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Review Paper On Breeding Common Bean (Phaseolus Vulgaris L.) Genotypes For Acidic Soil Tolerance

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Abstract: Common bean (Phaseolus vulgaris L.) is a food legume grown on more than four million hectares annually in Africa. It provides dietary protein for over 100 million people in rural and poor urban communities, with an annual per capita bean consumption of 50 to 60 kg in Eastern Africa being the highest in the world. Common bean provides proteins, essential amino acids, minerals such as Fe, Cu, Zn, P, K, Mg and Ca, starch and dietary fibre which are less or absent indiets of of subsistence farmers in Africa and South America often contain high carbohydrates (through cassava, maize, rice, wheat. Eventhough the crop has this much contripution in the daily livelihood of the society, its production is affected by some biotic and abiotic factors. Soil acidity affects the bean production through different mechanisms including Aluminium and Mangans toxicity and inhibition of essential nutrient(P, K,N) avaliability to the crop. Aluminuim toxicity affect the growth and development of the crop by restricting root growth and enlongation. Even though Aluminum toxicity reduces both root and shoots growth, the most easily recognized symptom of A1 toxicity is the inhibition of root growth, and this has become a widely accepted measure of Al stress in plants. Common bean can tolarate Al toxicity through different mechanisms. Aluminum tolerance can be divided into mechanisms that facilitate Al exclusion from the root apex **(**external tolerance mechanisms) and mechanisms that confer the ability to tolerate Al in the plant symplasm **(**internal tolerance mechanisms**)**

Keywords: Al exclusion, Aluminum toxicity, Common bean, Soil acidity, plant symplasm

1. INTRODUCTION

Common bean (Phaseolus vulgaris L.) is the most important food legume for more than 300 million people, most of them in the developing world [1]. Common bean, locally known as 'Boleqe' also known as dry bean, Haricot bean, kidney bean and field bean is a very important legume crop grown worldwide and it is one of the most important and widely cultivated species of Phaseolus in Ethiopia. It is a major staple food crop in Africa. In a continent where over 30% of the households live below the poverty line [2], beans are valued as one of the cheapest sources of protein for vulnerable sections of the population, particularly the poor. It is an annual crop which belongs to the family Fabaceae. It grows best in warm climate at temperature of 18 to 24oC [3]. It is one of the principal food and cash legumes grown in the tropical world and most of the production takes place in developing countries [4]. Its high protein content (20-25%) supplements diets based on cereals, root and tuber crops and banana; a balanced diet can be obtained if cereals and legumes are consumed in the ratio 2:1[5]. Common bean is most likely introduced to Ethiopia by the Portuguese in the 16th century [6]. Common bean production is very heterogeneous in terms of ecology, cropping system and yield. It predominantly grows from low land (300-1100 m.a.s.l.) to mid highland areas (1400-2000 m.a.s.l.) of the country. It is well adapted to areas that receive an annual average rainfall ranging from 500–1500 mm with optimum temperature range of 16 °C–24 °C, and a frost free period of 105 to 120 days. Moreover, it performs best on deep, friable and well aerated soil types with optimum pH range of 6.0 to 6.8 [7]. Major common bean producing regions are central, eastern, and southern parts of the country and in central Ethiopia; farmers grow early maturing white pea bean types for export as their cash crop [8]. Common bean (Phaseolus vulgaris L.) is a food legume grown on more than four million hectares annually in Africa. It provides dietary protein for over 100 million people in rural and poor urban communities, with an annual per capita bean consumption of 50 to 60 kg in Eastern Africa being the highest in the world [9]. However, these benefits derived from the crop are challenged in many parts of the continent by multiple constraints that limit productivity [10]. Diets of subsistence farmers in Africa and South America often contain high carbohydrates (through cassava, maize, rice, wheat, (extra), but are poor in proteins [5]. Common bean provides proteins, essential amino acids, minerals such as Fe, Cu, Zn, P, K, Mg and Ca, starch and dietary fiber [5]. In nutritional terms, beans are often called the "poor man's meat" because they are a source of inexpensive protein and rich in minerals (especially iron and zinc) and B-vitamins [11]. However, in addition to the nutritional components, beans also contain some anti-nutritional factors such as protease inhibitors, tannins, and phytic acids [12]. In Ethiopia, Common bean is grown predominantly under smallholder producers as an important food crop and source of cash. It is one of the fast expanding legume crops that provide an essential part of the daily diet and foreign earnings for most Ethiopians [13]. It is considered as one of the most important grains for human alimentation and is planted worldwide on approximately 26 million hectares [14]. The current national production of common bean in Ethiopia is estimated at 323,317.99 hectares; with a total production of 513,724.807 tons and average productivity of 1.59 tons per hectare [15]. The crop grows well at the altitude between 1400 and 2000m above sea level [16] and in warm climate at temperature of 18 to 24oC [3]. This wide range of growth habits of haricot bean among varieties has enabled the crop to fit many growing situations Soil acidity is a significant problem that agricultural producers in tropical and subtropical regions are facing and limit legume productivity [17]. This is aggravated by the inherent poor fertility and acidity in most tropical soils [18]. Soil acidity occurs when there is a build-up of acid forming elements in the soil. The production of acid in the soils is a natural process; caused by rainfall and leaching, acidic parent materials and organic matter decay [19], hence many soils in high rainfall areas are inherently acidic [20]. About 40% of the Ethiopian total land is affected by soil acidity [21]. About 27.7% of these soils are dominated by moderate to weak acid soils (pH in KCl) of 4.5 to 5.5, and around 13.2% by strong acid soils (pH in KCl) <4.5) [21]. Acidic soils cause poor plant growth resulting from aluminium (Al^{+3}) and manganese toxicity (Mn^{+2}) or deficiency of essential nutrients like phosphorus, calcium and magnesium. Acidic soils cause poor plant growth resulting from aluminium (Al^{+3}) and manganese toxicity (Mn^{+2}) or deficiency of essential nutrients like phosphorus, calcium and magnesium. Restoring, maintaining and improving fertility of this soil is major priority as a demand of food and raw materials are increasing rapidly. Suitability of soils as a medium for crop growth and development considerably depend on its reaction. Liming acid soil make the soil environment better for leguminous plants and associated microorganisms as well as increase concentration of essential nutrients by raising its pH and precipitating exchangeable aluminium [22]. Availability of essential nutrients and biological activity in soils are generally greatest at intermediate pH at which organic matter break down and release essential nutrients like N, P and S is enhanced. Thus, the objective of this work is to review the works done so far on the breeding activities to develop common bean genotypes that are tolerant to acidic soil.

2. Breeding common bean genotypes for Acidic soil Tolerance

2.1. Description of the crop

Common bean (Phaseolus vulgaris L), also referred to as dry bean, is an annual leguminous plant that belongs to the genus, Phaseolus, with pinnately compound trifoliate large leaves [23]. Cultivated forms are herbaceous annuals, which are determinate or indeterminate in growth habit. On germination, the plant is initially tap-rooted, but adventitious roots emerge soon thereafter, and dominate the tap root which remains 10-15 cm in length [24].

2.1.1. Origin, domestication and distribution of common bean

The genus Phaseolus L. includes numerous wild and cultivated species that originated in the New World, the exact number is still unknown [25]. Common bean belongs to family Fabaceae, subfamily Papilionoideae, tribe Phaseoleae [26]. The common bean was originated in Tropical America (Mexico, Guatemala, and Peru), but there are also evidences for its multiple domestication within Central America [7]. There are four major gene pools; namely Mesoamerican, Andean, Northern Andean and Columbia. Two major gene pools of common bean were first recognized in the wild form, Mesoamerican and Andean [27]. It was most likely introduced to Ethiopia by the Portuguese in the 16th century [6]. Common bean was domesticated independently in two centers of diversity, giving rise to two gene groups: Mesoamerican and Andean [11]. The evidence for the existence of these two gene pools was supported by phaseolin seed proteins [28], allozymes [29], morphological traits [30], and DNA markers [31].

2.1.2. Morphology and Botanical characteristics of the crop

Most beans are herbaceous annuals, although, under tropical conditions, some beans (such as large limas) may behave as short-lived perennials. Seeds are non-endospermic and vary greatly in size and colour from the small black wild type to the large white, brown, red, black or mottled seeds of cultivars, which are 7-16 mm long [32]. The common bean flower has an elongated twisted keel containing the style and ten stamens. Inside the flower the anthers drop pollen on to the style in the evening before it opens. Seeds may be round, elliptical, somewhat flattened or rounded elongate in shape and a rich assortment of coat colours and pattern exists. Common bean shows variation in growth habits from determinate bush to indeterminate, extreme climbing types. The bushy type bean is the most predominant type grown in Africa [33].

2.1.3. Crop Development

Beans show a high variation in growth habit, which appears to be continuous from determinate bush to indeterminate, extreme climbing types although for Simplicity, [34] classified the bean growth habits into four major classes (type I = determinate upright or bush; type II = indeterminate upright bush; type III = indeterminate prostrate, non-climbing or viny semi climbing and type IV = Indeterminate strong climbers) and suggested a key for their identification based on the type of terminal bud (vegetative vs. reproductive), stem strength (weak vs. Strong), climbing ability (non climber vs. strong climbers), and fruiting patterns (mostly basal vs. along entire stem length or only in the upper part).

2.1.4. Ecology of the Crop

Common bean is a warm-season crop that does not tolerate frost or long periods of exposure to near-freezing temperatures at any stage of its growth. However, high temperatures (>30ºC) can cause flower blasting (dropping of buds and flowers; [35], which reduces yield. In general, flower and pod abortion rates in bean may vary between 60-80% [36]. Common bean is well adapted to areas that receive an annual average rainfall ranging from 500–1500 mm with optimum temperature range of 16°C–24°C, and a frost free period of 105 to 120 days. Dry weather is desirable for the maturation of the crop and for harvesting. Late rains may also discolor the beans and lower their grade and market value [37]. Moreover, it performs best on deep, friable and well aerated soil types with optimum pH range of 6.0 to 6.8 [7].

2.2. Common Bean Production and its Economic Importance in Ethiopia

Common bean is the world‘s most important grain legume for direct human consumption [5], with 20.3 million tons of dry beans harvested from 27.9 million ha worldwide in 2008 (FAOSTAT, 2010). It is cultivated primarily for dry seeds, green pods (as snap beans), and green-shelled seed. There are wide ranges of common bean types grown in Ethiopia including mottled, red, white and black varieties

[38]. The most commercial varieties are pure red and pure white color beans and these are becoming the most commonly grown types with increasing market demand [39]. Common bean production is heterogeneous in terms of ecology, cropping system and yield [40]. Common bean is grown predominantly in low land area (300-1100m) mainly in the rift valley and some mid highland areas (1400-2000m) of the country. Common bean produced in the rift valley is mainly white pea beans that are preferred for export markets [41]. Beans offer a low cost alternative to beef and milk because bean seed is rich in protein, iron, fibres, and complex carbohydrates [42]. Ethiopian farmers grow beans for two major consumption uses namely: canning and cooking types. The white navy beans are grown for export canning industry and other types are mainly for households' food for national and regional markets. In Ethiopia, dry beans are grown by small scale famers. They are major source of proteins in the lowlands where they are consumed as Nifro, Wasa, Shirowat, soup and samosa. They are important export crop especially navy beans from the Central Rift Valle region and some parts of east and west highlands. With regard to economic importance of common bean, it is used as a source of foreign currency, food crop, means of employment, source of cash, and plays great role in the farming system [8]. Common bean protein is high in lysine, which is relatively deficient in maize, cassava and rice, making it a good complement to these staples in the diet. It is grown for its green leaves, green pods, and immature and/or dry seeds.

2.3. Acid Soils

Acid soils, which are soils having a pH of 5.5 or lower, is one of the most important limitations to agricultural productions worldwide. Approximately 30% of the world's total agricultural land is covered by acid soils, and as much as 50% of the world's potentially arable lands are acidic [43]. Acid soils mainly occur in two global belts: the northern belt of organic acid soils in the humid temperate zone, and the southern belt of mineral acid soils in the humid tropics. The tropics and subtropics account for 60% of the acid soils in the world. In tropical areas, about 43% of the soils are acidic comprising about 68% of tropical America, 38% of tropical Asia, and 27% of tropical Africa [44]. In Ethiopia, soil acidity is a problem that has been barely addressed. It is observed that most of these soils are found in the highlands receiving high rainfall [45], which amounts to greater than 1500 mm per year. An inventory of the current soil acidity status in western and central Ethiopian Nitsols was carried out in West Wollega, East Wollega and West Showa zones by [46], indicated that collected from the three study zones were acidic and the degree of soil acidity varied among the study zones, districts and peasant associations. As a case in point, a site-specific study of soils around Asosa and Wollega revealed that, in aggregate, 67% of the soil samples have pH values less than 6 and some are very strongly to strongly acidic [47]. Of these, 2.2% were extremely acidic (pH < 4.5), 34% were very strongly acidic (pH 4.5 to 5.0), 32.8% are strongly acidic (pH 5.1 to 5.5.) and 27% were moderately acidic with a pH range of 5.6 to 6.0. Of the total, only 3% are slightly acidic (pH 6.1 – 6.5), and 1% was neutral. Soil acidity constrains symbiotic N2 fixation [48], limiting Rhizobium survival and persistence in soils and reducing nodulation and causes nutrient imbalance [49]. Increased soil acidity may lead to reduced yields, poor plant vigour, and nodulation of legumes [50]. [51] indicated that multiplication of Rhizobium in the rhizosphere and nodulation were inhibited at pH 4.3. Soil pH relates to both soil's capacity to supply nutrients and to its aluminium and manganese toxicity problems [52]. Common beans are sensitive to high concentration of aluminium, boron and sodium [53].

2.3.1 Common Bean Production on Acid Soils

Common bean often experiences different a biotic stresses including drought, toxicities of Al and manganese, low soil fertility, and high temperatures under field conditions, [54]. Among these, Al toxicity and drought are the two major a biotic stresses for bean production in the tropics [54]. About 40% of the common bean production areas in Latin America and 30–50% of central, eastern, and southern Africa are affected by Al phytotoxicity resulting in yield reductions of 30–60% [26]. The majority of soils in East Africa also have pH limitations for bean growth, with 52% of soils in this region and 42% of soils in southern African having a pH of 5.2 or less [55]. Common bean is considered to be relatively more sensitive to Al toxicity compared to other crops [56]. However, in contrast to maize (Zea mays L.), in common bean, Al applied to the elongation zone of the root apex contributed to the overall inhibition of the root elongation [57]. The major sites of Al perception and response are the root apex [58], and the distal part of the transition zone (1 -2 mm) is the most Al sensitive apical root zone [59]. Common bean exhibits a typical pattern II type of response to Al treatment characterized by a delay of several hours in Al induced exudation of organic acids, particularly citrate [60]. However, efforts to develop adapted genotypes indicate that there are genotypic differences in Al resistance in the bean germplasm [1]; [61]. Like many legumes, common beans prefer well aerated, sufficiently drained soil with a pH of 6.0 to 7.5, the critical pH thresholds being 5.0 and 8.1 [62]. Common bean generally cannot withstand waterlogging though some cultivars do well in standing water [63]. It is sensitive to Al, B, Mn and high levels of Na. Deficiencies in Zn, Mg and Mo may arise in calcareous soils and sandy soils, respectively [63]. The two major common bean producing regions in Ethiopia are Oromiya and Southern Nations, Nationalities and People's Region (SNNPR), which produce 70 and 60 thousand tons per year, respectively, and these two regions make up 85% of the total production [8].

2.3.2. Effects and Mechanisms of Aluminium Toxicity

According to [64], Al is the third most abundant element in the earth's crust, comprising about 7% of the total mass of the earth. [65] Considered that Al is one of the most abundant toxic elements with the ability to contaminate soil, water and trophic chains. Nonetheless, the specific biological functions of Al for animals and plants are unknown, and so it is not regarded as an essential element [66]. Fortunately, in terms of agronomic activity, most Al is bound to be in insoluble forms such as alumino-silicates and/or precipitated as Al hydroxide sulfate [67]. Al is solubilized from silicates and oxides (not toxic forms) to

Al3+, which is phototoxic only under conditions of low pH [68]. Even though Aluminum toxicity reduces both root and shoots growth, the most easily recognized symptom of A1 toxicity is the inhibition of root growth, and this has become a widely accepted measure of Al stress in plants. Some reports indicated that Al-induced leaf necrosis [69], leaf yellowing [49], stunted leaf growth [68] and late leaf maturity [70] are effects of Al-toxicity. These changes were accompanied by a reduction in chlorophyll content [68] and photosynthesis rate and abnormal chloroplast structure [71]. The major constraints to the plant growth in acid minerals soils are: High hydrogen, aluminium, and manganese concentrations inducing toxicity; Low calcium, magnesium, potassium, phosphorus inhibition of root growth and water uptake, inducing nutrient deficiency and drought stress [72].

2.4. Aluminum Tolerance Mechanisms

Aluminum tolerance can be divided into mechanisms that facilitate Al exclusion from the root apex **(**external tolerance mechanisms) and mechanisms that confer the ability to tolerate Al in the plant symplasm **(**internal tolerance mechanisms**)** **(**[73]; [74]; [64]). Due to the common assumption that most Al in the root is apoplasmic and that penetration of Al into the symplasm in general is very low, the amount of research addressing internal tolerance mechanisms is limited compared to research on external mechanisms.

2.4.1 Genetic Mechanisms of Aluminum Tolerance

Acidity in the surface soil can be corrected by applying agricultural lime. When the subsoil layers are acidic, amelioration of the surface layer will not allow the plant roots to penetrate the acid layer and reach critical water and nutrient supplies below it. Selection and development of genotypes with enhanced tolerance to acid soils and toxic levels of Al is the only reasonable solution to this problem. The genetics and chromosome localization of aluminum tolerance genes have been extensively studied in cereal crops, with emphasis on wheat. For chromosome manipulation in wheat and triticale breeding, it is important to know which wheat and rye chromosomes carry genes for aluminum tolerance [75].

2.4.2. Strategies for Screening for Aluminum Tolerance

Different screening methods have been used to evaluate Al tolerance: cell and tissue culture [76], nutrient solution culture [77], soil bioassays [78], and field evaluations [79]. Laboratory and greenhouse-based techniques for screening for Al tolerance are widely used because they are quick, highly accurate, non-destructive, and can be applied at early developmental plant stages. Field-based techniques are more laborious [74].

3. Summery and Conclusion

Common bean often faces different a biotic and biotic stresses including drought, toxicities of Al and manganese, low soil fertility, and high temperatures under field conditions. Out of these stresses Al toxicity and drought are the two major a biotic stresses for bean production in the tropics. Al phytotoxicity affects common bean production areas in Latin America and central, eastern, and southern Africa resulting in yield reductions of 30–60%. Common bean is considered to be relatively more sensitive to Al toxicity compared to other crops. Al treatment of Common bean causes a delay of several hours in Al induced exudation of organic acids, particularly citrate. Al is one of the most abundant toxic elements with the ability to contaminate soil, water and trophic chains. In addition to reducing both root and shoots growth, the most easily recognized symptom of A1 toxicity includes induction of leaf necrosis, leaf yellowing, stunted leaf growth and late leaf maturity. These changes were accompanied by a reduction in chlorophyll content and photosynthesis rate and abnormal chloroplast structure. Plant tolerates Aluminum toxicity can be through mechanisms that facilitate Al exclusion from the root apex **(**external tolerance mechanisms) and mechanisms that confer the ability to tolerate Al in the plant symplasm. Selection and development of genotypes with enhanced tolerance to acid soils and toxic levels of Al is the only reasonable solution to this problem. Different screening methods have been used to evaluate Al tolerance: cell and tissue culture nutrient solution culture, soil bioassays, and field evaluations. Laboratory and greenhouse-based screening techniques for Al tolerance are widely used because they are quick, highly accurate, non-destructive, and can be applied at early developmental plant stage.

4. Reference

[1]. Rangel, AF, Mobin, M., Rao, IM. and Horst, WJ. 2005. Proton toxicity interferes with the screening of common bean (Phaseolus vulgaris L.) genotypes for aluminum resistance in nutrient solution. Journal of Plant Nutrition and Soil Science, 168:607–616.

[2]. World Bank. 2006. Interim country assistance strategy, Ethiopian Country Management Unit, Report No 35142-ET. 56 pp.

[3]. Teshale, Assefa, Girma, Abebe, Chemeda, Fininsa, Bulti, Tesso & Abdel-Rahman M. Al-Tawaha. 2005. Participatory Bean Breeding with Women and Small Holder Farmers in Eastern Ethiopia. World Journal of Agricultural Sciences, **1**: 28-35.

[4]. Pachico, D. (1989). Trends in world common bean production. In: H.F. Schrwartz and M.A. Pastor-Corrales, Bean Production Problems in the Tropics, CIAT, Cali, Colombia, pp1-8.

[5]. Broughton WJ, Hernández G, Blair M, Beebe S, Gepts P, Vanderleyden J (2003). Beans (Phaseolus spp.) - model food legumes. Plant. Soil. 252: 55-128.

[6]. Wortmann, C.S. and C. A. Eledu. 1997. Distribution of bean types in Eastern Africa Annual Report of the Bean Improvement Cooperative, 40: 30-31.

[7]. Kay, D.E. 1979. Food Legumes. Tropical Product Institutes. 56/62 Gray's lnn Road London. p. 25.

[8]. Central Statistical Authority (CSA). 2005. Agricultural sample survey, Area and production of temporary crops, private holdings for the 2004/05. Meher season

[9]. ISAR. Bean Program, Rwanda Agricultural Research Institute. http://www.isar.rw/spip.php. 2011, (last accessed 5 December, 2011).

[10]. Buruchara R, Chirwa R, Sperling L, Mukankusi C, Rubyogo JC, Muthoni R and MAbang Development and diversity of bean varieties in Africa: the Pan Africa bean Research Alliance (PABRA) model. African Crop Sci. J.2011; 19(4):227-245.

[11]. Beebe S, Skroch PW, Tohme J, Duque MC, Pedraza F and J NienhuisStructure of genetic diversity among common bean landraces of Middle American origin based on correspondence analysis of RAPD. Crop Sci.2000; 40: 264–273.

[12]. Supradip S, Singh G, Mahajan V and HS Gupta Variability of Nutritional and Cooking Quality in Bean (Phaseolus vulgaris L) as a Function of Genotype. Plant Foods Human Nutrition.2009; 64:174–180.

[13]. Girma Abebe. 2009. Effect of NP Fertilizer and Moisture Conservation on the Yield and Yield Components of Haricot Bean (Phaseolus Vulgaris L.) In the Semi-Arid Zones of the Central Rift Valley in Ethiopia. Advances in Environmental Biology, **3**: 302-307.

[14]. Emam, Y, A Shekoofa, F Salehi, and A H Jalali. 2010. ―Water Stress Effects on Two Common Bean Cultivars with Contrasting Growth Habits‖ 9 (5): 495–499.

[15]. Central Statistical Authority (CSA). 2015. Agricultural sample survey, Area and production of temporary crops, private holdings for the 2014/15. Meher season.

[16]. Fikru, Mekonnen. 2007. Haricot ban (Phaseolus Vulgaris L.) variety development in the lowland areas of Wollo. Proceedings of the 2nd Annual Regional Conference on Completed Crops Research Activities 18 - 21 September 2007, Bahir Dar, Ethiopia, pp 86-93.

[17]. Bordeleau LM, Prevost D. 1994. Nodulation and nitrogen fixation in extreme environments. Plant and Soil, 161(1):115-125.

[18]. Okalebo, J. R., Othieno, C. O., Woomer, P. L., Karanja, N. K., Semoka, J. R. M., Bekunda, M. A., Mugendi, D. N., Muasya, R. M., Bationo, A. & Mukwana, E. J. 2006. Available technologies to replenish soil fertility in Eastern Africa. Nutrient Cycling in Agro ecosystems, 76: 153-170

[19]. Havlin JL, JD B, SL T, WL N. Soil fertility and fertilizers: An introduction to nutrient managemnt. New Jersey: Pearson prentice hall; 2005.

[20]. McCauley A, C J, J J. Soil pH and organic matter, nutrient managements module. Bozeman, USA: Montana State University, 2009.

[21]. Mesfin Abebe. 2007. Nature and Management of Acid Soils in Ethiopia. Alamaya University of Agriculture.18 pp.

[22]. Kisinyo, P.O., S.O. Gudu, C.O. Othieno, J.R. Okalebo and P.A. Opala. 2012. Effects of lime, phosphorus and rhizobia on Sesbania sesban performance in a Western Kenyan acid soil. African Journal of Agricultural Research, 7: 2800- 2809.

[23]. Katungi E., Chianu J.F., Sperling L. And Beebe S., 2009. Common bean in east Africa: A situation and outlook analysis. ICRISAT.

[24]. Duke, J.A. 1981. Handbook of Legumes of World Economic Importance. Plenum Press, New York. 345p.

[25]. Debouck, D. G. 1999. Diversity in Phaseolus species in relation to the common bean. In: Singh, S.P. ed. Common bean improvement in the twenty-First century. Kluwer Academic Publishers, Dordrecht, Boston, London, pp. 25-52. declining renewable resources. Plant Physiol. **2001**, 127, 390–397.

[26]. CIAT (Centro International de Agricultura Tropical). 1992. Constraints to and opportunities for improving bean production. A planning document 1993-98 and an achieving document, 1987–92. CIAT, Cali, Colombia.

[27]. Gepts, P. 1998. Origin and evolution of common bean: Past events and recent trends. Hortscience 33, 1124-1130.

[28]. Gepts, P., Osborn, T.C., Rashka, K. & Bliss, F.A. 1986. Electrophoretic analysis of phaseolin protein variability in wild forms and landraces of the common bean, Phaseolus vulgaris: Evidence for multiple centers of domestication. Economic Botany 40, 451-468.

[29]. Singh, S.P, Nodari, R. & Gepts, P. 1991. Genetic diversity in cultivated common bean. I. Allozymes. Crop Science 31, 19-23.

[30]. Singh, S.P., Gepts, P. & Debouck, D.G. 1991. Races of common bean (Phaseolus vulgaris, Fabaceae). Economic Botany 45, 379-396.

[31]. Becerra-Velásquez, V.L. & Gepts, P. 1994. RFLP diversity of common bean (Phaseolus vulgaris L.) in its centres of origin. Genome 37, 256-263.

[32]. Cobley, L.S. and W.M. Steele (1976). An introduction to the botany of tropical crops, Longman group Limited, London

[33]. Buruchara, R. 2007. Background information on common bean (Phaseolus vulgaris. L.).

[34]. Singh, S.P. 1982. A key for identification of different growth habits of Phaseolus vulgaris L. Annual report of Bean Improvement Cooperative 25, 92-95.

[35]. Fageria, N.K., Baligar, V.C. & Jones, Ch.A. 1997. Growth and mineral nutrition of field crops. 2nd ed. Marcel Dekker, Inc. New York, Basel, Hong Kong, 624 pp.

[36]. White, J.W. and J. Izquierdo, 1991. Physiology of yield potential and stress tolerance. In: A. van Schoonhoven and O. Voysest (eds.), Common Beans. Research for Crop Improvement, pp. 287-382. CAB int CIAT, Colombia.

[37]. Free, J.B. 1993. Insect pollination of crops. 2nd edition, Academic Press, Harcourt Brace Jovanoich, Publishers. London, San Diego, New York, Boston, Sydney, Tokyo, Toronto. pp 371-381

[38]. Ali, K.Gemechu, A.S, M.R, Beniwal, S.Makkouk and Halila.M. 2003. Food and forage legumes of Ethiopia; Progress and prospects on food and forage legume Proceeding of the workshop, 22-26 September 2003, Addis Ababa, Ethiopia.

[39]. Ferris S and Kaganzi E. 2008. Evaluating marketing opportunities for haricot beans in Ethiopia. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 7. ILRI (International Livestock Research Institute), Nairobi, Kenya. 68 pp.

[40]. Belay Semane, Wortmann C. W. S. and Hoogenboom G., 1998. Haricot bean agro ecology in Ethiopia: Definition using agro climatic and crop growth simulation models. African Crop Science Journal 6 (1): 9–18. biotechnology, breeding and seed systems for African crops.

[41]. Yayis Rezene, Setegn Gebeyehu and Habtamu Zeleke, 2011. Genetic variability for drought resistance in small red seeded common bean genotypes. African Crop Science Journal 19(4):303 – 311.

[42]. Mwale, M.V., M.J. Bokosi1, M.C. Masangano, M.B. Kwapata1, V.H. Kabambe, and C. Miles. 2008. Yield performance of dwarf bean (Phaseolus vulgaris L.) lines under researcher designed farmer managed (RDFM) system in three bean agroecological zones of Malawi. African Biotechnology Journal, 7(16): 2847-2853.

[43]. Von Uexkull, H.R. and Mutert, E. 1995. Global extent, development and economic impact of acid soils. In RA Date, NJ Grundon, GE Raymet, ME Probert, eds, Plant-Soil Interactions at Low pH: Principles and Management. Kluwer Academic Publishers, Dordrecht, the Netherlands, pp. 5-19.

[44]. Yang, Z.B., Eticha, D., Albacete, A., Rao, I.M., Roitsch, T. and Horst, W.J. 2012. Physiological and molecular analysis of the interaction between aluminium toxicity and drought stress in common bean (Phaseolus vulgaris). J Exp Bot. 63:3109–3125.

[45]. Paulos Dubale. 2001. Northeast African Studies, (ISSN 0740-9133), 8(1) (New Series), pp. 27-52.

[46]. Abdenna Deressa, Negassa Chewaka, Tilahun Geleto. 2007. Inventory of Soil Acidity Status in Crop Lands of Central and Western Ethiopia. (http://www.tropentag.de/2007/abstracts/links/Deressa_kmwmgGa s.pdf).

[47]. Tadesse Yohannes. 1990. Management of Acid Soils in Asosa and Wollega Regions. In: Natural Resources Management for Conservation and Development. Institute of Agricultural. Research, Addis Ababa. pp 68 – 73.

[48]. Munns DN. 1986. Acid soils tolerance in legumes and rhizobia. Advances in Plant Nutrition, 2:63–91.

[49]. Foy, C. D. 1984. Physiological effects of hydrogen, aluminium, and manganese toxicities in acid soil. In: Soil acidity and liming, 2nd edition, F. Adams, Ed., 57–97. Madison, WI: ASA, CSSSA and SSSA.

[50]. Kang BT, Juo ASR. 1986. Effect of forest clearing on soil chemical properties and crop performance. In: Lal R, Sanchez PA, Cummings RW (eds.) Land clearing and development in the tropics Rotterdam, Netherlands: A.A. Balkema. pp. 383-394.

[51]. Wood M, Cooper JE, Holding AJ. 1984. Soil acidity factors and nodulation of Trifolium repens. Plant and Soil, 78 (3):367-379.

[52]. Kimani, P.M., Buruchara, R.A., Ampofo, K., Pyndji, M., Chirwa, R. and Kirkby, R., 2010. Breeding beans for smallholder farmers in Eastern, Central, and South Africa: Constraints, achievement and potential. Crop improvement. Nairobi: CIAT. 15-24 pp.

[53]. Horneck, D.S., Ellsworth, J.W., Hopkins, B.G., Sullivan, D.M., Stevens, R.G., 2007. Managing Salt-Affected Soils for Crop Production. PNW 601-E. Oregon State University, University of Idaho, Washington State University, 21p.

[54]. Ishitani, M, Rao, I, Wenzl, P., Beebe, S. and Tohme, J. 2004.Integration of genomics approach with traditional breeding towards improving abiotic stress adaptation: drought and aluminum toxicity as case studies. Field Crops Research, 90:35–45.

[55]. Wortman, C.S., Kirkby, R.A., Eledu, C.A. and Allen, D. J. 1998. Atlas of Common Bean (Phaseolus vulgaris L.) Production in Africa. CIAT, Cali, Colombia.

[56]. Thung, M.D.T. and Rao, I.M .1999. Integrated management of abiotic stresses. In: Common bean improvement in the 21st century. Singh SP (ed). Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 331-370.

[57]. Rangel, A.F., Rao, I.M. and Horst, W.J. 2007. Spatial aluminium sensitivity of root apices of two common bean (Phaseolus vulgaris L.) genotypes with contrasting aluminum resistance. J. Exp. Bot. 58: 3895-3904.

[58]. Ryan, P.R., DiTomaso, J.M. and Kochian, L.V. 1993.Aluminium toxicity in roots: an investigation of spatial sensitivity and the role of the root cap. Journal of Experimental Botany. 44:437-446

[59]. Kollmeier, M., Felle, H.H. and Horst, W.J. 2000. Genotypic differences in aluminum resistance of maize are expressed in the distal part of the transition zone. Is reduced basipetal auxin flow involved in inhibition of root elongation by aluminum? Plant Physiology, 122: 945-956.

[60]. Stass, A., Kotur, Z. and Horst, W.J. 2007. Effect of boron on the expression of aluminium toxicity in Phaseolus vulgaris. Physiologia Plantarum. 131: 283-290.

[61]. Manrique, G., Rao, I.M. and Beebe, S. 2006. Identification of aluminum resistance common bean genotypes using hydroponic screening method. Paper presented at the 18th world congress of soil sciences, Phila de phia, USA, July 9-15.

[62]. Lunze L., Kimani P.M., Ngatoluwa, R., Rabary B., Rachier G.O., Ugen M.M., Ruganza V., Awad Elkarim E.E. 2007. Bean improvement for low soil fertility in adaptation in Eastern and Central Africa. In: Bationo, A., Waswa, B., Kihara, J. & Kimetu J. (Eds.) Advances in integrated soil fertility management in sub-Saharan Africa: Challenges and Opportunities, pp. 325 – 332. Springer, Dordrecht, The Netherlands.

[63]. Ecocrop, 2013.FAO, Rome, Italy http://ecocrop.fao.org/ecocrop/srv/en/home

[64]. Kochian, L.V. 1995.Cellular mechanisms of aluminum toxicity and resistance in plants. Annual Review of Plant Physiology and Molecular Biology, 46: 237-260.

[65]. Yakimova, E. T., Kapchina-Toteva, V. M. and Weltering, E. J. 2007. Signal transduction events in aluminum-induced cell death in tomato suspension cells. J. Plant Physiol. 164:702 - 708.

[66]. Poschenrieder, C., Gunse, B., Corrales, I. and Barcelo, J. 2008. A glance into aluminum toxicity and resistance in plants. Science of the Total Environment, 400, 356–368.

[67]. Takahashi, T., Ikeda, T., Fujita, K. and Nanzyo, M. 2006. Effect of liming on organically complexed aluminum of non-allophanic Andosols from northeastern Japan. Geoderma 130, 26 - 34.

[68]. Wang, J., Raman, H., Zhang , G. Mendham, N. and Zou, M. 2006. Aluminum tolerance in barely (Horidium vulgarie L.): Physiological mechanisms, genetic and screening methods. Journal of Zhejiang University Science, 7:769-787.

[69]. Zhang Xiao-Bin, Peng L., Yang, Y.S. and Gen-Di, Xu. 2007. Effect of Al in soil on photosynthesis and related morphological and physiological characteristics of two soybean genotypes. Botanical Studies, 48: 435-444

[70]. Rout, G.R, Samantaray, S. and Das, P. 2001. Aluminium toxicity in plants: a review. Agronomy, 21: 2 -21.

[71]. Peixoto, H. P., da Matta, F. M. and da Matta, J. C. 2002. Responses of the photosynthetic apparatus to aluminum stress in two sorghum cultivars. Journal of Plant Nutrition 25: 821- 832.

[72]. Marschner, H. 1997. Adaptation of plants to adverse chemical soil conditions. In: Mineral Nutrition of Higher Plants 2nd Ed. Academic Press, London. pp. 596-680.

[73]. Taylor, G.J. 1988. The physiology of aluminum phytotoxicity. In: Metal ions in biological systems: Aluminum and its rule in biology,

Sigel, H., and A. Sigel (eds.). Vol. 24:123-163, Marcel Dekker, New York.

[74]. Carver, B.F., and J.D. Ownby. 1995. Acid Soil Tolerance in Wheat. Advances in Agronomy 54:117-173.

[75]. Aniol, A., and J.P. Gustafson. 1984. Chromosome location of genes controlling aluminum tolerance in wheat, rye, and triticale. Can. J. Genet. Cytol. 26:701-705.

[76]. Conner, A.J., and C.P. Meredith. 1985. Large scale selection of aluminum-resistant mutants from plant cell culture expression and inheritance in seedlings. Theor. Appl. Genet. 71:159-165.

[77]. Baier, A.C., D.J. Somers, and J.P. Gustafson. 1995. Aluminum tolerance in wheat: Correlating hydroponic evaluation with field and soil performances. Plant Breed. 114:291-296.

[78]. Ring, S.M., R.P. Fisher, G.J. Poile, K.R. Helyar, M.K. Konyers, and S.G. Morris. 1993. Screening species and cultivars for their tolerance to acidic soil conditions. Plant Soil 155/156:521-524.

[79]. Johnson, J.P., B.F. Carver, and V.C. Baligar. 1997. Productivity in Great Plains acid soils of wheat genotypes selected for aluminium tolerance. Plant and Soil 188:101-106.

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