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Review on Epidemiology and Management of Faba Bean (*Vicia fabae*) Chocolate Spot (*Botrytis fabae*), Root Rot (*Fusarium solani*) and Rust (*Uromyces vicia fabae*) in Ethiopia

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Abstract- Of all pulse crops grown in Ethiopia, faba beans stand 2nd after common beans and before chickpeas which are all considered to be the top export crops accounting 90% by volume and 85% total earnings. However, diseases such as chocolate spot, root rot and rust are the major biotic constraints affecting yield wherever the crop grows. Yield losses of up to 61% on susceptible cultivars and 30-50% under favorable conditions for chocolate spot were reported. Root rot was also recognized to cause complete crop loss during severe infections and yield loss may reach 100% in susceptible cultivars. Rust epidemics in addition identified to reduce faba bean yields with losses of up to 30%, while, in combination with chocolate spot, yield reductions of up to 50% have been reported. Control options for disease in general include high levels of resistant cultivars, planting good quality seed and fungicide applications integrated either with cropping system or early planting to manage faba bean chocolate spot. Integrated management was also reported to control faba bean root rot with the help of biocontrol agents. In this regard, soaking seeds in biocontrol agents (Bacillus megaterium and Trichoderma viride) and the use of Trichoderma harzianum as seed dressing or soil application with improved faba bean cultivars and fungicidal seed treatments consistently found to improve emergence and seed yield of faba bean. Artificially inoculated faba bean seedlings with the native antagonistic Bacillus isolates found to suppress black root rot. Integration of improved faba bean cultivars with protective fungicides application was also reported to gain higher monitory advantage. Similarly, faba bean-maize row intercropping and compost fertilization using host resistance and other crop management practices have found best to manage faba bean rust. In this review, developments discussed on management of chocolate spot, root rot and rust of faba bean were focusing on an integrated management either through host resistance with cropping systems and fungicide applications or host resistance with biocontrol agents. However, almost all the earlier findings were mainly limited either to research stations or greenhouse and laboratory experiments. This is, therefore, the current review is initiated with the objective that future research works to explore these best practices under farmers' field condition along with supplementation of greenhouse and laboratory experiments considering mass production of the locally identified indigenous biocontrol agents in particular for seed or soil borne diseases such as faba bean root rot.

Index Terms- Botrytis fabae, Faba bean, Fusarium solani, Management, Uromyces vicia fabae

I. Introduction

The pulse sector has the potential to be a key accelerator of agricultural development and growth in Ethiopia. Of all pulses in the country, common beans, faba beans and chickpeas are the top export crops accounting for 90% of export volumes and 85% of export earnings [44]. Faba bean (*Vicia faba* L.) is one of the earliest domesticated food legumes in the world, mainly used as human food in developing countries and as animal feed in industrialized countries [30]. The crop covers nearly 370,000 hectares of land with annual production of about 450, 000 metric tons and grows from 1800 to 3000 m a s l with annual rainfall of 700-1000 mm in Ethiopia [32].

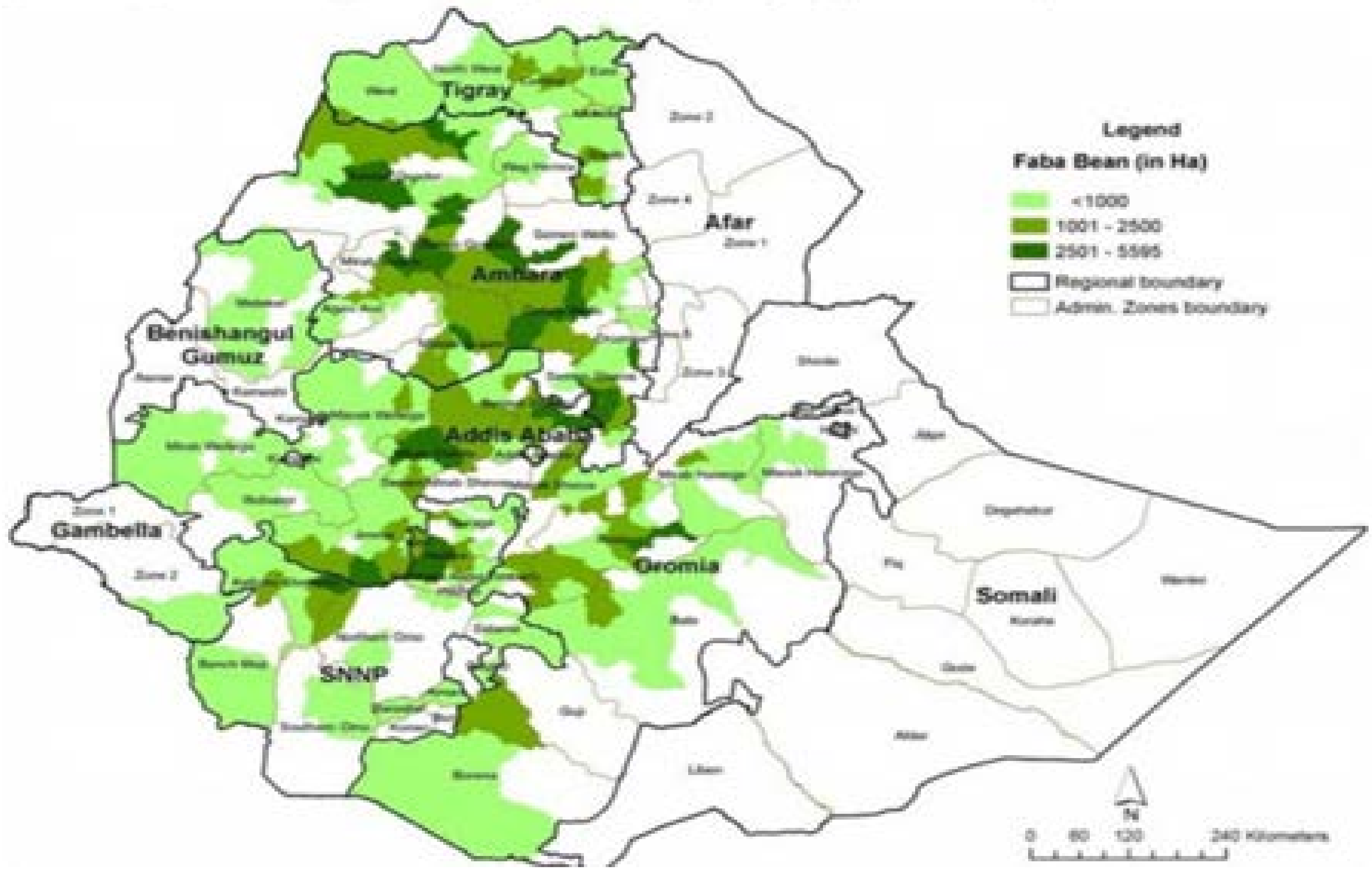

Fig 1. Land area in hectares under faba bean in Ethiopia
Source: IFPRI (2010b)

The growing importance of faba bean as an export crop in Ethiopia has led to a renewed interest by farmers to increase the area under production [38]. However, the average yield of this crop under small-holder farmers in the country ranges from 1.0-1.2 t ha^{-1} [2], as compared with its potential (more than 3 t ha^{-1}) under farmers' conditions that employ improved crop management practices [28]. In spite of its huge importance, the productivity of faba bean has been constrained by several biotic and abiotic factors among which chocolate spot (*Botrytis fabae*), root rot (*Fusarium solani*) and rust (*Uromyces vicia fabae*) are considered to be the most important biotic factors and destructive in Ethiopia. Yield losses of up to 61% on susceptible cultivars and 30-50% under conditions favorable for disease development due to chocolate spot were recorded [16, 35].

Chocolate spot can result in flower abortion or poor seed set so monitoring your fields closely and being able to act quickly when symptoms appear is important for protecting healthy tissue [22]. Control options for disease include choosing more resistant varieties, fungicide applications, and planting good quality seed with low infection levels. Integration of faba bean varieties with foliar sprays protected high chocolate spot epidemics, increased yield, yield components and maximized marginal benefit compared to a single control approach [13]. It was also reported from Northern and South-Eastern Ethiopia that fungicide applications integrated with cropping systems (faba bean with cereals), considerably reduced disease severity and increased faba bean grain yield and system productivity [36].

Root rot is another threat to production of faba bean in the high lands of Ethiopia [8] resulting in complete crop loss during severe infections and yield loss may reach 100% in susceptible cultivars [31]. It was reported [18] that the pathogens causing root rot live near the rhizosphere and survive for a long period by forming resistant structures that make management of the disease difficult.

Rust epidemics can significantly reduce faba bean yields. Alone the disease has caused losses of up to 30%, while, in combination with chocolate spot, yield reductions of up to 50% have been documented [34]. Disease survey [26] also revealed that the incidence and severity of faba bean rust showed higher association with altitude, and high occurrence and distribution in different districts of the Hararghe Highlands of Ethiopia. Effective management of faba bean diseases is paramount importance to ensure food security in the country and to improve availability of raw material for local industry and export markets. Effective disease management in general relies on selection of suitable disease resistant variety, most suitable field and clean seed, best agronomic practices and fungicide applications integrated with resistant hosts, cropping systems and biocontrol agents where it is feasible in particular for faba bean diseases. Therefore, the current review is initiated with the intention that future research works to explore the integrated management practices under end users (farmers') field condition considering mass production of the locally identified indigenous biocontrol agents along with supplementation of greenhouse and laboratory experiments in particular for seed or soil borne diseases such as faba bean root rot. In the future especially in our country full exploitation of the indigenous biocontrol agents should be emphasized above all.

II. Disease Epidemiology

1.1. Chocolate spot of faba bean

Chocolate spot of faba bean caused by *Botrytis fabae* has developed worldwide, occurring in almost all regions where faba beans are grown and is capable of devastating unprotected crops up to 67% [9, 17].

The pathogen *Botrytis fabae* induces lesions or symptoms equally on the upper and lower leaf surfaces of faba bean with large number of spots called "chocolate spots" appear on the leaflets, petals and pods, elongated on the stems, and tend to be evenly distributed [25]. The disease is first seen as reddish to chocolate brown, slightly flattened spots appearing on lower leaves. This is its 'non-aggressive' phase, which is thought to have little effect. However; if mild, wet conditions persist for several days, the disease will spread quickly and be termed 'aggressive'. The disease progresses up the canopy, with the spots rapidly expanding into large patches, which blight the leaves. Plants defoliate and lose flowers and pods. Stems can become reddish-brown and weakened, with a strong tendency to lodge. Young leaves expanding at the top of the plant may outgrow the disease if conditions dry out; lost flowers and pods cannot be recovered [29]. The greatest risk period is normally from late July to late September in most faba bean growing areas. Chocolate spot is considered to be the most important and destructive in Ethiopia causing the yield loss of up to 61% on susceptible cultivars [16].

A mean disease severity of 35.4% and 68.9% was reported from two locations on local faba bean:barley unsprayed intercropping in the Arsi Highlands, Southeastern Ethiopia [40]. The disease is favored by warm temperature (15-22^{0}C) and humid weather (above 90% RH) conditions. Mean disease incidence of 47 to 100% and disease severity of 17 to 49% were reported from surveys conducted in 2004 and 2005 in Northern Ethiopia [37]. Chocolate spot epidemics occur frequently and caused yield losses since farmers grow local susceptible landraces and do not apply fungicides to manage the disease especially in the highlands of Ethiopia. Planning and implementing of successful fungicide spray programs that relay on crop monitoring, correct disease identification and timeliness of spraying with the correct product are crucial. Be aware of the critical periods for disease management.

Disease progress of chocolate spot based on severity scores of selected representative varieties in greenhouse at Ambo Plant Protection Research Center revealed resistant faba beans, moderately resistant and susceptible varieties showed different reactions to the disease [6] (Table 1).

Table 1. Disease progress of chocolate spot based on severity scores of selected representative faba bean varieties in the greenhouse at Ambo plant protection research center (APPRC).

Genotype	GDS (%)	Reaction	RAUDPC (AUDPC)	Grain yield (t ha-1)	Rank based on GDS
Gebelcho	14.848	MR	0.30 (516.6)	3.99	47
Moti	16.493	MR	0.36 (629.5)	4.69	57
Dosha	17.707	MR	0.33 (584.3)	4.09	66
CS-20-DK	23.468	S	0.39 (680.9)	2.68	94
NC58	24.554	S	0.38 (662.5)	2.59	96
Bulga-70	24.557	S	0.37 (649.8)	3.42	97
Kasa	32.251	S	0.40 (698.9)	2.66	100
Trial Mean	15.402			3.43	

Descriptions: R= resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible. RAUDPC: relative area under disease progress curve value, number in bracket AUDPC, GDS: general disease severity score

Disease surveys of faba bean [10] have also shown that Fusarium root rot is an important soil-borne disease and approximately 30% of several commercial fields had infected taproots and damaged fibrous roots, which resulted in stunting, wilting, and yield loss.

2.3. Faba bean rust

Faba bean rust is among the most important fungal foliar diseases which provoke partial defoliation and decreases photosynthesis and yield [41]. The disease is first seen on leaves as small, light green spots which erupt into red powdery (rusty) lesions. These increase in time to densely cover the leaf surface, and later to develop on the stems [29]. If the fungus infects a young plant, it can seriously stunt bean growth, leading to severe yield loss.

The presence of a high weed population in a field increases the humidity within the crop canopy which is more favorable for Uromyces viciae-fabae infection and the development of rust epidemics. Once inside the plant, the fungus grows and develops in the leaf. Leaves wither and die: as the fungus grows through the leaf, it reduces the area that can be used for photosynthesis. It steals food from the plant using specialized feeding structures (haustoria). The fungus matures after 10-12 days and forms pustules, which burst back through the breathing holes and release more rusty colored spores into the environment. The fungus grows best in July and August, as it requires warm and prolonged wet conditions to infect bean plants. Bean rust can reduce the crop yield by up to 30% on its own and when combined with the chocolate spot, yields can drop by 50% [7].

Rust can survive on crop debris or on volunteer crops. Rust pustules can often be found on the lower leaves of volunteer plants surviving in the previous year's fields. However, spore production is encouraged by high humidity and warm temperatures. Spores are released from the maturing pustules and can be blown large distances by wind until they are deposited on a susceptible host crop. Spore germination occurs quickly in the presence of a light film of moisture on the leaf surface. Infection of the rest of the foliage and the surrounding plants follows further production of spores from the new pustules [7]. Survey conducted [26] in the Eastern Highlands of Ethiopia indicated that environmental and cultural variables were associated with faba bean rust incidence and severity either singly or in combination. It was identified that in different districts, altitude, growth stage, sowing date and weed management influenced faba bean rust epidemics. There were also a higher number of rust-infected plants within fields when faba bean was planted as sole compared with fields intercropped with field pea, barley, wheat, maize, and sorghum. Accordingly, integration of resistant varieties, better cultural practices and fungicide applications are considered suitable if they are combined with cereal-faba bean cropping system.

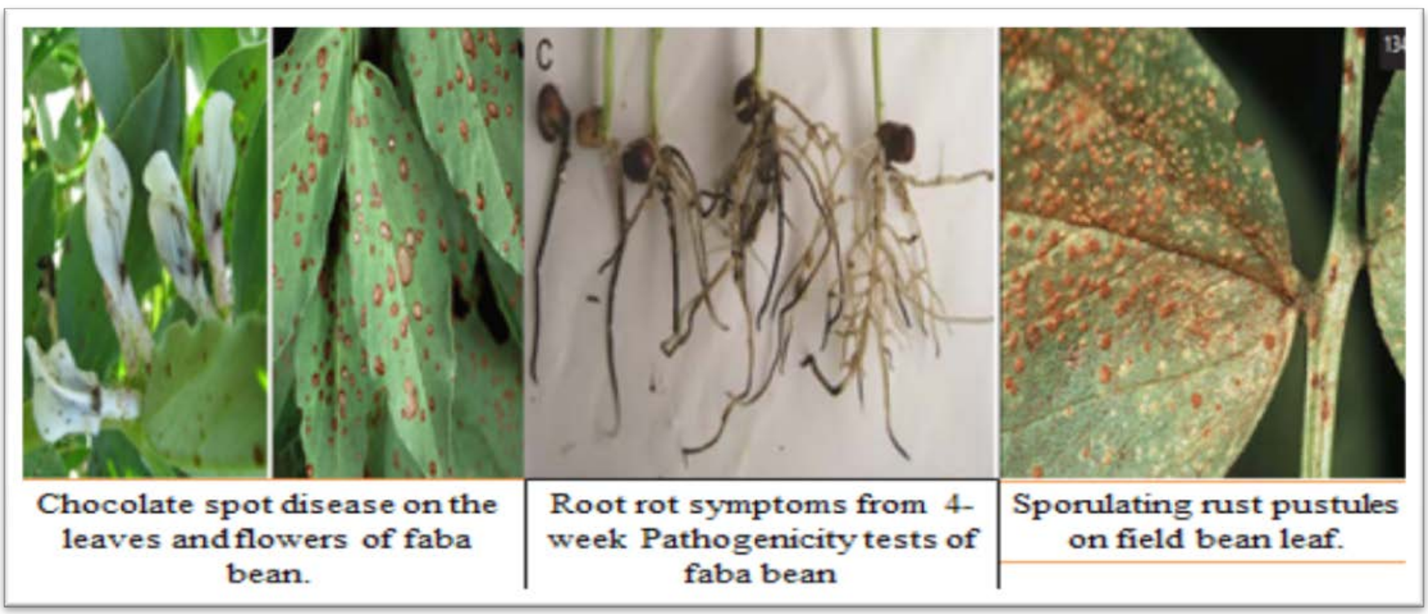

Figure 2. Disease symptoms of faba bean chocolate spot, root rot and rust (left to right), respectively.
Source: [3, 21]

III. Disease Management

3.1. Chocolate spot

Faba bean total harvested area is increasing in Ethiopia which is attributed to the demand of the crop in the country. This is a challenge to breeders and therefore, management should be prioritized for the major problem to improve faba bean productivity [12]. Chocolate spot can result in flower abortion or poor seed set, so monitoring fields closely and being able to act quickly when symptoms appear is important for protecting healthy tissue. Once tissues become infected there is no way of curing it. Control options for disease include choosing more resistant varieties, planting good quality seed with low infection levels and fungicide applications [22]. Several methods may be applied to manage the chocolate spot of faba bean which include cultural practices, chemical control, and integrated pest management.

Applications of fungicide integrated with faba bean:barley intercropping considerably reduced disease severity and increased faba bean grain yield and system productivity (LER) by a mean relative yield advantage of 35% in the Arsi Highlands, South-Eastern Ethiopia [40]. Study by Samuel [36] also revealed that the mixed cropping of faba bean with barley and maize contributed to the slowing of chocolate spot epidemics and increased grain yield of faba bean. Participatory evaluation of a high yielding and disease resistant faba bean variety such as Hachalu has a yield advantage than the local varieties and the highest seed weight for export purpose to increase farmers' income in Northern Ethiopia [43]. Early sowing integrated with fungicide application had enabled growers' to effectively manage chocolate spot on faba bean in Central and South-Eastern Ethiopia [14, 19]. As reported from Northern Ethiopia [39], Biocontrol agents, particularly of Trichoderma species are prevalent on faba bean leaves and can be further explored and developed into effective mycofungicides for faba bean chocolate spot management.

3.2. Faba bean root rot

Integrated management is the most promising alternative to control faba bean black root rot that cause up to 70% on farm yield loss in severe conditions in Ethiopia [1]. Soaking faba bean seeds in biocontrol agents (Bacillus megaterium and Trichoderma viride) and chemical inducers [salicylic acid and hydrogen peroxide (H_2O_2)] individually or in combination significantly reduced damping-off, root rot and increased survival of plants either under green house or field conditions. Habtegebriel and Boydom [24] also reported that the use of antagonistic indigenous fungus Trichoderma harzianum as seed dressing or soil application treatment in combination with three faba bean varieties viz. Kasa (susceptible), Wolki (moderately resistant) and Wayu (resistant) in two consecutive cropping seasons in a sick plot showed significantly less percentage of dead plants (65.64%) than the treatments without Trichoderma harzianum (86.04%) (Figure 3).

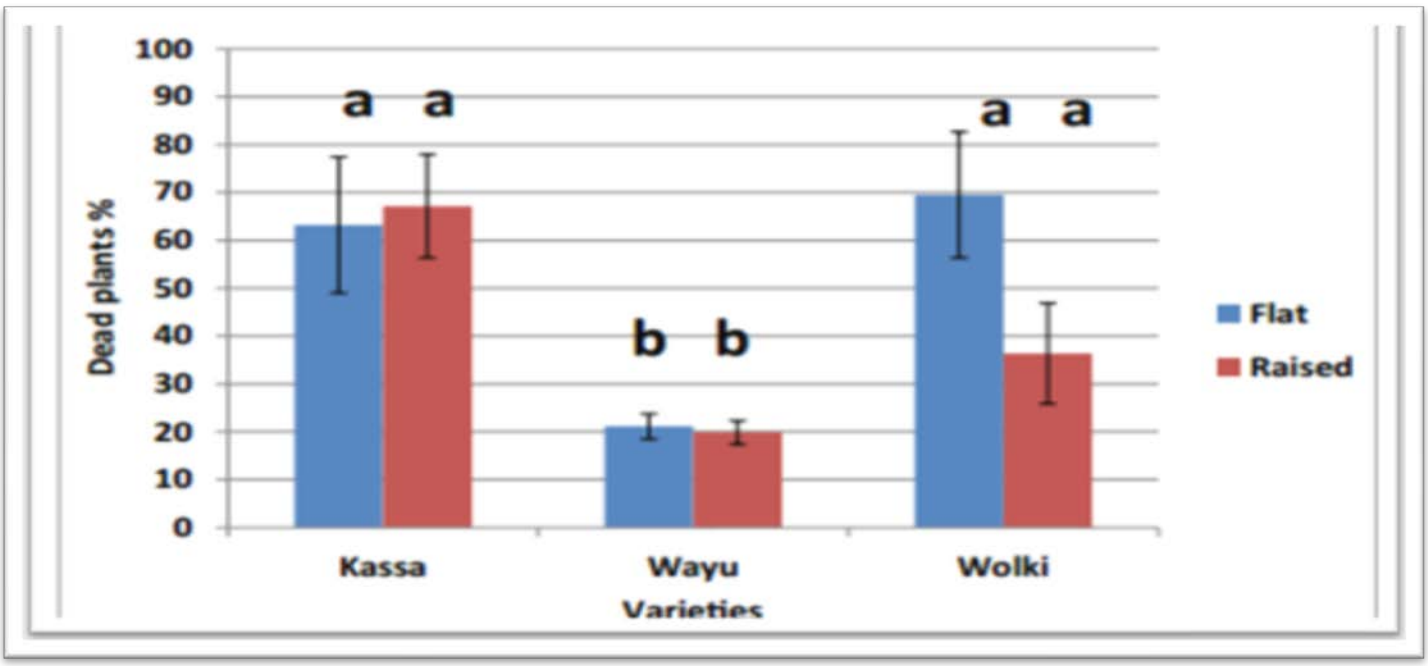

Figure 3. Percentage of dead plants due to black root rot for three faba bean varieties and drainage methods on raised and flat beds.

Fungicidal seed treatments with Apron Maxx (Fludioxonil + Metalaxyl) and Vitaflo 280 (Carbathiin + Thiram) consistently improved emergence and seed yield in trials inoculated with Fusarium avenaceum and Rhizoctonia solani in Canada [11]. Study conducted in North Shoa of Ethiopia by Habtegebriel and Boydom [24] also revealed that the integration of varietal resistance (either Wolki or Wayu), drainage method and sowing date's adjustment are important for effective management of faba bean root rot. However, emphasis should be given to varietal resistance and use of raised beds especially on vertisols for higher yield and variety improvement programs. In vivo experiment on artificially inoculated faba bean seedlings showed the native antagonistic Bacillus isolates kept black root rot severity lower than 50% disease suppression, compared to the untreated control [20]. The above promising results can initiate more widespread faba bean cultivation through exploitation of the indigenous biocontrol agents in combination with resistant hosts and appropriate fungicide applications particularly in the highlands of Ethiopia where there is heavy clay soil condition that can aggravate the risk of faba bean root rot. Integration of appropriate cultural practices and native biocontrol agents are also supposed to be crucial for sustainable crop productivity and faba bean root rot sound management.

3.3. Faba bean rust

Climate change resilient cultural practices alone and in integration found to be effective to slow the epidemic progression of faba bean rust and improve crop productivity in the prevailing climate change effects in the Hararghe Highlands, Eastern Ethiopia [42]. According to this report, faba bean-maize row intercropping and compost fertilization in row intercropping in particular using host resistance and other crop management strategies to manage faba bean rust had significantly reduced disease progress rate, AUDPC and severity by up to 36.5% and 27.4% during the 2012 and 2013 cropping season, respectively. Study in the United Kingdom [7] revealed that there are several ways to prevent faba bean rust which include growing different crops each year and removing left over plants to prevent fungal spores building up. Planting faba bean varieties that are resistant to rust and spraying fungicides as an integrated management strategy should be considered best option to kill the fungus.

Survey results from the Hararghe Highlands, Eastern Ethiopia [26] suggested the importance of research on weed management and other related cultural practices to supplement effective rust management options in the surveyed areas and elsewhere with similar agro-ecological settings. Moreover, extensive and consistent survey is recommended to know the intensity of the disease in similar agro-ecology of the country where the crop is widely grown. It was also reported that improved faba bean cultivar Gebelcho when integrated with fungicide (mancozeb) applications gave higher monitory advantage than the other treatments. Therefore, according to this study, mancozeb can be recommended to manage faba bean rust on both local (NC58) and moderately tolerant (Gebelcho) cultivars and when mancozeb is not available it is possible to use the systemic fungicide, triadimefon. Preventative fungicides (mancozeb and chlorothalonil) application at early time have a season lasting effect through delaying buildup of faba bean rust inoculum under field condition [45].

IV. FUTURE TRUST

Faba bean diseases particularly chocolate spot, root rot and rust are more serious in Ethiopia now days than they were in the past unless more effective and sustainable methods of management strategies are applied of which the following options will be considered best.

i) Make faba bean part of a cropping system: Involving either crop rotation or mixed/row intercropping of faba bean associated with cereal crops (wheat or barley or maize) is crucial.

ii) Choose the right variety and disease free-seed: Grow varieties with resistance; sow disease-free seed; sow away faba bean from bean residues of the previous year more than 500m (including self-sown plants) [7]. This will isolate the crop from sources of infection by fungal diseases. Volunteer faba bean plants appearing in late seasons can help to carry over diseases and should be eradicated.

iii) Sowing time: Minimize the risk of foliar diseases such as chocolate spot and faba bean rust due to excessive vegetative growth. Early emergence leads to early exposure to disease and early canopy closure, increasing development of disease. However, early planting integrated with fungicide applications was found the most promising strategy to manage faba bean chocolate spot [19].

iv) Sowing rate and spacing: Higher than ideal seeding rates and plant populations lead to a dense crop canopy and increase disease risk. Risk of chocolate spot is greatest in dense, early sown or lodged crops. Wider rows can delay canopy closure, reducing the risk of chocolate spot in particular. Any increased lodging may increase the chance of foliar disease. Therefore, optimal seeding rates and proper spacing can be considered ideal methods to control the disease and to maximize seed yield of faba bean.

v) Fungicide application: Know the disease threats to faba beans in specific locations, and how to manage them. The impact of fungal diseases on yield can be diminished in most areas through the use of fungicides either by seed dressing or foliar applications: (a) Success is dependent on monitoring, correct disease identification, coverage, rate and timeliness of sprays with the correct fungicide, (b) Reduce seed transmission of disease with Thiabendazole + Thiram application (helps control Botrytis fabae of faba bean and seedling root rots). (c) Chlorothalonil, mancozeb or metiram used as a foliar spray to control chocolate spot has the added benefit of controlling ascochyta seed staining and rust [27].

vi) Integrated disease management (IDM): To reduce the risk of disease damage growers will need to implement an integrated disease management strategy. This strategy should give more emphasis above all to a combination of cultural practices (crop rotation, cereal-faba bean mixed or row intercropping, etc.), resistant host plants, scheduled fungicide applications and the use of indigenous biocontrol agents for effective, economical, safe and sustainable management of faba bean chocolate spot, root rot and rust to increase the crop productivity that can help in ensuring food self-sufficiency in the country.

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