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Full Length Research Paper

Comparative productivity and profitability of organic and conventional tef *[Eragrostis tef (*Zucc.)Trotter] production under rainfed condition: Tigray, Northern Ethiopia

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A field experiment was conducted to examine tef yield, yield attributes, infiltration rate and macro invertebrates under rain fed conditions. The objective of the study was to evaluate the comparative productivity and profitability of organic and conventional tef production and as such, 50 composite soil samples were collected for soil analysis in the laboratory. A total of 50 plots were selected (25 plots each for organic and conventional farm). In addition, 50 respondents were identified through stratified sampling of organic and conventional farming users and interview schedule was developed and used. The interview was done using semi-structured questionnaire to capture data pertaining to costs, revenue, demographic aspects and agronomic practices in each farming. The results from the field experiment of organic tef farming showed significantly higher plant height (87.64 cm), biomass yield (5.12 ton/ha), organic matter content (1.6%), infiltration rate and richness and diversity of soil macro invertebrates. Organic tef production was profitable than conventional tef production with financial internal rate of return (110%). It was also found that 100% of both respondents said that organic and conventional tef have no grain storage problem and they experience also similar disease or insect pest occurrence. Therefore, Organic farming has a profound vitality from the strategic importance of agro-ecological and environmental health point of view and sustainable crop production system; the farming community should use organic fertilizers in place of mineral fertilizer to increase tef productivity and profitability.

Key words: Organic farming, conventional farming, productivity, profitability, tef, *Eragrostis tef*.

INTRODUCTION

The agricultural sector in Ethiopia is increasingly being confronted with the pressure from a rapidly growing population, which has resulted to change in the use of land, and has been the major cause of environmental degradation (Feoli et al., 2002). Agricultural activities causes change in soil chemical, physical, and biological

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properties, and play a major role in soil degradation. Conventional crop production uses large quantities of chemical pesticides and fertilizers. They are harmful to the environment as they kill beneficial insects and pollute soil and water. In the organic farming, the absence of chemical sprays and increased biodiversity results in a better eco-balance between pests and beneficial insects. Chemical pesticides can cause poisoning as well as long-term effects on human health. Whereas organic farming is free of chemical pesticides and produces safe and healthy food crops. Frequent use of chemical fertilizers and narrow crop rotation can cause declining soil fertility, while organic farming improves soil fertility through rotating leguminous crops like chickpea and field pea (Jonathan, 2011).

Productivity and profitability persist to be the two most important indicators in assessing the success or failure of crop production. But high levels of productivity (though not necessarily profitable) have been and continue to be achieved through heavy use of energy-based cultural inputs together with fertilizer-responsive high-yielding crop varieties, farm mechanization which facilitates timeliness of field operations, and irrigation which help the crop from any yield-depressing effect of water deficit during the sensitive growth stage (Jones, 1989; Hall *et* al., 1992; Pimentel et al., 1994; Jensen, 1978 as cited in Mendoza, 2002).

Tef has an advantage to farmers, and as a result the cultivation increased year to year. It is one of the major cash sources for the majority of farmers. High market value and many other desirable characteristics, including higher nutritional value, low incidence of damage by insects, better adaptation to drought, adaptive to poor drainage and high straw value have made tef attractive for cultivation (Seyfu, 1997).

While numerous studies have been conducted in Ethiopia to examine the determinants and the resulting economic impact of chemical fertilizer, improved seeds, and physical conservation structures (Dercon and Christiaensen, 2007; Kassie et al., 2008), no attempt has been made to comparatively analyze the yield gap, soil fertility, profitability and farmers‟ perception under organic and conventional tef production in the country in general and in Tigray Regional State in particular. Therefore, the aim of this research was to evaluate the comparative productivity and profitability of organic and conventional tef production under rain fed conditions.

MATERIALS AND METHODS

Study site

Abreha -we-Atsbeha Watershed is one among the 21 *Kebelles* of Kilte Awlaelo woreda located in the Eastern Zone of Tigray at a distance of 15 km from Wukro town to the west (Figure 1). The watershed is geographically located between 39^0 30‟ E - 39^0 45‟ E longitude and 13^0 45‟ N - 14^0 00‟ N latitude.

Rainfall distribution is largely mono-modal that spreads from June to first week of September. The mean annual rainfall distribution varies from 350 to 600 mm. Moreover, the annual average temperature ranges from 16 to 27°C.

The soil types of the study area are dominated by Arenosols (67.25%), followed by Fluvisols (25%) and Vertisols (7.75%).

The land use pattern of the study area is classified as cultivated land (1047 ha; 15.5%), forest land and area closure (4325 ha; 64%), grazing land (206 ha; 3%), and the rest (1188.25 ha; 17.5%) is occupied by houses, roads, waterways, etc.

The main economic source of the area is agriculture and mixed farming is widely practiced. It has a population of 4,845 with average land holdings of 0.76 ha/household. The prevailing agro-climatic condition of the watershed favors farmers to grow a wide variety of crops. Smallholder farmers of the area grow a variety of food crops as a source of food and income. The main food crops grown are tef, barley, maize, wheat, chick pea, sorghum, finger millet and linseed.

Study site selection criteria

The study site was selected based on the presence of organic farming practitioners, and conventional farming practitioners. From field experience, the watershed is known to be relatively homogenous in terms of agro ecology, access to resources, history of extension and others.

Experimental design

In total 50 organic and conventional farmers‟ managed plots and a 1m x 1m quadrant was used to collect yield and yield components data, counting macro invertebrates and taking soil sample along X – shape transect. The quadrant was thrown five times on sample points at least 5 m apart.

Tef yield and yield components data collection

From each group of farmers identified as practicing organic and conventional method of production, fields of 25 farmers were used to collect data on grain yield data, plant height, straw yield, and harvest index was collected in the cropping season of 2011/12 G.C. Plant height was measured using meter and a grain yield and straw yield was measured using spring balance. Whereas the harvest index is the ratio of grain yield to biomass yield

Soil sampling procedure and soil physico-chemical determination

Both disturbed and undisturbed soil samples were

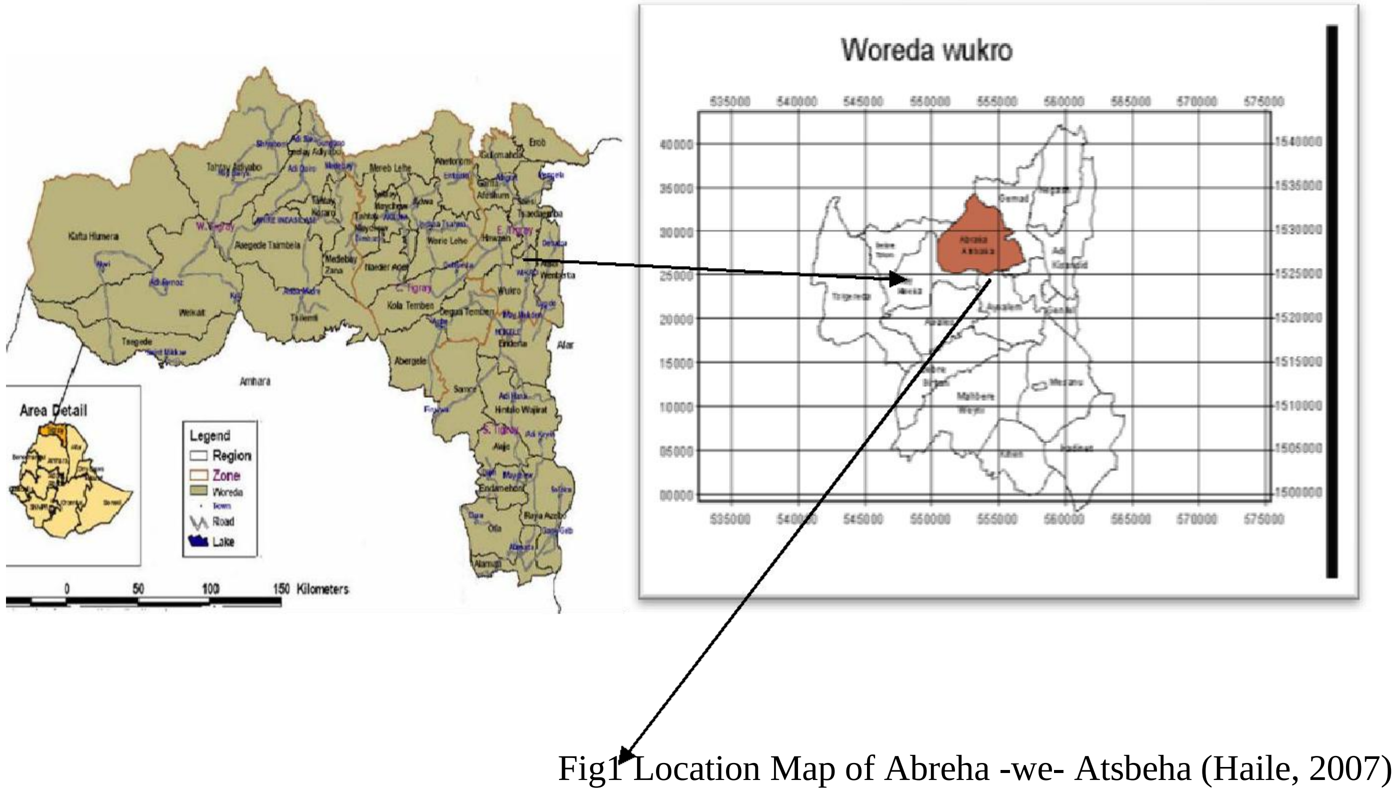

Figure 1. Location Map of Abreha -we- Atsbeha (Haile, 2007).

collected. Undisturbed soil sample was collected using a core sampler for bulk density determination and a composite of 50 disturbed soil samples from both organic and conventional plots were collected from 0 to 25 cm depth in order to evaluate the soil organic matter, pH and moisture content. Soil samples were air-dried and passed through a 2-mm sieve for Soil Organic Carbon and pH and was analyzed in the laboratory of Mekelle University.

Soil organic carbon (SOC) was determined following the procedures described by Walkley and Black (1934). The soil organic matter (SOM) was then determined after multiplying SOC by a standard factor 1.724. Soil pH was determined in 1:2.5 soil water ratios as described in Rowell (1994).

Infiltration rate was measured using a double ring infiltrometer of 10 cm installed in to the soil and 17 cm above the soil surface with 30 and 60 cm diameter of inner and outer ring, respectively and calculated as described in Horton (1940).

Bulk density was calculated as the dry weight of soil divided by its volume and the soil moisture content was expressed by weight as the ratio of the mass of water present to the dry weight of the soil sample. In counting soil macro invertebrates, a monolith (30cm x 30cm x 30cm) was installed in to the soil at a 30 cm depth 5 times on 25 samples of each organic and conventional plots along X – shape transect. Consequently, richness and evenness (how evenly individuals are distributed) was determined using Shannon‟s index (1948).

Estimating tef yield

The agricultural potential of a given area, through biomass and yield estimation was predicted using FAO (1979) model as given in Equation (1):

$$Y = \frac{(0.36 * Bgm * KLAI * Hi)}{\frac{1}{L} + 0.25ct} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, Y is the yield; 0.36 and 0.25 constant numbers; Bgm is the maximum gross biomass production; Hi is the harvest index; KLAI is the correcting factor for leaf area index; L is the length of growing cycle and ct is the coefficient of respiration.

Identifying tef yield and yield gap analysis

The gap was calculated from the yield difference of organic and conventional, organic and estimated, conventional and estimated.

Farm profitability analysis

Before running the Cost-Benefit Analysis, a detailed costing of all the inputs and valuing of all the benefits were done. Likewise, the cost items mainly included material costs of seed, fertilizer, manure and farm tools, whereas labor costs were accounted for land preparation, sowing, weeding, chemical spraying, fertilizer/manure application, harvesting, threshing, loading/unloading and transport of produce and inputs. All these were treated based on prevailing and actual prices.

Assessment of farmers' perception on organic and conventional tef production systems

Interview was conducted using pretested semi-structured questionnaire to capture data pertaining to costs, revenue, perception, demographic aspects and agronomic practices. In selecting farmer respondents, a stratified random sampling was used. A list of organic farming practitioners and conventional farming practitioners was obtained from village leaders and extension agents and sample farmers were randomly selected from the provided list.

Statistical analysis

The data analysis focused on two domains namely, productivity and profitability of the two farming systems. Descriptive statistics like percentages and averages were used to describe farmers" perception, constraints of tef production and profitability on organic and conventional farms. In addition, independent-Samples T -Test was used to compare tef yield and yield components, organic and conventional farm effects on soil fertility.

RESULTS AND DISCUSSIONS

Ecological adaptability of Abreha-we-Atsbeha watershed for Tef production

The length of growing period (LGP) of the study area started from on the 22nd June and ended on the 17th October, stretching over 114 days. In addition, the study revealed that the start and end of the humid period are 3rd July and 7th September, respectively.

The LGP of the area is suitable dominantly for early and medium maturing crop varieties. The rain fall pattern of the area is mono-modal and suitable for growing of crops between June and October. The sowing period started from the first decade of July during which 47.7 mm rain was obtained. Furthermore, this study revealed that among the crop types, G-I of C3 and G-IV of C4 photosynthetic pathway crops are suitable to grow. Since tef is a G-IV of C4 cereal crop, the area is definitely suitable for tef production.

Tef yield and yield components of conventionally and organically managed plots

Plant height

A significant difference has been observed between organic farming (87.6 cms) and conventional farming (79.3 cms) in mean plant height, showing the superiority of organic tef (Table 1). This could be due to organic manure and compost effect.

Biomass production

Significant higher mean biomass yield (5.12 ton/ha) was also recorded for organic farming compared to the conventional farming (4.01 ton/ha). This shows that organic farm had a higher grain and straw yield than the conventional and this could be attributed to higher plant height of organic tef than the conventional (Table1).

Harvest index

Significantly higher harvest index was observed on conventional farming system (0.25) at (p=0.028) compared to organic farming (0.22) (Table1). This could be due to the fact that organic farm had high amount of straw yield rather than grain yield which increases biomass production, whereas in the conventional farm, grain yield to biomass ratio was higher than that of the organic farm.

Grain yield

Slightly higher mean grain yield was obtained in the organic farming (1.11 ton/ha) compared to conventional farming (0.95 ton/ha), though there was no statistically significant difference among the two farming systems (t = 1.88) (Table 1). Similarly, Offermann and Nieberg (2000) showed that despite the overall lower yields of organic farms, some individual crops had yields as high as or higher than nearby conventional reference yields.

Generally, the significant difference in plant height and biomass yield under the organic farming could be mainly due to the use of organic fertilizers such as compost and manure.

Effect of conventional and organic tef production on soil fertility

Soil organic matter

The mean soil organic matter in the organic and conventional farm was 1.6% and 0.81%, respectively. Therefore, organic farming system had significantly higher soil organic matter (t= 4.7, p=0.000) than the conventional farming (Table 2). The significantly higher

Table 1. Comparison of yield and yield components of tef under organic and conventional farming systems.

Agronomic parameter	Organic farming N=25			Conventional farming N=25		
	Mean	SD	t-v	Mean	SD	t-v
Plant height(cm)	87.64	10.28	2.85(p=0.006)**	79.33	10.28	_
Grain yield (ton/ha)	1.11	0.25	1.88(NS)	0.954	0.32	_
Biomass yield (ton/ha)	5.12	1.18	2.99(p=0.004)**	4.01	1.41	_
Harvest index	0.22	0.03	-2.26(p=0.028)**	0.25	0.05	_

SD: Standard deviation; t-v t- value; NS: Non significant; ** significant at 5% probability level; N: Number of sample plots.

Table 2. Selected soil properties from organic and conventional farmland.

Soil parameter	Organic farming N=25			Conventional farming N=25		
	Mean	SD	t-v	Mean	SD	t-v
Moisture content (%)	2.5	1.24	1.3(NS)	1.99	1.48	-
Bulk density (g/cm^3)	1.56	0.11	-0.83(NS)	1.58	0.08	-
pH	6.7	0.14	-1.34(NS)	6.8	0.27	-
Organic matter (%)	1.6	0.7	4.7** (p=0.000)	0.81	0.49	-

SD: Standard deviation; t-v t- value; NS: Non significant; ** Significant at < 5%; N: Number of sample plots.

SOM in organic farming was most probably due to the application of manure and compost. The same result was reported by Bell et al. (1997) where the organic matter content of soil was increased by the addition of animal Manure, crop residues such as straw and root residues particularly of grass sward.

pH

Insignificant difference in pH between organic and conventional farmland was observed (Table 2). This was observed among the farming system type.

Moisture content

Insignificant difference was observed in moisture content among organic and conventional farmland (Table 2).

Bulk density

As shown in Table 2, insignificant difference of bulk density was recorded among both farming plots. The result may be affected since the area covered with 67.25% of sandy soils is highly compacted and the organic farming may not be well aggregated due to the fact it was practiced for few years. According to Nyle (2008), sandy soils have relatively high bulk density since total pore space in sandy is less than that of silty or clayey soils. Fine-textured soils, such as silty and clayey loams, that have good structure have higher pore space and lower bulk density compared to sandy soils.

Effect of organic and conventional farming on soil infiltration rate

Silty soil

Infiltration rate in silty soil in the organic farmland was relatively high at the beginning of the event, then decreasing until it becomes constant with a rate of above 180 min. Whereas the silty soil in the conventional farmland had a lower infiltration rate at the beginning and being constant at a time of greater than 130 min. Comparison of the two soils revealed that water infiltration is faster in the organic silty soil than in the conventional farmland. This explains that the soils from the organic fields are better aggregated and well structured than the conventional fields.

Sandy soil

In the first 4 min, the infiltration rate in the conventional farm was observed faster. However, infiltration rate in the organic farm after 4 min was faster than the conventional farm and continues up to 240 min by decreasing gradually and finally approached a constant rate. But infiltration in the conventional farm continued up to 170 min and finally becomes constant. This result shows that the organic farm had faster infiltration rate than the conventional one. Higher infiltration rate of organic farm indicates that there is high organic matter content than the conventional farm. Taffa (2002) has explained that organic matter is important for the soil structure, that is, the various degrees of aggregation of individual soil particles which determines porosity patterns in soils thus in turn govern the movement of water and their degree of aeration.

Clayey soil

The infiltration rate of clayey soils in the organic farm was more rapid in the first 64 min than clayey soils in the conventional farm. But in 64-120 min, both organic and conventional farm had equal infiltration rate. Thus, the comparison shows that the organic farm had better infiltration rate in the beginning. This result might be due to organic materials which improve the soil condition in the beginning, though as the soil depth increases, the organic matter may decrease thereby increasing the compaction. As a result, the organic and conventional farm infiltration rate becomes equal.

Organic farming effect on soil macro invertebrates

As shown in Table 3, a higher mean number of Giant grub (7,555.48) and Black ant (11,999.88) per hectare basis was observed in the organic farm than that of the conventional farm with a mean number of (444.44) Giant grub and (7,111.04) Black ant. The overall mean difference on the number of organisms in organic farm per hectare was higher (8,582) than that of the conventional farm (3,703). The richness of species in the organic farm (2.1) was statistically higher at (t=5.58, p=0.000) than that of the conventional farm (1.11). Diversity of the organisms in the organic farm (3.0) was significantly higher at (t= 5.1, p=0.000) than the conventional farm (1.8). However, species evenness (0.9) in the organic farm and (0.8) in the conventional farming shows statistically insignificance. Comparatively, lower richness and diversity of macro invertebrates in the conventional farming could be due to agro chemicals application which can create unfavorable condition to them in the soil. In agreement to this, Martinez et al. (2010) reported that soil organisms are sensitive indicators, and reflect the influence of human management and climate changes. Furthermore, soil organisms are considered as indicators of soil health because the diversity and abundance may be related to functions such as decomposition of organic matter, plant and root development (competition), sequestration and detoxification of heavy metals, pesticides and other pollutants, disease-suppressive soil, and presence of pathogens in soil and plant. This is a proof that fertilization based on organic residues, as implemented in organic agriculture, is highly beneficial for earthworms and soil quality.

Tef yield and yield gaps

The mean yield of organic tef was higher than that of the conventional tef farming, though not significant and the yield gap between the two was 0.156 ton/ha. With respect to the estimated yield of 3.3 ton/ha as calculated from the study area, the yield of organic tef was less by 2.19 ton/ha. Similarly, conventional tef yield was lower by and 2.346 ton/ha from estimated yield. The estimated yield was higher than any of the organic and conventional tef yield.

The gap between organic and conventional tef yield could be due to organic fertilizer effect. The gap between organic and estimated yield might be due to lack of improved tef varieties. The gap between conventional and estimated might be due to unwise use of inputs, failure in using the recommended chemical fertilizer rates and erratic and inadequate rain fall. Schneider and Anderson (2010) also reported similar results for yield gap determinants.

Profitability of organic and conventional tef production

As given in Table 4, the annual average earning power of organic tef for the farmers practicing organic farming as measured by the financial internal rate of return (FIRR) was found to be 110.3% and the Benefit Cost Ratio (BCR) was 2.48. Similarly, the corresponding figures for the conventional tef farming were 81.9 and 2.34%, respectively. The average annual earning of organic farming was higher by 28.4% points. This implies that organic tef farming has better financial net returns. Hence, organic farming helps farmers to earn a better income than that of the conventional farming practitioners. This could be attributed to the lower cost of production in organic farming. Whereas the study by Rick (1999) provided a useful guide to the circumstances under which organic agriculture may or may not be as profitable as conventional agriculture.

Farmers' perception on organic and conventional tef production

Farmers" perception on the attributes identified was assessed among farmers practicing organic and conventional farming in the study area. Out of the total respondents practicing organic farming, 96% preferred organic farming; whereas 56% of those who practice conventional farming preferred organic farming and the remaining 44% preferred the conventional farming system. In most of the attributes, organic and conventional farming respondents have the same perception on organic farming, that is, they agreed that organic farms resist shortage of rain fall, store more moisture in the soil, are good habitat for soil macro organisms and, organic straw is preferred by animals for feed as compared to that of the conventional farming system. In regard to comparison of organic tef yield to

Table 3. Soil macro invertebrates mean number/ha, richness, diversity and evenness.

Order	Common name	Organic farm N=25		Conventional farm N=25	
		Mean	t-v	Mean	t-v
Coleoptera	Giant grub	7,555	3.17(p=0.003)**	444	-
Hymenoptera	Black ant	11,999	2.43(p=0.019)**	7,111	-
Isoptera	Termites	6,222	1.48(NS)	3,555	-
	Mean	8582		3703	-
	Richness	2.1	5.58(p=0.000)**	1.11	-
	Diversity	3.0	5.11(p=0.000)**	1.8	-
	Evenness	0.9	1.51 (NS)	0.8	

** Significant difference at less than 5%; NS: Non significant difference; t-v t value; N: number of sample plots.

Table 4. Comparison of results of worth measures for organic and conventional tef farming.

Farming type	FIRR (%)	BCR	NPV (ETB)
Tef-Organic	110.3	2.48	3613
Tef-Conventional	81.9	2.34	2635
Difference	28.4	0.15	979

ETB Ethiopian Birr.

conventional tef yield, about 36% of organic farm respondents believe that organic tef is superior, while 20% of them said tef yield from conventional farming is better, whereas about 44% of them said that there is no difference in yield of both systems. Meanwhile, of the total conventional farm respondents, about 12% opted for organic farming, 40% for conventional, and 48% said that there are no differences in yield of both systems. In the case of tef straw yield, for 12 and 68% of the organic tef farm respondents, high straw yield was obtained from organic and conventional systems, respectively while for 20% of the organic farm respondents, there is no difference in straw yield between the two. On the other hand, from all the conventional tef farm respondents, about 20, 32, and 48% of them opined that tef straw yield is higher for organic, conventional and no difference, respectively. In relation to tenure issue, 100% of organic producers had land ownership, whereas about 48% of conventional producers owns‟ their land and about 52% of them had shared and rented land. Thus land ownership is a major constraint for being organic or conventional producer.

Tef production constraints as perceived by farmers

As regards the pests and insects occurrence in the production season, the highest percentage (88%) of organic tef respondents said “no” whereas in the case of conventional tef farm respondents, 92% said no. Likewise, out of the total respondents from the organic farm group, 28% said that shoot fly damages are common in organic farms, 16% said that it is common in conventional and for 56% of them the occurrence is the same in both types of farm. But the difference could be attributed to the fact that if high amount of organic fertilizer is applied, it damages organic farms and if high amount of chemical fertilizer is applied it damages the conventional farm. Moreover, concerning lodging problem, 48% of organic farm respondents is of the opinion that this happens in the organic farms, 8% of them said that it occurs in the conventional farm only, while 44% said it occurs in both farm types. On the other hand, regarding conventional farm respondents, 16% of them stated that lodging happens in organic farm only; for 20% of them it occurs in conventional farm only, whereas for 64% of the conventional farm respondents it occurs in both farm types. As regards grain storage problem, 96% of respondents from both farms were of the opinion that there are no storage problems for tef produced from both farm systems.

Farmers’ response to profitability of organic and conventional tef production

Organic farm respondents said, the most profitable farming system is the one they currently practice (76%), while only 4% of them opined that conventional farming is better than theirs. However, 20% of these respondents said that both farming types are equally profitable. In the case of conventional farming, out of the total respondents

64% of them replied that organic farming has better profitability; 32% of them said that conventional farming brings better profits and 4% of them said both are equally profitable. In relation to some important differences observed in both farming systems, 54, 22 and 24% of organic tef farm respondents observed better taste, good threshability and increased quantity of straw in organic farming, respectively. From the conventional farming respondents‟ point of view, nearly 50% observed better taste; 36% observed better threshability and 14% of them got better quantity of straw from conventional farming. Regarding the market and certification of organic products, 100% of respondents from both farming types replied that there is no special market and certification of organic products in the study area.

Conclusions

The study was conducted to evaluate the productivity and profitability of organic and conventional tef production in Abreha -we- Atsbeha watershed, Kilte Awlaelo woreda, Eastern zone of Tigray National Regional State, Ethiopia.

The area is suitable for G-I (C3) and G-IV (C4) crop species like potato, chickpea, lentils, rapeseed, cabbage, sunflower, barley, bread wheat, linseed, tomato, rye, grape, sugar beet, tef, sorghum and maize. Since tef is one of the crops found in G-IV, the area is quite suitable for tef production.

From the field experiment results, organic teff farm was significantly higher in plant height, biomass yield, organic matter content, infiltration rate and richness and diversity of soil macro invertebrates. Even though the grain yield difference of organic and conventional teff was not statistically significant, there was significant difference as compared with estimated yield. This shows that the area has high potential for tef production, but farmers have poor soil management. In general, based on the worked-out production cost of both farming systems, organic teff production is found to be more profitable than conventional teff production.

The survey result showed that land ownership had effect on being organic producer or not. Those farmers who did not own land but have leased-in plots, preferred to practice the conventional way of production using inorganic fertilizer rather than improving the productivity of soil using organic fertilizer as they might not use the land permanently. Most of the farmers who practice conventional farming in the study area have small farm lands far away from their homesteads; as a result, they need to use chemical fertilizer and minimize labor requirement for transporting manure and compost. In the study area, there is no special market for organic teff and certification of organic products to motivate the teff producing farming community.

The respondents of both organic and conventional teff farming had common perception on some attributes of organic farming that organic farming is resistant to shortage of rain fall, stores more moisture, is good habitat for soil macro organisms, its straw is preferred by animals and is more profitable than the conventional farming system.

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