

## Evaluation of Barley Varieties against Russian Wheat Aphid (*Diuraphis noxia* M.) under Greenhouse Condition

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**Abstract:** Russian wheat aphid (RWA) (*Diuraphis noxia* M.) is the major insect of barley in many areas in the world. It was reported in the Wukro (Atsbi) and Adigrat regions of northern Ethiopia in 1972/73 and western Welo region of northwestern Ethiopia in 1974. RWA causes severe damage to barley in the highlands of Ethiopia. However, only little information is available on the control of this pest in the country. An experiment was conducted in the 2013/2014 off-season at South Gondar Zone (Debreabor). The experiment aimed at evaluating some resistant sources of barley varieties against RWA was conducted in greenhouse conditions of the university site. Five barley varieties (Burton, RWA-1758, 3296-15, Holker and local susceptible) were studied in complete randomized design. The number of aphids per tiller decreased on the resistant varieties as compared to the control; this is probably due to their own inherent resistant character. There were also significant differences ( $p < 0.001$ ) in mean chlorosis, leaf rolling, RWA population, leaf number per tiller and tiller number per plant among the resistant and the susceptible varieties. Severe plant damage (36.6%) was observed on the local barley variety while the least damage was observed on Burton, followed by RWA-1758. Burton and RWA-1758 were therefore highly resistant and moderately resistant, respectively. The damage to barley lines 3296-15 and Holker was greater than Burton and RWA-1758 and highly lower than the local one. From the result, it was noted that resistant varieties provided much lower damaged plants and population of RWA per tiller and much higher yield components than the susceptible varieties. This indicates that the most effective approach in managing the RWA is the use of resistant variety. Hence it is concluded that the use of host plant resistance is an important avenue for RWA management, and is one of the favored control options for aphids.

**Keywords:** Russian wheat aphid, *Diuraphis noxia*, barley, *Hordeum vulgare* L. host resistance

### 1. Introduction

Barley (*Hordeum vulgare* L.) is one of the most important staple food crops grown in the highlands of Ethiopia and believed to have been cultivated in Ethiopia as early as 3000BC (Hailu and Leur, 1996). In the main season (*Meher*, Amharic version), it is the fifth major cereal crop after maize, sorghum, tef and wheat in terms of area coverage and total production (CSA, 2013). In the off-season (*Belg*, Amharic version), barley is the second major cereal crop after maize in terms of area coverage and total production (CSA, 2013). The crop is grown in diverse ecologies with altitudinal range of 1800 to 3400 m (Lakew *et al.*, 1993).

Russian wheat aphid (RWA), *Diuraphis noxia* (Mordvilko), is the major insect that reduces yield of barley and has worldwide distribution including the

Middle East, U.S.A., South Africa, and Ethiopia (Girma *et al.*, 1993). RWA was reported in the Wukro (Atsbi) and Adigrat regions of northern Ethiopia in 1972/73 and western Welo region of northwestern Ethiopia in 1974 (Adugna and Tesema, 1987). In about a year, the insect was recorded from all barley and wheat growing regions of the country (Adugna and Tesemma, 1987.)

Crops damaged by RWA include wheat, *Triticum aestivum* L.; barley, *Hordeum vulgare* L.; oat, *Avena sativa* L.; rye, *Secale cereale* L.; and triticale, *X tritico-secale* (Wittmack) (Walters *et al.*, 1980); but barley and wheat are the most affected by RWA. Alternate hosts for RWA include volunteer wheat and barley such as wild species of *H. vulgare* spp *spontaneum* (Badr *et al.*, 2000) and a number of cool and warm-season grasses on which it survives the dry

period in between harvests (Kindler and Springer, 1989). Bayeh and Tadesse (1994) reported that the successive cropping system of barley and wheat in the highlands of Ethiopia enables the pest to migrate from one field to another and survive from one season to the next.

In Ethiopia, the yield of barley is very low in which 0.96 to 1.33 t ha<sup>-1</sup> is in both in the *meher* and *belg* seasons (Lakew *et al.*, 1993). This is very low compared to the potential maximum yield of 13.3t ha<sup>-1</sup> reported by other countries (FAO, 1994). The major reason for low yield is that the crop is produced under numerous constraints including RWA.

In spite of the increasing importance of RWA on barley production in Ethiopia, only few works have been done in the area of varietal host resistance. Host plant resistance to insect pests of crop plants is generally seen as an effective, environmentally responsible, economically and socially acceptable method of pest control which plays an integral role in sustainable agricultural systems (Wiseman, 1999).

Host plant resistance is an important avenue of pest management, and it is one of the favored control tactics for the cereal aphids (Robinson, 1992). The use of host plant resistance in Ethiopian situation is often limited to avoidance of susceptible barley varieties and the subsequent shift to early maturing varieties by farmers. The only barley variety so far identified by Holetta Agricultural Research Center as resistant to RWA was a barley line 3296-15.

Yield losses due to RWA are severe with individual plant losses as high as 90% possible (Du Toit and Walters, 1984). Robinson (1992) recorded crop losses of 68% in Ethiopia and 35-60% in South Africa for wheat. This insect generally causes yield losses of 41-79 % in barley and up to 86% in wheat in Ethiopia (Miller and Adugna, 1988). This severe grain and biomass yield reduction is associated with these symptoms. Typical white, yellow and purple to reddish purple longitudinal streaks occur on the leaves of plants infested with RWA. The aphids are found mainly on the adaxial surface of the newest growth, in the axils of leaves or within rolled leaves. Heavy infestations in young plants cause the tillers to become prostrate, while heavy infestations in later

growth stages cause the ears to become trapped in the rolled flag leaf (Walters *et al.*, 1980). RWA infestation leads to a drastic reduction in chlorophyll content (Kruger and Hewitt, 1984) and reduced photosynthetic ability (Fouche *et al.*, 1984) which, when combined with the characteristic leaf rolling that occurs, causes a considerable loss of effective leaf area of susceptible plants (Walters *et al.*, 1980).

In an attempt to better understand host plant resistance to RWA and their use as management measures in the form of resistant cultivars, this study is highly significant to investigate mechanisms (i.e. antixenosis, antibiosis and tolerance) of resistance to RWA and the influence of resistance on population development of RWA in the field. This may assist breeders in future efforts to better understand and therefore, successfully exploit genetic resistance to this damaging pest. In addition, quantifying the yield loss due to RWA damage, in commercially available resistant cultivars will illustrate the practical application of this resistance under field conditions. It is therefore necessary to evaluate host plant resistance efficiently against RWA on barley. Thus, this study was initiated with the objective of evaluating barley varieties against Russian wheat aphid populations under green house conditions.

## 2. Materials and Methods

### 2.1. Description of the study area

The pot experiment was carried out in South Gondar Zone at Debretabor University's site. Debretabor is located at the latitude of 11° 51' N and longitude of 38° 00' E. The elevation is 2500 m above sea level. The area is situated in woina dega agro-ecological zone of the region, which is characterized by low and erratic rainfall. Annual rainfall ranges from 1500 to 2000 mm while the average maximum and minimum temperature is 22.1 and 9.5 °C, respectively. The soil type is mainly clay loam. The major crops grown in the area are barley, wheat, potato, bean, millet, and lentil.

### 2.2. Experimental design and treatments

The study was conducted in a greenhouse as pot experiment in controlled conditions. Two Russian wheat aphid resistant barley varieties from the United States (Burton and RWA-1758) (Bregitzer *et al.*, 2005) (MARC), one tolerant barley variety (3296-

15) from HARC, one improved malty barley variety (Holker), improved standard check from AARC and a susceptible local check (kinkina) from North Western Ethiopia (Debretabor) were included in the experiment. The experimental design was complete randomized design (CRD) with three replications. There were a total of 15 treatments.

### 2.3. Experimental procedures

Five seeds from each entry were placed to a depth of 2.5 cm in a plastic pot filled with a medium composed of 2:1 silt/sand mixture. The height and diameter of the plastic pot used were 25 and 20 cm, respectively. Six kilo grams of soil were used for each pot. Pots were placed on the table with 50 cm height above the ground. The space between pots was 20 cms. Then, emergence seedlings were thinned to three plants per pot. Plants were infested with 5 RWA adults at Zadok's 3- leaf stage (Zadok *et al.*, 1974). The RWAs were placed on each plant after 14 days with a soft brush. Each pot was received equal number of insects. Infested plants were immediately covered with mosquito nets (perforated net to allow ventilation) until the plant reaches flowering stage. Pots were covered with a fine net cloth for easy entry of air and to prevent the movement of the aphids from one pot to another. The area covered to avoid the movement of the aphids from one pot to another was 4 m x 2 m (8 m<sup>2</sup>). The height and width of the area covered with fine net cloth were 1 m x 2m (2 m<sup>2</sup>). The RWA populations (colonies) that served as a source of infestation were obtained from nearby barley fields that were planted one month before the start of the experiment. A local barley variety was planted on the field with plot size of 2 m<sup>2</sup> to harbor these aphids. The aphids were taken from the leaves of the tillers by dusting them over paper using soft brush and then infesting the pots with 5 RWAs properly. Care was also taken by carefully selecting the RWAs to avoid parasitism. Plants were examined for aphid populations and plant damage 14 days after being infested. Each plant was evaluated for the following data (Zadok *et al.*, 1974).

### 2.4. Data collection

*Chlorosis* was recorded visually from the leaf of tillers after seedling emergence to flowering stage with 14 days intervals using 0-9 scoring scale (Webster *et al.*, 1987), where 0: Immune, 1: plants

appear healthy, may have small isolated chlorotic spots, 2: isolated chlorotic spots prominent, 3: chlorosis  $\leq$  15% of the total leaf area, chlorotic spots coalesced, 4: chlorosis  $>$  15% but  $\leq$  25% of the total leaf area chlorotic lesions coalesced, streaky appearance, 5: chlorosis  $>$  25% but  $\leq$  40% of the total leaf area, well defined streak, 6: chlorosis  $>$  40% but  $\leq$  55% of the total leaf area, 7: chlorosis  $>$  55% but  $\leq$  70% of the total leaf area, 8: chlorosis  $>$  70% but  $<$  85% of the total leaf area, and 9: plant death or beyond recovery.

*Leaf rolling* was recorded visually from the leaf of tillers after seedling emergence to flowering stage with 14 days intervals on a rating scale of 1-3 (Webster *et al.*, 1987) where 1: No leaf rolling, 2: One or more leaves conduplicately folded, and 3: One or more leaves convolutedly folded.

*RWA population count per tiller* was taken from the leaves of the tillers by dusting the aphids over paper using soft brush and then counting them individually every two weeks interval after infestation.

*Plant height* was recorded as the length of the plant in cm from the base of the main stem to the tip of the panicle excluding the awns at late flowering stage.

*Number of tillers per plant* was recorded at the average number of total tillers per plant without panicle excluding the main shoot.

*Number of leaves per tiller* was recorded at the average number of total leaves per tiller.

### 2.5. Data analysis

The collected data were analyzed using the GenStat 12<sup>th</sup> Edition statistical software (VSN international Ltd, 2009). The count data were subjected to square root transformation. Analysis of variance procedure was employed. Fisher's tests were also used to separate the means whenever found significant at 1% probability label.

## 3. Results and Discussion

### 3.1. Evaluation of Barley varieties' resistance to RWA population under greenhouse conditions

Analysis of variance for plant damage (chlorosis and leaf rolling), RWA population count, number of leaves per tiller, number of tillers per plant and plant height as influenced by host plant resistance is

presented in the respective Tables. Significant differences ( $p < 0.001$ ) were observed among all the varieties for all variables except for the plant height which is not significant at  $p > 0.01$  level.

### 3.1.1. *Chlorosis*

The mean Chlorosis score of the tested barley varieties is presented in Table 1. Significant differences in leaf chlorosis ( $p < 0.001$ ) were observed among the tested barley varieties as compared with local check. Larger chlorotic streaks and higher chlorotic scores (7.00) were observed on the local susceptible variety, resulting from the depression of cytokinin synthesis or loss of chlorophyll molecule by the sucking action of RWA population. Wiese (1987) reported that Russian wheat aphid and certain other species inject toxic saliva that causes localized discoloration of host tissue of susceptible varieties. The least chlorotic score was observed on Burton (1.46) followed by RWA-1758 (2.10) (Table 1). As the result indicated, the two tested barley varieties Burton and RWA-1758 are resistant to the RWA populations on a rating scale of 0-9 (Webster *et al.*, 1987). In case of cereal plant resistance to aphids, success has been achieved with the RWA that causes easily detectable plant damage, and selections can be based on reduced chlorotic symptoms (Berzonsky *et al.*, 2003).

The chlorosis score for the barley line 3296-15 and Holker (3.76) was in fact higher compared to Burton and RWA-1758, but it was lower than that of the susceptible local variety. According to Bayeh *et al.* (2008), the barley line 3296-15 had a lower leaf chlorosis score of 4.33 to the Shewa RWA populations. In this study, however low leaf chlorosis score was recorded with the Gondar RWA population indicating a probable genetic variation between RWA populations of Gondar and Shewa. Least chlorosis is often associated with a resistant reaction as several workers (Botha *et al.*, 2005) have not reported significant changes in leaf color (chlorosis) and a reduction in photosynthetic activity for resistant cereal hosts.

### 3.1.2. *Leaf rolling*

The mean of leaf rolling of the tested barley varieties is also presented in Table 1. The leaf rolling caused by RWA was significantly influenced ( $P < 0.001$ ) by

the degree of resistance. Leaf rolling was high on the local susceptible variety, whereas Burton had the lowest leaf rolling score, which was significantly different from the other varieties, though the reaction of RWA-1758 was relatively closer to Burton. Similarly, barley line 3296-15 had a leaf rolling score of 1.70 which was again significantly different from the rest of the varieties. The reaction of Burton was considered as flat leaf as stated by Burd *et al.* (1993). So, Burton is highly resistant from all the tested varieties regarding leaf rolling to the RWA populations. The leaf rolling value of the RWA-1758 was (1.33) and that reaction was in sooth highly lower compared to the local variety (2.43) and it was rated as less than fully folded leaves on a rating scale of 1-3 (Webster *et al.*, 1987).

Barley line 3296-15 had a tolerant leaf rolling reaction of 3.17 on a 0-9 scale at Holetta (Bayeh *et al.*, 2008). The reduction of leaf rolling score of 1.70 (moderate resistance reaction) on a 1-3 scale of Webster *et al.* (1987) could also be another indication of genetic variation between RWA population of Shewa and Gondar. Holker variety in fact was higher (2.10) than Burton and RWA-1758 but it can be considered as moderate susceptible as compared to the local variety which scored 2.43 according to the rolling scale. Feeding damage by RWA to plant leaves results in yellow or red chlorotic streaks with a convoluted rolling of the leaf for susceptible plants. Khan *et al.* (2011) confirmed that rolling of the leaves reduces photosynthetic area and protects aphids from contact insecticides and natural enemies. The heads that developed on tillers that had severe leaf rolling were trapped and did not extrude from the flag leaf sheath and this was particularly true for the susceptible variety (Table 1). On such heads, there was no seed development at all. Susceptible barley lines become stunted under heavy aphid attacks and prepanicle infestations can result in curling of the flag leaves and panicle deformations (Jones *et al.*, 1989; Kindler and Hammon, 1996). In contrast to the reactions of the susceptible variety, the resistant varieties Burton and RWA-1758 barley lines were essentially asymptomatic. RWA feeds on host plants in dense colonies within tightly curled leaves, which result in rolling up of fully expanded leaves and by preventing the normal unrolling of newly emerging leaves (Hewitt *et al.*, 1984).



Thus, the observations of far larger RWA populations on the susceptible variety relative to the resistant varieties were expected. Leaves are rolled as a result of the stress created by the sucking action of the aphids and it is quite natural for leaves not to roll when grown host plant resistance and that could be one of the possible reasons for reduction in degree of rolling of leaves. This is in line with the findings that host plant resistance plays important roles in controlling pests and protecting of natural enemies in an agroecosystem (Francis *et al.*, 2001; Messina and Sorenson, 2001), and the effect on application of insect resistance plant varieties in reducing pest damage is considered to be conspicuous (Painter, 1958).

### 3.1.3. RWA population per tiller

The population density of RWA was significantly influenced ( $P < 0.001$ ) by the tested barley varieties. The mean RWA population of the tested barley varieties is presented in Table 1. The highest population of RWA per tiller was recorded on the local variety (26.80) and the lowest populations of RWA were recorded on Burton (7.36) followed by RWA-1758 (10.50) (Table 1). Brewer *et al.* (1999) also reported that the abundance of *Diuraphis noxia* on resistant barley lines was lower than that on more susceptible lines. The number of aphids per tiller was lowest on the resistant varieties as compared to the control; this is probably due to their own inherent resistant character. Leszczynski *et al.* (1995) reported that resistant varieties have higher concentrations of allelochemicals which restrain aphid development on plants, reduced fecundity and inherent rate of increase.

Indeed the population density of RWA for the barley line 3296-15 was greater than Burton and RWA-1758, but it was less than that of the susceptible local variety. The aphids were raised on susceptible barley under greenhouse conditions (Starks and Burton, 1977). The RWA population of the local variety was 26.8 and the population number of the barley line 3296-15 was 22.95. This shows that the barley line 3296-15 was by far lower aphid populations as compared to the local variety, but it was higher than Burton (7.36) and RWA-1758 (10.50). The incidence of aphids has been reported to be significantly different on different cultivars of wheat (Aheer *et al.*,

1993; Ahmad and Nasir, 2001) because their pre-reproductive, reproductive and post-reproductive periods and fecundity are significantly affected by crop varieties (Saikia *et al.*, 1998).

The population of the aphids on Holker was recorded very low (12.15) as compared to barley line 3296-15 (22.95), but the chlorotic and rolling capacity were very high. This is probably due to the lack of inherent resistance/loss of resistant gene behind the variety. Similarly, host plant resistance is one of the most vital factors which can handle aphid infestation well below the economic threshold level. Host plant resistance also lessens the chances of biotype development (Lowe, 1987; Riazuddin *et al.*, 2004).

Similar results were reported by Michel *et al.* (1994) where they found differences in RWA densities among barley lines and significantly more numbers of RWA per plant were recorded on susceptible varieties. In general, significantly lower numbers of RWA per tiller were recorded on the resistant varieties (Table 2). Akhtar and Hashmi (1992) confirmed that adequate aphid resistance against aphid pests could be achieved by implementing resistant varieties.

The findings demonstrate that resistant varieties affect the population of RWA and they may be used in integrated pest management systems. As stated by Smith (1989), the use of a resistant variety alone should not be expected to control pests under all conditions or in all locations where the crop may be grown. Instead, resistant varieties should be used in combination with other pest suppression measures including treatments of the susceptible varieties to reduce RWA damage drastically. When screening for resistance to pests and diseases for the purpose of selecting resistant plant genotypes, the common procedure is to grow different genotypes in greenhouses or climate chambers within a restricted area, in order to compare plants under similar environmental conditions (Smith, 1989).

**Table 1. Reaction of barley varieties to RWA population, leaf chlorosis and leaf rolling under greenhouse experiment**

Varieties	Plant damage parameters		
	Leaf rolling	Chlorosis	RWA population/tiller

Burton (V <sub>1</sub> )	1.10 <sup>a</sup>	1.46 <sup>a</sup>	7.36 <sup>a</sup>
RWA-1758 (V <sub>2</sub> )	1.33 <sup>a</sup>	2.10 <sup>b</sup>	10.50 <sup>b</sup>
3296-15 (V <sub>3</sub> )	1.70 <sup>b</sup>	3.76 <sup>c</sup>	22.95 <sup>c</sup>
Holker (V <sub>4</sub> )	2.10 <sup>c</sup>	3.76 <sup>c</sup>	12.15 <sup>d</sup>
Kinkina (local) (V <sub>5</sub> )	2.43 <sup>c</sup>	7.00 <sup>d</sup>	26.80 <sup>c</sup>
Mean	1.73	3.82	15.95
CV (%)	12.55	8.44	5.52

Means in columns followed by the same letter are not significantly different at  $p < 0.001$

### 3.1.4. Number of leaves per tiller

The mean of the leaves per tiller of the tested barley varieties is presented in Table 2. Significant differences ( $p < 0.001$ ) were detected in the number of leaves per tiller in the tested barley varieties. A significant difference was observed between the varieties (Burton and RWA-1758), the barley line (3296-15) and the local ones. But non-significant differences were recorded between the resistant varieties Burton and RWA-1758, and between Holker and the local barley variety. The highest number of leaves per tiller was recorded on the RWA-1758 (2.86) followed by Burton (2.83). The densities of trichomes on the leaf surface of some cultivars deter feeding and sometimes oviposition. Leaf trichome density and position may act as a physical obstacle to aphid feeding. According to Oberholster (2002, 2003) the high trichome density on the leaf veins could prevent the aphid from finding a suitable feeding site.

The number of leaves per tiller on barley line 3296-15 and Holker compared to the number of leaves on the local variety was higher (Table 2), whereas the least number of leaves per tiller (2.56) was recorded on the local variety on which the highest populations of aphids were recorded. An abundance of aphids adversely affects the nitrogen and protein contents (Ciepiela, 1993) and results in a reduction of total chlorophyll (Ryan *et al.*, 1987) and reduction in plant biomass (Holmes *et al.*, 1991). RWA had a greater impact on infesting leaf number of the susceptible barley variety. According to Burd *et al.* (1993), RWA

feeding typically reduces leaf number in susceptible cereals.

### 3.1.5. Number of tillers per plant

Analysis of variance for the number of tillers per plant revealed significant differences ( $p < 0.001$ ) between the tested barley varieties. The mean of tillers per plant of the tested barley varieties are presented in Table 2. The variety Burton had the largest (3.47) number of tillers per plant followed by RWA-1758 (3.19). This result agrees with the findings of Mornhinweg (1994) who reported that resistant varieties had less percentage of tillers damaged by RWA than the susceptible varieties. The rest varieties had almost equal number of tillers per plant that is why no significant differences were observed between them. Anonymous (1995, 2013) also reported that aphids can affect the development in the early stages of the crops; long lasting infestation can reduce tillering.

### 3.1.6. Plant height

The mean plant height for the tested barley varieties is presented in Table 2. There was no significant difference ( $p > 0.001$ ) among the barley varieties in plant height. Burton and RWA-1758 had almost the same plant height (Table 2). From the result RWA-1758 was the longest (63.57) followed by Burton (58.80) where as the local variety was the shortest (42.40) one. Similarly, in Kenya Kiplagat (2005) reported extensive chlorosis and leaf rolling due to RWA retarded plant development and delayed ear emergence.

The barley line 3296-15 had relatively longer (57.50) plant height as compared with the local susceptible variety. A field study of Russian wheat aphid RWA on yield and yield components of field grown susceptible and resistant spring barley showed highly resistant lines, increased yield components and grain yield (average grain yield increase 5%) under aphids feeding pressure and susceptible cultivars had a large reduction in yield components and grain yield (average reduction 56%) (Mornhinweg *et al.*, 2006). On the other hand, the local variety had the shortest one which was not significantly different from the other barley varieties (Table 2). Burd *et al.* (1993) determined that plant stunting as best predicted the quantitative damage response to RWA infestations in

oats, wheat, and triticale and that susceptible germplasm was stunted. While testing 557 wheat lines Li *et al.* (1998) found that there were significant differences in resistance among yield and other yield related parameters (height of plants, number of spikes/plant, number of spikelets/spike, length of spike/plant, and 1000 grain weight).

**Table 2. Barley varieties of the number of leaves per tiller, number of tillers per plant, and height of the plant under greenhouse conditions**

Varieties	Yield component parameters		
	Number of leaves/tiller	Number of tillers /plant	Plant height
Burton (V <sub>1</sub> )	2.83 <sup>a</sup>	3.47 <sup>a</sup>	58.80 <sup>a</sup>
RWA-1758 (V <sub>2</sub> )	2.86 <sup>a</sup>	3.19 <sup>a</sup>	63.57 <sup>a</sup>
3296-15 (V <sub>3</sub> )	2.73 <sup>b</sup>	2.70 <sup>b</sup>	57.50 <sup>a</sup>
Holker (V <sub>4</sub> )	2.63 <sup>c</sup>	2.830 <sup>b</sup>	53.20 <sup>a</sup>
Local variety (V <sub>5</sub> )	2.56 <sup>c</sup>	2.50 <sup>b</sup>	42.40 <sup>a</sup>
Mean	2.72	2.94	55.09
CV (%)	2.62	6.68	17.81

Means in columns followed by the same letter are not significantly different at  $p < 0.001$

#### 4. Conclusion and Recommendation

There were significant differences in mean chlorosis, leaf rolling, RWA population per tiller, leaf number per tiller and tiller number per plant among the resistant and the susceptible varieties. Severe plant damage was observed on the local susceptible barley variety. The least damage was observed on Burton variety followed by RWA-1758. From the result, the tested Burton and RWA-1758 barley varieties are resistant on a rating scale of 1-3 leaf rolling and 0-9 leaf chlorosis. The barley line 3296-15 was moderate resistant. From the result, host plant resistance was more effective in the control of RWA compared with the control and use of resistant varieties. It substantially reduced plant damage by RWA. This indicates that the most effective approach in managing the RWA is the use of resistant variety. This study conclusively demonstrated that population abundance of RWA was influenced by using host plant resistance, and the use of host plant resistance

did not result in higher aphid infestation, instead their reduction.

Future research should concentrate on the interaction of host plant resistance and natural enemies as it is extremely important to provide the Ethiopian barley producer with an effective and inexpensive RWA control strategy.

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#### References

- Adugna Haile. 1981. Cereal Aphids: Their Distribution, Biology and Management on Highland Barley. M.Sc Thesis, School of Graduate Studies, Addis Ababa University, Addis Ababa, Ethiopia.
- Adugna Haile and Kemal Ali. 1985. A review of research on the control of insect pest in Ethiopia. P.5768. In: Abate T (ed.), proceedings of the first crop protection research in Ethiopia, 4-7 February, 1985, Addis Ababa, Ethiopia.
- Adugna Haile and Tesema Megenasa. 1987. Survey of aphids on barley in parts of Shewa, Wello, and Tigray, Ethiopia. *Ethiop. J. Agric. sci.* IX: 39-40.
- Aheer, G.M., Rashid, A., Afzal, M., and Ali, A., 1993. Varietal resistance / susceptibility of wheat to aphids, *Sitobion avenae* F. and *Rhopalosiphum rufiabdominalis* Susaski, *J. Agric. Res.* 31: 307-311.
- Ahmad, F., and Nasir, S., 2001. Varietal resistance of wheat germplasm against wheat aphid (*Sitobion avenae* F.). *Pakistan Entomol.* 23: 5-7.
- Akhtar, N., and Hashmi, A.A., 1992. Resistance in Pearl Millet against Green bug, *Schizaphis graminum* (Rondani). *Proc. Pakistan. Congr. Zool.*, 12: 299-303.
- Anonymous, 1995-2013. Insect pest management in winter cereals. Department of Agriculture, Fisheries and Forestry, Australia. [http://www.daff.qld.gov.au/26\\_19744.htm#Aphids](http://www.daff.qld.gov.au/26_19744.htm#Aphids)

- Badr, A., Muller, K., Schafer-pregl, R., El Rabey, H., Effgen, S., Ibrahim, H., Pozzi, C., Rohde, W., Salamini, F., 2000. On the origin and domestication history of barley (*Hordeum vulgare*). *Molecular biology and evolution* 17: 499-510.
- Bayeh Mulatu and Tadesse Gebremedhin. 1994. Russian Wheat Aphid a major pest of barley in Ethiopia. PP. 169-174. In: Frank, B.P., and M.K. C.L. Kroening, Simmons (eds.) Proceeding of the sixth Russian Wheat Aphid workshop, January 23-25, 1994, Colorado State University, Colorado.
- Berzonsky W. A, Ding H, Haley C, Harris M.O, Lamb R.J, Mckenzie R.I.H, Ohm H.W, Patterson F.L, Peairs F.B, Porter D.R, Ratcliffe R.H, Shanower T.G., 2003. Breeding wheat for resistance to insects. *Plant Breed. Rev.* 22:221-296
- Botha A.M., L. Lacock, C. Van Niekerk, M.T. Matsioloko, F.B. Preez, S. Loots, E. Venter, K.J. Kunert and Cullis C.A., 2005. Is photosynthetic transcriptional regulation in *Triticum aestivum* L.cv. 'TugelaDN' a contributing factor for tolerance to *Diuraphis noxia* (Homoptera: Aphididae)? *Plant Cell Reports* ISSN: 0721-7714 (Paper) 1432-203X (Online) DOI: 10.1007/s00299-005-0001-9.
- Bregitzer, P. Mornhinweg, D.W. Hammon, R. Stack, M. Baltensperger, D.D. Hein, G.L. O'Neill,
- Brewer M., Mornhinweg D., Huzurbazar S., 1999. Compatibility of insect management strategies *Diuraphis noxia* abundance on susceptible and resistant barley in the presence of parasitoids. *BioControl*. 43(4): 479-491.
- Burd, J.D., R.L. Burton and Webster J.A., 1993. Evaluation of Russian wheat aphid (Homoptera: Aphididae) damage on resistant and susceptible hosts with comparisons of damage ratings to quantitative plant measurements. *J. Econ. Entomol.* 86: 974-980.
- Ciepiela, A.P., 1993. The harmful effect of cereal aphid on winter wheat crop. *Ochrona-Roslin*, 37: 9-10.
- CSA (Central Statistics Agency). 2013. Agricultural Sample Survey 2012/2013 (2005 E.C.). Volume I. Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Statistical Bulletin 532, Addis Ababa, Ethiopia.
- Du Toit, F. and Walters M. C., (1984). Damage assessment and economic threshold values for chemical control of the Russian wheat aphid, *Diuraphis noxia* (Mordvilko) on winter wheat,; Pp 58-62. In: M C walters (ed). Progress in Russian wheat aphid (*Diuraphis noxia*) research in the Republic of South Africa
- FAO, (Food and Agricultural Organization of the United Nations). 1994. Production yearbook. Vol. 48. FAO Statistics Series No. 125.
- Fouche, A. Verhoeven, R.L. Hewitt, P. H, Walters, M. C, Kriel, C. F and De Jager, J., 1984. Russian wheat aphid (*Diuraphis noxia*) feeding damage on wheat related cereals and a *Bromus* grass species. In: M C walters (ed). Progress in Russian wheat aphid (*Diuraphis noxia*) research in the Republic of South Africa, 22-23
- Francis F, Lognay G, Wathelet JP, Haubruge E., 2001. Effects of Allelochemicals from First (Brassicaceae) and Second (*Myzus persicae* and *Brevicoryne brassicae*) Trophic Levels on *Adalia bipunctata*. *J. Chem. Ecol.* 27(2): 243-256.
- GenStat, 2009. GenStat Release 12.1 ( PC/Windows XP) 06 January 2011 10:28:44 Copyright 2009, VSN International Ltd.
- Girma, M., G.E. Wilde and Harvey T.L., 1993. Russian Wheat Aphid (Homoptera: Aphididae) affects yield and quality of wheat. *J. Econ. Entomol.* 86: 594-601.
- Hailu Gebre and van Leur. 1996. Barley research in Ethiopia: past work and Future prospects. Proceeding of the first barley research review work shop, 16-19 October 1993, Addis Ababa: IAR/ICARDA. Addis Ababa, Ethiopia.
- Hewitt, P.H., G.J. Niekerk, M.C. Walters and Fouche A., 1984. Aspects of the ecology of the Russian Wheat Aphid, *Diuraphis noxia*, in the Bloemfontein district. I. The colonization and infestation of sown wheat, identification of summer hosts and causes of infestation symptoms. Tech. Commun. Dept. Agric. Repub. S. Afr. No. 191, 3-13.
- Holmes, R.L., Burton, R.S., Burd, J.D., and Ownby, J.D., 1991. Effect of greenbug (Homoptera: Aphididae) feeding on carbohydrate levels in wheat. *J. Econ. Entomol.* 80: 897-901



- Jones, J.W., Byers, J.R., Butts, R.A., and Harris, J.L., 1989. A New Pest in Canada: Russian Wheat Aphid, *Diuraphis noxia* (Mordvilko) (Homoptera: Aphididae). *Can Entomol.*, **121**(7): 623-624.
- Khan, A.A., A.M. Khan, H.M. Tahir, M. Afzal, A. Khaliq, S. Y.Khan and Raza I., 2011. Effect of wheat cultivars on aphids and their predator populations. *Afr. J. Biotechnol.*, 10(80):18399-18402.
- Kindler, S.D., and Hammon, R.W., 1996. Comparison of Host Suitability of Western Wheat Aphid with the Russian Wheat Aphid *J.Econ. Entomol.*, **89**(6): 1621-1630
- Kindler, S.D. and Springer T.L., 1989. Alternate hosts of Russian Wheat Aphid (Homoptera: Aphididae). *J. Econ. Entomol.* 82: 1358-1362.
- Kiplagat, O. K., 2005. The Russian wheat aphid (*Diuraphis noxia* Mord.): Damage on Kenyan wheat (*Triticum aestivum* L.) varieties and possible control through resistance breeding . Thesis, Wageningen University, The Netherlands. ISBN 90-8504-175-9
- Kruger, G.H.J. & Hewitt, P.H., 1984. The effect of Russian wheat aphid (*Diuraphis noxia*) (Mordvilko) extract on photosynthesis of isolated chloroplasts: Preliminary studies. In: M.C. Walters [ed], Progress in Russian wheat aphid (*Diuraphis noxia* Mordvilko) research in the Republic of South Africa.
- Lakew B, Gebre H and Alemayehu F., 1993. Barley Production and Research in Ethiopia. Proceeding of the First National Barley Research and Strategy Workshop, 16-19 October, 1993. Addis Ababa, Ethiopia. 192 p.
- Lapitan, N.L., Botha-Oberholster Y., Li, A.M., 2005. The Russian wheat aphid and its interaction with wheat. Plant and Animal Genome Conference XIII:W262.
- Leszczynski B., Dixon A.F.G., Bakowski T., Matok H., 1995. Cereal allelochemicals in grain aphid control. *Allelopathy J.* 2 (1): 31-36.
- Li, S. J., Z. Y. Zhang, X. Y. Wing, H. J. Ding, H. X. Ni, S.R. Sun, D. F. Cheng and Chen J.L., 1998. Evaluation of resistance of wheat lines to aphids using fuzzy recognition. *Pl. Protect*, 24 (5): 15-16.
- Lowe H.J.B., 1987. Breeding for Resistance to Insect Wheat Breeding. (F.G.H. Lupton, ed.). Chapman and Hall Ltd., UK: 423-454.
- Messina F.J, Sorenson S.M., 2001. Effectiveness of Lacewing Larvae in Reducing Russian Wheat Aphid Populations on Susceptible and Resistant Wheat. *Biol. Control.* 21(1): 19-26.
- Michel, J., W.M. Dolores and Snehalata H., 1994. Compatibility of insect management strategies. *Diuraphis noxia* abundance on susceptibility and resistant barley in the presense of parasitoids. *J. Bicon.* 43(4): 479-491.
- Miller, R.H. and Adugna Haile. 1988. Russian Wheat Aphid on barley in Ethiopia, Rachis. 7: 51-52.
- Mornhinweg, D., M. Brewer and Struttman J., 1994. Effect of Russian Wheat Aphid on yield and yield components of barley lines differing in seedling damage response: a field assessment. pp. 117-121. In: F.B. pearis, M.K. Kroening and C.L. Simmons (eds.), proceedings, sixth Russian Wheat Aphid workshop. Colorado State University, Fort Collins
- Mornhinweg D.W, Brewer MJ, Porter D.R., 2006. Effect of Russian wheat aphid on yield and yield components of field grown susceptible and resistant spring barley. *Crop. Sci.* 46(1): 36-42.
- Painter R.H., 1958. Resistance of Plants to Insects. *Annu. Rev. Entomol.* 3(1): 267-290.
- Iazuddin, Anayatullah M., Khattak M.K., 2004. Screening resistant wheat lines against aphids. *Pak. Entomol.* 26 (1): 13-18
- Robinson, J., 1992a. Russian Wheat Aphid a growing problem for small grain farmers. *Outlook on Agric.* 21: 57-62.
- Robinson, J., 1992b. Predators and parasitoids of Russian Wheat Aphid in central Mexico. Southwest. *Entomol.* 17: 185-186.
- Ryan, J.D. Johnson, R.C. Eikenbary, R.D. and Dorschner K.W., 1987. Drought/ Greenbug interaction: photosynthesis of greenbug resistant and susceptible wheat. *Crop Sci.* 27: 283-288.
- Saikia, S.K. Dutta, S.K. Saikia, D.K. and Devroy T.C., 1998. Reproductive parameters of Indian grain aphid *Sitobion miscanthi* (Tak.) on wheat varieties. *J. Agric. Sci.* 11: 66-69.
- Smith, M.C., 1989. Plant Resistance to Insects: A fundamental Approach. Wiley, New york, 286 PP.

- Starks K.J, Burton R.L., 1977. *Preventing greenbug outbreaks. Rep. No. 309*, USDASci. Educ. Admin. Leaflet. Washington, DC
- Walters, M.C, F. Penn, T.C. Botha, K. Aalbersberg, P.H. Hewitt and Broodry S.W. k., 1980. The Russian Wheat Aphid. Farming in South Africa Leaflet series wheat C3:1-6.
- Walters, M.C., 1984. Progress in Russian wheat aphid (*Diuraphis noxia* Mordvilko) research in the Republic of South Africa. *Department of Agriculture, Republic of South Africa, Technical Communication* 191.
- Webster, J.A., K.J. Starks and Burton R.L., 1987. Plant resistance studies with *Diuraphis noxia* (Homoptera: Aphididae), a new United State wheat pest. *J. Econ. Entomol.* 80: 944-949.
- Wiese, M.V., 1987. Compendium of wheat disease. The American Phytopathological Society, USA. 2-1-91 pp.
- Wiseman, B.R., 1999. Successes in plant resistance to insects. In: B.R. Wiseman and J.A. Webster (Eds.), economic, environmental and social benefits of resistance in field crops. Thomas Say Publications in Entomology: *Proceedings. Entomological Society of America*.
- Zadok, J.C, Chang T.T and Konzak C.F., 1974. A decimal code for growth stages of cereals. *Weed Science* 14: 415-421

## Gender Disparity in the Utilization of Agricultural Extension Services in Bure Woreda, North Western Ethiopia

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**Abstract:** Globally, rural women face a particular burden in division of labor. Providing better agricultural extension services to rural women is essential in using agriculture for development. Hence, this study sought to ascertain the status of agricultural extension services utilization with the existing gender gaps in Bure Woreda, North Western Ethiopia. The survey was conducted in three purposively selected PKAs which have the maximum number of FHHs. Thus 160 samples were selected via multistage random sampling. Pre-tested structured interview schedule and other secondary sources were used to collect primary and secondary data, respectively. Key informant interviews and focus group discussions helped to generate the necessary qualitative data. Frequency, means, standard deviation, t-test and chi-square were used for analysis. The core survey result showed that on average 60.76% MHHs and only 29.71% FHHs utilized the selected agricultural extension services in the last three years (2009/10-2011/12). The analysis result depicted gender differences related to FHHs which include illiteracy, less ownership of productive resources plus less utilization of extension services. Therefore, adult education, efficient extension service systems, intervention to improve livestock sector via livestock credit, creating strong linkage with extension contacts, and giving reasonable place for women in farmers' organizations were strongly recommended to boost agricultural development in the study area.

**Keywords:** Gender, Gender Disparity, Extension Package, Extension Program, Utilization

### 1. Introduction

Globally, rural women, especially those from poor households, face a particular burden. In view of the gender division of labor, they spend considerable time fetching water, getting healthcare for their children, and reaching markets. Girls have less access to education than boys, and maternal mortality is high. Providing better extension services to women is not only necessary to realize their rights, but it contributes to economic growth and poverty reduction (Quisumbing et al., 1995; IFPRI, 2000; and Mason and King, 2001, 2005). Providing better services to rural women is also essential in using agriculture for development (World Bank, 2007; World Bank, FAO, and IFAD, 2008). Women, particularly in Africa, play an important role in agriculture but this role often goes unrecognized due to perception bias. The perception of the roles that men and women play in agriculture is biased toward men, and as a consequence, perceptions about the

need for rural services are biased toward men as well (Sen, 1990a, 1990b; World Bank, FAO, and IFAD, 2008).

The gender division of labor in agriculture means that female and male farmers usually have different extension needs. However, extension services worldwide remain dominated by men. It is estimated that globally only 15 % of extension agents are women (IFAD, 2009). The female farmers' agricultural activities have been least priority in countries' research agenda. They lack improved extension packages and services that assist them to improve their productivity. So far, the extension system in Ethiopia is unable to address the cultural taboos against the participation of female farmers in ploughing and sowing, which subsequently reduces the rigid division of labor both at the household and field levels (EARO, 2000).

In Ethiopia especially in the Amhara Region, the need for policy review is obvious. Thus, the

important contributions made by women in agriculture justify the necessity to make the system more equitable (ANRS BoA, 2013). Therefore, specific situations need to be reviewed and respective action to be taken. Generally speaking, women and men in Bure woreda have clear separate labor roles to play. The main criteria for the division of labor in the area are age and sex. Women are responsible for reproductive activities in and around the household while men do most of the work on farm or work for wage (BWAO, 2013). Thus, one can argue that many rural women are exposed to social and economic problems due to the existing gender disparity in utilizing agricultural extension services based on their division of labor in the study area. Hence, developing effective and sustainable extension service for women farmers within the context of broader rural development strategies has also become a challenge (Lisa and Jacob, 1992). Therefore, location or content specific situation analysis of the gender disparity in agricultural extension service delivery is essential. However, there is no specific empirical information about gender gaps in utilizing extension services between female and male farmer groups especially in the proposed study area. Hence, this study had been conducted to produce empirical data that can provide a clear understanding of their circumstances of gender disparity in agricultural extension service delivery, in Bure Woreda, West Gojjam Zone of the Amhara National Regional State.

Generally, as an objective, the study tried to investigate the status of agricultural extension services' utilization among rural households with the existing gender differences in the study area to answer the research questions .i.e. how the delivered agricultural extension services are utilized by farmers; and how gender gaps occur in the utilization status of agricultural extension services delivery.

Literature indicated that extension service is vital for rural people, which they can use to improve their productivity, income and welfare and to manage the resources, on which they depend, in sustainable way. An effective agricultural policy on gender is very important to institutionalize gender equality and empowerment in agriculture and rural development strategies of Ethiopia. The conditions of both rural male and female farmers in Ethiopia can be

significantly enhanced if agricultural development policies are improved and the existing gender-neutral extension services are made gender responsive and access by female farmers to productive resources improved through the formulation and implementation of effective gender empowerment strategies (WB, 2001). Organizational or institutional situations, economic conditions, and socio-cultural variables, rural female farmers' access to agricultural services such as credit, extension services and rural institutions enable them to manage their environmental and socio-economic challenges in agriculture on a sustainable basis so as to control and benefit from the delivered agricultural extension services. Thus, empowering rural female farmers and improving their access to productive resources, extension services and rural institutions can play a significant role in enhancing their extension services' utilization to enhance productivity, food security and sustainable development (Ibid). Based on this and similar areas of conceptual constructs, assessing the status of agricultural extension services utilization with the existing gender gaps are considered as an objective of this investigation.

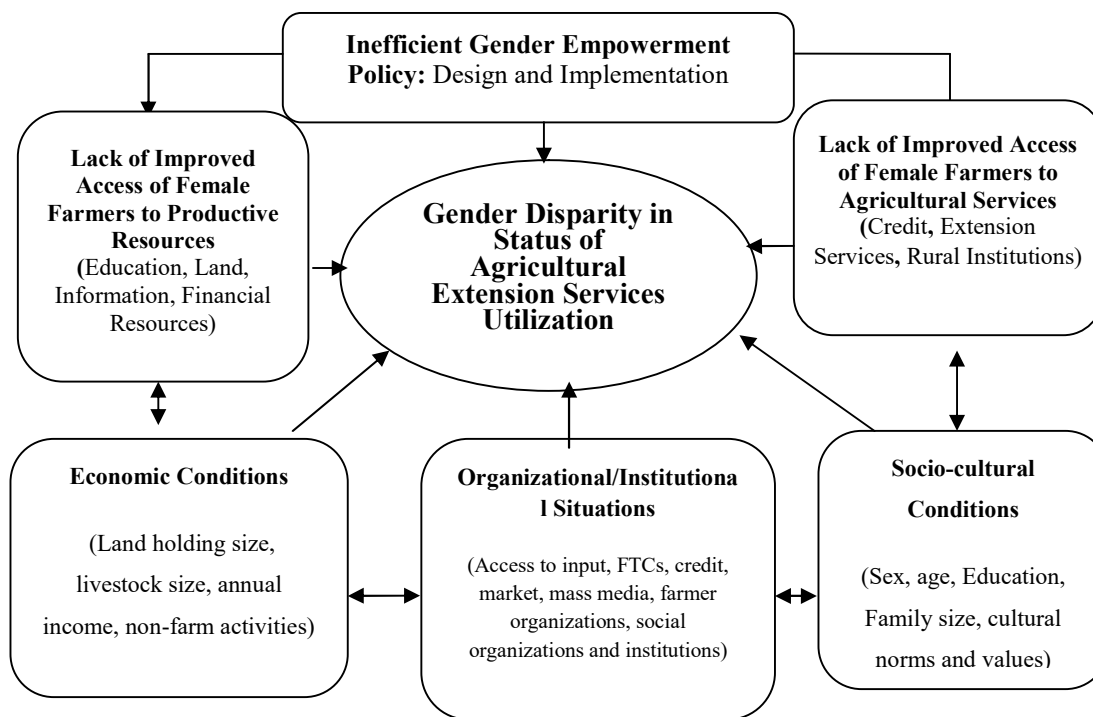


Figure 1. Conceptual framework of the study

## 2. Materials and Methods

Bure, located on the North-western part of Ethiopia is one of the 11 Woredas of West Gojjam Administrative Zone. Bure, the main town of the Woreda is located at a distance of 400 kms from Addis Ababa and 148 kms from Bahir Dar. According to the data obtained from BWAO (2013), the total population of the Woreda is 116,076 of which 110,511 live in rural areas while 5,565 live in urban area. The topography of the area has different features; 76% gentle slope, 10% mountains and the remaining 14% is uneven land. The main source of economy for the Woreda population is land which is majorly used for crop and livestock production (BWAO, 2013).

Generally, multistage sampling had been used for this study since it accommodates different techniques at a time. At the first stage, Bure Woreda was purposely selected because of its high productivity potential and its highest number of women population in the North Western part of Ethiopia (CSA, 2007). Secondly, from the total 20 PKAs of the Woreda, only three PKAs with the highest number of FHHs were selected purposely to acquire the maximum number of FHHs for analysis. Thirdly, stratified random

sampling was employed to stratify respondents into MHHs and FHHs. The scenario behind stratified random sampling was to determine and come up with equal number of sample size from the two (male and female) strata. Finally, Systematic random sampling technique was employed to select 160 sample households out of 4,123 household heads found in the sampled PKAs. The principle of probability proportional to size (PPS) or ratio sampling was used as a basis to fix the number of FHHs and MHHs selected from respective PKAs.

Data were collected from both primary and secondary sources to answer the research question. Primary data were collected from primary sources such as from respondents through pre-tested individual interview schedule, key informant interviews and focus group discussions. Secondary data were collected from secondary sources such as journal articles, books, and unpublished documents such as extension package manuals and reports from the Woreda agricultural office.

The quantitative data were tabulated and analyzed by using both descriptive (range, frequency, percentage, mean and standard deviation) and inferential



statistical tools (chi-square and independent sample t-test). The qualitative data were interpreted and described by using interpretations, categorizations, and narrative explanation of facts to supplement the findings of quantitative data analysis.

### 3. Results and Discussions

The discussion part mainly compared the two household heads (MHHs and FHHs) groups and showed the gender differences in the status of utilization on selected agricultural extension services.

Households are important institutional units for most development processes including agricultural extension service delivery (Etenesh, 2001). Thus, discussing on the demographic features of household respondents and the inferential results (Table 1) would be important to see the status of utilizations among rural households.

According to the survey result displayed in table 1, the mean age of the total sample respondents is 47.11 years with minimum and maximum age of 33 and 74 years, respectively. However, the result of the t-test indicated that there is no statistically significant difference between the mean age of FHHs and MHHs. The average family size of MHHs and FHHs was found to be 6.01 and 5.81, respectively. However, the independent sample t-test indicated no significant mean differences between the two categories at 10% probability level. According to Deribe (2007) on a survey conducted in Dale woreda of SNNPR, family size contributes to the variation in getting access and utilization of agricultural extension information. This is because the higher number of family members leads to decisions to take risk for participation in utilization of technology packages. This also leads to exposure to get information. Therefore, family size contributes to the variation in getting access and utilization of agricultural extension information. So, the larger family size of MHHs in the study area enables them to fully participate and utilize different agricultural extension services.

The survey showed that 90% of FHHs and 21.25% of MHHs are illiterate. There is a significant mean difference ( $\chi^2=77.242$ ) between MHHs and FHHs at less than 1% significance level. Poor educational

background of FHHs affected their utilizations of agricultural extension services negatively. This is because farmers with better educational status have a capability to understand and interpret the information transferred to them from Development Agents (DAs) easily, and others. Accordingly, IFPRI (2012) reported that education level is significant in male heads' access to different types of extension services, but education level matters to female heads only in accessing or visiting demonstration plots. Similarly, lack of education and poor awareness level may be a bottleneck to utilize the extension service delivered appropriately. Additionally, Asres (2005) on a survey conducted in Dire Dawa administrative council proved that educational level of the sample household heads is one of the variables that affect their participation in agricultural extension services.

Table 1 Distribution of respondents based on their demographic characteristics

Demographic Descriptions		HHs Category (N=160)				Total HHs (N=160)	
Age Group (Category)		MHHs (N=80)		FHHs(N=80)		Total HHs (N=160)	
		N	(%)	N	(%)	N	(%)
	18-33	4	(5)	0	(0)	7	(4.4)
	34-59	66	(82.5)	64	(80)	130	(72.2)
	>59	10	(12.5)	16	(20)	26	(14.4)
	Mean	46.68	47.54	47.11			
	Standard Deviation	9.54	10.25	9.88			
	t-value	0.551 NS					
Family size Category		MHHs (N=80)		FHHs(N=80)		Total HHs (N=160)	
		N	(%)	N	(%)	N	(%)
	1-3	0	(0)	1	(1.25)	1	(0.62)
	4-6	52	(65)	55	(68.75)	107	(66.88)
	7-9	28	(35)	24	(30)	52	(32.5)
	Mean	6.01	5.81	5.91			
	Standard Deviation	0.95	1.49	1.25			
	t-value	-1.011 NS					
Educational level of respondents		HHs Category (N=160) Total sample (N=160)				Total HHs (N=160)	
		MHHs (N=80)		FHHs(N=80)		Total HHs (N=160)	
		N	(%)	N	(%)	N	(%)
	Illiterate	17	21.25	72	90	89	55.6
	Literate	63	78.75	8	10	71	44.4
	$\chi^2$ -value	77.242***					

NS= Not significant at 10% probability level \*\*\*= Significant at less than 1% probability level

Where: N= Number of respondents HHs= Household heads; MHHs= Male household heads; FHHs= Female household heads

Land and financial resources are of prime importance for poor rural women, but technology, seeds and fertilizer, livestock and fisheries, irrigation, marketing opportunities and off-farm employment are also essential (ECOSOC, 2014). Land is the primary source of livelihood for all rural households. The size of the land reflects ownership of an important fixed farm asset. The larger farm size implies more resources and greater capacity to invest in farm and increased production. However, a noticeable gap exists in entitlement to this important resource between FHHs and MHHs (ANRS BoA, 2013). According to the survey result, the average land holding size of MHHs and FHHs was 2.286 ha and 1.183 ha, respectively. There is a statistically

significant mean difference ( $t = -12.132$ ) on land holding size between FHHs and MHHs at less than 1% level of significance. From this result, one can understand that the number of landless farmers is high at FHHs. This also indicates that FHHs have less access to productive resource when compared with MHHs. Thus, this difference shows that land holding size affects the extension services utilization. Although the survey result showed that, on average a household have 5.75 TLU (6.83 for MHHs and 4.66 for FHHs) with a standard deviation of 2.44 (2.36 for MHHs and 2.52 for FHHs), the number of TLU owned by MHHs was greater than FHHs. There was a significant mean deference ( $t = -5.630$ ) at less than 1% level of significance between MHHs and FHHs.

The reason for the difference is the low socio-economic status of FHHs to own such important assets.

Concerning farm resources, Umeta *et al.*'s (2011) survey result conducted in the central rift valley's of Ethiopia clearly indicated that, FHHs access to productive resources is low when compared with MHHs. FHHs owned a mean of 1.43 ha whereas MHHs owned a mean of 2.03 ha of farm size and their difference is significant at 1% significant level ( $t = 3.28$ ,  $p = 0.001$ ). MHHs have better access to oxen than FHHs and their difference is significant at 1% probability level ( $\chi^2 = 6.88$ ,  $p = 0.009$ ). In general, these great variations of resource level between MHHs and FHHs favored the MHHs to have more access to financial capital by selling their livestock to purchase extension package inputs from suppliers. In addition, farmers who owned a large number of livestock have the capacity to bear risks of using the available extension packages. This by itself encourages the use of technological packages. Similarly, IFPRI (2012) reported that land size and asset in the form of livestock matters for both male and female heads as a factor affecting visit by extension agents and attendance in community meetings. Therefore, the findings indicated that MHHs in the study area have a better utilization status of agricultural extension services.

### 3.1. Utilization Status of Agricultural Extension Services

The agricultural extension services provided for farmers are so many and difficult to measure due to their multi-faceted nature. However, for the purpose of this study, the major extension services given in the study area were identified based on the result of Focus Group Discussions (FGDs) and with the help of BWAO. Thus, crop production packages (maize, wheat, *teff* and horticultural crops), livestock development packages (cattle fattening, sheep and goat production, sheep and goat fattening, and poultry production), extension programs (extension training, on-farm trial and demonstrations and farmers field day), credit and home economics services are mainly identified for this study to see their status of utilization by FHHs and MHHs in the last three consecutive years (2009/10-2011/12).

Crop production packages as a whole include the use of improved or high yielding seed variety, fertilizer, planting techniques and use of chemicals. Livestock development package usually includes improved breeds, housing, feeding, and veterinary services. Meanwhile, services like participation on extension programs, credit and home economics are delivered in a single entity either directly or indirectly to implement packages (ANRS BoARD, 2004).

The result of FGDs clearly revealed that even if there was a good coverage of extension services, low status and low level of participation of resource-poor and women farmers' in utilization of agricultural extension services was reported. Additionally, the discussion that was made with Woreda experts and DAs indicated that, extension workers tend to work with resource-rich male farmers who had shown an interest in the extension packages to achieve the minimum number of packages assigned to each DA and Woreda expert.

For example, in Ethiopia, researchers note that male extension agents are prevented from interacting with female farmers by strict cultural taboos. Another issue noted is that male extension officers more likely subscribed to the common misconception that women are not farmers and overlooked women in the household (Moore *et al.*, 2001).

S.N	Extension Packages/ Programs/ Services	HHs Category (N=160)				$\chi^2$ -value; (P-level)	Total (N=160)	
		MHHs(N=80)		FHHs(N=80)			Yes (%)	No (%)
		Yes (%)	No (%)	Yes (%)	No (%)			
1	Maize package	80(100)	0(0)	4(5)	76(95)	144.762** *; (0.000)	84(52.5)	76(47.5)
2	Teff package	17(21.25 )	63(78.75 )	0(0)	80(100)	19.021*** ; (0.000)	17(10.6)	143(89.4)
3	Wheat package	15(18.75 )	65(81.25 )	2(2.5)	78(97.5)	11.123*** ; (0.001)	17(10.6)	143(89.4)
4	Horticulture package	20(25)	60(75)	24(30)	56(70)	0.502 NS	44(27.5)	116(72.5)
5	Cattle fattening package	59(73.75 )	21(26.25 )	19(23.75 )	61(76.25 )	40.025*** ; (0.000)	78(48.75)	82(51.25)
6	Sheep and goat production package	45(56.25 )	35(43.75 )	32(40)	48(60)	4.231**; (0.040)	77(48)	83(52)
7	Sheep and goat fattening package	45(56.25 )	35(43.75 )	31(38.75 )	49(61.25 )	4.912**; (0.027)	76(47.5)	84(52.5)
8	Poultry production package	24(30)	56(70)	36(45)	44(55)	3.840**; (0.050)	60(37.5)	100(62.5)
9	Extension trainings	80(100)	0(0)	36(45)	44(55)	60.690*** ; (0.000)	116(72.5)	44(27.5)
10	Practicing on-farm trail and demonstrations	80(100)	0(0)	4(5)	76(95)	144.762** *; (0.000)	84(52.5)	76(47.5)
11	Participation in farmers field day	77(96.25 )	3(3.75)	0(0)	80(100)	148.434** *; (0.000)	77(48)	83(52)
12	Credit services	71(88.75 )	9(11.25)	54(67.5)	26(32.5)	10.569*** ; (0.001)	125(78)	35(22)
13	Home economics services	19(23.75 )	61(76.25 )	67(83.75 )	13(16.25 )	57.926*** ; (0.000)	86(53.75)	74(46.25)

Source: Own computation (2013); \*\*\*, \*\*= Significant at less than or equal to 1% and 5% probability level respectively

Where: NS= not significant at 10% level of significance N=Number of respondents (%) = percentage HHs= Household heads

MHHs= Male household heads, FHHs= Female household heads

Maize, wheat and *teff* are the major cereal crops produced in the study area to enhance food security. Additionally, horticulture is also the major package used by farmers to enhance the income of the household (BWAO, 2013). Hence, an assessment was made to examine its status of utilization by farmers (Table 2). As indicated in table 2, out of the total (160) sampled households, on average, 52.5%, 10.6%, 10.6% and 27.5% participated in maize, *teff*, wheat, and horticulture packages, respectively. The participation of FHHs in crop production packages was insignificant; i.e. only 5%, 0% and 2.5% of FHHs participated in maize, *teff* and wheat packages, whereas MHHs took the highest utilization share (100%, 21.25% and 18.75%, respectively) except in the horticulture package which 30% of FHHs and 25% of MHHs utilized. Statistically, there is a significant mean difference at 1% level of significance ( $\chi^2 = 144.762, 19.021$  and  $11.123$ ) between MHHs and FHHs in producing maize, *teff* and wheat packages. The same result had been found by Edlu (2006) on a survey conducted in Enemore and Ener Woreda, Gurage Zone. The result clearly proved the dominancy of MHHs in utilizing crop production packages. Even if the number of FHH users (30%) are greater than MHH users (25%) in horticulture package, there is no significant mean difference between them ( $\chi^2 = 0.502$ ). This result implies that FHHs in the study area probably preferred small backyard horticulture package with much less production cost due to their less land holding size. This result is in line with IFPRI (2011) that the Women's Development and Change extension package emphasizes extension advice on traditional women's activities such as home gardens and poultry in Ethiopia.

Fattening and other production packages are the major components of livestock packages that have been utilized in the study area. Expanding improved poultry package towards women to improve food security and cash income is also one of the extension domains that have been strongly pushed in the study area (BWAO, 2013). Hence, an assessment was made to examine its status of utilization by farmers (Table 2). Firstly, out of the total respondents, 73.75% MHHs and 23.75% FHHs; 56.25% MHHs and 40% FHHs; and 56.25% MHHs and 38.75% FHHs participated in cattle (cow and oxen) fattening, sheep

and goat production, and sheep and goat fattening package, respectively. There is a statistically significant mean difference ( $\chi^2 = 40.025, 4.231$  and  $4.912$ ) at less than 1% probability level between MHHs and FHHs in using cattle fattening package; and at less than 5% probability level for both sheep and goat (sheep and goat production;  $P=0.040$  and sheep and goat fattening;  $P=0.027$ ) packages. Secondly, 37.5% of HHs (30% MHHs and 45% FHHs) participated in poultry production package and there is a significant mean difference ( $\chi^2 = 3.840$ ) at 5% significance level between MHHs and FHHs. In describing gender differences, the dominance of MHHs on livestock fattening and production packages is clearly observed except in poultry production package. It is clear that livestock ownership of FHHs in sheep (0.54) and goat (0.39) is higher than their counterparts; that is, 0.41 and 0.26 respectively. Generally, the reason for this result may be the economical advantages gained due to more livestock ownership. MHHs get more extension support from extension workers because they are able to pay either down payment or cash to utilize those packages than poor FHHs. Several authors have also indicated that gender and resource status differences in using recommended modern technology are also causes (Bezabih, 2000; and Techane, 2002).

Participation in various areas of extension programs of training, practicing on-farm trial and demonstration, farmers' field day or visit, etc. enables farmers to identify their farm problems and to set sound solutions for further measure (ANRS BoARD, 2004). However, the results of the study indicated that the beneficiaries of these services are mainly male farmers than women. All MHHs participated in extension trainings and practiced on-farm trials and demonstrations. While 96.25% of MHHs participated in farmers' field day, only 45% and 5% FHHs participated in extension trainings and practiced on-farm trials and demonstrations in the past three years' cropping season both in Farmers' Training Centers (FTCs) and other demonstration centers. Meanwhile, all FHHs have not participated in farmers' field day and visiting programs. There is a significant mean difference ( $\chi^2 = 60.690, 144.762$  and  $148.434$ ) between MHHs and FHHs at less than 1% significance level in participating on extension trainings, on-farm trials and demonstrations and



farmers' field day or visiting programs, respectively. Gender disparity is clearly reflected in participation of extension programs, since on average, only 16.67% FHHs have participated in various components of extension programs. In contrast, 98.75% MHHs participated on various areas of extension programs conducted in the previous three years cropping season. This result is in line with Umeta *et al's* (2011) survey result in the central rift valley of Ethiopia which reported that an average participation of women farmers in extension events like training, field days and demonstration is very low (<21%). The reason reported was that DAs focus on inviting MHHs for the extension program thinking that male farmers are in a good position to practice the technology after the training or the visit. It is also easy for the DAs to fulfill the targeted quota plan given from the Woreda. In addition, low female HHs' participation in the extension program was due to their poor communication skills, fear of walking with male HHs in the field, lack of invitation by DAs, and reasons associated with their household workload and cultural influences. Similarly, Mahilet (2006) on a study conducted in Alemaya Woreda stated that MHHs, have better contact with DAs, and thus they are in a better position than FHHs in accessing extension services such as attending demonstration, participating in field day or training, and receiving written information. Similar results were also found by Habtemariam (1996) indicating that only 37% of the women have participated in extension advice and training in Ethiopia. Moreover, Asres (2005), on a study conducted in Dire Dawa administrative council, showed that out of the total respondents, only 8.1%, 7.5%, 6.3%, 6.9% and 1.3% of women had participated in extension planning, training, farmers' field day, demonstration and on-farm trial and extension exhibition, respectively. Luqman *et al's* (2006) and Kizilaslan's (2007) studies also support the above finding that extension programs are the main components in the rural development strategies to enhance the livelihoods of the rural people. But women's participation in extension programs is not sufficient. Considerably, they have little access and benefit from extension trainings and/or services. However, the participation of females in various areas of extension programs facilitates the effectiveness and efficiency of the utilization agricultural extension services.

Credit helps farmers alleviate current liquidity constraints and enhances the use of technology package and services correspondingly (ANRS BoARD, 2004). Different institutions like the Amhara Credit and Savings Institution (ACSI) and the Commercial Bank of Ethiopia (CBE) give saving and credit services for farmers in the study area (Abebe, 2011). Thus, out of the total 160 HHs, 88.75% MHHs and 67.5% FHHs have utilized credit services. There is also a significant mean difference ( $\chi^2 = 10.569$ ) at less than 1% probability level between MHHs and FHHs (Table 2). This finding is in line with Umeta *et al's* (2011) survey result, that 52.9 % of MHHs have received a sort of credit at least for one or more than one times, whereas only 47.1% of FHHs received it. Edlu (2006) stated the reasons for the significant mean difference between male and female farmers towards using credit service. The reasons include female HHs may face high interest rate, shortage of farm land size, inability to pay down payment, and lack of collateral to take credit. However, credit is an effective policy option to encourage utilization of agricultural extension packages or services. It has been suggested by many authors that credit has strong and significant role in enabling the use of technological packages (Bezabih, 2000; and Techane, 2002). Therefore, households that have the access and utilization to credit service would positively and significantly affect the household heads' participation in full extension package service.

To achieve food security at household level and to improve the life standard of farmers, delivering home economics services is the only choice. The service includes food preparation, post-harvest technologies and improvement of house standards. The users may be either female or male and can use the services either alternatively in a single entity or as a whole based on their interest and environmental situations (ANRS BoARD, 2004). The result of the study indicates that only 23.75% MHHs and 83.75% FHHs have utilized home economics services either in a single entity or as a whole. Statistically, there is a significant mean difference ( $\chi^2 = 57.926$ ) at less than 1% probability level between FHHs and MHHs. This result indicates that females were more responsible and performed much higher than males with regard to the tasks that were usually carried out around home.

As a result, rural women's participation and utilization of extension services have been found to be minimal. In line with the above finding, UN (1992) reported that women are mostly proposed for programs of home economics which, though very useful, disregard their role in agricultural production.

In line with the above finding, Buchy and Basaznew (2005) found crucial shortcomings both in the gender sensitivity of extension provision and in the way gender and women's affairs were situated within the bureaucracy in the Awasa Bureau of Agriculture. While farmers in general were underserved by extension agents, women farmers made up only a small fraction of farmers receiving extension services. They seldom went to extension field visits unless they were related to home economics. Even where training by agricultural staff was in principle open to men and women farmers, the training times were selected without consideration of women's time burdens.

#### 4. Conclusions and Recommendations

The major resources required for farm activities in the study area; i.e. land and livestock assets are relatively better in male headed households than female-headed households to undertake crop and livestock production and to use the services rendered by professionals to those activities. In line with this idea, FHHs' utilization of inputs based on their need in terms of type and amount was found to be minimal. Only very few FHHs were having links with the DAs of PKAs to get advice and benefits. Therefore, MHHs benefited more from agriculture outputs and led live better life. Generally, the MHHs were stronger in different aspects of life than the FHHs.

As the results of this study revealed, the education level of the respondent had a significant mean difference among HHs which significantly influenced their extent of utilization of extension services. Thus, addressing gender disparities in accessing to rural education via provision of continuous information and special, adult education programs is vital and is strongly recommended.

It was found that land holding size significantly affected the utilization of agricultural extension services. Thus, in addition to fair farmland

distribution, developing and disseminating technologies and strategies are relevant to FHHs to increase productivity.

Since livestock is one of the significant assets influencing farmer participation and utilization of agricultural extension services, intervention to improve the sector should be encouraged through empowering farmers to own livestock through provision of credit. Furthermore, development of improved livestock feed and health service should be paid attention to improve their productivity.

Linkages of the society to extension workers and their institutions have a great impact on the success of the farming community. Hence, the community must have strong linkage with extension workers (Umata *et al.*, 2011).

Finally, reasonable place should be given for women in the participatory extension programs and development process, even by reserving specific minimum quota in committees or leadership, both in formal and informal farmers' organizations.

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#### References

- Abebe Getahun. 2011. Women Participation in Rural Cooperatives: The Case of Bure Woreda, West Gojjam Zone, Amhara National Regional State. M.Sc. Thesis Presented to the School of Graduate Studies of Haramaya University, Ethiopia.
- ANRS BoA (Amhara National Regional State Bureau of Agriculture). 2013. *Six month work plan execution and evaluation report*.
- ANRS BoARD (Amhara National Regional State Bureau of Agriculture and Rural Development). 2004. *Crop Production Package, Dairy Farms*

- and Livestock Development Package and Home Economics Package*. Training Manuals for FTCs. Bahir Dar, Ethiopia.
- Asres Elias. 2005. Access and Utilization of Development Communication by Rural Women in Dire Dawa Administrative Council, Eastern Ethiopia. M.Sc. Thesis Presented to the School of Graduate Studies of Alemaya University.
- Bezabih Emana. 2000. The role of new crop varieties and chemical fertilizer under risk: the case of smallholders in Eastern Oromia, Ethiopia. Ph.D. Thesis, University of Hannover, Germany.
- Buchy, M., and F. Basaznew. 2005. "Gender-Blind Organizations Deliver Gender-Biased Services: The Case of Awasa Bureau of Agriculture in Southern Ethiopia." *Gender, Technology and Development* 9 (2): 235–251.
- BWAO (Bure Woreda Agriculture Office). 2013. *Six month work plan execution and evaluation report*.
- CSA (Central Statistics Authority). 2007. The 2007 population and housing census of Ethiopia, Central Statistics Authority, Addis Ababa, Ethiopia.
- Deribe Kaske. 2007. Agricultural Information Networks of Farm Women and the Role of Agricultural Extension: The Case of Dale Woreda, SNNP Region. M.Sc. Thesis Presented to the School of Graduate Studies of Haramaya University.
- EARO (Ethiopian Agricultural Research Organization). 2000. Institutionalizing Gender Planning in Agricultural Technology. Generation and Transfer Processes, Addis Ababa.
- ECOSOC (Commission on the Status of Women). 2014. Emerging issues, trends and new approaches to issues affecting the situation of women or equality between women and men. "Women's access to productive resources". ISSUES PAPER. Thursday, 13 March 2014.
- Edlu Badwo. 2006. Extension Program Coverage and Utilization by Different Categories of Farmers in Enemore and Ener Woreda, Gurage Zone. M.Sc. Thesis Presented to the School of Graduate Studies of Haramaya University, Ethiopia.
- Etenesh Bekele. 2001. Factors maintaining the gender –gap in entitlements to rural resources in Ethiopia; Department of Agricultural Extension, seminar papers presented on 19-20 November 2001, Alemaya University.
- Gurmesa Umeta, Felekech Lemecha and Taha Mume. 2011. Survey on women access to agricultural extension services at selected woredas of Mid Rift Valley of Ethiopia. *Journal of Agricultural Extension and Rural Development* Vol. 3(3), PP. 51-63, March 2011.
- Habtemariam Kassa. 1996. Agricultural Education, Research and Extension in Ethiopia: Problems and Linkages. In: Mulat D., Aregay W., Tesfaye Z., Solomon B.: Sustainable Intensification of Agriculture in Ethiopia. Proceedings of the Second Conference of the Agricultural Economics Society of Ethiopia, held in Addis Ababa 3-October 1996. Agricultural Economics Society of Ethiopia, Addis Ababa, PP 161-181.
- IFAD (International Fund for Agricultural Development). 2009. *Value chain Development in the Eastern Region, Dominican Republic*, Project Design Document.
- IFPRI (International Food Policy Research Institute). 2000. *Women: The Key to Food Security: Looking into the Household*. Washington, DC: IFPRI.
- IFPRI (International Food Policy Research Institute). 2005. *Women: Still the Key to Food and Nutrition Security*. Report No. 33. Washington, DC: International Food Policy Research Institute.
- IFPRI (International Food Policy Research Institute). 2012. Agricultural Extension Services and Gender Equality. An Institutional Analysis of Four Districts in Ethiopia. Working Paper No. 28, August 2011.
- IFPRI (International Food Policy Research Institute). 2012. Gender Differences in Access to Extension Services and Agricultural Productivity. ESSP II working paper 49.
- Kizilaslan, N. 2007. Rural Women in Agricultural Extension Training. Department of Agricultural Economics, Faculty of Agriculture, *Research Journal of Social Science*, 2: 23-27 Gaziosmanpasa University, Turkey.
- Lisa, S., and K., Jakob. 1992. *Agricultural Extension in East Africa*, World Bank technical papers. The World Bank Washington D.C.
- Luqman, M. N., M., Hussain and A. K., Saeed. 2006. Extent of Rural Women's Participation in

- Agricultural and Household Activities. Department of Agricultural Extension, University of Agriculture, Faisalabad, *Journal of Agriculture and Social Science*. 02 (1): 5-9.
- Mahilet Abitew. 2006. Gender Analysis in Agriculture: Implication for Agricultural Extension in Alemaya Woreda, Ethiopia. M.Sc. Thesis Presented to the School of Graduate Studies of Alemaya University.
- Mason, A., and E. King. 2001. *Engendering Development: Through Gender Equality in Rights, Resources, and Voice*. Washington, DC: World Bank; Oxford, UK: Oxford University Press.
- Moore, K. M., S. Hamilton, P. Sarr, and S. Thiongane. 2001. Access to technical information and gendered NRM practices: Men and women in rural Senegal. *Agricultural and Human Values* 18 (1): 95-105.
- Quisumbing, A., L. Brown, H. S. Feldstein, L. Haddad, and C. Pena. 1995. *Women: The Key to Food Security*. Report No. 21. Washington, DC: International Food Policy Research Institute.
- Sen, A. 1990a. "Gender and Cooperative Conflicts." In *Persistent Inequalities*, edited by I. Tinker, 123-150. New York: Oxford University Press.
- Sen A. 1990b. "More Than 100 Million Women are Missing." *The New York Review of Books*, December 20, 37.
- Techane Adugna. 2002. Determinants of fertilizer adoption in Ethiopia; The case of Major cereal Producing Areas, M.Sc. Thesis Agricultural Universities Alemaya University.
- UN (United Nations). 1992. *Survey of economic and social conditions in Africa*, Economic Commission for Africa, United Nations, New York.
- World Bank. 2001. *Engendering Development: Through Gender Equality in Rights, Resources and Voice*. Policy Research Report. Washington DC.
- World Bank. 2007. *Global monitoring report 2007: Millennium development goals—Confronting the challenges of gender equity and fragile states*. Washington, D.C.
- World Bank, FAO (UN Food and Agriculture Organization), and IFAD (International Fund for Agricultural Development). 2008. *Gender in*
- Agriculture Sourcebook*. Washington, DC: World Bank.

## Impacts of Fish Introduction on Aquatic Environment: a Study with Special Reference to Common Carp/ *Cyprinus Carpio*, (Linnaeus, 1758)

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**Abstract:** *Fish introduction was practiced for years in the world for economical, social, biological and ecological purposes without consideration of the deleterious impacts on the aquatic environment. The most important environmental impacts caused by fish introduction were competition for resources, predation, disease and parasites, genetic impacts, fish community alternation, physiological changes, impact on other aquatic fauna, habitat alternation and socioeconomic impacts. The impacts of fish introduction were evaluated on the following criteria: species suited to the physico-chemical properties of the intended water body; attractiveness and profitability of the fish to the fishers; fish with good flesh quality for the consumers; and fish that fill a vacant niche to establish balanced community. Fish introduction in Ethiopia started during the Italian invasion and then the practice expanded in many natural and man-made waters. Information on management, status and impact on the aquatic environment were not well documented. The literature review, focus group discussion and field observation indicated that ill-conceived and poorly monitored fish introduction was practiced. As the rule of thumb, well-organized and adequate knowledge on fish introduction management is essential in 'Resource Management Challenged Environments' and for 'Meeting the needs of the society, and keeping the balance of aquatic environment.*

**Keywords:** Anthropogenic, biodiversity, ecology, exotics, information, management

### 1. Introduction

Over the past 70 years, large-scale movements of fish, including a total of 1354 introductions of 237 species into 140 countries, have occurred (Cowx, 1994). It has been identified at least 134 fish species had been introduced or relocated within 29 European countries, especially Central and Eastern Europe. Holcik (1991) indicated that poor success was recorded for most as well as measurable ill-effects on native fish and their habitats.

The reasons for introduction of fish are many and varied. European Inland Fisheries Advisory Commission put the reasons into three main categories which are related to the status of the wild stocks, the impact of anthropogenic activities and the ease with which factors limiting natural production can be removed or ameliorated. Based on these reasons and identified objectives, introduction was carried out for mitigation, enhancement, restoration and creation of new fisheries. A number of

transplantation and introductions of exotic species for culture have been made and many of them have established the new environments with very little adverse effects providing important sources of food or recreation.

Indiscriminate introductions that may lead to environmental problems are discouraged and many governments have imposed restrictions on imports. The most important ecological effects of an introduction or transplantation of a species to new environment is its influence on the local plants and animal life /fish species/, transmission of diseases, genetic dilution from exotics, interbreeding with wild fish and altering the genetic make-up of the native fish (Pillay, 1992). Any intended water body for fish introduction should be studied and the scientific information of the fish on economical, biological, ecological, social and environmental values should be considered (Stephanou, 1990). It is now widely accepted in different parts of the world that in the



establishment and management of fish productions by introduction requires appropriate studies to determine the need and the desirability (Pillay, 1990).

Introduction programs must share the objectives of effective aquatic ecosystem management in order to provide benefits on a sustainable basis (Dogde and Mark, 1994). The introduction density in terms of the carrying capacity of the ecosystem in consideration of the existing stock biomass and allowances for migration/dispersal, predation and predicted survival of the stocked fish in order to avoid over introduction is the most important issue to be accounted.

There is evidence from experience in several instances that adequately planned release of spawner of hatchery-raised young in sufficient numbers for required periods of time has resulted in remarkable increases in commercial catches. Generally, introduction in rivers and lakes is done to enhance economically important ones or to occupy ecological niches in the fauna. Therefore, these water body systems need appropriate studies to determine the need and desirability for introduction (Pillay, 1990).

Fishes have often been moved from lake to lake, sometimes with the laudable goal of increasing the yield of human food. Except in lakes and man-made reservoirs without fish, such efforts have failed to achieve the desired objectives and sometimes the results have been disastrous. When large lakes whose fisheries are immensely important as sources of human food are involved, especially in areas where other animal protein is scarce, much is at stake. A major scientific objection to such introductions is that the outcome is often unpredictable and irreversible. An additional danger, not considered here, is that introductions may lead to introgression of new genes. This can hamper taxonomic and evolutionary studies and hinder progress in aquaculture, as it is happening among the economically important tilapiine cichlid fishes of Africa (Barel *et al*, 1985).

The Chinese cultured common carp (*Cyprinus carpio*) and goldfish (*Cyprinus .crassus*) for food and ornamentation before the present era (BP) (MacCrimmon, 1968; Balon, 1974). During the past 400 years, carp has been intensively cultured in Europe and introduced into many countries around the world (Balon, 1974). Evidence suggests that the

Romans first cultured carp collected from Danube River and expanded it in monasteries throughout the Middle Ages. Although little evidence is available showing that these and others species were purposely introduced into wild environments, there is no doubt that ponds and waterways failed as frequently then as they do in modern times so that cultured fish were released to new environments to start new population (Dogde and Mark, 1994).

Historical, zoogeographical, morphological and physiological information was used in explaining the origins and history of domestication of the *C. carpio*. *C. carpio* are an introduced species throughout most of the world and are generally considered a nuisance and potential pest (Chumchal, 2002). They are important food fish throughout most of the world except in Australia and North America where the fish is considered unpalatable (MacCrimmon, 1968; Balon, 1974)

In Africa, the primary purpose of introductions of fish species was to maintain or increase yields and harvests, sport fish and control of vectors (e.g. malaria). Some introductions met this purpose but others may have compromised long-term sustainable harvests, in part by altering the aquatic environment and competing with native species. The short-term benefits have been increased fish protein supply in these countries. But more research and assessment are necessary to understand how introductions serve reaching long-term objectives (Oguto Ohwayo *et al*, 1991).

Many fish introductions have been practiced in natural and man-made waters in different parts of Ethiopia including the Amhara National Regional State (Yared, 2010; Shibru and Fisseha, 1981). Specific information of the introduced fish species, management strategies of, status assessment and the impacts of introduced fish species on the aquatic environment are not well-documented in an accessible way for further evaluation. Fish introduction programs have been frequently carried out without much prior thought and planning and with poor knowledge of the biology of the introduced species or of the local fauna (Abebe and Stiassny, 1998). The objectives of this survey were (1) to collect integrated baseline information on current and

projected future activities in fish introduction, and (2) to recommend an intervention mechanism in fish introduction to sustain the well-being of the biodiversity and the aquatic ecosystem.

## 2. Materials and Methods

Relevant literature review, field data, focus group discussion and personal experience (1986- to the present on fisheries management as expert and researcher) to overview exotic fish introduction and indigenous fish translocation to different aquatic ecosystems were employed. Besides, impacts of introduction on the aquatic ecosystems and fish biodiversity with special reference to *cyprinus carpio* (L.1758) were considered. Occasional field work was carried out on Lakes Lego (2013 & 2014), and Maibar (2005 & 2006) in South Wollo, Geray reservoir (2012 & 2013) in West Gojjam and Lake Zengena (2004 and 2006) in Awi zone. The Focus group discussion (2013) was organized with people in Lake Lego bordering kebeles (05, 12, 15) engaged in fishing activities. Each focus group consisted of eight members selected based on educational status (from illiterate to grade 10 complete), age (19 to 43 years) and fishing experience (1 to 20 years). The focus group

discussion was carried out separately in each kebele on the current fisheries problems of Lake Lego. Descriptive statistics was used to analyze the data.

## 3. Results and Discussion

The surveyed water bodies were introduced with exotic and indigenous fish species (Table 1). The abundance of introduced fish species in the surveyed water bodies varied spatially. *C. carpio* dominated in the surveyed water bodies followed by *O. niloticus* and *T. zilli*. The proportion of *C. carpio*'s dominance on the surveyed water bodies except Geray reservoir was observed (Table 2). The focus groups' discussion carried out on the Lego fisheries problem emphasized that deterioration of the fishing activities was worsened after unintentional introduction of *C. carpio* from Lake Ardibo's irrigation canal through Ankerkeha River. The focus groups' discussion also expressed that there were various problems on the Lego ecosystem such as wetlands degradation, monofilament gillnets use with very small mesh size up to four centimeter against the allowed lowest, ten centimeter mesh size, open access fishery activities that created 'Too many boats chasing too few fish' situation that resulted the deterioration of the Lego fishery from time to time.

**Table 1 Surveyed water bodies and fish species abundance**

Water bodies	year	Fish species	caught in number	Total species caught	% Species caught
Lake Lego	2013 & 2014	<i>O. niloticus</i>	6	61	9.84
		<i>C. garipinus</i>	4		6.56
		<i>C. carpio</i>	51		83.60
Maibar	2005 & 2006	<i>O. niloticus</i>	109	432	25.2
		<i>C. carpio</i>	323		74.8
Zengena	2004 & 2006	<i>T. zilli</i>	1	26	3.85
		<i>C. carpio</i>	25		96.15
Geray	2012 & 2013	<i>O. niloticus</i>	86	144	59.72
		<i>C. carpio</i>	58		40.28

Ethiopia has 172 freshwater fish species (Froese, R. and D. Pauly, 2014). The freshwater fish species comprises of 39 endemic and 11 introduced (Table 2). Fish introduction activities started in the Ethiopian aquatic ecosystems during the Italian invasion. The introduction of Eastern mosquito fish *Gambusia holbrooki* in Lake Tana for control of malaria and northern pike *Esox lucius* for fishery enhancement is a typical example practiced during

the Italian invasion. Exotic fish introduction and translocation of indigenous fish species for enhancing fisheries in lakes, reservoirs and small water bodies have been practiced broadly since 1975 through the Sebeta Fish Breeding and Research Centre, now a research wing of the Ethiopian Institute of Agricultural Research.

Table 2 Introduced fish species in Amhara Region

Water body	Introduced species	
	native	exotic
Lake Lego	<i>O.niloticus</i> & <i>T.zilli</i>	<i>C. carpio</i>
Ardibo	<i>O.niloticus</i> & <i>T.zilli</i>	<i>C. carpio</i>
Golbo	<i>O.niloticus</i> & <i>T.zilli</i>	<i>C. carpio</i>
Maibar	<i>O.niloticus</i> & <i>T.zilli</i>	<i>C. carpio</i>
Tirba	<i>O.niloticus</i> & <i>T.zilli</i>	
Bahir Giorgis	<i>O.niloticus</i> & <i>T.zilli</i>	<i>C. carpio</i>
Zengana	<i>O.niloticus</i> & <i>T.zilli</i>	<i>C. carpio</i>
Lai Bahir	<i>O.niloticus</i> & <i>T.zilli</i>	<i>C. caprio</i>
Tach Bahir	<i>O.niloticus</i> & <i>T.zilli</i>	<i>C. carpio</i>
Geray reservoir	<i>O.niloticus</i> & <i>T.zilli</i>	<i>C. carpio</i>
W asha reservoir	<i>O.niloticus</i> & <i>T.zilli</i>	<i>C. carpio</i> and <i>C.carassius</i>
Ango-Mesk reservoir	<i>O.niloticus</i> & <i>T.zilli</i>	<i>C. caprio</i>

Source: Yared Tigabu Ecohydrology and Hydrobiology 2010

The different water bodies found in different regional states of Ethiopia were introduced with different exotic and native fish species (Yared, 2010). Common carp /*Cyprinus carpio*/ is most dominantly introduced exotic fish species in many parts of Ethiopia (Yared Tigabu 2010). Even though *C. carpio* was widely introduced in Ethiopia, little was known about its reproductive biology (Mathewos, 2013). Adequate information on introduced fish species, strategies of management, assessment of current status and the impacts of introduced fish species on the aquatic environment is not well-documented in an accessible way for further evaluation and monitoring (Abebe and Stiassny, 1998).

The Fisheries Legislation Proclamation No. 315/2003 of Federal Democratic Republic of Ethiopia and Fisheries Legislation Proclamation No. 92/2003 of the Amhara National Regional State were declared to manage fisheries resources. The two proclamations by the same token share common objectives: conservation of fish biodiversity and environment, making use of fisheries' resources with appropriate fishing gear and preventing as well as controlling of overexploitation of the fisheries resources. They also create enabling environment for fisheries' development to have proper contribution to speed economic growth through the expansion of aquaculture development in natural and man-made water bodies. Besides, they increase the supply of safe and good quality fish and ensure a sustainable food security. They also create conducive

environment to get economic benefit and job opportunities.

In reality, these Fishery Legislation Proclamations (No. 315/ 2003 & No. 92/2003) were not implemented to alleviate the fisheries problems that have been observed for years. The conservation of freshwater biodiversity and the freshwater aquatic environment are managed in a 'Business -as- usual' context. There are numerous ways in which fish introduction activities can harm the native fish stocks in particular and the aquatic ecosystem in general. Based on a review of relevant scientific literature, the more common impacts of fish introduction in general and *C. carpio* introduction in particular have been identified and summarized as follows.

**1. Competition for Resources:** Aquatic macrophytes are integral to ecosystem functioning through their provision of habitat for phytophilic zooplankton and refuge for planktonic species from fish predation (Perrow et al., 1999). *C. carpio* indirectly reduce abundance of other fishes through reductions in spawning and nursery habitats. They disturb the benthic sediments of freshwater lakes and slow-flowing rivers during feeding, disrupting the production of aquatic invertebrates and damaging aquatic macrophytes, especially the delicate species (Cahn 1929; Crivelli 1983; Fletcher et al. 1985; Pinto et al. 2005).

**2. Predation:** Introduced species can reduce or

eliminate native species through predation at any life stage of the native fishes (He and Kitchell, 1990; Arthington, 1991). Based on a review of several inland lakes in Québec, Chapleau *et al* (1997) suggested that piscivory by introduced fishes was probably responsible for the local extinction of many small-bodied fishes. Conversely, predation by indigenous fishes can be important in suppressing an introduced or invading species (Christie *et al.*, 1972). *Cyprinus carpio* is regarded as a serious pest because of its disturbance of the habitat, its ability to occupy a wide variety of habitats, and its predation on the eggs of other fishes. Carp also reduces zooplankton and macro invertebrate populations by predation and by eliminating macrophytes that provide cover.

**3. Diseases and Parasites:** Fish introductions have been associated with the transfer of diseases and parasites to new aquatic ecosystems in different regions (Arthington, 1991; Fernando, 1991; Holcik, 1991). The potential consequences of introducing disease or parasites include direct mortality, establishment of a reservoir of infection, reduced performance and increased sensitivity to stressors (Goede, 1986). Introduction of exotic species could have catastrophic socioeconomic consequences if it involves negative impacts, and particularly the occurrence of new disease or the genetic deterioration of cultured brood stocks.

**4. Genetic Impacts:** Introgression, the transfer of genetic information from one species to another through hybridization and repeated backcrossing, is a common phenomenon. Hybridization reduces the effective population size of the native species thereby increasing the incidence of inbreeding leading to the potential for eliminating unique genomes or producing undesirable changes in allelic frequencies. Interspecific hybridization can result in infertile hybrids having intermediate characteristics of the parents (Arthington, 1991; Ferguson, 1990; Verspoor and Hammar, 1991).

In Australia, hybridization between two or possibly more imported varieties of the European carp, *Cyprinus carpio*, has given rise to the vigorous and aggressive “Boolarra” strain which spread explosively in the 1960s and 1970s, becoming far more widespread and problematic than the other originally

introduced stocks which remained confined to their original sites of introduction. The tendency to cause a general decay in water quality and the high fecundity of carp has caused them to be generally regarded as a nuisance (McCrimmon, 1968).

**5. Physiological Changes:** Maturing at small size with large number of oocytes is one of the physiological advantages of the traits of the carp which appear to have provided their population with resilience to the exploitation by providing rapid growth to maturity and the opportunity for early life reproduction prior to their capture. The establishment and year round reproduction of *C. carpio* in a tropical environment with high fecundity has shown that introducing the species to other natural lakes with prior indigenous fish can threaten their ecology (Mathewos, 2013).

**6. Fish Community Alteration:** The introduction of a new species can upset the natural balance of the fish community and create ecological instability. A typical example of the disastrous effects of introducing species is available from Lake Victoria, the world’s largest tropical lake. In the 1970s, there were over 300 endemic cichlid species, representing 99 per cent of the lake’s fish species. The physical and biological properties of the lake changed considerably since the introduction of the exotic fish, Nile Perch (*Lates niloticus*). The majority of cichlids endemic to the lake became extinct and now the group represents only one per cent of the lake’s fish diversity. This can be manifested in terms of altered growth and survival of indigenous fishes, and decline in the yields of fisheries which are sought (Ogutu-Ohwayo & Hecky, 1991; Stiassny, 1996).

*C. carpio* are distributed worldwide and considered one of the most wide-spread, detrimental invasive species (Lowe *et al*, 2004) because of their ability to attain extreme densities (up to 1000 kg/ha) (Panek, 1987; Koehn, 2004) and alter freshwater ecosystems (Weber & Brown, 2009). Introduction of the notorious *C. carpio* into the waters of the United States has caused great ecological damage to the environment and population of desirable native fishes (Stroud, 1975). Centrarchids can experience reductions in growth and survival in the presence of *C. carpio* (Wolfe *et al*, 2009), and inverse relations

between *C. carpio* and some fishes have been documented (Jackson et al. 2010).

**7. Impacts on other Aquatic Fauna:** There is also evidence to indicate that some fish introductions have had a pronounced impact on other aquatic fauna by reducing or eliminating the numbers of large-bodied epibenthic-limnetic taxa including amphibians and invertebrates (Bradford *et al.*, 1998). *C. carpio* reduce macrophyte biomass in three ways: 1) Bioturbation- Carp often uproot aquatic macrophytes when feeding, 2) Direct Consumption- Carp have been known to feed on tubers and young shoots, 3) Indirectly by increasing turbidity which in turn limits the available sunlight (Fletcher *et al.*, 1985; Loughheed *et al.* 1998).

**8. Habitat Alteration:** Exotic fish introductions can also produce more subtle changes to the ecosystem, including habitat conditions, which can impact on native species. *C. carpio* is one of the more obvious nuisance species with respect to habitat modification and increase of turbidity (Welcomme, 1988). In the United States, Europe, India, South Africa and Australia, carp has acquired a reputation for causing the degradation of aquatic habitats and water quality (Crivelli, 1983; Fletcher *et al.*, 1985; Welcomme, 1988; Khan *et al.*, 2003).

The behavior of carp is believed to increase turbidity levels by re-suspending sediments and the fish excrete nutrients contribute to accelerated eutrophication (McClaren, 1980; Williams *et al.*, 2002; Miller & Cowl, 2006). Carp act as "nutrient pumps" when they consume the nutrient rich benthic sediments and then excrete those nutrients back into the water column in a form that is available to other organisms (Hestand & Carter, 1978; Welcomme, 1984).

**9. Socio-economic Impact:** Impacts of exotic fish introduction do not only concern biological and ecological parameters, but also directly or indirectly affect socio-economical factors. In Lake Victoria, fishery was based on the use of small mesh gill nets before introduction of *Lates niloticus*, as most of the captured fishes were small cichlids. When these native species declined and got replaced by Nile perch, eight million people in Kenya, Uganda and Tanzania who depended on this lake for food were

affected and induced a shift from subsistence fisheries to commercial operations for export leaving many in vain (Stiassny, 1996). Sociological impact is not an easily quantifiable parameter. In the present context, the introductions have resulted in a significant contribution to the protein supply to the poorer people and a significant number of job opportunities have been created or lost as a result of the introduction.

*C. carpio* has been the keystone of many aquaculture development projects and has been introduced into different regions from several sources on several occasions. The introduction of fish in many African countries has positive impacts on food supply and protein supply. Carp are an important food fish throughout most of the world except in Australia and North America where the fish is considered unpalatable (McCrimmon, 1968). The fishery has benefited from the presence of carp (*Cyprinus carpio*) apart from the increase in fish biomass. Carp are considerably large, easier, to catch and preferred species to the native fish in most areas, especially in the highlands (Coates *et al.*, 1995).

#### 4. Conclusion and Recommendation

Knowledge-driven exotic fish introduction and indigenous fish translocation should be considered to decide the trade-offs of fish introduction activities. Prior studies are very essential to generate and to have clear understanding of the future fish introduction and translocation management for various purposes. Scientific interventions to reduce spread of disease and parasites, genetic dilution, habitat alternation, resource competition, biodiversity conservation, sustenance of livelihoods and sustainable aquatic resource management for the present and the next generations is critical. Ogutu-Ohwayo *et al* (1991) emphasized exotic fish introduction needs regulation and guidelines. As a result of the dangers and risks caused by introductions, many European countries have introduced measures to control them (Holcik, 1991).

Fish introduction practices in Ethiopia have been frequently carried out without much prior thought and planning and with inadequate scientific knowledge of the biology of the exotic fish species, the native fish, and the local fauna in the aquatic



system and the possible impacts that emerge after introduction. The attempts to evaluate the success or failure of fish introduction practices in Ethiopia are handicapped by poor statistics and inadequate information. Unplanned and inadequately monitored exotic fish introduction and indigenous fish translocation should be regulated by the Fisheries Legislation Proclamations No. 315/ 2003 and No. 92/2003. The fish introduction going on 'Business-as-usual' should be based on appropriate precautions and research directed.

## References

- Abebe Getahun and Melanie L. J. Stiassny 1998. The freshwater biodiversity crisis: the case of Ethiopian fish fauna. *SINET: Ethiopian Journal Science*, 21 (2), 207-230.
- Arthington, A. H. 1991. Ecological and genetic impacts of introduced and translocated freshwater fishes in Australia. *Canadian journal of fisheries and aquatic sciences* 48(supplement 1): 33-43.
- Balon, E. K. 1974. Domestication of the carp (*Cyprinus carpio*) Royal Ontario museum life science miscellaneous publication, 27-34.
- Barel, C. D. N., Dorit, R., Greenwood, P. H., Fryer, G., Hughes, N., Jackson, P. B. N., Kawanabe, H., Lowe-McConnell, R. H., Nagoshi, M., Ribbink, A. J., Trewavas, E., Witte, F., and Yamaoka, K. 1985. Destruction of fisheries in Africa's lakes. *Nature* **315**: 19-20.
- Bradford, D. F., S. D. Cooper, T. M. Jenkins, K. Kratz, O. Sarnelle and A. D. Brown. 1998. Influences of natural acidity and introduced fish on faunal assemblages in California alpine lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 55 : 2478-2491.
- Cahn, A. R. 1929. The effect of carp on a small lake: the carp as a dominant. *Ecology* 10, 271-274.
- Chapleau, F., C. S. Findlay and E. Szenasy. 1997. Impact of piscivorous fish introductions on fish species richness of small lakes in Gatineau Park, Quebec. Project Report, University of Ottawa, Ottawa, Ontario. 30 p.
- Christie, W. J., J. M. Fraser and S. J. Nepszky. 1972. Effects of species introductions on salmonid communities in oligotrophic lakes. *Journal of the Fisheries Research Board of Canada* 29: 969-973.
- Chumchal, M. 2002. "Cyprinus carpio" (On-line), Animal Diversity Web. Accessed July 07, 2014 at [http://animaldiversity.ummz.umich.edu/accounts/Cyprinus\\_carpio/](http://animaldiversity.ummz.umich.edu/accounts/Cyprinus_carpio/)
- Coates, D and Ulaiwi, W. K. 1995. A simple model for predicting ecological impacts of introduced aquatic organisms: a case study of common carp (*Cyprinus carpio*) L., in the Sepik-Ramu River basin, Papua New Guinea. *Fisheries Management and Ecology*, **2**: 227-242.
- Cowx, I. G. 1994. Introduction strategies. *Fisheries management and ecology*, volume **1**, Issue **1**, 15-30.
- Crivelli, A. J. 1983. The destruction of aquatic vegetation by carp. *Hydrobiologia* 106, 37-41.
- Dodge, D. P., and Mark, C. (1994). Direct control of fauna and role of hatcheries, Fish introduction and fishing regulation In: Peter Calow and Geoffrey E Petts. *The river hand book*, Vol. **2**, 386-399.
- Ferguson, M. M. 1990. Genetic impact of introduced fishes on native species. *Canadian Journal of Zoology* 68: 1053-1057.
- Fernando, C. H. 1991. Impacts of fish introductions in tropical Asia and America. *Canadian Journal of Fisheries and Aquatic Sciences* 48(Supplement 1): 24-32.
- Fisheries Development and Utilization proclamation 2003. Federal Negarit Gazeta - 9<sup>th</sup> Year No 32 4<sup>th</sup> February 2003 of the Federal Democratic Republic of Ethiopia Addis Ababa.
- Fisheries Development, Prevention and Utilization Proclamation 2003. Zikre Hig - 9<sup>th</sup> Year No 3, 17<sup>th</sup> December 2003 of the Amhara National Regional State, Bahir Dar.
- Fletcher, A. R., Morison, A. K. & Hulme, D. J. 1985. Effects of carp, *Cyprinus carpio* L. on communities of aquatic vegetation and turbidity of water bodies in the lower Goulburn river basin. *Australian Journal of Marine and Freshwater Research* 36, 311-327.
- Froese, R. and D. Pauly. 2014) Editors Fish Base. World Wide Web electronic publication. Available at: <http://www.fishbase.org>, version (08/2014).
- Goede, R. W. 1986. Management considerations in introduction diseased or carrier fish. p. 349-355

- In R. H. Stroud [ed.]. Fish Culture in Fisheries Management, American Fisheries Society, Bethesda, Maryland.
- He, X. and J. F. Kitchell. 1990. Direct and indirect effects of predation on a fish community: A whole lake experiment. Transactions of the American Fisheries Society 119: 825-835.
- Hestand R.S. & Carter C.C. 1978 Comparative effects of grass carp and selected herbicides on macrophyte and phytoplankton communities. Journal of Aquatic Plant Management 16, 43-50
- Holcik, J. 1991. Fish introduction in Europe with particular reference to its Central and Eastern part. *Can.J.fish.Aquatic Sci.* 48(1), 13-23.
- Jackson, Z.J., Quist, M.C., Downing, J.A. & Larscheid, J.G. 2010. Common carp (*Cyprinus carpio*), sport fishes, and water quality: ecological thresholds in agriculturally eutrophic lakes. *Lake and Reservoir Management* 26: 14–22
- Khan T.A., Wilson M.E. & Khan M.I. 2003 Evidence for invasive carp mediated trophic cascade in shallow lakes of western Victoria, Australia. *Hydrobiologia* 506, 465-472.
- Koehn, J.D. 2004. Carp (*Cyprinus carpio*) as a powerful invader in Australian waterways. *Freshwater Biology* 49: 882–894.
- Lougheed, V.L., Crosbie, B. & Chowfraser, P. 1998. Predictions on the effect of common carp (*Cyprinus carpio*) exclusion on water quality, zooplankton, and submergent macrophytes in a great lakes wetland. *Canadian Journal of Fisheries and Aquatic Sciences* 55: 1189–1197
- Lowe, S., Browne, M., Boudjelas, S. & De Poorter, M. 2004. 100 of the world's worst invasive alien species: a selection from the Global Invasive Species Database. Auckland, New Zealand: The Invasive Species Specialist Group, World Conservation Union
- Mathewos Hailu 2013. Reproductive aspects of common carp (*Cyprinus carpio* L, 1758) in a tropical reservoir (Amerti: *Journal of Ecology and the Natural Environment* 5(9), pp. 260-264
- McClaren P. 1980 Is carp an established asset? *Fisheries* 5, 31-32
- McCrimmon, H. 1968. Carp in Canada. Fisheries Research Board of Canada.
- Miller, S. A. & Cowl, T. A. 2006. Effects of common carp (*Cyprinus carpio*) on macrophytes and invertebrate communities in a shallow lake. *Freshwater Biology* 51, 85-94.
- Neess, J.C., Helm, W.T. & Threinen, C.W. 1957. Some vital statistics in a heavily exploited population of carp. *Journal of Wildlife Management* 21: 279–292.
- Oguto-ohwayo, R. and Hecky, R. E., 1991. Fish introductions in Africa and some of their implications. *Canadian Journal of Fisheries and Aquatic Sciences* 48, Suppl 1, 8-12.
- Panek, F.M. 1987. Biology and ecology of carp. In: Cooper, E.L., ed. *Carp in North America*. Bethesda, MD: American Fisheries Society, pp. 1–15
- Perrow, M. R., Jowitt, A. J. D., Stansfield, J. H. & Phillips, G. L. 1999. The practical importance of the interactions between fish, zooplankton and macrophytes in shallow lake restoration. *Hydrobiologia* 396, 199-210.
- Pillay, T.V.R. 1990. *Aquaculture Principles and Practices*. Fishing News Books, Blackwell Scientific Publications Ltd, UK. 575 pp.
- Pillay, T.V.R. 1992. *Aquaculture and environment*. Fishing News Books, Blackwell scientific Publications Ltd, 189
- Pinto, L., Chandrasena, N., Pera, J., Hawkins, P., Eccles, D. & Sim, R. 2005. Managing invasive carp (*Cyprinus carpio* L.) for habitat enhancement at Botany Wetlands, Australia. *Aquatic Conservation: Marine and Freshwater Ecosystems* 15, 447-462.
- Richard H Stroud 1975. The introduction of exotic fish species into waters of the United States. The seventh British coarse fish conference. The University of Liverpool. pp. 3–13
- Shibru Tedla and Fisseha Haile-Meskel 1981. Introduction and transplantation of freshwater species in Ethiopia. *SINET: Ethiopian Journal of Science* 4(2) 69 -72.
- Stephanou, D. 1990. Twenty years of experience in managing Cyprus reservoirs for angling, In: W. L. T. Van Densen, B. Steinmetz and R. H. Hughes, *Management of freshwater fisheries*, Wageningen (Netherlands), Pudoc, pp. 1-13.
- Stiassny, M.L.J. 1996. An overview of freshwater biodiversity with some lessons from African fishes. *Fisheries* 21(9): 7-13
- Verspoor, E. and J. Hammar. 1991. Introgressive hybridization in fishes: The biochemical

- evidence. *Journal of Fish Biology* 39 (Supplement A): 309-334.
- Weber, M.J. & Brown, M.L. 2009. Effects of common carp on aquatic ecosystems 80 years after 'Carp as a dominant'; Ecological insights for fisheries management. *Reviews in Fisheries Science* 17: 524–537.
- Welcomme, R. L. 1988. International introductions of inland aquatic species. Fisheries Technical Paper No. 213, Food and Agricultural Organization, Rome, Italy.
- Welcomme R.L. 1984. International transfers of inland fish species. In: W.R. Courtenay Jr. & J.R. Stauffer (eds). *Distribution, Biology and Management of Exotic Fishes*. Baltimore: John Hopkins University Press, pp. 22-40
- Williams, A. E., Moss, B. & Eaton, J. 2002. Fish induced macrophyte loss in shallow lakes: top-down and bottom-up processes in mesocosm experiments. *Freshwater Biology* 47, 2216-2232.
- Wolfe, M.D., Santucci, Jr, V.J., Einfalt, L.M. & Wahl, D.H. 2009. Effects of common carp on reproduction, growth, and survival of largemouth bass and bluegills. *Transactions of the American Fisheries Society* 138: 975–983.
- Yared Tigabu, 2010. stocking based fishery enhancement program in Ethiopia, *Ecohydrology and Hydrobiology* **10** (2-4) 241-246.

## Traditional uses of non-timber forest products in southwest Ethiopia: Opportunities and challenges for sustainable forest management

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**Abstract:** Southwest (SW) Ethiopia, characterized by high biophysical and cultural diversity, contains Afromontane rainforests and most indigenous people are dependent on these natural forests for their livelihoods and socio-cultural demands, with non-timber forest products (NTFPs) forming the most important one. Besides economical roles, a variety of NTFPs including wild coffee in the region have different socio-cultural roles for local inhabitants. However, these roles are under the challenges of forest degradations and socioeconomic changes. This paper was, therefore, initiated to summarize available information on the traditional and cultural uses of NTFPs, and their implication for SFM in SW Ethiopia, and to forward recommendations on the option of using these roles of NTFPs as a tool for SFM, and to sustain these uses for the local people. Based on available information, NTFPs in SW Ethiopia contribute 24 to 30% of the total livelihoods of rural households and fulfill different socio-cultural needs of the local people including primary health care, traditional beliefs and other socio-cultural activities, such as success in marriage arrangement, dispute settling, child birth, etc. But, these uses are challenged by deforestations, cultural and lifestyle changes of local inhabitants associated with changes in religion, and expansion of settlements and large plantation crop investments, and problems related to policy and land-use right law implementation. As the available literature focused mainly on some NTFPs that have international market demands, e.g., coffee, spices and honey, information on all available NTFPs and their traditional uses and contribution to SFM in the region is generally scarce. Thus, in addition to the known NTFPs, exploring and popularizing of locally important NTFPs together with their traditional uses, and opportunities and challenges to use them as a tool for SFM in SW Ethiopia is needed.

**Keywords:** Bio-cultural diversity, NTFPs, opportunities, threats, SW Ethiopia

### 1. Introduction

Non-timber forest products (NTFPs) are defined as 'all products of biological origin other than timber extracted from forests, woodlands and trees outside forests for human use' (Demel *et al.*, 2010; CIFOR, 2011). Typical NTFPs include fruits, seeds, bulbs, barks, fibers, roots, leaves, fishes, games as well as small wooden poles and firewood, amongst others (Peters, 1994; Cunningham, 1996). They have been key to satisfying household's subsistence needs in terms of nutrition, medical care, energy demand, construction purposes, and cash income amongst others, as well as cultural self-conceptions and traditional belief-systems (Rojahn, 2006; Heubach, 2011). Under the Millennium Ecosystem Assessment,

NTFPs are classified as provisioning ecosystem services (MEA, 2005).

Utilization of NTFPs has a long history and for millennia, NTFPs have been forming an inherent part of the livelihoods of rural communities living in different parts of the world including SW Ethiopia (Heubach, 2011; Mohammed Chilalo and Wiersum, 2011; Feyera Senbeta *et al.*, 2013). For most of the evolutionary history of human, forests have been valued for their numerous NTFPs, but little or no for their timber production (Tefera, 2005). However, in the ages of 'civilization' and until the recent past (1970s), the production function of a forest was often estimated by its timber values, less by its NTFPs

values while they have a significant role for livelihood of local communities, especially for forest-dwelling ones (Reenen, 2005). Currently, the important roles of NTFPs for livelihood and sustainable forest management (SFM) are again recognized and became more and more clear (Tefera, 2005; Reenen, 2005). With increasing awareness on rapid forest resource degradation and NTFP's importance for SFM and livelihood, the need for identifying NTFPs and their appropriate management options gradually become the research and development agenda.

Similarly, NTFPs in Ethiopia are traditionally utilized by local communities for ages in various forms and different contexts: as subsistence needs, gap filling and cash income. Most of the households in southwest (SW) Ethiopia still derive higher proportions of their total income from NTFPs (Reenen, 2005; Mohammed and Wiersum, 2011). As subsistence, NTFPs are used as food, feed, construction materials, utensils, medicines, etc. However, utilization and management of NTFPs in this region have got attention for SFM very recently, and some information on major NTFPs has already been documented (Reenen, 2005; Tefera, 2005; Mohammed and Wiersum, 2011; Abebe and Koch, 2011; Feyera *et al.*, 2013). In addition to their ordinary uses, some NTFPs are deeply linked to some cultures.

SW Ethiopia is a region in the country that contains the remnant fragments of the Afromontane rainforests of the country. Particularly, Sheka, Kafa and Bench-Maji Zones are known for their natural forests with 60, 20 and 15% of forest cover, respectively (Mohammed and Wiersum, 2011), which contain over 107 woody species and gene pools of some important food plants such as *Coffea arabica*, *Aframimum corrorima* (*korarima*) and *Piper capense* (long pepper- *timiz*) (Zewdie, 2010). These forests are also one of UNESCO's designated Biodiversity Hotspot of global interest with *C. arabica* as a flagship species (Mohammed and Wiersum, 2011).

SW Ethiopia is also characterized by cultural diversity. More than ten indigenous ethnic groups in the abovementioned zones reside adjacent to each

other and in mixed patterns of settlement, with specific and common socioeconomic history. Most of them are dependent on natural forests for their livelihoods, with NTFPs forming the most important one. For example, the Sheko, Kaficho, Shekecho and Bench people are chiefly employed in NTFP extraction and small-scale subsistence agriculture. Menjo, Mandjah, Meinit and Mejenger are traditional beekeepers and hunters/gatherers (Avril, 2008; Mohammed and Wiersum, 2011).

This bio-cultural diversity and high dependency on forests as sources of NTFPs reasonably imply the existence of a range of traditional and cultural uses of NTFPs as well as management of forests. The objectives of the paper, therefore, were (1) to summarize the available information on the traditional and cultural values of NTFPs, and their implication for SFM in SW Ethiopia, and (2) to forward recommendations on the option of using traditional and cultural functions of NTFPs as a tool for SFM, and on sustainable use of these functions of NTFPs for the future.

## 2. Types of NTFPs in SW Ethiopia

Ethiopia's forest and other vegetation resources offer diverse NTFPs that provide substantial inputs for the livelihoods of a very large number of people in the country and an estimated annual turnover more than \$US 2.3 billion to the notational economy (Table 1). Some of the NTFPs such as wild coffee, gum-resins, honey and bees' wax and ecotourism occupy key position in the State's economy, particularly in foreign currency earnings through export (Demel *et al.*, 2010). SW Ethiopia, still its large parts covered with natural vegetation, is rich in NTFPs, which contribute 24 to 30% of the livelihood of households in the region (Mohammed and Wiersum, 2011) and 52%, 41% and 23% of annual cash income of households in Bench Maji and Sheka zones and Gore districts, respectively (Demel Teketay *et al.*, 2010).

Based on their contribution to total products and household income, coffee, honey, spices (*korarima*, long pepper and wild pepper), climbers, fruits and bamboo are cited as the major NTFPs in SW Ethiopia (Reenen, 2005; Mohammed and Wiersum, 2011; Abebe and Koch, 2011). Only few authors (e.g., Rojahn, 2006; Aseffa, 2007) have documented other



important NTFPs (such as bees wax, *gesho* [*Rhamnus prinoides*, a condiment used in making a local drink, *teji* and *tela*], *desha* [used to clean the oven], *ensosela* [*Impatiens tinctoria*, a plant used for decorating the skin with color and healing rheumatism], liana, palm, wild fruits, fuel wood and charcoal) in the region. In the coffee forests of Yayu, Sheko, Bonga and Harena, Feyera *et al.* (2013) identified 143 locally useful wild plant species, which are used for material sources (69 species), medicine (50 species), food (38 species), honey forage (32 species), animal fodder (9 species), environmental uses (4 species) and social services (2 species). However, other locally important NTFPs (e.g., grasses, barks and leaves of trees and shrubs, wild animals, fishes, aromatic and ornamental plants used for food, feed, construction, medicine, condiments, beautification and other purposes in the region), nationally and internationally important NTFPs (e.g., civet musk), and forest grazing and browsing have not been well-considered and quantified by any of the studies. Conversely, the role of these types of NTFPs to rural livelihood was reported in other regions of Ethiopia, e.g., Dendi district (Demel *et al.*, 2010) and countries, e.g., India, Nigeria and South Africa (Singh, 1999; Ogundele *et al.*, 2012; Tewari, 2012). In general, the NTFPs extracted in SW Ethiopia can be categorized into different use groups: food, fodder, local construction materials, medicines, spices, income sources, fuel wood, farm implements and household furniture.

### 3. Traditional and cultural Uses of NTFPs

Most of NTFPs in SW Ethiopia except coffee, honey, spices and civet musk, which are also used for sale in both local and national markets, are used only for household consumption, and almost all of the NTFPs collected in this region have cultural values. Some of the traditional and cultural uses of some common NTFPs, such as coffee, honey, spices, bamboo and medicinal plants are discussed below.

#### Coffee

SW Ethiopia as the centre origin of *C. arabica* and still containing wild coffee, utilization of coffee as NTFP might have been started in this region. The forest-based (wild or semi-managed) coffee production system provides 70,000 to 90,000 metric tons of coffee, contributing about 30-35% of annual

coffee production of the country and US\$ 130 million per year to the national economy (Table 1, Demel *et al.*, 2010).

The historical, cultural and economical relationship between coffee and Ethiopians including local communities in SW Ethiopia is deep-rooted and multifaceted (Stellmacher, 2006). It plays a significant role in the national economy, daily life of the local people, and it is much more than a beverage and has lots of cultural values. It contributes about 33% of the country's foreign currency earnings (ICO, 2013) and 10% of the gross domestic product, and supports the livelihoods of around 20 million people in one way or another (Demel *et al.*, 2010). It is used for various religious, cultural and social purposes. For example, it is often made and drunk as sign of confirmation for marriage arrangements, settling of disputes, agreements on some issues, and after some events like birth, death, and the like. Morning coffee is often used to express good wish and fortunate day for the family, the villagers and the country. Some individuals use coffee beans or a coffee cup to spiritually express the fortunes or illness of individuals.

Coffee prepared from dried berries and young leaves is also used for various social and cultural purposes. For example, *bunakela*, prepared from dry roasted coffee berries mixed with butter and/or roasted barley, wheat or chickpea, is usually used by long distance travelers or hunters in Gedio and Borena, and in special cultural and family occasions of Oromo people in Wollega, e.g., first dish to celebrate a child birth and circumcision, an expression of success in marriage arrangement or fortune telling events. *Chamo* (a tea of coffee leaves), prepared from dried coffee leaves and spiced with pepper and ginger, is a favorite drink and used as medicine for sick and weak individuals in Kefa, Benchi-Maji and Sheka Zones and Godre district. Both the normal drinking coffee and *chemo* are used by Sheko communities to dilute some traditional plant medicines (Mirutse *et al.*, 2010). Similar uses are also there in some other areas of the country. In Hararghe, for example, *Kuti*, infusions of roasted and grinded coffee leaves, and *Hoja*, powder of coffee husk mixed with milk and salt, is commonly used.



## Honey

Ethiopia has also a long tradition of beekeeping. It is one of the major bees wax and honey producing countries in the world and the fourth largest wax exporter to the world market after China, Mexico and Turkey (Girma Deffar, 1998; Demel *et al.*, 2010). About 30,000 - 50,000 metric tons of honey and 4,000 metric tons of bees wax with estimated gross financial values of \$US 86.5 and 19.8 million, respectively are annually produced in Ethiopia most or all of which is forest/vegetation based in terms of nectar provision, bee colony hosting and construction material supply (Table 1, Demel *et al.*, 2010).

In the forest areas of SW Ethiopia, honey is primarily produced by hanging up beehives made of wood, bark or bamboo on the branches of trees (Fig. 1). Honey can also be collected from feral source in the hollow wood, soil or rock, or from managed bee colonies foraging in forests or cultivated plants. The forest honey in SW Ethiopia constitutes the important NTFPs which are used as a source of food, tonic, cash and medicine for local communities (Tefera, 2005). For example, the annual honey production in Sheko and Yayu districts is worth US\$ 14.6 and US\$ 11.6 per ha, respectively (Rojahn, 2006).



Figure 1 Traditional beekeeping and uses of honeybee products in SW Ethiopia (Tadesse 2007)

Until very recently that forest honey producers have started supplying honey to national and international markets, the honey collected from forests was almost exclusively used for local consumption, to a very large extent for the local brewing of mead, known as *tej* (honey-wine) (Fig. 1, Rojahn, 2006), and to some extent for food sweetening and traditional medicine. SW Ethiopia is, thus, not only known for its natural forests, coffee and spices, but also for its quality honey *tej*, a very common traditional drink and business in this region. Apart from business, honey *tej* is also brewed for many social events like holidays, weddings, and other similar events.

The owners of local *tej*-houses and small honey retailers separate the honey from wax and retail it themselves (Rojahn, 2006). The wax is usually sold as a by-product to wax collectors who, in turn, trade with processing companies. According to Rojahn (2006), however, bees wax in Sheko and Yayu districts is regarded as a by-product of *tej*-making and is not used. Wax is also used to make local candle, called *tuaf*, which is used to light home and in church or in religious events of the Orthodox Christian.

## Spices

In Ethiopia, five species of spices grow in the wild (Goettsch, 1997), and SW Ethiopia supplies a significant amount of two of these spices (*Korarima* and long pepper) annually to national and international markets. For example, Kefa Zone supplied an average of 402.94 metric tons between 1991 and 1995, and Kefa and Sheka Zones together about 1,208 metric tons in 1999 with estimated value of \$US 2.7 million (Table 1). However, the supply greatly fluctuated and the total annual *korarima* export between 1994 and 1998, for instance, was less than 60 metric tons (Demel *et al.*, 2010).

Of the five wild spices in Ethiopia (Goettsch, 1997), *Korarima* and long pepper, both are native to Ethiopia, constitute the two important wild spices harvested and traded in many areas of southern and southwestern Ethiopia (Fig. 2). *Korarima* grows naturally in the forest, almost the same habitat as natural coffee, whereas long pepper grows in forest margins and disturbed areas or forest gaps (Tadesse, 2007; Avril, 2008). Both spices are totally harvested from wildy grown plants in the forest although farmers have recently started domesticating them in the gardens, fields or forest borders (Avril, 2008).



**Figure 2 Traditional extraction and marketing of spices in SW Ethiopia (Avril, 2008)**

*Korarima* is renowned food flavoring spice and medicinal plant. Its dried fruits are used in the daily dishes (e.g. *wot* [stews or sauces traditionally eaten with *injera* - a [sourdough](#)-risen [flatbread](#) with a unique, slightly spongy texture and a national dish of Ethiopia and Eritrea], coffee and sometimes local bread) of most Ethiopians. It is also used as a carminative, purgative and tonic in traditional medicine (Jansen, 1981). An ethnobotanical survey conducted in Gamo Gofa, Debub Omo and Kafa showed that all plant parts (seeds, leaves, rhizomes, roots, pods and flowers) of *korarima* are used as a medicine for different ailments (Eyob *et al.*, 2008). Long pepper is also used to spice *wot*, and preferred

by local consumers because of its lower price and greater availability in a local market than exotic spices (Goettsch, 1997). However, the indigenous communities in rural areas of the study area use these spices very often for cash income and less for own consumption as they do not use *wot* with *injera* traditionally (Reenen, 2005; Avril, 2008). As a result, the consumption of the spices collected in this region is delocalized in towns and other areas where *wot* with *injera* or *wot* with spaghetti are very common.

## Bamboo

Two indigenous species of bamboo namely the African alpine bamboo (*Arundinaria alpine*) and the lowland bamboo (*Oxytenanthera abyssinica*) are



recognized in Ethiopia (Fig. 3). Ethiopia has one of the largest bamboo resources in the world with estimated land area cover of over 1.1 million ha (150,000 ha of highland and 959,000 ha of lowland) (Ensermu *et al.*, 2000). This is 67% of all African

bamboo resource and 7% of that of the world total (Kassahun, 2003). Bamboo in Ethiopia provides an estimated annual turnover of over \$US 10.5 million (Table 1).



Figure 3 Distribution, traditional extraction and use of bamboo. The baskets are used for transportation of honey combs in SW Ethiopia (Aseffa, 2007)

**Table 1 An estimated annual production of NTFPs and their gross financial values in Ethiopia and South West Ethiopia**

Product Type	Ethiopia		SW Ethiopia
	Annual production (tons)	Estimated annual turnover in \$US (x1000) <sup>a</sup>	Annual production/Average annual yield supplied to Addis Ababa market (tons) <sup>b</sup>
Wild coffee	70,000-90,000	210,000	230.22
Honey	30,000-50,000	86,500	3.24 <sup>c</sup>
Bees wax	4,000	19,840	14.64
Spices	1,208	2,700	402.94
Herbal medicine	56,000	2,055,484.3	ND
Bamboo	ND	10,555.6	ND
Civet musk	400	183	ND
Gum/Incense	5000	6,800	ND
Essential oils	ND	ND	ND
Forest Grazing(Fodder)	ND	ND	ND
Forest food(wild food)	ND	ND	ND
Total		2,305,122.9	

<sup>a</sup> includes sales on export and domestic markets; ND denotes no data available

<sup>b</sup> Average (1991-1995) annual coffee, honey/bees wax and spice yields supplied to Addis Ababa market from Bonga

<sup>c</sup> Annual production of honey in Sheko and Yayu districts calculated from Reichhuber and Requate (2007)

Sources: Demel *et al.*, (2010); PFMP (2004); Reichhuber and Requate (2007)

In Sheka, Kefa and Benchi-Maji Zones of SW Ethiopia, bamboo stands cover a total of land area of 29,619 ha (Ensermu *et al.*, 2000), and bamboo is one of the most important NTFPs with several uses in the region (Fig. 3). The local people extract bamboo for house construction, especially the roof structures; fencing homesteads and farmlands to protect the crops from free grazing animals; and making beehives, floor mat, flutes, and household equipment and utensils like chairs, drinking cups, baskets, shelf, *dollo* (water container), cups, *gamo* (traditional tray), pipe used for smoking tobacco, bed, and food for their households or for sale (Fig. 3). It is also sharpened like a knife and used to separate edible parts of an *enset* plant (*Ensete ventricosum*) from the fiber (Ensermu *et al.*, 2000; Reenen, 2005; Tadesse, 2007). In some parts of Ethiopia, ingredients from black bamboo help to treat kidney disease, roots and leaves to treat venereal disease and cancer, sap to reduce fever and ash will cure prickly heat.

### Medicinal Plants

Healthcare in rural areas of Ethiopia largely depend on traditional medicines drawn mostly from plants used both by women in the home and traditional health practitioners (THPs) (Girma, 1998). THPs are normal farmers who know how to prepare medicine from medicinal plants and usually keep this

knowledge as a secret within a family. In Ethiopia, about 56,000 metric tons of medicinal plants are harvested and used per annum, and an estimated number of 80,000 traditional healers (about 9,000 of them officially registered ones) use traditional medicines (Table 1, Demel *et al.*, 2010). Six hundred species of medicinal plants are distributed all over Ethiopia, with greater concentration in south and SW of the country (Girma, 1998). As per Demel *et al.* (2010), however, the figure of indigenous plant species that have herbal medicinal applications is a bit higher (about 1,000 species), most of which are wild plants. They have been used in traditional health care system to treat nearly 300 physical disorders, from childhood leukaemia to toothaches and mental disorders.

In some ethnic groups of SW Ethiopia, 196 medicinal plants (20 in Kafficho, 71 in Sheko, 35 in Bench, 65 in Meinit and 5 in Mejenger) are documented (Endeshaw, 2007). Ethnobotanical studies in three ethnic groups (Meinit, Sheko and Bench) showed 157 medicinal plants (Mirutse *et al.*, 2009a, Mirutse *et al.*, 2009b; Mirutse *et al.*, 2010). Of which 33.8% were trees, shrubs, vines and climbers that can be considered as NTFPs and the remaining 66.2% were herbs (Table 2). The majority of the latter were uncultivated weed species growing in disturbed

habitats and found in abundance near to homes. Medicinal tree species, e.g., *Bersama abyssinica*, *Ritchiea albersii* and *Vernonia auriculifera*, were found as remnant trees scattered in farms or forests faraway from homes. Some woody medicinal plants,

particularly trees, unlike herbaceous ones are rapidly declining due to selective cutting for construction, fuel wood, etc (Mirutse *et al.*, 2009a; Mirutse *et al.*, 2009b; Mirutse *et al.*, 2010).

**Table 2 Medicinal plants that can be considered as NTFPs and used by three different ethnic groups in Bench-Maji Zone, South West Ethiopia**

Ethnic group	Scientific Name	Growth Form	Parts Used	Ailment Treated	Administration Route
Sheko	<i>Capparis erythrocarpos</i> Isert	Climber	Fruit, leaf	Boil	Topical
	<i>Cayratia gracilis</i> (Guill. & Perr.) Suess.	Climber	root	Wound	Topical
	<i>Clausena anisata</i> (Willd.) Hook. f. ex Benth.	Tree	Leaf	Evil eye	Nasal
	<i>Clematis longicauda</i> Steud. ex A.Rich.,	Climber	Itching skin	Leaf, stem	Topical
	<i>Clematis simensis</i> Fresen	Climber	Wound, eye infection	Leaf	Topical
	<i>Coffea arabica</i> L.	Tree	Headache	Leaf	Oral
	<i>Cucurbita pepo</i> L.	Climber	Taeniasis	Seed	Oral
	<i>Embelia schimperi</i> Vatke	Shrub	Taeniasis, Ascariasis	Fruit, root	Oral
	<i>Euphorbia ampliphylla</i> Pax	Tree	Wart	Sap	Topical
	<i>Garcinia buchananii</i> Baker	Tree	Ascariasis	Fruit	Oral
	<i>Microglossa pyrifolia</i> (Lam.) Kuntze	Shrub	Jaundice	Leaf	Oral
	<i>Millettia ferruginea</i> (Hochst.) Baker	Tree	Wound	Stem bark	Topical
	<i>Momordica foetida</i> Schumach.	Climber	Wound	Leaf	Topical
	<i>Phytolacca dodecandra</i> L'Hér.	Shrub	Rabies	Root	Oral
	<i>Stellaria sennii</i> Chiov	Climber	Eye infection	Leaf	Local (eye)
	<i>Stephania abyssinica</i>	Climber	Rabies	Leaf	Oral
	<i>Vepris dainellii</i> (Pic.-Serm.) Kokwaro	Tree	Boil	Root	Topical
	<i>Vernonia amygdalina</i> Delile	Tree	headache	Leaf	Topical(head)
	<i>Carica papaya</i> L.	Tree	Malaria	Leaf	Oral
	<i>Microglossa pyrifolia</i> (Lam.) O.Ktze.	Shrub	Meningitis( <i>tikus</i> ) Cow mastitis	Root/leaf Leaf	Oral, topical Oral
	<i>Phytolacca dodecandra</i> L'Hérit.	Shrub	Dog rabies Rabies	Root Leaf	Oral Oral

Bench	<i>Prunus africana</i> (Hook.f.)	Tree	Ear infection	Stem bark	Local (ear)
	Kalkm.		Toothache		Local (tooth)
	<i>Ritchiea albersii</i> Gilg	Tree	Meningitis( <i>tikus</i> )	Leaf	Topical
	<i>Smilax anceps</i> Willd.	Climber	Ear infection	Root	Local (ear)
	<i>Trichilia dregeana</i> Sond.	Tree	Tinea capitis	Leaf	Topical
Meinit	<i>Vernonia amygdalina</i> Del.	Tree	<i>Michi</i>	Leaf	Topical(face), Local (nose)
	<i>Acalypha volkensii</i> Pax	Climber	Wound	Leaf	Topical
	<i>Bersama abyssinica</i> Fresen.	Tree	Tonsillitis	Stem bark	Oral
	<i>Carissa spinarum</i> L.	Shrub	Evil eye	Root	Nasal
	<i>Cissampelos mucronata</i> A.Rich.	Climber	Stomachache, retained placenta	Root	Oral
	<i>lematis hirsuta</i> Perr. & Guill.	Climber	Respiratory tract problem, Cataract	Root Leaf	Oral Local (eye)
	<i>Clerodendrum myricoides</i> (Hochst.) Vatke	Tree	Wound	Leaf	Topical
	<i>Croton macrostachyus</i> Del.	Tree	Snake bite	Root	Oral
	<i>Embelia schimperi</i> Vatke	Shrub	Taeniasis	Fruit	Oral
	<i>Ficus vasta</i> Forssk.	Tree	Itching skin	Topical	Topical
	<i>Gardenia ternifolia</i>	Tree	Malaria	Stem bark	Oral
	<i>Hoslundia opposita</i> Vahl	Shrub	Stomachache	Root	Oral
	<i>Indigofera garckeana</i> Vatke	Shrub	Diarrhoea (cattle), stomachache, headache	Root	Oral
	<i>Microglossa pyrifolia</i> (Lam.) O.Kuntze	Shrub	Stomachache Hard swell on skin	Leaf	Nasal, topical Oral topical
	<i>Phytolacca dodecandra</i> L'Hérit.	Shrub	Rabies	Root	Oral
	<i>Rhus ruspolii</i> Engl.	Shrub	Wound	Leaf	Topical
	<i>Ricinus communis</i> L.	Tree	Stomachache	Root bark, seeds	Topical
	<i>Ritchiea albersii</i> Gilg	Tree	Wound	Leaf	Topical
	<i>Rubus steudneri</i> Schweinf.	Shrub	Stomachache with diarrhoea	Root	Oral
	<i>Stephania abyssinica</i> (Dillon. & A.Rich.)Walp.	Climber	Stomachache, Retained placenta	Root	Oral
	<i>Tephrosia elata</i> Deflers	Shrub	Respiratory tract problem	Root	Oral
	<i>Vernonia amygdalina</i> Del.	Tree	Wound	Leaf	Topical



<i>Vernonia auriculifera</i> Hiern.	Tree	Toothache	Root	Local (tooth)
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Sources: Mirutse *et al.* (2009a); Mirutse *et al.* (2009b); Mirutse *et al.* (2010)

In SW Ethiopia, most traditional plant remedies are used against human ailments, some against both human and livestock ailments, and a few against livestock ailments (Table 2, Endashaw, 2007). As they could be harvested freely from the immediate environment, most of these plant medicines, except those used as food, are not sold at local markets, and prepared and administrated at a household level (Mirutse Giday *et al.*, 2009a; Mirutse *et al.*, 2009b; Mirutse *et al.*, 2010). As per Rojahn (2006), however, medical plants in Sheko and Yayu districts are mostly collected and prepared by THPs and they offer a gross annual income of US\$ 1382.40 for each THP, and total net income of US\$ 3.00 and US\$ 1.80 per ha for Sheko and Yayu, respectively.

#### 4. Opportunities and Challenges for Sustainable Use of NTFPs

SW of Ethiopia is physically diverse with high and reliable rainfall and high forest cover that contains gene pools of some important food plants of global interest, e.g., *Coffea Arabica* (Wood 1993; Zewdie, 2010). The region has a considerable agricultural potential for a wide range of crops, including plantation crops like coffee, tea, rubber and the like. This attracts large plantation crop farms, logging companies and settlers, which results in high forest resource degradation. The area, therefore, can be seen as one of the last resource frontiers in the country, which is being used with increasing intensity as the population grows and deforestation occurs (Wood, 1993). Conversely, forests in SW Ethiopia is a major source of livelihoods for local people, contributing up to 44% of their income in some areas of the region, e.g., Chewaka-Uto in Sheka Zone (Tadesse and Masresha, 2007). Due to this high level of dependency on forest resources, local communities have developed traditional management practices based on religious taboos and customary tenure rights, e.g., Kobo system. The Kobo system is a forest (tree) tenure institution that grants first claimers an exclusive use right of a block of forests, usually for collection of NTFPs such as forest coffee, honey and others. Once claimed, the forest block is *de facto* individual property, respected by fellow

citizens of the area and the owner has the right to exclude others (Demel *et al.*, 2010). Some ethnic groups in the region (e.g., Shekecho people) also have a culture of keeping some forest areas (e.g., upper stream and riverbank forests) intact for religious/spiritual purposes. Such traditional management practices have sustained the forests and uses of their NTFPs of the region for centuries in a better condition as compared to other parts of the country (Tadesse and Masresha, 2007; Mohammed and Wiersum, 2011). However, deforestation, pesticide application by large plantation crop farms, policy and land-use right law execution problem and cultural and lifestyle changes of local people due to influx of large number of settlers and large farms affect the sustainable uses and cultural values of NTFPs in SW Ethiopia. Deforestation is mainly due to expansion of agriculture, settlements, large plantation crop (coffee, tea and rubber) investments, road constructions, and tree cuttings for timber, beehive, construction, fuel wood and charcoal (Fig. 1, 3 and 4). Pesticide applications by large plantation farms affect honey production and pollinators (Rojahn, 2006; Tadesse, 2007). Policy problems such as leasing of forestlands to the plantation crop investment projects without free and informed consent of local people, denying of customary tenure systems and weak institutional set up to implement policies (Tadesse and Masresha 2007; Demel *et al.*, 2010) also affect sustainable uses of NTFPs. For example, besides 16,075 ha of the former state owned coffee farms (CPDE, 2011), over 43 coffee and tea plantation investment projects with a land area of more than 20,451 ha have recently given license and are operating on forestlands of Sheka Zone (Table 3). Similar activities have also been observed in other zones and districts of the region (e.g., Kafa, Bench Maji, Godre and Gore). The licensing and implementation processes of land leasing for these investments were not based on free and informed consent of local inhabitants. It has also violated the traditional tenure rights and taboos (e.g., spiritual areas). Moreover, customary forests, which were in the hands of clan leaders, have become protected state forests (Tadesse and Masresha, 2007). Another

important problem is institutional capacities and arrangements at different levels. The institutions are weak, inefficient and poorly organized to implement forest and investment policies (Tadesse and Masresha, 2007, Demel *et al.*, 2010, Andualem,

2011), and to follow up the implementations of investment projects and harmonize the benefits of local inhabitants with that of the investors (Tadesse and Masresha, 2007).



**Figure 4 Forest areas converted to agriculture in SW Ethiopia: coffee plantation with shade trees (top left), tea plantation with *Gravillea* planted on the edge (top right), crop and grazing lands with some remnant trees (bottom left), and large trees felled for making of traditional beehives (bottom right) (Tadesse, 2007, Zewdie , 2007)**

**Table 3 Some of the major allotted forest areas for plantation investments in Sheka Zone**

Investment group name	Area (ha)	District	<i>Kebele</i> *
Azage Anbelo	80	Anderacha	Yokchichi
Abebe Anteneh and Belay Welashe	1,500	Anderacha	Yokchichi
Shishi Opi	120	Yeki	Depi
Worku Ado	170	Anderacha	Echi
Awel Muzein	160	Yeki	Alamu
Denbi Fuaquate	240	Yeki	Achane
Gahiberi	85	Yeki	Achane
Tesfaye Ibro	120	Yeki	Dayi
Yebora Agri Dev't	109	Yeki	Shimerga
East African Tea Plantation	3,435	Masha	Chewaka
Gemadro Coffee Plantation	2,295	Anderacha	Gemadro
Gemadro Coffee Plantation II	1,000–2,000	Anderacha	Duwina
Kodo coffee	70	Masha	Uwa
Shebena coffee	67	Anderacha	Shebena
	20,451		

\* *Kebele* is the smallest administrative unit in Ethiopia

Source: Sheka Zone Investment Office (Tadesse and Masresha, 2007)

Moreover, it is reported that the investment projects have changed the culture and lifestyle of local people, from farming and NTFP collectors to daily laborers that make them to undervalue the native forest management practices (Zewdie, 2007). Cultural change of local people has also been brought by 'modernization' acculturation, change in religion from cultural and/orthodox to protestant Christianity; native culture adulteration with other cultures of the immigrants; and violations of taboos (destruction of forests used for spiritual purposes by plantation companies) (Zewdie, 2007; Mirutse *et al.*, 2009a; Mirutse *et al.*, 2009b; Mirutse *et al.*, 2010). This results in an expansion of a new culture of resource use—selling of firewood and charcoal and a shift of attitudes in the traditional forest resource management practices, e.g., some community members unusually engaged in deforestation. Certification of forest coffee and honey as organic products, which receive a premium price in the world market, and registration of some forest fragments in Bonga, Sheka and Yayu areas as UNESCO Bioserve where their buffer zones are accessible for

local people to collect NTFPs, on the other hand, may promote sustainable use of NTFPs and management of forests in the region (Reenen, 2005; Mohammed and Wiersum, 2011).

## 5. Conclusions

Local people in SW Ethiopia have ever been using varieties of NTFPs in traditional ways for fulfilling their demand for long. In addition to their economical functions, most NTFPs are used for social, cultural and religious/spiritual functions. Coffee and Honey (*tej*), for example, are much more than a usual business and a daily beverage. They are used in many religious and cultural events, most often with spiritual and cultural meanings. Many tribal societies in the region have also strong belief on folk medicine and prefer to visit traditional healers for their health problem. Furthermore, the cultural communities in the region maintain certain forest areas and/ or plants as sacred places for ritual work in the traditional religions, e.g. *Deedo* in Sheka zone (Fig. 5). *Deedo* is a type of tree under which prayer or religious ceremony is conducted.





**Figure 5** *Deedo* at the back of clan leader's home where prayer and ritual is conducted in Sheka Zone, SW Ethiopia (Zewdie, 2007)

However, studies on NTFPs from local use perspectives are very limited. Many studies have focused on those few NTFPs that have international market demand (Reenen, 2005; Mohammed and Wiersum, 2011; Abebe and Koch, 2011), and forgotten the traditional and cultural uses of many NTFPs, and their roles for local people's livelihood and SFM. The traditional and cultural uses of NTFPs in this region are also under extreme pressure due to rapid rate of deforestation and cultural changes as well as policy and land-use right law implementation problems. This possibly shows a need to popularize such uses and link some of them with the existing or potential markets, as tried in certification of coffee and honey as organic forest products (Reenen, 2005), which may, in turn, contribute to the reduction of deforestation. Exploring of different ethnobotanical information and NTFPs that have local importance for generations may also be needed to be conserved. The high dependency and long time traditional uses of NTFPs in SW Ethiopia possibly show the deep-rooted cultural linkage between the society and forests and its NTFPs. Thus, keeping this linkage may help to reduce deforestation.

In conclusion, in addition to the known NTFPs, exploring and popularizing of locally important NTFPs together with their traditional and cultural uses is forwarded to conserve these uses of NTFPs, may be as cultural heritage, and thereby for SFM in SW Ethiopia. Besides economical linkage, it also seems logical to conclude that keeping the cultural linkage between the society and forests and its non-timber products helps reduce deforestation.

Domestication of some economically valuable NTFPs and improving their use and trade at the local level are also important. Building of institutional capacities at different levels to implement policies, and education and awareness creation on the importance of traditional and cultural uses of NTFPs for livelihood and SFM is also pertinent.

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#### References

- Abebe Damte and S.F. Koch. 2011. Non-timber forest products dependence, property rights and local level institutions: Empirical evidence from Ethiopia. Working Paper University of Pretoria, Pretoria.
- Aseffa Seyoum. 2007. Economic value of afromontane natural forest in Sheka Zone, southwest Ethiopia. In: Forests of Sheka. MELCA Mahiber and the African Biodiversity Network, pp. 183-218.
- Avril M. 2008. A study case on *Timiz* (*Piper Capense*). [http://horizon.documentation.ird.fr/exl-doc/pleins\\_textes/divers11-06/010050910.pdf](http://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers11-06/010050910.pdf), retrieved on 25 November 2011.
- CPDE. 2011 Coffee Plantation Development Enterprise (CPDE) annual report 2010/2011.
- CIFOR. 2011. Forests and non-timber forest products. CIFOR fact sheets. <http://www.cifor.cgiar.org/publications/corporate>

- [/factSheet/NTFP.htm](#), retrieved on 13 September 2011.
- Cunningham, A.B. 1996. People, park and plant use. Recommendations for multiple use zones and development alternatives around Bwindi Impenetrable National Park, Uganda. UNESCO, Paris.
- Demel Teketay, Mulugeta Lemenih, Tesfaye Bekele, Ynas Yemshaw, Sisay Feleke, Wubalem Tadesse, Yitebetu Moges, Tesfaye Hunde and Demeke Nigussie. 2010. Forest Resources and Challenges of Sustainable Forest Management and Conservation in Ethiopia. In: F. Bongers and T. Tennigkeit (eds.) *Degraded Forests in Eastern Africa: Management and Restoration*. Earthscan, UK, pp. 19-63.
- Endeshaw Bekele. 2007. Study on actual situation of medicinal plants in Ethiopia. [www.jaica.or.jp/publications/ethiopia\\_ac.pdf](http://www.jaica.or.jp/publications/ethiopia_ac.pdf), retrieved on 22 November 2011.
- Ensermu Kelbessa, Tamrat Bekele, Alemayehu Gebrehiwot, Gebremedhin Hadera. 2000. A socio-economic case study of the bamboo sector in Ethiopia: An analysis of the production-to-consumption system. Addis Ababa, Ethiopia.
- Eyob S., M. Appelgren, J. Rohloff, A. Tsegaye and G. Messele. 2008. Traditional medicinal uses and essential oil composition of leaves and rhizomes of korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen) from southern Ethiopia. *South African Journal of Botany* 74: 181-185.
- Feyera Senbeta, Tadesse Woldemariam, M. Denich and Ensermu Kellbessa. 2013. Diversity of useful plants in the coffee forests of Ethiopia. *Ethnobotany Research and Application* 11: 49-69.
- Girma Deffar. 1998. Non-wood forest products in Ethiopia. Data collection and analysis for sustainable forest management in ACP countries - linking national and international efforts. EC-FAO partnership programme (1998-2000).
- Goettsch E. 1997. Spice germplasm in Ethiopia. In: Engels J.M.M., Hawkes J.G., Melaku Worede (eds.), *Plant genetic resources of Ethiopia*. Cambridge University Press, Cambridge, pp. 223-230.
- ICO (International Coffee Organization). 2013. Trade statistics. [http://www.ico.org/trade\\_statistics.asp?section=Statistics](http://www.ico.org/trade_statistics.asp?section=Statistics), retrieved on 30 November 2013.
- Heubach, K. 2011. The socio-economic importance of non-timber forest products for rural livelihoods in West African savanna ecosystems: current status and future trends. PhD Dissertation, Johann Wolfgang Goethe-Universität, Germany, pp. 6-9.
- Jansen P.C.M. 1981. Spices, condiments and medicinal plants in Ethiopia. Their taxonomy and agricultural significance. [Agricultural Research Reports](#) 906. Centre for Agricultural Publishing and Documentation, Wageningen.
- Kassahun Embaye. 2003. Ecological Aspects and Resource Management of Bamboo Forests in Ethiopia. Doctoral thesis, Swedish University of Agricultural Sciences, Sweden, p.8.
- MEA (Millennium Ecosystem Assessment). 2005. Ecosystems and Human Well-Being: A Framework for Assessment. Washington D.C.
- Mirutse Giday, Zemed Asfaw, Zerihun Woldu and Tilahun Teklehaymanot. 2009b. Medicinal plant knowledge of the Bench ethnic group of Ethiopia: an ethnobotanical investigation. *Journal of Ethnobiology and Ethnomedicine* 5(34). Doi: 10.1186/1746-4269-5-34.
- Mirutse Giday, Zemed Asfaw and Zerihun Woldu. 2010. Ethnomedicinal study of plants used by Sheko ethnic group of Ethiopia. *Journal of Ethnopharmacology* 132:75-85.
- Mirutse Giday, Zemed Asfaw and Zerihun Woldu. 2009a. Medicinal plants of the Meinit ethnic group of Ethiopia: An ethnobotanical study. *Journal of Ethnopharmacology* 124:513-521.
- Mohammed Chilalo and K.F. Wiersum. 2011. The role of non-timber forest products for livelihood diversification in Southwest Ethiopia. *Ethiopian e-Journal Research and innovation Foresight-Agriculture and Forestry Issue* 3(1): 44-59.
- Ogundele F.O., E.A. Utin, A.I. Iwara, G.N. Njar and T.N. Deekor. 2012. An assessment of non-timber forest products (NTFPs) utilization on rural livelihoods in Ini local government area of Akwa Ibom State, Nigeria. *Journal of Biodiversity and Environmental Sciences* 2(8): 1-13.
- Peters, C.M. 1994. Sustainable harvest of non-timber plant resources in tropical moist forest: an ecological primer. USAID Biodiversity Support Programme, Washington DC.



- PFMP. 2004. FARM Africa and SOS Sahel International/ UK Participatory Forest Management Programme (PFMP): Commercialization of Spices in Bonga (Project Profile).
- Reenen van M. 2005. Non timber forest products research and development project in SW Ethiopia: Livelihood categories and NTFP-based options for development interventions to relieve poverty. Wageningen University and Research, Wageningen.
- Reichhuber A. and T. Requate. 2007. Alternative Use Systems for the Remaining Cloud Forest in Ethiopia and the Role of Arabica Coffee - A Cost-Benefit Analysis, Economics working paper / Christian-Albrechts-Universität Kiel, Department of Economics, No. 2007,07, <http://hdl.handle.net/10419/22023>, retrieved on 12 December 2014.
- Rojahn D.A. 2006. Incentive mechanisms for a sustainable use system of the montane rain forest in Ethiopia. PhD Dissertation, Christian Albrechts University, Germany, pp. 6-105.
- Singh M.K. 1999. Managing non timber forest products for sustainability of joint forest management: The case of Dewas and Jhabua District in M.P. State, India. PhD Dissertation, Technical University of Dresden, Germany, pp. 1-98.
- Sisay, Andualem. 2011. Ethiopia's Challenge: Balancing Agriculture with Environmental Protection. [http://newbusinessethiopia.com/index.php?option=com\\_content&view=article&id=536:ethiopia-challenge-balancing-agriculture-with-environmental-protection-&catid=28:enviroment&Itemid=51](http://newbusinessethiopia.com/index.php?option=com_content&view=article&id=536:ethiopia-challenge-balancing-agriculture-with-environmental-protection-&catid=28:enviroment&Itemid=51), retrieved on 16 December 2012.
- Stellmacher T. 2006. Governing the Ethiopian coffee forests: A local level institutional analysis in Kaffa and Bale mountains. PhD Dissertation, Rheinischen Friedrich-Wilmelms University, Germany, pp. 1-223.
- Tadesse Woldemariam. 2007. The impact of landuse/landcover changes on biodiversity in Masha and Anderacha *Woredas* of Sheka. In: *Forests of Sheka*. MELCA Mahiber and the African Biodiversity Network, pp. 57- 88.
- Tadesse Woldemariam, and Masresha Fetene. 2007. Forests of Sheka: Ecological, social, legal and economic dimensions of recent land use/land cover changes-overview and synthesis. MELCA Mahiber and the African Biodiversity Network, PP. 1-20. <http://www.melca-ethiopia.org/images/stories/Publication/Forests%20of%20Sheka.pdf>, retrieved on 22 November 2011.
- Tefera Belay. 2005. Dynamics in the Management of Honey Production in the Forest Environment of Southwest Ethiopia: Interactions between Forests and Bee Management. MSc Thesis, Wageningen University, The Netherlands, pp. 1-65.
- Tewari D. D. 2012. Promoting non-timber forest products (NTFPs) to alleviate poverty and hunger in rural South Africa: A reflection on management and policy challenges. *African Journal of Business Management* 6(47): 11635-11647.
- Wood A.P. 1993. Natural Resource Conflicts in South-West Ethiopia: State, Communities, and the Role of the National Conservation Strategy in the Search for Sustainable Development. *Nordic Journal of African Studies* 2(2): 83-99.
- Zewdie Jotte. 2007. The impact of cultural changes on the people of Sheka and their traditional resource management practices: the case of four kebeles in Masha Woreda. In: *Forests of Sheka*. MELCA Mahiber and the African Biodiversity Network, pp. 89-136.
- Zewdie Jotte. 2010. Institutions, incentives and conflict in coffee forest use and conservation: the case of Yayo forest in Iluu Abba Bora Zone, southwest Ethiopia. PhD Dissertation, Rheinischen Friedrich-Wilhelms University, Germany, pp. 1-186.

## Assessment on the Socio-Economic Significance and Management of Woynwuha Natural Forest, Northwest Ethiopia

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**Abstract:** A study was conducted in Woynwuha natural forest, Goncha Siso Enesie district, North West Ethiopia to assess the socio-economic significance and management of the Woynwuha natural forest. Data has been collected from 50 randomly selected households through questionnaire and key informant interview. The household socioeconomic data analysis result indicated that identified constraints for the conservation of the forest stand were stoniness of the land, lack of awareness of the community, heavy dependence on the forest products, illegal cutting, expansion of farm land towards the forest estate, open and free grazing, forest fire and lack of budget for forest development works. In order to better conserve the Woynwuha natural forest from further degradation, appropriate forest management planning has to be formulated and emphasis should be given towards educating the local community.

**Keywords:** Socio-economic Significance, Forest Management Problems, Woynwuha Natural Forest

### 1. Introduction

The impact of environmental degradation is most severe for people living in poverty, because they have few livelihood options on which to depend (IUCN's, 2010). Most of the natural forests in Africa face pressure from communities who derive their basic livelihood from forests, or the land on which they grow crops, and even greater pressure come from commercial plantation companies and extractors of timber and other products. Conflicts often occur because of competition for forest resources from local people's livelihoods, commerce, wildlife and forestry, and the alarming rate of forest loss in African forests poses an international concern (Leon Bennun *et al.*, 2004).

The deforestation of mountain forests in Ethiopia seems to have occurred relatively early, and it was extensive in comparison to other East African countries (Bonnefille & Hamilton, 1986; Siiriäinen, 1996). However, the disappearance of the forests has been drastic during the past hundred years, and a maximum deforestation rate was reached in the 1950s and early 1960s (Pohjonen and Pukkala, 1990).

As a result of deforestation, the natural conditions on the study area have been changed. From this, it can be predicted that until acceptable alternatives can be found, deforestation will undoubtedly continue and the natural forest resource will be exhausted in the coming few years. This, in turn, may lead to reduction of soil fertility, drying up of streams and loss of flora and fauna. In order to conserve the Woynwuha natural forest from degradation, appropriate forest management planning has to be formulated and emphasis should be given towards educating the local community.

### 2. Materials and Methods

#### Description of the study area

Woynwuha natural forest is located in Debreyakob kebele, Goncha Siso Enesie district, East Gojjam Zone, Amhara National Regional State (Figure 1). The study site is located between 10°51'314"–10°63'168" North latitude and 38°13'311"–38°14'990" East longitudes. The study natural forest has an area of 162.057 ha.

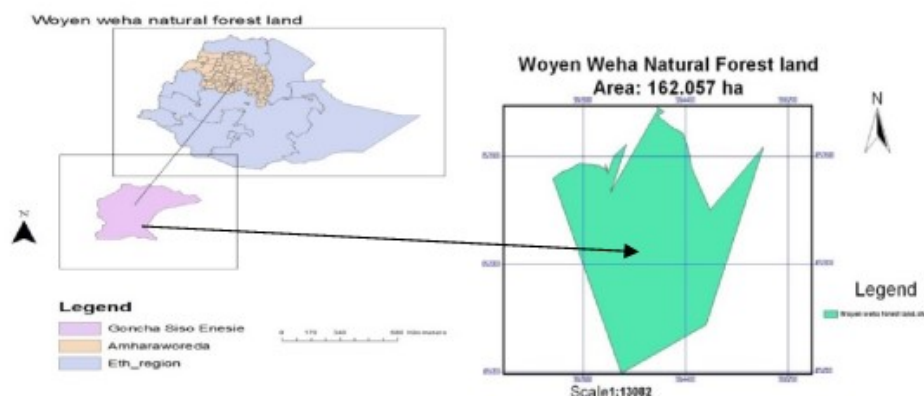


Figure 1 Map of the study area and forest.

### Topography, land use and soil

According to the Goncha Siso Enesie District Finance and Economic Development Office's 2009/10 budget year statistical bulletin (October, 2010), the topography of the study area is generally characterized by undulating hill and consists of mountains (39%), plain land (45%), terrain (15.871%), and water body (0.129%). The total area of the district is 98383 ha. More than seven types of land use are identified in the district: cultivated land (47.4%), forest land (4.78%), lakes (0.07%), shrub land (9.58%), grazing land (11.93%), settlement (16.3%) and others (9.94). Scientific description of the soil types is not done in the district. According to Debre Markos Soil Laboratory (2007), four types of soils namely red (15%), black (5%), brown (60%) and light brown (20%) soils are identified in the district by color. The soils are mostly acidic with pH values ranging from 4.2 to 7.3. The elevation of the study forest ranges from 2009-2733m.a.s.l and bounded by two PA (Debreyakob and Gufu) and four Gots namely Tach Dinjet in the north, Gufu Giorgis in the east, Debreyakob kola in the west and Jibra Kola in the south. Woynuha natural forest is owned and managed by local community.

### Climate, Vegetation and wild life

Traditionally, the districts have three major types of agro-climatic zones: *Dega* (12%), *Weina-Dega* (48%) and *Kolla* (40%). The natural forest under study is characterised as sub-humid climate. The mean annual rainfall is in the range of 1100-1800mm. The monthly mean temperature is 19.5°C, and the annual average maximum and minimum temperature of the study area is 24°C and 15°C, respectively (WAO, 2011/12).

The area around Debreyakob PA has been covered by continuous vegetation until recently. However, the vegetation in the area is being destroyed by human activities mainly by agricultural expansion, excessive exploitation for wood products and human settlement. In the study district, there is 1898 ha of natural forest and 2810 ha of plantation forest. These forests are habitat for numerous wild animals including *Lepus habessinicus*, *Tragelaphus scriptus*, *Canis aureus*, *Papio hamardias*, *Silvicapra grimmia*, *Oreotragus grimmia*, *Felis silvestris*, *Cercopithecus pygerythrus*, *Panthera pardus*, *Corcuta corcuta* and a variety of bird species (FTC, 2012/13). The most commonly known plant species are *Albizia gummifera*, *Olea europaea*, *Carissa edulis*, *Acacia abyssinica*, *Juniperus procera* and *Croton macrostachys*. Bush, Shrub and herbs are also common in the area.

### Demographic characteristics and socio-economic features

The district consists of 37 rural and 1 urban PAs. According to CSA's (2009) census, human population of the district was 156012 with 77495 (49.7 %) male and 78516 (50.3 %) female with an average household size of about 5 people. The number of rural HHs was 32687, among which 82.1% were men and 17.9 % were women headed. The average land size in the area is 1.43 ha per household. Out of the total land size, on average, 0.26ha and 1ha of land is allocated for private grazing and crop production, respectively (CSA, 2009).

The people around the study area employ a mixed subsistence agriculture where crop production and animal husbandry is carried out side by side. The major crops grown in the district are *Eragrostis tef*,

*Sorghum bicolor*, *Triticum aestivum*, *Eleusine coracana* dgs, *Oryza sativa*, *Sesamum indicum*, *Carthamus tinktorius*, *Brassica carinata*, *Hordeum sp* (*Phaseolus vulgaris*, horse bean, *Pisum sativum*, *Cicer arietinum*, soya bean and *Vicia faba*), *Guizotia abyssinica*, *Linum usitatissimum* and vegetables. The dominant livestock in the study area include: cattle, sheep and goats, horses, donkeys, and also some bee keeping activity.

#### Data collection

Before the actual data collection started, reconnaissance survey has been conducted in the study area for three consecutive days in order to get general information about the physiognomy of the vegetation, and the nature of the landscape. After conducting the reconnaissance survey, actual data were collected from December 2012 to May 2013. Socio-economic data were collected to assess the perception of the local community towards the forest and about their management practices. The socio-economic data were collected using semi-structured questionnaire and key informant interview. Semi-structured interviews as described by Martin (1995) and Cunningham (2001) were used to obtain both qualitative and quantitative data from the community.

In order to determine sample size on total households living in the forest surrounding, data were obtained from DAs of the two PAs. The total household heads residing in the forest were 216. The number of sample household selected for the interview was determined by using the following formula (Cochran, 1977).

$$n_0 = \frac{Z^2 pq}{d^2}$$

$$n = 1 + \frac{\left(\frac{n_0}{n_0 - 1}\right)}{N}$$

Where,

$n_0$  is the desired sample size when the population is greater than 10000

$n$  is number of sample size when population is less than 10000

$Z$  is 95% confidence limit i.e. 1.96

$p$  is 0.1 (proportion of the population to be included in the sample i.e. 10%)

$q$  is 1-0.1 i.e. (0.9)

$N$  is total number of population

$d$  is margin of error or degree of accuracy desired (0.05)

Based on the above sample size determination, a total of 50 sample households who live around the forest from two PAs and four Gotte were randomly selected (19 from Debreyakob Kola, 13 from Jibra Kola, 13 from Gufu Giorgis, 5 from Tach Dinjet) depending on population size, accessibility and familiarity to the forest and key informants were identified purposively from people who are knowledgeable about the general overview of the socio-economic aspects of the study area.

Thus, socio-economic information collected include tree/shrub species preference and types, perception of farmers on the forest and its degradation, family size, age, religion and educational statuses. For better communication with the respondents, questionnaires were translated into the local language (Amharic). Also video and digital camera photographs of the study site were used.

#### Data Analysis

Socio-economic information obtained through field observation, semi-structured interview and key informant interview were summarized and described using descriptive statistics like mean. The use values of species were calculated and ranked following frequencies and percentage of the respondents. The qualitative and quantitative data were analyzed using frequencies, tables, and histograms by means of Statistical Package for Social Sciences (SPSS) version 16 software and with Microsoft Excel.

### 3. Results and Discussions

#### Perception of the community towards the forest

According to the views of the respondents (88%), the current forest statuses against its status which used to be before have increased. However, 10% of the respondents said that there gradual decline in the condition of the forest, while 2% said the status is the same (Table 1)

**Table 1 Current forest status against its previous status**

Current status	Number of respondents	Percent
Increased	44	88.0
Decreased	5	10.0
Same	1	2.0
Total	50	100.0

**Socio-economic importance of the forest**

According to the response from the key informants, there are different economic, social and ecological benefits being obtained from the forest (Table 2). Moreover, during the focus group discussion, it

was learnt that there is also holly water (*lideta tsebel*) that originates from the forest that is positively contributing for the conservation of the forest. Apart from this, there is a rock stele called 'miseso dingay' that serves as tourist attraction and income generation (Figure 2).

**Table 2 Socio-economic importance of Woynwuha natural forests**

No,	Socio-economic importance	Number of respondent	Percent	Rank
1	Source of fuel wood	7	14.0	2
2	Used as grazing land	5	10.0	3
3	Source of construction material	5	10.0	4
4	Cultural value/ holly water	2	4.0	5
5	Climate amelioration	1	2.0	6
6	Recreation	1	2.0	7
7	All of the above	29	58.0	1
Total		50	100.0	

**Figure 2 Miseso Dingay, D/kidanemihret church and Millennium Park in the study area****Economic importance**

The discussants from the group discussion mainly underlined that due to the closure of the area and rehabilitation of the vegetation, the community is getting grass both for roof thatching and animal feed in drought season under the permission of the

PA administration agricultural offices free of charge. The residents used to go far in search of grass for roof thatching (Table 3 and Figure 3).

**Table 3 Economic importance of Woynwuha natural forest**

Economic importance	Number of respondent	Percent (100%)
Fuel wood	16	32.0
Grazing	11	22.0
Both	23	46.0
Total	50	100.0



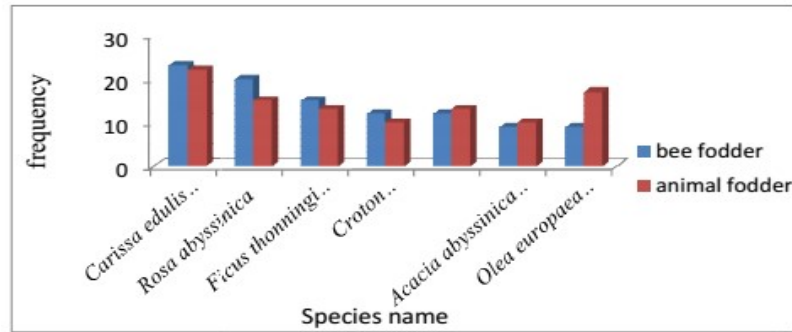


Figure 3 Species preference for bee forage and other domestic animal fodder

#### *Social importance and view of local people*

According to the respondents during group discussion, there was unrestricted fuel wood collection and free grazing before some years. The enclosure of the area helped the rehabilitation and growth of different vegetations and has contributed for the maintenance of the traditional knowledge regarding plant species and their use. The results of the interview made with local community (Table 4) showed that 96% (48 of the respondents) have agreed on the benefits from the forest, which include availability of woody species, wind break by the vegetation, and growth of grasses used for different purposes. Ecotourism outweighs its negative impacts like restriction of domestic animals from entrance into the forest, domestic animal hunting and crops damaged by wild animals and lack of benefit sharing. Moreover, greater than 88% (44 of the respondents) strongly emphasized

the sustainability and willingness for managing the area (Table 4). Perception of the local people is a key issue to the successful management of communal resources (Emiru, 2002). Even though, few of the respondents have negative attitude, 98% (49 of the respondents) have positive attitude towards the sustainability and rehabilitation of the forest (Table 4).

Table 4 Beneficiaries and participants in the management of Woynwuha natural forest

Respondents	Answer	Number of respondent	Percent (100%)
Beneficiary	Yes	48	96.0
	No	2	4.0
Participant	Yes	44	88.0
	No	6	12.0
Feeling	Happy	49	98.0
	Unhappy	1	2.0
Degree of participation	Excellent	29	58.0
	Good	5	10.0
	Medium	14	28.0
	Poor	2	4.0

About 15 of the respondents (30%) feel that the enclosure of the forest is the reason that made them landless/shortage of farmland (Table 5). Yet, there seems to be a visible reluctance to take full

participation in the conservation effort, and considerable incidences of intrusions are recorded. This may be due to the crises that people had experienced before.

**Table 5 Major problems due to the presence of Woynwuha natural forest**

Problem	Number of respondent	Percent
shortage of farm land	15	30.0
damages on crops and domestic animals by wild animals	5	10.0
no problem	30	60.0
Total	50	100.0

The respondents stressed that the forest will have great benefit for the future only if it is managed by the alliance of the government and the local community (Table 6). According to the rules and regulations set by the local people, if domestic animals entered the territory of the forest, the owner will pay 10 ETB per animal as punishment. Besides this, the local people have great tendency

to listen seriously whatever is told to them by their own community members and elders rather than any outsider. This shows that including such knowledgeable persons has tremendous value for future awareness creation campaigns and sustainable conservation of the resources in Woynwuha natural forest.

**Table 6 Management approach of Woynwuha natural forest**

Management approach	Number of respondents	Percent
State management	2	4.0
Community management	2	4.0
Collaborative management	46	92.0
Total	50	100.0

#### ***Ecological importance/change in the ecosystem***

About 96% of respondents have sense of ownership on Woynwuha natural forests. The major reasons are increase in the availability of multipurpose trees (54%), decrease in soil erosion and drought (16%) and increase in species diversity (26%). Now, they observed that there was ecological benefit that people of the study area obtained from the forest including rejuvenation of different woody species and grasses, re-occurrence of different wild animals, gully stabilization, good air regulation and recreation to the surrounding town of Mertule Mariam and other neighboring villages.

After the closure, the gullies became stabilized and the expansion stopped. From this point of view the respondents from the surrounding dwellers realized the importance of protecting the area and some knowledgeable consider the protected areas as part

of their daily life because directly or indirectly their life is associated with the resources in the forest. Based on individual's interview of 50 informants, the economic importance ranked first, ecological importance takes the second rank, whereas social importance ranked least.

#### **Common tree/shrub species and their use**

The most common tree/shrub species preferred in order of dominance of response include *Olea europaea* (17.82%), *Albizia gummifera* (14%), *Carissa edulis* (13.55%), *Rhus retinorrhoea* (11.21%), *Dodonaea viscosa* (7.94%) and *Croton macrostachyus* (7.48%) (Table 7). The most common tree/shrub species managed currently in order of dominance of response include *Albizia gummifera* (18.39%), *Olea europaea* (13.33%), *Carissa edulis* (11.67%), *Allophylus abyssinicus* (10%) and *Rhus retinorrhoea* (9.4%).

**Table 7 List of previous and current dominant tree species**

List of previously dominant tree species		List of currently dominant tree species	
Species name	Percent (%)	Species name	Percent (%)
<i>Olea europaea</i>	17.82	<i>Albizia gummifera</i>	18.39
<i>Albizia gummifera</i>	14.00	<i>Olea europaea</i>	13.33
<i>Carissa edulis</i>	13.55	<i>carissa edulis</i>	11.67
<i>Rhus retinorrhoea</i>	11.21	<i>Allophylus abyssinicus</i>	10.00
<i>Dodonaea viscosa</i>	7.94	<i>Rhus retinorrhoea</i>	9.40
<i>Croton macrostachyus</i>	7.48	<i>Cordia Africana</i>	8.33
<i>Acacia seyal</i>	7.00	<i>Juniperus procera</i>	8.33
<i>Rosa abyssinica</i>	7.00	<i>Rosa abyssinica</i>	8.33
<i>Juniperus procera</i>	7.00	<i>Dodonaea viscosa</i>	6.11
<i>Ficus vasta</i>	7.00	<i>Eucalyptus spp</i>	6.11

#### Management problem of Woynwuha natural forest

Analysis of some of the factors affecting woynwuha forest conditions depicted that stoniness of land, lack of awareness, heavy demand of forest products, illegal cutting, expansion of farm land; open grazing, lack of budget and forest fire have been problems in Woynwuha natural forest (Table

8 and Figure 4). The major management intervention that improves regeneration of tree species in the forest include reducing grazing intensity, reducing intensity of wood harvest, transplanting seedlings, sowing seeds combining with litter removal and selecting/creating micro sites (Alemayehu, 2002).

**Table 8 Major Management problem in Woynwuha natural forests**

Production constraints	Number of respondent	Percent
Human population increment	2	4.0
Lack of awareness	2	4.0
Illegal cutting	16	32.0
Expansion of farm land	13	26.0
Open grazing	4	8.0
Forest fire	4	8.0
Stoniness	2	4.0
Lack of budget	7	14.0
Total	50	100.0

**Figure 4 Major problems observed that threaten Woynwuha natural forest**

#### *Human population increment induced higher demand for forest products*

According to the information from group discussion and individual informants, 86% of the respondents whose daily life depends on animal husbandry and crop production see the forest as the

only place where they get grazing land/fodder which is also true in farm land expansion. As it is indicated in Table 9, 16% of individual respondents agreed that most of the people living around the forest have very low income, which even does not satisfy their daily need. Consequently, they have to secretly sneak and collect wood, in spite of the risk

of being caught by the guards and the consequence

that follows.

**Table 9 Wealth status of the respondents**

Wealth status	Number of respondent	Percent
Poor	8	16.0
Medium	40	80.0
Rich	2	4.0
Total	50	100.0

#### *Lack of awareness*

The fuel wood demand is high. This is the case both among rural and urban people that wood is the major energy source for cooking (Derejje, 2006). The saddening situation is that these people do not collect only the dried trees but also peel the barks of the green trees to make sure that it will get dried

when they come back again. Such irresponsible activities are said to be predominantly done by illegal dwellers. This justifies and reinforces the necessity of introducing fuel saving stoves and alternative energy source, which greatly contribute to the minimization of the demand for fuel wood (Tables 10 and 11).

**Table 10 Sources of fuel wood in selected PA**

Source of fuel wood	Number of respondent	Percent
From the surrounding forest	12	24.0
From back yard	11	22.0
From farm area	5	10.0
All	22	44.0
Total	50	100.0

**Table 11 Interventions to overcome shortage of fuel wood**

Way of solving shortage of fuel wood	Number of respondents	Percent
Planting seedling around the home and farm land boulder	10	20.0
Using improved energy saving cooking stove	11	22.0
Both	29	58.0
Total	50	100.0

#### *Illegal cutting*

Almost all houses are made of wood. 48% of individual respondents mentioned that people living around the forest use wood from the forest for construction (Table 12). Such needs unless met with other alternatives would remain a pressure. Besides, people's intrusion in the forest has to be discouraged by all means to the extent that dependence of the residents on construction wood decreases and their interference in the forest minimizes. Newly emerging ecosystems may help to strive to restore ecosystems that will be adaptive and resilient to local and global changes (Derejje, 2006). The existing forests provide great opportunities for restoration. They can serve as stepping stones to restore the surrounding degraded landscape. They can lead area enclosure programs

to full-scale restoration trajectory and, in turn, enclosures can ensure future sustainability of forests (Alemayehu, 2005).

Illegal cutting is ranked first (Table 8 and Figure 5) as it is related to the livelihood of the local community followed by expansion of farm land and free grazing which has direct or indirect influence on the properties of the people around the forest. Whereas, lack of awareness take the last rank as it has no great problem on the daily activities of the local people and on the management and sustainable use of the Woynwuha natural forest as compared to other problems affecting the sustainability and rehabilitation of the forest.



**Figure 5 Illegal cutting problems**

#### ***Expansion of farmland***

According to key informants' group discussion and 26% of individual respondents, expansion of the farmland has been a major problem in the study. The enclosure area could not be fenced due to

shortage of budget and other problems. Moreover, fencing can protect the farmers' livestock from entering the forest and farmland expansion (Figure 6).



**Figure 6 Expansion of farmland problems**

#### ***Conflicts of wild animals of the forest and the local community***

Even though the majority of the respondents agreed on the positive benefit of the forest, they stressed that their crops and domestic animals are frequently damaged and eaten by wild animals. According to key informants' group discussion, protecting their cattle and crops from wild animals becomes extremely difficult. Most of the respondents suggested that the completion of the fence would significantly reduce these negative impacts. They emphasized that the number of warthogs and hyenas has become so large that it needs arrangement of legal hunting mechanism as a means of mitigating their damage on crops and animals. Legal hunting minimizes the magnitude of the damage the animals are inflicting on the people on one hand, and generating income from controlled hunting on the other. Such suggestions also indicate the awareness level of the community members.



Table 12 Summary of the respondents' view on uses of different tree species associated to the Woynwuha natural forest

Tree/shrub	Use value %										Total value	Rank	
	Fuel wood	Construction	Farm tools	Food	Soil and conservation	water	Shade	Fencing	Recreation	Timber			Cattle feed/ fodder
<i>A. abyssinica</i>	6.43				25.28		7.37	20.45				59.53	6
<i>A. donax</i>					20.84							20.84	14
<i>A. gummifera</i>		13.4	26.5				7.37		18.75			66.02	5
<i>A. vera</i>					15.59							15.59	15
<i>Al. abyssinicus</i>	11.62	18.56	11.76				5.26				11.63	58.83	7
<i>C. Africana</i>			7.5	7.5			15.79		21.87	39.4	8.19	100.25	3
<i>C. edulis</i>	20.46			19.58	19.8			31.81			29.06	120.71	2
<i>C. tomentosa</i>								12.52				12.52	17
<i>D. abyssinica</i>				12.88								12.88	16
<i>E. abyssinica</i>								10.23				10.23	18
<i>E. spp</i>	16.05	28.87						13.63				58.55	8
<i>F. sur</i>				16.78			21.05			9	9.3	56.13	9
<i>F. vasta</i>				13.18			24.21			16.7		54.09	11
<i>J. procera</i>							7.37		18.75	28.8		54.92	10
<i>O. europaea</i>	28.4	24.74	35.22				11.58		18.75	6	17.4	142.09	1
<i>P. falcatus</i>									21.87			21.87	13
<i>R. abyssinica</i>				22.38	18.49			11.36			24.42	76.65	4
<i>R. vulgaris</i>				7.7								7.7	19
<i>R.retinorrhoea</i>	17.04	14.43	19.02									50.49	12

***Stoniness and Man-made forest fire***

From field data observation, young man who lives round the forest cut trees and set fire for increasing football field. Relatively, few respondents (12%) mentioned that part of the land is covered by stone,



**Figure 7 Stoniness and man-made forest fire problems**

***Lack of budget***

Shortage of budget is mentioned as one of the major problems to protect Woynwuha natural forests, to implement effective conservation activities and rehabilitation works. The newly regenerated forest type (*Juniperus* forest, with *Olea* and *Celtis*) is different from the earlier type (*Podocarpus-Juniperus* forest) (Darbyshire *et al.*, 2003).

***Free grazing***

Our results confirmed that livestock grazing is the major factor limiting seedling establishment and seedling survival and growth in Woynwuha forests. Almost none of the sown seeds were able to germinate in unfenced millennium park. Studies in

Ethiopian highlands showed that heavy grazing pressure significantly increased surface runoff and soil loss and reduced infiltrability of the soil, which, in turn, undermines suitability of sites for germination (Mwendera and Mohamed, 1997). The major challenge for seedlings' survival and growth again is livestock grazing. We observed signs of browsing and trampling damage in almost all seedlings in the unfenced millennium park. Open grazing has affected the seedling establishment and seedling survival and growth. Along the gradient of forest interior to edge and open field, in general, seedling establishment was more successful inside the forest. The surrounding land is protected from grazing intervention and farming (Figure 8).



**Figure 8 Free grazing problems**

***Water Supply / Stream flow***

In the forest, there are three streams namely Wochit wuha, Shotel wonz and Sengev wonz (Figure 9).

These are sources of water for wild animals and nearest people to the forest. In order to solve the problem of damage on both domestic animals and crops by wild animals coming out of the forest for

search of water, the informants pointed out constructing physical and biological soil and water

conservation structures.



Figure 9 Water supply / Stream flow in Woynwuha

#### Human impacts on the forest ecosystems

The survey showed that the increasing demand for agricultural lands and wood products, spurred by human population growth, has led to the destruction of Woynwuha natural forests. At present, the forest resources are under great human pressure and will diminish in the near future unless appropriate and immediate measures are taken. Overexploitation of the forest for wood products has resulted in the reduction of some of the economically important tree species.

From field observation, plantations (Millennium Park) around Woynwuha natural forest and area

enclosure programs are well integrated; and restoration of the lost vegetation in Debreyakob PA is possible. Caused by illegal cutting, the area has suffered a heavy loss in natural vegetation cover. Expansion of agricultural land, harvesting of construction wood and collection of fuelwood were the most important underlying causes of the loss of natural vegetation cover. Sustainable forest management systems attempt to develop systems whereby the renewable resource (e.g. wood or non-wood forest products) can be extracted without harming the environment and future generations.

Table 13 Reasons of respondents for the presence of guard

Reasons of respondents	Frequency	Percent
decreases workless people	9	18.0
thinks as owner	4	8.0
reduces illegal cutting	24	48.0
teaches the people who have lack of awareness about forest	2	4.0
All	11	22.0
Total	50	100.0

#### 4. Conclusion and Recommendations

The socio-economic significance and management problem of Woynwuha natural forest was studied, and the results showed that Woynwuha natural forest covered dramatically. Rehabilitation and growth of different vegetations due to presence of guard and enclosure took place in the area. If appropriate management activities are applied, the nature of the study area will be improved.

Moreover, except some complaints associated to damages on crops and domestic animals by wild animals, the majority of the local respondents had positive attitude towards the preservation of the

Woynwuha natural forests. This is an opportunity for forest conservation. Therefore, the isolated remnant forests with their higher woody diversity are potential for *in-situ* and *ex-situ* conservation sites. Despite its ecological, social and economic importance of Woynwuha natural forest, it is not under proper management.

The forest provides various products such as fuel wood, construction material, timber, farm tools, shading, animal fodder, bee forage, recreation and edible fruits. Despite their socio-economic and ecological importance, at present, the forests are under increased human pressure. Livestock grazing, illegal tree cutting for various purposes

and farmland expansion are the major threats to the forest resources. The community has played a vital role in the maintenance of the forest. Integrating conservation measures would be more effective. In general, Woynwuha natural forest is creating different opportunities and benefits to the nearby communities.

In order to ensure the conservation, management and sustainable utilization of the Woynwuha natural forest, the following recommendations were forwarded for effective management in the study area:

- Participatory forest management of the area by the local people and concerned Governmental and/or NGO's for sustainable use of the resources in the natural forests should continue.
- Make use of knowledgeable community members in the awareness creation campaigns, considering the fact that people have great tendency to listen seriously whatever is told to them by their own community members and elders rather than any outsider.
- Building strong extension services and legal protection to build awareness of the community about sustainable conservation and utilization of resource.
- Integrated research and development interventions have to be carried out for further studies on effective management in the area.

## References

- Alemayhu Wassie, Teketay D, Powell N. 2002. Church forests in North Gonder Administrative Zone, northern Ethiopia. *Forests, Trees and Livelihoods*, 15:349–373.
- Alemayehu Wassie. 2005. *Opportunities, constraints and prospects of the Ethiopian Orthodox Tewahido Churches in conserving forest resources: the case of churches in South Gondar, northern Ethiopia*. MSc.Thesis, Swedish University of Agricultural Sciences.
- Bonnefille, R. and Hamilton, A. 1986. Quaternary and late tertiary history of Ethiopian vegetation. In: Hedberg, I., (Ed.). *Research on the Ethiopian flora*. Proceedings of the first Ethiopian Flora Symposium held in Uppsala May 22-26, 1984. Uppsala, pp. 48-55.
- Cochran W., 1977. *Sampling Techniques*. 3<sup>rd</sup> ed. John Wiley and sons. USA.
- CSA. 2009. Ethiopian Statistical Authority. *Central Statistics Authority*. Federal Republic of Ethiopia, Addis Ababa.
- Cunningham A and B. 2001. *Applied Ethnobotany: People, Wild Plant Use and Conservation*. London: Earthscan.
- Darbyshire, I., Lamb, H. & Umer, M. 2003. Forest clearance and regrowth in northern Ethiopia during the last 3000 years. *Holocene*, 13(4), 537-546.
- Debreyakob PA Farmer Training Center Office. 2012/13 annual report, Gonch siso enesie, Amhara, Ethiopia.
- DMSL (Debere Markos Soil library). 2007. Debere Markos Soil library Manual, Debere Markos, Ethiopia.
- Dereje Mekonnen. 2006. *Woody species composition of Dilfaqar Regional park and its socio-economic Importance*. MSc.Thesis, Addis Ababa, Ethiopia.75pp.
- Emiru Birhane. 2002. *Actual and potential contribution of Enclosures to Enhance biodiversity in dry lands of eastern Tigray With particular in woody plants*. Msc Thesis. Swedish University of Agriculture (SLU).
- Goncha Siso Enesie District agricultural Office. 2010/11. annual report, Amhara, Ethiopia.
- IUCN (International Universal Conservation of Nature). 2010. *A Good Practice Guide Sustainable Forest Management, Biodiversity and Livelihoods*.
- Leon Bennun, Glyn Davies, Kim Howell, Helen Newing, Matthew Linkie. 2004. *African Forest Biodiversity: A Field Survey Manual for Vertebrates*
- Martin, G.J. 1995. *Ethnobotany: A Methods Manual*. Chapman and Hall. London, UK, pp 268.
- Mwendera EJ, Mohamed Saleem MA. 1997. Infiltration, surface runoff, and soil loss as influenced by grazing pressure in the Ethiopian highlands. *Soil Use and Management Vol 13*. No: pp35–54.
- Pohjonen, V. and Pukkala, T. 1990. *Eucalyptus globulus* in Ethiopian forestry. *Forest Ecology and Management* 36: 19-31.
- Siiräininen, A. 1996. Man and forest in African history. In: Palo, M. and Mery, G. (eds.). *Sustainable forestry challenges for developing*

countries. Kluwer Academic Publishers,  
Dordrecht, pp. 311-326.



## Are Mineral Fertilizers Panacea for Increase in Crop Yield? Review

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**Abstract:** Fertilizers are important in increasing crop yield and many of the increases in world food production are attributed to the judicious application of mineral fertilizers. Among the 18 essential elements, nitrogen, phosphorus and potassium are the major ones and the first two are imported to and used in Ethiopia. Nitrogen is the most limiting nutrient in plant growth. It is a constituent of chlorophyll, plant proteins, and nucleic acids. Phosphorus is essential component of Adenosine triphosphate, deoxyribonucleic acid and ribonucleic acid, whereas potassium is useful in activation of enzymes, photosynthesis, starch synthesis, nitrate reduction and sugar degradation as well as helping plants withstand stresses like drought, winter hardiness, tolerance to diseases, insect pests and frost damage. The other macro and micro nutrients are also important in the various physiological processes of plants. Mineral fertilizers have been responsible for an important share of worldwide improvement in agricultural productivity and fertilizers account for more than half of the increase in yield worldwide. The yield increase recorded in Ethiopia has been attributed mainly to the use of mineral fertilizers together with improved seeds. It is, however, important to note that fertilizers will be effective if other conditions are fulfilled. These factors include soil factors (soil reaction, clay mineralogy and clay content, moisture regime of the soil, impermeable soil layer, soil texture and bulk density and availability of other nutrients in the soil, availability of moisture; climatic factors (temperature, light intensity and length of the day); crop factors (crop adaptability to local conditions, fertilizer requirement, resistance to disease, pests, drought and other stress factors); fertilizer characteristics and management practices (erosion control, land preparation, planting date and practice, weed, and pest and disease management). Crop yield, therefore, can be improved not by application of mineral fertilizers alone but by the combination of genotype (G), optimum environmental condition (E), appropriate management practices (M) and  $yield = G \times E \times M$ .

**Keywords:** Crop yield, environment, genotype, management, interaction

### 1. Introduction

Tremendous population growth, food shortage and malnutrition have been a major challenge in Ethiopia. Hence, the importance of increasing agricultural productivity to secure sufficient food for growing population is obvious (Havlin *et al.*, 2005). One of the major factors responsible for increasing crop yield is judicious application of mineral fertilizers.

Mineral fertilizers are concentrated sources of essential nutrients in a form that is readily available for plant uptake. Since the invention of mineral fertilizers in the 19th century until the 1980s, fertilizer use, improved seeds and planting materials have been the major drivers of improved productivity in agriculture; and increased use of mineral fertilizers has been responsible for an important share of

worldwide improvement in agricultural productivity (Handbook of Integrated Fertility Management, 2012). Fertilizers account for more than 50% of the increase in yield worldwide (FAO, 1984). Yield increase in Ethiopian agriculture has been mainly due to application of mineral fertilizers to different crops (Yesuf and Duga, 2000a; Getachew Alemu, 2001; Amare *et al.*, 2005; Getachew *et al.*, 2007).

Although mineral fertilizers increase crop yield, they have also negative consequences. In some cases, excessive mineral fertilizer use in industrialized countries has resulted in leaching of N and P into water bodies, causing water contamination and eutrophication. Care must be taken, therefore, to avoid the negative effects that accompany excessive fertilizer use. Moreover, application of mineral

fertilizers cannot be taken as panacea to boost agricultural production. Increase in crop yield is possible only through the integrated availability of optimum conditions for crop performance besides the judicious application of fertilizers. These include soil factors, climatic factors, crop factors, fertilizer characteristics and management practices (Ignatieff and Page, 1968; Mortvedt *et al.*, 1999). In this paper, a review of the factors that affect efficiency of applied mineral fertilizers is presented.

## 2. Methodology

This article is based on intensive literature review of published materials like books, articles and other scholarly materials.

## 3. Results and Discussion

### 3.1. Role of Mineral Fertilizers in Crop Yield

Mineral fertilizers are substances that are synthesized by fertilizer industries and that carry essential elements required for growth and development of plants. There are 18 essential elements for growth and development of plants (Brady and Weil, 2000). Among these nutrients nitrogen, phosphorus and potassium are the major ones ranking from first to third. Nitrogen is the most limiting nutrient in plant growth. It is a constituent of chlorophyll, plant proteins, and nucleic acids (Brady and Weil, 2000) and useful for vegetative development (Pocock *et al.*, 1988; Scott and Jaffard, 1993; Yihenew, 2007). However, nitrogen is believed to be the most frequently deficient nutrient in crop production (Havlin *et al.*, 2005; Yihenew and Suwanarit, 2007). Phosphorus is an essential component of Adenosine triphosphate (ATP), deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) (Brady and Weil, 2000). Potassium is useful in activation of enzymes, photosynthesis, starch synthesis, nitrate reduction and sugar degradation (Askegaard *et al.*, 2004). It is also important in helping plants withstand stresses like drought, winter hardiness, tolerance to diseases, insect pests and frost damage (Brady and Weil, 2000).

Results of several researches conducted in Ethiopia demonstrated that fertilizer applications increased crop yield in Ethiopia. Yesuf and Duga (2000a) reported that judicious application of N increased yield and protein content of wheat at farmers' fields.

Phosphorus fertilizer also improved yield of field pea (Amare *et al.*, 2005) and faba bean (Getachew *et al.*, 2007). Wassie Haile (2009) showed that integrated application of NPK fertilizers (at the rate of 110/40/100 kg ha<sup>-1</sup>, respectively) increased potato yield by 208% over the control. Daniel *et al.* (2008) emphasized that integrated use of 75% of recommended fertilizer rate along with farmyard manure improved tuber yield of potato by 29.59 ton ha<sup>-1</sup> over the control. Getachew Alemu (2001) also showed that combined application of N and P significantly improved grain yield and yield components of barley in Welo highlands of Ethiopia. Nevertheless, yield cannot be increased to the maximum unless other conditions are fulfilled (Ignatieff and Page, 1968).

### 3.2. Other Conditions Determining Efficiency of Mineral Fertilizers

Factors affecting crop response to fertilization can be grouped into five categories. They are soil factors, climatic factors, crop factors, fertilizer characteristics and management practices (Ignatieff and Page, 1968; Mortvedt *et al.*, 1999).

#### 3.2.1. Soil Factors

##### Soil Reaction

Two fundamental features limit the fertility of acid soils: impoverished nutrient status and the presence of toxic levels of some elements such as Al and Mn (Hynes and Naidu, 1991). Nitrogen availability is affected by soil pH. It has been reported that nitrogen is more available at a pH of 6.5 and 5.5 for mineral and organic soils, respectively (Miller and Donahue, 1990). Foth and Ellis (1997) also indicated that nitrogen availability is greatest between pH 6 and 8. Soil reaction has a tremendous effect on the activity and growth of microorganisms involved in mineralization of organic matter, hence it affects the availability of nutrients to plants (Robson and Abbott, 1989). Cornfield (1953) reported that acidification of a neutral soil (pH = 6.5) to pH 4.0 decreased ammonification and almost completely suppressed nitrification. Dancer *et al.* (1973) also has shown that nitrification did not occur when soil pH (1: 2.5, soil: water) was less than 4.1. Moreover, Morrill and Dawson (1960) indicated that the optimum pH values for the growth of *Nitrobacter* and *Nitrosomonas* were greater than 6.6 and 7.6,

respectively. Soil acidity has also long been recognized as harmful to symbiotic (Tisdale *et al.*, 1985) and non-symbiotic (Granhall, 1981) nitrogen fixation.

Alkaline pH reaction also has a detrimental effect on availability of nitrogen. When ammoniacal nitrogen fertilizers are spread on the surface of the soil with pH values greater than 7, ammonia could be lost by volatilization (Blackmer, 2000; Tisdale *et al.*, 1985). It was also reported that absorption of  $\text{NH}_4^+$  increases as pH increases (Lumbanranja and Evangelou, 1994), because 2:1 clay minerals dominate at higher pH values.

Soil reaction plays a tremendous role in availability of phosphorus. Phosphorus availability in most soils is at a maximum in the pH range of 6.0 - 6.5 (Hynes and Naidu, 1991). At low pH values, the retention of P results largely from the reaction with iron and aluminum and their hydrous oxides. A study conducted on some Paleudults of Southern Nigeria indicated that phosphate sorption at high P additions generally decreased with the increase in soil pH (Eze and Loganathan, 1990). The continuous decrease in phosphate sorption with increase in pH was due to the increased concentration of hydroxyl ions as pH increased and resulted in greater competition of these ions with phosphate ions for sorption. Ignatieff and Page (1968) indicated that the availability of phosphorus in superphosphate as well as the ability of plant roots to absorb it is lower in acid soils and thus higher applications are needed. In acidic soils, roots appear coralloid with many stubby lateral roots and branching of fine roots is restricted, which limits plants' ability to absorb water and nutrients (Prasad and Power, 1997).

There is also some evidence to show that phosphate sorption decreased with increase in pH up to 5.0 - 6.0, beyond which it increased. This is related to the availability of Ca and Mg, which forms precipitates (Barrow, 1987; Sims and Ellis, 1983; Tisdale *et al.*, 1985). Chen and Barber (1990) also reported that P in soil solution decreased with an increase in pH, which was explained by the formation of calcium phosphate with increase in solution Ca. Chen and Barber (1990) also studied the effect of change in pH by liming acid soils of three soil orders (Mollisols, Ultisols and

Oxisols) on soil solution, P concentration, labile P content and P uptake by maize. Results showed that increasing soil pH generally decreased soil solution P concentration and P uptake by the crop but increased labile P for all soils. The decrease in solution P was attributed to the formation of Ca phosphates. High soil pH values of about 7.5 to 8.0 and above favor the conversion of water soluble fertilizer phosphorus into less soluble forms of lower availability to crops (Tisdale *et al.*, 1985). Likewise, the availability of P especially in fertilizers containing no water-soluble phosphate is less in calcareous or alkaline soils (Ignatieff and Page, 1968).

Some reports also indicated that liming highly weathered soils above pH approximately 5.0 does not usually lead to increased P solubility although it may lead to increase in P uptake by plants (Fox *et al.*, 1991). Similarly, an equilibrium study of Lucedale sandy loam soil (fine loamy, silicious, thermic Rhodic Paleudults) with an initial pH of 5.2 showed that solution P levels increased with liming up to a pH of 5.7 then decreased at pH 6.2 and decreased further at 6.6 if the lime was added before the P (Soltanpour *et al.*, 1974).

In general, as soil pH increases from 4, the root and microbial environment changes. Therefore, there is a tendency for plant growth to increase with an increase in soil pH as the factors that limit growth were ameliorated. A plateau yield is reached where further increase in soil pH has little if any effect on plant growth (Foth and Ellis, 1997). The optimum soil pH for crop production is generally considered to be between 6.5 and 7.0 (Prasad and Power, 1997). The results of the experiment designed to investigate the effect of soil pH on maize grain yield on acid Ultisols indicated that grain yield was significantly reduced ( $p < 0.05$ ) when the pH was less than 5.5 (Fox, 1979). Similarly, Pearson (1975) reported that in the humid tropics liming, when the soil pH falls below 5.0 or the Al concentration exceeds 15%, increased maize yields. Foy (1984) also reported that in acid soils toxicities of aluminum and manganese and deficiencies of calcium and molybdenum might be as important as effects of hydrogen ions *per se*. Increasing pH of variable charge soils increases the cation exchange capacity of the soil, precipitates Al

that otherwise competes for exchangeable sites (Fox *et al.*, 1991).

#### **Clay Mineralogy and Clay Content**

The clay mineralogy of the soil plays a tremendous role in affecting the availability of nitrogen. Ammonium is fixed between the lattice of 2:1 expanding clays like illite and montmorillonite (Prasad and Power, 1997). Up to 10% of the total N in surface soils and 30% in sub-soils is reported to be adsorbed as  $\text{NH}_4^+$  in soil clay minerals in a non-exchangeable (fixed) form (Lumbanranja and Evangelou, 1984).

The more clay content the soil has, the more the CEC and the more the adsorption of  $\text{NH}_4^+$  will be (Anon, 1979). Prasad and Power (1997) also reported that most ammonium fixation occurs in the clay fraction of the soil, while some may occur in the silt fraction. Jensen *et al.* (1989) separated clay and silt fractions of four Danish soils by ultrasonic technique and found that fixed ammonium in the clay fraction it varied from 255 to 430  $\mu\text{g N g}^{-1}$ , while in the silt fraction varied from 72 to 166  $\mu\text{g g}^{-1}$ . Similarly, for a Canadian soil with 37% clay, Kowalenko and Ross (1980) reported ammonium fixation of 35  $\mu\text{g g}^{-1}$  for clay and 8.3  $\mu\text{g g}^{-1}$  for silt.

Owusu-Bennoah and Acquaye (1989) indicated that P sorption maxima of Ghanaian soils was significantly correlated with clay content ( $r = 0.894$ ), free  $\text{Fe}_2\text{O}_3$  ( $r = 0.830$ ) and free  $\text{Al}_2\text{O}_3$  ( $r = 0.912$ ) contents. Soils high in clay content and kaolinite clay minerals retain or fix more added P than other soils (Anon, 1979). The presence of amorphous materials such as allophane on the exchange complexes is also often associated with high P-fixation capacities and reduced P use efficiencies (Sanchez, 1976).

#### **Moisture Regime of the Soil**

The growth of many plants is proportional to the amount of water present in the soil since growth is restricted both at very low and very high levels of soil moisture (Tisdale *et al.*, 1985). A very close relationship exists between the continuous availability of soil moisture and the response of a crop to fertilizer applications. If soil moisture becomes a limiting factor during any stage of the growth of a crop, the addition of fertilizer may even

adversely affect the yield. This is because, the more vigorous early growth while moisture is available in the soil may cause the limited water supply to be exhausted more rapidly (Ignatieff and Page, 1968).

Nutrients will only be recovered efficiently if the crop has sufficient water. The amount of rainfall captured and made available to crops can be increased in areas that are prone to drought. Most approaches aim to harvest extra water by installing structures that decrease runoff (e.g., the Zaï system used in the Sahel or the use of planting basins in Southern Africa), or by maintaining organic mulch on the soil surface to promote infiltration and reduce evaporation from the soil surface. All such practices require extra resources (Handbook of Integrated Fertility Management, 2012)

Broadbent *et al.* (1988) found that a 10% reduction in applied water, expressed as a percentage of crop's evapotranspiration requirement by sorghum, decreased dry matter production by 1.6  $\text{Mg ha}^{-1}$ , grain yield by 1.9  $\text{Mg ha}^{-1}$ , total N uptake by 22  $\text{kg ha}^{-1}$  and grain N uptake by 9.3  $\text{kg ha}^{-1}$ . Power *et al.* (1961) also reported that 53% of the variation in fertilizer response of spring wheat (*Triticum aestivum* L.) on medium P soils was because of variation in available soil moisture. Tisdale *et al.* (1985) similarly indicated that crop response to fertilizer nitrogen is very dependent on moisture supplies during the growing season. It was observed that increasing nitrogen rates up to 168  $\text{kg ha}^{-1}$  under dry land conditions increased rape yield; however, high rates of nitrogen in combination with irrigation resulted in nearly fourfold increase in yield.

Excess moisture also adversely affects plant growth and development. Soils with poor drainage conditions have poor aeration and under such conditions most crops do not grow (Ignatieff and Page, 1968). Anaerobic soil condition has serious effect on the metabolism and growth of sensitive plants. Species intolerant of water logging experience an acceleration of endogenously produced ethanol and acetaldehyde, cell membranes become leaky and ion and water uptake is impaired which has the characteristic symptoms of wilting and yellowing of leaves (White, 1997). Tisdale *et al.* (1985) also reported that flooding of soil pores by excessive amounts of

moisture is detrimental since the resultant lack of oxygen restricts root respiration and ion adsorption.

In anaerobic conditions  $\text{NO}_3^-$  reduction and evolution of  $\text{N}_2\text{O}$  and  $\text{N}_2$  (denitrification) takes place that reduces the efficiency of fertilizers applied. Denitrification loss is serious in agricultural soils especially those exhibiting a mosaic of aerobic and anaerobic zones, because the aerobic condition supplies  $\text{NO}_3^-$  that will eventually denitrifies in the anaerobic layer (White, 1976). Excess gravitational water from heavy rainfall or irrigation will also move nitrate deeper in the soil profile, particularly in soils with rapid internal drainage like sands and loams, which minimize the efficiency of applied fertilizer (Strong and Mason, 1999).

#### **Impermeable Soil Layer**

A layer in the soil which is impermeable to plant roots (pan) restricts the soil volume which the plant roots may exploit. The soil declines more rapidly in fertility when the pan is close to the surface. This is because nutrients cannot be brought up from below the impermeable layer (Campbell *et al.*, 1974; Ignatieff and Page, 1968).

Continuous management on soils that are prone to compaction can result in a sub-surface soil barrier to crop root growth. Breaking such hardpans by deep ploughing or chisel ploughing to a depth of up to 30 cm allows roots to penetrate the hardpan and access more nutrients and water, resulting in better crop growth (Handbook of Integrated Fertility Management, 2012).

#### **Soil Texture and Bulk Density**

On coarse textured soils, it is often necessary to apply nitrogen fertilizer in several doses during the season because of the potential leaching of applied fertilizers (Ignatieff and Page, 1968). The higher the bulk density, the more compact the soil is and this is quite frequently reflected in restricted plant growth (Tisdale *et al.*, 1985). This is associated with poor water, nutrient and air supply which reduces nutrient use efficiency. Carter and Tevernetti (1998) showed that cotton (*Gossypium hirsutum* L.) yield decreased as soil bulk density increased from 1.5 to 1.6  $\text{Mg m}^{-3}$  on a sandy loam soil.

#### **Availability of other Nutrients in the Soil**

The presence of one essential nutrient with the other gives a synergistic effect and increases yield. Russel (1961) reported that adequate supply of nitrogen in the absence of K increased potato yield by 0.4 ton, and adequate supply of K in the absence of N increased potato yield by 2.5 tons. When the two elements were given together in adequate amounts, yield increase was 4.3 tons, which was by far greater than the sum of the individual effects.

Presence of N was reported to improve P use efficiency. Adams (1980) indicated that nitrogen could increase P concentration in plants by increasing root growth, increasing ability of roots to absorb and translate P.

In a field experiment with mustard (*Brassica juncea* L.), grain yield response to N was greater when S was applied and the response to S was greater when N was applied. The combined effect of N and S was greater than the sum of the individual effects of N and S (Dubey and Khan, 1993). Similarly, Teng and Timmer (1994) also reported that white spruce seedlings receiving  $\text{NH}_4\text{NO}_3$  alone increased in biomass by 34% while monocalcium phosphate addition stimulated growth by 107%.

It has been indicated that additions of large amount of P fertilizers to soils ameliorates not only the status of P in the soil but also diminishes the effects of Al toxicity due to the direct precipitation of Al-phosphates in the zone of P incorporation (Alva *et al.*, 1986; McLaughlin and James, 1991; White, 1976). This improves the capacity of plants to uptake other nutrients and enhances metabolism of crops. Wilson (1993) concluded that the response to one nutrient depends on the sufficiency level of other nutrients and yield depressions were found when high levels of one nutrient were combined with low levels of other nutrients.

#### **3.2.2. Climatic Factors**

##### **Temperature**

Chemical reactions generally double for each  $10^\circ\text{C}$  increase in temperature until the optimum temperature for the reaction was reached (Wilkinson *et al.*, 2000). The range of temperature for growth of most agricultural plants is between  $15$  and  $40^\circ\text{C}$  (Tisdale *et al.*, 1985). Temperature affects



photosynthesis, respiration, absorption of water by roots, mineral element absorption and finally yield of crops (Tisdale *et al.*, 1985). Wilkinson *et al.* (2000) also reported that temperature affects the growth of roots, which may limit nutrient uptake to shoots and growth of tops at low nutrient supply. It has been indicated that an increase in temperature from 5°C to 29°C increased root and shoot P, Mn and Fe contents (Tisdale *et al.*, 1985).

Marschner (1995) also reported that P uptake is depressed more than other nutrients by low root zone temperatures. Under cool conditions, which are not conducive to rapid rates of decomposition and nitrification of organic matter, more nitrogen fertilizer is needed than under warmer conditions (Ignatieff and Page, 1968). Generally, temperature affects plant growth and consequently affects demand for nutrients (Wilkinson *et al.*, 2000).

#### ***Light Intensity and Length of the Day***

Tisdale *et al.* (1985) indicated that net photosynthesis rate in maize is almost linearly proportional to radiation interception, provided that soil moisture is adequate. Crops growing under long-day conditions in the higher latitudes would require more fertilizer nutrients than crops growing under short-day conditions (Ignatieff and Page, 1968).

#### ***3.2.3. Crop Factors***

##### ***Crop Adaptability to Local Conditions***

Crops like rice grow under widely different conditions. This affects the nutrient requirements of different varieties of the same crop. With low land paddy, almost all nutrients are supplied by the soil above the impermeable layer, whereas with upland rice the roots are able to forage deeply for nutrients. Hence, the latter may need relatively less fertilizer application (Ignatieff and Page, 1968).

Plants that have evolved in desert region have adapted to thrive on neutral and alkaline soils and many desert plants have great tolerance for soluble salts and soluble Na (halophytes). Plants that are native to the humid tropics have high tolerance for soluble Al (Foth and Ellis, 1997). Therefore, plants will respond to applied fertilizer if they are grown in areas where they have adapted.

#### ***Fertilizer Requirement of the Crop***

The differences among crops in their nutrient requirements depend upon differences in actual uptake of mineral nutrients, differences in the ability to obtain nutrients from the soil, and symbiotic relationships that may exist between crops and microorganisms (Ignatieff and Page, 1968).

Those crops that accumulate high biomass remove more nutrients from the soil than otherwise. A good crop of oats may utilize only 80 kg N ha<sup>-1</sup>, while maize would utilize 140 kg N ha<sup>-1</sup> (Ignatieff and Page, 1968).

The difference among crops in ability to absorb nutrients from the same medium may depend upon the size of the root system and the inherent characteristics of the roots themselves (Ignatieff and Page, 1968). In a field experiment where equal amount of N was applied to maize (*Zea mays* L.) and brome grass (*Bromus enermis* L.), N recovery was found to be greater with brome grass than with maize due to better root system and greater biomass production (Power *et al.*, 1973). Khasawneh and Copeland (1973) also found that root length had a linear relationship with cotton P uptake. It was reported that <1% of the soil volume is usually occupied by plant roots and, therefore, any factor influencing root system size or morphology will likely affect the quantity of soil P that is available to a plant (Fixen and Groove, 1990).

Cereals and legumes have different demands for external fertilizer inputs. Legumes can grow on soils too low in available N if correct strain of rhizobium bacteria in the soil exists for proper nodulation and fixation of nitrogen (Ignatieff and Page, 1968). Large increase in uptake of most elements from soil can also occur by fungal symbiosis with the root, both with ectomycorrhizal and endomycorrhizal infection of a wide range of species (Bown and Cartwright, 1977). Suwanarit *et al.* (1997) carried out a pot experiment to test effectiveness of some arbuscular mycorrhizal fungal species and found that maize plants inoculated with *Scutellospora* sp. and *Acaulospora spinosa* gave significant increases in plant dry matter yield.

Variation in crop yield also occurs as a result of varietal differences within a single crop species. High

crop yields produced with modern hybrids, varieties and lines require more plant nutrients than was necessary for the lower yields of the past, because under low-fertility condition a new high-yielding variety cannot develop its full yield potential (Tisdale *et al.*, 1985). It is a well known fact that improved varieties usually have a larger harvest index. They also usually have higher agronomic efficiency compared with 'local' varieties. Foth and Ellis (1997) also indicated that there are varieties of a particular crop that are efficient in utilizing limited amount of nutrient supply in the soil. Other crop factors affecting response of crops to applied fertilizer are resistance to diseases, pests, drought and other stress factors (Prasad and Power, 1997).

### 3.2.4. Fertilizer Characteristics

The response of crops to similar rates of one nutrient element from different sources may be different because the availability of an element found in different fertilizers is not equal. Nitrate is the preferred form of N for uptake by most plants, and it is usually the most abundant form that can be taken up in well-aerated soils (Blackmer, 2000). Prasad and Power (1997) also indicated that in most well-drained soils suitable for crop production, oxidation of  $\text{NH}_4^+$  to  $\text{NO}_3^-$  is fairly rapid and, therefore, most plants growing under well-drained conditions have developed to grow better with  $\text{NO}_3^-$ -N. Debreczeni (2000) tested the response of two maize hybrids to different nitrogen forms ( $\text{NH}_4^+$ -N and  $\text{NO}_3^-$ -N) and found that N uptake and grain yield of both varieties was considerably higher from  $\text{NO}_3^-$ -N source than  $\text{NH}_4^+$ -N source.

However, the quantities of  $\text{NH}_4^+$ -N can exceed those of  $\text{NO}_3^-$ -N in anaerobic soils (Blackmer, 2000). For crops growing under submerged conditions, like rice,  $\text{NH}_4^+$ -N is the ideal N source because  $\text{NO}_3^-$ -N under such conditions could be lost by denitrification (Prasad and Power, 1997). Some reports also indicated that growth of plants is often improved when they are nourished with both  $\text{NO}_3^-$ -N and  $\text{NH}_4^+$ -N rather than with either  $\text{NO}_3^-$ -N or  $\text{NH}_4^+$ -N (Hageman, 1984; Tisdale *et al.*, 1985).

Fertilizer sources affect the chemistry of the soil and indirectly determine the availability and uptake of nutrients. Some fertilizers change soil reaction to

acidity, others to alkalinity, but the third group have little or no effect. Ammonium fertilizers, like  $\text{NH}_4\text{Cl}$ , acidify soil reaction whereas nitrate sources, like  $\text{NaNO}_3$ , do the opposite. It has been confirmed by reports of many authors that ammonia-based nitrogen fertilizers reduce soil pH during the oxidation process to  $\text{NO}_3^-$ . In this case, 1 mole of  $\text{NH}_4^+$  produces 2 moles of  $\text{H}^+$  (Schwab *et al.*, 1990). Abruna *et al.* (1958) applied very high rates of  $\text{NH}_4^+$ -N (up to 1200  $\text{kg ha}^{-1} \text{ yr}^{-1}$ ) for three years and observed a change in pH from 7 to 3.9 in the surface soil (0 to 15 cm). Miller and Donahue (1990) also reported that about 1.8 kg of pure lime was required to neutralize the acidity of 1 kg of urea-nitrogen or ammonium-nitrogen. Fox and Hoffman (1981) observed the change in pH of surface 2.5 cm of a Typic Hapludult (pH = 6.7) receiving 202  $\text{kg N ha}^{-1} \text{ yr}^{-1}$  as  $\text{NH}_4\text{NO}_3$ , urea, UAN,  $(\text{NH}_4)_2\text{SO}_4$  for 5 years. After five years, the soil pH in plots that received N as  $\text{NH}_4\text{NO}_3$ , urea or UAN decreased to 5.7, while in plots receiving the same rate of N as  $(\text{NH}_4)_2\text{SO}_4$ , the pH dropped to 4.7.

Fertilizer characteristics also influence availability of P to plants highly. The amount of total P contained in rock phosphate and triple super phosphate (TSP) does not have a big difference. Rock phosphate contains 13 - 17% total P and TSP contains 20 - 22% total P. Nevertheless, only 0.8 - 2.2% from rock phosphate is available while the whole P in TSP is in available form (Miller and Donahue, 1990).

The response to mineral fertilizer is greater when fertilizer is applied with added organic resources (Handbook of Integrated Fertility Management, 2012). It is apparent that organic inputs have a lot of benefits. They are useful by increasing the crop response to mineral fertilizer; improving the soil's capacity to store moisture; regulating soil chemical and physical properties that affect nutrient storage and availability as well as root growth; adding nutrients not contained in mineral fertilizers; creating a better rooting environment; improving the availability of phosphorus for plant uptake; ameliorating problems such as soil acidity; and replenishing soil organic matter. Hence, integrated nutrient management is useful to maximize crop yield. Crop based farm system will require more artificial fertilizer and is less efficient than crop-

animal mixed farming system where organic matter is added to the soil in the form of manure.

### 3.2.5. Management practices

Farm management is a key for outstanding crop yield. Asnakew (1990), Lema *et al.* (1992), Yesuf and Duga (2000b) reported that improved wheat varieties were responsive to management and input. Therefore, farmers should follow the following to achieve high crop yield.

#### Erosion control

Soil erosion can be a serious problem, especially on fields with steep slopes, and on slightly sloping fields with coarse textured topsoil that is prone to erosion. Soil organic matter and nutrients are lost in eroded soil, which may substantially reduce the agronomic efficiency of applied inputs. Several measures can assist in controlling erosion, including planting of live barriers (e.g., grass strips), construction of terraces, or surface mulch application.

#### Land preparation

Appropriate seedbed preparation is a prerequisite to achieve good crop establishment, particularly with crops that produce small seeds. Germination is improved (and seed requirements may be reduced) when the top soil is cultivated to produce a tilth comprising small particles.

#### Planting date and practice

A delay in planting date usually affects yields negatively, particularly where the growing season is short. Planting date should be selected based on knowledge of the onset of the rainy season. Early planting is generally a prerequisite for achieving high yields.

When crops are planted together, they compete with each other for nutrients, light, and water. Appropriate planting densities, expressed as number of plants per hectare need to be adjusted for different environments and these are often reduced when rainfall and soil fertility conditions are suboptimal. It is also important to consider the distance between planting rows, the distance between plants within a row, and the number of plants per planting hole.

Seed viability should be at least 80% to achieve a full crop stand. Seeds of cereals and grain legume crops

should be planted at the correct depth. More seeds than required to reach the optimal planting density are planted to allow for thinning and incomplete germination.

#### Weed, pest and disease management

Weeds compete with crops for nutrients, water, and light, and their timely removal has a substantial impact on crop yield. It is also important to weed before applying top-dressed fertilizer so that the nutrients applied benefit the crop and not weed growth. Pests and diseases must be controlled at specific crop growth stages. Treated seed should be used where there is a risk of pest attack in the seed bed. In many crops, pest and disease control will be required, usually between flowering and pod or grain filling. Failing to do so will result in an unhealthy crop that will use nutrients and water inefficiently.

#### 4. Conclusion

Crop yield can be improved by the combination of genotype, optimum environmental condition and appropriate management practices which can be generalized by the formula:  $\text{Yield} = G (\text{genotype}) \times E (\text{environment}) \times M (\text{management})$ . The genotype refers to healthy seeds of high yielding varieties; environment refers to the soil's physical and chemical properties and climate in the particular location; and management refers to the farmers' ability and skill in managing crops and the farming system.

#### References

- Abruna, F., R. W. Pearson and C. B. Elkins. 1958. Quantitative evaluation of soil reaction and base status changes resulting from field application of residually acid-forming nitrogen fertilizers. *Soil Sci. Soc. Am. Proc.* 22 : 539-542.
- Adams, F. 1980. Interactions of phosphorus with other elements in soils and in plants. *Cited by* S. R. Wilkinson, D. L. Grunes and M. E. Sumner. 2000. Nutrient interaction in soil and plant nutrition, pp. D-89 – D-12. *In* M. E. Sumner ed. *Handbook of Soil Science*. CRC Press, LLC.
- Alva, A. K., D. G. Edwards, C. J. Asher and F. P. C. Blamey. 1986. Effects of phosphorus/aluminum molar ratio and calcium concentration on plant response to aluminum toxicity. *Soil Sci. Soc. Am. J.* 50 : 133-137.

- Amare G., CC. Du Preez and Taye Bekele. 2005. Effect of phosphorus fertilizer on grain yield and yield components of field pea (*Pisum sativum* L) cultivars. Ethiopian Journal of Natural Resources 7(1):1-21.
- Anon. 1979. Soil Fertility Manual. The Potash and Phosphate Institute, Atlanta, Georgia, USA.
- Askegaard, M., Erisksen, J., and A.E. Johnston. 2004. Sustainable management of potassium. pp.88-102. In SchjOnning, P., Elmoholt, S., and B.T. Christensen (eds.) Managing Soil quality: Challenge in modern agriculture. CAB International, London.
- Asnakew W. 1990. The response of bread wheat to the rate and time of nitrogen application. In Tanner, D.G and W. Mwangi (eds.) pp. 146-152. Six Regional Wheat Workshop for Eastern, Central and Southern Africa, Mexico D.F. CIMMYT.
- Barrow, J. J. 1987. Reactions with variable-charged soils. Fert. Res. 14 : 1-10.
- Blackmer, A. M. 2000. Bioavailability of nitrogen, pp. D-3 – D-18. In M. E. Sumner ed. Handbook of Soil Science. CRC Press, LLC.
- Bown, G. D. and B. Cartwright. 1977. Mechanisms and models of plant nutrition, pp.197-223. In J. S. Russel and E. L. Greacen eds. Soil Factors in Crop Production in a Semi-Arid Environment. University of Queensland Press, Australia.
- Brady, N. C. and R. R. Weil. 2000. Elements of the Nature and Properties of Soils. 12th ed. Printice-Hall Inc, Upper Saddle River, New Jersey. 759p.
- Broadbent, F. E., T. Nakashima and D. E. Rolston. 1988. Effects of salinity and moisture gradients on nitrogen uptake by sorghum and wheat. Soil Sci. Soc. Am. J. 146 : 232-240.
- Campbell, R. B., D. C. Reicosky and C. W. Doty. 1974. Physical properties and tillage of Paleudults in the Southeastern Coastal Plains. J. Soil Water Conserv. 29 : 220-224.
- Carter, L. M. and J. R. Traveretti. 1968. Influence of precision tillage and soil compaction on cotton yields. Trans. Am. Soc. Agri. Eng. 11 : 65-67.
- Chen, J. H. and S. A. Barber. 1990. Effect of liming and adding phosphate on predicted phosphorus uptake by maize on acid soils of three soil orders. Soil Sci. J. 150 : 844-850.
- Cornfield, A. H. 1953. The mineralization of nitrogen of soils during incubation: Influence of pH, total nitrogen and organic carbon contents. J. Sci. Food Agr. 3 : 343-348.
- Dancer, N. S., L. A. Peterson and G. Chesters. 1973. Ammonification and nitrification of N as influenced by soil pH and previous N treatments. Soil Sci. Soc. Am. Proc. 37: 67-69.
- Daniel M., L.M. Pant and Nigusie D. 2008. Effect of integrated nutrient management on yield of potato and soil nutrient status at Bako, West Shoa. Ethiopian Journal of Natural Resources 10(1):85-101.
- Debreczeni, K. 2000. Response of two maize hybrids to different fertilizer-N forms (NH<sub>4</sub>-N and NO<sub>3</sub>-N). Commun. Soil Sci. Plant Anal. 31 : 2251-2264.
- Dubey, O. P. and R. A. Khan. 1993. Effect of nitrogen and sulfur on dry matter, grain yield and nutrient content at different growth stages of mustard (*Brassica juncea* L.) under irrigated Vertisol. Cited by R. Prasad and J. F. Power. 1997. Soil Fertility Management for Sustainable Agriculture. Lewis Publishers, CRC Press, LLC. 356p.
- Eze, O. C. and P. Loganathan. 1990. Effects of pH on phosphate sorption of some paleudults of Southern Nigeria. Soil Sci. Soc. Am. J. 150 : 813-621.
- FAO (Food and Agriculture Organization of the United Nations). 1984. Fertilizer and plant nutrition guide. cited in D. van der Eijk. 1997. Phosphate fixation and response of maize to fertilizer phosphate in Kenyan Soils. Ph.D. Thesis, Department of Soil Science and Plant Nutrition, Agricultural University of Wageningen The Netherlands
- Fixen, P. E. and J. H. Groove. 1990. Testing soils for phosphorus, pp. 141-180. In R. L. Westerman ed. Soil Testing and Plant Analysis. 3<sup>rd</sup> ed. SSSA, Madison, Wisconsin.
- Foth, H. D. and B. G. Ellis. 1997. Soil Fertility. 2<sup>nd</sup> ed. Michigan State University, Michigan, USA. 290p.
- Fox, R. H. 1979. Soil pH, aluminum saturation and corn grain yield. Soil Sci. J. 127 : 330-334
- Fox, R. L., N. V. Hue, R. C. Jones and R. S. Yost. 1991. Plant- Soil interactions associated with acid weathered soils, pp. 197-204. In R. J. Wright, V. C. Valigar and R. P. Murrmann eds. Proc. 2<sup>nd</sup> International Symposium on Plant-Soil

- Interactions at Low pH. 24-29 June, 1990. Bockley, West Virginia, USA.
- Fox, R. H. and L. D. Hoffman. 1981. The effect of N fertilizer source on grain yield, N uptake, soil pH and lime requirement on no-till corn. *Agron. J.* 7 : 891-895.
- Foy, C. D. 1984. Physiological activities of hydrogen, aluminum and manganese toxicities in acid soil, pp. 57-97. *In* F. Adams ed. *Soil Acidity and Liming*. American Society of Agronomy, Madison, Wisconsin
- Getachew A. 2001. Response of barley to nitrogen and phosphorus applications in Welo highlands of Ethiopia: Yield and Yield Components. *Ethiopian Journal of Natural Resources* 3(1) 19-38.
- Getachew A. Taye B. and Agajie T. 2007. Phosphorus fertilizer and farmyard manure effects on faba bean in acidic Nitisols of central highlands of Ethiopia. *Ethiopian Journal of Natural Resources* 7(1):23-39.
- Granhall, U. 1981. Biological nitrogen fixation in relation to environmental factor and functioning of natural ecosystems, pp. 131-144. *In* F. E. Clark and T. Rosswall eds. *Terrestrial Nitrogen Cycles*. *Ecol. Bull.* 33, Stockholm.
- Hageman, R. H. 1984. Ammonium vs. nitrate nutrition of higher plants, pp. 67-85. *In* R. D. Hauck ed. *Nitrogen in Crop Production*. Am. Soc. Agron. Madison, Wisconsin.
- Handbook of Integrated Fertility Management. 2012. Edited by Thomas Hairhurst. Africa South Health Consortium. CAB International.
- Havlin, J.L., Beaton J.O., Tisdale S.L., and W.L. Nelson. 2005. *Soil fertility and fertilizers*. 6th edition. Prentice Hall, Upper Saddle River, New Jersey, USA. 499p.
- Hynes, R. J. and R. Naidu. 1991. Effects of lime additions on the availability of phosphorus and sulfur in some temperate and tropical acid soils, pp. 267-274. *In*: R. J. Wright, V. C. Baligar and R. P. Murrmann eds. *Proc. 2<sup>nd</sup> International Symposium on Plant-Soil Interactions at Low pH*. 24-29 June, 1990. Bockley, West Virginia, USA.
- Ignatieff, V. and H. J. Page. 1958. *Efficient Use of Fertilizers*. FAO, Italy. 355p
- Jensen, E. S., B. T. Christensen and L. H. Sorensen. 1989. Mineral-fixed ammonium in clay and silt-size fractions of soils incubated with <sup>15</sup>N ammonium sulfate for five years. *Cited by* R. Prasad and J. F. Power. 1997. *Soil Fertility Management for Sustainable Agriculture*. Lewis Publishers, CRC Press, LLC. 356p.
- Khasawneh, F. E. and J. P. Copeland. 1973. Cotton root growth and uptake of nutrient: relation of phosphorus uptake to quantity, intensity and buffering capacity. *Soil Sci. Soc. Am. Proc.* 37 : 250-254.
- Kowalenko, C. G. and G. T. Ross. 1980. Studies on the dynamics of recently clay-fixed NH<sub>4</sub> using <sup>15</sup>N. *Cited by* R. Prasad and J. F. Power. 1997. *Soil Fertility Management for Sustainable Agriculture*. Lewis Publishers, CRC Press, LLC. 356p.
- Lema Z., Zewdu Y., Tanner, D.G. and Eyasu Elias. 1992. The effects of nitrogen fertilizer rates and application timing on bread wheat in Bale Region of Ethiopia. *In* Tanner, D.G and W. Mwangi (eds.) pp. 494-502. *Seventh Regional Wheat Workshop for Eastern, Central and Southern Africa*, Nauru, Kenya.
- Lumbanranja, L. and V. P. Evangelou. 1994. Adsorption/desorption of potassium and ammonium at low cation concentrations in three Kentucky subsoils. *Soil Sci. Soc. Am. J.* 157 : 269-278.
- Marschner, H. 1995. *Mineral Nutrition of Higher Plants*. *Cited by* S. R. Wilkinson, D. L. Grunes and M. E. Sumner. 2000. Nutrient interactions in soil and plant nutrition, pp. D-89 – D-112. *In* M. E. Sumner ed. *Handbook of Soil Science*. CRC Press, LLC.
- Miller, R. W. and R. L. Donahue. 1990. *Soils: An Introduction to Soils and Plant Growth*. 6<sup>th</sup> ed. Prentice-Hall inc., NJ, USA. 768p.
- Morrill, L. G. and J. E. Dawson. 1962. Growth rate of nitrifying chemoautotrophs in soil. *J. Bacteriology* 83 : 205-206.
- Mortvedt J.J., Murphy L.S and Follet R.H. 1999. *Fertilizer technology and application*. Mister Publishing Co, USA. 199p.
- Owusu-Bennoan, E. and D. K. Acquaye. 1989. Phosphate sorption characteristics of selected major Ghanaian soils. *Soil Sci. Soc. Am. J.* 148 : 114-123.
- Pearson, R. W. 1975. Soil acidity and liming in the humid tropics. *Cited by* R. H. Fox. 1979. *Soil*



- pH, aluminum saturation and corn grain yield. *Soil Sci. J.* 127 : 330-334.
- Pocock, T., Milford, G.F.G., and M. Armstrong. 1988. Progress in search toward site-specific fertilizer requirements. *British Sugar Beet Review* 56:41-44
- Power, J. F., J. Alessi, G. A. Reichman and D. L. Grunes. 1973. Recovery, residual effects and fate of nitrogen fertilizer sources in a semi-arid region. *Cited by* R. Prasad and J. F. Power. 1997. *Soil Fertility Management for Sustainable Agriculture*. Lewis Publishers, CRC Press, LLC. 356p.
- Prasad, R. and J. F. Power. 1997. *Soil Fertility Management for Sustainable Agriculture*. Lewis Publishers, CRC Press, LLC. 356p.
- Robson, A. D. and L. K. Abbott. 1989. The effect of soil acidity on microbial activity in soils, pp. 139-165. *In* A. D. Robson ed. *Soil Acidity and Plant Growth*. Academic Press, Australia.
- Russel, E. W. 1961. *Soil Conditions and Plant Growth*. 9<sup>th</sup> ed. Longmans, UK. 849p.
- Sanchez, P. A. 1976. Properties and Management of Soils in the Tropics. *Cited by* W. R. Raun and H. J. Barreto. 1995. Regional maize grain response to applied phosphorus in Central America. *Agron. J.* 87 : 208-213.
- Scott, R and K.W. Jaffard. 1993. Crop physiology and agronomy, pp 178-237. *In*: D.A. Cooke and R.K. Scott (ed.). *The sugar Beet Crop: Science into Practice*. Chapman and Hall, London.
- Sims, J. T. and B. G. Ellis. 1983. Adsorption and availability of phosphorus following the application of limestone to an acid aluminous soil. *Soil Sci. Soc. Am. J.* 47 : 888-916.
- Soltanpour, P., N. F. Adams and A. C. Bennett. 1974. Soil phosphorus availability as measured by displaced soil solutions, calcium chloride extracts, dilute acid extracts, and labile phosphorus. *Soil Sci. Soc. Am. J.* 38 : 225-228.
- Strong, W. M. and M. G. Mason. 1999. Nitrogen, pp. 171-186. *In* K. I. Peverill, L. A. Sparrow and D. J. Reuter eds. *Soil Analysis: an Interpretation Manual*. CSIRO, Australia.
- Suwanarit, A., P. Suwanarit, S. Boonlue, P. Laoniphon, S. Buranakarn and R. Pitukdantham. 1997. Improving Nutrition Status of Soils in Thailand by the Use of Soil Microbiology Methods. Final Scientific Report STD 3 Project CT. 39-0256. Kasetsart University, Bangkok, Thailand.
- Teng, Y. and V. R. Timmer. 1994. Nitrogen and phosphorus interactions in an intensively managed nursery soil-plant system. *Soil Sci. Soc. Am. J.* 58 : 232-238.
- Tisdale, S. L., W. L. Nelson and J. D. Beaton. 1985. *Soil Fertility and Fertilizers*. 4<sup>th</sup> ed. Macmillan Publishing Co. Inc., New York. 754p.
- Wassie Haile. 2009. Onfarm verification of potassium fertilizer effect on the yield of irish potato grown on Acidic Soils of Hageremariam, Southern Ethiopia. *Ethiopian Journal of Natural Resources* 11(2):207-221.
- White, R. E. 1976. Studies on the mineral absorption by plants. III. The interaction of aluminum, phosphate and pH on the growth of *Medicago sativa*. *Plant Soil* 46 : 195-203.
- White, R. E. 1997. *Principles and Practices of Soil Science: A Soil as a Natural Resource*. 3<sup>rd</sup> ed. Blackwell Science Ltd. 198p.
- Wilkinson, S. R., D. L. Grunes and M. E. Sumner. 2000. Nutrient interactions in soil and plant nutrition, pp. D-89 – D-12. *In* M. E. Sumner ed. *Handbook of Soil Science*. CRC Press, LLC.
- Wilson, J. B. 1993. Macronutrient (NPK) toxicity and interaction in the grass *Festuca ovina*. *J. Plant Nutr.* 16 : 1151-1159.
- Yesuf A. and Duga D. 2000a. The effect of rate and time of N application on its uptake by bread wheat varieties and soil characteristics on farmers' fields. *Ethiopian Journal of Natural Resources* 2(2) 137-150.
- Yesuf A. and Duga Debele. 2000b Economic analysis of rate and time of N application on two recently released bread-wheat varieties on farmers' fields. *Ethiopian Journal of Natural Resources* 9(2):137-150.
- Yihenew.G.S. 2007. Evaluation of nitrogen and phosphorus as yield-limiting nutrients for maize grown on Alfisols of Western Amhara. *Ethiopian Journal of Natural Resources* 9(1):155-170.
- Yihenew G. and A. Suwanarit. 2007. Evaluation of soil-test methods for indexing availability of nitrogen for maize (*Zea mays* L.) grown on Alfisols of Northwestern Ethiopia. *Ethiopian Journal of Natural Resources* 9(2): 171-189.