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Improved Rice Seed Production and Marketing: Challenges and Opportunities; the Case of Fogera District of Ethiopia

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Abstract

Ethiopia has the potential to increase rice production and productivity, though the present availability of quality seeds falls well below present demand due to many constraints associated with seed production, marketing and delivery system. Consequently, the study has focused to assess the major constraints and opportunities of seed production and marketing for improved rice varieties. For this study purpose, 151 households were randomly drawn from three randomly selected Kebeles in probability proportional to size method in Fogera district of Ethiopia. The research results revealed that rice production is constrained by seed production and marketing bottle-necks; these includes, serious problems in accessing seed and fertilizer at planting time, lack of seed credit access and fair price of fertilizer, poor delivery systems of inputs, lack of access to farmers club and fair seed price. However, willingness of the households to adopt new rice varieties, training about the new varieties and fair grain prices were among the opportunities to the households. Therefore, to solve these problems, decision makers should pursue policies and investments to boost agricultural production and productivity, particularly with respect to the food staple crops like rice that are critical in reducing poverty. Hence, access and availability to improved production technologies orchestrate through production, marketing and delivery of improved seeds.

Key words: Rice seed production, Seed marketing, Constraints, Opportunities

1. Introduction

In the world, the largest volume of rice production is concentrated in countries China, India, Indonesia, Vietnam, Thailand, Bangladesh, Burma, Philippines, Brazil and Japan. The percentage share of the above top ten rice producing countries accounts for about 32.9 ,24.4, 11.0, 7.0, 6.0, 5.4, 5.3 2.9 and 1.8 % of the world production respectively. Ethiopia is 73rd in the world ranking with almost 0.0% (FAO, 2013).

Global rice consumption is expected to exceed rice production in 2016-17 and remain so in the next few years. In its projections for next five years up to 2018-19, the IGC says that global rice production is expected to continue rising over the projection period, but it is likely to be at a decreasing rate. Rice production growth in the period 2014-15 to 2018-15 is projected at 0.8%, lower than the demand growth projected at 1% in the same period. Global rice production is expected to grow to around 488 million tons in 2016-17. In 2017-18, estimated consumption of around 494 million tons is about 2 million tons more than the estimated production of around 492 million tons, while rice consumption of around 498 million tons in 2018-19 is about 3 million tons more than estimated global production of around 495 million tons. The slow growth rate in global rice production is attributed to an expected decline in rice production in China, the world’s largest producer and consumer of rice (IGC, 2014).

Rice is an important staple food crop in Africa with a growing demand that poses an economic challenge for the African continent. Annual rice production in Sub-Saharan Africa (SSA) is estimated at 14.5 million metric tonnes (MT), comprising 15 percent of the region’s cereal production. Most of this rice is produced by smallholder farmers. In contrast, Africa’s rice consumption is about 21 million MT creating a deficit of about 6.5 million MT per year valued at US$ 1.7 billion that is imported annually. Overall, imported rice accounts for roughly 40 percent of Sub-Saharan Africa local rice consumption (AATF, 2013). This indicates that the region needs to increase production and productivity to fill the gap of demand and supply created in rice consumption.

The Food and Agriculture Organization of the United Nations (FAO, 2013 sited by Nitrogen-Use Efficient, Water-Use Efficient and Salt-Tolerant Rice Project), forecasts that the world’s largest proportionate increase in rice consumption over the next 10 years will occur in Africa. The insufficient rice production affects the well-being of over 20 million smallholder farmers who depend upon rice as their main food. SSA countries are spending more than US$ 1.7 billion annually on rice imports. The rice production deficit along with the subsequent large outflow of foreign exchange presents a great development challenge to governments and development agencies in SSA. More than half of the rice consumed in SSA today is imported mainly due to very low yields being experienced by farmers. The average grain yield in Africa (2.2 t/ha) is below the world average (3.4 t/ha) by 49 percent[1]. This further imply that though there is a huge potential to cultivate rice in Africa, improving the productivity level due to the fact that by using, delivering improved varieties and production techniques would enhance and fill the productivity difference of Rice in Sub-Saharan countries and the world. According to the FAOSTAT data, rice production in Ethiopia showed a tremendous increase in production that is from 10,000 metric tons to 121,000 metric tons. Though there is no data on the rice import, Ethiopia imports, 17.412, 30, 44.41 and 22.4 metric tons of rice starting from 2005 up to 2008, respectively. The import level decreased from 44.41 to 22.40 metric tons in 2007 and 2008 respectively. This may be because of the increase in rice production from 11.244 to 71.4 metric tons.

Rice is a new crop for the country. Before seven years, there has not been any large-scale commercial rice farm (Esayas Kebede, 2011). The author further stated that, currently the development in commercial rice farming is encouraging. The Federal government administers 3.6 million hectares of land in Gambella, Benishangul Gumuz, Oromiya, and SNNP regions. Out of these, around 398,000 hectare of land has been transferred to local and foreign investors. From the total land transferred to investors, the share of rice farms is around 83,000 hectares, which about 21% of the commercial investment land.

Among the target commodities which have received due attention in promotion of agricultural production, rice is the one considered as the “millennium crop” expected to contribute to ensuring food security in the country. Accordingly, Ethiopian Institute of Agricultural Research (EIAR) has treated it as one of nationally coordinated research projects. As the crop is a recent introduction in the country, its research status is at infant stage. Almost all research activities are concentrated on variety development and there are only a few research activities on crop management, while the other research disciplines are yet hardly touched (Sewagegne, 2011).

So far, 20 improved rice varieties have been officially released officially for large-scale production. Of these, seven are upland New Rice for Africa (NERICA) rice varieties including NERICA-4 and NERICA-3 released for rain-fed upland ecosystem and NERICA-1, NERICA-2, NERICA-6, NERICA14 and NERICA-15 released for upland -irrigated ecosystem. NERICA rice varieties have been developed by Africa Rice (the ex-WARDA) scientists, and they are expanding and bringing the rice green revolution in different countries of Africa. Out of the remaining 13 released varieties, four varieties are irrigated, two varieties are lowland rain-fed, and seven varieties are upland rain-fed types. Moreover, Farmers have also given due attention not only for rice production but also for variety development as they have developed two varieties (one upland and one lowland

[1] Nitrogen-Use Efficient, Water-Use Efficient and Salt-Tolerant Rice Project. pp2.

rain-fed types) through selection. The two farmer-selected varieties (Demwoze and Nechu Ruz) have been produced widely in Fogera area (rain-fed lowland) of the Amhara Region and in Guraferda area (upland) of the Southern Nations, Nationalities, and Peoples Region (Sewagegne, 2011).

Therefore, to widely promote, disseminate and scale-up so far released improved varieties to smallholder farmers seed systems takes the lion share. However, seed systems and markets are subject to many constraints, of which mainly associated with failures that complicate early stages of seed market development. These constraints are contestable property rights relating to the improvement of cultivated varieties (cultivars); absent institutions in the market for improved cultivars; and information asymmetries in the exchange of seed between buyers and sellers (Gisselquist and Meer 2001; Hassan *et al.* 2001; Morris, 1998; Tripp and Louwaars, 1997).

Furthermore, rice seed systems in Africa in general and West Africa in particular faces both an opportunity and challenges. Among the sub-regional opportunities mentioned are initiatives to intensify cereal production, emergence of new better qualified stakeholders in the seed sector, availability of promising varieties (eg. NERICA varieties), and establishment of new seed policies to account seed harmonization and legislation), However, lack of establishing a dynamic and profitable seed system, lack of stakeholders capacity in different segments of the seed sector, lack of linkage to ensure joint planning of supply and demand, lack of producers access to credit and quality seed and timely provision of performing varieties are among the challenges (Omar, 2010).

In Ethiopia, progress in developing the seed system has already been made, and can be built on, including further development of improved varieties, increased farmer knowledge about input potential, and a clear policy direction that involves all stakeholders. Increasing quality and usage of improved seed (along with other best practices such as irrigation, fertilizer adoption, and mechanization) has the potential to dramatically increase Ethiopia's annual crop production. This implies that creating a vibrant seed sector through enhanced access and availability of seed has the potential to greatly improve smallholder productivity; there is currently a substantial gap between the country's production of commercial seeds and farmers' demand, knowledge, access and usage of these seeds. A series of constraints span both the hybrid maize and Self Pollinating seed systems (Dawit, *et al*., 2008).

Generally, the seed systems in Ethiopia are considered inefficient and inadequate. Hence, infrastructure, delivery system and vague estimates of the actual demand for improved seed amongst smallholder farmers, barriers to seed dissemination result because of a number of socio--economic constraints, like price and price variability, preferences and practices (Dawit *et al*., 2008)

As a result, this research paper tried to identify challenges and opportunities in rice seed production and marketing in Fogera, which is the potential rice growing area in Ethiopia. Generally, production, marketing and biological constraints, challenges and opportunities of rice seed system were analysed to improve the seed marketing system of rice at households and institutional levels are identified to address the stated objective of the study.

Results of the study would help the development planners and policy makers in preparing the rice production and supply plan as an alternative strategy for food security problem for the study area, taking into consideration the local factors. Hence, these information will be necessary when designing and improving farm input policy, modelling seed distribution systems and crafting strategies to improve adoption and reduce poverty in rural areas.

2. Materials and Methods

2.1 Description of the study area

Based on the CSA (2008), Amhara Region has a population of 17.2 million of which about 8.6 million were men and 8.5 million were women. Urban inhabitants were 2.1 million or 12.3% of the total population. With an estimated area of 0.16 million square kilometres, this region has an estimated population density of 108.15 people per square kilometre. For the entire region about 4 million households were counted. This results to an average of 4.3 persons per household. The average family size in urban and rural area is 3.3 and 4.5 persons, respectively.

Fogera Wereda is one of the 106 Woredas of the Amhara Regional State and found in South Gondar Zone. It is situated at 11^{0} 58 N latitude and 37^{0} 41 E longitude. Woreta is the capital of the Woreda and is found 625 km from Addis Ababa and 55 km from the Regional capital, Bahir Dar. The woreda is bordered by LiboKemkem Woreda in the North, Dera Woreda in the South, Lake Tana in the West and Farta Woreda in the East. The Woreda is divided into 29 rural kebeles and 5 urban Kebeles (RDBOA, 2007/8).

The total land area of the Woreda is 117,414 ha. The current land use pattern includes 44 percent cultivated land, 24 percent pasture land, 20 percent water bodies and the rest for others. The total population of the Woreda is 251,714. The rural population is estimated at 220,421. The proportion of male and female population is almost similar in both rural and urban areas. The number of agricultural households is 44,168.

The mean annual rainfall is 1216.3 mm, with Belg and Meher cropping seasons. Its altitude ranges from 1774 up to 2410 masl allowing a favourable opportunity for wider crop production and better livestock rearing (IPMS, 2005). Most of the farm land was allocated for annual crops where cereals covered 51,472 hectares; pulses cover 9819.98 hectares; oil seeds 6137 hectares; root crops 1034.29 hectares; and vegetables 882.08 hectares (CSA, 2003). The major crops include *teff*, maize, finger millet and rice, in order of area coverage. According to IPMS (2005), average land holding was about 1.4 ha with minimum and maximum of 0.5 and 3.0 ha, respectively.

1.2 Method of Data Collection and Analysis

1.2.1 Method of data collection

The data for this study were collected from primary sources and from different secondary sources. Primary data were collected from samples of the respondents. The data was collected through a questionnaire survey on input usage, credit facilities, and agricultural extension service, marketing information, and institutional support activities and used to analyze production and marketing support services in improved rice seed production and marketing. Samples of respondents that cultivate both upland and lowland rice varieties were selected randomly proportional to their population size. The sample frame of the study is the list of households obtained in the Fogera Woreda of agricultural office. Hence, out of 29 rural KAs with population size of 44, 168 only 15 KAs and with population size of 12,162 cultivate both upland and lowland varieties. Three KAs were selected randomly in order to get adequate information about the subject matter. Finally 151 (see appendix 1) households were selected using probability proportional to size from each Kebeles. Appendix 1 shows clearly the population size of each Kebele Administration with respect to rice grower households in each Kebele using the following formula.

$$n = \frac{N}{1+N(e^2)}; \qquad (1)$$

Where n is sample size to be computed, N is the total households in the study area and e is the level of precision. Before selecting households to be surveyed, rice growers were identified in collaboration with the aforementioned stakeholders.

1.2.2 Method of data analysis

The collected data from the sample respondents were analyzed using appropriate software for analysis purpose. The challenges and opportunities of rice seed production and marketing were identified. The descriptive analysis made use of tools such as mean, percentages, standard deviation and frequency. Econometric analysis was used to identify the major constraints and opportunities of rice seed production and marketing. The statistical significance of the variables was tested using chi-square (χ^2) to make inferences. To analyze the challenges and opportunities of rice seed production and marketing, we employed chi-square (χ^2) and t-test in the analysis because most of the variables are limited dependent variables (dummy) and OLS and other econometric models are difficult to use for analysis and inferential purposes.

3. Results and Discussion

3.1 Rice Production Characteristics

3.1.1. Land holding and allocation pattern

The study indicated (Table 1) that the average size of land held by the households is 1.58 with standard deviation of 0.58. The maximum is 3 hectares while the minimum is 0.5 hectares. The average size of own land held by the household is 1.27 with standard deviation of 0.55. The maximum is 3 hectares and the minimum is 0 hectares. The average area of cultivated own land is about 1.1 hectares maximum of 2.5 hectare and minimum of 0.0 with standard deviation of 0.46. Moreover, the average size of shared in cultivated land is 0.18 hectares with standard deviation of 0.25. The maximum is 1.0 hectare and the minimum is 0.00. Thus, this shows that the households in the area allocate more land for rice cultivation.

Table 1: Average land holding and allocation patterns for the households (in ha)

Description	N	Minimum	Maximum	Mean	Std. Dev.
Total land holding size	151	0.50	3.00	1.58	0.58
Own land	151	0.00	3.00	1.27	0.55
Cultivated own land	151	0.00	2.50	1.09	0.46
Rented out own land	151	0.00	0.50	0.013	0.07
Shared out own land	151	0.00	0.25	0.002	0.02
Rented in total land	151	0.00	1.75	0.08	0.24
Rented in cultivated land	151	0.00	1.75	0.09	0.25
Fallow own land	151	0.00	0.75	0.17	0.17
Rented in fallow land	151	0.00	0.75	0.02	0.08
Shared in cultivated land	151	0.00	1.00	0.18	0.25

The survey results showed that the households' possession of cultivable land ranged from the smallest 0.5 ha to the highest 3 ha (See Table (1)). The average size of cultivable land owned by the sample respondents was about 1.58 ha. Non-adopter households owned on the average 1.39 ha of land and the corresponding figure for the adopters was 1.84 ha. The mean difference of total land holdings for the two groups was significant at 1 % significance level (Table 2). This means, adoption tends to increase as farm size increases. This is probably because farmers perceive improved rice technologies cultivation practices take proportionally more land to avert risk of cultivating the rice new cultivars. Hence, on small land holdings the farmers allocate more land for their variety other than the new varieties.

The mean land cultivated by the households was 1.09 ha. The mean area under cultivation for non-adopters and adopters was 0.94 ha and 1.29 ha respectively. The adoption status and cultivated land of the respondents was significant at less than 1 % of probability level (Table 2). Moreover, the mean area allocated for rice for non-adopters and adopters was found to be 0.81 ha and 1.13 ha of land respectively. The difference in area allocation for rice in the cropping season was significant at less than 1% statistical level of significance for the groups (Table 2). This implies that households that allocate land for rice adopt new varieties to increase production and productivity.

Table 2: Farm assets ownership of sampled households in 2013

Characteristic	Non-Adopters	Adopters	Total	Difference	t-test
Total land holdings of the HHs	1.39	1.84	1.58	-0.45	-5.147***
Area under cultivation	0.94	1.29	1.09	0.35	-4.952***
Total Land allocated for rice	0.81	1.13	0.95	-0.31	-4.229***

***, ** and *statistically significant at 1%, 5% and 10 % respectively

3.1.2. Supply of rice to the Market

As indicated in Table 3, the minimum area of land allocated for rice in the production year was o.25 ha. (Table 3), shows that the minimum amount of rice produced by a household is 4.0 quintal. This gives per hectare productivity of 5.20 tons of rice is produced per hectare of land. However, this figure deviates more from the average productivity of rice for the District for the production year, which was 4.58 tones ha^{-1}. This result was consistent with Tilahun *et al.*, (2012), a survey done on rice value chain at Fogera district of Ethiopia. This variation of productivity is attributed to input usage differences mainly improved seeds and fertilizers. Moreover, incidence of flood was reported during the survey.

Table 3: Rice produced and sold (in Qt) by households in 2013

Description	Minimum	Maximum	Mean	Std. Dev.	Percent supplied to market
Production of rice in quintal per household	4.00	100.00	43.10	21.25	
Rice supplied to market in quintal per household	0.0	60.00	20.56	16.07	48.39

The survey indicated that 48.39 percent of rice produced by farmers in 2013 was supplied to market. As indicated on the table below, about 14.2 percent of it was consumed and 9.21 percent was retained for home consumption. About 2.45, 1.45 and 1.17 was used payment in kind for land, labor and seed respectively. The average production of rice per household was 45.80 quintal with standard deviation of 21.25. The maximum production per household was 100.0 quintal and the minimum was 4.0 quintal. The average amount of rice supplied to market per household was 20.56 quintal with standard deviation of 16.07. This implies that there is a variation on the utilization of rice among the households for home consumption and supply to the market i.e. the maximum amount of rice supplied by farm households was 60 quintal and some of the households produce rice for home consumption purpose only.

Table 4: Households rice production and utilization in 2013 (in Qt)

Description	N	Minimum	Maximum	Mean	Std. Dev.	Proportion
Rice produced in 2013	151	4.00	100.0	43.10	21.25	48.39
Rice sales	151	0.00	60.0	20.56	16.07	23.08
In-kind payments for land	151	0.00	30.0	2.18	5.13	2.45
In kind payments for labor	151	0.00	18.0	1.29	2.82	1.45
Stored for seed	151	0.25	2.10	1.04	0.51	1.17
Rice consumed	151	1.25	33.0	12.69	6.91	14.25
Available stock for consumption	151	0.50	32.00	8.20	6.47	9.21

3.2. Major Rice Seed Production and Marketing Constraints

There are a number of rice seed production, marketing and delivery constraints and opportunities. Those, which are considered as major ones, are discussed below.

3.2.1. Production constraints

Irrespective of the availability of favorable climatic condition that allow rice/ rice seed production, in Fogera District, out of the randomly selected households, only 65 (43.05 %) were improved rice users. This is due to different bottle necks which are related to technical inputs, shortage of capital, lack of sound extension services and other related problems. Each of the problems is discussed in detail below.

Technical inputs

Improved seeds availability: Recently, there are more than six rice seed varieties released for Fogera areas namely, NERICA-4, NERICA-3, SUPPERICA, TANA- , EDGET and GUMARA and X-Jigna (which is used for more than 4 decades). According to the survey results, Edget is relatively widely used type of improved rice seed followed by NERICA-4 and Gumara. Though the availability of rice varieties released to the area, about 114 (77.47 %) of the sampled households responded that there is no adequate improved rice seeds both in time and quantity (see Table 5). In line with this, availability of rice seed is significantly related with adoption of improved rice seeds at 5 % probability. Thus, it indicates that adequate availability of improved rice seed will enable farmers use improved varieties. Therefore, development endeavors needs to supplement with rice inputs supply and delivery systems both spatially and temporally.

Quality of improved rice seeds: To increase production and productivity and to enhance local seed business certified seed availability is basic and paramount. Seed quality problem occurred more probably with lack of seed multiplication site, availability of experts like seed technologist, seed mixture, and other capital problems. Due to those reasons, almost all the households (95.63 %) responded that lack of quality of improved rice seed is a problem. Table 5 shows that there is a statistically significant relationship between seed quality and adoption at less than 1 % probability level showing that seed quality is an important variable to participate in adoption of improved rice varieties. This implies that delivering quality seed will enable farmers in sustainably using improved rice seeds.

Fertilizer: However, soil sample analysis has not been done due to financial constraints of the researcher. Because perceptions are often difficult and result in varied outcomes as it depends on various factors such as knowledge, experience, etc...; as suggested by the reviewers of the paper. However, we suggest soil scientists to proof or disproof the farmers' perception using soil sample analysis and its results. The survey result showed that fertilizer is not commonly used for rice production in the district. However, due to yield reductions of their respective plot, farmers are starting application of fertilizer in recent years. As a result, about 83.44 percent of them mentioned unavailability of fertilizer as one of their problems. According to Table 5, fertilizer availably is significantly related to use of improved rice seeds at 5% significance level. This implies that to cultivate improved varieties, availability of fertilizer on time is crucial and contributes to use of improved varieties.

Table 5: Rice seed and grain production, marketing, processing and biological constraints

Type of Constraint	Adoption Status				Total		χ2
	Non-adopters		Adopters				
Production constraints	Yes	No	Yes	No	Yes	No	
Lack of rice seed availability	61	25	56	9	117	34	4.92**
Lack of rice seed credit availability	61	25	55	10	116	35	3.89**
Lack of fertilizers availability	67	19	59	6	126	25	4.43**
Lack of fair price of fertilizers	60	26	59	6	126	25	9.78***
Lack of fertilizers credit availability	68	18	49	16	117	34	0.2882
Marketing constraints							
Lack of fair price of improved seeds	57	29	62	3	119	32	18.78***
Lack of improved seed market information	80	6	64	1	144	7	2.47
Cooperative membership	24	62	43	22	67	84	21.94***
Access of training about improved rice seeds	3	83	60	5	67	84	120.1***
Processing Problems							
Lack of Miller Machine	84	2	63	2	147	4	0.08
Biological Challenges							
Flooding	45	41	20	45	65	86	7.02***
Insect and pests	54	32	18	47	71	79	17.75**
Disease problem	60	26	20	45	80	71	22.60***
Perceptions of soil fertility problems	68	18	61	4	129	122	6.49**

Source: survey results, 2014
***, ** and *statistically significant at 1%, 5% and 10 % respectively

In addition to the above statement, price of fertilizer is the major constraint to the households and about 83.44 % were responded price of fertilizer is high. From Table 5, price of fertilizer is strongly related to adoption of improved rice seeds at 1 % level of probability. It implies that, fair price of fertilizer will contribute to cultivate improved varieties both adequately and timely to individual smallholder farmers. Furthermore, about 77.48 % of the sampled households respond lack of availability of credit to fertilizer is also a major constraint.

Capital: Like unavailability of credit on fertilizer, unavailability of credit on seed was also mentioned by 76.82 percent of the respondents. Availability of capital to the smallholder farmers is a key problem in the study area. As shown in Table 5, capital availability to purchase seed is statistically significant at 5 % probability level with adoption status. It implies that availability credit to seed contributes to participate in improved rice cultivation.

According to Table 6, 42.86 % of the households were not responded for the reason for not accessing credit for seeds. However, 18.49 percent of the respondents were mentioned borrowing is risky. Lack of credit associations and high cost of capital (interest rate) was mentioned by 13.45 and 12.61 percent of the respondents respectively.

Table 6: Reason for not accessing credit for seed

Reasons	Frequency	Percentage
Too much paper work	8	6.72
No credit associations available	16	13.45
Borrowing is risky	22	18.49
interest is high	15	12.61
Expected to be rejected	7	5.88
Not voluntary to respond	51	42.86
Totals	119	100.00

3.2.2. Marketing constraints

In addition to production constraints, rice seed marketing is constrained by different factors. The most prominent ones are the following:

Price of Improved seed: According to the survey results, households in the study area considered that the price of improved rice varieties is expensive. However, the grain and seed price in the study area is almost the same. The farmers assumed that as the cost of their own seed is zero, they are not willing to buy seed from the seed suppliers and prefer to use their own rice seeds. Consequently, about 119 (78.80 %) of the surveyed households responded price of improved rice varieties is a major problem. Table 5 shows that seed price is significantly related to adoption status at 1 % probability level. This indicates that policies that subsidize the input side will enable to enhance technology participation. Alternatively, engaging participant farmers in local seed business by creating linkage with consumers of rice seeds can encourage farmers in accepting and disseminating improved seeds.

Lack of market information: The study results revealed that there are underdeveloped market information and lack of knowledge/understanding on the incentive for improving productive capacity and quality of the households. About 95.36 percent of the households responded that market information is a constraint and the remaining did not.

Cooperative membership: It is obvious that different cooperatives/ farmers participate in developmental activities by delivering inputs like fertilizer, seeds, plant protection chemicals, and other related services. As a result, farmers' club membership and / or availability of cooperatives in the nearest locality may enable farmers to those agricultural inputs. Moreover, farmers would have bargaining power in input and output marketing due to the information and service delivered by the cooperatives. During focus group discussions, the smallholders pointed out that, they trust cooperatives/farmer groups than any other traders in the locality.

Table 6 also indicates that about 55.63 percent of the respondents are members of farmers club. Further, the table shows that farmers' club membership and adoption are statistically significant at 1 % probability level. It implies that, access and or participation to such institutions will enable farmers to get services and improved seed distribution scheme.

Lack of market linkage or liaison service: Seed quality is very important in production activities and maximum care is needed to seed qualities. Part of this, adequate knowledge on production, packaging, transportation, storing and marketing of seeds is crucial. According to focus group discussion with farmers, the farmers pointed out that linkage between different stakeholders in the seed production, marketing and delivery system is very weak.

About 55.63 % of the respondents reported that they never attend any training on improved practices of rice before and after 2013, while 44.37 % of the respondents were attending /ed training on improved management related to rice and about 95.24 % of the households that got training were adopters. According to the statistical test table below, training on any improved practices of rice and adoption status were highly related and significant at 1 % probability level. Thus, implies that capacity building on farmers training centre, contact with DAs, and Woreda experts will contribute to the use of improved technologies by gaining knowledge and skills among farmers and experts.

In line with the above statement, during the focus group discussion the farmers explained that extension agents, Woreda experts and sometimes researchers give some service on production aspects, but the farmers carry out marketing of agricultural products without significant support from any institutions. The farmers and dealers reported that they want a supporting institution for liaising (linking) them with useful organizations for selling rice seed produce.

Table 7: Means of accessing market information

Source of Information	Frequency	Percent	Valid Percent	Cumulative Percent
Not sold	6	3.97	3.97	3.97
Observation	60	39.74	39.74	43.71
Discussion	62	41.06	41.06	84.77
Telephone	23	15.23	15.23	100.00
Total	151	100.00	100.00	

According to the survey results, lack of marketing linkage was one of the constraints and about 41.06 percent of the households' access market information through informal discussion with their peer groups followed by personal observation and telephone, which accounts 39.74 and 15.23 percent respectively. Consequently, the grain and improved rice seed price is equal in the study area. During the focus group discussion, the farmers and dealers mentioned that there were no incentives to seed growers except some technical feedbacks from experts on production aspect only.

3.2.3. Processing problems

Lack of milling machine: Though availability of milling machines seems to have no relationship with seeds, it is important that availability of miller contribute to use improved rice varieties by selling their paddy rice through value addition. Table 5, shows that almost all (97.35 %) of the sampled households faced lack of miller in their locality.

3.2.4. Biological challenges

Flooding: Fogera area is known as swampy area, which is very comfortable especially for lowland rice varieties. However, due to high rainfall amount in the area, flooding is the major natural hazard for 43.05 % of the respondents and it is not a problem for the remaining 56.95 %. According to focus group discussion, the farmers explained that flooding is a problem especially at seedling age of crop. Table 5 above shows that flooding is strongly related to the use of rice varieties at 1 % significance level. Thus, it implies that working on strong stock rice cultivars and /or flood break will assist to enhance improved rice cultivations in the study area.

Insect and Pests: Like other commodities, rice production is constrained by many environmental factors like insects and pests. The common types of insects and pests in rice include stalked eyed flies, termite, stem borers, stick bug, rice mealy bug, and weevil. About 47.01 % of the households responded that insect and pests are the major biological challenges in the area. Table 14 also shows that pest infestation is highly related with adoption of improved varieties. This further implies thatstrengthen pest management activities will contribute for better seed production.

Diseases: The common diseases in rice includes rice blast, rice yellow mottle virus, brown spot, sheath blight, leaf scaled, and grain root. According to the household survey result, about 52.93 % of the households respond that disease is a major problem. The statistical test table below indicates that, disease is strongly related with adoption status at 1 % significance level. Thus, implies that disease resistance and tolerance contributes to households to adopt the cultivars.

Fertility Status: Soil fertility is a key factor for rice cultivation. According to the survey results, soil fertility is recently a major problem for the households. About 85.43 % of the households reported that soil fertility is the main problem. The table below shows that, fertility is significantly related with adoption status at 5 % probability level. Thus, it implies that practices that enhance soil fertility will contribute for the use of improved technologies.

Generally, we have tried to identify the challenges in the production system as described above. However, this research is limited to identification of challenges and their degree of association between production and marketing challenges. Therefore, we suggest that other researchers could work on the identified problems to what extent could the identified problems affect production and marketing of rice.

3.3. Opportunities for Rice Seed Production and Marketing

Reasonable grain prices: The ultimate goal of innovation in agriculture especially in developing countries is to achieve food security and then profitability by implementing the new practices at the ground. It is therefore, using agricultural inputs like seed under normal condition will enable farmers to enhance production and productivity. As a result, production is valued by the market price of the commodity under investigation. This indicates that grain price directly or indirectly affects the use of improved technologies. For instance, the current grain price will affect next year farmers' production decisions.

Table 8 below, indicates that about 80.79 % of the households, respond that the market price of rice is fair relative to the past years. During the survey, the researcher discussed with farmers to have some insight on the historical trends of rice seed production and marketing. The farmers generally reported that grain and seed price is equal though the price varies from time to time. As a result, almost all the farmers sell rice to the market for grain traders. The seed producers are also expected premium price to produce seed otherwise. Since the grain and seed price are equal, this discourages farmers to produce quality rice seed. Moreover, rice grain and seed production was not profitable at the study area before 2010 as per the focus group discussions with smallholder farmers.

However, they reported that in 2010/11, with introduction of improved rice, seed price increased from 5 to 12 Birr/kg during the cropping season. Consequently, even the rice grain price is currently about Birr 10.31 kg^{-1} on average. To inquiry into this matter, the researcher analyzed gross profitability for the 2013 production year at smallholder farmer's level.

During the focus group discussion the farmers reported that, upland rice varieties (like NERICA-4) are now days become popular in the area and the price of rice seed/ grain is almost nearest to teff, irrespective of their yield differences. From the same table of test of statistical significance, fair grain price is highly related to cultivation of rice varieties at 1 % probability level. This implies that availability of fair market price will enable the farmers to be profitable by engaging in cultivating improved rice cultivars.

Cultivable Land Availability: The average land holding size of the surveyed households of Fogera area is twice than that of national average land holding size. Hence, this opportunity will enable farmers to produce improved rice seeds and distribute to another areas. Moreover, Fogera district is swampy area that makes it conducive environment for both upland and lowland rice varieties.

Table 8: Rice seed production opportunities

Variables	Adoption Status				Total		$\chi2$
	Non-adopters		Adopters				
	Yes	No	Yes	No	Yes	No	
Availability of reasonable grain prices	60	26	62	3	122	29	15.66***
Willingness to get training and adopt new rice varieties	63	23	60	5	122	29	8.90 ***

***, ** and *statistically significant at 1%, 5% and 10 % respectively

Availability of comfortable agro-ecology to cultivate rice - Fogera District is well known for its favorable agro ecology for rice cultivation in Ethiopia. That is why the national rice research training center of Excellency is Fogera National Rice Research Center. However, the potential has not yet been utilized due to production as well as marketing constraints.

Interest in and willingness to plant improved rice varieties- Willingness of the smallholder farmers to be trained on management practices of improved rice varieties, input market information and output market is important in the agricultural inputs production and delivery system. About 80.79 % of the sampled households were willing to participate in capacity building on new varieties, input and output markets. Table 7 indicates that there is high and strong relation in willingness to get training on improved rice seeds, input and output markets. Thus, it implies that increasing support for smallholders will enable in achieving plan for modern agriculture.

High Population: Since rice is one of the staple food crops both in Ethiopia and Sub-Saharan Africa, increase in the population in regional and country level assures presence of sustainable demand for rice products.

4. Conclusions and Recommendations

The production constraints are related to technical inputs; including improved seeds availability, quality of improved varieties, fertilizer availability and fertilizer price availability, capital; (including credit availability to buy fertilizer and improved rice seeds). In addition to production constraints, rice seed marketing is constrained by different factors. The most prominent ones include price of improved seed, lack of market information, farmers group (cooperatives) and lack of market linkage or liaison service. The major processing constraint is also lack of availability milling machine in the locality. Fogera area is known as swampy area, which is very comfortable for both upland and lowland rice varieties. However, it is obvious that agriculture is under the gamble of nature. As a result, environmental factors' including flooding, insects and pests, diseases, and soil fertility problems affect rice production according to the survey results collected from sampled households.

Given the current potential and demand in production, marketing and consumption of rice, both at domestic and foreign markets, improving the production and marketing of rice through adoption of improved varieties is needed. Based on the results of the study, the following recommendations are drawn:

- To increase production and productivity and to enhance local seed business, certified seed availability is basic and crucial. An intervention is needed in areas of outsourcing information on rice seed production: quality management and marketing to improved quality seed delivery scheme. Moreover, sourcing information and knowledge in areas of disease control, insect and pest management, soil and water management and watershed management enables to minimize the risk of environmental factors.
- Agricultural inputs like seeds and fertilizer needs to be delivered both spatially and temporally so as to produce quality seeds and the market actors in the seed system. In line with this, credit access facility and setting fair price of fertilizer will contribute to produce healthy rice seeds and to deliver timely to individual smallholder farmers.
- Cooperative institutions should be strengthened to enhance the bargaining power of households in input and output marketing due to the information and service delivery system. As a result, access and participation to such institutions will enable farmers to get services and improved seed

distribution scheme. Moreover, cooperatives must be empowered both in capital and material like storage, and transportation.

- Training on improved practices of rice on producing, packaging, transporting, storing and marketing of seeds is very important in improving knowledge and skills of the rice seed market actors. Therefore, linkage and synergy with stakeholders in seed production, marketing and consumption must be established. This could be achieved by creating linkage and capacitating building on farmers training centre, contact with DAs, and Woreda experts, traders and cooperatives.
- Entrepreneurial training and advice should be given to smallholder farmers on rice seed and grain agribusiness to take the advantage and add value at farmers' level. This can be achieved through establishing rice processing plant at the nearest area or linkage should be created to processors at the country level to milk the advantage of fair grain prices.

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Effect of N, P and Farmyard Manure on Noug (*Guizotia abyssinica* Cass.) Yield in Ebinat District

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Abstract

A field experiment was conducted under rain fed condition at Fakoy site in Debir Abajalie Peasant Administration of Ebinat District, Amhara Region on farmers' field to study the response of integrated NP and FYM fertilizers application on yield and yield components of noug. The experiment was conducted using a factorial experiment laid out in a randomized complete block design with three replications. Four rates of FYM 0, 2.5, 5 and 10 t ha^{-1} and four levels of NP; 0-0, 10.25-5.75, 20.5-11.5, and 41-23 kg N and P_2O_5 ha^{-1}, respectively were used. The analysis of variance for growth and yield of noug revealed that there were highly significant ($P<0.01$) effects due to FYM and NP fertilizer levels. Generally, 10 ton ha^{-1} FYM with 20.5-11.5 kg ha^{-1} NP gave higher seed yield (1679 kg ha^{-1}). Economic evaluation of noug against the treatments showed that net return (7305.00EB ha^{-1}) was the highest for treatments that received 5 tonne FYM and 41-23 kg NP ha^{-1} in drill planting method. The present results emphasized the practical significance of integrated 5 tonne ha^{-1} FYM and 41-23 kg ha^{-1} NP fertilization were adequate for seed yield and oil content of noug in drill planting method.

Key words: chemical fertilizer, farmyard manure, noug, oil content, seed yield

1. Introduction

Noug (*Guizotia abyssinica* Cass.) is an oilseed crop cultivated in Ethiopia and India. It is the earliest crop plants in Ethiopia ever brought to domestication (IAR, 1992). Noug in major production areas is used for human food and for edible oil extraction (Seegeler, 1983). The left-behind after oil extraction is rich in protein and fiber and can be used as animal feed (Ramadan and Morsel, 2002; Kandel and Porter, 2002). It is also used in the preparation of soap, paints and as carrier of scent in perfume industry (Kandel and Porter, 2002).

Organic agricultural practices aim to enhance biodiversity, biological cycles and soil biological activity so as to achieve optimal natural systems that are socially, ecologically and economically sustainable (Akbari *et al*., 2011). Manure has always been considered as a valuable input to the soil for crop production. In a broad sense, manure management relates to the appropriate use of animal manure according to each farm's capabilities and goals while enhancing soil quality, crop nutrition, and farm profits. Manure management is defined as a decision-making process aiming to combine profitable agricultural production with minimal nutrient losses from manure, for the present and in the future (Akbari *et al*., 2011).

It is important to exploit the potential of organic manures, composts, crop residues, agricultural wastes, biofertilizers and their synergistic effect with chemical fertilizers for increasing balanced nutrient supply and their use efficiency for increasing productivity, sustainability of agriculture, and improving soil health and environmental safety (Kapila *et al*., 2012.). Soil fertility maintenance or nutrient replenishment through use of integrated organic and inorganic fertilizer (Achieng *et al*., 2010) for noug is essential to improve its production and productivity. Particularly, nitrogen and phosphorus are deficient in many soils of tropical Africa (Girma and Ravishankar, 2004), which also true for many Ethiopian soils (Yihenew Gebreselassie, 2002; Teklu Erkossa *et al*., 2006). Balanced fertilization at right time by proper method increases nutrient use efficiency in noug (Amare Aleminew, 2012). Experiments have been conducted at different centers with the integrated use of organic manure, green manure, crop residue, and biofertilizers along with inorganic fertilizers increased yield of crops. Integrated nutrient management not only reduces the demand of inorganic fertilizers but also increases the efficiency of applied nutrients due to their favorable effect on physical, chemical and biological properties of soil. There is a research result on the NP rate for noug production (Amare Aleminew, 2012), but not for integrated farmyard manure and NP levels. The limited information available in Ethiopia pertaining to the N, P and farmyard manure needs of noug mainly focused on seed yield and oil content. In Ethiopia, improper fertilizer application is the most common problem encountered, particularly in the high land areas. Therefore, integrated farmyard manure and NP fertilizers application was an important research issues that was dealt with as a strategy for increasing noug yield components. Thus, the present study was conducted to test the optimum requirement of integrated nitrogen-phosphorus and optimum farmyard manure fertilizers for growth, yield, oil content and oil yield of noug production in Ebinat district, Amhara Region.

2. Materials and Methods

2.1 Description of the Study Area

A field experiment was conducted under rain fed condition during the main cropping season (April 2012 to April 2013) at Fakoy site in Debir Abajalie Peasant Administration of Ebinat District, Amhara Region on farmers' field. Ebinat District is located between 11^0 and 12^0 North latitude, and 37^0 and 38^0 East longitude (SERA, 2000). The mean annual rainfall of the District is 600-800 mm while the monthly mean temperature of the district is 18^0C (SERA, 2000). The elevation of the experimental site is 2100 m above sea level (asl). The analyzed soil physico-chemical properties of the experimental site is indicated as (Table 1). The land used for the present field experiment had not been fertilized for over the last two years with either organic or mineral fertilizers. Map of the study area is depicted here below in Figure 1.

Table 1. Relevant soil physico-chemical properties of the noug field before planting

Soil sample	pH by KCl		Av. P (ppm)		OM (%)		TN (%)		Soil Texture			Textural Class
	Value	R	Value	R	Value	R	Value	R	Sand (%)	Silt (%)	Clay (%)	
SSBPFS	3.83	VSA	10.08	L	2.15	M	0.11	L	17	29	54	Clay

Note: SSBPFS=Soil sample before planting at Fakoy site; pH=Power of Hydrogen; Av.P=Available Phosphorus; OM=Organic matter; TN=Total Nitrogen; L=Low; VSA=Very strongly acidic; MA=Moderately acidic; M=Medium; R=Rating

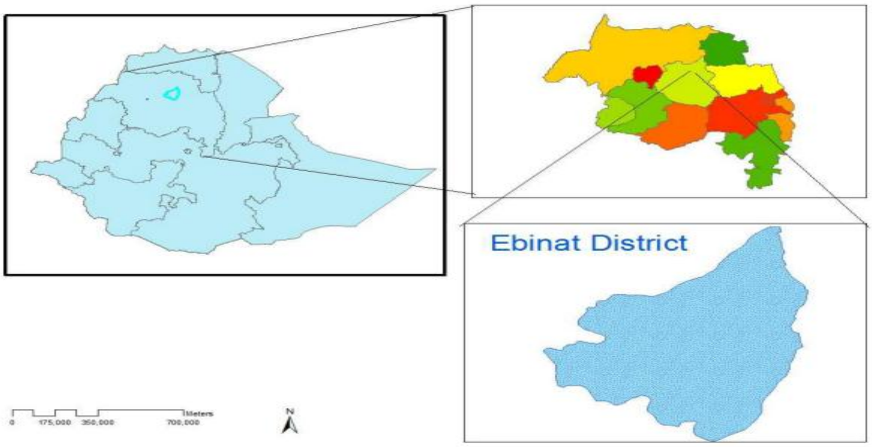

Figure 1. Map of the study area

2.2 Planting Materials Used for the Study

Fogera-1variety of noug was used as a planting material. Planting was made on the mid of June 2012 by hand drilling of the seeds in rows spaced 30 cm apart at a rate of 7.5 kg ha^{-1}.

2.3 Experimental Design and Treatments

Factorial experiment of four levels of NP and FYM fertilizer levels under drill planting method was laid out in randomized complete block design (RCBD) with three replications. The four levels of NP fertilizers were 0-0, 10.25-5.75, 20.5-11.5, and 41-23 kg ha^{-1} N and P_2O_5, respectively; while the four levels of FYM fertilizers were 0, 2.5, 5 and 10 t ha^{-1}. A 3 m × 1.8 m (5.4 m^2) plot size was used as an experimental unit. The blocks were separated by 1 m wide open space, whereas the plots within a block were separated by 0.5 m wide space. Nitrogen was applied in two equal splits; 50% of the N rate was applied basal at planting time. The remaining half of N was top dressed at 5-10 cm far from the plants by drilling which occurred 30 days after germination using urea as a source (46% N). Volatilization of nitrogen was reduced by covering soil and preferably coinciding with adequate rain fall. All P fertilizer was applied during planting time as P_2O_5 as a source of DAP. Weeds were removed manually three times (at early growth stages, developmental growth stages and before flowering). No insecticide or fungicide was applied as there was no serious incidence of insect pests or diseases. Harvesting was done manually using hand sickles. The required amount of farmyard manure was applied before two weeks of sowing for each allocation of treatments in the form of sun-dried cow dung and it was covered by soil immediately to reduce the volatilization of nitrogen from the cow dung. The rate of farmyard manure determination for noug was used the blanket recommendation as other crops used (Karma *et al*., 2009; Molla Adissu *et al*., 2011). According to estimates of Molla Adissu *et al*. (2011), application of 2000 kg of farmyard manure will supply 8.4 to 9.6 kg N ha^{-1}. The chemical composition of farmyard manure applied to the soil during the experiment was OM (45 %), P (23.15 ppm), N (0.572 %) and K (19.65 meq $100g^{-1}$).

2.4 Data Collection and Analysis

Plant height (average of 10 plants/plot), number of leaves per plant (average of 10 plants/plot) and number of branches per plant (average of 10 plants/plot) were considered as important growth parameters of the present study. Seed yield per hectare, thousand seed weight, total biomass yield, oil content and oil yield were also considered as yield parameters. The oil content was estimated by using Nuclear Magnetic Resonance (NMR) spectrometer at Holetta Agricultural Research Centre oil testing laboratory and it was expressed in percentage. Data of many important growth and yield parameters collected during the experimental periods were purified and arranged for further analysis. The analysis of variance (ANOVA) was carried out for growth and yield parameters of the study following statistical procedures appropriate for the experimental design using Statistical Analysis

System (SAS) program package version 9.0 (SAS, 2002). Whenever treatment effects were significant at 0.01 or 0.05 level of error, the means were separated by using the least significant difference (LSD) test procedures at 0.05 probability level of significance.

2.4.1 Composite Soil Sampling and Analysis

Eight soil samples were taken from all directions of the experimental land at a depth of 0-30 cm before planting to form a composite sample for the experimental site to appraise some physico-chemical properties like pH, texture, total nitrogen (%), organic matter (OM) (%) and available P (ppm). The collected soil samples were air-dried and ground to 2 mm size for analysis. Particle size distribution was determined by Hydrometer method (Day, 1965). The soil pH by KCl method was measured by using a digital pH meter (Page, 1982). The organic matter content of the soil was determined by Walkley and Black method (Dewis and Freitas, 1970). Total nitrogen was determined by micro-Kjeldahl method (Dewis and Freitas, 1970). The available P was estimated following standard procedure Bray II methods.

3. Results and Discussions

3.1 Growth Parameters of Noug as Influenced by FYM and NP Fertilizers

3.1.1 Plant height

Plant height was showed highly significant (P<0.01) difference for all main and interaction effects of FYM and NP fertilizers at Fakoy site (Table 2). The tallest plant height (186.5 cm) was recorded by applying 10 ton ha^{-1} FYM + 20.5-11.5 kg ha^{-1} NP (Table 2). Likewise, plant height was taller (155.6 cm) at higher levels of 10 ton ha^{-1} FYM, and (179.4 cm) at NP fertilizer levels of 41-23 kg ha^{-1} (Table 2). The shortest plant height was recorded (89.5 cm) at 0 × 0-0 ton ha^{-1} FYM by kg ha^{-1} NP fertilizer levels (Table 2). The shortest plant height was also recorded (137 cm) at FYM fertilizer levels of 0 ton ha^{-1} as well as at NP fertilizer levels of 0-0 kg ha^{-1} (Table 2). Plant height increased with the increasing rates of FYM and NP. The increase of plant height at higher rates of FYM and NP fertilizers would likely be associated with the effects N and P on vegetative growth promotion and stem strengthening, respectively. These results are in conformity with the findings of Amare Aleminew (2012) and Dejene Mengistu and Lemlem Mekonnen (2012).

3.1.2 Number of branches per plant

Number of secondary branches per plant was highly significantly (P<0.01) affected by NP fertilizer levels and by the interaction of FYM and NP fertilizer levels (Table 2). Number of branches per plant increased as NP fertilizer rates increased. The highest number of branches per plant (8.22) was obtained at 41-23 kg ha^{-1} NP (Table 2). Similarly, increased FYM and NP fertilizer rates increased the number of branches per plant (Table 2). The highest number of branches per plant (9.27) was obtained at 10 ton ha^{-1} FYM + 20.5-11.5 kg ha^{-1} NP (Table 2). The least primary branches per plant (3.80) was recorded at 0 ton ha^{-1} FYM by 20.5-11.5 kg ha^{-1} NP because of zero level of FYM (Table 2). Increased number of branches per plant with increased levels of FYM up to 10 tonne and NP rates of 20.5-11.5 kgha^{-1} might be due to the vegetative growth promoting effect of nitrogen as well as branch development effect of phosphorous. These results are in agreement with those documented by Amare Aleminew (2012) and ICAR (1992).

Table 2. Mean main and interaction effects of FYM and NP fertilizer levels on growth and yield parameters of noug at Fakoy site of Ebinat district

	Yield and yield components					
Factors	PH	NBP	TSW	SYH	TBH	OC
Main Factors						
Applied FYM (ton ha^{-1})						
0	137.00d	6.52	2.86	951.00b	3326.00c	39.30c
2.5	145.90c	6.58	3.54	889.00d	3564.00b	40.42b
5	146.50b	6.75	3.02	926.00c	2922.00d	39.23d
10	155.60a	6.58	3.72	1000.00a	3720.00a	40.45a
LSD (5%)	0.44**	NS	NS	20.00**	121.00**	0.02**
Applied NP (kg ha^{-1})						
0-0	101.90d	4.27d	3.74	568.00d	1420.00d	39.83c
10.25-5.75	142.60c	6.05c	3.19	889.00c	3654.00b	40.11a
20.5-11.5	161.10b	7.90b	3.13	975.00b	3488.00c	39.91b
41-23	179.40a	8.22a	3.07	1333.00a	4969.00a	39.55d
LSD (5%)	11.50**	0.22**	NS	56.00**	117.00**	0.07**
Interactions						
FYM × NP						
0 × 0-0	89.50p	4.07n	3.85	593.00k	2142.00j	39.37j
0 ×10.25-5.75	108.30n	4.93l	3.83	593.00k	1169.00l	40.43d
0 ×20.5-11.5	98.70o	3.80o	3.73	346.00l	823.00m	39.23k
0×41-23	111.10m	4.27m	3.57	741.00j	1548.00k	40.27e
2.5 × 0-0	142.40k	6.47i	2.43	889.00g	3506.00f	39.57h
2.5 ×10.25-5.75	124.30l	5.07k	3.57	790.00i	3086.00h	40.90a
2.5 ×20.5-11.5	143.30j	6.33j	3.10	840.00h	3086.00g	39.70g
2.5×41-23	160.40g	6.33j	3.67	1037.00e	4938.00b	40.27e
5 × 0-0	145.50i	7.73f	2.73	938.00f	2469.00i	39.50i
5 ×10.25-5.75	171.70d	8.20b	3.00	938.00f	4815.00c	40.57c
5 ×20.5-11.5	157.60h	7.60h	2.58	840.00h	2593.00h	38.8m
5 ×41-23	169.70f	8.07d	4.20	1185.00d	4074.00e	40.70b
10 × 0-0	170.80e	7.80e	2.43	1383.00b	5185.00a	38.77m
10 ×10.25-5.75	179.20c	8.13c	3.77	1235.00c	5185.00a	39.77f
10 ×20.5-11.5	186.50a	9.27a	2.67	1679.00a	5185.00a	39.10l
10 ×41-23	181.20b	7.67g	3.43	1037.00e	4321.00d	40.57c
LSD (5%)	0.88**	0.05**	NS	36.13**	98.77**	0.06**
CV (%)	5.45	12.10	13.78	11.11	13.45	7.83

Note: Means within a column followed by the same letter(s) are not significantly different at 0.05. ** = Significant at $P< 0.01$; NS = non-significant; PH = Plant height (cm); NBP = Number of branches per plant (No); TSW = Thousand seed weight (g); SYH = Seed yield per hectare (kg ha^{-1}); TBH = Total biomass yield per hectare (kg ha^{-1}); OC = Oil content (%)

3.2 Yield Parameters of Noug as Influenced by FYM and NP Fertilizers

3.2.1 Thousand seeds weight (TSW)

All main and interaction effects of FYM and NP fertilizer levels did not significantly (P>0.05) improve 1000 seed weight (Table 2), which is in agreement with the findings reported by Amare (2012). In the present study, the highest TSW (4.20g per plot) was obtained from plots applied with 5 ton ha^{-1} FYM with 41-23 kg ha^{-1} NP (Table 2). The lowest TSW (2.43 g) was recorded with 2.5 and 10 ton ha^{-1} FYM and 0-0 kg ha^{-1} NP (Table 2). Generally, TSW was shown non- significantly differed as FYM and NP rates increased. This result was in line with NP fertilizer studied by Amare Aleminew (2012).

3.2.2 Seed yield per hectare

Seed yield of noug was highly significantly (P<0.01) affected by FYM and NP alone and their interaction (Table 2). The result is in line with Amare Aleminew (2012) who reported marked effect of the application of nitrogen and phosphorus on seed yield of noug . Seed yield significantly increased from 889 to 1000 kg ha^{-1} with the increase of FYM level from 0 tonne ha^{-1} (the control) to 10 tonne ha^{-1} (Table 2). Similarly, noug seed yield increased from 568 to 1333 kg ha^{-1}with increasing level of NP from 0-0 kg ha^{-1} (control) to 41-23 kg ha^{-1} (Table 2). Increasing NP rate from 0-0 to 41-23 kg ha^{-1} resulted in increasing noug seed yield very significantly. This could be mainly due to increasing plant height and number of primary and secondary branches per plant that might attribute for the increase of noug seed yield indirectly through increasing the number of capitula per plant and number of seeds per capitulum (Amare Aleminew, 2012). Moreover, the lower organic matter and lower total N contents observed on the surface soils of the experimental site might also attributed to the positive response and increase of noug seed yield with higher application doses of mineral N fertilizer up to 41 kg ha^{-1}. Similar results were reported by Mohamed and Ayman (2009). They reported that under inadequate soil N content, addition of N into the soil significantly increased noug seed yield. Nevertheless, some authors noted combined application of organic and inorganic fertilizers increased agricultural productivity, improve soil fertility and decrease environmental pollution (Dejene Mengistu and Lemlem Mekonnen, 2012; Hocking *et al*., 2007).

Interaction effects of FYM and NP fertilizer levels had also an effect on seed yield of noug (Table 2). Seed yield significantly increased from 346 to 1679 kg ha^{-1} with 0 and 10 ton ha^{-1} FYM and 20.5-11.5 kg ha^{-1} NP levels (Table 2). This might be due to an increase in seed yields attributed to increments in yield components such as plant height and number of branches per plant and thereby leading to increase in number of capitula per plant and number of seeds per capitulum. Increasing in yield components are associated with better nutrition, plant growth and increased nutrient uptake (Sharma, 1990). Therefore, higher fertilizer rates gave higher seed yield than that of lower fertilizer rates. These findings are in agreement with the results obtained from mineral fertilizer studies on noug (Amare Aleminew, 2012).

3.2.3 Total biomass yield

Total biomass yield of noug was very much significantly (P<0.01) affected by FYM and NP alone and FYM by NP as interaction effects (Table 2). The highest total biomass yield (3720 kg) was recorded at FYM level of 10 ton ha^{-1} and (4969 kg) at 41-23 kg ha^{-1} NP fertilizer levels (Table 2). Similarly, the highest total biomass yield (5185 kg) was also obtained at 10 tonne ha^{-1} FYM by 0-0, 10 tonne by 10.25-5.75 and 10 tonne by 20.5-11.5 kg ha^{-1} NP fertilizer levels (Table 2). In this study, total biomass yield of noug was positively and very much significantly (P<0.01) associated with the increase of both growth and yield parameters concurrently (Amare Aleminew, 2012). The promotion of noug biomass with an application of higher FYM and optimum NP observed in the present study demonstrated apparently the importance of nitrogen and phosphorous for optimal vegetative and generative growth and development of plants. N is essential for plant growth since it is a constituent of all proteins and nucleic acids whereas, P is essential for the production and transfer of energy in plants. Dejene Mengistu and Lemlem Mekonnen (2012), and Mohamed and Ayman (2009) have also observed the enhancement of total biomass yield due to combined use of FYM and NP fertilization.

3.2.4 Oil content

In the present study, the oil content of noug was highly significantly (P<0.01) affected by FYM and NP alone and their interactions (Table 2). The highest oil content (40.45%) was obtained at 10 ton ha^{-1} FYM followed by 10.25-5.75 kg ha^{-1} NP (40.11%) (Table 2). Similarly, the highest oil content (40.90%) was also obtained at 2.5 ton ha^{-1} FYM plus 10.25-5.75 kg ha^{-1} NP (Table 2). Increasing N fertilizer rates from 0 to 10.25 kg ha^{-1} increased noug seed oil content by 40.1%, but it was decreased then after as N levels increased. According to Amare Aleminew (2012), more N fertilization reduced total oil production of noug due to its decreasing effect on yield. The possible reason for the increased seed oil content of noug as N levels increased might be due to the decrease of proteins and applications of FYM together with NP fertilizer levels, while N is the major constituent of proteins. Since oil content has inverse relationship with protein, a decrease of seed protein content with application of high FYM and PN fertilizer rates might attribute to the increase of seed oil content of noug in general.

3.3 Cost Benefit Analyses in Noug Production as Influenced by FYM and NP Fertilizers

To evaluate the costs and benefits associated with different treatments, partial budget analyses were carried out by taking mean seed yield and prices of input and output of noug row planting in reference to the nearby Ebinat market (Table 3). Marginal rates of return (MRR) were calculated by adjusting seed yield of noug by 10% to account the sensitivity of price fluctuations. Furthermore, minimum acceptable rate of return (MARR) was compared to see most profitable treatments (CIMMYT, 1988). As a result, 5 × 41-23 treatment is accepted in the present study which gave higher MRR and net benefit (7305.00 EB ha^{-1}) over that of other treatments. Accordingly, using 5 ton ha^{-1} FYM and 41-23 kg ha^{-1} NP fertilizers in drill planting method of noug under the prevailing price structure can be as promising new practice for farmers in the district.

Table 3. Cost benefit analyses of noug FYM and nitrogen-phosphorus fertilizers trials in drill planting method in Ebinat district

Treatments FYM(ton/ha) × N-P (kg/ha)	Average seed yield(kg/ha)	Adjusted yield (kg/ha)	TVC, EB/ha	GFB, EB/ha	Net benefit, EB/ha	MRR%
0 × 0-0	593	533.70	2492.50	8005.50	5513.00	-100
0 × 10.25-5.75	593	533.70	2917.50	8005.50	5088.00	39.74
0 × 20.5-11.5	346	311.40	3342.50	4671.00	1328.50	56.70
0 × 41-23	741	666.90	4192.50	10003.50	5811.00	423.61
2.5 × 0-0	889	800.10	4742.50	12001.50	7259.00	-32.15
2.5 × 10.25-5.75	790	711.00	5167.50	10665.00	5497.50	-177.82
2.5 × 20.5-11.5	840	756.00	5592.50	11340.00	5747.50	161.51
2.5 × 41-23	1037	933.30	6442.50	13999.50	7557.00	-5.50
5 × 0-0	938	844.20	6992.50	12663.00	5670.50	-237.08
5 × 10.25-5.75	938	844.20	7417.50	12663.00	5245.50	-255.65
5 × 20.5-11.5	840	756.00	7842.50	11340.00	3497.50	161.53
5 × 41-23	1185	1066.50	8692.50	15997.50	7305.00	100.83
10 × 0-0	1383	1244.70	11492.50	18670.50	7178.00	-79.07
10 × 10.25-5.75	1235	1111.50	11917.50	16672.50	4755.00	370.12
10 × 20.5-11.5	1679	1511.10	12342.50	22666.50	10324.00	-309.65
10 × 41-23	1037	933.30	13192.50	13999.50	807.00	83.64

Note: SR = seeding rates in kg/ha; N = nitrogen in kg/ha; P = phosphorus in kg/ha; EB = Ethiopian Birr; TVC = total variable costs; GFB = gross field benefit; MRR = marginal rate of return; MARR = minimum acceptable rate of return

4. Conclusions and Recommendations

Improved soil management practices such as integrated fertilizers application is important for noug production. It is possible to recommend that noug varieties must be planted at a FYM of 5 ton ha^{-1} and NP fertilizer level of 41-23 kg ha^{-1} for drill method of sowing. The present results stress on the importance of integrated fertilizer application (FYM and NP) for high seed yield and oil content of noug. The integrated use of organic and inorganic fertilizer sources are proved to improved soil health and increased crop yield. In addition, integrated use of organic and inorganic sources could help to save money, improve soil organic matter content as well as essential plant nutrients. Therefore, site-specific nutrient management through integrated nutrient management should be adopted to improve the existing low yield levels obtained by the subsistence farmers.

Thus, it is a one year and one site response of noug to both FYM and NP fertilizer levels trial, further studies concerning fertilizer sources for instance macro and micro nutrient fertilizer sources such as Ca, Mg, S and B are needed to get good noug seed formation and oil content. Furthermore, different growth hormones should be applied to increase the seed yield of noug. Therefore, further investigations to obtain high-quality oil content and seed production of noug in the country aimed at promoting integrated soil fertility management and formulation of fertilizer recommendations on soil test basis over locations are desirable and should be given special attention.

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Non-Farm and Off-Farm Activities in Achieving Livelihood Security in the Amhara Region: Case Study of Lay Gayint District

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Abstract

In areas where agricultural activities are highly limited because of unpredictable rainfall, land degradation and recurrent drought, livelihood diversification can increase households' income and food security. However, a range of factors from physical environmental circumstances to policy and institutions related issues determine households' participation in non/off-farm activities in the study area. The general objective of the study was to identify factors that determine households' participation in non/off-farm activities in drought- prone areas of the Amhara Region using Lay Gayint district as a case study site. Questionnaire survey, in-depth interview and focus group discussions were the major data collection techniques. Both qualitative and quantitative research methods were used for data analysis and the later included descriptive statistics and regression modeling. A major finding is that despite the low level of productivity related to local environmental constraints, rural livelihoods remain undiversified with small-scale rain-fed agriculture providing the primary source of livelihood for the large majority of sample households. Only small percentage of respondents (25%) participated in some form of non-farm/off-farm activities, with little contributions to their sources of income. The study found out that non/off-farm activities that meet the shortfall of consumption needs such as selling charcoal and fuel wood, causal labor and out migration were the major sources of income for the poor and vulnerable households. The study forwarded that improving livelihood security of rural households in the study area requires integrated development interventions aimed at improved natural resources management and livelihood diversification including interventions in the area of non-farm employment opportunities and skill trainings at household level.

Key words: Agro-ecology, wealth categories, gender, livelihood diversification, Lay Gayint

1. Introduction

The thinking of livelihood diversification to development had been recognized since the late 1980s when the concept becomes popularized by the prominent researchers such as Chambers and Conway (Devereux *et al*., 2004; Kollmair and Juli, 2002). As a result, the promotion of livelihood diversification as a way out of poverty has gained widespread support among development agencies (Ibekwe *et al*., 2010). In this regard, Thomas *et al.* (2006) indicated that contrary to the traditional image, diversification into rural nonfarm employment is extremely imperative in augmenting the livelihoods of the poor in many developing countries. Hence, diversification of income sources has been put forward as one of the strategies households employ to minimize household income variability and to ensure a minimum level of food self-sufficiency (Ahmed, 2012). Ibekwe *et al.* (2010) added that the rural households in sub-Saharan African countries usually have to cope with both poverty and income variability to shift from subsistence agriculture to a more pluriform society where farm and non-farm opportunities are available. In general, livelihood diversification is the process by which rural families construct a diverse portfolio of activities and social support capabilities for survival and improve standards of living (Ellis, 2000). As indicated by Ibekwe *et al*. (2010), though livelihood diversification is a viable way in reducing poverty and destitution, little policy efforts have been made to promote these activities in many sub-Saharan Africa countries.

For generations, rural communities in Ethiopia practiced livelihood diversification such as sharecropping, renting land, water-harvesting techniques, growing different types of crops, rearing varieties of livestock and engaging in off-farm and non-farm activities to keep up the food security status of their families. Despite some minor changes in livelihood diversification, agriculture continues to play a crucial role to the livelihoods of the majority of the rural households in Ethiopia. Josef and Laktech (2009) as well as Mamo and Ayele (2003) in Ethiopia and Libo Kemekem of the Amhara Region, respectively indicated that, nearly 90% of the rural poor are dependent on agriculture for their major livelihood security. This is due to the fact that governments in many developing countries have focused solely on agricultural developments as the way to reduce rural poverty and achieve sustainable economic growth (Ahmed 2012). However, according to Thomas *et al*. (2006) agriculture as a traditional vision of rural economies is clearly obsolete. That is, farm households across the developing world nowadays earn an increasing share of their income from nonfarm/off-farm sources away from agriculture. In this regard, writers such as Barett *et al*. (200), John *et al*. (2014), Tagel (2012), Woldeamlak and Conway (2007), Woldeamlak (2009), Yishak et *al.* (2014) and Yaro (2006) substantiated that in developing countries the carrying capacity of the agricultural sector is declining because of increasing population growth, erratic rainfall/occurrence of drought, high input prices and sever land degradation.

These situations made livelihood diversification to become a norm for many rural poor households in many developing countries and very few households collect their income from single source (Adugna, 2005; Barett *et al.*, 2001). Those households who are engaged only in agriculture are among the most vulnerable to food insecurity and they are unable to produce enough food to feed their families throughout the year (Yaro, 2006). For instance, a study made in Ghana by Asmah (2011) indicated that while recognizing the urgent need to maintain a robust agricultural sector, it is increasingly becoming clear that the agricultural sector alone cannot be relied upon as the core activity for rural households as a means of improving livelihoods and reducing poverty. Likewise, Josef and Laktech (2009) a study made in Ethiopia indicated that in a setting with limited agricultural potential or highly variable weather, income from non-farm/off-farm activities can augment and smooth income flows for rural households. Mesay (2009) stated that non-farm activity is an important factor in rural economy as it allows farmers' greater access to commercial farm inputs that could enhance agricultural production. According to Ahmed (2012), non-farm earnings account for a considerable share of farm household income in rural Africa, typically more so than in other world regions. The same author further pointed out that very few household collect all their income from one source and use their assets in just one activity. Nevertheless, the contribution of non-farm activities to households' income were insignificant mainly due to lack credit availability, deficiency of skilled labor power, absence of job opportunities, lack integrated market situations and limited infrastructural development (Barett *et al.*, 2001; Josef and Laktech, 2009). The push factors on the other hand, like frequent occurrence of drought, insufficient and degraded farmland and shortage of food for several months in the year forced the rural poor to engage in causal labor and out migration (Barett *et al.*, 2001). In this regard, this paper contributes in providing sound empirical information on issues related to non-farm and off-farm activities that require policy attention.

Few scientific works (Alebachew, 2011; Adugna, 2005; Degefa, 2005; Kebede *et al.*, 2014; Kune and Mberengwa, 2012; Mamo and Ayele, 2003; Yenesew *et al.*, 2014; Yared, 2001) had been done in different parts of Ethiopia in relation to livelihood diversification. However, they were not able to give adequate information on households' participation in non-farm and off-farm activities by gender, wealth categories and agro-ecological zones. This is due to the fact that the constraints faced by heterogeneous households who are engaged in heterogeneous set of non-farm/off-farm activities and placed in varied ecological zones; generalization without considering gender, wealth categories and agro-ecological zones becomes too shallow for policy makers. More importantly, as the knowledge of the writer of this paper is concerned, no study has been done so far in relation to livelihood strategies in the study area. This study, therefore, fills these knowledge gaps by focusing on a severely degraded, impoverished and drought-prone area where research evidences on livelihood diversification in augmenting households' income is lacking. The general objective of the study was to identify the determinant factors affecting households' participation in non/off-farm activities in the study area. The specific objectives include to assessing the situations of non-farm/off-farm activities between gender, wealth categories and agro-ecological zones and identifying the factors influencing rural households' participation in non-farm/off-farm activities in the study area.

2. Materials and Methods

2.1. Description of the Study Area

The study was carried out in Lay Gayint district in the Amhara Region (Figure 1). Lay Gayint covers a total area of 1320.3 km^2 and has a population density of 185 persons per km^2 (CSA, 2010), which makes it one of the most populated districts in the Region. The topography is rugged with elevations varying between 1200 m to above 4000 m asl. The area receives annual rainfall of 898.3 mm. June, July and August are the rainy months. The mean annual temperature ranges from 4^{0}C (on top of Guna Mountains) to 28^{0}C (at the bottom of the Tekeze river valley). Black and red (*Cambisols*) soils, black (*Vertisols*) soils and *Leptosols* are the dominant types of soils in the district (District Agriculture and Rural Development, 2011). Based on the traditional agro-ecological classification, three agro-climatic zones are found in the area: *Dega* (cool), *Woina-Dega* (temperate) and *Kolla* (hot tropical). Small scale mixed agriculture is the dominant source of livelihood to the local people. Barely, wheat, *tef* and potatoes are the principal crops, and from the livestock cattle, sheep, and goats are the dominant ones.

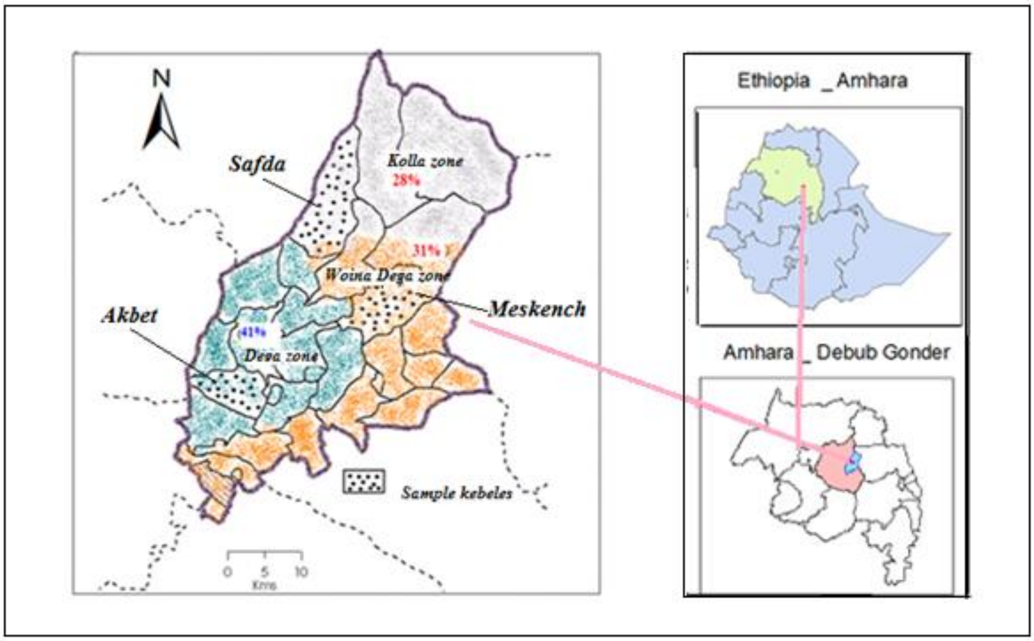

Figure 1. Location map of Lay Gayint district in South Gondar Administrative Zone of ANRS

2.2. Data Collection Instruments

The study employed purposive, stratified and random sampling methods to select specific sample sites and households. Selection of the study district was purposive based on the researcher's prior knowledge of the area. The specific Rural *Kebele* Administrations (RKAs) were selected in a stratified sampling methods where all the RKAs in the district were first classified into three major agro-ecological zones (*Kolla*, lowland; *Woina-Dega,* mid-highland and *Dega*, highland, with respective elevations of 500-1500, 1500-2300 and above 2300 m asl). The assumption was in similar agro-ecological zones the households share similar opportunity to secure their livelihoods. Households in each RKA were further grouped into wealth categories based on the information obtained from focus group discussions (FGDs), key informants interview, authors' prior experience and secondary sources. It was assumed that the same risk/shock has different impact on households in different wealth groups. The total households in the three selected RKAs were 4100. For a population of about 4000, margin error = 0.03, alpha = 0.01 and t = 2.58, the minimum sample size assigned is 198 (Barrett *et al*., 2001). For this study, fear of missing data, 210 sample sizes were determined to fill the questionnaire. In relation to this, Naing *et al*. (2006) indicated that it is wise to oversample 10% - 20% in case there is missing data. Finally, a total of 210 households were sampled for a questionnaire survey from the three RKAs using proportional stratified systematic sampling techniques based on the sampling frames obtained from the RKAs offices. However, nine questionnaires were not correctly filled for analysis in *Kolla* agro-ecological zones; this made the total sample size to be 201in the three selected RKAs. In addition to the household survey, a total of six key informant interviews and three focus group discussions were conducted in each of the three RKAs.

Data collection techniques for this study include structured interview, key informant interview, focus group discussions and direct observation. Structured interview covered issues such as households' participation in non-farm and off-farm activities and challenges faced in the engagement of non/off-farm activities. Key informants interview and focused group discussions (FGDs) were held with the subjects such as the role of non/off-farm activities for livelihood outcomes and households' perceptions about food shortage and vulnerability to food insecurity.

2.3. Data analysis Techniques

Information collected through in-depth interview, FGDs, life history narratives and observations were documented and analyzed textually to substantiate the statistical results from the structured questionnaire. The data generated by the structured questionnaire were entered into the statistical package SPSS and were analyzed using frequencies, tables and percentages as well as statistical modeling. Hence, in analyzing the quantitative data, descriptive statistics and inferential statistics were used. Binary logistic regression model was employed to identify determinant variables affecting households' participation in non-farm/off-farm activities. Such kind of model is suitable when the dependent variable is dummy in this case participation of households in non-farm/off-farm activities. A range of biophysical (farmland owned, number of plots and location), socio-economic (age, sex, family size, number of oxen, occupation and education) and institutional factors (credit services and cash-for-work) generally influences households participation in non-farm/off-farm activities. In relation to this, Adugna (2005) identified the determinants of off-farm/non-farm activities as demographic, livestock ownership, farmland, risk perception, and farm income. In this study, participation of households in non-farm/off-farm activities was taken as a proxy indicator to their livelihood outcomes and hence the dependent variable for the binary logistic regression modeling.

Checking the goodness-of-fit is imperative for binary logistic regression model (Quinn and Keough, 2001). The Pearson χ^2 statistic based on the observed (o) and the expected (e) is used to visualize the two (binary response) and contingency tables (Quinn and Keough, 2001). This showed that the fitness of the logistic model is determined by how similar the observed values are to the expected or predicted values. The null hypothesis that the model fits the data against the alternative hypothesis was also tested using Hoemer- Lemeshow Test. Hoemer - Lemeshow's goodness of fit test indicates that the predicted frequency and observed frequency should match closely; and the more closely they match, the best fit it yields (Alemu, 2007; Tang, 2001). According to Babu and Sanyal (2009), the binary logistic regression model best fits, if the value of the Hosmer-Lemeshow goodness of fit approaches to one.

Once the model is fitted to the observed and expected of the binary response variable, a thorough examination of the extent to which the fitted model provides an appropriate description of the observed data is vital in the modeling process (Alemu. 2007). According to the same author, the fitted logistic regression model may be inadequate because a particular observation, termed as outliers or influential values might have an impact on the conclusions drawn from the results. Some of the statistical techniques, which are employed to examine the model of adequacy, include tolerance and variance inflation rate (VIF). Multicollinearity indicates the strength of the interrelationship between independent variables however, how much the inflation of the standard errors caused by collinearity effect could be checked using tolerance (1 - R^2) and VIF (1/tolerance). As a rule of thumb, the VIF rate greater than 10 shows high multicollinearity and tolerance close to zero also indicates high multicollinearity between independent variables (Gupta, 1999).

4. Results and Discussion

4.1. Participation of Households' in Non-Farm/Off-Farm Activities

Under ecological stress and/or severe land degradation, unpredictable rainfall and scarcity of farmland, livelihood diversification is a necessary condition in which the agricultural activities alone are not able to ensure household food security. Livelihood diversification includes non-farm, off-farm and on-farm activities. Non-farm incomes include wage paying activities and self-employment in commerce, remittances, traditional/cottage industries and other services in rural areas (Ellis, 2000). Off-farm activities on the hand include participating in casual labor, selling of fuel wood, charcoal, grass and cake dung, while non-farm activities consist of petty trading, handcrafts, grain milling, and blacksmith, weaving and selling of local alcohols. The survey results showed that public works and causal labor (out migration) were the major activities in the three agro-ecological zones and accounted for 49% and 15.4%, respectively. Causal labor was the highest in the *Dega* zone because of its accessibility to the main road and its nearness to the main town of the district (Nefas Mowucha). The least reported activities were carpentry (1%), blacksmithing (2%) and weaving activities (2.4%). As the KIs and FGDs informed, the majority of the communities in the study area consider these activities as inferior jobs performed by the poor and dismayed households. Kune and Mberengwa (2012) indicated that despite the age-old importance of blacksmiths and other cottage industries in producing, shaping and repairing farm tools, the community attached derogatory names for their services and people looked them down.

The study found out that in all agro-ecologies, about 25% of the respondents were engaged in non-farm/off-farm activities during the field survey, which is lower than the average country's share (30%) (Tadesse, 2010) and higher than the ANRS (20%) (MoFED,2012). Likewise, a study made by Kebede *et al.* (2014) in northern part of Ethiopia also indicted that 26.7% of the respondents were non-farm employed. The total income per household of the sampled households in all agro-ecologies in the year 2010/11 was Eth. Birr 1,129.1 (Table 1). On per capita basis, it was Eth. Birr 215.2. Agro-ecologically, *Dega* zone with the total income Eth. Birr 2,013 per household was the leading in non-agricultural activities and *Woina- Dega* zone with the total income Birr 443 per household was the least among the three agro-ecological zones. This means that non-farm activities as an alternative strategy in generating additional income outside agriculture is the least developed in all agro-ecologies in the study area. Josef and Laktech (2009), a study made in Ethiopia indicated that non-farm activities are small and own very little capital and the average per capita income per household was roughly Eth. Birr 194 in 2009. KIs and FGD participants indicated that lack of wage labor, shortage of startup capital, limited skills, weak marketing systems and less importance given by the district authorities were the major factors contributing to the poor performance of these activities in the study area. Previous study (Yared, 2001) also indicated that low demand for the products, lack of financial know how, low labor stipulation and distance from urban centers were some of the bottlenecks to engage in non-farm activities. The study revealed that grain trading, grain milling and public works were the dominant sources of income in *Dega* zone. However, the total share of income from grain milling seems the highest, insignificant households (2%) in all agro-ecological zones were participated in this activity. Three of them found in *Dega* zone and the rest (one) is found in *Kolla* zone.

Table 1. Total incomes from non-farm and off-farm activities by agro-ecological zones (Eth. Birr) in 2010/11 (Eth. Birr 17.67 = US$ 1.0)

Sources of income	*Dega*	*Woina- Dega*	*Kolla*	Total	% of total
Grain trading	14,760	500	3500	18,760	8.27
Livestock trading	3,000	4,300	5000	12,300	5.42
Selling local alcohol	380	1,250	6807	8,437	3.72
Weaving	2,300	-	5,850	8,150	3.9
Selling commodities	1,000	600	-	1,600	0.7
Carpenter	-	280	-	280	0.1
Public works	29,200	19,630	15,500	64,330	28.3
Blacksmith	5,000	0.0	1,300	6,300	2.8
Grain milling	48,000	0.0	2,000	50,000	22.0
Causal labor	25,047	4,150	2605	31,802	14.0
Selling cake dung	2,000	-	3270	5270	2.3
Selling of charcoal/fuel	7,145	-	7,000	14,145	6.2
Selling of grass	3,080	300	2,200	5,580	2.5
Total income	140,912	31,010	55,032	226,954	100
Total	**2013.0**	**443.0**	**902.2**	**1129.1**	

One-way ANOVA result showed that there were statistically significant associations between agro-ecologies and engagement in non/off-farm activities (at $p < 0.001$). The multiple comparisons of ANOVA (Table 2) showed that *Dega* zone is significantly different from *Woina-Dega* and *Kolla* zone (at $p < 0.05$ and at $p < 0.1$, respectively) while *Woina-Dega* zone does not show significant difference from *Kolla* zone (at $p > 0.1$).

Table 2. Multiple comparisons among agro-ecological zones

Dependent variable	(I) agro-ecological zone	(J) agro-ecological zone	Mean Difference (I-J)	Std. Error	Sig.
Non/off-farm income	*Dega*	*Woina-dega*	535.78571*	189.08582	0.014
		Kolla	439.70843	195.93620	0.066
	Woina-dega	*Dega*	-535.78571*	189.08582	0.014
		Kolla	-96.07728	195.93620	0.876
	Kolla	*Dega*	-439.70843	195.93620	0.066
		Woina-dega	96.07728	195.93620	0.876

* The mean difference is significant at the 0.05 level.

The mean difference of 535.78571 in Table 2 showed that *Dega* have more than Ethiopian Birr (ETB) 535.78571 to *Woina Dega* households and more than ETB 439.70843 to the *Kolla* zone.

4.2. Engagement in Non-Farm and Off-Farm Activities by Wealth Categories

The study revealed that the average incomes for the better-off, the middle and the poor households were Eth. Birr 2,633.70, 688.10 and 990.35 per household, respectively (Table 3). This showed that the poor were relatively better than the middle because the poor might engage in causal labor and out migration better than middle households might. Misselhorn (2006) in her close analysis of the interview findings indicated that, while financial source is undeniably an important indicator of vulnerability to food security, the means to generate non-farm income significantly differs between wealth categories. As it is shown in Table 3, grain mills, and grain trading (that need high start-up capital), were dominated by the better-off households, while causal labor and public works (which demand little capital) were the major activities of the poor households.

Table 3. Total incomes from non-farm and off-farm incomes by wealth categories (Eth. Birr) in 2010/11 (Eth. Birr 17.67 = US$ 1.0)

	Wealth category			
Source of income	Better-off	Middle	Poor	(%) of total
Grain trading	14,400	2,360	2000	8.3
Livestock trading	6000	3300	3000	5.4
Selling local alcohol	0.0	1187	7250	3.7
Weaving	0.0	1000	7150	3.9
Selling commodities	0.0	400	1200	0.7
Carpentry	0.0	280	0.0	0.1
Public work	0.0	9,085	55,245	28.3
Blacksmithing	4000	1000	1300	2.8
Grain milling	46,000	4000	-0.0	22.0
Income from causal labor	687	8,250	22,865	14.0
Selling cake dung	570	1500	3,200	2.3
Selling charcoal/ fuel woo	800	7445	5900	6.2
Selling grass	1300	1480	2800	2.5
Total income	73,757	41,287	111,910	100
Total	**2,634.2**	**688.1**	**990.4**	

Consistent with this result, Adugna and Wagayehu (2012) noted that off-farm activities (agricultural wage, land rent and environmental gathering) are survival mechanisms pursued mainly by the poor households. Barrett *et al*. (2001), in a study made in Rwanda, evidently stated that the poor with the least agricultural assets and income are also typically the least able to make up this deficiency through non-farm earnings because they cannot meet the investment requirements (start-up capital) for entry into remunerative non-farm activities. Thus, the better-off as opposed to the poor have greater freedom to choose among a wider range of non-farm activities. Nevertheless, some writers such as Alebachew (2011), Davis (2003) and Degafa (2005) indicated that the poor were engaged more in non-farm activities than the better-off. These differences might arise because of temporal and financial variations.

The One-way ANOVA result showed that there were statistically significant relations between wealth categories and engagement in non/off-farm activities (at $p < 0.001$). As it can be seen in Table 4, the multiple comparisons showed that the better-off households are significantly different from the middle and the poor households (at $p < 0.001$) while the middle does not differ from the poor households (at $p > 0.1$). The mean difference in Table 4 showed that the better off have more than ETB 3213 to the middle households and more than ETB 3627 to the poor households. The descriptive statistics indicated that the minimum was zero and the maximum was 50,000, which was owned by the better-off households.

Table 4. Multiple comparisons among wealth categories

Dependent Variable	(I) wellbeing	(J) wellbeing	Mean Difference (I-J)	Std. Error	Sig.
Non-farm/off-farm	better off	Middle	3213.20833*	864.67193	0.001
		Poor	3627.47080*	797.54644	0.000
	middle	better off	-3213.20833*	864.67193	0.001
		Poor	414.26246	603.49388	0.772
	poor	better off	-3627.47080*	797.54644	0.000
		Middle	-414.26246	603.49388	0.772

* The mean difference is significant at the 0.05 level.

4.3. Gender and Engagement in Non-Farm and Off-Farm Activities

The study showed that there were variations in non-farm/off-farm activities between sexes of the households in which 33% female-headed households were engaged in non-farm/off-farm activities against 21% male-headed households. The result was consistent with the works of Josef and Laktech (2009) a study made in Ethiopia who found out that 35% of female-headed households participated in non-farm/off-farm activities against 25% of male-headed households. Nkurunziza (2006) noted that only 26% of African female- headed households are engaged in rural non-farm/off-farm activities, which was much lower than the present study. In relation to this, a study made by kebede et al. (2014) showed that 40% of the female-headed annual income and 5% of the male-headed annual incomes were obtained from non-farm activities. The independent T-test also showed that there was significant association between sex of the households and participating in non/off-farm activities (at $p < 0.01$). Though female-headed households were busy in domestic roles such as childcare, cooking, washing cloth, gathering fuel wood, fetching water, they were also engaged in non-farm and off-farm activities to supplement their meager sources of cash. In relation to this, female KIs indicated that activities such as selling of charcoal, fuel wood, local alcohol (*tella*, *arqie*) and food during marketing days were the major activities run by female-headed households in their communities. This evidenced that female-headed households were self-employed. On the other hand, poor male-headed households were engaged in causal labor hired to the better-off households. Dolan (2005) confirmed that female-headed households are highly dependent on selling cooked food, alcohol and charcoal, which are an indicator of women's self-employment activities compared with their male counterparts. The result was inconsistent to the works of Smith *et al*. (2001) which says female-headed households engaged in less diversified activities than their counterparts did. In relation to these scenarios, one female-headed household in *Woina-Dega* zone narrated her experience as follows:

> *I engaged in selling tella and arqie (local alcohol) to the surrounding communities. During marketing days, I also sell food (injera with wot, tea and bread). All these activities helped me to have some cash to buy food to my family. I have five family members: most of them are dependent and I am the responsible person to feed them. The incomes obtained from different sources are used for household food consumption and no more savings. The land I owned was sharecropped but the productions collected were too small to feed my family. Before engagement in non-agricultural activities, my family suffered from food shortage. Presently, I am also a member of PSNP run by the government of Ethiopia.*

From the discussions, it can be said that female-headed households in the study area are employed in relatively varied livelihood portfolios to satisfy their needs; however, there is no sign of reducing the problem of food security and hunger since about 86% of the female-headed households were food insecure during the field survey. Thus, non-farm/off-farm activities run by female-headed households did not uplift them from asset poverty; they were rather in a vicious cycle of destitution. This is because they were engaged in such activities as selling alcohol, fuel wood and charcoal that paid least for the products. If non-farm/off-farm incomes were taken as a proxy indicator of welfare, female-headed households were extremely disadvantageous since more than 92% against 60% male-headed households earn a total annual income much less than Eth. Birr 1500 from these activities during the field survey. Dolan (2005) confirmed that the mean per capita income of female-headed households was much lower than that of the male-headed households in the three districts of Uganda.

4.4. Challenges to Engage in Non-Farm and Off-Farm Activities in the Study Area

Non-farm and off-farm activities can supplement the farming incomes where the latter are not able to satisfy the needs of the households. As information collected from KIs, FGDs and survey results, non-farm/off-farm activities have faced multifaceted problems that directly affect the improvements of the households' livelihoods. For example, poor access to credit and high interest rate (18%) were the major drawbacks mentioned by KIs and FGD participants to engage in non-farm activities. Many farmers interviewed indicated that they have a desire to have credit services but they always feel fear for the reason that crop production will fail and difficult repay the loans leave alone to improve further non-farm activities. Poor infrastructure and weak rural development agents that did not have the capacity to spread non-farm activities in the rural areas were also the barriers for the development of the sector. In this regard, KIs in the *Kolla* zone indicated that there is lack of integrated market situations and infrastructure, especially roads, to sell the products to the consumers. The other serious problem mentioned by KIs and FGDs were products produced from non-farm sector (weaving, blacksmith, tanning) were not competitive to the manufactured goods and services. Among these, weaving and tanning have potential threat to compete with the modern products partly because of lack of demand and the market is flooded with imported materials due to globalization. For example, clothes made of nylon and polyester with different colors has attracted the rural women who were once the most consumers of locally woven products. Hence, nylon and/or polyester, which are durable and easy to wash, are the dominant type of clothes almost for all households in the study area. Industrial sacks replaced tannery products such as local sacks (*aqumada*). As compared to other non-farm activities, participating in petty trading had shown better development, though it is suffered from twin problems. One of the problems was lack of finance (85% of the respondents). The other problem mentioned by KIs and FGDs was it is more of seasonal, commonly practiced for not more than three or four months (from January to April) in the year. This result was also consistent with the works of Kune and Mberengwa (2012). In the other months, farmers were busy in agricultural activities. What makes non-farm activities peculiar in the study area is that much of the work is done by very few or a single person. This is very small in nature to make significant contribution to improve the livelihoods of the poor. This means that the income derived from non-farm/off-farm sources was not sufficient to meet the food demand of the sample households (let alone savings).

4.5. Determinant Variables for Households' Participation in Non-Farm/Off-Farm Activities

As it is shown in Table 5, a total of 12 variables were selected for the model. Eight variables were significant at 1%, 5% and 10% probability levels. The omnibus test of model coefficients has a Chi-square value of 37.227 on 11 degrees of freedom, which is strongly significant at $p < 0.001$ indicating that the predictor variables selected have a high joint effect in predicting households' participation in non-farm/off-farm activities. The predictive efficiency of the model showed that out of the total sample households included in the model, 94.1% were correctly predicted. The sensitivity and specificity were found to be 64.7% and 95.4%, respectively. The model summary indicated that the Cox and Snell R Square and Nagelkerke R Square were 0.43 and 0.61, respectively. These results showed that the model is fitted to run the binary logistic regression model.

The binary logistic regression results showed that the larger the number of oxen owned, the less likelihood that a household would participate in non-farm activities. As oxen ownership increases by one unit, the odds of being engaged in non-farm activities decreased by a factor of 0.438, which is significant at $p < 0.01$. The descriptive result evidenced that from the total sample households who engaged in non/off-farm activities, 67% owned one or no ox. This result is consistent to the works of Adugna (2005). As hypothesized, educational attainment of household heads was found to be an important factor in participating households' in non/off-farm activities. As educational attainment of household heads increases by one unit, the odds ratio of a household being participating in non-farm activities increases by a factor of 10.803 (at $p < 0.1$). The result was inconsistent with the works of Tadesse (2010) and Gebrehiwot and Fekadu (2012) which says education has not significant role in improving non-farm activities.

Table 5. Determinants of participating in non/off-farm activities

	B	S.E.	Wald	Sig.	odds ratio
Agro-ecological zone (Dega as a reference)	2.45	0.293	11.873	0.003***	7.214
Woina Dega	-3.509	1.242	7.978	0.005***	0.030
Kolla	0.079	1.085	0.005	0.942	1.082
Household size	-0.010	0.092	0.011	0.916	0.990
Age of the household	0.028	0.015	3.292	0.070*	1.028
sex of the household (male as reference)	-3.234	1.317	6.031	0.014**	0.039
Number of oxen	-0.363	0.129	7.907	0.005***	0.438
Farm size	-1.024	0.485	4.461	0.035**	0.359
Number of plots	-0.792	0.512	2.395	0.122	0.453
Level of education	2.380	1.290	3.401	0.065*	10.803
Cash for work	0.466	0.818	0.324	0.569	1.593
Occupation of the households	2.422	1.510	4.645	0.098*	11.271
Constant	-5.749	2.705	4.517	0.034**	0.003

*Significant at 0.1, **significant at 0.05, *** significant at 0.01, *ns* = not significant

With respect to agro-ecology, it was found out that location in *Dega* zone increased the odds of being participating in non-farm activities by a factor of 7.214 and location in *Woina-Dega* zone decreases participation of non-farm activities by a factor of 0.03. From the discussion, it was learnt that *Dega* is located near to the main town of the district and hence engagement in non-farm activities was much better than the other two zones. Josef and Laktech (2009) and Nkurunziza (2006) noted that non-farm activities are the highest in rural towns and the lowest in remote/inaccessible rural areas. Likewise, Mintewab *et al.* (2010) reported that in low-income rural economies with little infrastructure and thin supplementary markets, the potential of non-farm/off-farm opportunities as alternative to agricultural activities are limited. Consistent to the results

Yishak *et al.* (2014) identified that diversifying the livelihoods into farming with non-farming increases as we go from *Kolla* to *Dega*.

Other variables being constant an increase of male-headed households by one unit the odds ratio in participating in non-farm activities decreases by a factor of 0.039 (at $p < 0.05$). The result was consistent to the works of Josef and Laktech (2009), Adugna (2005) and Yishak *et al.* (2014). Farm size has strong relations to non/off-farm activities in which 71% of the sampled households who owned less or equal to one hectare of land were engaged in these activities. Other variables being constant an increase of farm size by one unit the odds of being engaging in non-farm activity decreases by a factor of 0.359 (at $p < 0.05$). The result was consistent with the works of McDongh (2005) which says people engaged in non-farm/off-farm activities in areas where land becomes too scarce to run fully the farming activities. This showed that households who suffer from scarcity of farmland are supplemented by non-agricultural activities to overcome shortage of cash.

5. Conclusions and Recommendations

Nowadays academicians and politicians recognized the importance of livelihood diversification for the reason that agriculture as a major activity is not able to feed the growing population due to natural and socio-economic constraints. In the study area, livelihood diversifications that can supplement households' source of income were extremely low and few households were participated in non-farm/off farm activities during the field survey. In the study area, lack access to non-farm and off-farm activities is perhaps a major cause for the low coping capacities of households at times of food crises. The results of the study indicated that non-farm activities that can be used as a base for cottage industries have faced technological challenges mainly due to globalization and socio-cultural influences. Study participants indicated that lack of wage labor, shortage of startup capital, limited skills, weak marketing systems and less importance given by the authorities were the major factors contributing to the poor performance of non-farm activities. In drought prone areas such as Lay Gayint district where rainfall is unpredictable, it is difficult to imagine an effective rural poverty reduction strategy that does not aim to increase the potential of non-farm sector. Hence, well-integrated interventions that stimulate rural non-farm economy are imperative for poverty reduction in the study area in particular and the country in general. The study also recommends in providing microcredit services with affordable interest rate and considerable maturation period; delivering skill training for the rural poor, creating awareness about the importance of non-farm activities to the rural communities are found to be imperative for the improvement of non-farm activities.

This study strongly underlined the role of policy makers to give focus in providing the necessary incentives for agricultural households to increase crop production per hectare and try to minimize the constraints by inspiring households to engage in robust livelihood diversification.

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Potential of Biotechnology for Livestock Feed Improvement: A review

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Abstract

Application of recent advancements of biotechnology in recent years allowed the use of non-toxic fungi to improve fibrous feeds like straw or poor quality roughages. In particular, the white rot fungi have been used because of their ability to digest in to usable product of the plant material. In addition, wide variety of feed additives, many of biotechnological origin are known to modify rumen fermentation in ruminant animals. They include components that can reduce methanogenesis, enhance propionic acid production, reduce protein degradation, improve microbial protein synthesis and inhibit protozoa. Among such additives are antibiotics, probiotics and specific substrates like pre-biotics. Moreover, due to advances in biotechnology, more effective enzyme preparations can now be produced in large quantities and relatively inexpensively. Therefore, supplementation of the diet as a means of improving nutritive value is becoming routine. Still another area of application of biotechnology is reduction of less important microbes from rumen and increase feed efficiency of animals. The ultimate goal of using biotechnology in animal nutrition is to improve the plane of nutrition through the use of enzymes to improve the availability of nutrients from feed and to reduce the wastage of the feed.

Key words: Feed Additives, Feed Nutritive Improvement, Forage Breeding, Antibiotics, Enzymes, Probiotics and Prebiotics.

1. Introduction

Demand for livestock products is increasing because of the increasing human population, growth in income and urbanization (Thornton, 2010) in these parts of the globe. For example, total meat production in the developing world tripled between 1980 and 2002, from 45 to 134 million tons (World Bank, 2009). Demand for meat will grow only 0.6% in developed countries compared with an annual increase of 2.8% in developing countries. Most food of animal origin consumed in developing countries is currently supplied by small-scale, often mixed crop-livestock family farms or by pastoral livestock keepers (John and Maria, 2001). Hence, productivity of animals in developing countries will need to be substantially increased in order to satisfy increasing consumer demand, to more efficiently utilize scarce resources and to generate income for a growing agricultural population (John and Maria, 2001). Conventional methods of livestock improvement have been used in the past served the purpose of increasing livestock productivity (Madan, 2005). However, these options can no longer sustain production; consequently, new intensive techniques including biotechnology are now required to augment productivity. Modern biotechnology has the potential to provide new opportunities for achieving enhanced livestock productivity in a way that alleviates poverty, improves food security and nutrition and promotes sustainable use of natural resources (Mahesh and Madhu, 2013). Hence, the objective(s) of this review article is therefore to indicate the potential application of biotechnology in animal feed improvement in developing countries.

2. Fibrous Feed Improvement

Fibrous feeds of low digestibility comprise the major proportion of feeds accessible to most ruminants under smallholder situations in developing countries (Lebbie and Kagwini, 1996). It is well known that some micro-organisms, including cellulose enzymes from anaerobic bacteria and white rot fungi (*Pleurotus ostreatus*) can degrade lignin in the cell walls. Several fungal strains have been used for lignocellulosic hydrolysis such as *Asprigullus niger, A. terreus, Fusarium moniliforme and Chaetomium celluloyticum* (Kim *et al*., 1985; Abdel-Azim *et al*, 2011). However, among many species of fungi white rot fungi have been reported to be suitable for treatment of roughages so far. Zadrazil *et al*. (1995) found that, the white rot fungi have the capacity to attack lignin polymers, open aromatic rings and release low molecular weight fragments. In addition, Yu *et al*. (2009) have tested several such strains of white-rot fungi on sawdust and found that digestibility of the sawdust in vitro was improved, and the degree of improvement was highly correlated with the degree of lignin removed. In related work, Kirk and Moore (1972) found two strains, which increased the digestibility in vitro of sawdust from 46 to 74% in a period of 2–3 months. The sawdust lost 20% of its original weight and 50% and 20% of its original lignin and carbohydrates, respectively. These results are certainly encouraging and experiments using these organisms on straw should be taken up. Significant results were reported by Akinfemi *et al*. (2009) for CP (14%) of maize cob treated with fungi species (*Pleurotus pulmonarius and Pleurotus sajor-caju).*

It must be remembered, however, that whatever organism is grown on the roughage must obtain its energy from the roughage itself (Leng, 1991). In general, the organisms that suit for this purpose must have a number of special properties. They must be capable to grow on a wide range of carbon sources, have high growth rates to minimize the size of the fermentation system and have a high efficiency in converting of substrate to biomass with high protein content (Mahesh and Madhu, 2013). Another indirect approach to the enhancement of fibre digestion in ruminants is through modification of silage inoculants. In silages containing low carbohydrate contents, inclusion of amylase, cellulase or hemicellulase enzymes has been shown to increase lactic acid production by releasing sugars for growth of lactobacilli reviewed by Mahesh and Madhu (2013). Thus, inoculation of silage bacteria genetically modified to produce such enzymes has been proposed to obtain better ensiling and/or pre-digest the plant material in order to lead to better digestibility in the rumen. Scheirlinck *et al*. (1990) reported that recombinant *Lactobacillus plantarum*, a species used as silage starter, were constructed to express alpha-amylase, and cellulase or xylanase genes. The competitive growth and survival of such modified lactobacilli in silage has been reported by other workers (Sharp *et al*., 1992), although the impact on silage digestibility has not been studied.

3. Forage Breeding

Genetically engineered forage crops, with a range of potential benefits for production, the environment and human health, have been developed (Spangenberg *et al*. 2001). Genetically engineered forage crops are genetically modified using recombinant DNA technology with the objective of introducing or enhancing a desirable characteristic in the plant or seed. These transgenic forage crops are aimed at offering a range of benefits to consumers, as well as developers and producers. Products to be consumed by humans, derived from animals fed on transgenic forage crops, are not themselves transgenic. Thus, food products derived from animals fed on transgenic forage crops offering human health benefits may receive different levels of support from the public than the currently available set of transgenic food crops (Spangenberg *et al*. 2001).

Protein content and feeding quality are being targeted for improvement in biotech crops (Edwards *et. al*., 2000).. Scientists can modify the protein content of crops either indirectly (by improving nitrogen assimilation) or directly (by modifying key biochemical pathways or introducing proteins with a different amino acid composition). Researchers by elevating the levels of sulfur-containing amino acids in lupins, improved the performance of broiler chickens (Ravindran *et al*. 2008) as well as wool growth and weight gain in sheep.

High lignin content reduces the efficiency of feed utilization and thereby reduces animal growth. Conventionally breed forage varieties with reduced lignin are available, but they tend to have weaker stems and poor stand ability in the field. Researchers have developed engineered alfalfa with 20 percent less lignin and 10 percent more cellulose, a combination that makes it more digestible (Madan M.L., 2005). The ability to modify specific components of fiber biosynthesis may allow scientists to develop reduced-lignin forage that is more digestible and still has the stem strength needed for good field performance. It is known that forage legumes are comparatively low in sulphur-containing amino acids and their availability to ruminants is further adversely affected during rumen digestion (Croissant *et. al.*, 1976). This leads to the reduction of the optimum for animal growth level of essential amino acids. Plant genetic modification with genes encoding for a sulphur amino acid-rich proteins, resistant to rapid rumen degradation can compensate this deficiency. Agronomic researchers around the globe are currently using recombinant DNA technology to create new and altered species of plants.

Leng (1991) indicated that plants in order to survive insect, fungal and bacterial attack have developed secondary compounds, which detract from these organisms colonizing the leaf tissues. In another study, researchers at the Noble Foundation have been successful in manipulating lignin composition and levels in alfalfa and other forages to improve their digestibility and the conversion of biomass to biofuels (Chen and Dixon, 2007). Some shrubs and trees respond to leaf damage as occurs by grazing and produce greater quantities of secondary compounds that often make them inedible. Using biotechnology, scientists may be able to enhance the oil content of crops where there is no natural variation for this trait. High-oil corn reduces the amount of feed required for a livestock diet, and this in turn reduces the volume of manure (Etherton *et al*., 2003). Furthermore, conventional high-oil crops often have lower yield or protein content than their lower oil counterparts, whereas traits introduced via biotechnology can modify oil accumulation only at specific growth stages and in targeted tissues to minimize such deleterious effects. Biotech modification of the oil composition of feeds, such as raising the level of oleic acid, may also improve the quality of the resulting animal products for processing and human nutrition (Wieczorek , 2003).

Evidence suggests that genetically modified crops are more acceptable if they provide benefits for the consumer or the environment. For example, research indicated medical applications of genetic engineering are more acceptable to the public than food applications (Small et al, 2002). However, unlike genetically engineered food, forage crops are not eaten by people, rather, they are eaten by food animals; animals, the products of which (e.g., milk and meat), humans consume. In addition to consumer benefits, animal forages like soybeans, corn, canola, and cotton modified for agronomic input traits such as herbicide tolerance and insect protection are all used in livestock rations. They are present either as a whole crop such as corn silage, or as specific crop components or co-products such as corn grain or oilseed meals. Studies by Phipps *et al*. (2005) showed that the inclusion of genetically modified feed ingredients in dairy cow diets did not affect feed intake or milk production.

4. Feed Additives

Feed additives are materials that are administered to the animal to enhance the effectiveness of nutrients and exert their effects in the gut (Fuller, 2004). Feed additives include antibiotic, enzymes propbiotics and prebiotics (McDonald *et.al*. 2010).

Antibiotics

Antibiotics are antimicrobial pharmaceutical, usually of plant or fungal origin and are also synthesized in the laboratory (Fuller, 2004). Although the primary use of antibiotics is in the treatment of infections, certain antibiotics are used as feed additives in order to improve growth and feed conversion efficiency. Among antibiotic groups are ionophores (McDonald *et al*., 2010) which are ion-bearing compounds, which surrounds cations so that the hydrophilic ion can be shuttled across hydrophobic cellular membranes to defeat the normal concentration gradient essential in living cells (Fuller, 2004). For example, valinomycin is a cyclic peptide which binds potassium, while monensin is a carboxylic ionophore which displays a binding preference for sodium. Ionophores are used in ruminant animals like cattle to improve feed efficiency by shifting rumen fermentation towards the production of more propionic acid, which can be used by the animal and less methane, which is lost. Ionophores hereby change the pattern of rumen microorganisms, reducing the production of acetate, butyrate and methane, and increasing the proportion of propionate (McDonald *et al*., 2010). Since methane is a waste product, the efficiency of rumen activity is improved. Ionophores also reduce the total mass of bacteria and thereby decrease the amount of dietary protein degraded. Avilomycin is licensed for use in pigs, broiler chickens and turkeys. Salinomycin is an ionophore available for use in pigs and also used to prevent coccidiosis in broiler chickens (Fuller, 2004).

McGuffey *et al*. (2001) also reviewed that ionophores have general metabolic role within the animal through improving production efficiency by providing a competitive advantage for certain microbes at the expense of others. In general, the metabolism of the selected microorganisms favors the host animal. In another report, broilers receiving the diet supplemented with antibiotic had significantly lower total aerobic bacterial counts in the small intestines compared to those on the other dietary treatments (Sarica *et al*., 2005). The combined supplementation of the antibiotic and enzyme resulted in a significantly lower *Escherichia coli* concentration in the small intestines compared to the basal diet and the other dietary treatments.

Enzymes

As a result of advances in biotechnology, more effective enzyme preparations can now be produced in large quantities and relatively inexpensively (McDonald *et al*., 2010). Therefore, supplementation of the diet as a means of improving nutritive value is becoming commonplace. The enzymes used as food additives act in a number of ways. According to Fuller (2004), enzymes are mainly used in the diets of non-ruminants but are also added to ruminant diets. Their main purpose is to improve the nutritive value of diets, especially when poor-quality, and usually less expensive, ingredients are incorporated. Common example of enzymes is use of phytase feed enzyme in monogastric diets. Phytase feed enzymes have more general application as their substrate is invariably present in pig and poultry diets and their dietary inclusion economically generates bio-available phosphorous and reduces the phosphorous load on the environment. The prohibition of protein meals of animal origin, which also provide phosphorous, has accelerated the acceptance of phytase feed enzymes in certain countries (Fuller, 2004).

Amino acid digestibility may also be improved with phytase supplementation. In a study with finishing pigs, Zhang and Kornegay (1999) reported that the digestibility of all amino acids except proline and glycine increased linearly as phytase supplementation increased. In ruminant nutrition, enzymes improve the availability of plant storage polysaccharides (e.g. starch), oils and proteins, which are protected from digestive enzymes by the impermeable cell wall structures. Thus, cellulases can be used to break down cellulose, which is not degraded by endogenous mammalian enzymes. Enzymes are essential for the breakdown of cell-wall carbohydrates to release the sugars necessary for the growth of the lactic acid bacteria. Although resident plant-enzymes and acid hydrolysis produce simple sugars from these carbohydrates, addition of enzymes derived from certain bacteria, e.g. *Aspergillus niger* or *Trichoderma viridi* (Parawira and Esther,2008) increases the amount of available sugars. Commercial hemicellulase and cellulase enzyme cocktails are now available and improve the fermentation process considerably (Hooper *et. al*., 1989) . However, prices of these products preclude their viability for farm level application, especially in developing countries. Supplementation of a wheat by-product diet with cellulase increased the ileal digestibility of non-starch polysaccharides from 0.192 to 0.359 and crude protein from 0.65 to 0.71(McDonald *et al*., 2010). Typically, these enzymes fall into the general classification of cellulases or xylanases (Renaville and Burny, 2001). However, most commercial preparations are not single gene products, containing a single enzyme activity. The diversity of enzyme activities within commercially available enzyme preparations is probably advantageous, in that a single product can target a wide variety of substrates Renaville and Burny (2001).

Probiotics and prebiotics

Probiotics are feed supplements that are added to the diet of farm animals to improve intestinal microbial balance (Fuller, 2004). In contrast to the use of antibiotics as nutritional modifiers, which destroy bacteria, the inclusion of probiotics in foods is designed to encourage certain strains of bacteria in the gut at the expense of less desirable ones (McDonald *et. al*.,2010). Besides, these microorganisms are responsible for production of vitamins of the B complex and digestive enzymes, and for stimulation of intestinal mucosa immunity, increasing protection against toxins produced by pathogenic microorganisms. In ruminants, they are more effective in controlling the diseases of the gastrointestinal tract of young animals, as there is no complication of the rumenmicro-flora. The initial colonization of the small intestine is from the dam’s microflora and the immediate surroundings, and usually includes streptococci, *E. coli* and *Clostridium welchii.* When milk feeding commences, the lactobacilli become the predominant bacteria present. Calf probiotics contain benign lactobacilli or streptococci and are likely to be valuable only when given to calves that have suffered stress or have been treated with antibiotics that have destroyed the natural microflora (Fuller, 2004). Addition of probiotics to the diet produces variable benefit, depending on whether the animals are in poor health. It is also difficult to determine which bacterial species would be beneficial in any given circumstance. Probiotics have sometimes been found to be beneficial in protecting pigs from infectious diseases. Lactic acid bacteria isolated from the gastrointestinal tract of pigs, such as *Enterococcus faecium* and *L. acidophilus*, can inhibit enteric indicator strains, such as *Salmonella enteritidis*, *S. cholera suis*, *S. typhimurium* and *Yersinia enterocolitica*. Dry yeast (*Saccharomyces cerevisiae*) has the advantage over bacterial probiotics that it is more tolerant of extreme pH and environmental conditions. Probiotic use is subject to extensive legislation designed to protect farm animals and consumers. In adult ruminants, yeasts may be used as probiotics to improve rumen fermentation (Fuller, 2004).

Prebiotics are defined as non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth and activity of one or a limited number of bacteria in the colon (Gibson and Roberfroid, 1995). The most common prebiotics are oligosaccharides, which are non-digestible carbohydrates. The way in which prebiotics act is by (1) supplying nutrients to beneficial microbes, or (2) tricking pathogenic bacteria into attaching to the oligosaccharide rather than to the intestinal mucosa. This reduces the intestinal colonization thereby decreasing the incidence of infection in the birds. Because the oligosaccharide is non-digestible, the microbes that are attached will travel along the gastro-intestinal tract with the ingesta, and are excreted from the bird along with other undigested food.

Live microbial cultures and their extracts, particularly of *Aspergillus oryzae* and *Saccharomyces cereuisiae*, have been used as feed additives for many years. Their widespread use as manipulating agents for ruminal fermentation, so called direct-fed microbials, is more recent, as are most of the research papers (Wallace and Newbold, 1992). The improved feed intake seems to be driven partly by an improved rate of fiber breakdown and partly by an improved duodenal flow of absorbable amino-nitrogen. These two observations are suggested to arise from a more active microbial population: the most reproducible effect of microbial feed additives is that they increase the viable count of anaerobic bacteria recovered from ruminal fluid. Increases of 50 to 100% are common (Wallace and Newbold, 1993), but increases of more than 10-fold compared with controls have been observed. Cellulolytic bacterial numbers are increased (Wallace and Newbold, 1993) and lactic acidutilizing bacteria are stimulated by the dicarboxylic acids present, thus explaining in part the improvement in fiber breakdown and increased stability of the fermentation in animals receiving yeast and *A. oryzae*. Mehdi *et al*. (2011) reported that dietary inclusion of probiotic and prebiotic supported a superior performance of chicks and can be applied as antibiotic growth promoter substitutions in broilers diet.

5. Defaunaion

Protozoa, unlike bacteria, are not vital for the development and survival of the ruminant host, and their elimination (defaunation), although producing a less stable rumen environment, has been found to reduce gaseous carbon and nitrogen losses (Fuller, 2004). It has been established that ruminants can survive with or without these organisms; however, manipulating their population may affect protein metabolism in the rumen (Wael *et. al*., 1998). The control of the rumen protozoal population by inhibition compounds would seem attractive because their eukaryotic cell nature would allow them to be susceptible to a number of compounds that would have little or no effect on the prokaryotic bacterial cells (McDonald *et al*., 2010). However, the rumen methanogenic micro-organisms could also be sensitive because of their archaebacteriai cell nature and loss of these hydrogen-gas-utilizing methanogenic organisms would drastically disrupt the entire rumen fermentation system. The metabolism of other bacterial species would also have to be genetically engineered to provide a hydrogen sink. One possibility would be to engineer *Eubacterium limosum*, a relatively numerically minor species in the rumen, preferentiallyto form acetate and butyrate from HP and carbon dioxide.

In another study (Hsu, 1991), defaunation did not decrease total free amino acid concentrations in ruminal fluid, but it altered the profile of free amino acids. Although defaunation increased ruminal bacterial numbers, no increases in total microbial crude protein or organic matter concentrations in ruminal contents were observed. Diaz *et al.* (1993) reported that for sheep based forage rudediets as protozoal population reduced (84%), the degradability of the dry matter at 24 h also increased significantly. An important implication of this study is the possibility of developing a practical way to maintain a reduced number of protozoa in ruminants while at the same time being a source of nutrients.

6. Conclusion

Biotechnology in animal production in developing countries has been applied only in a few areas such as conservation, animal improvement, healthcare and augmentation of feed resources. Poor quality feeds are the major bottleneck for livestock production and productivity. It could be concluded that there are several potential opportunities for improving the efficiency of ruminant digestion and possibilities for utilizing a wider range of feeds than is currently possible. The fibrous feeds, including crop residues, of low digestibility constitute the major proportion of feeds available to most livestock species of smallholder situations in developing countries. Although use of biotechnology in animal feed improvement is a new avenue in the developing world, there are still possibilities to improve fibrous feeds through biological treatments such as development of white rot fungi on fibrous feeds. Modifying forage resources is another option in which digestibility, amino acid composition and overall feed value is improved. Additives to animal nutrition, such as enzymes, probiotics, single-cell proteins and antibiotics in feed, are already widely used in intensive production systems worldwide to improve the nutrient availability of feeds and the productivity of livestock. It can be concluded that there are several potential opportunities for improving the efficiency utilizing a wider range of feeds than is currently possible. The microbial flora of the rumen can be successfully manipulated if such manipulations are adding exogenous fibrolytic enzymes to ruminants can potentially improve cell wall digestion and the efficiency of feed utilization. The use of biotechnology to improve post-ingestion quality of fibrous forages is on the verge of delivering practical benefits to ruminant production system. The microbial flora of the rumen can be successfully manipulated if such manipulations are adding exogenous fibrolytic enzymes to ruminants can potentially improve cell wall digestion and the efficiency of feed utilization.

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Effect of Growth Media, Starter N and P Fertilizers on Growth and Yield of Tomato under Rainfed Condition in the Central Rift Valley of Ethiopia

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Abstract

Experiment was conducted to evaluate media mix ratios (various soil: sand: and decomposed FYM proportions) and to study the effect of supplementary inorganic nitrogen (0 and 25 kg N ha^{-1}), and phosphorous (0 and 23 kg P ha^{-1}) for container grown tomato crop during the rainy season under field condition at Melkassa Agricultural research, Ethiopia. Three factors, namely, media proportions; supplementary N and P applications rates were combined factorially with three replications. Data on canopy characteristics such as plant height, stem diameter, main lateral branch length, canopy width, canopy depth were measured from sample plants and canopy cover (CC) was estimated. Additionally, tomato early blight was scored using the scale of 0-5 and all data were analysed using SAS. The results indicated that among the tested six media mixes, MR3 (4:1:1) produced the highest total fruit yield, followed by MR4 (3:2:1) in the form of field soil: manure: sand order. Thus, the proposed media mixes based on the results of this study is MR3 (4:1:1) that suits organic tomato production. Use of FYM further prevented crusting and sealing of the media, which is a problem associated with top soil in the Central Rift Valley area of Ethiopia. Although there was no significant difference between supplementary application of 25 kg N ha^{-1}and no N application for container grown tomato, application of N at the rate of 25 kg ha^{-1}was found to be better yielding. Similarly, compared to 0 kg P ha^{-1}, application of 23 kg P ha^{-1} produced higher fruit yield. Although there was increase in fruit yields of tomato crop, further research is required for management of supplementary N and P fertilizer uses in container grown tomato cultivation under both rainfed and irrigated conditions.

Keywords: farmyard manure, growth media, starter fertilizers, tomato, topsoil

1. Introduction

Tomato is grown in media ranging from soil in the field, under homestead gardens, under greenhouses in potted media or nutrient solutions or hydroponics (Peet and Welles, 2005; Jones, 2008). It is clear that if tomato is grown in containers or in hydroponics conditions, all essential nutrients are required. Tomato growers in the Central Rift Valley of Ethiopia use various rates of Urea and DAP (Edossa *et al*., 2013b). For container grown tomatoes, it is important to select best media mixes from locally available cheap materials that provide better growth, development and fruit yield. Beside media mix ratios, N and P nutrient amendments are important as starter nutrients in tomato production (Jones, 2008).

Growing tomatoes in containers is very common and many gardeners want to grow just a few tomato plants in a pot or other container like plastic structures, and fertilizer sacks are common in urban and around pre-urban areas like Adama city, Ethiopia. There are many media mixtures and container designs available in the markets in other parts of the world for tomato cultivation (Heuvelink, 2005; Jones, 2008). Increased tomato production per unit of greenhouse space through the application of improved technology (automation and hydroponic culture) through cultivar development and control of the greenhouse environment has been considerable in the past years. Different researchers considered various soil mix recipes depending on its availability. Teshome *et al*. (2010), tried /experminted that tomato seedling raised on mixed red ash, coarse sand, termite tomb and fermented cow dung in the ratio of 4:3:2:1 (in the proportion of 4 part red ash, 3 part coarse sand: 2 part termite mound, one part fermented cow dung). This experiment at Adami Tullu Research Centre in the CRV of Ethiopia resulted in the production of the highest marketable fruit yield compared to the stunted plants grown in a sole soil medium (control). The authors attributed the problem of low marketable tomato fruit production in the control treatment to crusting of the surface, which causes difficulty in water passage and aeration for normal physiological function of the container grown tomato seedlings.

In the present scenario of continuous demand of vegetables and shrinking land holding, protected cultivation or greenhouse technology, home garden and front door cultivation are a better alternative for using land and other resources more efficiently; different researchers gave various soil mix recipes depending on the availability. A supplementary pot experiment in green house to test the response of tomato to N and P application conducted at Melkassa Research Centre in a greenhouse (using the same N and P levels with the sole top 30 cm soil depth) was not successful. This was mainly due to soil sealing and crusting problem in a container caused by frequent irrigation water using a plastic bucket. There are many published (Itanna, 2005) and unpublished reports that soils around Melkassa (in the CRV area) usually form sealing and crusting after rainfall and furrow irrigations.

Many authors such as Singer (2006) and Shainberg (1992) explained that sealing and crusting are soil surface conditions and it is sign of physically degraded soils. These authors described that seals and crusts have higher density, higher shear strength, finer pore size distribution, and lower saturated hydraulic conductivity than uncrusted soils (Shainberg, 1992). Similarly, Itanna (2005), described that surface crusting and hardpan formation of the soils of CRV areas are the obvious symptoms of the land degradation. Many explained that these crusts and seals have greatly reduced infiltration rates because of their low porosity and lack of macropores (Singer, 2006). In addition, seals and crusts have slow gas exchange and because of their high shear strength, crusts reduce emergence of fine-seeded crops. The result is a much reduced infiltration rate and increase in volume of soil splash and overland flow. In general, many suggested that soil sealing and crusting problems could be reduced through organic matter management and the addition of amendments that help to stabilize soil aggregates (Brady and Weill, 2008).

Besides this, the addition~~s~~ of organic matter~~s~~ like FYM for the improvement of plant nutrients and soil structures for container grown tomatoes; proper fertilizer formulations and rates are usually applied; starter fertilizers can promote rapid root development and early plant growth of tomatoes (Kelley and Boyhan, 2010). These authors explained that starter fertilizers for tomatoes should contain a high rate of phosphorous. Similarly, Taber and Lawson (2007) described that even if a soil test indicates that the phosphorous level is high to very high, starter fertilizers high in P are often used with the *Soalanaceous* crops such as potatoes and tomatoes. OMAFRA (2010) also strongly suggested that application of a high-phosphorous starter fertilizer during transplanting of tomato is very important; and there are various recommendations for the starter P fertilizer applications depending on the weather conditions. Tomatoes are very responsive to P additions at pre-planting or at the time of transplanting (Taber and Lawson, 2007; Edossa, 2014; Edossa *et al*., 2013a). Hence, this experiment was conducted to select suitable locally available media mixes (soil, FYM and sand combinations) for optimum tomato growth and development, and to evaluate supplementary inorganic nitrogen and phosphorous fertilizer applications required for optimum growth and development for container grown tomato crop during main rainy season under field condition at Melkassa Research Centre, Ethiopia. The objectives of the study are to evaluate media mix ratios (soil: sand: and decomposed FYM proportions) for container grown tomato under rainfed growing condition; to evaluate the effect of starter inorganic nitrogen and phosphorous fertilizers for container grown tomato crop during the rainy season under unprotected field condition; to determine optimum for enhanced quality of tomato fruits under container-grown rainfed tomato planted on media with varying mixes.

2. Materials and Methods

Three factors, namely, media proportions (mixes); and supplementary N and P applications rates were combined factorially.

2.1 Treatments and treatment combinations

The treatments consisted of two levels of N (0 and 25 kg N ha^{-1}), two levels of P (0 and 23 kg P ha^{-1}) and six media mix ratios (Table 49).

Factor I. Media proportions and mixes (V/V)

Locally available decayed animal manure and livestock droppings were collected and mixed with sand and topsoil at various proportions (V/V) as shown in Table 1.

Table 1. Various media mixes and proportions used for tomato grown in a container under rainfed condition at Melkassa, Ethiopia

Treatment	Proportion of media mixes [a] (V/V)			Mix Ratio
	Field soil (forest/ top soil	Well decomposed manure	Sand	
1	100	0	0	6:0:0
2	80	15	0	5:1:0
3	65	15	15	4:1:1
4	50	30	15	3:2:1
5	35	35	15	2.5:2.5:1
6	15	50	30	1:3:2

[a] =Media mix ratios are in the form of Field Soil**:** Manure: Sand order

Factor II. Supplementary N applications

N application: Inorganic nitrogen fertilizer at two levels: without N (N at 0 kg rate ha^{-1}) and with at 25 kg N rate ha^{-1} (Table 2).

Factor III. Supplementary P application

P application: Inorganic phosphorous fertilizer at two levels: without P (at 0 P kg ha^{-1}) and with P at 23 kg P rate ha^{-1} (Table 2).

Table 2. Nitrogen and phosphorous fertilizer levels used with various media mixes and proportions for container grown tomato under rainfed conditions

Levels	Nitrogen and phosphorous fertilizers*		Remakes
	N (UREA)	P	
1	Without N	Without P	
2	25 kg N ha^{-1} (As starter fertilizer)	23 kg P ha^{-1} (As starter fertilizer)	(applications of P once and N twice)

*= P Fertilizers were thoroughly mixed before placing the media into the containers before transplanting, N were applied in two splits

Experimental design: Two levels of N and P were combined to give four factorially combined N and P treatments, which were again combined with six media mix ratios giving twenty four treatment combinations. The container (pot) size used was 0.17 m^3 volume. The experiment was replicated three times and 72 pots were used for each plot for the field experiment.

The experiment was laid out as a completely randomized block design in a factorial arrangement and replicated three times per treatment. The variety used was *Melakshola* tomato variety. The container (pot) size used was 0.17 m^3 volume size. This experiment was conducted under rainfed condition during the main season. However, supplementary irrigation was provided for the containerized tomato plants during establishment in the dry spell days, and then left as a rainfed crop.

Bases for N and P rate determinations: Determination of N and P rates was based on plant population per ha, since these mixes were made from FYM, sand and disturbed top soil collected from the area assumed to be uncultivated for five years.

Preparation of FYM: Decayed FYM was collected from animal barren grazing natural feed and put in a pit for further decomposition and better conditions for micro-organisms activity

Mixing of the ratios: The growth media mixtures were prepared at predetermined ratios (v/v) of soil, sand and FYM; and thoroughly mixed, put for a month as a pile until filling into the pots (container) with the size of approximately 60 cm length and 50 cm wide (Appendix Figure 7).

2.2 Determination of physical and chemical properties of the media mixes:

Sample of FYM was analysed for the determination of the content of each essential element, namely, C, N, and C: N ratio. Additionally, some major and minor essential elements contained in the FYM, namely, Na, K, Ca, available P, Cu, Fe, Mn and Zn contents were analysed. The following general procedures and methods of routine soil analyses were made at Deber Ziet Agricultural Research Centre Soil Laboratory. These are soil reaction, pH(H_2O), Texture (Bouycus Hydrometer Method), ECe (dS m^{-1}) by Saturation Paste Extract Method (1:2.5) H_2O, Exchangeable Cations (by neutral ammonium acetate method), CEC [($cmol_c$ kg^{-1} soil)], organic carbon (Walklay and Black, 1934); total nitrogen [Micro Kjeldshl Method, (1982)]; and available P (mg kg^{-1} soil) by using Olsen *et al*. (1954) methods.

Samples were taken from thoroughly mixed media for the determinations of these physical and chemical properties of the soil and availability of both macro- and micronutrients in the media mixes was determined through the analyze.

Field experiment: Seeds were sown in the nursery on 5 May 2011 and transplanting of the seedlings was done on 10 June 2011. The experiment was established in an open space during the main rainy season. Seedlings were staked immediately when it grew to the height of 60 cm from the ground. Supplementary irrigation was provided when there was no enough rainfall at the intervals of three to four days until sound establishment of the seedlings. Precautions were made to minimize the draining of nutrient solutions (leachates) since re-utilization of the drained nutrient solutions were not possible.

Data collection and measurement: Data on growth and canopy characteristics such as plant height, stem diameter (above the soil surface ≈5 cm), main lateral branch length, canopy width, canopy depth (cm) (with in row) were measured from 10 randomly selected plants per plot. Canopy cover (CC) was estimated by multiplying mean canopy width with mean canopy depth and dividing the products by the area covered by the plant (spacing between rows multiplied with spacing between plants). Additionally, tomato early blight was scored using the scale of 0-5, where 0 indicates = Freedom from disease, 1= indicates 10% infestation, 2 = indicates lower 10-20 % infestation, 3 = indicates middle of about 21-50% infestation, 4 = indicates upper 51-75% infestation and finally 5 = indicates76-90% fruit infestation (Dent, 2000). This early blight disease score was taken by senor technical assistant from MARC.

3. Results and Discussion

3.1. Physico-chemical properties of topsoil, media mix and FYM

The physico-chemical properties of the media used for this experiment are viewed from three perspectives: nutrient content of topsoil, media mix ratios, and FYM. These are discussed separately as shown below:

Nutrient contents of topsoil alone

All selected physical and chemical properties of topsoil (Check, MR1) are presented in Appendix Table 1. As compared to MR2, MR3, MR4, MR5 and MR6, the nutrient of MR1 is much lower in organic carbon (OC, very low rating) and organic matter (OM), total N, C:N ratio, available P and micronutrients (Cu, Fe, Mn and Zn) concentrations (Appendix Table 1). The media MR1 (sole field soil) has very high Ca content as compared to final mixtures. The Ca: Mg balance ratio, 13.18 indicate that the top soil (MR1) was Mg deficient (Hazelton and Murphy, 2007).

Nutrient contents of media mixtures

The chemical and physical properties of soil media were modified through addition of FYM and sand. Although addition of FYM improved soil pH with small scale, the concentrations of some of the essential nutrients in the media mixtures increased; total nitrogen increased from 0.21 to 0.26 %, whereas available P increased from 37.22 to 41.00 mg kg^{-1} (Appendix Table 1).

The amount of micronutrient concentrations were also increased manifold through addition of FYM; Cu increased from 0.11 ppm to 0.34 ppm; Fe from 0.08 to 0.47 ppm; Mn from 7.9 to 27.00 ppm; and Zn from 0.708 to 3.643 ppm (Appendix Table 1). The concentration of K increased five-fold from 1.93 to 9.8 ppm. The concentration of Mg increased more than six-fold, from 2.20 to 14.4 ppm. However, the concentration of Ca in the media mixture was reduced three-fold from 29.00 to 10.10 Cmol (+) kg^{-1}. Addition of FYM to topsoil changed some of the chemical properties like Ca: Mg balance ratio in various ways, improved the low Ca for MR2 (7.94) Hazelton and Murphy (2007) rating and MR3 (8.09 low Ca rating). Further addition of FYM increased Ca: Mg ratio; MR4 (5.05 balanced rating) and MR5 (4.56 balanced), and addition of more FYM brought low Ca: Mg balance (MR6, 2.49, low Ca rating) indicating Ca deficient media. The ratio of high Ca: Mg as in MR1 indicates the presence of proportionally high Ca in the media, which may disrupt Mg uptake and vice versa.

Many researchers (Garner *et al*., 1930; Sims *et al*., 1995; Spiers and Braswell, 1994) reported that high calcium concentrations in solution or in field soils sometimes limit magnesium accumulation and may elicit magnesium deficiency symptoms). In tomato, the magnesium concentration in shoots (Gunes and Alpaslan, 1998) and fruits (Paiva *et al*., 1998) decreased as the calcium fertilization rate increased. Penalosa *et al*. (1995) also proved that increased calcium concentrations inhibited magnesium uptake in common bean (*Phaseolus vulgaris* L.).

Brady and Weill (2008) reported a strong antagonism between calcium and magnesium, suggesting that calcium influenced magnesium translocation to leaves. The authors suggested that optimum leaf Ca: Mg ratios are considered to be approximately 2:1; however, Ca : Mg ratios >1:1 and <5:1 can produce adequate growth without the expression of magnesium deficiency (Ericsson and Kahr, 1995; Mills and Jones, 1996).

The low Ca: Mg balance in treatment MR6, might probably contribute to low tomato yield due to cationic balance. Handreck and Black (1999), gave the general recommendations for containerized crop production and the sufficient calcium and magnesium addition to produce an extractable Ca: Mg ratio of 2:5. Navarro *et al*. (2000) reported that there is an antagonist effect of calcium on magnesium accumulation in melon (*Cucumis melo* L.).

Nutrient concentration of FYM

The average nutrient contents of FYM alone used for media mix were 0.30% N, and 40.82 ppm for P (Table 51). Very high Cu (2.39 ppm) and Mn (61.96 ppm) values were recorded; values for [10.1 cmol (+) kg^{-1}] were low while that of Mg [14.4 cmol (+) kg^{-1}] were high in the FYM. The animal manure can support crop growth, in particular where unbalanced Ca: Ma ratios exist; high content of Ca^{+2} can influence the uptake of Mg^{+2} (Hazelton and Murphy, 2007).

Due to its higher content, big losses of N could occur due to leaching during the heavy rain events (excess irrigation) and ammonia volatilization might occur during hot and dry conditions, as hot day is very common in this CRV area. Consistent with this suggestion, Misselbrook *et al*. (2002) reported that some fertilizers like Urea, farmyard manure, etc... may lose large amounts of nitrogen through gaseous emissions of ammonia during and after application, depending on the spreading pattern and the prevailing weather condition.

The C: N ratio measurement is relevant to the breakdown of organic materials in the soil and is especially applicable in discussing the effects of crop residues on soil nitrogen levels and the rate of breakdown of crop residues. Based on the analyze result, the ratings for C: N ratio for the FYM are low (Hazelton and Murphy, 2007) indicating high content of nitrogen and low content of carbon; where a range from 10 to 15 are grouped somewhat as higher N for decomposition. However the result had shown that the C: N ratio for the check (topsoil) is low; as Hazelton and Murphy (2007) described that the C: N ratio is usually lower for soil carbon.

3.2. Effects of application of N, P and media mix ratios on growth, and yield components of container grown rainfed tomato

Analyze of variance indicated that the use of various media mixtures, application of starter N and P showed various effects on the growth characteristics, physiological responses, yield and yield components. However, combination of application of N, P and use of media mixes ratios did not affect significantly (P < 0.05 and P< 0.01) any of the growth parameters assessed (Appendix Table 2).

Growth characteristics: Use of media mix ratios in combination with application of starter P fertilizer had a significant effect (P < 0.01) on some plant growth characteristics of tomato such as shoot fresh weight, canopy diameter and marketable fruit number (Appendix Table 2). Application of starter N had highly significant (P < 0.01) influence on canopy width, leaf fresh weight, leaf dry weight, leaf area and canopy cover. Similarly, application of starter N had significant effect (P < 0.05) on mean marketable fruit number per plot (Appendix Table 2).

Plant height: Application of starter N, P, use of media mix ratio or their combinations showed non-significant effect (P< 0.05) on tomato plant height during the rainfed season (Appendix Table 2). As compared to rainfed field grown tomato, very short plant growth (a height of 51.50 cm) was recorded; this is probably due to root confinement of tomato under container growth environment. Thus, proper container size should be determined for container grown tomato in Ethiopia.

Canopy diameter: Use of various media mix ratio had brought ~~a~~ significant effect (P< 0.01) on the canopy development of rainfed container grown tomato (Appendix Table 2). The mean separation at P = 0.05 probability level indicated that the highest canopy diameter was recorded from MR6 while the smallest canopy size was recorded from the check (Table 3). This study indicated that combination of application of inorganic P fertilizer with media mix ratios also brought a highly significant effect (P < 0.01) on the growth of tomato canopy diameter (Appendix Table 2). The relationship of use of application of starter P and use of media mix ratio is presented in Figure 1 where use of MR 2, MR 3 and MR 4 with starter P gave the highest fruit yield whereas use of MR 1, MR 5 and MR 6 with starter P gave the lowest tomato fruit yield.

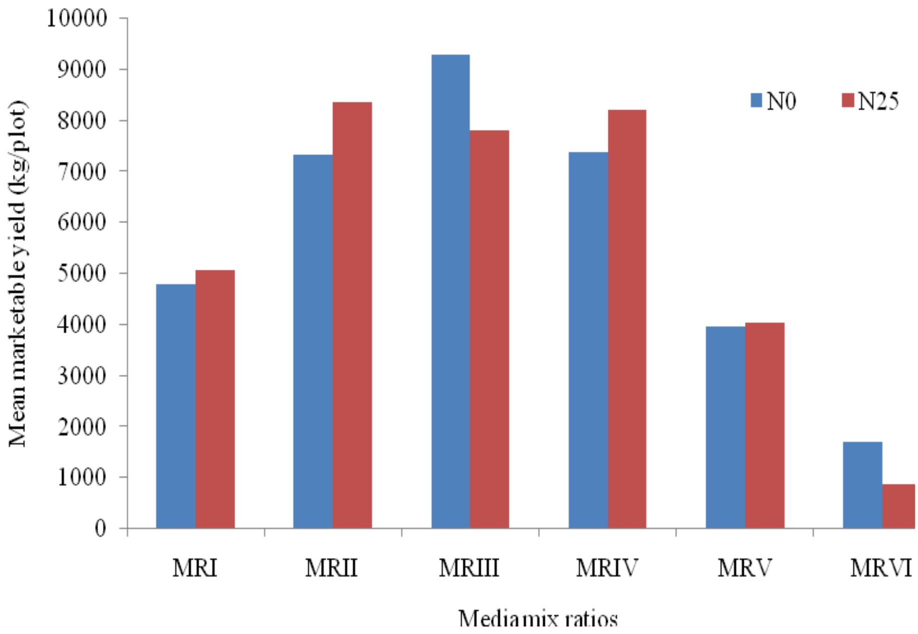

Figure 1. Average marketable fruit weight of tomato as affected by media mix ratios and application of starter N fertilizer

Canopy width: Use of application of starter nitrogen and media mix ratios had brought an independent and a highly significant effect ($P < 0.01$) on the canopy growth of container grown rainfed tomato (Appendix Table 2). Mean separation at $P = 0.05$ probability level showed that the highest canopy width was recorded from tomato grown under media mixtures while the smallest canopy width size was recorded from the check (Appendix Table 2).

Stem diameter: Among tested treatments individually and in combinations, it was only media mix ratios that brought a highly significant effect ($P < 0.01$) on stem diameter (Appendix Table 2). Mean separation at $P = 0.05$ probability level indicated that the highest stem diameter was recorded from media mix ratio MR6 and lowest stem diameter was recorded from the control (Table 3).

Leaf fresh weight: There were no combined interaction effects ($P < 0.05$) due to the application of starter N, P, and use of media mixtures on the leaf fresh weight of tomato '*Melkasholla*' variety under container grown conditions at Melkassa. On the other hand, application of starter N had shown a highly significant effect ($P < 0.01$) and similarly, use of media mixtures (MR) had shown a highly significant effect (Appendix Table 2). Mean separation at $P = 0.05$ probability level showed that the highest leaf fresh weight was recorded from use of starter N and lowest from the check, while use of MR6 gave highest leaf fresh weight whereas the lowest was recorded from the check (Table 3).

Total shoot fresh weight: Among the treatments tested, there was no combined effect ($P < 0.05$) from use of starter N, P application and media mix ratio treatments. While application of starter N brought a highly significant effect ($P < 0.01$) on the total shoot fresh weight. The mean separation using LSD test at $P = 0.05$ probability level showed the highest shoot fresh weight use of starter N whereas the lowest was recorded from the check.

Leaf dry weight: Use of starter N and various MR have shown a highly significant effect ($P < 0.01$) on the leaf dry weight of container grown tomato '*Melkasholla'* variety at Melkassa. The LSD test at $P = 0.05$ probability level showed that highest leaf dry weight was obtained from use of starter N whereas the lowest was recorded from the check. The highest leaf dry weight was obtained from use of MR 6 where as lowest was recorded from the check.

Shoot dry weight: Use of media mix ratios showed a highly significant effect ($P < 0.01$) on the shoot dry weight of container grown tomato at Melkassa. The LSD test at $P = 0.05$ probability level showed that the highest shoot dry weight was obtained from those media mixtures whereas the lowest shoot dry weight was recorded from the check.

Leaf area: Among the treatments tested, there was no combined effect ($P < 0.05$) of use of starter N, P application and media mix ratio treatments. On the other hand, application of starter N and use of various MR brought a highly significant effect ($P < 0.01$) independently. The LSD test at $P = 0.05$ probability level indicated that the highest leaf area was obtained from using starter N whereas the lowest leaf area was recorded from the check. Similarly, highest leaf area was obtained from MR 3 whereas the lowest leaf area was recorded from the check. Melton and Dufault (1991) also found similar results where, as N application rate increased for tomato plant from 25 to 225 mg·liter^{-1}, there was as increase in the total leaf area.

Canopy Cover (CC): Use of starter N and media mixtures for container grown rainfed tomato at Melkassa showed a highly significant ($P < 0.01$) influence on canopy cover independently (Appendix Table 2). The LSD test at $P = 0.05$ probability level indicated that the highest CC was obtained from using starter N whereas the lowest leaf area was recorded from the check. Similarly, high CC was obtained from using media mixtures whereas the lowest leaf area was recorded from the check. Application of starter P alone did not have a significant effect on any of the container grown tomato plant growth parameters except shoot dry weight per plant which was significant at $P < 0.05$ (Appendix Table 2). However, mean separation using LSD at $P = 0.05$ probability level indicated that there was a trend of increasing vegetative growth parameters for those tomato plots that received starter P (Table 3). Thus, further study may be required for confirmation of this result.

Table3. Mean response values of selected vegetative growth, yield components and physiological response of tomato planted under different media mixes, N and P application rates under rainfed growing conditions*

Media mix ratio	Plant height (cm)	Canopy diameter (cm)	Canopy width (cm)	Stem diameter (mm)	Leaf fresh weight per plant [a] (g)	Shoot fresh weight per plant [a] (g)	Leaf dry weight per plant [a] (g)	Shoot dry weight per plant [a] (g)	Leaf area (mm^2)
MR1	48.075	34.50 B	33.079 B	10.195 C	56.13 (107.3) C	(107.33)	8.875 C	14.750 (14.7)B	447305 C
MR2	52.263	41.250 A	38.588 A	12.059 AB	104.50 (198) AB	(198.00)	13.083 B	23.875 (23.8) A	748943 AB
MR3	52.875	41.142 A	39.404 A	12.138 AB	125.63 (207.8) AB	(207.83)	13.917 AB	22.750 (22.7) A	823151 A
MR4	50.046	39.496 A	38.342 A	11.903 B	96.71 (209.5) AB	(209.50)	12.000 B	22.625 (22.6) A	648459 B
MR5	53.008	39.892 A	38.050 A	12.441 AB	103.53 (184.6) AB	(184.63)	12.208 B	21.708 (21.7) A	749473 AB
MR6	52.729	40.383 A	39.933 A	12.767 A	125.50 (217.5) A	(217.50)	15.375 A	25.000 (25) A	694723 AB
Mean	51.499	39.450	37.899	11.917	101.997	(187.465)	12.576	21.784	685342.2
LSD (0.05)	NS	2.551	3.333	0.836	0.115	NS	0.0854	0.0839	173618.0
N (kg ha^{-1})									
0	50.758	38.927	36.29 B	11.74	(87.21) B	(178.028) B	11.222 B	(21.389)	592077 B
25	52.240	39.970	39.50 A	12.086	(116.77) A	(196.903) A	13.930 A	(22.181)	778607 A
Mean	51.499	39.450	37.899	11.917	(101.997)	187.465	12.576	(21.784)	685342.2
LSD (0.05)	NS	1.473	1.924	NS	0.0664	0.044	0.0493	NS	100239
P (kg ha^{-1})									
0	50.772	38.466	37.347	11.680	(95.99)	(185.042)	12.333	(20.944) B	650875
23	52.226	40.433	38.451	12.155	(108.00)	(189.889)	12.819	(22.625) A	719810
Mean	51.499	39.450	37.899	11.917	101.997	187.465	12.576	(21.784)	685342.2
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

[*]= Average of three replications. Means in a column followed with the same letters are not significantly different using LSD at P = 0.05 level of significance respectively; [a] = Data were transformed, means in brackets are original data

Table 3. Continued...

Media mix ratio	Marketable fruit weight [a](g per plot)	Unmarketable fruit weight [a](g per plot)	Total yield per plot (g)	Early blight [a](Scale)	CC	Leaf chlorophyll fluorescence	Leaf quantum yield	Leaf chlorophyll content
MR1	(4935.9) B	(1832.4) C	6768.3 C	2.458 (2.45) BC	0.3888 B	308.11	0.57122 AB	39.317
MR2	(7840.4) A	(3528.2) AB	11368.6 B	2.958 (2.95)AB	0.5317 A	290.17	0.58801 A	39.600
MR3	(8560.4) A	(4389.3) A	12949.7 A	1.8333 (1.83) C	0.542 A	289.86	0.53793 B	42.408
MR4	(7799.5) A	(2987.8) B	10787.2 B	2.6660 (2.66) B	0.5073 A	288.03	0.54971 AB	40.525
MR5	(4010.3) C	(3559.2) AB	7569.4 C	2.375 (2.37) BC	0.5079 A	310.14	0.57329 AB	40.858
MR6	(1293.8) D	(1878.4) C	3172.2 D	3.4583 (3.45) A	0.539 A	306.19	0.59222 A	42.450
Mean	5740.021	(3029.201)	8769.22	2.625	0.503	298.750	0.568	40.859
LSD (0.05)	30.113	0.1057	1560	0.7974	0.066	NS	0.0473	NS
Nitrogen (kg ha^{-1})								
0	(5747.2)	(2881.4)	8628.6	(2.250) B	0.472 B	292.509	0.55160 B	38.539 B
25	(5732.8)	(3177.0)	8909.8	(3.000) A	0.533 A	304.991	0.58586 A	43.181 A
Mean								
LSD (0.05)	NS	0.0422	NS	0.0551	0.0386	NS	0.0273	2.29
P (kg ha^{-1})								
0	(5684.3)	(2916.8)	8601.1	(2.500)	0.484	296.750	0.56525	40.953
23	(5795.7)	(3141.7)	8937.4	(2.750)	0.521	300.750	0.57220	40.767
Mean								
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

[*]= Average of three replications. Means followed in a column with the same letters are not significantly different using LSD at $P = 0.05$ level of significance respectively; [a] = Data were transformed, means in brackets are original data

Yield and yield components

Marketable fruit yield: Use of combination of starter N and MR showed a significant effect *(P* < 0.05) on the marketable fruit yield of container grown tomato variety '*Melkasholla'* (Appendix Table 2).

Use of media mixtures alone showed a highly significant ($P < 0.01$) effect on the marketable fruit yield of container grown tomato (Appendix Table 2). The LSD test at $P = 0.05$ probability level showed that the highest marketable fruit yield was recorded from MR3, while the lowest marketable fruit yield was recorded from MR6 (Table 5). There yield increase over the grand mean of MR3 has 149.13%, while MR2 has 136.58%, MR6 has 135.89%, MR1 has 85.98%, MR5 has 69.86% and MR6 has 22.53% over the grand mean. Thus, MR3 media mixture was found to be the best media mixtures produced highest tomato fruit yield. The tomato plants produced the highest marketable fruit yield in the medium that had 4:1:1 (60% soil: 15%: farmyard manure and 15% sand). The sole soil medium treatment (check) in this experiment suffered from moisture stress in the afternoons at the time of dry spells, which was disastrous during the critical growth stages prior, at and after flowering, which caused reduced growth and yield.

Total fruit yield: Use of media mix ratio showed a highly significant effect ($P < 0.01$) on the total fruit yield of container grown tomato (Appendix Table 2). The LSD test at $P = 0.05$ probability level showed that MR3 yielded the highest total fruit yield while MR6 gave the lowest total fruit yield (Table 3). It is concluded from this experiment that use of the ratio of 4 field top soil: 1 manure: 1 sand order gave the highest fruit yield for container grown tomato around Melkassa during the rainy season; increasing the ratio of manure beyond this proportion reduced the tomato fruit yield.

Unmarketable fruit yield: Similar to marketable fruit, use of media mixtures had highly significant ($P < 0.01$) influence on the unmarketable fruit yield of container grown rainfed tomato (Appendix Table 2). The highest unmarketable fruit yield record was obtained from MR3 treatment while the lowest unmarketable fruit yield was obtained from the check and MR6.

Early blight: Use of media mixtures and application of N had a highly significant ($P < 0.01$) effect on the occurrence of early blight of tomato (Appendix Table 2). Both factors affected occurrence of early blight in tomato separately. The highest blight score was recorded from MR6, and the lowest score was recorded from MR3. This probably indicates that heavy application of FYM predisposed tomato plants to the incidence of the early blight disease. This may be attributed to the increased succulence of plant leaves in response to the increased supply of nitrogen, which makes easy for the pathogen to attack and penetrate the leaves. This view is consistent with that of Barker and Bryson (2007) who reported that increased supply of nitrogen to crop plants increases susceptibility of the plants to disease. Higher score of early blight record was observed from application of 25 kg N ha^{-1} than the control treatment (Table 3).

Tomatoes grown under different media mix ratios and supplementary N and P fertilizers actually faced two major problems that limited their growth and development; one problem was root confinement and another was the intermittent moisture stress as they were grown under rainfed conditions. Tomato plants grown in field were less affected by low moisture stress during the dry spell as compared to container grown tomato; probably, field grown tomato plant roots explored more volume of soil.

Treatments with FYM were found to be less stressed during dry spells as compared to the check plot, indicating that FYM improves water holding characteristics of the media. In addition, the media containing FYM were less affected by crusting and sealing as this problem was observed in the greenhouse experiment, probably due to association with soil structure, low organic matter content of the topsoil. This is probably because farmyard manure increases organic matter content of the media, which is food for soil biota that enhance the availability of nutrients such as phosphate through increased solubilization. In addition, the organic matter holds moisture like a sponge, avoiding stress during dry days throughout the growth period of tomato plant (Muchovej *et al*., 2008).

3.4. Correlations between growths, physiological responses and yield components of tomato grown under N, P application rates and media mix ratios

The partial correlation analyze indicated that variables such as total fruit weight vs. leaf area, total fruit weight with marketable fruit number, total fruit weight with unmarketable fresh weight showed strong and positive correlations (r^2). This direct relationship indicates that improving one variable improves the corresponding variable in the growth and development of container grown tomato. On the other hand, the total fruit weight with canopy diameter, total fruit weight with leaf fresh weight, total fruit weight with shoot fresh weight had significant ($P < 0.05$) correlation coefficient (r^2) (Table 4). Some other variables such as total fruit weight with plant height, canopy width and total fruit weight with stem diameter showed very weak positive associations.

Among the yield components, leaf area (LA) had strong and positive correlations with plant height (r^2= 0.34**), canopy diameter (r^2= 0.54**), canopy width (r^2= 0.64**), shoot diameter (r^2= 0.48**) and shoot fresh weight (r^2= 0.476**). The total fruit yield showed strong and direct positive correlation with LA (r^2 = 0.333**), marketable fruit number (r^2 = 0.857**), and with unmarketable fruit number (r^2 = 0.74**). The results of partial correlation of physiological parameters such as leaf fluorescence, quantum yield and leaf chlorophyll content indicated that there was no direct relationship with each other and with all other parameters assessed.

Table 4. Estimation of correlation coefficient (r^2) within and between selected growth characteristics and selected yield components for tomato as influenced by application of supplementary N, P and various media mix ratios grown during rainy season

	PH	CD	CW	SD	LFW	SFW	LA	Ft	QY	ChlCon	LDW	SDW	MFN	MFW	UFW
CD	0.494**														
CW	0.342**	0.690**													
SD	0.226*	0.410**	0.565**												
LFW	0.442**	0.646**	0.668**	0.622**											
SFW	0.412**	0.648**	0.688**	0.613**	0.822**										
LA	0.34**	0.54**	0.64**	0.48**	0.676	0.476**									
Ft	0.015	-0.068	0.043	0.038	0.176	-0.14	0.073								
QY	0.063	0.019	0.125	0.091	0.146	-0.015	0.175	0.52							
ChlCon	0.121	0.023	0.181	0.281	0.248*	0.132	0.148	-0.06	0.083						
LDW	0.364**	0.423**	0.503**	0.507**	0.748**	0.587**	0.473**	0.138	0.137	0.20					
SDW	0.400**	0.464**	0.549**	0.515**	0.580**	0.749**	0.21	-0.08	-0.06	0.07	0.469**				
MFN	-0.027	0.049	-0.038	-0.106	-0.066	0.028	0.063	-0.22	-0.169	-0.06	-0.169	-0.017			
MFW	-0.039	0.037	-0.047	-0.131	-0.068	-0.044	0.119	-0.17	-0.169	-0.06	-0.159	-0.078	0.973**		
UFW	0.256*	0.412**	0.328**	0.277*	0.499**	0.483	0.465	-0.08	-0.033	0.18	0.197	0.334**	0.54**	0.524	
TFW	0.132	0.26*	0.187	0.070	0.23*	0.223*	0.333**	-0.15	-0.129	0.05	0.077	0.149	0.857**	0.89**	0.74**

Note: ** indicates significant at $P < 0.01$, and * significant at $P < 0.05$. The decimal numbers without any asterisk are non-significant at $P = 0.05$ probability levels

PH: Plant height, CD: Canopy diameter, CW: Canopy width, SD: Stem diameter, LFW: Leaf fresh weight, SFW: Shoot fresh weight, LDW: Leaf dry weight, SDW: Shoot dry weight, LA: Leaf area, FMY: Fruit Marketable yield, FUY: Fruit unmarketable yield, TFY: Total fruit yield, QY: Quantum yield, ChloCon: Chlorophyll content, ChloFt: Chlorophyll Fluorescence, MFN: Marketable fruit number, MFW: Marketable fruit weight, UFN: Unmarketable fruit number, UFW: Unmarketable fruit weight, TFW: Total fruit weight, ChlCon: Chlorophyll content, QY: Quantum yield, Ft: Chlorophyll Fluorescence, [a] = Data were transformed

4. Conclusions and Recommendations

Investigations were made to evaluate media mix ratios (various soil: sand: and decomposed FYM proportions); in the ratio of 6:0:0, 5:1:0, 4:1:1, 3:2:1, 2.5:2.5:1 and1:3:2 proportions and to study the effect of supplementary inorganic nitrogen (0 and 25 kg N ha^{-1}), and phosphorous(0 and 23 kg P ha^{-1}) for container grown tomato crop during the rainy season under field conditions. Three factors, namely, media proportions (mixes); and supplementary N and P applications rates were combined factorially with three replications. The results indicated that among the tested six media mixes, MR3 (4:1:1) produced the highest total fruit yield, followed by MR4 (3:2:1) in the form of field soil: manure: sand order. Since alternative fertilizer nitrogen substitution by FYM in vegetable production is commonly practiced for container grown tomato, the proposed media mixes based on the results of this study is MR3 (4:1:1) that suits organic tomato production. Use of FYM further prevented crusting and sealing of the media, which is a problem associated with top soil in the CRV area.

Although there was no significant difference between supplementary applications of 25 kg Nha^{-1}and no N application for container grown tomato, application of N at the rate of 25 kg ha^{-1}was found to be better yielding. Similarly, compared to 0 kg P ha^{-1}, 23 kg P ha^{-1} produced higher fruit yield. Although there was increase in fruit yields of tomato crop, further research is required for management of supplementary N and P fertilizer uses in container grown tomato cultivation under both rainfed and irrigated conditions.

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Woody Plant Species Diversity, Structure and Regeneration Status Of Woynwuha Natural Forest, North West Ethiopia

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Abstract

A study was conducted in Woynwuha natural forest, North West Ethiopia to investigate woody plant species diversity, structure, and regeneration status of the forest. A total of 50 square quadrats each having an area of 625m^2 were used for vegetation data collection. Vegetation data were collected through field observation, species counting, speciemen collection and height and DBH measurements. Data was analysed using Shannon Weiner diversity index, Simpson's index, important value index and height and diameter distribution graphs. A total of 69 woody plant species belonging to 41 families and 59 genera were recorded. Fabaceae was the most species-rich family in the area. The overall average Shannon-Wiener Diversity Index (H`) was 3.24 and the average evenness values (E') was 0.76 indicating high diversity with more or less even distribution. The computational result of the important value index indicated that *Carissa edulis* was ecologically most important species. The tree cumulative diameter class frequency distribution in general resembles interrupted inverted-J-shape pattern indicating the existence of much seedling than big sized trees. The same pattern was also observed with regard to height class distribution indicating the selective removal of higher trees by the local communities.

Key words: Species Diversity, Population Structure, Regeneration Status, Important Value Index, and Woynwuha Natural Forest.

1. Introduction

The conservation and sustainable use of biological diversity and the eradication of extreme poverty are two of the main global challenges of our time. It has been recognized by the international community that these two challenges are intimately connected, and require a coordinated response. The protection of biodiversity is essential in the fight to reduce poverty and achieve sustainable development. Seventy percent of the world`s poor lives in rural areas depend directly on biodiversity for their survival and well-being. The impact of environmental degradation is most severe for people living in poverty, because they have few livelihood options on which to fall back (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 biodiversity loss in African forests poses an international concern (Bennun *et al.*, 2004).

Ethiopia is one of the few countries in the world that possesses a unique characteristic flora and fauna with a high level of endemism (WCMC, 1991). It is estimated that between 6,500 and 7,000 species of higher plants occur in Ethiopia, of which about 15% are endemic (WCMC, 1992). Ethiopia is the fifth largest floral country in tropical Africa (WCMC, 1991). The remnant natural forests in the central and northern highlands are found only as isolated small patches at inaccessible locations and around the numerous churches and burial grounds (Alemnew Alelign, Demel Teketay,Yonas Yemshaw & Sue Edwards,Tropical ecology 48(1): 37-49, 2007).

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 be undoubtedly continue and the natural forest resource will be exhausted in the coming few years. This intern may lead to loss of flora and fauna. Information on the composition, structure and regeneration status of woody plant species is lacking for the study area.Therefore, the present study was initiated to investigate woody plant species diversity, vegetation structure, and regeneration status of Woynwuha natural forest in Goncha Siso Enesie district, North West Ethiopia. The specific objectives of the study were to provide a species list of the study area, to investigate woody plant species diversity of the forest, to assess the structure and regeneration of woody plant species in the forest.

2. Materials and Methods

2.1 Description of the Study Area

2.1.1 Location

Woynwuha natural forest is located in Debreyakob kebele, Goncha Siso Enesie district, East Gojjam Zone, Amhara National Regional State (Fig 1). The district is located about 338 km north-west of Addis Ababa, the capital city of Ethiopia. The study site is located between 10^{0} $52^{'}$ North latitude and 38^{0} $14^{'}$ East longitudes. The study natural forest has an area of 162.057 ha.

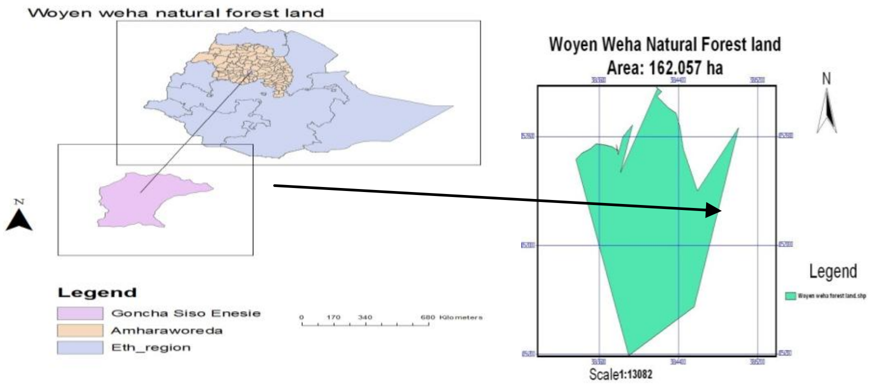


Figure 1. Map of the study area and forest.

2.1.2 Topography, soil and Climate

Topography of the study area is generally characterized by undulated hill and the total area of the district is 98383 ha. The soils are mostly acidic with pH values ranging from 4.2-7.3 (Debre Markos Soil Labratory, 2007). The elevation of the study forest ranges from 2009-2733m.a.s.l and boarded by two Kebeles and four Gotts namely Tach Dinjet in the north, Gufu Giorgis in the east, Debreyakob kola in the west and Jibra Kola in the south. It is under communities' forest. Traditionally the districts have three major types of agro-climatic zones: '*Dega*' (12%), '*Weina-Dega'* (48%) and *'Kolla'* (40%). the natural under study lies in sub-humid climate. The mean annual rainfall is in the range of 1100-1800mm and monomodal rainfall pattern of distribution, which occurs in the months of June to September. The monthly mean temperature is $19.5^{0}{}_{C}$ the annual average maximum and minimum temperature of the study area is 24^{o}c and 15^{o}c, respectively (WAO, 2011/12). Based on the data from Motta (58 kilometres from the study forest) and Bahir Dar (180 kilometres from the study forest) meteorological stations, the five years (1987-1991) average rainfall and temperature pattern of Goncha Siso Enesie *District* are presented in (Fig 2.)

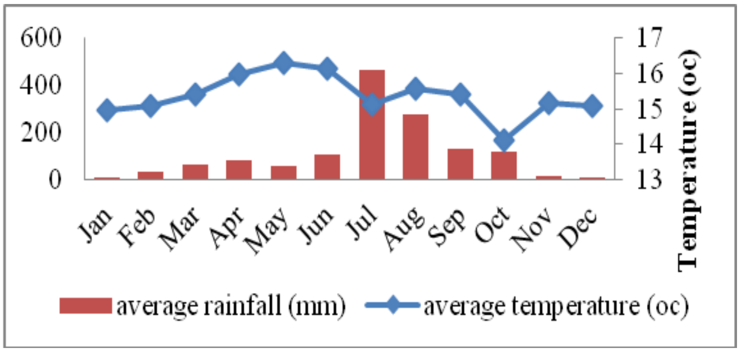


Figure 2. Average rainfall and temperature data for five years (1987-1991) of Goncha siso Enesie *District* (Source: National meteorological data, Motta and Bahir Dar stations, 2012).

2.2 Methods of Data Collection

2.2.1 Sampling Design

In this study, a systematic sampling method was employed to collect data. by laying 11 transect lines each spaced 150m apart following the homogeneity of the vegetation and elevation gradient of the forest following (Blanquet, 1932; Zerihun Woldu, 1980 and 1985;Tamrat Bekele, 1994 and Scholder, 1999). The first transect line was laid out randomly at one side of the forest along the gradient, with the help of a Silva explorer compass (type 3NL). A total of 50 rectangular sampling plots (quadrats) each having an area of 625m^2 (25m X 25m) were laid on the transect lines. The spacing between sampling plots were a distance of 100m using measuring tape. The altitude and position of each plot were measured with Garmin etrex10 GPS. Within each major sampling plots, three sub-plots each having an area of 20m^2 (2m X 10m) two at the end of the main quadrants and one at the center were laid for the purpose of saplings and seedlings inventory following Haile Adamu (2012). At all major sampling plots, all woody plant species were identified, counted, and recorded.

Diversity data were collected by summing up the number of species identified directly in the field. For the sake of species identification, local names of all woody species were listed and then scientific names were identified following colored plant identification guides such as flora of useful trees and shrubs in Ethiopia Azene Bekele (2007) and referring to the published volumes of Flora of

Ethiopia and Eritrea (1994) were used. In case identification was not possible tree species specimens were taken to the National Herbarium at the Department of Biology in the Addis Ababa University and identification was made latter.

Tree height and diameter at breast height (DBH) were measured using clinomeater and caliper/measuring tap, respectively. DBH of all trees above 1.3m from the ground were measured. In cases where a tree bole branched at breast height or below, the diameter were measured separately for the branches and averaged as one DBH and in cases where tree boles buttressed, DBH measurement were undertake from the point just above the buttresses. Apart from DBH data, data on number of saplings and seedling for all plants were collected each sub-plots.

The height (m) and collar diameter (diameter at the ground level) of seedlings and saplings within each main quadrats (plot) were measured using a meter marked stick and a verner caliper, respectively. Within each main quadrats, data on number of sapling and number of seedling for all plant species and regeneration status of woody species were assessed by counting seedling (woody species of height ≤50cm and DBH ≤2.5cm) and sapling (woody species of height ≥50cm and DBH ≤ 2.5 cm).

2.3 Data Analysis

2.3.1 Composition and vegetation structure analysis

The number of species (species richness) was determined by summing up the number of species identified directly in the field from each plot and then relative abundance, frequency, the Shannon-wiener index were calculated.

Two sets of abundance (number of individuals of a species in the area) were calculated in this study. These were (1) Average abundance per quadrant, calculated as the sum of the number of stems of species from all quadrants divided by the total number of quadrants, and (2) Relative abundance, calculated as the percentage of the abundance of each species divided by the total stem number of all species per hectare following Kindeya Gebrehiwot (2003).

2.3.2 Plant diversity and equitability analysis

The species diversity is the combination of the species richness (the number of species in the sample plots) and evenness of species (abundance distribution among species). Based on these results, the Shannon wiener diversity index (H`), evenness and richness were summarized with respect to the identified species through the analysis of two components of species diversity.

- Shannon diversity index is calculated as follows (krebs, 1999, Kent and Coker, 1992 and Jayarman, 2000)

$$H' = \sum_{i=1}^{s} p_i \ln p_i \text{ ------------------------------- } (1)$$

Where; H' = the Shannon-Weiner Diversity Index, Pi = the proportion/probability of individuals found in the ith species, s = total number of species (1, 2, 3…..s), Ln = natural logarithm. Species richness was taken from all species encountered in each plot

S = number of species/plot area--------------------------- (2)

- The Shannon's evenness index (E) was calculated from the ratio of observed diversity to maximum diversity using the equation.

$$EH = \frac{\sum_{i=1}^{s} p_i \ln p_i}{\ln s} \text{ ----------------------- } (3)$$

Where, EH= Equitability (evenness) index which has values between 0 (a situation in which the abundance of all species are completely disproportional) and 1 (all species are equally abundant).

2.3.3 Structural Data Analysis

To analyze the vegetative structure of woody species, all individuals of each species encountered in the quadrat were grouped into diameter and height classes (Kershaw, 1973, Shimwell, 1984). Then table and histograms frequency were developed using the diameter and height classes versus the number of individuals categorized in each of the classes using Microsoft Excel Computer Software. To see the regeneration status of the woody plants or to evaluate the level of disturbance in the forest, all types of disturbances were record. Furthermore, checklist of plant species record in each plot, including their local uses and parts use were prepared.

2.3.4 Importance value index

The importance value index (IVI) indicates the importance of individual tree/shrub species in the land use systems. It is a composite index based on the relative measures of species frequency, abundance and dominance (Kent and Coker, 1992; Jose and Shanmugaratnam, 1994). This index is used to determine the overall importance of each species in the community structure (Relative Density, Relative Dominance and Relative Frequency) which describes the structural role of a species in a stand.

- Importance Value Index was calculated with the following formula.

$$\text{Importance value index} = \text{Relative Density} + \text{Relative frequency} + \text{Relative Dominance} \text{------ } (4)$$

$$Relative\ density = \frac{\text{Density of species A}}{\text{Total density of all species}} * 100 \text{---------------------------} \quad (5)$$

$$Relative\ frequency = \frac{\text{Frequency of speciese A}}{\text{Total frequency of all species}} * 100 \text{-------------------} \quad (6)$$

$$Relative\ Dominance = \frac{Basal\ area\ of\ speciies\ A}{\text{Total Basal area of all species}} * 100 \text{-------------------} \quad (7)$$

- To compare the diversity between plot and with another forest, Sorenson Similarity index was used (Lamprecht 1989; Kent and Coker, 1992).

$$S_s = \frac{2C}{(2C+A+B)} \text{--} \quad (8)$$

Where, Ss = Sorensen's similarity index, A = number of species forest in natural forest A, B = number of species in natural forest B, C = number of species common to both forests.

3. Results and Discussion

3.1 Floristic Composition

Floristic composition of the vegetation was described in terms of its richness in species, abundance, dominance, and frequency (Lamprecht, 1989). In the studied forest, a total of 67 native woody species and 2 exotic tree species were recorded belonging to 41 families and 59 genera (Appendix 1) in the altitudinal range between 2009–2626m.a.s.l. The trees had the largest proportion of the life forms. Of these species, 34 (49%) were trees, 25(36%) were tree/shrubs, 7(10%) were shrubs and 3(4%) were climbers (Fig. 3). About 67(97%) of the woody species were endemic to Ethiopia.

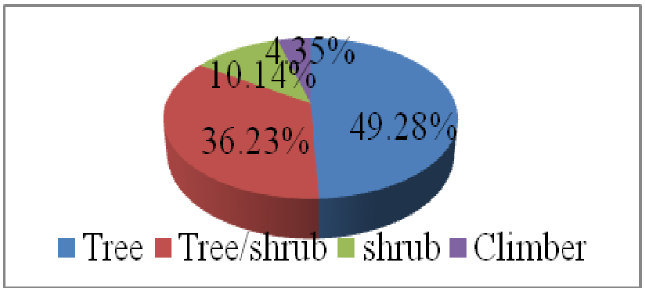


Figure 3. Life form percentage of the vegetation of the studied forest.

Fabaceae was the most species-rich family comprising 9 (13.04%) species from the total plant species identified followed by *Euphorbiaceae* and *Moracea* each represented by four species. *Euphorbiaceae* and *Moracea* together comprised 11.59% of the total species. The next dominant families were *Anacardiaceae, Asteraceae, Oleaceae, Sapindaceae, and Sapotaceae* with 15 species together (21.72%) each represented by three species. The fourth dominant families were *Apocynaceae, Myrtaceae, Rosacea and Rubiaceae* each represented by 2 species and together accounted 11.59% of the total identified species. The remaining species belong to 29 families (42.03%) and each represented by a single species.This indicating the dominance of fabaceae family, which might be due the adaptation potential of Fabaceae families to wider agro-ecologies.

The overall average Shannon-Wiener Diversity (H`) Index and the average evenness values for the entire forest were 3.24 and 0.765, respectively (Appendix 2). According to Kent and Coker (1992), the Shannon-Weiner diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5. Shannon diversity index is high when it is above 3.0, medium when it is between 2.0 and 3.0, low when between 1.0 and 2.0 and very low when it is smaller than 1.0 (Cavalcanti and Larrazabal, 2004). From this study, it can be concluded that the study forest is with high diversity and more or less even representation of individuals of all species encountered in the studied quadrants except a few species are dominant.

Species area curves were drawn to judge the adequacy of sampled areas to represent the species diversity and related vegetation qualities. The leveling out of the species area curve is used to determine whether adequate samples were taken. The species area curve is a cumulative curve that relates the occurrence of species with the area sampled. When the curves grew up and flattened at the end, this indicates that the number of plots taken is sufficient (Lamprecht, 1989, Gotelli and Colwell, 2001).

Species diversity curve rises relatively rapidly at first, and then much more slowly in later samples as increasingly rare taxa are added (Gotelli and Colwell, 2001; Rosenzweig, 1995). In agreement with above statements, ten sample plot was taken randomly, the species diversity curves of the vegetation of the study Forest showed that species richness across quadrants was good and pattern of diversity curve owing to the fairly enough number of quadrats observed (Fig 4).

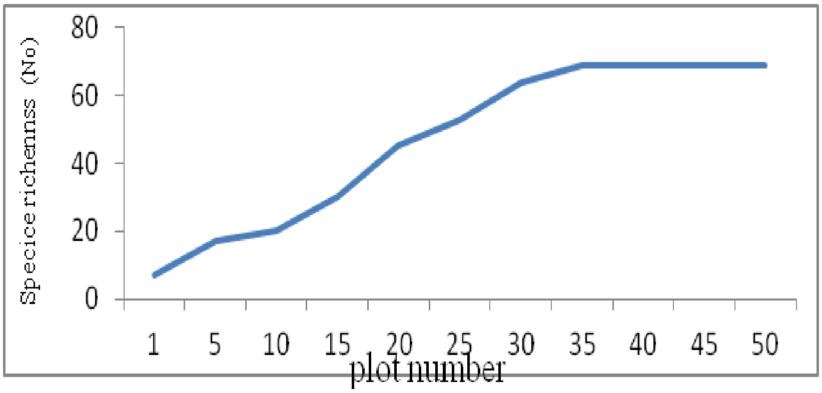


Figure 4. Species richness curve of the whole vegetation.

The number of species (69) recorded in the study area was found to be also higher than the number of species recorded in other Ethiopian Afromontane forests like Dilfaqar Regional Park forest (51) (Dereje Mekonnen, 2006), Bonga forest (51) (Abayneh Derero *et al*., 2003) and Jibat (54) (Tamrat Bekele, 1994). However, the total number of species in the study area was lower than that of reported for Hugumburda forest (79) (Ermias Aynekulu, 2011), Belete forest (79) (Kitessa Hundera and Tsegaye Gadissa, 2008), Abebayen and Tara gedam forest (143) (Haileab Zegeye, 2005), Afer-Shala Luqa (216) species (Teshome Soromessa *et al*., 2004), Chilimo (90) (Tadesse W.mariam *et al*., 2000) and Wof-Washa forest (252) (Demel Teketay and Tamrat Bekele, 1995).

Generally, factors like social and environmental influences might have impacted the forest composition and species richness (Espinosa and Cabrera, 2011) though it depends on intensity and persistency of influences (Kuffer and Senn-irlet, 2004). Possible reasons for these diversity differences may be also forest size. This means as the forest area is getting wider, the probability of getting new species increases contributing to higher divesrsity value.

3.2 Abundance and Population Structure of Woody Plant Species

Species-abundance measures are ways of expressing not only the relative richness but also evenness and there by assessing diversity (Barnes *et al*., 1998). A total of 8698 individuals of woody plants (2783 individuals per ha) were encountered from 50 studied quadrats. The ten most abundant woody species in their order of highest density were: *Carissa edulis*, *Maytenus arbutifolia*, *Calpurnia aurea*, *Croton macrostachyus*, *Acacia abyssinica*, *Mimusops kummel*, *Allophylus abyssinicus*, *Otostegia integrifolia*, *Bersema abyssinica* and *Rosa abyssinica*.

Generally speaking, only few species were dominating the vegetation of the study area in their abundance while many of the species were very rare or low in their abundance. Such a result reflects either adverse environmental situations or random distribution of available resource in the study area (Feyera Senbeta, 2005, Tatek Dejene, 2008). It can be further inferred about this study result from the above authors point of views in that the woody plants were distributed in uneven manner may be due to inability of individuals to cope up harsh environmental condition, human disturbance, livestock trampling and grazing, and other biotic and abiotic impairments in the area.

In this study both diameter and height class distribution of the population structure of the study area reflected an interrupted reversed J-shape (L-shape), which seemed to show a pattern where species frequency distribution had the highest frequency in the lower diameter and height classes and a gradual decrease towards the higher classes. Eighty one percent of the total density lies between the first, second, third and fourth diameter classes, whereas, about 15.5% and 4 % of the density were found to be in the middle diameter classes (16-36 cm) and in the higher diameter classes (36-44cm), respectively (Fig 5). This indicated that there was drawing out of middle and high diameter class trees for various purposes by local dwellers like for fencing, construction and fuel wood.Similarly, the density distribution of woody individuals in different height classes also showed a similar pattern with diameter classes although there were a very high decrease in density of class three, four, five and six. Generally, it showed a decrease in density with increasing height classes (Fig 6).

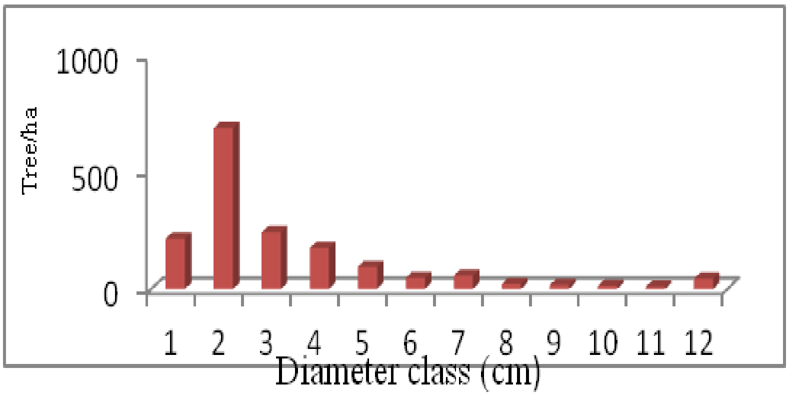


Figure 5. Diameter class frequency distribution of selected tree species.

DBH class: (1=<4 cm; 2=4-8 cm; 3=8-12 cm; 4=12-16 cm; 5=16-20 cm; 6=20-24 cm; 7=24-28 cm; 8=28-32 cm; 9=32-36 cm, 10=36-40 cm, 11=40-44 cm, 12=>44 cm

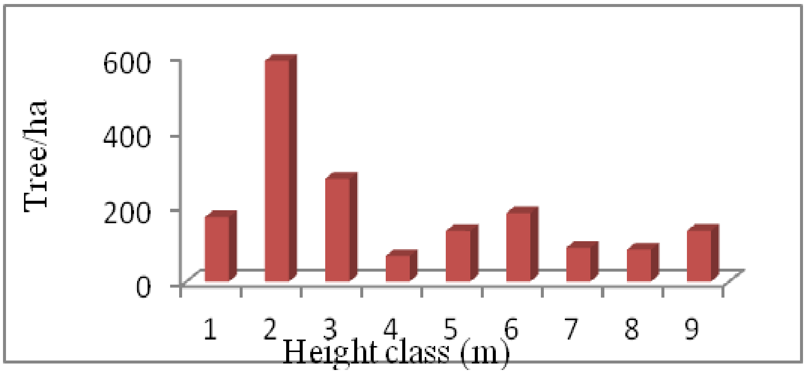


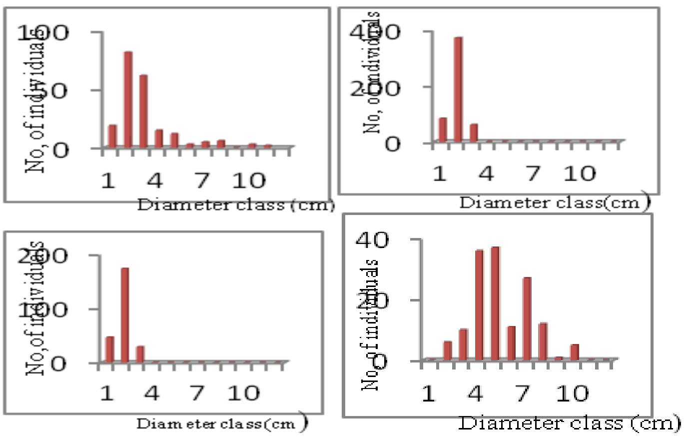
Figure 6. Height class frequency distribution of woody species.

Height class (1=<2 m; 2=2-4 m; 3=4-6 m; 4=6-8 m; 5=8-10 m; 6=10-12 m; 7=12-14 m; 8=14-16 m, 9=>16 m**)**

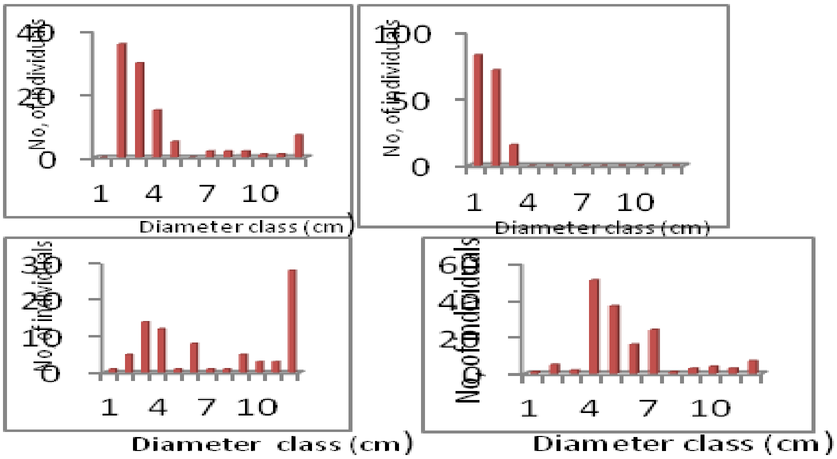
Information on population structure of a tree species indicates the history of the past disturbance to that species and the environment and hence, used to forecast the future trend of the population of that particular species (Demel Teketay, 1997; Tamrat Bekele, 1994). The population structure of selected species from the vegetation of the study area fell into one of the four general diameter class distributed patterns. These are: 1) interrupted reversed J-shape, which seemed to show a pattern where species frequency distribution had the highest frequency in the lower diameter classes and a gradual decrease towards the higher classes; but showing either a complete absent or a very high decrease in density somewhere in the lower classes or middle classes. 2) J-shape, which showed a type of frequency distribution in which there was a low number of individuals in the lower diameter classes but increased towards the higher diameter classes. 3) Bell-shape, which showed a type of frequency distribution in which a number of individuals in the middle classes were high, and decreased towards the lower and higher diameter classes and 4) Irregular-shape, which seemed a Bell-shape distribution pattern but a complete absent of individuals in some class and a fair representation of individuals in other class (Haile Adamu, 2012). These patterns were illustrated by the eight dominant species that had been selected based on their relative frequency distribution and importance value index.

Accordingly, diameter class of *Croton macrostachyus* (Fig 7a), *Carissa edulis* (Fig 7b), *Maytenus arbutifolia* (Fig 7c), *Allophylus abyssinicus* (Fig 7e) and *Calpurnia aurea* (Fig 7f) were depicted an interrupted Inverted-J-shape pattern *Olea europaea* (Fig 7g), *Albizia gummifera* (Fig 7h) were depicted in the Irregular-shape patern and *Acacia abyssinica* (Fig 7d), depicted in the Bell-shape pattern. This reflects a hampered regeneration status of the species due to possible reasons like human disturbance, livestock trampling or browsing in the area (impacts of domestic animals such as goat. sheep and caw).

The patterns of Diameter at Breast Height (DBH) class distributions indicated the general trends of population dynamics and recruitment processes of the species. From the DBH class distributions of the species, two types of regeneration status were determined, i.e. good and poor regeneration. Some species possessed high number of individuals in the lower DBH classes, particularly in the first class, which suggests that they have good regeneration potential. Other species possessed either no or few number of individuals in the lower DBH classes, particularly in the first class, which indicates that the species are in poor regeneration status.



(a) *Croton macrostachyus* (b) *Carissa edulis* (c) *Maytenus arbutifolia* (d) *Acacia abyssinica*



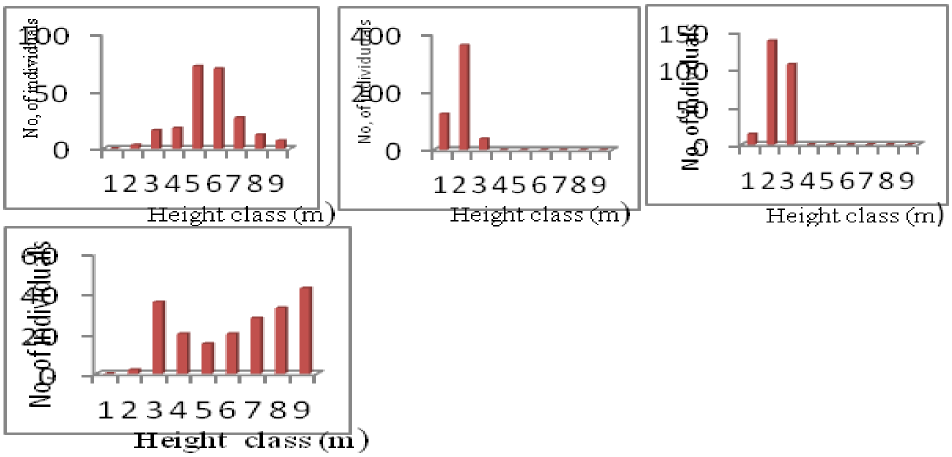
(e) *Allophylus abyssinicus* (f) *Calpurnia aurea* (g) *Olea europaea*

(h) *Albizia gummifera*

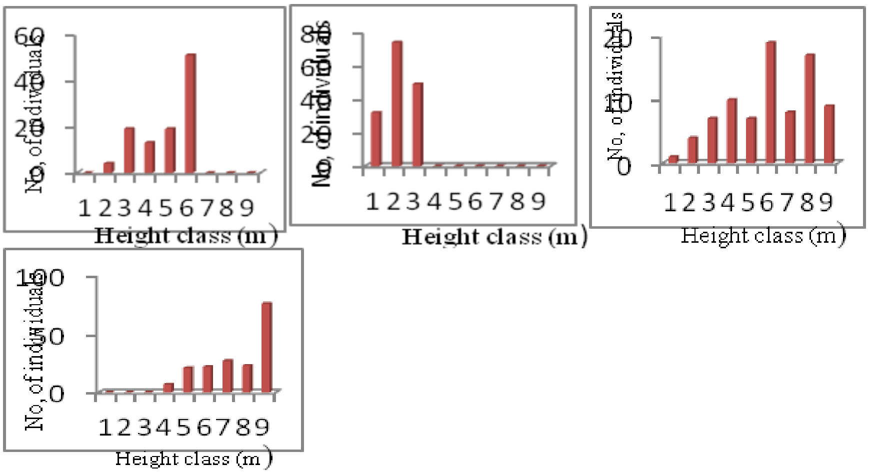
Figure 7. Diameter class frequency distribution of selected tree species.

DBH class: (1=<4 cm; 2= 4-8 cm; 3= 8-12 cm; 4= 12-16 cm; 5= 16-20 cm; 6= 20-24 cm; 7= 24-28 cm; 8= 28-32 cm; 9=32-36 cm, 10=36-40 cm, 11=40-44 cm, 12=>44 cm).

On the other hand, the patterns of height class distribution fell into three categories (Fig 8). These were: 1) interrupted reversed J-shape, which seemed to show a pattern where species frequency distribution had the highest frequency in the lower height classes and a gradual decrease towards the higher classes. But showing either a complete absent or a very high decrease in density somewhere in the lower classes or middle classes. 2) J-shape, which showed a type of frequency distribution in which there was a low number of individuals in the lower height classes but increased towards the higher height classes, and 3) Irregular-shape, which generally seemed a Bell-shape distribution pattern but a complete absent of individuals in some class and a fair representation of individuals in other class. Accordingly, height class of *Allophylus abyssinicus* (Fig 8e), *Albizia gummifera* (Fig 8h) were J-shape pattern. *Carissa edulis* (Fig 8b), *Maytenus arbutifolia* (Fig 8c), *Calpurnia aurea* (Fig 8f) were depicted an interrupted Inverted-J-shape pattern, *Croton macrostachyus* (Fig 8a), *Acacia abyssinica* (Fig 8d), *Olea europaea* (Fig 8g) nearly irregular shape (Bell-shape).



(a) *Croton macrostachyus* (b) *Carissa edulis* (c) *Maytenus arbutifolia* (d) *Acacia abyssinica*



(e) *Allophylus abyssinicus* (f) *Calpurnia aurea* (g) *Olea europaea* (h) *Albizia gummifera*

Figure 8. Cumulative height class frequency distribution of woody species.

Height class (1=< 2m; 2= 2-4m; 3= 4-6m; 4= 6-8m; 5= 8-10m; 6= 10-12m; 7= 12-14m; 8=14-16m, 9=>16m)

3.3. Basal Area, Frequency and Importance Value Index (IVI)

Basal area provides the measure of the relative importance of the species than simple stem count, (Lamprecht, 1989). Species with largest contribution in dominance value through higher basal area could be considered as the most important species in the study vegetation. Otherwise, in most cases shrubs could be the dominant species if only we consider density as a measure to indicate the overall dominance of the species (W.Adefires, 2006; S.Simon and B.Girma, 2004).

The average basal area of all woody species was 20.03 m^2/ha. The following species made the largest contribution to the basal area: *Albizia gummifera* (22.87%), *Olea europaea* (17.77%), *Croton macrostachyus* (15.76%), *Acacia abyssinica* (14.30%), *Carissa edulis* (10.95%), *Maytenus arbutifolia* (3.85%), *Allophylus abyssinicus* (3.79%) and *Juniperus procera* (3.75%). But the other remaining species contributed only 6.94 %. This implies that the above-mentioned eight species are the most ecologically important woody species in Woynwuha natural forests.

Important value index (IVI) is a good index for summarizing vegetation characteristics, ranking species management and conservation practices. It reflects the degree of dominancy and abundance of a given species in relation to the other species in the area (Kent and coker, 1992). The result of IVI which is calculated from relative density, relative basal area (relative dominance) and relative frequency, of woody species is shown in (Appendix 3). According to Lamprecht (1989), stands that yield more or less the same IVI for the characteristic species indicate the existence of the same or at least similar stand composition and structure, site requirements and comparable dynamics among species.

The result of the index showed that the ten most important woody species with the highest IVI in decreasing order were *Carissa edulis* (8.57%), *Maytenus arbutifolia* (6.44%), *Pittosporium viridiflorum* (5.52%), *Coffiee Arabica* (4.74%), *Myrsine africana* (4.08%), *Albizia gummifera* (3.25%), *Jasminum abyssinicum* (3.06%), *Calpurnia aurea* (2.99%), *Bersema abyssinica* (2.82%) and *Croton macrostachyus* (2.72%). These contributed to over 44.22% of the total importance value indices; this implies that these woody species are the most ecologically important woody species in the study area. Whereas, species with small contribution to the total IVI were like *Ficus vasta*, *Erica arborea*, *Cordia africana*, and others those woody species which have IVI rank less than ten are threaten and it needs of immediate conservation measure (Appendix 3).

Albizia gummifera (22.873), *Olea europaea* (17.774), *Croton macrostachyus* (15.759), *Acacia abyssinica* (14.3040, *Carissa edulis* (10.957) were species with the highest relative basal area, and *Carissa edulis* (15.624), *Maytenus arbutifolia* (10.692), *Calpurnia aurea*. (7.657), *Croton macrostachyus* (7.243) were species with the highest relative density, On the other hand *Croton macrostachyus* (7.579), *Carissa edulis* (7.024), *Maytenus arbutifolia* (6.47), *Acacia abyssinica*

(5.545), *Allophylus abyssinicus* (5.36), *Calpurnia aurea* (5.176), *Olea europaea* (5.176), *Albizia gummifera* (4.621), *Rosa abyssinica* (3.327) were species with highest relative frequency in Woynwuha natural forests. The most abundant species in this study is *Carissa edulis* (434.88/ha) followed by *Maytenus arbutifolia* (297.6/ha).

Frequency reflects the pattern of distribution and gives an approximate indication of the heterogeneity of a stand (Z.Haileab, 2005; Lamprecht, 1989). The highest relative frequency was scored by *Croton macrostachyus* which has relatively highest relative density and the highest relative basal area. These may be due to the fact that these species might have a wide range of seed dispersal mechanisms like by wind, livestock, wild animal, birds and the like. Studies pointed out that high values in higher frequency classes (class A and B) and low values in lower frequency classes (classes C and E) indicated constant or similar species composition following S.Simon and B.Girma, (2004). High values in lower frequency classes and low values in higher frequency classes on the other hand indicate a high degree of floristic heterogeneity. In the present study, high values were obtained in lower frequency classes whereas low values were in higher frequency classes (Fig 9). This showed that floristic heterogeneity exists in Woynwuha natural forests.

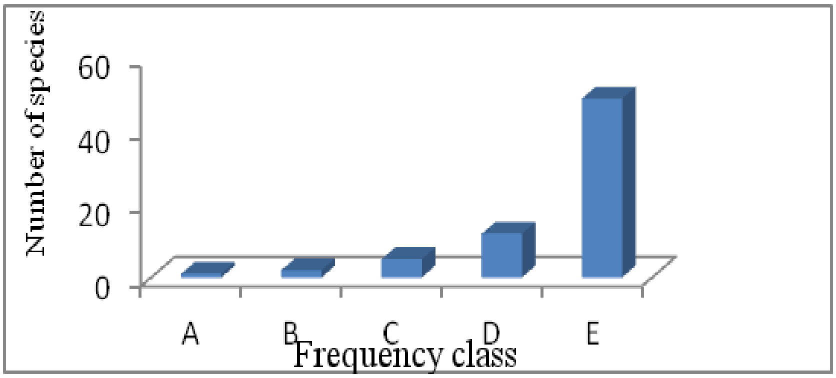


Figure 9. Frequency distribution of woody species of Woynwuha natural forests.

Frequency class: (A= 81-100%; B= 61-80%; C= 41-60%; D= 21-40%; E= 0-20%

3.4 Regeneration Status

Composition and density of seedlings and saplings would indicate the status of regeneration in the study area. The population structure helps to study the regeneration pattern of a species (Swamy *et al*. 2000). The study forests had relatively high number of saplings 3274 (37.64%) followed by seedlings 2950 (33.92%) and mature trees 2474 (28.44%). A total of 6224 individual (1991.68 individuals/ha) seedlings and saplings belonged to 61 species were counted from all quadrants, while a total of 3274 individuals (1047.68 individuals/ha) saplings counted for 58 species, and a total of 2950 individuals (944 individuals/ha) seedling counted for 56 species.

Accordingly, the following species made the largest contribution to the seedling counts per hectare: *Maytenus arbutifolia* (267.2), *Carissa edulis* (214.72), *Calpurnia aurea* (163.52), *Croton macrostachyus* (129.6), *Acacia abyssinica* (108.16), *Otostegia integrifolia* (101.44), *Bersema abyssinica* (90.24), *Allophylus abyssinicus* (87.36), *Albizia gummifera* (77.76), *Rhus vulgaris* (72.64), *Rosa abyssinica* (76.8), *Cassipourea malosana* (52.16), *Dodonaea viscose* (48), *Olea europaea* (41.28), *Myrsine africana* (34.24), *Rhus retinorrhoea* (41.6) (Fig 10). In this seedling and sapling assessment, *Carissa edulis*, *Maytenus arbutifolia*, *Calpurnia aurea*, *Croton macrostachyus*, *Acacia abyssinica* and *Allophylus abyssinicus*, were with good recruitment status relative to other species. On the other hand, some species like *Pouteria altissima*, *Albizia lophantha*, *Crassocephalum sarcobasis* and *Cordia africana* showed less recruitment status of seedling and sapling. This may be due to the selective browsing effect of animals and ecological adaptation problem in the study area. Generally, good regeneration was observed for most bush/shrub species than trees which needs further study.

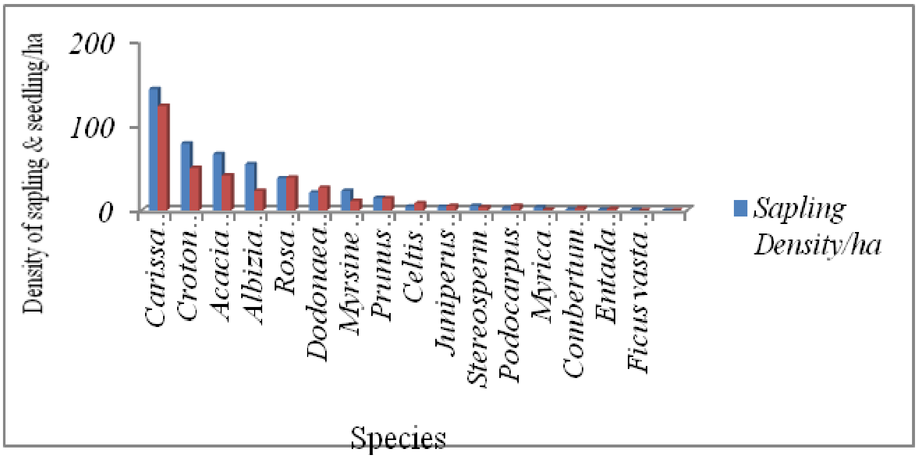


Figure 10. Regeneration status (seedling and sapling) of woody tree species.

3.5 Similarity in Woody Species Composition

The trend of species composition varied from one forest to another. From the total species identified in the study forests 36 (44.44%) species, 22 (21.78%) species, 8 (7.34%) species were found in Tara Gedam forests, Debrelibanos forests, Metema forests respectively. 34 (20.98%) species, 47 (46.53%) species, 61 (55.96%) species in the study forests only when we compare with the selective above site 56 species (34.56%) in Tara Gedam forest, 32 species (31.68%) in Debrelibanos forest, 40 species (36.69%) in Metema forests only.

The similarity in species composition between the study forests and Tara Gedam forests was 0.44, the study forests and Debrelibanos forests was 0.36, the study forests and Metema forests was 0.14. The similarity coefficient was below 0.5 (maximum is 1.0), indicating that there is low similarity among the forests and each forest has its own characteristic species under uniform climatic conditions.

Hence, it seems likely that other factors such as the type of plantation species, edaphic conditions of the stands, management practices, age, and altitudinal difference between the selective sites etc. may have contributed to the differences in the similarity of species composition among the selective sites. Other authors (S.Feyera 1998; S.Feyera *et al.,* 2001; Pande *et al*., 1988) have reported similar results. Thus, the study forests, Tara Gedam forests, Debrelibanos forest and Metema forests are important in terms of floristic diversity and sensitive from a conservation point of view.

Tabel 1. Similarity coefficient between Woynwuha natural forest and selective site

W= Woynwuha forest, Tg= Tara gedam forest, Dl= Debrelibanos forest, M=Metema forest

	Wv_sTg		Wv_sDl		Wv_sM	
	Spp type	%	Spp type	%	Spp type	%
Both	36	44.44	22	21.78	8	7.34
other site	56	34.56	32	31.68	40	36.69
Woynwuha	34	20.98	47	46.53	61	55.96
Total	126	100	101	100	109	100

4. Conclusiosns and Recommendations

Woynwuha natural forest has high floristic composition and diversity with good distribution. Fabaceae was the dominant vegetation family. The Shannon winner diversity index also showed higher diversity value as compared to other forests. Moreover, the forest has more or less even species distribution. However, the results of woody species revealed that only few species were scored high density and basal area. Both the cumulative diameter and height class frequency distribution patterns of woody individuals resulted in an interrupted inverted-J shape, which is the reflection of a more or less good regeneration profile in the area. Similarly, the population structure of the eight selected important species resulted as all of them were in good regeneration status though the degree of the problems varies from species to species. *Cordia africana* was the most critically hampered species followed by *Crassocephalum sarcobasis, Albizia lophantha and Pouteria altissima.*

In general, the results of this study showd that high IVI. If appropriate management activities are applied, the nature of the population structure of most of the tree species will be improved. The study forests possess high species richness and evenness, including endemics plant species. The similarity in species composition between woynwuha and other selected the forests were low, indicating that each forest has its own characteristic species. The diversity and evenness indices indicate the need to conserve the forests from floristic diversity points of view.

In order to ensure the conservation of the Woynwuha Natural forest, the following recommendations were forwarded for effective use in the study area:

- 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 than any outsider and assigning qualified person for conserving and rehabilitation of woynwuha natural forests.
- The most important option to save the remaining forest urgently is to solve the key problem of the community. The government and its institutions should play roles and responsibilities for solving the problem. This option also needs to be linked with strong extension services to build awareness of the community about sustainable conservation and utilisation of woody species.
- The legal protection of the forest should be strengthened to make more effective protection mechanisms of the natural forest.

- In-situ and ex-situ conservation methods have to be employed for the conservation of indigenous species having low IVI values and poor regeneration status.
- Integrated research and development interventions have to be carried out for further studies on patterns of the composition, structure and regeneration states of the forest through effective management in the area.

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Effects of Nitrogen Inhibitors and Slow Nitrogen Releasing Fertilizers on Crop Yield, Nitrogen Use Efficiency and Mitigation of Nitrous Oxide (N_2O) Emission

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Abstract

Improving the production and productivity of crops through appropriate nutrient management including nitrogen fertilizer is one of the most important means to satisfy the food demand of the ever increasing world's population. Consequently, intensive use of nitrogen fertilizers increase cost of production and cause environmental pollution through different forms of nitrogen losses such as nitrate (NO^-_3) leaching, ammonia (NH_3) volatilization and nitrous oxide (N_2O) emission. The main aim of this paper is, therefore, to review the effects of nitrogen inhibitors and slow nitrogen releasing fertilizers on crop yield, nitrogen use efficiency and mitigation of N_2O emission. Various research results showed that application of nitrification inhibitors (DCD, DMPP, thiosulfate, neem, and N-serve), urease inhibitors such as agrotain, PPD, NBPT and hydroquinone, and slow nitrogen releasing fertilizers like polymer and sulfur coated urea substantially improved nitrogen use efficiency and yield of crops as well as significantly mitigating GHG (N_2O) emission. Therefore, application of such technologies has great contribution to reduce environmental pollution caused by intensive utilization of nitrogen fertilizers while increasing crop yields.

Keywords: Nitrogen fertilizer, leaching, nitrogen loss, agrotain, mineralization

1. Introduction

Nitrogen is required by all living organisms for the synthesis of proteins, nucleic acids and other nitrogen-containing compounds (the James Hutton Institute, 2014). Although 78 % of the air is nitrogen gas (N_2), it is not directly available to plants. In order to become available to plants, nitrogen must be fixed to form ammonium (NH_4^+) or nitrate (NO_3^-) through the process of making industrial fertilizers (Haber-Bosch process) and/or through nitrogen-fixing bacteria associated with the roots of legumes (Clark, 2014).

Leguminous plants and soil microorganisms contribute significant amounts of nitrogen in the soil that can be used by crops. However, high crop yields require more nitrogen than provided by natural means (Ribaudo *et al*., 2011). Therefore, nitrogen is usually supplied in the form of artificial fertilizer, which is produced through a chemical process (Haber-Bosch process) that converts atmospheric nitrogen into ammonium(NH_4^+) using very high quantities of energy (James Hutton Institute, 2014).

Chemical fertilizer has played a major role in the global food production over the past 60 years. It supplies about 50 % of total N required by crops. However, its use efficiency in crop production is low (10-50 %) mainly due to loss of N through nitrate (NO_3) leaching, volatilization of ammonia (NH_3) and nitrous oxide (N_2O) emission resulting in pollution of groundwater and atmosphere (Zhaohui *et al*., 2012; Galloway *et al*., 2003). Moreover, the production cost of nitrogen fertilizer is very high. These scenarios lead to the use technologies such as nitrogen inhibitors and slow nitrogen releasing fertilizers given as fertilizer additives to increase nutrient uptake, fertilizer use efficiencies and yields of crops (Frame and Reiter, 2013). Slow released fertilizers, nitrification and urease inhibitors are the three possible types of products that control nitrogen loses and consequently improve nitrogen use efficiency (Schwab and Murdock, 2010). Therefore, the main aim of this paper is to review the effects of nitrogen inhibitors and slow nitrogen releasing fertilizers on crop yield, nitrogen use efficiency and mitigation of N_2O emission.

2. Nitrogen Inhibitors, Slow Releasing Fertilizers and their Effects on Crops

Nitrification and urease inhibitors are called nitrogen inhibitors. Nitrification inhibitors are substances that inhibit biological oxidation of ammonium to nitrate (Schwab and Murdock, 2010). Some of nitrification inhibiting products includes dicyandiamide (DCD), 3,4-dimethyl-1H-pyrazoliumdihydrogen (DMPP), thiosulphate, neem, karanjin, and nitrapyrine (N-serve) (Khan *et al.,* 2013). Exudates of some plant species have also the capacity to inhibit nitrification process in the soil (Al-Ansari and Abdulkareem, 2014). Urease inhibitors are substances that inhibit conversion/hydrolysis of urea to ammonia and carbon dioxide and hence minimize ammonia volatilization losses (Schwab and Murdock, 2010). The common urease inhibitor products are phenyl phosphorodiamidate (PPD), hydroquinone (HQ), N-(n-butyl) thiophosphorictriamide (NBPT), phenyl mercuric acetate (PMA), and catechol. Controlled-released fertilizers are fertilizers such as urea that are coated with a polymer or sulfur (Khan *et al.*, 2013).

2.1 Effects of Nitrogen Inhibitors on Crop Yield

The results of various researches showed that treating of fertilizers with nitrogen inhibitors improves yields of various types of crops. Significantly higher yields of maize were for example obtained when urea is treated with agrotain or NBPT (N-butyl thiophosphoric triamide). It increased yield of maize by 6.6% at 87 kg N ha-1and by 9.1% at the dose of 115 kg N ha^{-1} compared to untreated once (Khan *et al.*, 2014). Similarly Dawar *et al*. (2011) found that urea treated with agrotain increased grain and biomass yield of maize by 27% and 30%, respectively, compared with urea alone. Agrotain also increased biological and grain yield of wheat by 25.2% and 37.5%, respectively, at 60 kg N ha^{-1} as indicated in Table 1. Whereas at 120 kg N ha^{-1} it increased the biological and grain yield by 17.4% and 22.6%, respectively, compared to untreated urea (Khan *et al*., 2013).

Table 1. Increase in biological and grain yield of wheat by urease (Agrotain) and super-urea inhibitors

Treatment	Biological yield (kg/ha)	Increase by inhibitors (%)	Grain yield (kg/ha)	Increase by inhibitors (%)
Urea at 60 kg N/ha	7231	-	2794	-
Agrotain treated urea at 60 kg N/ha	9668	25.2	4470	37.5
Supper urea (agrotain + DCD) 60 kg N/ha	10365	30.2	4897	42.9
Urea at 120 kg N/ha	8806	-	3826	-
Agrotain treated urea at 120 kg N/ha	10666	17.4	4942	22.6
Supper urea (agrotain + DCD) at 120 kg N/ha	11743	25.0	5282	27.6

Source: Khan *et al*., 2013

Research results also confirmed the potential of neem (*Azadirachta indica*) as nitrogen inhibitor. Based on the results of their research, Joshi *et al*., (2014) have been recommended to apply neem coated urea at 100 kg/ha in 3 splits to achieve higher growth and yields of maize with better monetary returns. Neem coated urea resulted 6.2% yield increment of maize compared to non-coated urea (Figure 1).

Similarly, Makinta *et al*., 2014 showed that the application of 150 kg N ha^{-1} treated with 30% crushed neem seed was superior and most economical for maize production. Such treatment produced the highest total dry matter (5,808 kg ha^{-1}) and grain yields (1,501 kg ha^{-1}) of maize.

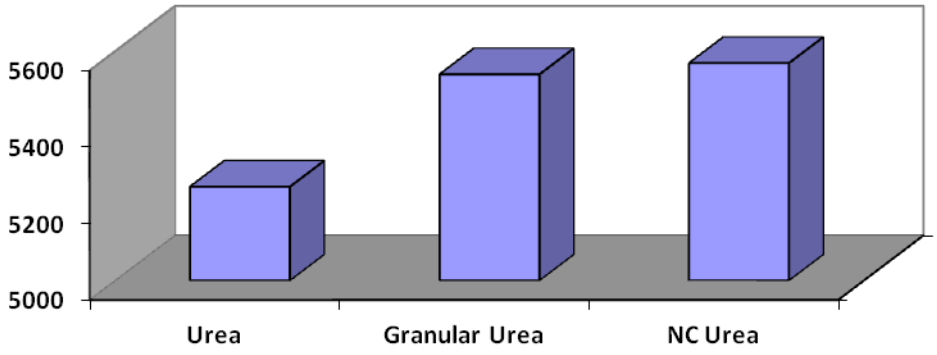

Figure 1. Effects of neem as nitrogen inhibitor on yield of maize (kg ha^{-1})

NC= neem coated

Source: Joshi *et al*., 2014

According to Arafat *et al*. (1999), treating urea with 0.04% neem cake increased rice yield by 26% compared to urea alone. Besides amonium sulfate treated with 0.02% and 0.04% neem cake increased rice yield by 14.4 and 25.6% , respectively, over that of amonium sulfate alone (Table 2). Coating of urea with tar and engine oil also increased rice yield compared to uncoated urea (Sannagoudra *et al*. (2012).

Table 2. Effects of nitrogen inhibitors on rice yield

Treatments	Yield (g/pot)	Treatments	Yield (g/pot)
Control	26.60 [e]	Control	26.60 [e]
Urea	49.40 [d]	**Amonium Salfate (AS)**	51.12[c]
Urea +N serve	62.10 [b]	AS +N serve	59.80 [b]
Urea + 0.02% neem cake	52.00 [c]	AS + 0.02% neem cake	59.00 [b]
Urea + 0.04% neem cake	63.70[a]	AS + 0.04% neem cake	64.60[a]
Urea + 0.02%tea waste	50.70 [c]	AS + 0.02%tea waste	50.40[cd]
Urea + 0.04%tea waste	51.30 [c]	AS + 0.04%tea waste	49.90 [d]
LSD (0.05)	*1.22*	*LSD (0.05)*	*1.58*

Source: Arafat *et al*., 1999

Not only the individual use of urease and nitrification inhibitor but also their combination hampers the loss of nitrogen and improves its utilization. Zhang *et al*. (2010) found that amending urea with combination of urease and nitrification inhibitors improve maize yield, while saving urea fertilizer by 30% and protecting the environment. Application of 126 kg N ha^{-1} treated with combination of NBPT and DMPP gave comparable biomass and grain yield of maize to that of 180 kg N ha^{-1} without treatment. Similarly, Khan *et al*. (2013) found that the highest grain yield (5,282 kg ha^{-1}) of wheat was obtained by application of super-urea, urea treated with the combination of agrotain and DCD), at 120 kg N ha^{-1}. Super-urea increased wheat yield by 42.9% at 60 kg N ha^{-1} and by 27.6% at 120 kg N ha^{-1} compared to respective untreated urea as indicated in Table 1.

Similarly, blending of urea with the combination of neem cake and tar has increased grain yield of rice (Figure 2) significantly. These results indicated the potential benefit of combined use of urease and nitrification inhibitors than single inhibitor alone.

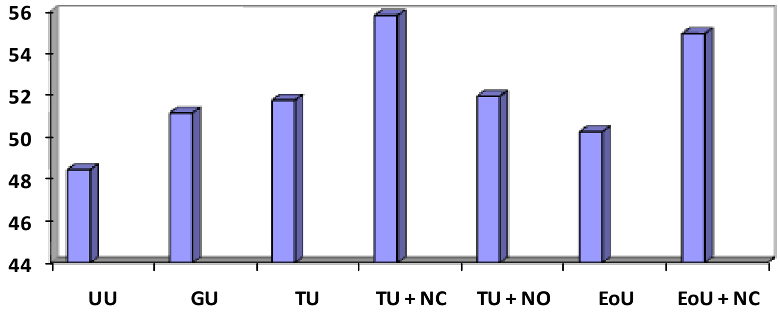

Figure 2. Effects of nitrogen inhibitors on the yield of rice (qt ha^{-1})

UU= uncoated urea, GU = Granular urea, TU = Tar coated urea, NO = neem oil, EoU = Engine oil coated urea, NC = Neem coated urea

Source: Sannagoudra *et al*., 2012.

2.2 Effects of Slow Nitrogen Releasing Fertilizers on Crop Yields

Research results revealed that slow nitrogen releasing fertilizers improved crop yields appreciably. According to Wang *et al*. (2013), control released urea (CRU) and combination of 60% CRU and 40% urea gave 12.4% and 4.5% higher cotton yield compared to that of urea without treatment as basal and split application (Figure 3). Other research results showed that applying controlled release fertilizer and its combination with urea at the ratio of 3:7 increased rice yields by 7.8% and 9.8%, respectively, compared to urea alone (Ji *et al*., 2011). Similar research result showed compared to basal application of untreated one, polymer-coated urea increased rice yields by 15.1%–51.4%, while compared with split application of untreated urea it increased the yield by 7.9%–31.7% (Xi-shengYe *et al*., 2013). Fu-liang *et al*. (2012) also observed that sulfur-and polymer-coated urea increased wheat yield, protein and starch contents by 6.5-10.4%, 5.8-18.9%, 0.3-1.4%, respectively, compared with that of untreated urea fertilizer application methods.

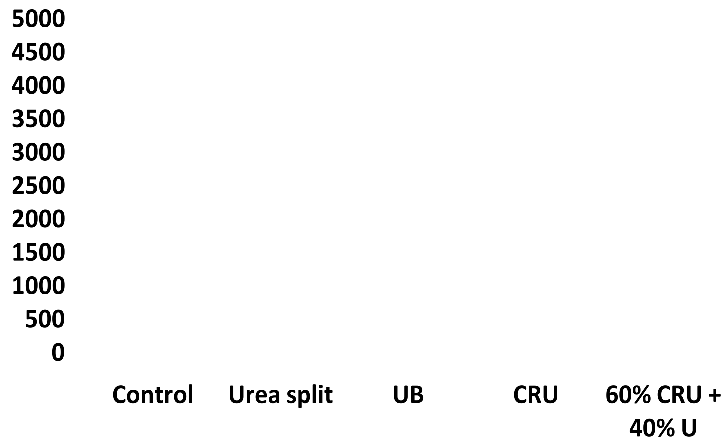

Figure 3. Effects of controlled-release urea on yield of cotton (kg/ha)

CRU = controlled release urea, UB = base application of urea

Source: Wang *et al*., 2013

3. Effects of Nitrogen Inhibitors and Slow Nitrogen Releasing Fertilizers on Nitrogen Uptake and Use Efficiency

In addition to the increment of crop yields, results of various researches have also shown positive effects of nitrogen inhibitors and slow nitrogen releasing fertilizers on nitrogen uptake and use efficiency of plants. For instance, significantly higher nitrogen uptake of rice was recorded by treating urea with neem cake + tar (Sannagoudra *et al*., 2012) and treating with 0.02% neem cake (Arafat *et al*., 1999). According to Khan *et al*., (2013), the highest nitrogen uptake of wheat (108.9 kg ha^{-1}) was obtained from urea treated with the combination of urease and nitrification inhibitor (supper-urea) at 120 kg N ha^{-1} followed by super urea at 60 kg N ha^{-1} (104.0 kg ha^{-1}). Super-urea increased the nitrogen uptake by 45.1 % at 60 kg N, while agrotain, (urease inhibitor) at 60 kg N $ha^{-1}$and 120 kg N ha^{-1} increased nitrogen uptake by 38.0 % and 29.2 %, respectively (Table 3).

Controlled released urea (CRU) increased cotton nitrogen uptake by 13.01% and 52.03% compared to urea applied by split application and 60% CRU + 40% urea treatment, respectively (Wang *et al*., 2013). Placement of blended urea with CRU at the rate of 225 kg N ha^{-1} improved wheat N uptake efficiency by 28.5% compared to urea alone at the same dose (Yang *et al*., 2011).

Generally, super-urea performed better than agrotain in terms of increasing nitrogen use efficiency. The use of inhibitors with low level of urea (60 kg N ha^{-1}) was better than with high (120 kg N ha^{-1}) level of urea (Khan *et al*., 2013). Apparent nitrogen recovery of applied nitrogen increased from 35% for prilled urea to 55.0, 52·5 and 37·5% for super granules urea, neem-cake-coated urea and DCD coated urea, respectively (Chauhana and Mishraa, 1989).

Table 3. Effect of agrotain and super urea on wheat N uptake

Treatment	N-uptake (kg/ha)	Nitrogen uptake increase by inhibitors (%)
60 kg/ha N without inhibitors (2splits)	57.1	-
60 kg/ha N with agrotain inhibitor (2splits)	92.3	38.0
60 kg/ha N with supper urea inhibitor (2splits)	104.0	45.1
120 kg/ha N without inhibitors (2splits)	77.1	-
120 kg/ha with agrotain inhibitor (2splits)	108.9	29.2

Source: Khan *et al*., 2013

Compared with the conventional urea, the slow released urea significantly increases apparent nitrogen efficiencies by 63.3%–139.9%. Compared with the conventional urea split, the polymer-coated controlled released urea and the 70% sulfur-coated controlled released urea combined with 30% conventional urea increased the agronomic nitrogen efficiencies by 2.2%–17.6% (Xi-shengYe *et al*., 2013). Polymer-coating improved urea-nitrogen use efficiency of wheat by 58.2-101.2% (Fu-liang *et al*., 2012).

4. Effects of Nitrogen Inhibitors and Slow Nitrogen Releasing Fertilizers in N_2O Emission and Other Forms of Nitrogen Losses

Nitrous oxide is one of the most important greenhouse gases produced at different level of nitrogen cycle. Both nitrification and denitrification reactions in the soil produce the intermediate gaseous nitrous oxide (N_2O), which is ultimately released into the atmosphere (Kanyama and González, 2007). The N_2O concentration in the atmosphere is increasing by 0.25% per annum (IPCC 1997). This in turn causes global warming and stratospheric ozone layer depletion, which shields the earth from biologically harmful ultra-violet radiation (IPCC, 1997; Johnston, 2005). The global warming potential of N_2O is 300 times more damaging than CO_2 (Clark, 2014). Reducing N_2O emission from agricultural soils using nitrification inhibitors is very important. One of the potential mitigation methods to reduce these emissions from the agricultural soils is to use nitrification inhibitors that slow down the conversion of NH^+_4 to NO^-_3 in the soil.

In line with this, various research results revealed that application of nitrogen inhibitors significantly reduced N_2O emission and other N losses. When urea was applied without nitrification inhibitors, 72 to 84% of applied nitrogen was lost from the soil of cotton field, but treating urea with acetylene, phenylacetylene, and nitrapyrin reduced nitrogen losses to 57%, 52%, and 48%, respectively (Chen *et al*., 1994). Application of urea together with formaldehyde, dicyandiamide & hydroquinone, hydroquinone & thiosulphate and hydroquinone & DCD in different crops reduced N_2O emissions by 42%, 33-63%, 5%-31% and 7% -29%, respectively as indicated by research results of Jianga *et al*., (2010) and Malla *et al*., (2005).

As reported by Sanz-Cobena *et al*. (2012), a two-year field experiment using irrigated maize showed that N_2O emissions were effectively abated by NBPT (urease inhibitor) and its combination with DCD (nitrification inhibitor). It was found that treating urea with NBPT alone and with combination of NBPT + DCD reduced N_2O emission by 54 and 24%, respectively (Sanz-Cobena *et al*., 2012). Similarly, Shojia *et al*. (2001) observed that dicyandiamide and polyolefin treated urea in barley field reduced N_2O emissions by 81 % and 35 %, respectively.

Application of DCD on grazed pasture soils was also found to be very effective in reducing N_2O emissions. Total N_2O emission was reduced by 61-73% when the animal urine was applied with DCD in pastureland (Cameron *et al*., 2007). Similarly, Di and Cameron (2003) reported that treating the soil with DCD decreased N_2O emissions by 76% in 6 autumn months of experimental periods, whereas in 3 months of spring N_2O flux was decreased by 78% with the same treatment. Other study indicated that applying a combination of Agrotain and DCD at the ratio of 1:7 w/w 5 days prior to urine application significantly decreased NH_3 volatilization by 38% in autumn and by 28% in spring compared to urine alone. Moreover, DCD treatment significantly reduced NO_3^{-1} leaching by 43% (Zamana and Nguyen, 2012).

Research results indicated that nitrification inhibitors reduced volatilization of ammonia and nitrates leaching. In sunflower field trial, it was found that when urea was treated with NBPT, the total NH_3 los was 5.9 % compared to 10.1% NH_3 loss of untreated urea (Sanz-Cobena *et al*., 2008). Combined application of NBPT and DCD increased soil $NH4^+$ by 2%-53% and decreased soil NO_3 concentration (Jiao *et al*., 2004). Combination of hydroquinone and DCD effectively inhibited oxidation of the $NH4^+$, which decreases the accumulation of NO_3^- in soil and hence the potential leaching of NO_3 (Chen *et al*., 2005). In two years rice-rape rotation experiment, it was also found that urea treated with DMPP increased $NH4^+$

concentrations by 19.1–24.3% and reduced NO_3^- concentrations by 44.9–56.6% compared to the urea alone (Li *et al*., 2008). Controlled released fertilizer and its combination with urea at the ratio of 3:7 decreased N_2O emission during rice growth season by 59.6% and 40.4%, respectively compared with urea alone (Ji *et al*., 2011).

5. Conclusion

Use of nitrification and urease inhibitors as well as their combination in the application of nitrogen fertilizer appreciably improved yield, nitrogen uptake and its use efficiency by various crops. In addition, treating urea fertilizer with polymer and sulfur coating materials increased crop yields by reducing nitrogen loss through volatilization, nitrification and leaching. Furthermore, such treatments reduced nitrous oxide emission, a greenhouse gas that has a great contribution to global warming. Therefore, the use of such new technologies may contribute to the reduction of environmental pollution caused by intensive application of nitrogen fertilizers in agriculture while increasing the crop yield.

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