Journal of
Plant Pathology & Microbiology
ISSN: 2157-7471

Belete and Bastas, J Plant Pathol Microbiol 2017, 8:3
DOI: 10.4172/2157-7471.1000403

Review Article Open Access

Common Bacterial Blight (*Xanthomonas axonopodis* pv. phaseoli) of Beans with Special Focus on Ethiopian Condition

Belete T[1]* and Bastas KK[2]

[1]*Department of Plant Sciences and Horticulture, College of Dry Land Agriculture, Samara University, Samara, Ethiopia*
[2]*Department of Plant protection, Faculty of Agriculture, Selcuk University, Campus/Konya, Turkey*

Abstract

Common bacterial blight (CBB) is the most devastating factor that affects common bean crops in all common bean growing areas. This review was to review with an objective of reviewing the biology, economic importance of CBB of common bean crop disease and its management options, with an emphasis on the future research direction and priorities. CBB disease, caused by the gram-negative bacterial pathogen *Xanthomonas axonopodis* pv. phaseoli (*Xap*) and its fuscans variant *Xanthomonas fuscans* subsp. *fuscans (Xff)* is the major bottleneck in bean production in the world as well as in Ethiopia. It is a serious bacterial disease of common bean which causes lesions on the leaves, stems, pods and seeds of the plant. The disease affects seed quality and can reduce yield by up to 45%, may be more in susceptible cultivars. CBB is very difficult to control due to seed-borne nature of the bacteria and its capacity to produce huge amounts of secondary inoculum. Since the disease is very important in causing economic losses of yields on bean crop, developing and using effective and appropriate management options is unquestionable. Using resistant varieties supplemented with chemical seed treatment and proper cultural practices could be the best alternative options in managing common bacterial blight of common bean and avoiding yield loss. In general, integrated disease management is the preferred strategy because of increased understanding on residual effects of chemical control on non-target organisms and environment as well as the limitation of a single alternative management option to achieve the same level of control and reliability as that of chemical. In the case of Ethiopia, emphasis should be given to developing multi line resistance varieties by suitable breeding practice and developing molecular markers to enhance marker assisted selection.

Keywords: CBB; *Xap*; Common bean; Seed; Yield loss; Disease; Seed borne

Introduction

Common bean (*Phaseolus vulgaris* L.) is a nutritionally and economically important food crop grown around the world [1-3]. The annual global common bean production is approximately 12 million metric tons, with 5.5 and 2.5 million metric tons alone in Latin America Caribbean (LAC) and Africa, respectively [4,5]. The highest producer is India at more than 4 million metric tons per year [6]. In general, in 2010, global common bean production was approximately 23,816,123t, with 24.4 and 17.7% of the world production in LAC and Africa, respectively [7].

Common bean is an important source of nutrients about 500 million people in parts of Africa and Latin America, representing 65% of total protein consumed, 32% of energy [4,8,9]. Minerals and nutrients such as iron, phosphorus, magnesium, potassium, calcium, zinc and folate (B vitamin) are found in common beans and contribute to a balanced healthy diet [10,11].

It is assumed that common bean was introduced to Ethiopia in the 16th century by Portuguese [12]. Economic significance of common bean in Ethiopia is quite considerable since it represents one of the major food and cash crops. It is often grown as cash crop by small-scale farmers and used as a major food legume in many parts of the country where it is consumed in different types of traditional dishes [13]. According to research results, under the optimal management conditions, productivity of common bean can reach to 2.5 to 3.0 ton per hectare in Ethiopia. However, the actual average production from 2008 to 2010 production year is only 1.4 ton per hectare which is very far from the potential yield of the crop. It is mainly grown in eastern, southern, south western, and the Rift valley areas of Ethiopia [14,15]. Especially in semi-arid and sub-humid highlands of Hararghe, it is grown mostly intercropped with sorghum, chat and maize and seldom as a sole crop by subsistence farmers [16,17].

The production constraints reported in the literature for common beans are poor agronomic practices, soil infertility, lack of improved cultivars, moisture stresses, weed competition, and damage caused by pests and diseases [18,19]. Rust (*Uromyces appendiculatusa* (Pers., Unger), anthracnose (*Colletotrichum lindemuthianum* (Sacc.) Magnas), common bacterial blight (*Xanthomonas axonopodis* pv. phaseoli), angular leaf spot (*Phaeoisariopsis griseola* (Sacc. Ferr), web blight (*Rhizoctonia solani* pv. phaseoli (Kuhn.), root rots (*Fusarium solani* pv. Phaseoli (Mart.) Sacc bean common mosaic virus (BCMV) and bean golden mosaic virus (BGMV) are the major diseases identified and cause considerable yield reduction in Ethiopia [13,20].

Common bacterial blight (CBB) is a significant seed borne disease of common bean, caused by the gram-negative bacterial pathogen *Xanthomonas axonopodis* pv. phaseoli (*Xap*) and its fuscans variant *Xanthomonas fuscans* subsp. *fuscans (Xff)* [21,22]. Both strains cause identical symptoms but *Xanthomonas phaseoli* var. *fuscans* has been reported to be more aggressive [23].

CBB affects foliage, pods and seeds of common bean and is considered as the major problem in most common bean production areas of the world. During extended period of warm and humid weather, the disease can be highly destructive and causes losses in both yield and seed quality of bean in many production areas of Ethiopia [24,25]. It is widespread

***Corresponding author:** Belete T, College of Dry Land Agriculture, Department of Plant Sciences and Horticulture, Samara University, JTM-17-311[R]371, Samara, Ethiopia, Tel: (307)7663103; E-mail: tibebubelet@su.edu.et

Received March 09, 2017; **Accepted** March 22, 2017; **Published** March 29, 2017

Citation: Belete T, Bastas KK (2017) Common Bacterial Blight (*Xanthomonas axonopodis* pv. phaseoli) of Beans with Special Focus on Ethiopian Condition. J Plant Pathol Microbiol 8: 403. doi: 10.4172/2157-7471.1000403

throughout African's bean growing area and most prevalent at low to mid altitude under warm condition [26]. CBB is seen wherever beans are produced and is an economically-important disease that can reduce yield from 10% to 45% depending on the environmental conditions and genotype [27]. It is not easily controlled by cultural practices or chemical application when disease pressure is high. The effect of the disease is most severe on non-resistant varieties grown in warm, humid growing conditions. The disease has been reported in many parts of Ethiopia and causes yield reduction of 22.4% in Eastern part of the country [24].

In Ethiopia, CBB is ranked among the most important and wide spread diseases of common bean. It is reported as the main constraints to common bean production throughout the country [13,24]. However, prevalence varies with growing area and seasons. For instance, for each percent increase in CBB severity in broadcast and mixed intercropping, about 5.2 kg ha^{-1} and 9.1 kg ha^{-1} seed yield losses, respectively, occurred at physiological maturity of the crop in Hararghe, eastern Ethiopia. At flowering, for each percent increase in CBB severity, there is 38.8 kg ha^{-1} and 71.1 kg ha^{-1} yield reduction in pure stand and row intercropping system respectively, in this area [24].

Knowing the general biology, ecology, epidemiology and symptom of the disease is very important to protect or mange and forecasting. Various crop protection practices and agronomic activities can influence CBB incident and epidemics under field conditions [28]. Knowing host pathogen interaction, use of resistant varieties supplemented with chemical seed treatment and proper cultural practices could be also the best alternative options in managing common bacterial blight of common bean and avoiding yield losses. Therefore, the objective of this review was to review the general ecology, epidemiology and economic importance of common bacterial blight of common bean crop disease and its management options, and the results of the scientific studies were summarized.

Economic Importance and Geographic Distribution of CBB

Its wide distribution, capacity to reduce yield and seed born nature of the disease and release of resistance variants make CBB one of the most economically important diseases affecting common beans worldwide [29,30]. CBB can cause significant losses in common beans in tropical and subtropical climates. Major losses have also occurred in temperate climates. It also attacks different legume crops as a secondary host and make a reasonable losses [31].

Greater damage is more likely when early plant infection occurs. This is due to premature defoliation, which reduced the photosynthetic area available, interferes with translocation and reduces seed number and size. Lesions on seed and pods reduce quality. In 1983 in Uganda, there was a bacterial blight outbreak at the main seed multiplication site [23]. The report has also shown that for each 1% increase in the incidence of CBB during reproductive growth there is a yield loss of 3.5 kg/ha to 11.5 kg/ha, depending on the season [23]. This caused the operation to be abandoned and delayed the release of seed to farmers.

The internally contaminated seeds or even externally contaminated are the primary source of inoculum. It is estimated that a 1×10^3 cfu/ml inoculum concentration is sufficient to cause the disease [32]. The common bacterial blight has been one of the diseases that have led to big losses in bean cultivation on an industrial scale and on seeds production in various parts of the world, such as in South Africa [21] which represents the main limiting factor for exportation. In Kenya also, *X. axonopodis* pv. phaseoli is a constraint to bean production. Percentage crop losses of between 10% and 75% have been reported [33]. Intercropping bean with maize was shown to reduce the severity of common bacterial blight during 1987-88 in Tanzania [34].

Reports stated that both CBB and halo blight (HB) are the two most important bacterial bean diseases in East and Central Africa. CBB is ranked the fourth most important bean disease in Africa [35]. It causes losses of 220,000 t/year in Africa; of these 146,000 t are lost in Eastern Africa and nearly 70,000 t per year in Southern Africa [36].

In Ethiopia, common bacterial blight is reported as the main constraints to common bean production throughout the country [13,16,37]. P. vulgaris is the most important legume crop and over 300,000 ha are grown annually by smallholders in Ethiopia. Average yields vary between 500 kg/ha to 1000 kg/ha, the reasons for the low productivity being abiotic and biotic factors; *X. axonopodis* pv. phaseoli is considered to be a major disease. It has been reported in many parts of Ethiopia and causes yield reduction of 22.4% in Eastern part of the country [24]. Reports indicates that for every percentage increase in the severity of common bacterial blight, there is a loss of approximately 3.9 kg/ha to 14.5 kg/ha of seed [13]. In eastern Hararghe, in the 1999 and 2000 cropping seasons, an actual yield loss about 22% in sole cropping and 3.5% to 16.7% in common bean-maize intercropping under circumstances suited for CBB epidemic in the highlands of Hararghe, Ethiopia [24]. However, particularly in northern Eastern Amhara region there is a need to quantify the loss, distribution and economic in the region with empirical data through research. Even if yield loss was not quantified in this region, CBB is a major disease of common bean affecting the production and the occurrence of *Xanthomonas axonopodis* pv. phaseoli and *Xanthomonas axonopodis* pv. phaseoli var. fuscan strains on common bean leaves were investigated from isolates randomly collected at intervals of 5 km from 14 fields in 3 districts with naturally infection [25]. Similarly field experiments were conducted in Ethiopian Central Rift Valley (at Melkassa and Arsi Negelle) experimental stations in 2006 summer cropping season using two moderately resistant (Awash Melka and Awash-1) and one susceptible (Mexican-142) white bean varieties indicated that, CBB disease was a major disease [38]. During 2011/2012 main cropping season, field experiment was conducted by [39] in Southwest Ethiopia at Chena District by using four resistant common bean cultivars and one susceptible local check approved that the pathogen *Xanthomonas axonopodis* pv. phaseoli was also a serious disease. Therefore, based on the above scientific studies, *Xanthomonas axonopodis* pv. phaseoli is the main production constraints of common bean in every corners of the country.

Now a days, the pathogen, *Xanthomonas axonopodis* pv. phaseoli is distributed all over the world including Africa [Angola, Burundi, Central African Republic, Congo Democratic Republic, Egypt, Eritrea, Ethiopia (widespread), Kenya, Lesotho, Madagascar, Malawi, Mauritius, Morocco (formerly present), Mozambique, Nigeria, Rwanda, Somalia, South Africa (widespread), Sudan, Swaziland, Tanzania, Tunisia (restricted distribution, Uganda, Zambia, Zimbabwe (widespread)], [40-43]. In general, the disease is widespread throughout Africa's bean growing regions, and is favored by warm to high temperatures and high humidity [44].

Indications of Common Bacterial Blight (Symptomatology)

CBB is considered mainly a foliar disease. Both strains of *Xanthomonas axonopodis* pv. phaseoli induce identical symptoms on leaves, stems, pods, and seeds. Leaf symptoms initially appear as water-soaked spots which enlarge and frequently coalesce with adjacent lesions. Infected tissues appear flaccid and lesions are often encircled by

Figure 1: Necrotic lesions and yellowing on bean leaves.

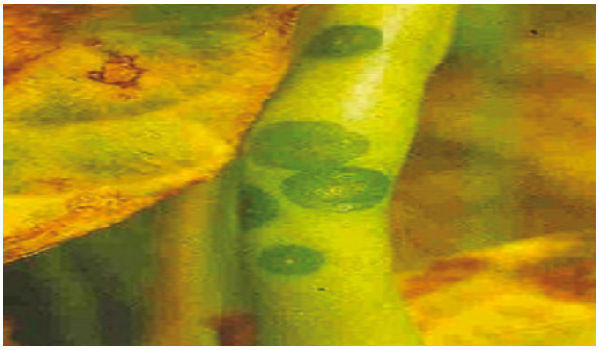

Figure 2: Initial water soaked and sunken circular spots on bean pods.

Figure 3: Spots on pods later dry and develop a reddish brown narrow border.

Figure 4: Infected seeds.

a narrow zone of lemon-yellow tissue. Necrosis then develops and may become extensive enough to cause defoliation or stem girdle [44-46].

During warm, wet condition, the lesions rapidly enlarge and merge. Lesion varies in size depending on the plant stage and pod. As the lesion develop, the center becomes dry, brown, and surrounded by a distinct, narrow, zone of yellow tissue (Figure 1). In highly susceptible cultivars, the lesions continue to expand until the leaves appear scorched or sun scalded. Heavily infected leaves may become tattered when wind whipped to the plant later, they wither and drop off. Bacteria exit through stomata providing inoculums for secondary spread. Symptoms on white seeds are evident as butter yellow and brown spots distributed throughout the seed coat or restricted to the hilum area. Severely affected seeds are frequently shriveled and exhibit poor germination and vigor [30,44].

Pods that become infected from bacteria in the plant vasculature have water soaked lesions (Figure 2) with a central yellow or cream colored bacterial colony and with time these lesions become sunken and dark reddish-brown blotches (Figure 3) [44]. If infection occurs during pod and seed development, infected seed may rot or shrivel but under severe infection, entire pods may be badly shriveled and seeds in such pods either fail to develop or are shriveled [44,47,48]. Seeds in less severely affected pods develop normally and show no signs of disease and others may become slightly wrinkled. When seeds containing the bacteria are planted, they may fail to germinate or germinate and produce seedlings with blight lesions on the cotyledons, stems, and first true leaves [49]. In humid weather, yellowish bacterial ooze, that later dries to form a crust, may be evident on the lesions on infected pods and leaves [44,50].

Seed infection occurs when the bacteria enter pod sutures via the pedicel or pod vascular system and pass into the funiculus through the raphe leading into the seed coat. The micropyle also may serve as a point of entry into the developing seed. Direct penetration through the seed coat has not been reported. If bacteria enter through the funiculus, only the hilum may become discolored. Studies have shown that infected seed can be found even in symptomless pods. Symptoms on seed manifest as butter-yellow spots on white or light-colored seeds (Figure 4), but are difficult to see on medium to dark-colored seeds. Seedlings which develop from severely infected seed may have damaged growing tips, be stunted, or killed [44,48,51].

The stems of seedlings may have water-soaked, sunken areas that enlarge and develop into reddish streaks. Any time during the season, affected stems commonly crack and become girdled by water-soaked cankers or rot. The tops may break over during raining or strong wind. Presence of sufficient amount of bacteria in the xylem tissue may cause plant wilting by plugging the vessels or disintegration of the cell wall. In humid weather, a yellowish bacterial ooze, that later dries to form a crust, may be evident on the lesions on infected pods, leaves, stems, and cotyledons. Secondary infection can occur from already infected plant material and is spread throughout the field by the same dispersal methods described for primary infection.

The Pathogen

Taxonomy, description and identification

The genus *Xanthomonas* is within the family *Xanthomonadacea* and order *Xanthomonadales* and it consists of 27 species that can cause disease in approximately 400 host plants and the pathogenic strains show a high degree of host specificity [52].

CBB is caused by *Xanthomonas campestris* pv. phaseoli and its fuscous variant, *Xanthomonas phaseoli* var. *fuscans*, which produces a brown pigment in culture media [21,25]. But nowadays, the pathogens are commonly called *Xanthomonas axonopodis* pv. phaseoli and *Xanthomonas axonopodis* pv. phaseoli var. *fuscans* [53]. The two organisms are found frequently in association and are reported to occur in many bean production region of the world [54]. During the 2003 cropping season a study by Selamawit showed that two variants/strains, including the fuscan type exist in the Central Rift Valley areas of Ethiopia [55]. Similarly, the occurrence of *Xanthomonas axonopodis pv.* phaseoli and *Xanthomonas axonopodis* pv. phaseoli *v*ar. *fuscan* strains on common bean leaves were investigated from isolates in Eastern Amhara Region of Ethiopia [25].

It is very difficult to visually distinguish *Xap* and *Xap* var. *fuscans*, the two causal agents of CBB, since both produce indistinguishable symptoms on bean plants [21]. And also the two isolated strains showed almost similar growth character on YDCA medium in Ethiopia condition [25]. The author also reported that, isolates shown brown pigmentation on KB media is identified as *fuscan (Xanthomonas axonopodis* pv pahseoli *var. fuscan)* and yellow pigmentation are identified as common type (*Xanthomonas axonopodis* pv pahseoli*)*. Due to this reason there have been numerous studies that attempt to dissect the genetic differences between species and also between pathovars of the same species of *Xanthomonas*, yet current taxonomical classification remains under debate [54].

Research using molecular techniques such as fluorescent amplified fragment length polymorphisms, restriction fragment length polymorphisms (RFLP), DNA-DNA hybridization and amplified DNA polymorphisms, identified the two pathovars as genetically distinct [53,56].

Generally, *X. axonopodis* pv. phaseoli is a non-spore-forming, gram-negative, rod-shaped with a single polar flagellum aerobic bacterium [57]. Colonies are yellow, convex and slimy on glucose-containing media. The fuscans variety can be distinguished by the production of a dark-brown diffusible pigment in media containing tyrosine and certain other media. The non-fuscous strains can also produce low levels of diffusible brown pigments if high levels of tyrosine are added to the culture media [25,58]. Apart from simple chemical tests, there is no well-organized study about the two strains of *Xanthomonas* in Ethiopia (Table 1).

Epidemiology of the causal agent

The disease cycle and survival: *Xanthomonas* are gram negative rod bacteria that range in size from 0.4 µm to 1.0 µm by 1.2 µm to 3.0 µm; however, cell length can vary even within strains [30]. Cells are motile with a polar flagellum and are surrounded by extracellular polysaccharide (EPS) slime, xanthan [59]. Minimum temperatures for growth range between 5°C and 9°C and maximum temperatures range from 30°C to 39°C [49]. The bacteria can progress through three main phases of growth: pathogenic, epiphytic and survival [60]. The bacteria cycles between surviving on organic matter or tools (survival), to growing on host tissue without penetration under favorable conditions (epiphytic), to tissue penetration and exponential growth (pathogenic) and back again. Typically *Xanthomonas* only cause disease in the host species they were originally isolated from and grow more slowly in host tissue compared to other bacterial species [30,61]. Plant age, tissue age, host resistance and vigour are all factors influencing bacterial growth and disease response.

As an epiphyte, *Xanthomonas* can grow on the plant surface without invading internal tissue for long periods of time. Growth can be affected by many factors including foliar age, host physiology, weather and other microflora. *Xanthomonads* are generally intolerant of sunlight and desiccation; however their EPS slime acts as a hydrophilic barrier, which may help tolerate unfavorable conditions. The bacteria can survive in the soil, volunteer plants, weeds, and on or in the seed itself [44,60].

Reports in African in general and in Ethiopia in particular indicates that, the bacteria can overwinter in previously infected debris in old bean field and as saprophytes on and in bean plant tissue [21,44,62]. The incidence assessed at flowering stage in eastern Ethiopia indicated that bean grown on the infested debris inoculated plot was higher by 59% compared to the bean from treated seed plots [62]. The bacteria may survive for 6 to 18 months in plant residue (on or above the soil surface and under dry conditions) in bean cull piles within or near fields, on volunteer plants from a previous crop, and even on the surface of weeds. Survival is higher in the debris at or near the soil surface than in the residue turned during plowing. The following year, surviving bacteria can multiply on emerging, contaminated volunteer beans and perennial hosts.

The bacteria may reside on the surface of bean leaves as epiphytes without causing disease, or may incite lesions under favorable environmental conditions. This primary inoculum can then be easily spread by wind and water into nearby bean fields, often resulting in subsequent disease outbreaks during favorable conditions. Infested soils are also primary sources of inoculum initiating disease spread during early epidemics [21,44,62]. The same studies have revealed that low seedling emergence, stand count, and seed yield were obtained from infested debris and soil inoculated plots. However, very little efforts have been made to manage the disease by reducing initial inoculum from different sources through integration of different management options in Ethiopia.

CBB is prevalent at low to mid altitude (1200-2500) m.a.s.l under warm condition and high humidity and rain favor rapid progress of the disease [25,49]. Research results in Ethiopia indicated that, under favorable condition, the disease can be destructive causing losses in both yield and seed marketability [16]. According to Kassahun higher CBB incidence and severity were recorded in fields of Chefa and Sirinka when there were high relatively high temperature, humidity and low rain fall distribution recorded [25]. CBB causing pathogen is spread by windblown rain, infested soil, and plant debris, contact between wet leaves, irrigation water, people, animals, and insects such as whiteflies and leaf miners [44,49]. Reducing of environmental suitability for the disease occurrence and spread is among management options that could be researched.

Transmission: In general, seeds are the primary source of inoculum for CBB (*X. axonopodis* pv. phaseoli*)* **[16,44,62].** Plants grown from infected seeds frequently bear lesions on the cotyledons or primary nodes. These lesions enlarge and under humid conditions, slimy masses of bacteria accumulate on the leaf surface. These are then spread to healthy plants. Approximately 1000 to 10,000 bacteria per seed is the minimum needed to produce infected plants under field conditions [61].

Isolate number	Isolate code	District	HR	KOH (0.3%)	Color on KB	Identified strain
1	CH-1A	Chefa	+	+	Brown	*Fuscan*
2	CH-5A	"	+	+	Yellow	Common
3	CH-6A	"	+	+	"	"
4	CH-7A	"	+	+	"	"
5	CH-15A	"	+	+	"	"
6	CH-16A	"	+	+	Brown	*Fuscan*
7	CH-17A	"	+	+	"	Common
8	CH-21A	"	+	+	"	"
9	CH-32A	"	+	+	"	"
10	CH-33A	"	+	+	"	"
11	CH-34A	"	+	+	"	"
12	CH-41A	"	+	+	"	"
13	CH-42A	"	+	+	"	"
14	Hik-11B	Haike	+	+	"	"
15	Hik -12B	"	+	+	"	"
16	Hik -13B	"	+	+	"	"
17	Hik -21B	"	+	+	"	"
18	Hik -22B	"	+	+	"	"
19	Hik -23B	"	+	+	"	"
20	Hik -23B	"	+	+	"	"
21	Hik -31B	"	+	+	"	"
22	SRI-5	Sirinka	+	+		"
23	SRI-6	"	+	+	"	"
24	SRI-8	"	+	+	"	"
25	SRI-9	"	+	+	"	"
26	SRI-14	"	+	+	"	"
27	SRI-17	"	+	+	"	"
28	SRI-20	"	+	+	"	"
29	SRI-21	"	+	+	"	"
30	SRI-24	"	+	+	"	"
31	SR-27	"	+	+	"	"
32	SRI-28	"	+	+	"	"
33	SRI-29	"	+	+	"	"
34	SRI-30	"	+	+	"	"
35	SRI-39	"		+	"	"
36	SRI-42	"		+	"	"

HR=Hypersensitive reaction, KOH (0.3%)=potassium hydroxide at 0.3%, KB=King *et al.* media, HR (+)=isolates show characteristic symptom of CBB for the test, KOH (+)=isolates show characteristic observation for the test, *Fuscan type=fuscan CBB* strain (*Xanthomonas axonopodis* pv *pahseoli* var *fuscan*) and *Non fuscan*=common type strain (*Xanthomonas axonopodis* pv *Pahseoli)* [25]

Table 1: Laboratory examination of CBB isolates collected from Chefa, Haike and Sirinka districts, in North-Eastern Amhara, Ethiopia during 2007.

The survival of seed borne *X. axonopodis* pv. phaseoli was reduced from 64% to 36% to 37% incidence during the first 6 months; however, seed stored at -18°C and 5°C maintained the contamination rate at 30 and 60 months, and it was concluded that the optimum temperatures for storing seed is similar to conditions favourable for *Xap* longevity [63]. Seed contamination may be internal or external [64] and even symptomless, which has serious implications for seed certification schemes. It has, however, been indicated that the development of *X. axonopodis* pv. *phaseoli* epidemics are depended on the level of horizontal resistance and climatic conditions rather than the population size of *Xap* in bean seeds and also had a significant higher percentage of seed to seedling transmission than *Xapf* [65]. *Xap* also survives on weeds and other host plants, and certain weed species may harbor the pathogen for up to 6 months [62].

Infection and host range: Infection occurs through natural openings and wounds. Severe epidemics can occur following storms with wind-blown rain, which can force the bacteria through openings, such as stomata, into the intercellular spaces. Wounds due to hail or insect feeding can create favorable sites for infection. Once inside the plant, *Xap* multiplies rapidly in the intercellular spaces and it can take as little as 10-14 days from initial infection until secondary spread occurs [49]. The optimal temperatures for infection to occur and also for disease development ranges 28°C to 32°C [48].

The bacteria can also enter the vascular system of many cultivars of common beans and then spread systemically in the plant. Infection of the seed coats can occur from pod infections. Moreover, wilting can result from vascular infection. Bacteria in the vascular system can also enter the developing pods and pass into the seeds [66]. Once the bacteria incite infection and enough inoculum more than 10^7 CFU/g of tissue there would be a host pathogen interaction and create a characteristic feature of disease symptom. Generally, plants appear to be more susceptible in the reproductive stage than in the vegetative stage. As the bacterial population increases, it can ooze onto the leaf surface and be spread further by water.

Reports in Ethiopia indicated that, both resistant and susceptible genotype seeds showed 10% to 15% CBB infection [62]. Seed to seedling transmission of CBB occurred in greenhouse and field at primary and first trifoliate leaf growth stage with a significance differences among treatments (genotype category) and there was a growth stages. This

was also in agreement with the report of [66], the pathogen is widely distributed because it infects seeds of both resistant and susceptible genotypes. Both internally infected and externally contaminated common bean seeds are the main sources of primary inocula for infection. An assessment was conducted in 2011 main cropping season of three districts of West Hararghe zone, Eastern Ethiopia, indicates that, CBB caused by *Xanthomonas campestris pv.* phaseoli or *Xanthomonas axonopodis* was the only bacterial disease found associated with bean seed samples and made an infection on sole seeds (75%) and intercrops (59.1%) [67].

In addition to common bean (*Phaseolus vulgaris*), *Xap* affects and make an infection on other leguminous and non-leguminous plants [30,68]. Particularly in Ethiopia, host specificity in *Xanthomonas* is poorly understood and should be investigated.

Management Practices of CBB

In line with the above epidemiological findings, CBB management options should include components that reduce initial inoculum such as field sanitation, eliminating weeds and volunteer beans, application of a foliar copper bactericide, proper crop rotation whenever feasible, planting healthy seed, early incorporation of bean debris into soil, burning of crop residues and effective seed treatment, in addition to developing resistant cultivars [44,46, 48].

Cultural control methods

Cultural practices are important in controlling common bacterial blight. Eliminating weeds, volunteer beans and other potential hosts of *Xap* will reduce disease incidence [49]. One of the reasons why CBB continues to be one of the most important bean diseases worldwide is that it is very difficult to control it due to seed-borne nature of the bacteria. Seed is the major source of primary inoculum and disseminates the bacteria nationally as well as all over the world during germplasm exchange and international seed trade. An effective management strategy for this disease is the use of pathogen free seed [27,69] because, it does not harbor primary inoculum source. Pathogen-free seed that has been inspected during production and tested for freedom from the pathogen causing CBB is very important to minimize disease epidemics. Although pathogen-free seed should be used whenever possible, its use does not guarantee a clean crop. Because plants with no symptoms can be colonized by *Xap* and the bacteria can systematically invade seed via vascular tissues. Hence, certified pathogen free seed may still be contaminated with CBB. Therefore, clean seed can be obtained by growing bean seed in areas that are unfavorable for pathogen development [70].

Sanitation can also be used as of the management options to reduce initial CBB inoculum that can survive in association with bean debris in the soil. Deep plowing exposes debris to microorganisms and results in rapid degradation and prevents survival of CBB in association with debris [71]. Thus, efforts should be made to avoid leaving contaminated debris in or on the soil surface. Since infested debris is important primary source of inoculum, disposal of debris through burning, plowing and removal by any means may be an effective management strategy [49]. This also reduces diseased plants, which provide the inocula responsible for disease outbreaks in nearby bean fields. *Xap* can also survive in common bean dust on contaminated harvesting equipment, seed-cleaning equipment and seed containers in store house.

Epidemics of CBB can effectively be reduced through employing crop rotation with beans. In contrast, the bean-onion scheme should be avoided as much as possible, since onions can provide a source of inoculum by asymptomatic epiphytic colonization [72]. Also, it should bear in mind that the use of sprinkler irrigation system favors the dispersion of bacteria compared with other irrigation systems [73].

On the other hand, intercropping is another cultural practice to reduce *Xap* infestation. For example, if beans are growing with maize or sorghum rather than a monoculture the incidence of *Xap* will be reduce [74,75] because the maize appears to provide a physical barrier to the movement of *Xap* between bean plants. This finding was also approved by the scholar [16,76] in Ethiopia, intercropping bean with maize delays epidemics onset, lowers disease incidence and severity, and reduces disease progress rate.

Generally, in the case of Ethiopia, reports on the efficacy of varietal mixture in the control of CBB in common beans are available from eastern and western Hararghe areas, Ethiopia [28]. For instance, varietal mixtures with the resistant variety, Gofta (G-2816), consistently reduce CBB incidence, severity, area under disease progress curve (AUDPC), and disease progress rate on the susceptible cultivar (Red Wolaita). The physical, physiological and heath qualities studies of common bean seed produced under sole crop and intercrop systems by smallholder farmers' eastern Ethiopia indicated that higher percentage of infection was found in sole seeds than those obtained from intercrops [67]. Generally, disease development decreased as the proportion of the resistant cultivar in the mixture increased [28]. The mixture had a maximum of 27% efficacy for CBB control. Therefore, cultivar mixtures can be used as a component of integrated disease management scheme for food type's common bean. Common bean production in the Central Rift Valley of Ethiopia is mainly for market purpose (local and export market) and using varietal mixture reduces the quality of the seed. Use of crop rotation may alleviate the problem. In this connection, teff (*Eragrostis tef*) may be considered as one of the major crops to rotate with common bean in the area. Especially in commercial farmers, even subsistence farmers exploiting cultural control methods alone would not be able to manage the disease up to economic threshold level rather need integration in to generate an economical return. For example, use of treated seeds of the cultivar Awassa dumme and AFR-702 with suggested cultural practice via planting on ridges is the best option for bean producers around Kaffa area to reduce the disease epidemic and to obtain high yield [39].

Chemical control methods

Various chemicals have been applied as seed treatment and foliage protectant to control CBB before severe infection is apparent. Because of unavailability as well as high cost of the chemicals for subsistence farmers, chemical control against CBB is not economical. But, as a component of an integrated approach to disease management, chemicals are options that can be wisely used under special circumstances such as seed and commercial production. Limited applications under conducive environmental conditions for reducing bacterial multiplication could help to keep bacterial population below the threshold level necessary for disease development and impede the spread of pathogen. This would be an effective strategy if coupled with the use of moderately resistant varieties [44,77].

Chemicals like copper sulphate, copper hydroxide, and potassium methyl dithiocarbamate can control foliage infection. Application of copper-based bactericides could reduce population of the bacteria [24,55,77]. Applying these contact bactericides early in the seasons every 7 to 10 days intervals during cool, moist weather can decrease establishment of bacterial pathogens [78]. Foliar fertilizer applications have been successful, for example, the application of manganese reduced

the severity of the disease by up to 49% in bean plants under greenhouse conditions [79]. A twice foliar sprays of Kocide-101 chemical at the rate of 3.0 kg ha^{-1} were significant in reducing CBB epidemics on common bean, increased seed yield and yield components of the crop and net return over cultivars at Eastern Amhara Region of Ethiopia [25].

According to different assessments in Ethiopia, the use of those chemicals singly or in integration with other cultural practices is limited particularly the Central Rift Valley and in north-Eastern part of the country. Therefore, investigation and evaluation of potential management components are the predominant and priority issues.

Use of resistance varieties

Planting of bean cultivars resistant to *Xap* is economically and technically the most practical and attractive method for effective management of CBB [3]. Breeders and plant pathologists were trying and sill working to develop a resistance commercial varieties of common bean by conventional and molecular breeding activities. They are using the genetic diversity in the gene pool system and wild populations as a source of germplasm. There are three *Phaseolus* gene-pools exploited for breeding purposes. The primary gene-pool consists of *P. vulgaris* and its wild progenitors, the secondary gene-pool consists of *P. coccineus, P. costaricenis, and P. polyanthus,* and the tertiary gene-pool consists of *P. acutifolius* and *P. parvifolius* [80]. The highest levels of genetic resistance to CBB are found in *P. acutifolius*, followed by *P. coccineus* then *P. vulgaris* [81]. Besides the introduction of resistant genes from other species, collection from different common bean growing areas in the world has been used as a source of resistance. As a result, different moderately resistant lines and Cultivars have been developed. Likewise, important interspecific crosses between tepary and common bean were carried out to create several different breeding lines and cultivars like HR45, HR67, and VAX 3-6 showing high levels of CBB resistance and these lines can be used in breeding programs as sources of resistance [82,83]. The germplasm line XAN159 was also developed from an interspecific cross between *P. vulgaris* and *P. acutifolius* (PI 319443) at UC Riverside and tested for CBB resistance at the International Center for Tropical Agriculture (CIAT) has been used in white and colored bean breeding programs in both the US and Canada due to its high levels of CBB resistance. Moreover, AG-7117 lines were reported from Turkey to be resistant to *Xap* [84].

CBB resistance in common bean is inherited quantitatively and heritability of resistance can vary from low to moderately high, depending on the study and mapping populations used [80]. Molecular marker studies have identified at least 22 QTL for resistance to CBB spread across all 11 chromosomes [81] in different bean lines. Expression of these QTL is influenced by environmental conditions, genetic background, disease pressure and certain agronomic characteristics [81]. CBB resistance is quantitatively controlled, usually by one major large effect allele and additional minor small effect alleles [80]. Negative epistatic interactions between QTL for resistance have been reported [85], in addition to negative associations between agronomic traits and resistance QTL [86]. In general, breeding for CBB resistance is difficult due to a variety of factors including: pathogen variability, variation in host-pathogen relationship, variation in QTL expression, linkage drag and different genes controlling resistance in multiple plant tissues [87,88].

In Ethiopian condition, both in regional and national research system, the established common bean nursery have been the basic activities for host plant resistance development program. Different resistance materials are released and still some are under production [89]. A varietal comparison study indicated that, CBB incidence, severity and disease progress rate was reduced in *Awash Melka* as compared to the varieties *Awash-1* and *Mexican-142* [38]. Similarly, resistant variety, *Awassa dumme* and *AFR-702*, had reduced CBB development and increased seed yield [39]. Generally, Host plant resistance screening remains the cheapest mechanism of cultivar development in both developed and developing countries, like Ethiopia, but, still alone could not meet the multidimensional needs of the common bean growers.

Biological control methods

Biological control is the method of controlling or suppressing of plant disease by using other microorganisms [90]. A study on some *Pseudomonas sp*. and *Rahnella aquatilis* strains have shown up to 39% of efficient control of *Xap* when applied from the seeds, mainly by the formation of phenolic compounds and high peroxidase activity [91,92]. A study under greenhouse and field conditions, bean variety "Giza 6" treated by *Rahnella aquatilis* resulted in marked disease suppression [92]. A high decrease of the disease was correlated with a reduction of the bacterial multiplication. The same author stated that, in physiological studies, bean plants treated by *Rahnella aquatilis* exhibited higher phenolic compounds contents and higher activity of peroxidase enzyme than untreated plants. Bioassays have been carried out in Brazil to select a biological control agent for *Xap* [93]. Isolates from soil planted with beans, isolates from bean pods and from bean leaves offered variable control of between 80% to 100% to *Xap*. The study was conducted at Italy by testing 162 isolates of Rhizobacteria from bean rhizosphere and 60 out of 162 inhibited the growth of CBB in *in vitro* condition. But six of them when applied to seeds before sowing, they reduced disease symptoms in *in vitro* and green house pathogenicity assay [94]. Another study at Iran was conducted to evaluated *Rhizobium leguminosarum* bv. phaseoli against CBB at green house and field condition. In this case *R. leguminosarum* bv. phaseoli was applied as a seed treatment and its effect on disease severity was compared with untreated control plants and this bacteria was tend to reduce CBB severity both green house and field condition [70].

In the case of Ethiopia, in regard to biological control methods for controlling common bacterial blight disease is not yet studied or investigated.

Integrated disease management

Integrated disease management is a disease control method that uses all types of management to keep disease pressure below the economic threshold level [95]. It is preferred strategy because of increased understanding on residual effects of chemical on the environment as well as inefficiency of sustenance of a single alternative management option to achieve the same level of control and reliability as that of chemicals by promoting biological, cultural, physical and mechanical control practices. These integrated approaches reduce or delay disease severity during the critical periods of vegetative and reproductive plant growth. Common bean growers must carefully integrate recommended strategies: crop rotation, sanitation, use of treated or healthy seeds, resistant or tolerant varieties, stress and wound avoidance and proper bactericide scheduling to minimize the impact of bacterial disease on bean. Use of resistant varieties supplemented with proper cultural practices and chemical seed treatment could be the best alternative options in managing common bacterial blight of bean and avoiding yield losses [3].

In Ethiopia, integrated disease management method for controlling CBB is the best preferred strategy. For Instance, integration of intercropping and varietal mixture can effectively control CBB in some cropping systems [28]. Intercropping with maize and different cropping

pattern can also minimize the damage [16,24]. The use of varieties resistant to CBB is one of the best ways of avoiding heavy losses. Seed treatment prior to planting with slurry containing a bactericide can kill the bacteria infesting the seed surface. Integrating of resistant varieties with chemical seed treatment and cultural practice were highly significant in reducing common bacterial blight development and increased seed yield and yield component of a bean in Ethiopia [39]. The highest percent severity index of common bacterial blight (71.95%) was observed in the control treatment when growing of local cultivar under farmer management practice while level was reduced significantly to below 26% when planting chemically treated seed of the cultivars Awassa dumme, AFR-702 and Ibado on the ridges, with an average yield of more than 22 qt/ha [39]. The effects of seed treatment integrated with biofumigation and fortnightly foliar sprays were significant in reducing CBB epidemics, increasing yield, yield components and net benefits [96]. They also reported that seed treatment integrated with biofumigation and foliar sprays at two weeks interval reduced severity up to 66.5% and 59.0% at Haramaya and Hirna, respectively. In addition, increased seed yield gain up to 67.61% at Haramaya and up to 53.13% at Hirna.

Combination of common bean-sorghum with once and twice foliar spray provided higher net benefit with higher marginal net profit in addition to reducing disease epidemics and yield increase in each susceptible and moderately susceptible cultivars [25]. Combination of seed treatment with once foliar spray provided higher net benefit with higher marginal rate of return in addition to reducing disease epidemics and yield increase in the two moderately resistant and one susceptible varieties [38]. Generally, integrating host resistance with seed treatment and cultural practice could reduce the severity of common bacterial blight and increase yield and yield component of the bean [39].

Therefore, integrated disease management practice is the best alternative and ecofriendly means of managing CBB to both small and large scale bean producers in Ethiopia in particular and in the world in general.

Conclusion

Among many diseases affecting common bean, common bacterial blight (CBB), is a significant seed borne disease of common bean, caused by the gram-negative bacterial pathogen *Xanthomonas axonopodis* pv. phaseoli (*Xap*) and its fuscans variant *Xanthomonas fuscans* subsp. *fuscans (Xff)* has been reported in many countries of the world including Ethiopia. The disease is prevalent in areas that experience warm weather conditions, causing up to 45% yield reduction. Common Bacterial Blight has been extensively studied and is a frequent problem in bean crops. However, the pathogen variability and the diversity of identification and diagnostic techniques, suggest the importance of selecting carefully the most appropriate ones for this pathogen studies. *Xap* is a non-spore-forming, gram-negative aerobic bacterium and can grows on a number of different media producing colonies that are yellow, mucoid and convex.

CBB can overwinter on many different plant tissues such as infected or healthy bean plants, buds, seeds, plant debris, in addition to surviving on tools and in the soil. It affects the leaves, pods, seeds and stems of the common bean plant and show considerable symptoms. In addition to common bean the pathogen of CBB affects and make an infection on other legume crops. Seeds are the primary source of inoculum for CBB therefore seed infection is the primary means by which the pathogen spreads, due to this reason the production and use of certified seeds is the main control measure that is effective in dealing with the disease. On the other hand, the disease management is directed towards implementing the use of resistance genes through varietal improvement and induction of plant resistance by biotic or abiotic inducers. However, the best management would be given by the knowledge of the pathogen and its prevention through incorporation of suitable management and control methods. Using resistant varieties supplemented with chemical seed treatment and proper cultural practices could be the best alternative options in managing common bacterial blight of common bean and avoiding yield loss. In general, integrated disease management is the preferred strategy because of increased understanding on residual effects of chemical control on non-target organisms and environment as well as the limitation of a single alternative management option to achieve the same level of control and reliability as that of chemicals.

Future Directions

In Ethiopia, much of the research on CBB has focused on some germplasm screening (conventional way), management options and control. While significant advances in understanding the biology and management of the disease have been gained, there is need for more research in a number of areas. The development of disease resistant bean cultivars remains a high priority since farmers are reluctant to employ labor-intensive disease control measures. This however requires a clear understanding of the molecular basis of interaction between the bacterium and the host plant, and an analysis of the intermediate products produced by both the pathogen and plant following infection. Additionally, determination of the population structure of the pathogen from a wider geographic area is required in order to develop a database on *Xap* isolates and consequently determine the best strategy for deployment of resistance and or to incorporate the non-matching resistance genes to the existing pathogen. Use of biotechnological approaches may be one of the best strategies in managing this disease. In addition, emphasis should be given to:

- Breeding for multiple disease resistance
- Biological disease control methods and antagonists
- Develop information on disease dynamics (race occurrence, varietal susceptibility). Conventional and molecular techniques may be used to study pathogen variability
- Identification of molecular markers to enhance marker assisted selection
- Use of GIS to map the distribution of major diseases

References

1. Yu K, Park SJ, Poysa V (2000) Marker-assisted selection of common beans for resistance to common bacterial blight: efficacy and economics. Plant Breed 119: 411-415.
2. http://www.harvestplus.org/sites/default/files/
3. Popovic T, Starovic M, Aleksic G, Zivkovic S, Josic D, et al. (2012) Response of different beans against common bacterial blight disease caused by *Xanthomonas axonopodis* pv. Phaseoli. Bulg J Agric Sci 18: 701-707.
4. Broughton WJ, Hernandez G, Blair M, Beebe S, Gepts P, et al. (2003) Beans (*Phaseolus* spp.) model food legumes. Plant Soil 252: 55-128.
5. CGIAR (2012) Common Bean.
6. FAO (2012) Food Balance Sheet.
7. FAO (2014) Statistics of dry bean. Accessed on 20 October 2016.
8. Blair M, Gonzales LF, Kiman PM, Butare L (2010) Genetic diversity, inter-gene pool introgression and nutritional quality of common beans (*Phaseolus vulgaris* L.) from central africa. Theor Appl Genet 121: 237-248.
9. Cortes AJ, Monserrate FA, Ramírez-Villegas J, Madriñán S, Blair M (2013)

Drought tolerance in wild plant populations: The case of common beans (*Phaseolus vulgaris* L.). PLoS ONE 8: e6289.

10. Mederos Y (2006) Quality indicators in bean grain (*Phaseolus vulgaris* L.). Cult Trop 27: 55-62.
11. Agriculture and Agri-Food Canada (2007) Dry Bean Profile. 2016: http://www4.agr.gc.ca/AAFC-AAC/display afficher.do?id=1174576605314&lang=eng. Accessed 13 October 2016.
12. Imru A (1985) Bean production in Ethiopia. In regional workshop on potential for field beans (*Paseolus vulgaris* L.) in West Asia and North Africa. Aleppo, Syria, 56 pp.
13. Tadesse T, Ahmed S, Gorfu D, Beshir T, Fininsa C, et al. (2009) Review of research on diseases food legumes. In: Tadesse A (Ed). Increasing crop production through improved plant protection. Volume 1. Proceeding of the 14th annual conference of the plant protection society of Ethiopia (PPSE), Ethiopia.
14. Habtu A, Sache I, Zadoks J C (1996) A survey of cropping practices and foliar diseases of common bean in Ethiopia. Crop Prot 15: 179-186.
15. Fininsa C, Yuen J (2001) Association of bean rust and common bacterial blight epidemics with cropping systems in Hararghe highlands, eastern Ethiopia. Int J Pest Manag 47: 211-219.
16. Fininsa C (2001) Epidemiology of beans bacterial blight and maize rust in intercropping. Ph. D Thesis. Swedish University of Agricultural Science, Sweden, Uppsala.
17. Eden T (2002) Uptake and response of haricot bean (*Phaseolus vulgaris* L.) varieties to different levels of phosphorus application on entisols of alemaya. M.Sc. Thesis. Alemaya University, Alemaya.
18. Kajumula MS, Muhamba TG (2012) Evaluation of common bean (*Phaseolus vulgaris* L.) genotypes for adaptation to low phosphorus. ISRN Agronomy 2012, 309614.
19. Rodríguez De Luque JJ, Creamer B (2014) Major constraints and trends for common bean production and commercialization: Establishing priorities for future research. Agron Colomb 32: 423-431.
20. Bako Agricultural Research Center (BARC) (2002) Bako research center; crop protection division progress report for 2001/2. Bako Agricultural Research Center, Bako Ethiopia.
21. Fourie D (2002) Distribution and severity of bacterial disease of dry beans (Phaseolus vulgaris) in South Africa. J Plant Pathol 150: 220-226.
22. Schaad NW, Postnikova E, Lacy GH, Sechler A, Agarkova I, et al. (2006) Emended classification of xanthomonad pathogens on citrus. Syst Appl Microbiol 29: 690-695.
23. Opio AF, Allen DJ, Teri JM (1996) Pathogenic variation in the causal agent of common bacterial blight in phaseolus bean. Plant Pathol 45: 1126-1133.
24. Fininsa C (2003) Relationship between common bacterial blight severity and bean yield loss in pure stand and bean-maize intercropping systems. Int J Pest Manag 49: 177-185.
25. Kassahun A (2008) Reaction of common bean cultivars to *Xanthomonas axonopodis* pv. phaseoli strains and integrated management of common bacterial blight in Eastern Amhara Region, Ethiopia. M.Sc. Thesis. Huaramaya University, Haramaya, Ethiopia.
26. Allen DJ, Ampofo JKO, Wortman CS (1996) Pests, diseases, and nutritional disorders of the common bean in Africa: A field guide. CIAT, Cali, Colombia.
27. Gillard CL, Conner RL, Howard RJ, Pauls KP, Shaw L, et al. (2009) The performance of dry bean cultivars with and without common bacterial blight resistance in field studies across Canada. Can J Plant Sci 89: 405-416.
28. Fikire L (2004) Effect of intercropping and cultivar mixtures on bean diseases and yield. Pest Manag J Ethiopia 8: 71-81.
29. Irigoyen ED, Garbagnoli C (1997) Common bacteriosis in common bean (*Xanthomonas axonopodis* pv. phaseoli (E.F. Smith) Dowson): Detection, infection and transmission through seeds. Fitopatologia 32: 166-172.
30. Agrios GN (2005) Plant pathology (5thedn). Academic Press, San Diego, USA.
31. de Carvalho OA, Cunha MD, Rodríguez R, Sudré CP, Santos IS, et al. (2011) Ultrastructural changes during early infection of vigna unguiculata and *Phaseolus vulgaris* leaves by *Xanthomonas axonopodis* pv. phaseoli and an unexpected association between chloroplast and mitochondrion. Acta Physiol Plant 33: 2025-2033.
32. Darrasse A, Bureau C, Samson R, Morris CE, Jacques MA (2007) Contamination of bean seeds by *Xanthomonas axonopodis* pv. phaseoli associated with low bacterial densities in the phyllosphere under field and greenhouse conditions. Eur J Plant Pathol 119: 203-215.
33. Makini FW (1995) Bean production and constraints in Kenya with emphasis on diseases. In: Danial DL (Eds.) Breeding for disease resistance with emphasis on durability. Proceedings of a regional workshop for eastern, central and southern Africa, held at Njoro, Kenya, October 2-6. Netherlands.
34. Kikoka LP, Katunzi AL, Teri JM (1989) Evaluation of effect of cropping systems on bean diseases and yield. Proceedings: Integrated Pest Management in Tropical and Subtropical Cropping Systems vol. 3, Germany.
35. Opio F, Kimani PM, Musaana SM, Buruchara R (2002) Research on common bacterial blight and halo blight of common bean in East and Central Africa. Bean Improvement Cooperative. Annual Report (USA) 45: 160-161.
36. Wortmann CS, Kirkby RA, Eledu CA, Allen DJ (l998) Atlas of common bean production in Afiica. CIAT, Cali, Colombia.
37. Abiy T, Fekede A, Chemeda F (2006) Lowland pulse diseases research in Ethiopia. In: Ali KA, Gemechu K, Ahmed S, Malhotra, Rajendra B, et al. (Eds.). Proceedings of food and forage legumes of Ethiopia: Progress and Prospects. The workshop on Food and Forage Legume, Ethiopia.
38. Tumsa K (2007) Integrated management of common bacterial blight of common bean through host resistance and chemical applications in the central rift valley, Ethiopia. M.Sc. Thesis. Haramaya, University, Haramaya, Ethiopia.
39. Belachew K, Gebremariam M, Alemu K (2015) Integrated management of common bacterial blight (*Xanthomonas axonopodis* pv. Phaseoli) of common bean (*Phaseolus vulgaries*) in Kaffa, Southwest Ethiopia. Malays J Med Biol Res 2: 147-152.
40. CABI/EPPO (2007) *Xanthomonas axonopodis* pv. phaseoli. Distribution maps of plant diseases, No. 401. (4thedn), CAB International, Wallingford, UK.
41. Chen HY, Xu XX, Duan CX, Wang SM, Zhu ZD (2012) Identification of pathogens causing common bacterial blight on common bean (*Phaseolus vulgaris* L.). Scientia Agricultura Sinica 45: 2618-2627.
42. EPPO (2014) PQR database. Paris, France: European and mediterranean plant protection organization.
43. Osdaghi E, Zademohamad AA (2016) *Phaseolus lunatus*, a new host of *Xanthomonas axonopodis* pv. phaseoli in Iran. J Phytopathol 164: 56-60.
44. Buruchara R, Mukankusi C, Ampofo K (2010) Bean disease and pest identification and management, Handbooks for small-scale seed producers International Center for Tropical Agriculture. (CIAT), Pan-Africa Bean Research Alliance (PABRA), Uganda, Kampala.
45. Harveson RM (2009) Common bacterial blight of dry beans in Nebraska.
46. OMAFRA (2009) Diseases of field crops. Edible Beans. In: Agronomy guide for field crops publication 811.
47. Shepphard JW, Roth DA, Saettler AW (1989) Detection of *Xanthomonas campestris* pv. phaseoli in bean. pp 17-29. In: Detection of bacteria in seed and other planting material. St. Paul, MN, American Phytopathology Society.
48. Schwartz HF, Steadman JR, Hall R (2005) Compendium of bean diseases (2ndedn), APS Press, USA.
49. Saettler AW (1991) Common bacterial blight. In: Compendium of bean diseases. In: Hall R (Ed). APS Press, USA.
50. Dillard HR, Legard DE (1991) Bacterial disease of beans: Fact sheet, Cornell University, 750 pp.
51. Schwartz HF, Pastor-Corrales MA (1989) Bean production problems in the tropics (2ndedn), CIAT, Cali, Colombia.
52. Benson DA, Karsch-Mizrachi I, Lipman DJ, Ostell J, Sayers EW (2009) GenBank. Nucleic Acids Res. 26-31.
53. Mahuku GS, Jara C, Henriquez MA, Castellanos G, Cuasquer J (2006) Genotypic characterization of the common bean bacterial blight pathogens, *Xanthomonas axonopodis* pv. phaseoli and *Xanthomonas axonopodis* pv. phaseoli var. fuscans by rep-PCR and PCR-RFLP of the Ribosomal Genes. J phytopathol 154: 35-44.
54. Schaad NW, Vidaver AK, Lacy GH, Rudolph K, Jones JB (2005) Evaluation of proposed amended names of several pseudomonads and xanthomonads and recommendations. Phytopathol 90: 208-213.

55. Selamawit C (2004) Occurrence of common bacterial blight strains and its effect on quality of bean seeds in Ethiopia. M.Sc Thesis presented to School of Graduate Studies of Alemaya University pp 56-60.

56. Alavi SM, Sanjari S, Durand F, Brin C, Manceau C, et al. (2008) Assessment of the genetic diversity of *Xanthomonas axonopodis* pv. phaseoli and *Xanthomonas fuscans* subsp. fuscans as a basis to identify putative pathogenicity genes and a type iii secretion system of the SPI-1 family by multiple suppression subtractive hybridizations. Appl Environ Microbiol 74: 3295-3301.

57. Bradbury JF (1986) Guide to plant pathogenic bacteria. CAB International, Wallingford, UK.

58. Goodwin PH, Sopher C R (1994) Water stress in leaves of *Phaseolus vulgaris* infected with *Xanthomonas axonopodis* pv. phaseoli. J Phytopathol 140: 219-226.

59. Swings J, Vauterin L, Kersters K (1993) The bacterium *Xanthomonas*. In: *Xanthomonas*. Chapman and Hall, London.

60. Stall RE, Gottwalk TR, Koizumi M, Schadd NC (1993) Ecology of plant pathogenic Xanthomonads. In: Swings JG, Civerolo EL (Eds.) Xanthomonas. Chapman and Hall, London.

61. Weller DM, Saettler AW (1980) Evaluation of seed-borne *Xanthomoas phaseoli* and var. fuscans as primary inocula in bean blights. Phytopathology 70: 148-52.

62. Fininsa C, Tefera T (2005) Effect of primary inoculum sources of common bean common bacterial blight on early epidemics, seed yield and quality aspects. Int J Pest Manag 47: 221-225.

63. Marques AS dos A, Guimarães PM, Santos JP dos, Vieira TM (2005) Survival and viability of *Xanthomonas axonopodis* pv. phaseoli associated with bean seeds stored under controlled conditions. Fitopatologia Brasileira 30: 527-531.

64. Allen DJ, Buruchara RA, Smithson JB (1998) The pathology of food and pasture legumes. CAB International, Wallingford, UK.

65. He Y (2010) Improved seed health tests for *Xanthomonas axonopodis* pv. phaseoli in common bean. Ames, USA: Iowa State University.

66. Aggour AR, Coyne DP, Vidaver AK, Eskridge KM (1989) Transmission of the common blight pathogen in bean seed. J Am Soc Hortic Sci 114: 1002-1008.

67. Oshone K, Gebeyehu S, Tesfaye K (2014) Assessment of common bean (*Phaseolus vulgaris* L.) seed quality produced under different cropping systems by smallholder farmers in eastern Ethiopia. Afr J Food, Agr Nutr Dev 4: 8566-8584.

68. Karavina C, Mandumbu R, Parwada C, Zivenge E (2011) Epiphytic survival of *Xanthomonas axonopodis* pv. phaseoli (E.F.Sm). J Anim Plant Sci 9: 1161-1168.

69. Tar'an B, Michaels TE, Pauls KP (2001) Mapping genetic factors affecting the reaction to *Xanthomonas axonopodis* pv. phaseoli in *Phaseolus vulgaris* L. under field conditions. Genome 44:1046-1056.

70. Osdaghi E, Shams-Bakhsh M, AlizadehA, Lak MR, Maleki HH (2011) Induction of resistance in common bean by *Rhizobium leguminosarum* bv. phaseoli and decrease of common bacterial blight. Phytopathol Mediterr 50: 45-54.

71. Gilbertson RL, Hagedorn DJ (1990) Survival of *Xanthomonas campestris* pv. phaseoli and pectolytic strains of *Xanthomonas campestris* in bean debris. Plant Dis 74: 322-327.

72. Gent DH, Lang JM, Schwartz HF (2005) Epiphytic survival of *Xanthomonas axonopodis* pv. allii and *X. axonopodis* pv. phaseoli on leguminous hosts and onion. Plant Disease 89: 558-564.

73. Akhavan,A, Baha, M, Askarian H, Lak MR, Nazemi A, et al. (2013) Bean common bacterial blight: Pathogen epiphytic life and effect of irrigation practices. Springer Plus 2:41.

74. Moreno R, Mora L (1984) Effect of cropping pattern and soil management on plant diseases. II. Common bean rust epidemiology. Turrialba 34: 41-45.

75. Sharaiha R, Haddad N, Blan HA (1989) Potential of row intercropping of FABA common bean, potato and corn on the incidence and severity of Alter aria leaf spot, late blight rust under the Jordan Vally conditions. Phytopathology medetranian 28: 105-112.

76. Fininsa C (1996) Effect of intercropping beans with maize on common bacterial blight and rust diseases. Int J pest manag 42: 51-54.

77. Gilbertson RL, Maxwell DP (1992) Common bacterial blight of bean. Prentice Hall Inc. Englewood Cliffs, New Jersey, USA.

78. Schwartz HF (2004) Bacterial blight of beans. Diseases fact sheet. Colorado State University, No. 2.913.

79. Viecelli CA, Moerschbächer T (2013) Control of the common bacterial blight in the bean crop by using foliar fertilizers. Scientia Agraria Paranaensis 12: 66-72.

80. Singh S, Schwartz H (2010) Breeding common bean for resistance to diseases: A Review. Crop Sci 50: 2199-2223.

81. Miklas PN, Kelly JD, Beebee SE, Blair MW (2006) Common bean breeding for resistance against biotic and abiotic stresses: From classical to MAS breeding. Euphytica 147: 105-131.

82. Park SJ, Dhanvantari BN (1994) Registration of common bean blight-resistant germplasm, HR45. Crop Sci 34: 548.

83. Singh SP, Munoz CG, Teran H (2001) Registration of common bacterial blight resistant dry bean germplasm VAX 1, VAX 3, and VAX 4. Crop Sci 41: 275-276.

84. Dursun A, Donmez MF, Sahin F (2002) Identification of resistance to common bacterial blight disease on bean genotypes grown in Turkey. Eur J Plant Pathol 108: 811-813.

85. Vandemark G, Fourie D, Larsen R, Miklas P (2009) Interactions between QTL SAP6 and SU91 on resistance to common bacterial blight in red kidney bean and pinto bean populations. Euphytica 170:371-381.

86. O›Boyle PD, Kelly JD, Kirk WW (2007) Use of Marker-assisted selection to breed for resistance to common bacterial blight in common bean. J Amer Soc Hort Sci 132: 381-386.

87. Yu K, Soon JP, Zhang B, Haffner M, Poysa V (2004) An SSR marker in the nitrate reductase gene of common bean is tightly linked to a major gene conferring resistance to common bacterial blight. Euphytica 138: 89-95.

88. Mutlu N, Miklas P, Reiser J, Coyne D (2005) Backcross breeding for improved resistance to common bacterial blight in pinto bean (P*haseolus vulgaris* L.). Plant Breed 124: 282-287.

89. MoARD (2014) Ministry of agriculture and rural development crop variety development department: Crop variety register. Issue number 18. Addis Ababa, Ethiopia.

90. Pal KK, McSpadden Gardener B (2006) Biological control of plant pathogens. The Plant Health Instructor.

91. da Silva EG, Moura AB, Deuner CC, Farias DR (2008) Study of biocontrol mechanisms of bacterial bean blight by bacteria. Revista Ceres 55: 377-383.

92. Sallam NM (2011) Biological control of common blight of bean (Phaseolus vulgaris) caused by *Xanthomonas axonopodis* pv. phaseoli by using the bacterium *Rahnella aquatilis*. Arch Phytopathol 44: 1966-1975.

93. Zanatta ZGCN, Moura AB, Maia LC, dos Santos A (2007) Bioassay for selection of biocontroller bacteria against bean common blight (*Xanthomonas axonopodis* pv. phaseoli). Bra J Microbiol 38(3): 1517-8382.

94. Giorgio A, Lo Cantore P, Shanmugaiah V, Lamorte D, Sante Iacobellis N (2016) Rhizobacteria isolated from common bean in southern italy as potential biocontrol agents against common bacterial blight. Eur J Plant Pathol 144: 297-309

95. Ciancio A, Mukerji KG (2008) Integrated management of diseases caused by fungi, phytoplasma and bacteria (1stedn.), Springer, Berlin, Germany.

96. Fetene S, Ayalew A (2016) Integrated management of common bacterial blight (Xanthomonas campestris pv. phaseoli) and its effect on seed yield of common bean (Phaseolus vulgaris L.). Int J of Life Sci 4: 336-348.