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Research article

Evaluation of common bean genotypes against root rot complex pathogens in West Hararghe, Eastern Ethiopia

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Abstract

Common bean root rot caused by different fungal pathogens is an important disease affecting common bean (*Phaseolus vulgaris* L.) production and productivity. In Ethiopia, this disease has become one of the most destructive biotic constraints to common bean production. Information on common bean root rot disease management is lacking for the Ethiopian common bean production system in general and West Hararghe in particular. Therefore, in the 2018 main cropping season, a field experiment was performed on 19 common bean varieties in two research fields, the 'Bareda and Oda Baso' farmers' training centers. The experiment was designed to evaluate the level of resistance of a common bean genotype against root rot complex pathogens under natural conditions using a Randomized Complete Block Design (RCBD) design with three replications. The levels of resistance were evaluated based on seedling emergence, disease incidence, and severity in parallel with grain yield data and subjected to analysis of variance (ANOVA). Based on the laboratory results, four pathogenic fungi, namely, *Fusarium oxysporum* f. sp. *Phaseoli (F. o.* f. sp. *Phaseoli), Rhizoctonia solani (R. soni), Sclerotium rolfsii (S. rolfsii)*, and *Macrophomina phaseolina (M. phaseolina)*, a Nematode sp., and stem maggot insect were identified. The combined analysis of variance showed very highly significant variation at ($p < 0.0001$) across the location. There was also very highly significant variation ($p < 0.0001$) among treatments except for seedling emergence, incidence, and severity, which were highly significant ($p < 0.001$). From the experiment, seven common bean varieties (Kufanzik, Roba, Hirna, SeR-125, Cranscope, Tinike, Awash-1) that showed resistance characteristics and two susceptible varieties (Choire and Argane) were selected and recommended.

Introduction

Common bean (*Phaseolus vulgaris* L.) is the most widely distributed species of the genus *Phaseolus*, as it is grown in all countries of the continents with a broad range of adaptation to various environmental conditions [1]. It is one of the most important legumes worldwide because of its high commercial value, extensive production, consumer use, and nutrient value [2].

The economic significance of the common bean in Ethiopia is quite considerable since it represents one of the major food and cash crops. It has great potential for the country, as it is duly recognized by many researchers and organizations for its economic importance and its domestic demands for various uses. Production of this crop is indispensable in the country to enrich staple cereal crops with sufficient and high-quality protein to overcome the problem of malnutrition [3]. Under optimal management conditions, the productivity of the common bean can reach 2.5 to 3.0 tons per hectare in Ethiopia [4]. However, the actual average production from 2008 to 2010 was only 1.4 tons per hectare [5], which is very far below the crop yield potential due to different factors. The major production constraints of common beans include moisture stress, diseases, insect pests, weeds, poor soil fertility, and a lack of improved seeds [6]. Among the diseases, root rot is a diverse disease type recorded in common bean and is categorized as having major importance. It is widely distributed around the world and is an economically important disease in common beans [7,8]. Root rot was caused primarily by *Fusarium solani*, *Rhizoctonia solani*, *Macrophomina phaseolina*, and *Pythium* spp., and *F. oxysporum* was recognized as one of the major problems limiting the yield of common bean crops Naseri, 2008 [9]. It causes seedling death that leads to poor plant stands and symptoms such as chlorosis and defoliation of leaves, reduced biomass, and plant stunting, finally resulting in reduced seed yield [10-12]. Poor seedling emergence and disease incidence during flowering and pod filling result in the most significant yield reduction. In addition, low or high temperatures, drought, and flooding can lead to more severe root rot [11]. Disease incidence and severity often vary greatly in areas with a history of the disease. This disease is an economic problem in most growing locations, where it shows up to 70% loss in some areas in northwest Iran [13]. It may range between 3.8 and 76% fewer seeds per plant under commercial production conditions (Naseri, 2008).

Considering the nature of the damage and survival ability of the pathogen, the use of resistant varieties is the only economical and practical solution. As a result, certified seeds tolerant or resistant to soil-borne disease have been recommended to bean growers since they could be the best way to increase production. In Ethiopia, root rot is widely distributed in every part of the country, especially for diseases that occur frequently in the bean-growing areas of eastern Oromia [14]. The diseases frequently occur in western Hararghe and still cause great threats to the area. Studies evaluating released common bean genotypes as alternative disease management strategies are highly important. In addition, breeding for resistance against the root rot complex was systematically conducted for common bean genotypes in west Hararghe in two locations (Habro and Oda Bultum) in districts at the Bareda and Oda base kebele, respectively. Hence, information gaps with respect to major soil-borne diseases, the aggressiveness of pathogens, and the reactions of released genotypes against root rot pathogens were evaluated in the greenhouse of Haramaya University in the 2016 dry season. From that experiment, six materials were selected for resistance, and two were selected for susceptibility against root and stem rot fungal pathogens. Similarly, the trial was tested to confirm in-field conditions under natural infestation during the 2018 main cropping season to identify sources of resistance among 19 selected common bean genotypes against root rot complex pathogen(s). Therefore, this research was designed with the objectives of determining the level of resistance and selecting resistant/tolerant common bean genotypes against root rot complex pathogens under natural infestation.

Materials and methods

Descriptions of the study area

The field experiments were conducted in two districts (Habro and Oda Bultum) of West Hararghe. The Habro district is located 404 km east of Addis Ababa, the capital city of Ethiopia, and 75 km south of Chiro town of the West Hararghe Zone. The district is bounded by with Guba Koricha district to the west, Boke to the east, Daro Lebu to the south, and Oda Bultum to the north. The altitude of the district ranges between 1600 to 2400 m.a.s.l., with maximum and minimum temperatures of 16 and 20 °C, respectively. The district receives an annual average rainfall of 650 mm to 1000 mm [15]. Major food crops grown in this district are maize, sorghum, and common bean, while coffee and *khat* are major cash crops grown by smallholder farmers.

Oda Bultum is also another district found in the West Hararghe Zone; the capital town of the district is named Badesa. Its altitudinal range is from 1040 to 2500 m.a.s.l., and the average altitude of the district is 1770 m.a.s.l. From the total land area/topography of the district, 60% is plain and 40% is a steep slope. The annual rainfall is 900 mm - 1100 mm). It has mean maximum and minimum temperatures of 28 and 25 °C, respectively. The maximum and minimum rainfall is 1200 and 900 mm, respectively [16]. In the 2018 cropping season, the data did not include the Daro Labu district because the field experiments were performed over two locations, namely, the Habro and O/Bultum districts.

Research design

The treatments were set up in a completely randomized block design (RCBD) with three replications. Plot size 3 m*4 m, distance between (b/n) plant/row 10 cm*40 cm. Samples were collected as described in the laboratory manuals of plant pathology, and reconfirmation of the pathogen was performed at the Haramaya University plant pathology laboratory.

Experimental materials

Nineteen common bean varieties (Roba, Tafach (SAB 632), Awash-2, Cranscope, Chorie, Chercher, Argene, Awash 1, SER-119, SER-125, Dendesu, Tinike (RXR-10), SAB736, Fedis, Babile, Hirna, Kufanziq and Dursetu) released by the Ethiopian Institute of Agricultural Research (EIAR) and HU along with one susceptible accession as a check (ZABR-16574/21F2Z) from the Machera Agricultural Research Center were used as treatments and evaluated under natural infestation (field conditions). Because those varieties were newly released and available material in agricultural research, there was no information about resistance against soil-borne diseases under natural infestation except in the greenhouse at HU for a further breeding program.

Treatment arrangement

T1= Ado (SAB 736), T2= Tafach (SAB 632), T3= Awash-2, T4= Cranscope, T5= Chorie, T6= Chercher, T7=Argene, T8=Awash 1, T9=SER-119, T10=SER-125, T11=Dendesu, T12=Tinike (RXR-10), T13=Roba, T14=Fedis, T15=Babile, T16=Hirna, T17=Kufanziq, T19= Dursetu and T19= ZABR-16574/21F2Z were used (Figure 1).

Sample collection and isolate preparation

During the 2018 main cropping season, one hundred sixty-nine (169), and one hundred forty (140) suspected common bean root rot samples were collected from both locations. From the 169 samples, 27 isolates of different fungal genera were isolated, purified, and identified. From 140 samples collected, 20 isolates of fungal genera, nematodes spp, and stem maggot insects were identified.

Experimental procedure for isolation of root rot pathogens

Common bean plants showing root rot symptoms were collected from the experimental field in the selected districts. The root portions were washed in running water, surface-sterilized using 1% sodium hypochlorite (NaOCl) for 30

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Figure 1: Released common bean genotype used in the experiment.

seconds, rinsed three times in sterile distilled water, and blotted dry. The segments were aseptically placed on Potato Dextrose Agar (PDA) amended with 50 ppm streptomycin and incubated for 7 - 14 days. After the incubation period of growth, each fungal colony was subcultured separately on PDA and identified macroscopically based on cultural and microscopic identification using characteristics such as colony color, growth type, mycelia, and spores. The microorganisms grown on the PDA were identified and then transferred to a new medium by incubating under darkness at 25 °C for further purification. The pure culture was prepared for each pathogen and reconfirmed.

Disease evaluation methods

In these experiments, disease evaluation was performed by taking 10 symptomatic plants per variety in each replication. It was done by carefully uprooting all the seedlings that emerged per variety, taking care not to damage roots and hypocotyls, and washing with clean tap water. The assessment of disease incidence data was performed based on percent seedling emergence after seedling germination. Root rot severity data were assessed by observing the roots and hypocotyls of diseased common bean crops and scores given based on a 1 to 9 disease scale developed at the International Center for Tropical Agriculture (CIAT) [17], which finally changed to mean percentage. The description of the scale was as follows: 1= no visible symptoms; 3= light discoloration either without necrotic lesions or with ≥ 10% of the hypocotyls and root tissues covered with lesions; 5 = ≥ 25% of the hypocotyl and root tissues covered with lesions but tissues remain firm with the deterioration of the root system; 7 = ≥50% of the hypocotyls and root tissues covered with lesions combined with considerable softening, rotting, and reduction of the root system; 9 = ≥75% or more of the hypocotyls and root tissues affected, with advanced stages of rotting combined with a severe reduction in the root system. Then, based on the combined mean results of seedling emergence, incidence, and severity data from all locations, the differences among the levels of resistance for the nineteen common bean varieties were determined. Although the varieties with high mean common bean root rot disease incidence and severity with small mean percentages of seedling emergence are considered more susceptible than the other varieties, those with lower mean common bean root rot disease incidence and severity with the highest mean percent seedling emergence (seedling survival) were considered resistant under tested environments. Based on these criteria, the tested varieties were grouped into three levels (Susceptible (S), Moderately Resistant (MR), and Resistant (R)). Therefore, varieties with a combined mean incidence (<20%) and emergency (>80%) were considered resistant (R), and varieties with a recorded combined mean incidence and emergency of 21% - 30% and 70% - 79%, respectively, were considered moderately resistant (MR), and varieties with a combined mean incidence and emergency of >31 and <69, respectively, were considered susceptible (S). Beebe, et al. (1981) also suggested that plant survival was a better criterion for resistance than measuring the severity of hypocotyl lesion formation.

Data collected

Average frequencies of identified pathogens, percent seedling emergence, incidence (%), severity (%), hundred seed weight, and adjusted grain yield (kg/Ha).

Statistical analysis

All data collected from both locations were combined and analyzed using SAS software. The treatment means were compared by the Least Significant Differences (LSD) at $p < 0.05$. The assumptions for the ANOVA were checked as in the root rot resistance study.

Results and discussion

Identification of major root rot-causing pathogens

Based on collected sample results, four fungal genera related to common bean root rot disease, three common saprophytes, one nematod spp., and stem maggot insect spps. were identified. Among the root fungal pathogens identified, *Fusarium oxysporum f.sp phaseoli*, *Sclerotium rolfsii*, *Macrophomina phaseolina* (*Syn. Rhizoctonia bataticola*), and *Rhizoctonia solani* were recorded at high frequencies compared with other common saprophytes, such as *Rhizopus solani*, *Aspergillus spp.*, and *Trichoderma spp.* (Table 1). Based on the orders of occurrence across the location, the highest average frequency of 48.60% was recorded by *F. oxysporum*, followed by *S. rolfsii* and *M. phaseolina*, with average frequency values of 22.28 and 22.13, respectively. The smallest average frequency of 17.83% was recorded by *R. solani*.

Except for common saprophytes, others cause root rot on common bean crops, which was similarly reported by Abawi and Pastor Corrales [10], damping-off [18], loss of plants, and limited establishment (Tu, 1992). Similarly, Le, et al. [19] also stated in their report that *Sclerotium rolfsii* causes root and stem rot in crops such as groundnut, maize [20], tomato, onion, and soybean [21], which are commonly grown in the Hararghe common bean production area. In addition to those pathogenic fungi, a number of some nematode spp. and stem maggot was also recorded in the study areas (Table 1). At both the Bareda and Oda Baso sites, plots that had been damaged by bean stem maggot were most affected by root rot. This result agreed

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with Letourneau & Msuku [22], who reported that plants that are attacked by bean seed flies are more susceptible to soil pathogens.

Reaction of genotypes against root rot disease across locations

Based on the analyzed results, common bean varieties showed significant differences ($p < 0.05$) in mean percent seedling emergence, incidence, and severity at the Bareda site. The adjusted grain yield (kg/Ha) and hundred seed weight (gm) showed very highly significant differences at the ($p < 0.0001$) level. In contrast, all parameters were not significant at ($p < 0.05$), except the mean percent severity at the Oda Baso site, which was highly significant at ($p < 0.001$). Even if it did not show any significant difference, there was a high mean variation in seedling emergence, incidence, adjusted grain yield (kg/Ha), and hundred seed weight (gm) (Table 2). Grain yield was very low at the Oda Baso site because of rain shortage, moisture stress, and cracking of soil both at seedling emergence and at the flowering stage, and the number of plant stands was reduced, which complements the yield reduction. From this experiment, the researcher observed that common bean root rot disease became severe during moisture stress. The results were also reported by both Abawi and Ludwig [17], and Harveson, et al. [9], who found that the symptoms of root rot are usually most obvious when the bean crop is subjected to a combination of moisture stress, poor drainage, and soil compaction. Additionally, early seedling mortality due to severe common bean root rot disease was recorded at Oda baso compared with Bareda, which resulted in yield reduction at the site. This result agreed with Harveson, et al. [9], who found that early infection by root rot pathogens causes damping-off that can lead to the death of common bean seedlings before or after emerging from the soil, resulting in uneven plant stands in the field. The incidence of root rot did not follow the same pattern as its severity (Table 2 and Tables 3, Figures 2A and 2B). Because the severity data was taken based on the International Center for Tropical Agriculture (CIAT) (1990) disease severity scale that had been taken from the diseased sample plant, this scale was converted to a percentage. On the other hand, the

Table 1: Average frequencies of identified pathogens and insect pests related to common bean root rot across the districts during the 2018 main cropping season.

Average frequency (%)						
2018 Cropping season						
Districts	Fo	Mp	Rs	Sr	N	Sm
Habro	51.3	22.04	15.52	32.1	7.25	13
Oda Bultum	45.91	22.23	20.15	12.47	13.01	21.5
Mean	48.6	22.13	17.83	22.28	10.13	17.25
Range	45.9-51.30	22.0-22.23	15.5-20.15	12.4-32.10	7.25-13.10	13.00-21.50

**Fo- *Fusarium oxysporum*, Mp- *Macrophomina phaseolina*, Rs- *Rhizoctonia solani*, Sr-*Sclerotium rolfsii*, N- Nematode sp, Sm-stem maggot.

Table 2: Mean percent (seedling emergence, incidence, severity) and mean (adjusted grain yield kg/ha and HSW) of common bean due to root rot disease at the Bareda and Oda Baso sites.

	Bareda site							Oda baso site		
Name_of_Entry	**%EM**	**% INCI**	**%SEV**	**HSW**	**ADGy**	**%EM**	**% INCI**	**%SEV**	**HSW**	**ADGy**
Fadis	87.77^{ab}	14.42^{bc}	47.41^{ab}	60.37^{a}	1513^{a}	70.56	29.44	47.66^{abcd}	24.7	181.36
SER-119	90.00^{a}	11.63^{c}	48.15^{ab}	28.40^{de}	1512^{a}	68.89	31.11	45.33^{abcd}	24.33	237.39
Dursitu	87.77^{ab}	13.98^{bc}	40.88^{ab}	22.07^{efg}	1471^{ab}	69.56	30.44	36.00^{d}	19.36	263
kufanzik	93.33^{a}	7.29^{c}	42.02^{ab}	36.80^{cd}	1394^{abc}	82.78	17.22	46.00^{abcd}	17.53	243.08
Roba	88.88^{ab}	12.61^{c}	51.64^{ab}	19.63^{efg}	1370^{abc}	73.89	26.11	51.00^{abcd}	13.9	214.83
Hirna	97.77^{a}	**2.28^{c}**	38.94^{b}	58.30^{a}	1359^{abc}	84.44	**15.56**	38.00^{d}	22.66	238.03
ZABR16574/21F2Z	92.22^{a}	8.66^{c}	51.48^{ab}	17.50^{fg}	1260^{abcd}	53.33	41.11	60.00^{a}	15.3	151.22
SeR-125	90.00^{a}	11.14^{c}	47.84^{ab}	27.87^{def}	1257^{abcd}	66.11	16.67	49.00^{abcd}	19.17	164.88
Babile	87.77^{ab}	16.61^{bc}	48.44^{ab}	47.43^{b}	1243^{abcd}	67.22	32.78	52.66^{abcd}	20.9	240.78
Cranscope	97.22^{a}	2.86^{c}	37.58^{b}	44.87^{bc}	1195^{abcd}	81.11	18.89	38.66^{cd}	26.6	287.25
SAB 632	89.44^{a}	12.04^{c}	47.87^{ab}	59.57^{a}	1059^{bcd}	54.44	**45.56**	50.66^{abcd}	17.67	172.09
Tinike	93.88^{a}	6.56^{c}	38.37^{b}	44.07^{bc}	1013^{cd}	80	20.00	40.66^{bcd}	17.36	102.61
Awash-2	96.66^{a}	3.51^{c}	56.87^{a}	17.63^{fg}	1002^{dc}	58.89	41.11	57.00^{abc}	14.43	120.42
Chercher	74.44^{bc}	**35.95^{ab}**	55.43^{a}	20.03^{efg}	931^{de}	58.33	41.67	57.66^{ab}	23.1	241.21
Awash-1	86.66^{abc}	15.49^{bc}	50.72^{ab}	15.30^{g}	898^{def}	79.44	20.56	54.33^{abcd}	14.23	241.11
Dendesu	84.44^{abc}	22.22^{abc}	43.77^{ab}	51.37^{ab}	892^{def}	78.33	21.67	43.66^{abcd}	17.9	199.58
SAB736	88.88^{ab}	13.65^{c}	48.98^{ab}	25.83^{ef}	598^{efg}	66.67	33.33	50.33^{abcd}	17.26	72.28
Choire	72.77^{c}	**38.90^{a}**	44.03^{ab}	21.33^{efg}	518^{fg}	43.33	**56.67**	45.00^{abcd}	19.25	180.42
Argane	83.88^{abc}	19.73^{abc}	53.40^{ab}	17.93^{fg}	322^{g}	55.56	44.44	47.00^{abcd}	25.96	151.17
LSD	0.01	0.026	0.01	<.0001	<.0001	NS	Ns	0.002	Ns	Ns
CV%	8.62	82.4	17.6	16.11	19.79	28.67	56.08	19.56	29.02	30.1

*** Means with the same letter are not significantly different, %EM- %Emergency, % Inci -%Incidence, %SEV-%Severity, %-percent, ADGyKg/Ha- Adjusted Grain yield kilogram per Hector, HSW-Hundred seed weight per plot.

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Table 3: The combined (ANOVA) result of a varietal reaction against root rot disease rating and its respective HSW and adjusted grain yield (kg/Ha).

Name _of Entry		EM %	INCI%	SEV%	HSW	ADGy
Fadis		79.16^{abc}	21.93^{bcd}	31.65^{abcde}	42.53^{a}	846.94^{ab}
SER-119		79.44^{abc}	21.37^{bcd}	31.63^{abcde}	26.36^{cde}	874.60^{a}
Dursitu		78.66^{abc}	22.21^{bcd}	26.44d^{e}	20.71^{ef}	866.89^{a}
Kufanzik		88.05^{ab}	12.26^{cd}	28.67^{cde}	27.16^{cde}	818.47^{abc}
Roba		81.38^{abc}	19.36^{bcd}	34.32^{abcd}	16.76^{f}	792.32^{abcde}
Hirna		91.11^{a}	8.91^{d}	25.80^{e}	40.48^{a}	798.38^{abcd}
ZABR16574/21F2Z		72.77^{abcd}	24.88^{bcd}	35.74^{abc}	16.40^{f}	705.42^{abcdef}
SeR-125		78.05^{abc}	13.90^{cd}	32.08^{abcde}	23.51d^{ef}	711.13^{abcdef}
Babile		77.50^{abcd}	24.69^{bcd}	32.99^{abcde}	34.16^{abc}	742.01^{abcdef}
Cranscope		89.16^{ab}	10.87^{d}	25.23^{e}	35.73^{ab}	740.94^{abcdef}
SAB 632		71.94^{abcd}	28.79^{bcd}	32.37^{abcde}	38.62^{ab}	615.59^{bcdef}
Tinike		86.94^{abc}	13.28^{cd}	25.96^{e}	30.71^{bcd}	557.85^{efg}
Awash-2		77.778^{abcd}	22.31^{bcd}	37.93^{a}	16.03^{f}	561.03^{efg}
Chercher		66.38^{cd}	38.80^{ab}	37.32^{ab}	21.56^{ef}	585.85^{cef}
Awash-1		83.05^{abc}	18.02^{cd}	34.41^{abcd}	14.76^{f}	569.78^{defg}
Dendesu		81.38^{abc}	21.94^{bcd}	29.16^{cde}	34.63^{abc}	545.92 ^{fg}
SAB736		77.77^{abcd}	23.49^{bcd}	32.88^{abcde}	21.55^{ef}	335.35 ^{h}
Choire		58.05^{d}	47.78^{a}	29.51^{bcde}	20.29^{ef}	349.33^{gh}
Argane		69.72^{bcd}	32.08^{abc}	34.53^{abc}	21.95^{ef}	236.64 ^{h}
Location	Bareda	88.62^{a}	14.18^{b}	33.48^{a}	33.48^{a}	1095.06^{a}
	O/Baso	68.04^{b}	30.75^{a}	19.56^{b}	19.56^{b}	194.88^{b}
	LSD(0.05)	<.0001	<.0001	<.0001	<.0001	<.0001
Treatment	LSD(0.05)	0.0390	0.0024	<.0001	<.0001	<.0001
Location* Treatment	LSD(0.05)	NS	NS	<.0001	<.0001	<.0001
CV%		18.91	65.56	25.17	25.17	26.81

*** Means with the same letter are not significantly different, %EM- %Emergency, % INCI -%Incidence, %SEV-%Severity, %-percent, ADGykg/Ha- Adjusted Grain yield kilogram per Hector, HSW-Hundred seed weight per plot, MR- moderately Resistant, R- Resistant, S- susceptible.

Figure 2: Status of common bean genotypic reaction against root rot disease under field conditions.

smallest percent disease incidence of 2.28% was recorded by the Hirna variety, followed by the Cranscope and Awash-2 varieties, which recorded (2.86 and 3.56)% disease incidence at the Bareda site, respectively. The highest percent disease incidence of 38.9% was recorded by the choire variety, followed by the chercher variety, which recorded a percent disease incidence of 35.95% at the Bareda site. Similarly, at the Oda baso site, the smallest percent disease incidence of 15.56% was also recorded by the Hirna variety, followed by the SER-125, Kufanziq, and Cranscope varieties, which were (16.67, 17.22, and 18.89)%, respectively. Again, the highest percent disease incidence of 56.67% was recorded by the choire variety, followed by the SAB632, Argene, and Chercher varieties, which recorded percent disease incidences of 45.56%, 44.44%, and 41.67%, respectively, at the Oda baso site (Table 2).

The results of the combined analysis of variance are shown in Table 3. The combined analysis of variance showed very highly significant differences ($p < 0.0001$) in all parameters over the location. Similarly, except for seedling emergence and disease incidence, the combined analysis of variance was very highly significant ($p < .0001$) among the treatments. The interaction of location versus treatments also showed very high significance at ($p < .0001$) over yield, while parameters related to disease intensity were not significant at ($p < 0.05$) (Table 3). The highest mean percent seedling emergence of 91.11, 89.16, and 88.05 was recorded by varieties named Hirna, Cranscope, and Kufanzik, respectively (Table 3). The lowest mean percent seedling emergence of 58.05 was recorded by the variety named (Choire). This variation was not due to varieties used for the trial, but it was only due to pathogens

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and environmental factors. Therefore, the seed used in this experiment had a germination percentage of 90%. This result was consistent with that of Conner, et al. [23], who suggested that seedling emergence was affected by different pathogens but not significantly by cultivars.

The combined mean results also showed that the highest and the lowest mean percent common bean root rot disease incidence of 47.78 and 8.91 were recorded by the Choire and Hirna varieties, respectively. Both the highest and lowest adjusted grain yields of 874.6 and 236.64 kg/Ha were recorded by the SER-119 and Argane varieties, respectively (Table 3). The varieties ZABR16574/21F2Z, SER-125, and Babile showed medium common bean root rot disease incidence and severity records with a better yield of approximately 700-742.09 kg/Ha and were selected as having moderate resistance to root rot disease under field conditions (Table 3). In this experiment, the varieties showed variable combined mean disease incidence and severity as well as percent seedling emergence. Similarly, the adjusted grain yield and hundred seed weight also varied. This means that those varieties with the highest records of common bean root rot disease incidence and severity and low seedling emergence compared to the other varieties were considered susceptible to the disease. This study supports the work of Beebe, et al. (1981), who suggested that plant survival was a better criterion for resistance than measuring the severity of hypocotyl lesion formation. Because of the existence of innate variable genetic potential of the tested varieties, pathogens and interactions of environmental factors such as moisture stress and cracking of the soil have also been reported by [10].

These experiments were performed in the Haramaya University greenhouse in 2017, and the results showed that approximately five common bean genotypes exhibited resistance characteristics (data not observed). Under field conditions, the same treatment was applied, and the data generated show that approximately seven resistant and nine moderately resistant varieties were selected. This means that there were many genetically resistant characters among the genotypes used. The results agreed with the Beebe, et al. (1981) report that resistance to *Fusarium* and *Rhizoctonia* root rot appeared to be common among bean lines, possibly due to natural selection for that trait. However, in some cases, there was variability among the tested environments (greenhouse and field conditions). From the greenhouse-tested varieties, some showed similar resistant characteristics under field conditions, and some varieties became susceptible (choire and argane) when their mean incidence and severity were compared with those of the check accession (ZABR16574/21F2Z). Similarly, the ZABR16574/21F2Z accession used as susceptible under the greenhouse test became moderately resistant (Table 3). Because of the presence of variability among the tested environments and synergistic effects in the field compared with the controlled conditions. Under the tested environment, all pathogens stated in Table 1 above were presented together, which increased their degree of virulence in the soil in the field compared with that under controlled conditions. In the greenhouse, environmental factors such as moisture stress, soil cracking, and water lodging problems were present in the optimum state, and the inoculum used for inoculation was pure-cultured and lacked synergy. The results were complemented by Abawi and Pastor Corrales [10], who reported that a synergistic interaction of different pathogens results in greater damage than the action of each pathogen alone. Similarly, Conner, et al. 2014 [23] also reported that combining *R. solani* and *F. solani f. sp. phaseoli* resulted in greater percent seedling emergence than that of *R. solani* treatment alone.

Conclusion and recommendation

In general, the present study investigated the resistance reaction of 19 common bean genotypes against root rot complex pathogen(s) and their grain yield performance. The tested genotypes showed varying responses to the incidence and severity of common bean root rot disease, which ranged from 8.91 - 47.78 and 25.8 - 29.51, respectively. Thus, there were sources of resistance against root rot disease. Among the evaluated genotypes, (Fadis, SER 119, Dursitu, Roba, Hirna, Cranscope, and Kufanzik) showed resistant reactions and higher yield potential. The Choire and Argane varieties showed higher incidence and lower grain yield, ranging from 32.08% - 47.78% and 236.64 - 349.33 kg/Ha, respectively. These results indicate that there is potential for disease resistance sources in line with higher grain yields in breeding programs. Thus, it is recommended to use genotypes (Fadis, SER 119, Dursitu, Roba, Hirna, Cranscope, and Kufanzik) with proper management of moisture stress, soil compaction, and cracking during the dry season to reduce common bean root rot damage and grain yield losses. Similarly, it is recommended to use those genotypes as sources of resistance to common bean root rot. However, the Choire and Argane varieties are recommended for use as susceptible genotypes. However, to confirm their consistency, evaluating the genotypes for more seasons and locations is important.

Author contribution statement

Abdela Usmael and Meseret Elias drafted and prepared the manuscript, and Muhidin Tahir revised the language and sequence of the manuscript. Finally, all authors read and approved the final manuscript.

Data availability

Data for this study are available from the corresponding author upon reasonable request.

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