disease occurrence rate among varieties could be associated with genotypic variability in the inheritance of gall disease resistant traits of the crops (Sheikh *et al*., 2015; Méndez-Natera *et al*., 2016; Behailu Mulugeta *et al*., 2018), a variation of the previous inoculum level of the disease pathogen (Teklay Abebe *et al*., 2014), soil types (Endalkachew Fekadu *et al*., 2018), and climate of the study area (Pszczółkowska *et al*., 2020). The variation of the climate could significantly influence the infection rate and spread of conidia of the test pathogen (Teklay Abebe *et al*., 2014). Significant variability among varieties allows us to select the faba bean accessions with better tolerance against gall disease.

In the present study, fourteen faba bean accessions revealed high yield performance among the tested accessions and local check at each experimental site and cropping seasons. A maximum of 100 seeds weight was harvested in the 2018 cropping season. Likewise, a maximum of 100 seeds weight was harvested from Midakegn, followed by Sululta, and Angolelana Tera districts. These findings were in line with Endalkachew Fekadu *et al*. (2018) who reported on the yield performance of faba bean varieties in Ethiopia in the case of pods per plant, and 100 seed weight, while slightly contradicted in the case of the number of seeds per pod. In agreement with the current finding, Bogale Nigir *et al*. (2017) stated that the number of pods per plant was significantly affected by faba bean varieties. Basha Kebede and Dembi Korji (2017) also reported a significant difference among faba bean varieties on yield parameters.

The observed difference of yield parameters could be correlated with the climate of the cropping seasons, inherent genetic differences of faba bean varieties, variation in the adaptive ability of the crops to the study area, the severity level of gall disease, and the occurrence of frost (Basha Kebede and Dembi Korji, 2017). The disease resistant variety can boost crop yield (Méndez-Natera *et al*., 2016). The climate of the study location influenced the growth and yielding of faba beans (Amalfitano *et al*., 2018; Pszczółkowska *et al*., 2020).

This study confirmed by Pearson correlation coefficient and regression analysis result the impact of climate of the study sites on faba bean gall disease pressure and yield parameters. The Pearson correlation coefficient

implied that altitude, precipitation, and average low temperature positively affected gall disease severity, while gall disease severity negatively influenced yield parameters. The linear regression analysis showed that for each unit increase in altitude of the study sites, there was an increment of percent disease severity index by 0.09%. This accounts for 98% variation in the faba bean gall disease percent severity index. On the other hand, for each unit increase in the percent severity index, 100 seeds weight of faba bean accessions decreased by 0.19% and accounted for 99% variations in 100 seeds weight of the crops.

CONCLUSIONS AND RECOMMENDATIONS

Faba bean accessions responded at various levels against gall disease at different study areas and cropping years. Gall disease negatively influenced faba bean yield parameters. No faba bean accessions was found resistant to gall disease. FB-Obse, FB-Hachalu, FB-26873, FB-Numan, and FB-26872 accessions revealed low DSI and high crop yield. However, they exhibited various level response in different study areas. Thus, a single faba bean variety cannot be considered best fit for all study sites. The following accessions; FB-Obse, FB-26872, FB-26873, and FB-Hachalu at Sululta; FB-Obse, FB-Tumsa, FB-Hachalu, and FB-26872 at Midakegn; whereas FB-Numan, FB-26885, FB-Tumsa, and FB-Obse at Angolelana Tera district are promising to the corresponding localities to be used for the management of faba bean gall disease. Efforts have to be made by researchers to develop faba bean varieties with gall disease resistant lines at multiple faba bean production areas.

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