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Integrated Management of Faba Bean Black Root Rot (*Fusarium solani*) through Varietal Resistance, Drainage and Adjustment of Planting Time

Belay Habtegebriel[1]* and Anteneh Boydom[2]

[1]*Ethiopian Institute of Agricultural Research, Plant Protection Research Center, P.O. Box 37, Ambo, Ethiopia*
[2]*Ethiopian Institute of Agricultural Research, Holleta Agricultural Research Center, Holleta, Ethiopia*

Abstract

Black root rot, caused by *Fusarium solani*, is one of the most important diseases of faba bean causing up to 70% on farm yield loss in severe conditions in Ethiopia. Integrated management is the most promising alternative to control the disease. Three faba bean varieties, two drainage methods and three planting dates were evaluated under high disease inoculum pressure on a sick plot for two consecutive cropping seasons in a 3×2×3 factorial experiment. Results showed that the resistant variety Wayu was least affected by the disease (18.86% dead plants at harvest) when sown early on a flat bed. The susceptible variety Kassa was highly affected by the disease (89%) on a raised bed. All the three varieties performed well on raised beds (41.16%) than on flat beds (51.29% dead plants). Early or late planting resulted in significantly lesser overall percentage of dead plants (38.85%) and (44.23%) respectively as compared to optimum planting date (55.59%). Significant interactions were observed between variety and drainage method (P=0.003, F = 6.94, df= 2) which resulted in the least percentage of dead plants (21% and 20% on a flat and raised bed respectively) of variety Wayu compared to the moderately resistant variety Wolki (69% on flat and 36% on raised) and the susceptible variety Kassa (63% flat and 67% raised). The yield (g/plot)also varied significantly with variety wolki giving the highest yield (856 g/plot) followed by variety Wayu (883 g/plot). It is concluded that all the three factors are important for management of the disease but emphasis should be given to varietal resistance and use of raised beds. The two varieties Wolki and Wayu are recommended with raised beds for higher yield and variety improvement programs.

Keywords: Faba bean; Root rot; *Fusarium solani;* Drainage; Varietal resistance

Introduction

Root rots are the most important diseases of faba bean (*Vicia faba* L.) which are caused by *Fusarium solani (*black root rot), *Rhizoctonia solani* (wet root rot) and *Sclorotium rolfsi* (collar rot) in most growing areas [1-3]. In particular field, grown beans are highly destructed by the black root rot pathogen *F. solani* (Mart) Appel and Wollenw [4]. *Fusarium solani* is among the most commonly isolated soil borne pathogens causing root rot [5]. The disease occurs at early stage in the growing season causing seedling death [6]. In Ethiopia also, black root rot disease is a major biotic stress in faba bean growing areas [7,8] causing up to 70% yield loss on farmers' fields in severe conditions [9,10]. Up to 84% yield, losses have been reported on other pulses such as the common beans due to root rot caused by *Fusarium solani* [11]. It is the second most important disease of faba bean and when favorable conditions prevail and severe infections occur, faba bean black root rot (BRR) can cause complete crop loss [6]. Some studies have shown up to 45% yield loss on farmers' fields [12].

Black root rot almost entirely occurs in black clay soils, which are characterized by water logging that predisposes the plant to the disease [6]. Severe rotting causes black discoloration of the roots followed by death of the plant [12,13]. Other symptoms include elongated reddish lesions on primary roots, longitudinal cracks on the outer root and destruction of the tap root [14]. Optimum soil temperature for the development of *F.solani* is 25°C [15].

Management of root rots is a difficult task as most pathogens live near the rhizospher and survive for a long period by forming resistant structures [16]. Chemical control of faba bean root rot is neither efficient nor economical. Management options are mostly agronomic practices such as crop rotation, good soil drainage and use of disease free or fungicide treated seeds that may help reduce losses and there are no adequate control measures for *Fusarium* rots in the field [17]. Use of broad bed furrows (BBF) and resistant varieties have also been suggested for the management of the disease [18]. However, the disease remains difficult to control especially in black clay soils.

The objective of this study was therefore to establish the roles of managing faba bean black root rot through the integrated use of varietal resistance, soil drainage and adjustment of planting time.

Materials and Methods

Three faba bean varieties viz. a resistant variety Wayu, a moderately resistant variety Wolki and a susceptible check variety Kassa were used for the experiments. Two drainage methods (flat bed and raised bed) and three planting times (early, optimum and late) were used. Each treatment contained a variety a drainage method and a planting time. There were a total of 18 treatments (Table 1) which were set up in a 3×2×3 factorial arrangement. The experimental design was randomized complete block design (RCBD) with three replications. Plot size was 4.8 m^2 and the distance between blocks and plots was 1.5 m and 1 m respectively. The spacing between rows and plants was 40 cm and 5 cm respectively. The experiments were carried out in a well-developed sick plot containing high amount of root rot inoculum at Ambo Plant Protection Research Center (APPRC). The experiments were carried out in two consecutive main cropping seasons (2009 and 2010).

***Corresponding author:** Belay Habtegebriel, Ethiopian Institute of Agricultural Research, Plant Protection Research Center, P.O. Box 37, Ambo, Ethiopia, Tel: +2511164626334; E-mail: belayhw@yahoo.com

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Treatment	Variety	Drainage	Time of planting
T1	Wolki	Flat	Optimum (June 26)
T2	Wolki	Flat	Early (June 11)
T3	Wolki	Flat	Late (July 3)
T4	Wayu	Raised	Optimum (June 26)
T5	Wayu	Raised	Early (June 11)
T6	Wayu	Raised	Late (July 3)
T7	Kassa	Flat	Optimum (June 26)
T8	Kassa	Flat	Early (June 11)
T9	Kassa	Flat	Late (July 3)
T10	Wolki	Raised	Optimum (June 26)
T11	Wolki	Raised	Early (June 11)
T12	Wolki	Raised	Late (July 3)
T13	Wayu	Flat	Optimum (June 26)
T14	Wayu	Flat	Early (June 11)
T15	Wayu	Flat	Late (July 3)
T16	Kassa	Raised	Optimum (June 26)
T17	Kassa	Raised	Early (June 11)
T18	Kassa	Raised	Late (July 3)

Table 1: Treatment combinations used for field experiments on management of faba bean black root rot using variety, drainage and time of planting.

Data collection was done at emergence, seedling, podding, maturity and harvesting stages by rouging out dead plants. Data analysis and statistical comparison was conducted using the ANOVA procedure of the SAS software version 9.2. followed by mean separation.

Results

In the 2009 cropping season, the percentage of dead faba bean plants grown under high disease pressure from black root rot at harvest ranged from 36.17 for variety Wolki sown late on flat bed to 84.87 for Kassa sown early on a flat bed. Although the disease appeared and caused the plants to die, there were no significant differences among all the individual factors and treatments including interaction effects at all the growth stages (Table 2). In the following cropping season (2010) however, significant variations were observed at different growth stages. The percentage of dead plants at harvest ranged from the least (18.86%) for the resistant variety Wayu sown early on a flatbed to the maximum (89.03%) for the susceptible variety Kassa sown early on a raised bed. The percentage of dead plants varied significantly among the individual factors i.e. varieties, drainage methods and planting time (Table 3). All the three varieties performed well on raised beds (41.16% dead plants) than on flat beds (51.29% dead plants). Early or late planting resulted in significantly lesser overall percentage of dead plants (38.85%) and (44.23%) respectively as compared to optimum planting (55.59%). There was no significant difference between planting early or late in the season.

However, as shown in Figure 1, interaction effects were significant only between varieties and drainage methods (P=0.003, df=2, F=6.94). The least percentages of dead plants in this interaction were 19.88% followed by 21.13% recorded from variety Wayu sown on raised and flat beds respectively. The susceptible variety Kassa showed the highest overall percentage of dead plants (65.21%) while the resistant variety Wayu exhibited the least (20.50%) over all dead plants in this interaction.

In the 2009 crop season, the yield (g/plot) did not vary significantly except for the overall effect of varieties (P = 0.0464 F= 3.35, df = 2) (Table 4) and the three way interactions among variety, planting time and drainage method (P= 0.0251, F= 2.78 df= 6) (Table 5). Variety Wolki sown late on flat beds (855.87 g/plot) gave the highest yield followed by variety Wayu sown at optimum date on flat beds (882.73 g/plot). The least yield was obtained from variety Wolki sown on a flat bed at optimum time (54.03 g/plot).

In the 2010 crop season, yield was significantly affected by the

Treatment	Before emergence	Seedling	Podding	Maturity	Harvesting
T1	36.0	62.9	66.7	75.2	83.1
T2	40.1	65.6	65.6	65.6	68.2
T3	27.6	30.3	30.7	30.7	36.2
T4	35.7	68.9	68.9	69.3	74.3
T5	21.5	58.1	58.1	58.1	66.7
T6	28.1	41.7	41.7	41.7	43.0
T7	16.9	65.1	65.1	65.1	72.8
T8	35.5	68.0	68.0	72.1	84.9
T9	21.1	59.6	59.6	59.6	68.6
T10	29.2	64.9	64.9	64.9	67.3
T11	21.3	65.6	65.6	65.6	65.6
T12	29.2	70.4	70.4	70.4	74.6
T13	25.9	39.3	39.5	39.7	43.0
T14	26.8	51.3	51.3	51.3	54.4
T15	22.1	91.7	91.7	91.7	91.7
T16	21.9	61.6	61.6	61.6	71.1
T17	28.3	59.0	59.0	59.0	59.2
T18	42.1	65.8	65.8	65.8	76.5
DMRT (0.05%)	ns	ns	ns	ns	ns

Table 2: Overall means of percentage of dead faba bean plants due to black root rot at different growth stages in 2009 crop season.

Variety					
	Kassa	Wayu	Wolki	F	P
Mean	65.21**a**	20.5 **c**	52.96 **b**	36.80	<0.0001
Drainage					
	Flat	Raised		5.32	0.027
Mean	51.29 **a**	41.16 **b**			
Planting time					
	Early	Optimum	Late		
Mean	38.85 **b**	55.59 **a**	44.23**b**	5.04	0.011

Table 3: One way table of means of percentage of dead plants due to black root rot for three faba bean varieties, two drainage methods and three planting times at harvesting in 2010 crop season.

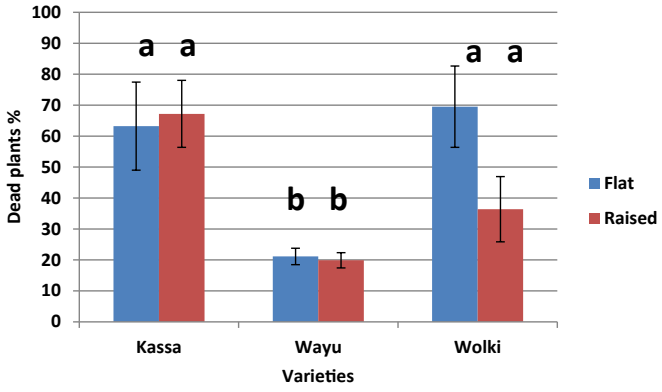

Figure 1: Variety X drainage interaction means ± standard error of percentage of dead plants due to black root rot for three faba bean varieties and two drainage methods at harvesting in 2010 crop season (P=0.003, F = 6.94, df= 2, LSD 5%).

Crop season	Variety					
		Kassa	Wayu	Wolki	F	P
2009	Mean	188.9 **b**	**497.4 a**	321.8.**a b**	3.35	<0.0464
	Variety					
2010		Kassa	Wayu	Wolki	F	P
	Mean	359.88 **c**	**844.51 a**	319.43. **b**	23.14	<0.0001

Table 4: One way table of means of yield (g/plot) for three faba bean varieties grown under disease pressure from black root rot in 2009 and 2010 crop seasons.

Varieties							F	P
	Kassa		Wayu		Wolki			
Drainage method	Raised	Flat	Raised	Flat	Raised	Flat		
Planting time								
Early	200.10	62.57	267.80	615.20	289.96	258.10	2.78	0.025
Late	209.47	396.13	752.43	82.96	127.33	855.87		
Optimum	182.97	82.05	383.03	882.73	345.30	54.03		

Table 5: Three way table of overall mean yield (g/plot) of variety X drainage X planting time interaction of three faba bean varieties grown under black root rot disease pressure at harvesting in the 2009 crop season.

Crop growth stage	Crop season	Variety					
			Kassa	Wayu	Wolki	F	P
Before Emergence	2009	Mean	3.18 b	16.52 a	2.12 b	67.4	<0.0001
		Variety					
			Kassa	Wayu	Wolki	F	P
Seedling	2010	Mean	10.38b	17.51 a	6.29 b	13.06	<0.0001
		Drainage					P
Seedling	2010		Flat	Raised		5.15	0.029
		Mean	13.45 a	9.33 b			

Table 6: One-way table of means of percentage of dead plants of three faba bean varieties grown under disease pressure from black root rot before emergence and at seedling stage in 2009 and 2010 crop seasons.

overall main effect of varieties (P = <0.0001, F = 23.14, df = 2). There were no other individual or interaction effects of the factors on the yield. The highest yield (844.51 g/plot) was obtained from variety Wayu (Table 4).

The overall percentage of seeds which died before emergence significantly varied among the three varieties in the 2009 field experiments with no interaction effects. Highest pre-emergence seed death was observed on variety wayu (16.52%) (Table 6). Similarly, the overall percentage of dead plants at the seedling stage significantly varied among the three varieties and between flat and raised seed beds in the 2010 crop season. Except these, no significant variations were observed in the rest of the crop stages both in 2009 and 2010 crop seasons (Table 6).

Discussion

Since controlling black root rot disease of faba bean by chemical means is unlikely, the use of alternative control methods is indispensible. In this study, use of resistant varieties (either the moderately resistant variety wolki or the resistant variety wayu) in combination with raised beds for adequate drainage showed significant reduction in the number of dead plants in a sick plot. Use of good cultural practices such as use of resistant varieties, adjustment of planting time and adequate drainage is known to reduce root rot incidence and have been suggested by many authors [17,18]. Similarly, this study has shown that varietal resistance and drainage methods play an important role in reducing disease pressure from black root rot and increasing yield of faba bean in vertisols where the disease is most serious.

In the 2009 field experiments, no significant differences were observed among the different factors at all the growth stages except at the pre-emergence stage. This may be attributed to the environmental conditions which favored the high disease pressure. Moreover, Fusarium root rot resistance, being quantitative, is strongly affected by the environment [19], but in the second year, variations became visible. The resistance of the varieties also varied depending on the year and the crop growth stage. For example variety wayu exhibited significantly lesser resistance (higher number of dead seeds) before emergence and at seedling stage in 2009 and 2010 respectively, while it performed well once emerged compared to the susceptible variety kassa which showed significantly higher emergence percent and less number of dead plants at seedling stage. Faba bean root rot can infect seeds prior to emergence or shortly after emergence resulting in damping off and death of seedlings which also results in uneven plant stands [11,20]. Faba bean root rot causes reduction in yield and efficiency of nitrogen fixation [20] which may weaken the plant's resistance. The significant interaction between varieties and drainage methods resulted in significantly lower percentage of dead plants for the variety wayu in 2010. Similarly, planting of resistant varieties on raised beds (ridges) has been proven to be useful in water logged soils [21]. This indicates the need for the use of more than one cultural practice. Combining two or more cultural practices have been reported to result in additive and positive interactions in root rot control [22]. In addition to cultural practices, application of DAP and farm yard manures (FYM) have been reported to improve tolerance to root rot indicating the need for integrated disease management which is most preferred for management of root rots [11]. In general however, in developing countries, where up to 100% yield loss is recorded from susceptible cultivars, use of resistant varieties is the most viable measure for root rot caused by *F. solani* [23]. For example, in Ethiopia, use of variety wayu and broad bed and furrow (BBF) for improving drainage has reduced the incidence of black root rot resulting in increased yield [19] Wayu is one of the varieties released in 2002 for root rot resistance in Ethiopia with another variety Selale to perform well under waterlogged conditions [24]. This study has further confirmed that wayu can perform even better when used in combination with raised beds and when planted early before the soils become waterlogged.

In conclusion, this study has demonstrated that all the three factors (varietal resistance, drainage method and sowing dates) are important for effective management of the disease. But emphasis should be given to varietal resistance and use of raised beds especially on vertisols. The two varieties Wolki and Wayu are recommended with raised beds for higher yield and variety improvement programs focusing on resistance to black root rot of faba bean caused by *Fusarium solani*. Black root rot disease is known to be a major problem in areas such as north shoa. Further studies on farmers' fields are recommended over locations where the disease is a problem every year such as north Shoa of Ethiopia.

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