Management of Root Rot Diseases of Cool Season Food Legumes with Special Emphasis on Lentil (Lens culinaris), Faba bean (Vicia faba) and Chickpea (Cicer arietinum) in Ethiopia

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Abstract
Particularly in Ethiopia legumes grown in 2014/15 covered 12.41 % (1,558,442.04 hectares) of the grain crop area and 9.88% (about 26,718,430.40 quintals) of the grain production was drawn from the same crops. Legumes, which occupy approximately 13 percent of cultivated land and account for approximately 10 percent of the agricultural value addition, are critical to smallholder livelihoods in Ethiopia. The major constraints to the production of these crops are diseases, insect pest attack, poor agronomic practices and lack of improved cultivars and crop protection technologies. Root rot diseases are a major limiting factor in legume production. The diseases depress seedling germination and cause post emergence damping off, resulting in poor crop stand and low yields. Several root rot casing pathogen such as *Rhizoctonia bataticola, Rhizoctonia solani and Fusarium solani* on chickpea, *Rhizoctonia bataticola and Rhizoctonia solani on lentil and Rhizoctonia bataticola, Rhizoctonia solani and Fusarium solani* on faba bean have been reported in Ethiopia. They can causes yield loss 45% and 50% yield in faba bean and chickpea if properly not manage. Several chemicals, cultural practice and bio-gent used to control this disease. Among bio-agent mostly used to control this disease are *Trichoderma viride* and *Bacillus megaterium* take a great share. In the future particularly in our country full exploitation of the potential of biological control of this disease has to be done. In general techniques which are based on the molecular techniques like marker assisted selection to deploy resistance have to be applied in the processes of creating resistant variety development.
Keywords: *Legumes, Root rot, Rhizocotonia, Fusarium and Trichoderma*

1. Introduction

The leguminosae (pea or bean family) are composed of some 690 genera and 18,000 species (Purseglove, 1968). It is the second largest family of seed plants (following the Gramineae) (Aykroyd and Doughty, 1964). Within the leguminosae, there are 18-20 species that are cultivated widely for their edible seeds which are high in protein (17-25+%) (Aykroyd and Doughty, 1964). The seeds of legumes are second only to cereals as the most important source of food for humans and animals (National Academy of Sciences, 1979). The term food legume generally is given to species of leguminosae, the seeds, pods, and/or leaves of which are eaten by humans. The word pulse is used in some countries colonized by Great Britain, like India and Pakistan, to denote the dry, mature seeds which are consumed by humans.

Particularly in Ethiopia legumes grown in 2014/15 (2007 E.C.) covered 12.41 % (1,558,442.04 hectares) of the grain crop area and 9.88% (about 26,718,430.40 quintals) of the grain production was drawn from the same crops. Faba beans, haricot beans (white), haricot beans (red), and chick peas were planted to 3.53 % (about 443,074.68 hectares), 1.00% (about 126,192.58 hectares), 1.57% (about 197,125.15 hectares) and 1.91% (about 239,747.51 hectares) of the grain crop area. The production obtained from faba beans, haricot beans(white) haricot beans (red) and chick peas was 3.10% (about 8,389,383.81 quintals), 0.75**%** (about 2,021,172.47 quintals), 1.15**%** (3,116,038.00 quintals) and 1.70**%** (4,586,822.55 quintals) of the grain production, in that order(CSA,2014/15).

Legumes, which occupy approximately 13 percent of cultivated land and account for approximately 10 percent of the agricultural value addition, are critical to smallholder livelihoods in Ethiopia. These legume crop have adverse roles top play in the country.

They contribute to smallholder income, as a higher-value crop than cereals, and to diet, as a cost effective source of protein that accounts for approximately 15 percent of protein intake and they correct important amino acid deficiencies in cereals.

Moreover, pulses offer natural soil maintenance benefits through nitrogen-fixing, which improves yields of cereals through crop rotation, and can also result in savings for smallholder farmers from less fertilizer use.

Pulses also contribute significantly to Ethiopia's balance of payments. They are the third largest export crop after coffee and sesame, contributing USD 90 million to export earnings in 2007/08 (International food policy research,2010).

The major constraints to the production of these crops are diseases, insect pest attack, poor agronomic practices and lack of improved cultivars and crop protection technologies. In addition, poor popularization of the recommended crop protection technologies following participatory approach is one of the main socio-economic reasons for low productivity of these crops. Root rot diseases are a major limiting factor in legume production. The diseases depress seedling germination and cause post emergence damping off, resulting in poor crop stand and low yields. The disease causal agents are seed borne but most farmers often use seeds saved from previous harvest, a practice that negates the principle of sanitary practices (Buruchara, 1990). The aim of these seminar was to present some available root rot management methods of legume crop and to make some suggestions on the methods which are not practice yet.

2.Literature review

2.1.Root rot Disease on Legumes

Soil-borne plant pathogens causing root rot and damping-off disease are among the limiting factors in plant production all over the world. These pathogens cause economic yield losses on faba bean (*Vicia fabae L.*),Lentil (*Lens culinaris)* and pea (*Pisum sativum L.*) and control is rather difficult (Agrios 2005). *Fusarium spp*., *Rhizoctonia solani*, *Pythium spp*., *Thielaviopsis basicola* and *Alternaria spp*. may be involved with root rot disease, independently or in general as a complex in any possible combination on each legume plant (Pieczarka & Abawi 1978a; Hatat & O¨ zkoc¸ 1997).

Although *Fusarium spp*. are common on beans and pea plants, especially *Fusarium solani. f. sp. phaseoli* on bean, *F. solani f. sp. pisi* on pea and *F. oxysporum f. sp. fabae* on faba bean causing root rot, damping-off and sudden death syndrome (Pierre & Wilkinson 1970; Huang & Hartman 1998). *Rhizoctonia solani* (Liu & Sinclair 1991; Nelson et al. 1996; Echavez Badel et al. 2000; Karaca et al. 2002; Erper 2003) and *Pythium spp*. (Karaca & Maden 2001) are also frequently isolated from the diseased legume plants.

Interactions between root rot pathogens can mostly increase disease severity. Yield loss of dry bean was greater when *Thielaviopsis basicola* and *F. solani f. sp. phaseoli* were together than when they were alone (Pieczarka & Abawi 1978a). Likewise, Hatat and O zkoc¸ (1997) found a high synergistic relationship between *Fusarium spp.* and *Rhizoctonia spp.* on bean plants.

Table1:List of root pathogen causing root rot of chickpea, faba bean and lentil in Ethiopia

No	Crop	Disease	Pathogen
1	Chickpea	Dry root rot	*Rhizoctonia bataticola*
		Wet root rot	*Rhizoctonia solani*
		Black root rot	*Fusarium solani*
2	Lentil	Dry root rot	*Rhizoctonia bataticola*
		Wet root rot	*Rhizoctonia solani*
3	Faba bean	Dry root rot	*Rhizoctonia bataticola*
		Wet root rot	*Rhizoctonia solani*
		Black root rot	*Fusarium solani*

Source: adapted from Nigussie et al.,1994

2.2 Symptom of root rot disease causing pathogen on legumes crop

After the seedling has emerged, continued cool wet weather often results in root rot. Symptoms will include stunted, yellow plants and may be mistaken for nitrogen. When the plant is dug up, the roots will be much thinner than a healthy plant or there may be no secondary roots at all. Roots will be discolored, and the color and pattern of discoloration depends on the pathogen infecting the roots. There are four main types: *Pythium root rot, Rhizoctonia root rot* (bare patch), *Fusarium root rot,* and *Aphanomyces root rot*. These fungal diseases affect a very broad host range, so crop rotation is of limited efficacy.

2.2.1. Pythium root rot

It is caused by the oomycete (water mold) *Pythium* spp. It is characterized by poor root system development, and can be difficult to diagnose. In general, roots will be brown in color and the outer cortex will peel off of the inner core of the root.

2.2.2. Fusarium root rot

It is caused by a number of different Fusarium species. Below-ground symptoms include brown to reddish brown discoloration and lack of secondary (small) roots. The severity of the infection often depends on the previous crop history and species of Fusarium present in the soil.

2.2.3. Rhizoctonia root rot

It is caused by the fungus *Rhizoctonia solani*. It is first diagnosed by poor or declining stands. Root development is poor and roots are generally black and soft. Rhizoctonia root rot will damage peas at relatively low soil temperatures (65°F or 18°C) but is most aggressive under warmer conditions (76° to 86°F or 24° to 30°C). *Rhizoctonia* infection and disease development can occur over a wide range of soil moistures.

2.2.4. Aphanomyces root rot
Its symptoms are similar to those of Pythium root rot. (Porter et al. 2009).

2.3. Economic significance of the root rot disease of cool season legumes crop
2.3.1. Economic significance of the root rot disease of chickpea
Root rots diseases that are caused mainly by *Rhizoctonia bataticola*(dry root rot),*Fusarium solani*(black root rot), *Rhizoctonia solani*(wet root rot) are the most important diseases worldwide. In Ethiopia, these diseases occurs in the main chickpea growing areas. But the major one being *Rhizoctonia bataticola* dry root rot(AARC,1992;Beniwal et al.,Tadesse et al.,1998a).When conditions are favorable for disease development causes up to 50%yield losses(Mengistu and Negash,1994).

2.3.2. Economic significance of the root rot disease of faba bean
The fungus *Fusarium solani* has been encountered on large number of hosts in Ethiopia, including on faba bean causing black root rot(PPRC,1998).Black root rot is the second most important disease of faba bean. Complete crop loss occur in severe infection conditions and when favorable condition prevail. In farmers' fields, a yield loss about 45% was estimated due to this disease.

2.3.3. Economic significance of the root rot disease of lentil
Wet root rot(*Rhizoctonia solani*) and dry root rot (*Rhizoctonia bataticola*)were the soil borne diseases affecting lentil production and productivity in Ethiopia. But as compared to root rot problem on faba bean and chickpea it is not a major problem affecting the lentil production. The major one problem is fusarium wilt (Ahmed and Ayalew,2006).

3. Control of root rot diseases of cool season legumes
Effective control strategies against root rot fungal pathogens have not been fully developed. Sanitation and use of clean planting material is the primary way of preventing root rot and other root diseases. Chemical seed treatment is a common practice before planting to prevent seed and seedling rots, damping off and other fungal diseases. However, problems arise when the chemical seed treatments are to be used in conjunction with rhizobia inoculants. In some cases the applied seed fungicide may fail to protect against the intended pathogen or suppresses the effectiveness of the rhizobia bacteria.

3.1 Control of the Root rot Diseases of chickpea
3.1.1. Cultural control
Cultivation methods involving destruction of inoculums pool in undecomposed fresh organic matter is an excellent medium for root rot causing pathogen at the time of seedbed preparation gives effective results in control of root rot disease(Ahmed and Ayalew,2006).*Fusarium solani* can be managed fungicide seed treatments and good weed control. Apply crop rotation with cereals. A longer crop rotation of at least 3 years is recommended after harvest of chickpea. Seed treatment with fungicides can reduce initial development of the disease. Timely sowing of chickpea should be done to avoid post-flowering drought and heat stresses, which aggravate the disease for controlling dry rot on chickpea.

3.1.2. Host plant resistance
Host plant resistance provides the cheapest and most sustainable disease control (Malik et al., 2006). Varietal differences exist in chickpea genotypes with respect to resistance to root rot pathogen(Ahmed et al.,1990; Bejiga and Anbessa,1994;Bejiga et al.,1998;Nigussie,1995).Three varieties namely Teji, Habru and Ejere selected directly from ICARDA lines, were released in 2004 and 2005.
They yield up to 4 t/ha, compared to 1 t/ha from landraces; and are resistant to root rot. They are large-seeded, fetching almost double the market price of traditional varieties(ICARDA,2010).

3.1.3.Biological control
Biological control may emerge as an alternative to chemicals, and offers economically viable and ecologically sustainable management of root rot disease. Study which are done in laboratory condition by Riyaz and his coilics(2012) using three bio-control agents such as *Trichoderma viride*, *Trichoderma harzinum* and *pseudomonas fleuresecense* revealed that, *Trichoderma viride* showed best performance against the pathogen, *Rhizoctonia bataticola*(Dry root rot), followed by *pseudomonas fluorescence*,(Table2) (Ruyaz et al.,2012)

Table2: Inhibitory effect of different bio-agents on the growth of Rhizoctonia bataticola in vitro incubated at 30 ± 1^0C

No	Bio-agents	Average diameter of fungal colony(cm)	% inhibition over control
1	*Trichoderma viride + Rhizoctonia Bataticola*	1.41	81.98
2	*Trichoderma harzium + Rhizoctonia Bataticola*	3.42	56.26
3	*Psedomonas Fleurescens + Rhizoctonia Bataticola*	5.55	29.15
4	Control	7.82	

Source: (Riyaz et al.,2012)

3.1.4. Integrated management of root rot of chickpea

Since the level of resistance in chickpea to fusarium root rot is not high, an integrated approach that includes cultural practices (drainage), maintenance of good seed vigor and genetic resistance is required. Study which was conducted by G.Amrutha and his colic,2016 by using different organic amendments like FYM, vermicompost and neem cake individually and in combination with potential fungicidal tolerant fungal antagonist *Trichoderma* isolate, bacterial antagonist screened from dual culture studies, also fungicide copper oxychloride were tested in their study against *Rhizoctonia bataticola* in pot culture under green house conditions.

Finally their result revealed that seed treatment with fungicide (Copper oxychloride) + soil application of potential fungal (*Trichoderma isolate)* and bacterial biocontrol agent was found to be superior as it recorded the highest germination percentage (100 %), highest initial (10.00) and final population of chickpea (9.66).

3.2 .Control of the root rot diseases of faba bean

3.2.1.Cultural control

Planting crops that are not host of *fusarium solani*: noug (*Guizota abyssinica*),rapeseed(*Brassica napus*) and linseed (*Linum usitatissimum* (PPRC,1996) in rotation with faba bean may reduce inoculum level in the soil. However, it is still not known to what extent would this inoculum reduction suppresses black root rot. The time interval occurring between the repeated cultivation of faba bean or another susceptible crop such as chickpea is not determined. Also proper drainage of faba bean field is essential to minimize the effect of this disease (Dereje and Tesfaye,1994a).Also planting of either the released faba bean cultivars Wayu (Moderately resistant) or local cultivar(Susceptible)with improved drainage system, roadbed and the furrow, reduce black root rot incidence and thereby increasing seed yield (ICARDA,2006).

3.2.2. Host plant resistance

The National Faba Bean Improvement Program and Regional Research Centers made efforts to identify sources of resistance to black root rot(PPRC,2003) and there by develop black root rot resistance varieties possessing high yield. These efforts resulted in the development and release of four black root rot disease resistance varieties of faba bean. namely Wayu, Selale, Lalo and Dagim (NAIA,2003).The first two varieties (Wayu and Selale) perform well under waterlogged condition and have been released for general cultivation in the country in 2002.Also screening which are done by using 10 released of for their reaction to black root rot pathogen/isolate revealed that varieties namely Wayu,Tesfa,Bulga,Kasa,CS20Dk and Holetta were not attack by the tested isolates.

3.2.3.Biological control

Biological control is proposed to be an effective and non-hazardous strategy to reduce crop damage caused by plant pathogens .The role of *Trichoderama viride* in protecting plants from the black root rot infection has been tested on the faba bean under green house conditions(Tesfaye,1999a).The results of this study suggest that the biological control agent *Trichoderama viride* can play a role in a means for the control of the black root rot in faba bean.

Another study which were done abroad with the basis of using of synthetic plant resistance inducers like salicylic acid (SA) and hydrogen peroxide (H_2O_2) as antimicrobial agents or disease resistance inducer revealed that the tested biocontrol agents and chemical inducers either individually or combination significantly reduced linear growth of Black rot casing fungi. In general, the combination between biocontrol agents and chemical inducers were more effective than used any of them individually. SA + *T. viride* and SA + *B. megaterium* were the most effective where they recorded the highest percentages of reduction in the tested pathogenic fungi. However, SA followed by H_2O_2 recorded the lowest reduction of growth in tested fungi. Generally from their study, biocontrol agents were able to reduce linear growth of the tested pathogenic fungi more than chemical inducers (Table3).

Table 3. Effect of biocontrol agents and chemical inducers individually or combination on growth of pathogenic tested fungi in vitro

No	Inhibition of linear growth (%)	
	Treatments	*Fusarium solani*
1	*Trichoderma viride*	55.58 c
2	*Bacillus megaterium*	49.22 d
3	Salicylic acid (SA)	13.56 e
4	Hydrogen peroxide (H2O2)	16.25 e
5	SA + *T. viride*	70.54 a
6	SA + *B. megaterium*	63.25 b
7	H_2O_2 + *T. viride*	59.25 bc
8	H_2O_2 + *B. megaterium*	57.47 c

Different letters indicate significant differences among treatments within the same column according to least significant difference test ($p \leq 0.05$).
Source: Motaser,2013

3.3. Control of the Root rot Diseases of lentil
In Ethiopia root rot disease of lentil is not a major problem the major problems are wilt and rust diseases. But, there are several works which are done to control root rot disease on lentil.

3.3.1.Chemical control of root rot disease on lentil
Several chemical (fungicides) were tested for control of root rot disease on lentil in the past. Study which were done abroad by M.A Hoque and his colic 2014, by using different fungicides revelead that, the tested fungicides significantly decreased incidence of root rot of lentil and increased yield. Among the fungicides they were tested highest performance was found with Secure 600wg (0.2%) (Fenamidone + Mancozeb) in controlling the incidence of root rot(Table4) (M.A Hoque,2014).

Table 4. Incidence of foot and root rot of lentil due to application of fungicides at seven days interval

Treatment	Disease incidence (%)				
	25 DAS	35 DAS	45 DAS	55 DAS	Mean
T1	1.48ab	4. 36c	6. 28b	7. 07c	4.80c
T2	0. 99d	1. 99e	3. 66d	5. 49d	3.03e
T3	1. 39c	5. 05b	7. 96a	11.18b	6.40b
T4	1. 51ab	3. 35d	5. 03c	6. 96c	4.21d
T5	1. 67a	6. 82a	8. 21a	13. 30a	7.50a
$LSD_{0.05}$	0.19	0. 55	1. 01	0. 530	0.57
CV%	7.77	8. 28	9. 57	3.70	7.33

Source: (M.A Hoque,2014).
T1= Rovral 50 wp; T2= Secure 600 wg; T3= Bavistin 70 wp; T4= Captan 50 wp; T5= Control Figures in the column having common letter(s) do not differ significantly at 5% levels by LSD.

3.3.2. Biological control
Biological control is proposed to be an effective and nonhazardous strategy to reduce crop damage caused by plant pathogens. Study which were done abroad with the basis of using of synthetic plant resistance inducers like salicylic acid (SA) and hydrogen peroxide (H_2O_2) as antimicrobial agents or disease resistance inducer revealed that the tested biocontrol agents and chemical inducers either individually or combination significantly reduced linear growth of wet root rot casing fungi. In general, the combination between biocontrol agents and chemical inducers were more effective than used any of them individually. SA + *T. viride* and SA + *B. megaterium* were the most effective where they recorded the highest percentages of reduction in the tested pathogenic fungi. However, SA followed by H_2O_2 recorded the lowest reduction of growth in tested fungi. Generally from their study, biocontrol agents were able to reduce linear growth of the tested pathogenic fungi more than chemical inducers(Table5).

Table 5. Effect of biocontrol agents and chemical inducers individually or combination on growth of pathogenic tested fungi in vitro

No	Inhibition of linear growth (%)	
	Treatments	*Rhizoctonia solani*
1	*Trichoderma viride*	38.47 d
2	*Bacillus megaterium*	32.33 e
3	Salicylic acid (SA)	8.87 f
4	Hydrogen peroxide (H2O2)	11.36 f
5	SA + *T. viride*	57.00 a
6	SA + *B. megaterium*	46.41 b
7	H_2O_2 + *T. viride*	42.24 c
8	H_2O_2 + *B. megaterium*	40.14 cd

Different letters indicate significant differences among treatments within the same column according to least significant difference test ($p \leq 0.05$).

Source: Motaser,2013

Another study which were conducted abroad by M.A Kashem,2014 to control root rot caused by *Fusarium solani* by bio-agents revealed that Macerated extract of *Fusarium solani* + *Trichoderma harzianum* showed the best result in controlling root rot of lentil with the highest seed germination(100%), radical length (1.56 cm), seedling emergence (95.73%), root length (8.16 cm), shoot length (17.75 cm), number of branches/5 plants (15.56). The lowest root rot (25.93%) was also observed in the treatment of *Fusariumsolani* + *Trichoderma harzianum*.

4. Summary and conclusion

The leguminosae (pea or bean family) are composed of some 690 genera and 18,000 species (Purseglove, 1968). It is the second largest family of seed plants (following the Gramineae) (Aykroyd and Doughty, 1964). The seeds of legumes are second only to cereals as the most important source of food for humans and animals (National Academy of Sciences, 1979).

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Soil-borne plant pathogens causing root rot disease are among the limiting factors in plant production all over the world. These pathogens cause economic yield losses on faba bean (*Vicia fabae L.*),Lentil (*Lens culinaris)* and pea (*Pisum sativum L.*) and control is rather difficult (Agrios ,2005). *Fusarium spp*., *Rhizoctonia solani*, *Pythium spp*., *Thielaviopsis basicola* and *Alternaria spp*. may be involved with root rot disease, independently or in general as a complex in any possible combination on each legume plant (Pieczarka & Abawi 1978a; Hatat & O zkoc¸ 1997).

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Several chemicals, cultural practice and bio-gent used to control this disease. Among bio-agent mostly used to control this disease are *Trichoderma viride* and *Bacillus megaterium* take a great share. In the future particularly in our country full exploitation of the potential of biological control of this disease has to be done. In general techniques which are based on the molecular techniques like marker assisted selection to deploy resistance have to be applied in the processes of creating resistant variety development.

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