

Research Application Summary

Enhancement of barley productivity through improved crop management practices in the semi-arid highlands of northern Ethiopia

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Abstract

Barley (*Hordeum vulgare*) is among the important cereal crops cultivated annually on 1.02 million ha of land in Ethiopia. However, its productivity is low (1.9 t ha⁻¹) compared to the potential attainable yield (5.3 ton ha⁻¹) due to water stress; low soil fertility; crop losses by weeds, insect pests and diseases; the use of low yielding local barley cultivars, and use of traditional cultivation methods. Enhancing crop productivity generally contributes to national food self-sufficiency and food security. Regional and national crop production can be increased by expanding the cultivation area and/or by enhancing crop productivity. Even though both options are feasible in Ethiopia, focusing on practices that improve crop productivity is the preferred alternative particularly in the Tigray region, northern Ethiopia. The focus of this study is to optimise soil water, soil fertility and weed managements, method of sowing, tillage operations and time of planting with respect to barley production in Ethiopia.

Key words: Crop productivity, field management practices, *Hordeum vulgare*, interaction of soil water, weed and soil fertility managements

Résumé

L'orge (*Hordeum vulgare*) est parmi les principales cultures céréalières cultivées annuellement sur 1,02 million d'hectares de terres en Éthiopie. Cependant, sa productivité est faible (1,9 t ha⁻¹) par rapport au rendement réalisable potentiel (5,3 t ha⁻¹) à cause du stress d'eau; la faible fertilité du sol; les pertes des cultures à cause des mauvaises herbes, les insectes nuisibles et les maladies; l'utilisation des cultivars locaux d'orge à faible rendement; et l'utilisation des méthodes de culture traditionnelles. Amélioration de la productivité des cultures contribue généralement à l'autosuffisance alimentaire nationale et la sécurité alimentaire. La production régionale et nationale des cultures peut être augmentée en élargissant la zone de culture et / ou en renforçant la productivité des cultures. Même si les deux options sont possibles en Éthiopie, mettre l'accent sur les pratiques qui améliorent la productivité des cultures est l'alternative préférée particulièrement dans la région du

Tigré, au nord de l'Éthiopie. L'objectif de cette étude est d'optimiser la rétention de l'eau du sol, la fertilité du sol, et la gestion des mauvaises herbes, la méthode de semis, les opérations de travail du sol, et le temps de planter à l'égard de la production d'orge en Éthiopie.

Mots clés: la productivité des cultures, les pratiques de gestion des champs, *Hordeum vulgare*, interaction de l'eau du sol, la gestion des mauvaises herbes et de la fertilité du sol

Background

Agriculture in Ethiopia contributes up to 46% of the national gross domestic product, and 80% of export earnings (Ethiopian Agricultural Transformation Agency, ATA, 2013). Barley (*Hordeum vulgare*) is among the important cereal crops cultivated in Ethiopia. It occupies 1.02 million ha of land and is ranked 5th in terms of production area (CSA, 2013). In Ethiopia, barley grain is produced mainly for human consumption and it is one of the most important staple food crops (Birhanu *et al.*, 2005). Furthermore, its straw is used as feed for cattle during the dry seasons.

To date, crop production in Ethiopia cannot satisfy its population needs. This is due to the imbalances between crop production and population growth, where the former lags behind the latter. Crop production can be improved by expanding the cultivation area and/or by improving crop productivity. Even though both options are feasible in Ethiopia, focusing on practices that enhance crop productivity is the preferred alternative in the Tigray region, northern Ethiopia.

According to estimates by CSA (2013), the average productivity of barley is 1.9 ton ha⁻¹ at national level and 1.7 ton ha⁻¹ at Tigray regional level. This is very low compared with about 5.3 t ha⁻¹ attained on research stations in Sheno (09°10' N, 39°21' E, 2750 meters above sea level, Ethiopia) for barley landrace line *Ardu 12-60B* (Berhane *et al.*, 1997), and the potential yield (9 t ha⁻¹) recorded in other parts of the world (Heyland and Werner, 2002). Soil water stress; low soil fertility (both macro and micro nutrients); crop losses to weeds, pests and diseases; the use of low yielding local barley cultivars, use of traditional cultivation methods, and water logging are among the factors limiting crop production in Ethiopia in general, and in Tigray region in particular (Fig. 1). Among these factors, soil water stress, low soil fertility and weed competition are the most important constraints and are thus the focus in this research.

Water stress as a threat in crop production

Crop production in Ethiopia is mainly rain-fed. However, rainfall is variable spatially and temporally. Late start and/or early cessation of rainfall often results in shorter growing period which consequently leads to crop failure. Various reports indicate that drought in Ethiopia occurs once every five years. The recent worst drought event occurred in 2016 throughout the country that resulted in severe production of food and feed for animals. The problem of water stress can be mitigated with the implementation of water conserving practices, weed management, use of drought tolerant genotypes, timely and in-row planting,

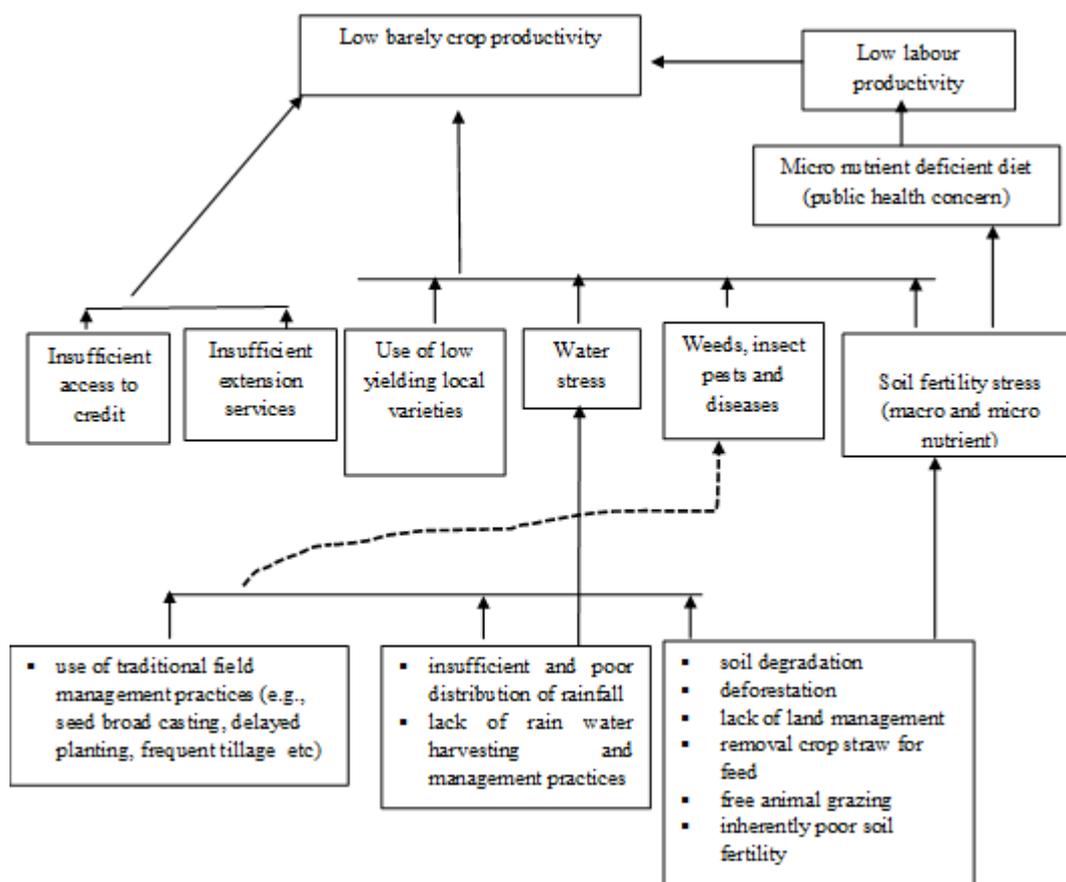


Figure 1. Conceptual framework

and supplementary irrigation at critical crop growth stages. On-farm research in semi-arid locations in Kenya and Burkina Faso showed a significant yield improvement with supplemental irrigation (Rockström *et al.*, 2002). Since deficit water stress is frequently encountered at flowering and grain filling stages in the northern Ethiopia, supplemental irrigation and water conservation practices together with other improved crop management practices are required. Alemtsehay (2012) studied the effect of supplemental irrigation during the flowering and grain filling stages in two different locations in the northern highlands of Ethiopia on tef, and found significant ($P < 0.05$) yield advantage over the rain-fed crop. Moreover, sowing in rows across the slope increases water infiltration and reduces runoff.

Traditionally, farmers plough their fields three times while the last tillage is performed during sowing by broadcasting. This practice delays sowing, and exposes the crop to drought. In addition, timely planting is regarded among the important aspects to be considered in dryland farming. This is very important especially in areas where rainfall starts late and ceases early. In line with this, Aggarwal and Kalra (1994) simulated wheat yield with WTGROWS crop model for the different date of sowing in India and reported a decrease of 50 kg wheat yield ha^{-1} day $^{-1}$ delay in sowing.

Soil fertility stress as a constraint in crop production

Low soil fertility is the next major constraint to barley production in Tigray region. Poor soil fertility is attributed to the many years of continuous cultivation with poor nutrient recycling, deforestation, soil erosion, improper land use systems etc. Nyssen *et al.* (2007) reported mean total soil loss of 57 ton ha⁻¹ year⁻¹ in the Geba catchment due to sheet and rill erosion. Moreover, most of the crop residues are collected for livestock feed and much of the animal manure is used for fuel, neglecting nutrient recycling. As possible consequences of the aforementioned land degradation processes, Mitiku *et al.* (2003) reported very low contents of N, P and K in most of the soils sampled in Tigray region. Di-ammonium Phosphate (DAP: P₂O₅ 46% and N 18 %) and urea (CO(NH₂)₂): N 46%) are the two main source of mineral fertilizer that have been recommended for use in cereal production in Ethiopia. However, only 30 percent of the total barley fields were applied with mineral fertilizers in Ethiopia in general (CSA, 2009). Moreover, most farmers apply an under dose of the recommended fertilizer rates due to financial limitations, fear of drought, or limited awareness on the importance of right dose application. The application of fertilizer also needs site specific prescription since soils in the Tigray region are highly heterogeneous in nutrient status, pH, nutrient holding capacity and other chemical properties (Gebreyohannes *et al.*, 2015). This is substantiated by a study (Berhanu, 2013) which reported up to 124% barley yield increment in fields applied with addition of 64 Kg N and 21 Kg N P₂O₅ per ha in Dejen (northern Ethiopia), while in another site (Maiquiha) the yield increment was relatively low (40%).

In addition to macro nutrients, micro nutrients have become deficient in some parts of the country. According to soil fertility status atlas of Ethiopia (ATA, 2014), available sulfur, and extractable iron, zinc and boron are deficient. These deficiencies result in reduced productivity and poor grain quality. Zinc and Fe are reported to be the most common micronutrient deficiencies in human population affecting health of over three billion people worldwide (Cakmak *et al.*, 2010). Zinc deficiency causes impairments in brain development and wound healing and increases susceptibility to infectious diseases including diarrhea, pneumonia, and malaria by weakening the immune system. Iron deficiency impairs physical growth, mental development and learning capacity in children, reduces productivity in adults and represents the most common cause of pneumonia. In most cases, the reason behind Zn and Fe deficiencies is inadequate dietary intake of Zn and Fe.

Are weeds a threat in crop production in the study area?

Weeds are also common in crop fields in Ethiopia. About 81 weed species were reported in fields cultivated with barley in Ethiopia among which, 26 were categorised as major (Takele *et al.*, 2011). *Avena* sp (wild oat), *Medicago polymorpha*, *Scorpiurus muricatus*, *Erucastrum arabicum*, *Cynodon dactylon*, *Lolium temulentum*, *Digitaria* sp. are among the most dominant weed species affecting barley production. In a field experiment conducted in Mekelle (northern Ethiopia) losses of 60% yield and 40% dry aboveground biomass were reported in fields artificially infested with 50% wild oat weed seeds at planting. The same study reported 37% barley yield loss under natural weed infestation. Hand weeding is the

most common weed control approach since farmers use family labor. Overall, most fields remain either not weeded or are weeded late due to limitations in labor availability. Religious holidays and the use of grassy weeds (e.g., wildoat) as a source of livestock feed (Berhanu, 2013) contribute to the buildup of weed infestation in crop fields. For effective weed control, integration of hand weeding with proper methods of sowing, timely and more effective fertilizer application and soil water management are crucial.

Other crop production constraints

A number of local barley varieties are cultivated in Tigray region (Ethiopia). These include: *Saesa*, *Tseda-sigem*, *Abederay*, *Tsemato*, *Burguda*, *Kintsbe*, *Atsa*, *Embaye*, *Mearo*, *Tselimo*, *Hagos*, *Keyih-shewa*, *Tseda-shewa*, *Atona*, *Rie* and *Himbilil* (Fetien *et al.*, 2008). The use of improved barley seed is negligible in Tigray region. According to CSA (2001-2011), only 0.3% of the area cultivated with barley was sown with improved seed. Fetien *et al.* (2008) also reported that none of the improved barley varieties were adopted in Tigray region. This was because of the inferior performance of improved varieties under low input conditions even though the reverse is true under good management practices (Berhane *et al.*, 1997; Fetien *et al.*, 2008). Among the local barley varieties, *Himbilil* and *Fetina* showed higher grain yield (5.3 tons ha⁻¹) in parts of Tigray region (Fetien, personal communication, 2012).

The general objective of this research therefore is to enhance barley yield through integrated crop management practices. The specific objectives are: (i) to enhance barley productivity through improved soil water and weed managements and reduced local tillage operations; (ii) to study the interaction of different date of planting, soil water and soil fertility management in improving barley yield, and (iii) to study the effect of macro- and micro-nutrients on grain yield and quality of barley planted with different method of sowing in the semi-arid environment.

In order to meet the objectives, three different studies are underway in two sites: (i) Dejen (13° 20' N and 39 22 E) in Hintalo-wejrat district, and (ii) Amdi Weyane (13° 25' N and 39° 33 E) in Enderta district (Tigray region, northern part of Ethiopia) where crop productivity is low due to water deficit and nutrient stresses, and weed competition. During the field research undertaking, (i) development agents of the farmers' training centers, to which the field sites belong to are engaged in research process, (ii) the best crop management practices (treatments of the research) are demonstrated to the nearby farmers, and (iii) the best field management practices obtained from the field research are incorporated in the crop production manual to improve crop productivity.

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