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Review on Effect of Soil Acidity on Barley *(Hordeum vulgare L.)* producing Central highlands of Ethiopia

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Abstract: **Barley is an important food crop grown in diverse agro-ecology, different seasons and production systems of Ethiopia. Soil acidity is now a serious threat to barley production in most high lands of Ethiopia and about 43% of the Ethiopian high land with altitude of >1500 arable land are affected by soil acidity. Acidic soils affected areas of Ethiopia found at western and southwestern, northwestern part of the country. Barley is considered to be more sensitive to acidic soils. The initial toxic effects of acid soil are stunted and shortened root growth then delay barley germination and initiation. This continued by delay of days to heading and days to maturity, decrease of plant height and increase severity of foliar diseases. Finally the overall effect of soil acidity is significantly expressed on biomass and grain yield and yield components barley.**

Keywords: **Barley, Soil acidity stress.**

1. INTRODUCTION

Barley (*Hordeum vulgare* L.) is the fourth most important cereal crop grown in the world after maize, wheat and rice with productivity of 3.3 ton ha^{-1}. On the African continent, Ethiopia, Algeria, Morocco, South Africa and Tunisia are the top five largest barley producers(FAO, 2020).In Ethiopia barley is the most important cereal crop following teff, maize, wheat and sorghum in bulk production and area coverage and fifth in yield (ton ha^{-1}) after maize, rice, wheat and sorghum with around 0.92 million ha and 2.3 million tons.In addition, the productivity of barley is 2.53 ton ha^{-1}(CSA, 2021).

Barley is an important grain food crop grown in diverse agro-ecology from1,500 to 3,500m altitude for many purpose in different seasons and production systems and a common food grain, especially for highlands of Ethiopia(Berhane *et al*.,1996; Muluken, 2013).

The abiotic stresses were indicated among the most important constraints in barley production (Bayeh and Berhane, 2011). From abiotic stress, soil acidity is one of the major constraintsfor barley production. The acidic soils mainly Nitosols or Oxisols are common in Ethiopian highlands, where the rainfall intensity is high and crop cultivation has been carried out for centuries(Desta,1987). Acid soils cause nutritional disorders, deficienciesor unavailability of essential nutrients such as calcium, magnesium, molybdenum and phosphorus and toxicity of aluminium, manganese and hydrogen ionsactivity in the soil (Foy *et al.*, 1978).Toxic elements like aluminium and manganese are the major causes for crop failure in acid soils. These elements are a problem in acid soils because they are more soluble at pH below 5 (Birhanu, 2008).Barley grows well on neutral to mildly acid soils with a pH range of 6–7. Increasing soil acidity may lead to poor plant vigor and crop growth, stunted root growth, persistence of acid-tolerant weeds, increased incidence of diseases, abnormal leaf color and reduced yield (Somani, 1996). Yields of the major cereal crops, particularly barley is reduced by 0.5 ton ha^{-1} as a result of soil acidity (Paoulos, 2001). Among small grain crops barley is one of the most sensitive species to acid soil among small-grain crops, but differences in acid soil tolerance exist among the genotypes (Zhao *et al.*, 2003).

Therefore, this research was conducted to asses the effect soil acidity on barley producing areas of Ethiopia.

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2. SOIL ACIDITY EXTENT AND DISTRIBUTION IN ETHIOPIA

Soil acidity is one form of chemical degradation of soils. The problems of acid soils are high in acidity and low amount of exchangeable cations especially calcium and it is considered to be one of the most important factors that affect the soil chemical fertility. Acid soils are phototoxic because of nutritional disorders, deficiencies or unavailability of essential nutrients such as calcium, magnesium, molybdenum and phosphorus and toxicity of aluminium, manganese and hydrogen activity (Foy *et al.*, 1978).

The main factors giving rise to increased soil acidity in Ethiopia include climatic factors such as rainfall and leaching, temperature, severe soil erosion, anthropological factors,acidic parent material, organic matter decay, removal of products from the farm or paddock and inappropriate use of nitrogenous fertilizers.Soil acidity is more easily understood when there is an abundance of acidic cations, like hydrogen (H^+) and aluminium (Al^{+++}) compared to the alkaline cations like calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^+) and sodium (Na^+) (Johnson, 1914;Temesgen*et al*., 2011).

In Ethiopia, about 43% of the Ethiopian high land with altitude of >1500 arable land are affected by soil acidity(Ethiosis,2014). The most strongly acidic soils are found in western and southwestern parts of Ethiopia, the central highlands and high rainfall areas of northwestern part of the country. Nevertheless, moderately acidic soils (pH 5.5-6.5) are distributed through much of the rest of the country (Taye, 2008).In moving from central (West Shewa) to Western Ethiopia (West Wellega), the degree of soil acidification is increased (ASP>60). In Western and eastern Wellege zones, the largest proportion of exchangeable acidity was due to exchangeable Al^{+++} while in West Shewa zone it was due to Exchangeable H^+. The acidity problem in East and West Wellega zone of Oromia region is critical (Abdenna*et al.*, 2007).

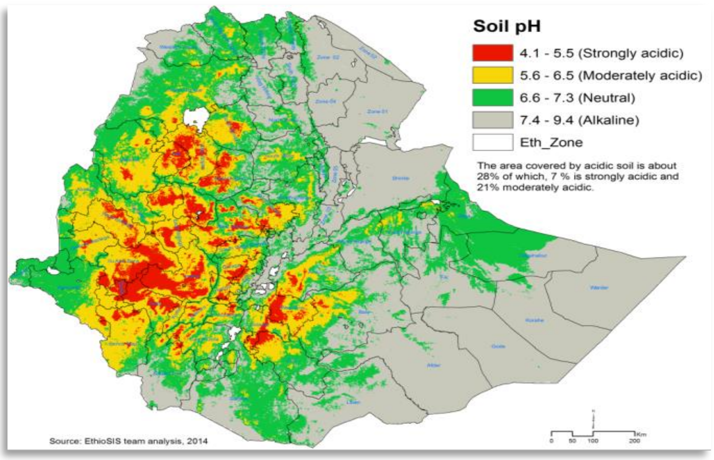

Figure 1. Distribution of acid soils in Ethiopia (Schlede, 1989, Behailu Kasahun, 2015)

The optimum soil pH for plant production is (pH 6-6.5), at this pH, soil microorganisms are most active and plant nutrients are readily available. Beyond to this delicate balance is disturbed and plant nutrients becomes deficient to plant growth. Some essential nutrients such as calcium, phosphorous, magnesium and molybdenum become unavailable if the soil pH becomes too acid (Eshetu, 2011).

Crop production on acid soils can be sustained by application of lime. The most important benefit of liming acid soils is reducedin solubility of the potentially toxic elements hydrogen, aluminium(Al^{3+}) and manganese (Mn^{2+}). Optimum nutrient uptake by most crops occurs at a soil pH near 7.0, and the availability of fertilizer nutrients such asnitrogen, phosphorousand potassium generally is reducedas soil pH decreases (Mark *et al.*, 2001).Thus, developingcultivars with improved tolerance to acid soil stress is a solution to address this problem (Scott and Fisher, 1989).

Effect of Soil Acidity on Growth, Development and Yield of Barley

The most important abiotic stress constraining the production of barley includes low soil fertility, low soil pH, poor soil drainage, frost and drought. From these abiotic stresses, soil acidity is one of the most importantconstraints in barley production, mainly on Nitisols or Oxisols, of the Ethiopian highlands (Taye and Höfner, 1993).

Barley is considered to be more sensitive to acidic soils than rye, oat, rice and wheat (Bona *et al.*,1993).The acid tolerance order reported as maize> rye> triticale> wheat>barley (Polle and Konzak, 1985).The initial toxic effects of acid soil are stunted and shortened root growth then limited growth and productivity of barley by restricting water uptake and nutrient absorption (Wang *et al.,* 2006).Because of inhibitory effect of soil acidity on root development, it decreases tolerance of plants to acidity and decreases use of subsoil nutrients and suppression of photosynthetic capacity of shoots. This is associated with cellular and ultra structural modifications in leaves, reduced stomatal opening and CO_2 assimilation, reduced chlorophyll concentration, chlorosis and leaf necrosis (Miyasaka *et al.,* 2007).

Soil aciditycause delay in barley germination and initiation. The principal factor responsible for delay emergence in acidic soil did not delay radical initiation, but delay initiation of hypocotyls elongation and these elongation of hypocotyls was highly associated with rate of tap root growth (Ritchey and Carter, 1993). Soil acidity had a reduction effect on agro-morphological traits of the studied barley genotypes compared to limed soil such as, delay of days to emergence, days to heading and days to maturity, decrease of plant height and increase severity of foliar diseases(Tigist and Thomas,2021)

Tiller numbers may also be reduced by poor nutrient availability(Baque *et al.*,2006).Mean value of number of fertile tillers per plant at both limed and not limed soil is stastically different and the limed have a higher mean value of fertile tiller (Temesgen,2014). The number of tillers plant^{-1}significantly ($P<0.05$) differed between cultivars as well as lime treatments. The number of tillers plant^{-1} were higher for plants grown in lime treated soil than in lime untreated soil (Tenaye and Tesfaye, 2014). Moreover, barley grown under acidic soil condition is remarkably shorter than lime treated soil. Plant height increased under lime treated soil; this isrelated to the increase in soil fertility and reduction of the toxic concentration of acidic cations(Chimdi *et al*., 2012).

Gallardo *et al*., (1999) reported that, the overall effect of soil acidity is significantly expressed on biomass and grain yield of crops. On barley 50% and 30% reduction of grain yield, respectively, for sensitive and tolerant cultivars when they were grown in naturally acidic soil (pH 4.9) with a large amount of extractable Al compared to that grown in non acidic soil (pH 5.8). The pH of the soil less than 5.5 resultsin very low yield of barley (0.5 ton ha^{-1})compared with barley growing soils of the country (Taye and Höfner, 1993).

Furthermore, non-amendedacidic soil produced the lowest harvest index (HI). The increased percent in HI obtained on acidic soils treated with different lime rate as compared to respective controls (non amended). Thisis highly likely associated with reduction of concentration of exchangeable acidity and enhancement of exchangeable bases, CEC and available P of the soils (Chimdi *et al*., 2012).All limed treatments had higher mean valuesof thousand seed weight (TSW), number of seeds per spike (NSPS) and hectoliter weight (HLW) relative to no lime (Temesgen, 2014). Soil acidity had also a significant effect on yield and yield components of barley genotypes (Table 5). Genotypes grown in unlimed soil had low number of fertile tillers per plant, spike length, numbers of kernels per spike, grain and biomass yields, harvest index, thousand kernel weight and hectoliter weight comparing to genotypes grown in limed soil((Tigist and Thomas,2021).

Genetics Mechanism of Barley (*Hordeum vulgare* L.) Risistance to Soil Acidity

Barley (*Hordeum vulgare* L.) is considered one of the most Al^{3+}sensitive cereal crops.Two main mechanisms of resistance have been proposed: exclusion mechanism and resistance mechanism. The exclusion mechanism prevents Al^{3+} from entering cells and minimizes Al toxicity, while the resistance mechanism allows plants to take up Al^{3+} and accumulate Al^{3+} within their cells (Kochian *et al*., 2004).

The Al^{3+} induced secretion of organic acid anions from roots is the best example of exclusion mechanisms in higher plants, such aswheat(*Triticum aestivum*) and sorghum(*Sorghum bicolor*) (Ryan *et al*., 2009; Tovkach *et al*., 2013). In wheat,both malate and citrate secretion from roots has been associated with Al3+ resistance (Ryan *et al*., 2009), whereas in barley,only citrate exudation from roots has been identified (Furukawa et al., 2007). In addition, aluminium resistance between resistant wheat and barley was significantly different. (Zhou *et al*., 2013). Thus, avariety of transporters and proteins have been demonstrated to be involved in Al3C resistance in plants. Recently, Dai *et al*. (2013) identified 35 Al3C-associated proteins from wild barley which were in volved in metabolism, cell growth, energy, protein storage, protein biosynthesis, signal transduction, and transporters,etc.There were four proteins specifically expressed in wild barley that were expressed in the Al3C.

3. CONCLUSION

Soil acidity is now a serious threat to barley production in most high lands of Ethiopia. The extent of acidity is increased in 2.1% within the past three decades, mainly due to continuous cropping system and use of acidifying fertilizers. However, the assessment of genetic variability in response to soil acidity based on the response mechanism among barely genotypes is indispensable to identify tolerant breeding plant materials to develop soil acid tolerant genotypes.

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