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Research article

Review on Adoption of selected Improved Agricultural Technology on Production of *Teff* in Ethiopia

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Agricultural new technologies are the factors of production which have undergone some form of amendment from their original state with the intent of enhancing their performance. Agricultural technology includes all kinds of improved techniques and practices which could affect the growth of agricultural outputs. The current review focused on the productivity of teff, it is the most important economic crop cultivated by small households in Ethiopia. Despite the agronomical and nutritional benefits of teff both the total production and productivity of teff is relatively low. The main reasons for inferior yield of teff are suboptimal genetic gain, low access to fertilizer and seeds of improved varieties and poor agronomic practices. To enhance the productivity of teff, the agricultural technology adoption needs to increase. The objective of this review was to review various improved agricultural technologies adopted by teff producers in Ethiopia and to assess the factors affecting adoption of agricultural technologies. The adoptions of agricultural technologies were highly influenced by socio-economic factors, institutional factors, location factors as well as agro-ecological factors and the characteristics of the farmers were those factors affecting the adoption of agricultural improved technologies. These include seeds of high-yielding varieties, fertilizers, and method of sowing.

Keywords: Adoption; Agriculture; New technologies, Teff

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INTRODUCTION

Background

Since the late 1970s to mid-1980s, many African countries implemented macroeconomic, sectorial and institution reforms aimed at ensuring high and sustainable economic growth, food security and poverty reduction. Despite all these accelerations, the agricultural sector's growth has remained insufficient to adequately address poverty, attain food security, and lead to sustained GDP growth on the continent [26]. More worrying is that the sector remains characterized by low use of modern technology and low productivity and thus unable to meet the increasing food needs of a growing population. While there has been some evidence of new crop varieties in some countries in Africa, adoption rates remain far below countries in Asia, casting doubts on the possibility of a green revolution.

Since the role of the agricultural sector of its

contribution to the Ethiopian economy is very immense, the success and failure of the Ethiopian economy is highly correlated to the Performance of this sector. This means that it is still the single largest sector of its contribution to GDP, employment, source of foreign exchange, and its impact on the overall performance of the economy is also significant [3].

Teff, *Eragrostistef (Zucc.)* Trotter, is the most important cereal of Ethiopia, accounting for about one-third of the total acreage and one-fifth of the gross grain production of all cereals cultivated in the country [21]. In Ethiopia, teff is annually cultivated by over 6 million smallholder farmers, and it is the staple food for about 50 million people. The cultivation of *teff* as a cereal grain has so far been restricted to Ethiopia, except that it appears in small quantities in Eritrea, and recently in the United States, Israel, the Netherlands and Spain. However, it grows as pasture or forage grass in the United States, South Africa, India, Australia and Kenya.

In Ethiopia, the cultivation of *teff* predates historical records, existing before the introduction of wheat and barley in the country. In spite of its low productivity (the current national average yield is 1.5 t ha−1), the Ethiopian farmers who engineered domesticating the crop have continued growing it over the millennia with its acreage increasing through time. The continued extensive cultivation of *teff* is attributed to its relative merits compared to the other cereals with respect to both husbandry and utilization [9, 11, 43, 45]. *Teff* has the largest value in terms of both production and consumption in Ethiopia and the value of the commercial surplus of *teff* is second only to coffee [50]. It also provides over two-thirds of the human nutrition in the country [46]. It is also the most desirable crop because of its straw quality for livestock feed, best "*Injera*" quality, and the ability to provide more satisfaction from a small weight of the grain [25]. In Ethiopia it occupies about 3.016 million hectares (24.03% of the grain crop area) of land which is more than any other major cereals such as maize and sorghum.

Many scholars stated as *teff* is the most widely adapted crop compared to any other cereal or pulse crops and can be grown under wider agro-ecologies (temperature and soil condition) in the country, the research conducted on this crop is shallow and more focus given to agronomic part of the crop [34]. Despite its importance in Ethiopia, its productivity is low. In the 2015 cropping season, yields were 1.57 t ha-1[22].Since *teff* is the staple food of most Ethiopian people, the current production system cannot satisfy the consumers' demand. This is because of agronomic constraints that include lodging, low modern input utilization, and high post-harvest losses and sowing method [7].

STATEMENT OF THE PROBLEM

The importance of agricultural technology adoption in ending poverty and food insecurity has been well discussed by [16, 28],[13], [49],and [14]. According to [5], in developing countries, improving the livelihoods of rural farm households via agricultural productivity would remain a mere wish if agricultural technology adoption rate is low. Hence, there is a need to adopt the proven agricultural technologies so as to heighten production as well as productivity and thereby changing the living condition of the rural poor. Furthermore, for developing countries, the best way to catch developed countries is through agricultural technology diffusion and adoption [35].

Teff has a significant role on Ethiopian Agriculture, food and trade sectors. Major Ethiopian farmers rely on *teff* production because *teff* is their daily consumption. Therefore Ethiopia has a great chance to assure food security by boosting *teff* production. Despite the agronomical and nutritional benefits of *teff* both the total production and productivity of *teff* is relatively low. The main reasons for inferior yield of *teff* are suboptimal genetic gain, low access to seeds of improved varieties, poor agronomic practices and lodging [2, 10].

Empirical evidence related to on how households' characteristics, farm characteristics and information access affect farmer's decision to adopt multiple *teff* technologies and their expected payoff for different mix of *teff* technology is important.

Hence, it is wise to attempt to review on improved agricultural technologies and the determinants of agriculture technology in single and multiple agricultural technology (row planting, improved seed and fertilizer) on *teff* productivity.

OBJECTIVES

General Objective

The general objective of this seminar is to review Adoption of Selected Improved Agricultural Technologies on *teff* Production in Ethiopia.

Specific Objectives

1. To review improved agricultural technologies (row planting, improved seed and fertilizer) adopted by *teff* producers in Ethiopia
2. To review factors that affect adoption of improved agricultural technology in *teff* production

LITERATURE REVIEW

Definitions and concepts

Various authors define technology in different ways.[47] define technology as the means and methods of producing goods and services, including methods of organization as well as physical technique. According to these authors new technology is new to a particular place or group of farmers, or represents a new use of technology that is already in use within a particular place or amongst a group of farmers. Technology is the knowledge/information that permits some tasks to be accomplished more easily, some service to be rendered or the manufacture of a product [47]. Technology itself is aimed at improving a given situation or changing the status quo to a more desirable level. It assists the applicant to do work easier than he would have in the absence of the technology hence it helps save time and labor [18].

Adoption: is defined in different ways by various authors. [47], defines adoption as the integration of a new technology into existing practice and is usually proceeded by a period of 'trying' and some degree of adaptation. As well as Bonabana-Wabbi defines adoption as a mental process an individual passes from first hearing about an innovation to final utilization of it. Adoption is in two categories; rate of adoption and intensity of adoption. The former is the relative speed with which farmers adopt an innovation, has as one of its pillars, the element of 'time'. On the other hand, intensity of adoption refers to the level of use of a given technology in any time period [18].

Defining technology adoption is a complicated task since it varies with the technology being adopted. For instance the study by [27] showed that adoption of improved seed in a survey classified farmers as adopters if they were using seeds that had been recycled for several generations from hybrid ancestors. In other studies adoption was identified with following the extension service recommendations of using only new certified seed [17, 27, 53]. Therefore in defining agricultural technology adoption by the farmers, the first thing to consider is whether adoption is a discrete state with binary response variables or not [27], That means the definition depends on the fact that the farmer is an adopter of the technologies or non-adopter taking values zero and one or the response is continuous variable [20]. The appropriateness of each approach depends on the particular context [27]. Many researchers use a simple dichotomous variable approach in the farmers' decisions of new technology adoption. This approach according to [42] is necessary but not sufficient because the dichotomous response reflects the status of awareness of improved technology rather than the actual adoption.

Improved agricultural technologies adopted by *teff* producers in Ethiopia

There is widespread belief that "Improved Land Management" [1] technologies are a viable alternative to boost agricultural production in SSA. The adoption of these technologies might be more suitable for the farming context in SSA because they substitute the use of capital intensive modern inputs, e.g., modern varieties, with the use of improved land or production management practices [29]. However, such technologies are complex because they require adequate understanding of the technology and significant management skills by [59] the adopting farmer to be employed profitably [39]. As a consequence, available empirical evidence on the productivity benefits of ILM technologies over conventional practices points to unclear and inconsistent results. Recent empirical assessments of Conservation Agriculture, and Integrated Pest Management (IPM) technologies all ILM technology packages have found that their impacts on crop productivity are ambiguous and context specific [19, 38, 55, 64].

Different development projects are being designed and implemented by the scarce resource of Ethiopia to improve the farm production and productivity of *teff* at the desirable level. Improved seeds, chemical fertilizers and row planting technology are being distributed among the adopters of the modern technology. However, the households receive very low amount from their farm lands because of the dominant traditional way of farming.

Improved seed variety

The intensity of use of improved *teff* varieties was high in Ethiopia; which is estimated about 84% [54]. This indicates that farmers have established a system whereby they produce and exchange the seed of improved *teff* varieties locally either sold by Ethiopian currency or exchange by items (exchange by another crop). The main *teff* seed sources were neighbors; own saving from the previous year; farmers union or cooperatives; local trader; extension agent; local seed producers and research institutes, among such types of seed sources; seed sources from neighbors are the first largest improved *teff* seed source; which is estimated about 47% [54].

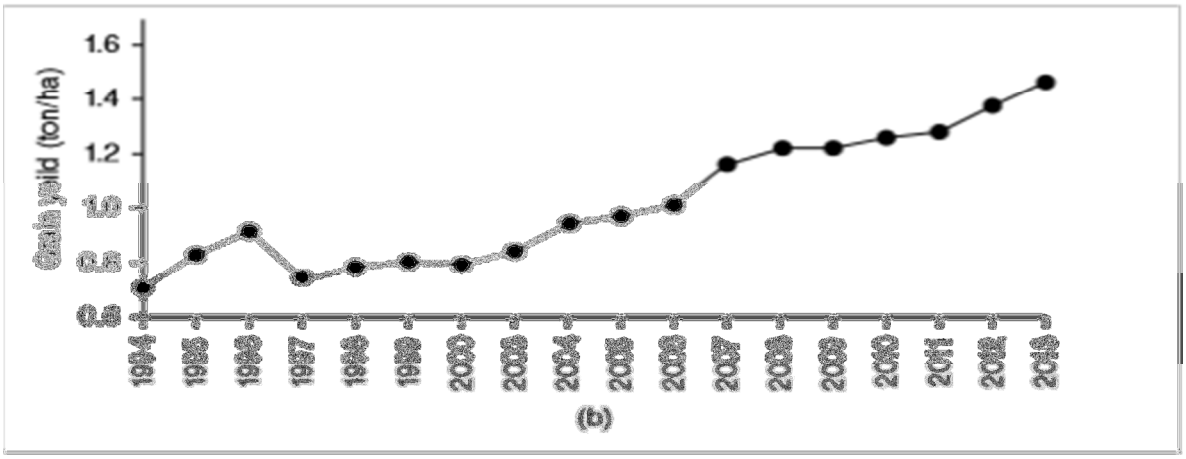
Improved seed gives a significantly higher yield, and better quality of crop products compared to locally produced variety of seeds. The use of these seeds still remains very low. Compared to the other inputs it has not been widely practiced by smallholder farmers. Although a total of 35 varieties have been released in Ethiopia through the National Agricultural Research System Of these, 21 varieties have been released by *Debre Zeit* Agricultural Research Center, while 14 were released by other six centres. Of the total number of varieties

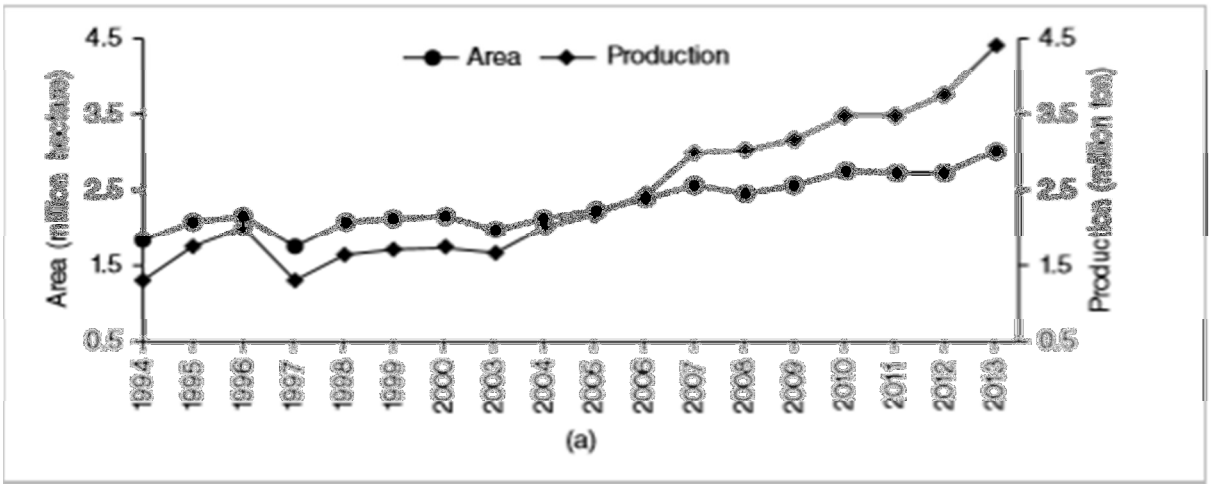
released to date, only 12 varieties were developed through hybridization, while the remaining 23 were developed using pure line selection technique from the land races. Four of the released varieties, namely Magna (DZ-01-196), *Enatite* (DZ-01-354), *Dukem* (DZ-01-974) and *Quncho* (DZ-Cr-387 RIL355), are widely adopted by farmers in areas with optimum rainfall in different parts of the country, while the relatively early-maturing varieties such as *Tsedey* (DZ-Cr-37), *Gemechis* (DZ-Cr-387 RIL127), *Simada* (DZ-Cr-285 RIL295) and *Boset* (DZ-Cr-409 RIL50d) are recommended for terminal low moisture stress areas [44].

In Ethiopia, the formal seed sector covers only 5% of the *teff* but 53% of the maize and 20% of the wheat seed requirement [8]. In general, smallholder *teff* farmers in Ethiopia depend on the informal system involving farmer-to-farmer seed exchange and use of their own recycled seeds. About 50% of farmers in *Lume* and *Minjar* areas reported that seed exchange among farmers is the major source of *teff* seed [33].

According to the study of [40] shows the positive impact of improved seed on productivity. As their study indicates improved seed verity increases productivity by 10 percent.

The amount of improved seed per hectare (improved seed application rate) for major cereal crops is increasing from year to year. Higher application rate was found for barley and wheat 2.4 & 1.8 quintal per hectare, respectively and the lowest application rate was for sorghum (0.23 quintal per hectare). The application rate for *teff* and maize were 0.35 quintal per hectare and 0.27 quintal per hectare of cultivated land, respectively [23].





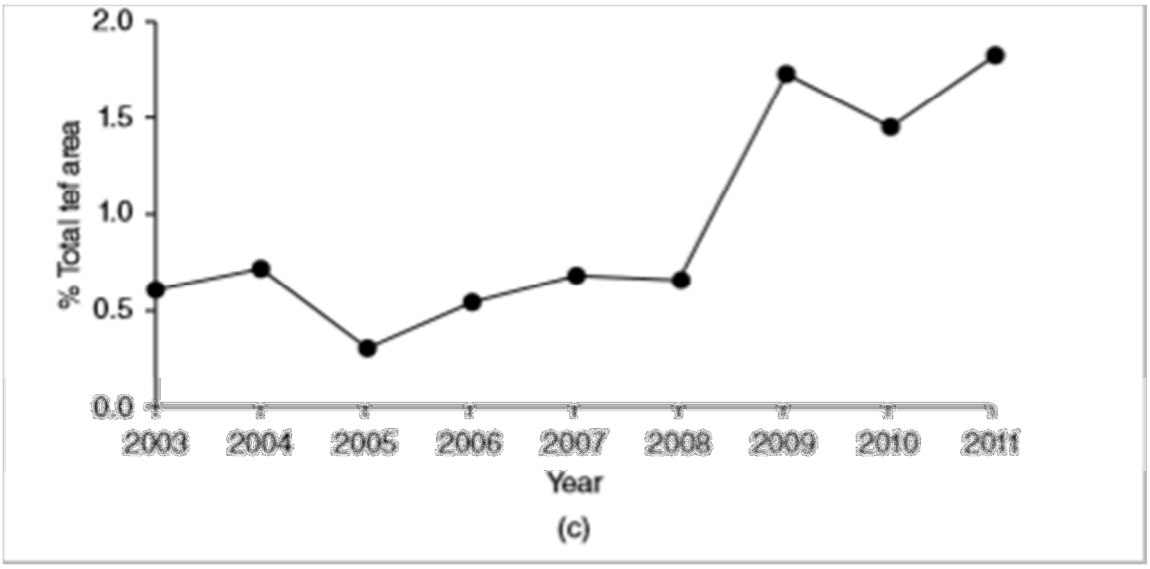


Figure 1; trend in the cultivation, production and use of improved *teff* seed in Ethiopia.
Source; Adapted from[21] Cited by [44]

(a) Both the acreage and total production of *teff* were significantly increased; (b) the productivity of *teff* raised from only 0.7 t ha-1 in 1994 to 1.5 t ha-1 in 2013; (c) the proportion of *teff* farmers using improved seeds are extremely low.

Method of sowing

The traditional planting method that is broadcasting seed by hand at high speed rates decrease yield because uneven distribution of the seeds makes hand weeding and hoeing difficult, and plant competition with weeds decreases wheat growth and tailoring. One of the crops commonly cultivated using the traditional broadcast planting is *teff*. Such a planting technique causes *teff* yield reduction. Improved agricultural Technologies such as row planting and transplanting, the seed rate is reduced and more space between seedlings is given, have been shown to achieve important production increments over traditional broadcasting sowing. Because improved agricultural technologies allow for better weeding, decrease competition between seedlings, and allow for better branching out and nutrient uptake of the plants [30].

In 2009, based in *Debre Ziet* research center, Tareke Berhe began experimenting with *teff* row planting and later confirmed that reduced seed rate and row planting could potentially double *teff* yields. At the time, the ATA argued that the lack of modern planting technologies, limited agricultural extension resources, and a resistance to adopting practices resulted in low adoption rates for these types of technologies [12]. Starting in 2011, the Ministry of Agriculture [51], ATA, and the Regional Bureaus of Agriculture initiated a large-scale trial of this approach. Demonstrations were made with 1,430 farmers and 90 Farmer Training Centers (FTCs), which resulted in 50-80% yield improvement compared to the national averages. Based on the success of these initial trials, the Transformation Council and the Ministry of Agriculture encouraged the Regional Bureaus of Agriculture (RBoA) to popularize these technologies in high yielding zones during the 2012 planting season. As the federal and region al infrastructure has expanded, as well as capacity and resources for agricultural extension expanded, adoption has only moderately risen. Yet, according to the ATA, most of the farmers who adopted new *teff* Row planting (RP) technology was introduced in 2010/2011 at farm level. Row planting of *teff* seed is considered to be superior compared to the traditional broadcasting method because a reduced seed rate decreases competition between the seedlings for water and nutrients.

Research conducted by international food policy research Institute (IFPRI), also found yield increases, but less than the 200% suggested by Dr. Tareke Berhe and also less than the 50-80% found by the ATA. IFPRI's field studies showed an increase of 22-27% [36, 60, 63].There are indications that in less than ideal settings, akin to reality of smallholder farmers, yield increase may be even less than significant as low as 2% [61].

Moreover, the even distribution of the *teff* seedlings makes weeding easier and less costly. In research trials, row planting has been shown to increase *teff* yields up to three times average yields and lowers seed costs, making it seemingly a good value proposition for *teff* farmers [15].

There is no agreement regarding the impact it has on

yields' of the *teff*. The study of [58] shows that row planting has significant and positive impact on yield of *teff*. Contrary the study of [62]; and [65] mentioned that row planting have insignificant impact on yield of *teff*. *Generally* the extent of adoption of row planting technology on *teff* in Ethiopia Vary across different agro-ecological zones, as the same time the debate about the impact of this technology on productivity differ time to time and influenced by different conditioning factors.

Fertilizer usage

According to [31]; fertilizers are mineral or organic substances, natural or manufactured, which are applied to soil, irrigation water or a hydroponic medium, to supply plants with nutrients or to enhance plant growth. The Natural fertilizer consists of the farm yard manure, compost, wood ashes... etc while the chemical type consists of DAP, UREA and NPS. The chemical fertilizer often called inorganic fertilizer.

Fertilizer is one of the most important agricultural technologies used to improve the soil fertility and enhance productivity. The demand of fertilizer increased more than double in the last 10 years. The amount of fertilizer sold in 2002 was 210,000 million tons and in 2012 it was 550,000 million tons representing a 6 percent annual increment [41]. However, the intensity of fertilizer use (i.e.18.5 kg/ha) in Ethiopia is below the African countries' average (i.e. 26 kg/ha) (World Bank, 2017). According to [22] data, in 2014; 8,591,247 hectare of land had used fertilizer. Of the total cultivated land covered by fertilizer, 90 percent where covered by cereal crops and *teff* crop alone constitutes 40 percent.

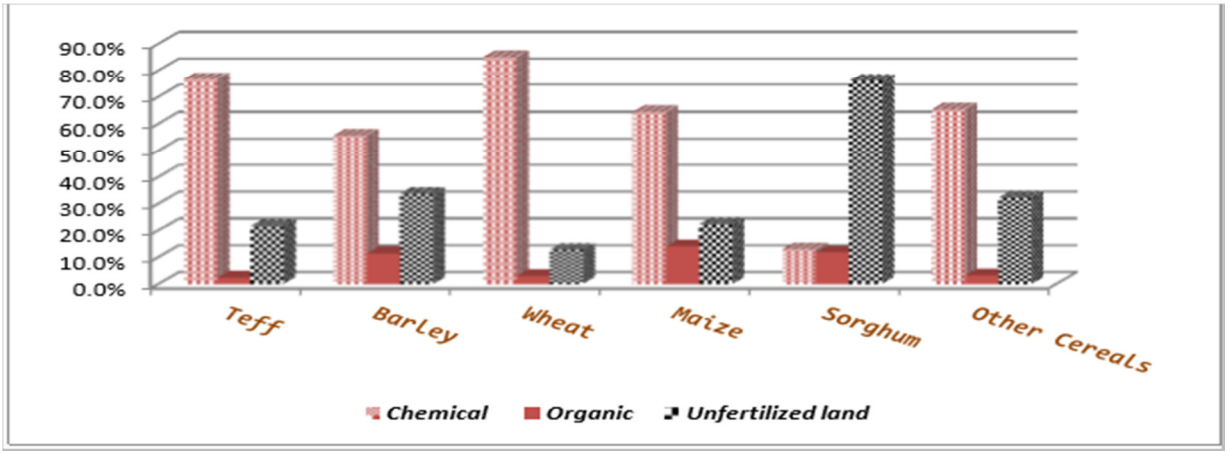


Figure 2; Percentage distribution of fertilized cultivated land by cereal crop
Source; CSA annual survey fertilizer data (2017/2018)

Factors Affecting Adoption of Agricultural New Technologies in Ethiopia

Despite rapid yield growth in agricultural production all over the world, the realized yields are still well below their genetic potential. Deviations from potential yields appear to vary remarkably among countries and regions even after adjusting for different soil, moisture and temperature environments. Other conditioning factors, such as different farm sizes and management capacities, access to markets, and legislative/institutional factors, play heavily in determining yield performance [32].

These factors are further categorized in to different dimensions for the sake of comprehension For example, [6] categorizes agricultural technology adoption into three, namely; economic, social and institutional factors; and [48] categorized them into farmer characteristics, farm structure, institutional characteristics and managerial structure. Again for further clarity, these factors are classified in to the one that affect the adoption decision in developing and developed nations.

This classification is based on the development context of the respective nation. For instance, provided that developing countries agricultural sector is characterized by high dependence on natural phenomenon, highly constrained by shortage of resources and undertaken by less educated farmers [52], it is assumed that factors that affect the adoption decision is closely related to this context.

The determinants of improved technology practice (row

planting, improved seed, and fertilizer) adoption and its impact on *teff* productivity have been demonstrated by a number of experimental studies. For instance, the study conducted by [4] on evaluating the impact of high yield verity and fertilizer on productivity shows that adopters of this technology got higher yield than non-adopters. His study also shows that farmers improved seed adoption decision is positively affected by the sex of the household, land ownership, irrigation use, access to credit, contact with extension agents, and participation on off farm activities. The adoption of High Yielding Variety (HYV) is negatively affected by age and distance to the nearest market.

[57] assumed that on technology adoption in developing countries including Ethiopia reveals that the various factors that influence technology adoption can be grouped into the following three broad categories 1, factors related to the characteristics of producers i.e., the farmers; 2, factors related to the characteristics and relative performance of the technology and 3, program and institutional factors.

[37] analyze using Double-hurdle approach to Modeling of Improved *Teff* Technologies Adoption and Intensity Use in Case of *Diga* District of East *Wollega* Zone. The result of descriptive statistics indicate that adopter farm households are more educated, participated on crop production training, having had farming experience and nearest to the marketing centers. The result of a double-hurdle econometrics model show that among 18 explanatory variables used in the regression analysis farming experience, participation on crop production training, education level, distance to nearest marketing center and the characteristics of new technologies like yield superior and maturity of the new crops over local cultivars were found to significantly influence farm households adoption decision and intensity production of improved *teff* technologies.

[24] analyze factors influencing adoption of *Quncho teff* in the case of *Wayu Tuqa* District. Farmers with better education level show willingness to take new ideas than less educated and farmers having higher livestock were better adopter than the lower livestock holders and also farmers nearest to market and high frequency of extension service were better adopter than the farmers who were not. Econometric result shows that distance from household residence to market center and age of the household were found to influence adoption negatively, family labor in-terms of man equivalent and participation of farmers in agricultural trainings were found to affect adoption positively, while farmers owning the oxen were found to influence negatively. Also education level of the respondents, livestock holding in-terms of tropical livestock unit, farmer's ability of meeting the family food consumption, frequency of extension contact was found to affect adoption of *Quncho teff* positively.

[56] analyzed the determinants and intensity of adoption of *teff* row planting in *Minjar shenkora woreda*, Amhara region. Out of a total of 15 explanatory variables estimated using the *logit* model 6 variables were found to be significant to affect the adoption of *teff* row planting. Age of the household, farmers experience, Total annual income, access to credit, training and perception are those variables that positively and significantly influenced the likelihood of adoption of *teff* row planting among farmers. Whereas, education level, farming experience, training, access to technology input supply and perception towards row planting positively and significantly influenced the intensity of adoption of *teff* row planting. On the other hand, while landholding size negatively affected the intensity of adoption of *teff* row planting, age of household head and land holding size negatively and significantly influenced adoption of *teff* row planting.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

In developing countries, improving the livelihoods of rural farm households via agricultural productivity is essential by improving agricultural technology adoption rate. Hence, there is a need to adopt the proven agricultural technologies so as to heighten production as well as productivity and thereby the living condition of the rural poor. Furthermore, for developing countries, the best way to catch developed countries is through agricultural technology diffusion and adoption. For a country like Ethiopia where persistent food insecurity and severe poverty is the main agenda for the government, enhancing productivity of agriculture is taken as a major solution. Therefore this study focuses on review the productivity of *teff*, which is one of the main cereal crops in the country. An improvement in the productivity of *teff* could contribute in achieving and reducing poverty because it is produced by around 4 million households and it is a staple food both in rural and urban areas of the country.

In Ethiopia, *teff* farmers have been adopting and using different agricultural technologies, these include seeds of high-yielding varieties, fertilizers and row planting. The adoption rate of the technologies has not at good level when compared with another cereal crops. The variables significantly affect the adoption of agricultural technologies by farmers are age, availability of training, education level, farm size, extension service provision, saving institution factor, and credit access.

Recommendation

There are different Agricultural Technology Practices going on rural area of Ethiopia. However, there is promising practices in some area while less than the expectation in somewhere else. The reason for this success and failure depend on various factors. Among the main reasons, lack of awareness and commitment to implement the new technology by farmers and other principal agents are the key factors.

Attention should be given to strengthening and scaling-up farmers' awareness on right and efficient utilization of those technologies which significantly affects *teff* productivity. There may not be a possibility of expanding cultivated land size. Therefore, household must be trained to improve productivity. The transfer of knowledge and information concerning to increase *teff* crop production is very crucial.

Great and prior attention should be given to afford further education opportunities to the farmers, to provide better access to credit services and encouraging farmers to use it, to encourage the farmers access to and use of improved variety of *teff* seed, to engage farmers more on practicing *teff* row planting, and fertilizer usage.

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REFERENCES

1. Abate, T., et al., *Factors that transformed maize productivity in Ethiopia.* Food Security, 2015. **7**(5): p. 965-981.
2. Abraha, M.T., et al., *Performance of tef [Eragrostis tef (Zucc.) Trotter] genotypes for yield and yield components under drought-stressed and non-stressed conditions.* Crop Science, 2016. **56**(4): p. 1799-1806.
3. Admassu, T., N. Workneh, and A. Sisay, *Does Farmer Field School Training Improve Technical Efficiency? Evidence from Smallholder Maize Farmers in Oromia, Ethiopia.* Journal of Economics and Sustainable Development, 2015.
4. Agegnehu, G., B. Lakew, and P.N. Nelson, *Cropping sequence and nitrogen fertilizer effects on the productivity and quality of malting barley and soil fertility in the Ethiopian highlands.* Archives of Agronomy and Soil Science, 2014. **60**(9): p. 1261-1275.
5. Ajayi, O.C., et al., *Adoption of improved fallow technology for soil fertility management in Zambia: Empirical studies and emerging issues.* Agroforestry systems, 2003. **59**(3): p. 317-326.
6. Akudugu, M.A., E. Guo, and S.K. Dadzie, *Adoption of modern agricultural production technologies by farm households in Ghana: What factors influence their decisions.* 2012.
7. Aleminew, A. and A. Legas, *Determination of Row Spacing and Fertilizer Rate for Transplant Planting Methods on the Growth and Yield of Teff in Eastern Amhara Region, Ethiopia.*
8. Alemu, D., et al., *An analysis of maize seed production and distribution systems in Ethiopia's Rift Valley, Research Report 72 Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia.* 2007.
9. Assefa, K., S. Chanyalew, and G. Metaferia, *Conventional and molecular tef breeding.* Tef Improvement, 2011: p. 33.
10. Assefa, K., S. Chanyalew, and Z. Tadele, *Tef, Eragrostis tef (Zucc.) Trotter.* Millets and Sorghum: Biology and Genetic Improvement, 2017: p. 226-266.
11. Assefa, K., et al., *Quantitative trait diversity in tef [Eragrostis tef (Zucc.) Trotter] germplasm from Central and Northern Ethiopia.* Genetic Resources and Crop Evolution, 2001. **48**(1): p. 53-61.
12. ATA, *"Results of 2012 New Tef Technologies Demonstration Trials Draft Report VF"* 2012.
13. Bacha, D., et al. *The determinants of fertilizer and manure use in maize production in Western Oromiya, Ethiopia*. in *Seventh Eastern and Southern Africa Regional Maize Conference Proceedings*. 2001.
14. Becerril, J. and A. Abdulai, *The impact of improved maize varieties on poverty in Mexico: a propensity score-matching approach.* World development, 2010. **38**(7): p. 1024-1035.
15. Berhane, G., Z. Paulos, and K. Tafere, *Foodgrain Consumption and Calorie Intake Patterns in Ethiopia.* 2011. **23**.
16. Besley, T. and A. Case, *Modeling technology adoption in developing countries.* The American economic review, 1993. **83**(2): p. 396-402.
17. Bisanda, S., et al., *Adoption of maize production technologies in the Southern Highlands of Tanzania*. 1998: CIMMYT.
18. Bonabana-Wabbi, J., *Assessing factors affecting adoption of agricultural technologies: The case of Integrated Pest Management (IPM) in Kumi District, Eastern Uganda*. 2002, Virginia Tech.
19. Brouder, S.M. and H. Gomez-Macpherson, *The impact of conservation agriculture on smallholder agricultural yields: A scoping review of the evidence.* Agriculture, ecosystems & environment, 2014. **187**: p.

11-32.
20. Challa, M., *Determining factors and impacts of modern agricultural technology adoption in West Wollega.* 2014.
21. CSA, *Agricultural sample survey for 2013/14, in Statistical Bulletin 532, Central Statistical Agency, Addis Ababa, Ethiopia.* 2014.
22. CSA, *Central stastics Agancy, Area and Production of Major of major crops (private peasant holdings, meher season). Statistical bulletin.* . 2014/15.
23. CSA, *The Federal Democratic Repulic of Ethiopia Centeral Statistical Agency. Agricultural sample survey.* 2017/2018.
24. Debelo, D., *Does adoption of quncho tef increases farmers' crops income? Evidence from small holder farmers in Wayu Tuqa District, Oromia Regional State, Ethiopia.* Journal of Economics and Sustainable Development, 2015. **6**(17): p. 87-102.
25. Dejene, M. and M. Lemlem, *Integrated agronomic crop managements to improve Teff productivity under terminal drought, water stress.* Tech Open Science, London, 2012.
26. Dessy, S., J. Ewoudou, and I. Ouellet, *Understanding the Persistent Low Performance of African Agriculture.* 2006.
27. Doss, C.R., *Understanding farm level technology adoption: lessons learned from CIMMYT's micro surveys in Eastern Africa*. 2003: CIMMYT.
28. Doss, C.R. and M.L. Morris, *How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana.* Agricultural economics, 2000. **25**(1): p. 27-39.
29. Ehui, S. and J. Pender, *Resource degradation, low agricultural productivity, and poverty in sub-Saharan Africa: pathways out of the spiral.* Agricultural Economics, 2005. **32**: p. 225-242.
30. Fahad, S., et al., *Weed growth and crop yield loss in wheat as influenced by row spacing and weed emergence times.* Crop Protection, 2015. **71**: p. 101-108.
31. FAO, *Agricultural Census Guide.* 2010.
32. FAO, *Annual report on food and hunger* 2012.
33. Ferede, S., *Tef seed system in Minjar-Shenkora and Lume-Ejere weredas of East Shewa. I, EIAR, Addis Ababa.* . 2012
34. Ferede, S., *18. Technological Change & Economic Viability in Tef Production.* Tef Improvement, 2013: p. 255.
35. Foster, A.D. and M.R. Rosenzweig, *Microeconomics of technology adoption.* Annu. Rev. Econ., 2010. **2**(1): p. 395-424.
36. Fufa, B., et al., *Strengthening the tef value chain in Ethiopia.* Addis Ababa: Ethiopian Agricultural Transformation Agency, 2011.
37. Gedefa, B., *A double-hurdle approach to modeling of improved teff technologies adoption and intensity use: The case of Diga district of East Wollega Zone, Ethiopia.* Global Journal of Environmental Research, 2014. **8**(3): p. 41-49.
38. Giller, K.E., et al., *Conservation agriculture and smallholder farming in Africa: the heretics' view.* Field crops research, 2009. **114**(1): p. 23-34.
39. Gollin, D., M. Morris, and D. Byerlee, *Technology adoption in intensive post-green revolution systems.* American Journal of Agricultural Economics, 2005. **87**(5): p. 1310-1316.
40. Hailu, B.K., B.K. Abrha, and K.A. Weldegiorgis, *Adoption and impact of agricultural technologies on farm income: Evidence from Southern Tigray, Northern Ethiopia.* International Journal of Food and Agricultural Economics (IJFAEC), 2014. **2**(1128-2016-92058): p. 91-106.
41. IFDC, *Ethiopian Fetilizer Assessment The African Fertilizer and Agribusiness.* 2012.
42. Jain, R., A. Arora, and S. Raju, *A novel adoption index of selected agricultural technologies: Linkages with infrastructure and productivity.* Agricultural Economics Research Review, 2009. **22**(347-2016-16726): p. 109-120.
43. Kebebew, A., et al., *Quncho: the first popular tef variety in Ethiopia.* International Journal of Agricultural Sustainability, 2011. **9**(1): p. 25-34.
44. Kebebew Assefa, a. Solomon Chanyalew, and Z. Tadele, *Tef, Eragrostis tef (Zucc.) Trotter* 2017.
45. Ketema, S., *Tef (Eragrostis tef (Zucc.) Trotter), Promoting the Conservation and Use of Under-utilized and Neglected Crops.* Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy, 1997: p. 12.
46. Lacey, T. and C. Llewellyn, *Eragrostis Teff as a specialised niche crop.* Government of Western Australia, Department of Agriculture Farmnote, 2005. **42**: p. 2005.
47. Loevinsohn, M., et al., *Under what circumstances and conditions does adoption of technology result in increased agricultural productivity? A Systematic Review.* 2013.
48. McNamara, K.T., M.E. Wetzstein, and G.K. Douce, *Factors affecting peanut producer adoption of integrated pest management.* Review of agricultural economics, 1991. **13**(1): p. 129-139.
49. Mendola, M., *Agricultural technology adoption and poverty reduction: A propensity-score matching analysis for rural Bangladesh.* Food policy, 2007. **32**(3): p. 372-393.
50. Minten, B., et al., *Ethiopia's value chain on the move: the case of teff.* ESSP Working Paper series 52, 2013: p. 1-26.
51. MOARD, *Federal Democratic Republic of Ethiopia, Ethiopia's agriculture sector policy and investment framework: Ten year road map (2010–*

2020). Final Report 2010.
52. Mwangi, M. and S. Kariuki, *Factors determining adoption of new agricultural technology by smallholder farmers in developing countries.* Journal of Economics and sustainable development, 2015. **6**(5).
53. Ouma, J.O., et al., *Adoption of maize seed and fertilizer technologies in Embu district, Kenya*. 2002: CIMMYT.
54. Setotaw, F. *Technological Change & Economic Viability in Tef Production*. in *Proceeding of the Second International Workshop*. 2011.
55. Stoop, W.A., N. Uphoff, and A. Kassam, *A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving farming systems for resource-poor farmers.* Agricultural systems, 2002. **71**(3): p. 249-274.
56. TEFERA, M., *DETERMINANTS AND INTENSITY OF ADOPTION OF TEFF ROW PLANTING IN MINJAR SHENKORA WOREDA*. 2018, St. Mary's University.
57. Teklewold, H., M. Kassie, and B. Shiferaw, *Adoption of multiple sustainable agricultural practices in rural Ethiopia.* Journal of agricultural economics, 2013. **64**(3): p. 597-623.
58. Tesfaye, W., T. Abdissa, and G.B. Yadessa, *Economic analysis of teff yield response to different sowing methods: Experience, Illuababora Zone, Ethiopia.* Journal of Economics and Sustainable Development, 6 (1), 2015.
59. Uphoff, N., A. Kassam, and W. Stoop, *A critical assessment of a desk study comparing crop production systems: The example of the 'system of rice intensification'versus 'best management practice'.* Field Crops Research, 2008. **108**(1): p. 109-114.
60. Vandercasteelen, J., et al., *The impact of the promotion of row planting on farmers' teff yields in Ethiopia*. 2013, International Food Policy Research Institute (IFPRI).
61. Vandercasteelen, J., et al., *Scaling-up adoption of improved technologies: The impact of the promotion of row planting on farmers' teff yields in Ethiopia.* LICOS-Discussion paper series 344/2013, 2013: p. 1-25.
62. Vandercasteelen, J., et al., *Row planting teff in Ethiopia: Impact on farm-level profitability and labor allocation*. Vol. 92. 2016: Intl Food Policy Res Inst.
63. Vandercasteelen, J., et al., *Perceptions, impacts and rewards of row planting of teff.* Available at SSRN 2530422, 2014.
64. Yang, H., et al., *Hybrid-maize—a maize simulation model that combines two crop modeling approaches.* Field Crops Research, 2004. **87**(2-3): p. 131-154.
65. Yonas, B., *The impact of row planting of teff crop on rural Household income: A case of Tahtay Maychew wereda, Tigrai, Ethiopia*. 2006, Mekelle University.