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**Volume 8 Number 10 October 2016**

Bekele Tesfaye, Temaro Gelgelu and Genet Dadi

Chakufwa Kaulanda Munthali, Victor Kasulo and Swithern Matamula

Berhe Gebregewergs Hagos
Full Length Research Paper

On-farm participatory Evaluation of Splitting Queen Rearing Technique (SQRT) at Ginnir District, Bale Zone, South-eastern Ethiopia

Bekele Tesfaye*, Temaro Gelgelu and Genet Dadi

Sinana Agriculture Research Center (SARC), P.O. Box: 208, Bale-Robe, Ethiopia.

Received 9 May, 2016; Accepted 25 July, 2016

Participatory evaluation of Queen Rearing using splitting technique (SQRT) at Ginnir District of Bale Zone, South-eastern Ethiopia was conducted from 2013 to 2014. Two Beekeepers Research Group (BRG) each having 10 beekeepers were established at two sites, Ebisa and Kebena. Beekeepers were purposively selected based on their willingness, having bee colonies, indigenous knowledge of handling honeybee and trained on colony selection, honeybee biology, management, and health, procedure of queen rearing in the first phase and on spot practical queen rearing in the second training phase. Two Development Agents and three livestock experts participated in training. Evaluation of queen rearing was carried out at back yard of seven volunteer beekeepers (four at Ebisa and three at Kebena sites). About 85.71% of the multiplied established their selves and performed well. Average honey yield of 14.29 kg and 16.99 kg was obtained from daughter (new) and maternal colonies respectively. The beekeepers expressed that the technology is simple to operate, assist to generate additional income. This indicates that the technology got acceptance by farmers. Thus scaling up of this technology is paramount important.

Key words: Participatory, honeybee colony, splitting, demonstration, queen rearing.

INTRODUCTION

Apiculture is one of the major income generating agricultural activities for the poorest and other beekeepers dwelling in areas where other livestock cannot exist and other income generating activity options are very limited. Ethiopia has a longstanding bee keeping practices and is also endowed with huge apicultural resources and it has been an integral part of other agricultural activities, where about one million households keep honeybees (NuruAdgaba, 2007). Today, honeybee colony population is in the state of continuous decline due to various reasons and it is also difficult to get new colony because of different factors among which population pressure, declining of forest, indiscriminate applications of agrochemicals, pests and predators, honeybee diseases are worth mentioning. Number of honeybee colonies in the country has been declining (CSA, 2012) and consequently the honey and beeswax production as well as export earnings fell down (Gezahegne, 2001).

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Honeybee colonies have their own breeding strategies which are very dependent on the potential of the queen and the general activeess of the worker bees in a colony (Laidlaw H. and Eckert J., 1962; Dan, 2006). Man can also stimulate honeybee colonies to multiply themselves. Different queen rearing technologies that fit to local condition and honeybee races were developed By Holeta Bee Research Center. Of these technologies, Splitting technique is simple and can be easily practiced by farmers, and 5 to 10 queens can be reared from a colony. However, this technique was not introduced to Bale, where shortage of honeybee colony is a major problem either to increase stocks or to start beekeeping. Therefore, the objective of this study is to evaluate the Splitting techniques under Bale condition.

MATERIALS AND METHODS

Descriptions of study area

The study was conducted in Ginnir district, Bale Zone, Oromia Regional State South-eastern part of Ethiopia, from 2013 to 2014 G.C. For the study, two rural kebeles (Kebena and Ebisa) were selected purposively based on their accessibility and potential for beekeeping. From each kebele, 10 beekeepers were purposively selected based on their willingness, having bee colonies, indigenous knowledge of handling honeybee and organized in a group (Beekeeper Research Group (BRGs)). The area is characterized by bimodal rainfall with the mean annual rainfall ranging from 750 to 1000 mm. The two seasons are locally known as the first 'Ganna' or 'Belg' which extends from March to July while the second 'Bona' or ‘Meher’ season extends from July to December (SARC, 2001). The area has diversified flora, including natural trees, shrubs and agricultural crops like spices and pulse crops.

Sites beekeepers and honeybee colony selection

Based on agro-ecology, two representative sites (RK) were selected and ten beekeepers were selected from each site. Then farmer research group was established considering beekeepers that had honeybee colony in frame hives with better experience were purposively selected. The groups were briefed with the objectives and outcomes of colony splitting activities including all the activities expected from them and the research group. Based on beekeepers information and simple observations colonies in a frame hive were assigned to the experiment from each of the selected beekeepers.

Experimental Procedures

Two Beekeepers Research Group (BRG) each having ten members or beekeepers were established in selected kebeles and briefed on the objective of the study. All members, Two Development Agents and three Experts of the districts were trained on maternal colony selection, honeybee biology, and management, health in the first phase and on spot practical queen rearing in the second training phase. At each site strong colonies were selected and fed with sugar syrup. A day before the splitting inspection was conducted to verify, the presence of adequate eggs, brood, store and, drones which are very important for success of the works. The existing resources were equally shared for both boxes (base and super). A day after arrangement of the resources, the splitting of the colonies was conducted using recommended procedures (Spivak and Reuter, 1997) Queen less colonies kept in the original apiary site while maternal colonies were moved 500 m away from its place to minimize risk of re-uniting. On the 3rd day after splitting, the queens less colonies were inspected to check queen cell construction. On the ninth day of splitting, less matured and deformed queen cells were culled while leaving good ones. On the 16th day the colony checked for, the emerged queen and all necessary management carried out. Queen rearing and all colony management rendered during course of demonstration and evaluation were under taken with farmers and professionals of the district participation.

Data collection

Data on number of beekeepers participated, time/season of splitting, number of queens reared honeybee colony established at each site, honey yield harvested from daughter and maternal colonies and fed back of beekeepers (opinion) were recorded and analyzed using SPSS version 20 Software.

RESULTS AND DISCUSSION

The study was conducted in the participatory approach with beekeepers at two sites (Kebena and Ebisa) in Ginnir district of Bale Zone from 2013 to 2014. Theoretical training was given at the beginning of the study for the BRG on honeybee's colony selection, honeybee biology, management, health, procedure of Queen Rearing techniques and cares to be given while conducting the study process. In addition, the beekeepers were advised to keep their apiary site clean and should be well managed.

Likewise, practical training was also given on spot site on Splitting Queen Rearing Technique for 2 experts, 2 Development agents and 20 beekeepers of BRG members established (Figure 1 and Table 1) during active season. The training was supported by a demonstration exercise of Splitting Queen rearing. After practical training, the groups followed the procedure of Splitting Queen rearing technique like checking on the third day the progress of constructing queen cell, on the ninth day observing less strong and deformed queen and aborted it by leaving the best queen cell as the last, on the 16th day, they checked emergence of the queen and returned to the original apiary site. The participatory demonstration beekeepers development agents and experts, evaluated the practice of splitting mother colony, discussed and shared their views and opinions. At each time, every data views and opinions of beekeepers development agents and experts were taken and recorded by the researcher. The overall activity was done during active season of the study area from November to December (first active season) and June to July (second active season) in two consecutive years.

For the study, seven honeybee colonies were divided by the BRG at backyard in active season during flowering time. During honeybee colonies splitting time, the groups
recorded the time taken to finalize the process by following correct procedure, and the average time taken was 36 min. However, out of the total honeybee colonies splitted, about 85.71% of the colonies were successful and only 14.29% colonies (Table 2) were absconded, and this was due to pests attack as reported by the group (BRG). Moreover, the individual beekeeper also started to split their own honeybee colonies after they could get awareness and knowledge with the BRG to increase the number of colonies at their own backyard.

The beekeepers Research Groups (BRG) also evaluated honey yield obtained from the daughter (new) and mother (old) colonies and they were harvested on average 14.29 and 16.99 kg from daughter and mother colonies, respectively (Table 3). External factors like feeding during dearth periods and managing (cleaning

---

**Figure 1.** Participatory practical training on Honeybees colony splitting techniques.

**Table 1.** Number of Participant Beekeepers, Development Agents and Experts on participatory evaluation and demonstration of Queen Rearing Technique (Splitting).

<table>
<thead>
<tr>
<th>Site</th>
<th>Development agents</th>
<th>Experts</th>
<th>Grouped Beekeepers (BRG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kebena</td>
<td>1</td>
<td>2*</td>
<td>10</td>
</tr>
<tr>
<td>Ebisa</td>
<td>1</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2</strong></td>
<td><strong>2</strong></td>
<td><strong>20</strong></td>
</tr>
</tbody>
</table>

*Experts participated were from Ginnir district Livestock development and marketing office.
Table 2. Number of honeybee colonies splitted Kebena and Ebisa sites.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Mother colonies</th>
<th>Daughter colonies</th>
<th>No. of daughter colonies successful</th>
<th>% of daughter colonies successful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kebena</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>66.67</td>
</tr>
<tr>
<td>Ebisa</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>85.71</td>
</tr>
</tbody>
</table>

Table 3. Average honey yields harvested from mother and Daughter colonies.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Honey yield from colonies in kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mother colonies</td>
</tr>
<tr>
<td>Kebena</td>
<td>15.57</td>
</tr>
<tr>
<td>Ebisa</td>
<td>13.00</td>
</tr>
<tr>
<td>Average</td>
<td>14.29</td>
</tr>
</tbody>
</table>

At the end of study period, check lists were prepared to collect back feed and opinions of the beekeepers.

Table 4. Suggestions of beekeepers on SQRT evaluation and demonstrations.

<table>
<thead>
<tr>
<th>No.</th>
<th>Opinion of beekeepers regarding to SQRT</th>
<th>% of beekeepers from BGR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>Lack of honeybee colony in area</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>Could you split your own colony</td>
<td>90</td>
</tr>
<tr>
<td>3</td>
<td>Have you succeeded in splitting honey bee colony</td>
<td>90</td>
</tr>
<tr>
<td>4</td>
<td>Not Labor and time consumer</td>
<td>90</td>
</tr>
<tr>
<td>5</td>
<td>It could increase number of colony</td>
<td>90</td>
</tr>
<tr>
<td>6</td>
<td>Not difficult to split</td>
<td>85</td>
</tr>
<tr>
<td>7</td>
<td>It could reduce risk of catch swarm</td>
<td>75</td>
</tr>
<tr>
<td>8</td>
<td>Could you continue this method in future</td>
<td>80</td>
</tr>
</tbody>
</table>

According to the perception of the beekeepers, Splitting Queen Rearing technique is not comparable with baiting hive to catch swarm in order to increase the number of honeybee colonies. Beekeepers also obtained good awareness from the participatory practical approach of splitting queen rearing technique. Majority of beekeepers showed their interest in the technology (Splitting Queen Rearing technique) and were willing to carry it out at their backyard and popularize it to nearby beekeepers. Generally, the Splitting Queen Rearing technique was found to be cost-effective, feasible and a time saver and the beekeepers were satisfied with the results as long as the researchers were involved in the procedure of the study from the begging up to the final periods. In addition, the groups suggested that they were enabled to obtain additional colonies (Table 4).

CONCLUSION AND RECOMMENDATION

Today, honeybee colony population is in the state of continuous decline due to various reasons and also, it is difficult to get new colony easily. On the other hand, the price of honeybee products became an expense for small farmers holder. It is believed and proven that SQRT could increase the number of honeybees colony existing stock on the beekeepers hand. Out of the total honeybee colonies splitted by BRGs, about 85.71% of the colonies were successful and only 14.29% colonies were absconded because of pests attack. Honey yield harvested from the daughter (new) and mother (old) colonies were on average 14.29 and 16.99 kg from daughter and mother colonies, respectively. Accordingly, beekeepers that were involved in the demonstration noticed that SQRT will improve the number of honeybee’s colony under local condition and beekeepers situation. At the end of demonstration, beekeepers have
shown interest on SQRT and are willing to succeed at their home and to popularize the technology to nearby beekeepers. The SQRT is accepted as a beneficial practice by most beekeepers and it will be successful and adopted in such areas where there are favorable honeybee forage resources available. Therefore, based on this conclusion it is forwarded that to capacitate or build the knowledge, beekeepers on honeybee colony splitting techniques could be scaled up in potential beekeeping area where there are favorable honeybee forage resources available.

Conflict of interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

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Full Length Research Paper

Smallholder farmers perception on climate change in Rumphi District, Malawi

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The effects and causes of climate change and variability have been a cause of controversy and debate for many years in many parts of the developing world. Perceptions vary about the effects and causes of climate change and variability. This study assessed smallholder farmers’ perceptions of climate variability and climate change adaptation in Bolero Community, Rumphi district in northern Malawi. Data were generated through a knowledge, attitude and practice survey using semi-structured interview and focus group discussions targeting 100 respondents in the study area. The data were analyzed using descriptive statistics and chi-square tests. The results revealed that 76% of the farmers that were interviewed perceived increased temperatures and 74% perceived decreased rainfall. Results on temperature were supported by meteorological data but rainfall data for Bolero area showed no significant changes overtime. Results, however, demonstrate increased awareness by smallholder farmers about the meaning of climate change and variability but are mixed on actual causes of this due to insufficient scientific knowledge. Some relate it to human activity while others associate it to traditional, cultural, and religious practices. Among the few who believe their own human activity contributes to the situation, they feel that easy access to markets, credit, water resources, irrigation services, tree seedlings and information on climate change, can motivate them to adopt coping and adaptation mechanisms to climate change and variability. Thus, it is important to improve the scientific knowledge of smallholder farmers in understanding the causes of climate change and variability through increasing the level of awareness among smallholder farmers about the impact and causes of climate change and variability. Furthermore, more programmes that motivate farmers to adopt coping and adaptation mechanisms in dealing with climate change and variability are needed. Such projects should consider cultural and traditional beliefs of smallholder farmers.

Key words: Adaptation, adoption, climate change, coping mechanism, Malawi, perception.

INTRODUCTION

In many parts of the world today, climate change and variability have affected rural livelihoods especially in the developing world (IPCC, 2007). In Africa, human activity is attributed to this significant change in climate
(Mings, 2008; Olsen, 2006). The increasing severity of droughts, floods, dry spells and strong winds are, at least in some part, due to human activity (IPCC, 2007; United Nations, 1992). However, issues of climate change and variability have been a cause of controversy and debate for many years around the world particularly in the low rainfall regions (Brody et al., 2012). It seems scientifically well established that clearing a forest reserve adversely affects rainfall. A reduced evaporation loss from a forest cover is regarded as a significant reason for low and erratic rainfall than other alternative land use cover (Lorup and Hansen, 1997). By examining climate change using the concepts, tools and languages of the sciences and humanities and the discourses and practices of economics, politics and religion will begin to see that depending on who one is and where one stands, the idea of climate change carries quite different meanings and seems to imply different courses of action (Huimé, 2009).

However, it seems most populations do not understand the fact that forests attract rainfall and that forests act as a sponge, whereby roots soak up water in the moist soils and release it slowly in the dry season as a result, there is increased levels of deforestation in most communities. Indecision by farmers about coping and adaptation mechanisms due to insufficient scientific knowledge shall remain a challenge especially in the agricultural sector (Vandamme, 2009). Understanding people’s knowledge, attitudes and practices (KAP) about climate change and variability can bring about important coping and adaptation systems for climate change to promote agriculture and sustain rural livelihood and welfare. Although, there is an increase in the number of climate change and variability studies that are incorporating the KAP approach (Ojomo et al., 2015; Arbuckle et al., 2013; CIMP, 2012; Oopen, 2012; Bruinders et al., 2009; Chambers and Smith, 2007; JCCEA, 2005), there is a limited number of location specific KAP surveys which is presumably the most important single factor bringing about increasing uncertainties in climate change and variability. Hence, there is a need to carry out community level studies that document farmers’ perceptions, knowledge, attitudes and practices in climate variability and change, before designing climate change adaptation programmes and strategies. Such studies would provide better location specific insights and generate information relevant to policy and interventions that would contribute to a higher adoption rate of climate change adaptation strategies. In this paper, the KAP approach has been taken as a conceptual framework to study human behavior and not as a specific methodology.

This paper presents preliminary results of a study conducted at Bolero Extension Planning Area (EPA) in Rumphi district, northern part of Malawi about people’s knowledge, attitude and practice about climate change and variability vis a vis their perceptions about coping and adaptation mechanisms to promote the rural livelihood. In Bolero area, the most susceptible sectors of human life which are sensitive to climate change and variability are agriculture, food security and natural resources.

**METHODOLOGY**

**Study area**

Bolero EPA was purposively selected being a designated community of practice (CoP) for rural livelihood by Mzuzu University. Bolero EPA is situated at approximately 10 km west of Rumphi district headquarters (Figure 1). The area falls under the jurisdiction of Paramount Chief Chikulamayembe with an estimated population of 58,550 people of which 51% are female6. The EPA has 11,710 farming families with average land holding size of 2.7 hectares each. Maize is the main staple food grown in the EPA, and tobacco and paprika are the main cash crops. These farming families also domesticate livestock mainly pigeons, chicken, goats and pigs as their main source of protein dietary intake. According to a socio-economic profile of Rumphi District, deforestation is rampant in the area due to increased demands for fuelwood, charcoal, burnt bricks, tobacco curing, and new farm lands is due in part to the burgeoning population. Poor land management, resulting in loss of soil fertility is also high in the area.

**Data collection and analysis**

The study was initiated during the 2014/2015 farming season between October and May. One of the aims was to monitor the impact of people’s knowledge, attitude and practice (KAP) on climate change and variability, thereby contributing to the process of replacing beliefs with facts regarding the effect of climate change and variability on agricultural productivity and rural livelihood, in particular. Semi-structured interviews (SSIs) were conducted covering a sample size of 100 households in four (4) villages. SSI was used to generate both quantitative and qualitative data from the sample unit about their knowledge, attitude, practice and perceptions about climate change and variability including their coping and adaptation mechanisms. The method was also used to gather qualitative data about the motivation factors by farmers to adapt to climate change and variability to improve their rural livelihood and welfare. In addition, meteorological data on rainfall and temperature for the area was collected from the Malawi Department of Climate Change and Meteorological Services. This data was used for comparisons with farmers’ perceptions on climate change. The quantitative data gathered was analysed by using Statistical Package for Social Sciences (SPSS) version 16.0. Meteorological data was analyzed using Microsoft Excel. In order to interpret the data, all results were presented in form of charts, graphs and tables. Chi-square test was used to test statistical significance particularly among the different respondents and their responses. A 0.05 level of significance was set. Qualitative data was analyzed by using content analysis.

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RESULTS AND DISCUSSION

Respondents profile

Out of the 100 respondents that participated in the study, 51% were females and 49% of the total was within the age range of 30 to 40 years. Majority (78%) of the respondents were married. On education levels, about 65% had attained primary education and 3% had not attended any formal education. In terms of occupation, majority of the respondents (98%) earned their living through subsistence farming and reported living for an average of 29 years in their current villages.

Smallholder farmers’ perception on climate variability

Temperature

Respondents were asked to indicate whether they had observed increased or decreased temperature trends over the past 10 years. The study results shows that more than half of the respondents (76%) reported that they had experienced increased temperatures in Bolero community for the past 10 years. A Chi-square test showed that the differences in farmers’ responses is statistically significant ($\chi^2 = 109.000; DF = 4; P$-Value =
0.0001) implying that it is unlikely that the differences in perceptions could be due to chance alone. The perception of farmers was compared with the meteorological data from Malawi Meteorological Services. Both minimum and maximum temperature readings for Bolero show a positive trend in temperature which indicates that there has been an increase in temperature for the past 33 years (Figures 2 and 3). Statistical analysis of the change in both maximum and minimum temperatures over time shows that they are significant (P = 0.0036 and P = 0.0017 respectively).

The above statistical analysis is in tandem with many other studies on farmers’ perceptions and adaptations to climate change and variability including Ethiopia, Zimbabwe, South Africa and Ghana (ATPS, 2013; Moyo et al., 2012; Fosu-Mensah et al., 2010; Gbetibouo, 2009) respectively. According to Shankara et al. (2013), farmers’ perceptions about changes in temperature often fall within observed meteorological data. Farmers’ perception of changes in temperature is usually in line with meteorological data since the farmers are in a position to rightly judge changes in evapotranspiration and dehydration in human bodies over time (Shankara et al., 2013).

Rainfall

Majority (74%) of the respondents indicated that there has been a decrease in rainfall over the past 10 years. A Chi-square test showed that the differences in farmers’ responses is statistically significant (χ² = 172.720; DF = 6; P-Value = 0.0001) implying that it is unlikely that the differences in perceptions could be due to chance alone. However, the rainfall data from Malawi Meteorological Services for Bolero, shows that there has been a moderate increase in rainfall during the past 10 years (Figure 4). However, a statistical analysis of the changes in rainfall over the period shows that it statistically insignificant (P = 0.603). These findings on rainfall pattern do not match with perceived rainfall patterns. Over the past 10 years, the actual rainfall data for the study area shows little variability. This is common in many studies which examine people’s perceptions about climate change and variability due to a number of reasons (Moyo et al., 2012; ATPS, 2013). In the study area, the smallholder farmers perceptions on rainfall pattern may have been influenced by the declining maize yield, which may not be related to rainfall as shown by meteorological data that the rainfall pattern has not significantly changed. It could be for the
Figure 3. Bolero Mean Annual Maximum Temperature from 1983-2013; Source: Department of Climate Change and Meteorological Services in Malawi.

Figure 4. Seasonal rainfall for Bolero from 1999/2000-2013/2014; Source: Department of Climate Change and Meteorological Services in Malawi.

reason that many smallholders opt to grow more tobacco as a ‘cash-spinner’ than maize.

Smallholder farmers may also perceive a decrease in rainfall due to the fact that the meteorological rainfall
data used in the study does not show the actual rainfall amount and rainy days within a month. From experience, most farmers know specific days or weeks within a critical crop growth period when a crop demand for water is highest and if it does not rain in those critical times, farmers might perceive it as a decrease in rainfall amount (ATPS, 2013). In addition, the meteorological rainfall data does not capture the observed changes in rainfall patterns whereby the growing season is becoming shorter (Khamis, 2006; Tadross et al., 2007).

Overall, smallholder farmers' perceptions of changes in both temperature and rainfall reveal that the perceptions are made based on local environment and are not linked to an understanding of climate change and variability in the national or global context. This brings some challenges. Basing perceptions of climate change to local events creates a challenge for climate change projects that take into consideration global or national view of climate change which is different from the local environment and perceptions. Such perceptions may have a bearing on adoption of international and national adaptation strategies in an area.

Smallholder farmers’ Knowledge on Climate Change

Respondents were asked to indicate if they had ever heard of climate variability and change. Overall 96% of respondents indicated that they had some idea and had heard about climate variability and change. However, when the respondents were asked to describe the meaning of climate change and variability, they gave a variety of answers. The most common understanding for the majority of the respondents of climate change and variability was the change in rainfall (48%) while 21% indicated that it was a change in both rainfall and temperature. Only 5% of the respondents indicated that it was a change in temperature (Figure 5). Results from the study show that smallholder farmers’ knowledge about climate change and variability is not in the context of the theoretical definition of climate change and variability. It is not surprising to note that most farmers associate climate change to changes in rainfall patterns because of its direct effect on agricultural production and food security. This is supported by Maddison (2006) who observes that farmers’ understanding of climate change is often linked to experiences of such events. Lack of knowledge in climate change and variability can equally affect adoption of adaptation strategies. Since the smallholder farmers in Bolero community do not understand the concept of climate change and variability fully, they need to be helped. It is important to ensure that smallholder farmers and other natural resource users in Bolero Community get the right information on climate change that is most relevant to them which should include meteorological data and seasonal climate forecasts. This would improve their existing knowledge gaps and increase their adaptive capacity and resilience to the negative effects of climate change and variability.

Smallholder farmers’ attitudes

In order to capture the farmers’ attitude towards climate change, the respondents were asked about their level of agreement with the statement that there is nothing that the community could do about climate change. The study revealed that the majority of respondents (88%) disagreed with the statement and only 6% of respondents agreed with the statement. A Chi-square test showed that the differences in farmers’ level of agreement is statistically significant ($\chi^2 = 241.100; DF = 4; P$-Value = 0.0001) implying that it is unlikely that the differences in attitude can be due to chance alone.

The respondents were also asked about their level of agreement with the statement that climate change is occurring in this community because of sins and failure to respect certain cultural and religious beliefs and practices. The results show that 60% of the respondents disagreed and 39% agreed. A Chi-square test showed that the differences in farmers’ level of agreement is statistically significant ($\chi^2 = 94.700; DF = 4; P$-Value = 0.0001) implying that it is unlikely that the differences in responses could be due to chance alone. This revelation shows that there still exist some smallholder farmers who believe that climate change requires divine intervention. This agrees with results from several studies from other places in Africa and Asia about ancestral beliefs and values such as Kondoa district in Tanzania (Slenger, 2008), Zambia (Nyanga et al., 2011) and Balochistan province in Pakistan (Ashraf and Routray, 2013). These beliefs cannot be taken for granted because it can lead to under-investment by some smallholder farmers in rain-fed agriculture, failure to adopt modern farming methods which are adaptive to climate change or the entire adoption of coping and adaptability mechanisms to climate change and variability. There is need to ensure that climate change education awareness is conducted in the community with the aim of re-orienting the community towards climate change issues and changing their negative mind-set.

Smallholder farmers’ practices related to climate change

The smallholder farmers were asked to state the major activities undertaken in their community that might have contributed to climate change and variability. These
activities were categorized into Government, community and households. As for households and community, the majority of the respondents (82 and 76% respectively) reported cutting down of trees as the major activity contributing to worsening effects of climate change. About 45% of the respondents indicated that encouragement of tobacco farming by Government was the major activity that was worsening the climate change and variability situation in the community (Figure 6). Thus, smallholder farmers need to be encouraged to diversify their income generating activities through crop diversification in order to reduce over dependency on tobacco farming.

Finally, the respondents were asked to rank the major factors that they believe motivate them to adopt adaptation strategies to climate change and variability.
From the findings, access to water (75%), access to farm research groups (61%), access to irrigation sites (58%), access to climate information (57%), access to pests and disease control services (54%) and access to formal credits (53%) were most frequently ranked by the respondents as the most important motivating factors while access to safety net was reported as the least important (Figure 7).

It is important to improve smallholder farmers’ access to affordable credits which will increase their financial resources and ability to meet transactional costs associated with the various adaptations options they might want to take and also have the means to access to markets. In addition, with more financial resources and access to markets, small holder farmers will be able to buy new crop varieties, new irrigation technologies, invest in livestock farming, which are among the motivating factors to their adoption of climate change adaptation strategies.

**Conclusion**

The paper presented smallholder farmers perception on changes in climate in Bolero Extension Planning Area in Rumphi District, northern Malawi. Majority of smallholder farmers are aware of climate change but debate continues on actual causes of this change. Among the few who believe their own human activity contributes to the situation, they feel there are some factors which can motivate them to adopt coping and adaptation mechanisms to climate change and variability. Some of the motivation factors cited include access to market, access to credit/loan facilities, access to water resources, access to irrigation services, access to information on climate, provision of farm inputs, small stocks, polythene tubes and tree seedlings. Programmes that can take into account these suggestions may help to motivate many farmers to adopt coping and adaptation mechanisms in dealing with climate change and variability in Malawi and beyond. It is also important to increase awareness about the current trends and causes of climate change and variability in the area and the impact human activity may have on climate change. In addition, scientists and development experts should consider the cultural and traditional beliefs of smallholder farmers when designing climate change projects.

**Conflict of Interests**

The authors have not declared any conflict of interests.

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Impact of agricultural technology adoption of small holder farmers on wheat yield: Empirical evidence from Southern Tigrai State of Ethiopia

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Ethiopian agriculture the back bone of the economy yet is characterized by small scale farming and experienced erratic rainfall as well as drought. The low produce can possibly grow through developing technology adoption and improved practices on the marginal farm lands. This study, therefore, examines the impact of wheat row planting technology adoption on small farms yield in Ofla Woreda, Southern zone of Tigrai, and Ethiopia using a primary data sources from a survey of a random sample of 300 small scale farm household heads. Of which 99 household heads were wheat row planting adopters (users) and the remaining 201were wheat grower households sow in broadcasting method non adopters (non users). To deal with this, propensity score matching (PSM) econometric tool was implemented. Next, the average treatment effects on the treated (ATT) estimated result was obtained using PSM method and has proven that wheat row planting technology adopter small farm household heads was gotten with a range of 40 to 60 quintal of wheat yield per hectare at a cost of sowing 4,800 ETB larger in a single production year unlike to the matched control group which is below 20 quintal at a Birr 3,600 cost of sowing. At the end, the researcher has recommended that scaling up of wheat row planting technology adoption as a package to increase wheat crop output on the marginal land and fasten the anti-poverty policy struggle is indispensable in Southern Tigrai, Ethiopia.

Key words: Impact, adoption, technology, row planting, wheat yield, PSM, Ofla, South Tigrai.

INTRODUCTION

In the case of Less Developed Countries (LDCs) in general and Sub-Saharan Africa (SSA) in particular, economic policy heavily depended on agriculture. Poverty reduction and income growth can generally be achieved through agricultural growth that creates spillover effects to the remaining sectors (World Bank, 2014). African Development Bank/AfDB, (2014) contends that African population living in poverty has fallen larger than 50% in 1981 unlike that of in 2012 which was reduced to 45%. Of which around 48% of the Sub-Saharan countries populations were found under food insecurity. One solution recommended to come up out of this abject
poverty is boosting agriculture. However, production and productivity of the agricultural sector in SSA is low due to low technological adoption and techniques among others (Abraham et al., 2014; Berihun et al., 2014; Gashaw et al., 2014; Tsegaye and Bekele, 2012; Lulit et al., 2012; MoFED, 2012).

Ethiopia, the leading SSA economy depends on smallholder farm agriculture. The contribution of the agricultural sector to Gross Domestic Product (GDP) is large (41%); 85% of the employment opportunity, 90% of the export level, and provides 70% of the country’s raw material demand of the large and medium scale industries found from this promising sector (MoFED, 2012). Nevertheless, around 29% of its population yet is living under poverty (World Bank, 2014). Expansion of farm lands and intensification or use of more inputs and new technologies per unit of land are the two possible ways of increasing agricultural productivity. Higher agricultural yield could possibly be obtained both from use of more inputs per unit of land and expanding the cultivable farm land in the agricultural sector (Berihun et al., 2014; Gashaw et al., 2014; Tsegaye and Bekele, 2012). Contrary to the expansion of cultivable farm land, adoption of agricultural inputs and techniques in line with the green development economic policy like Ethiopia today is the best remedy. After the Ethiopian peoples’ revolutionary democratic front E.P.R.D.F. led-government to come to power in 1991 the economic management of the country was transformed from a command economic system into market-led systems and the subsequent structural adjustment programs, brought the effect of reversing the collapsed, and healing of the overall economic status of the country (Fredu and Solomon, 2011). To alleviate that severe poverty, Government of Ethiopia (GoE) designed, introduced, and implemented the famous Agricultural Development Led Industrialization (ADLI) strategy since 1991 (Berihun et al., 2014; Lulit et al., 2012). GoE has adopted different new agricultural technologies for adoption as policy like fertilizers, certified seeds, irrigation, and row planting techniques. However, there is practically a limitation in adoption of these technologies and new techniques by small farms.

At the national level, around five million smallholder farmers are participating in producing wheat and produce approximately 40 million quintal (4 ton) of it per annum. Currently, 24-quintal per hectare (2.4 ton) is the national average yield of wheat and implies triple times larger as compared to that of eight quintal per hectare in 1990s production year (CSA, 2013; UNDP, 2014). Currently, the average wheat yield in the National regional state of Tigrai, Ethiopia is estimated 35 to 40 quintal per hectare in the production year 2013 (Abraham et al., 2014). However, lags behind China’s average yield of wheat ranges from 40 to 60 quintal per hectare (Lester, 2012; Gashaw et al., 2014). And even much lesser than the Western Europe, the average wheat yield is about 60 to 80 quintal per hectare (Lester, 2012).

Likewise, wheat is given due emphasis to increase its production among other cereals in the National state of Tigrai. Its area coverage is around 0.1million hectares and produce 1.93 million quintals of wheat per annum from the total cultivated land of 1.04 million hectares in the region (Fetien and Ibrahim, 2010). Around 45% of the regional total wheat production and 46.3% of wheat, area coverage has found from the Southern part of Tigrai and which is the focus of the study area (as cited in Teklay, 2012). Seeding is done until now by broadcasting, not in row and weeding which mainly depends on precise family laborites which contribute negatively to low productivity of crops in Ethiopia (Bezabih et al., 2010).

The result of recent studies prove that row planting method gives better output than most commonly practiced traditional method, conventional broadcasting. Consequently, in order to get higher grain of wheat yield, row planting method is advised by many scholars (Mishra et al., 2001; Mohammad et al., 2001; Abdulai and Huffman, 2005; Attaullah et al., 2007; and CAADP, 2012). Even if Ethiopia is the leading regional producer of wheat in SSA, yet the country spends more amount of US dollar to import about a million tons of the grain every year from abroad (Sarah, 2014). Especially, when there is limited supply of wheat for the industries (manufacturers) engaged in producing flour, spaghetti, macaroni, biscuits and bread over the country (Sarah, 2014). Though the demand for wheat grain has been increased at least among others due to increase in population, urbanization, and massive expansion of food complex processing industries, Ethiopia has not been able to satisfy the high demand and was obliged to import million tons of wheat every year to fill the gap by incurring more US dollars (Rashid, 2010).

Low technology adoption, low use of improved farm inputs, traditional farming, and rain-fall are the prime bottlenecks behind the poor performance of the sector in Ethiopia (Lulit et al., 2012). Though there are plenty of agricultural technologies (extension packages) over the country, the study is only limited to evaluate the impact of row planting (seed is sown at low rate) in agricultural technology adoption on wheat yield over smallholder farms’ in Ofa woreda¹ of the National regional state of Tigrai, Ethiopia.

As it can be recalled, in LDCs like East African countries including Ethiopia, there is limited work in the literature of agricultural technology adoption at small farm household’s level in general and mainly the impact of the newly introduced row planting technique (sowing in line) on wheat in particular yet is not examined in the local specific study area and in Tigrai regional state of Ethiopia as well. This paper sought to contribute to the limited knowledge on the impact of sowing in line technique that would have good policy relevance on the enhancement of wheat yield on the wheat belt areas of Tigrai. With this

¹ Woreda in this context is an administrative structure of governance next to zone level.
background and understanding, investigating the impact of row planting on small farm household’s wheat yield, therefore, is imperative in Ofla woreda of the Tigrai region of Ethiopia. The general objective of this study is therefore to investigate the impact of row planting agricultural technique adoption on small holder households’ wheat yield. The specific objectives are:

1. To investigate the determinant factors that affect adoption of -new agricultural technology on wheat yield.
2. To examine the impact of row planting technology adoption on wheat yield.

The remaining sections of this paper are organized as follows: the second section gives the literature review; the third section presents methods and econometric that was used to estimate the impacts of row planting technology adoption on wheat yields in this paper. The fourth section presents the results of the estimations for selected areas; the fifth and final section concludes and identifies possible recommendation.

LITERATURE REVIEW

The Ethiopian agricultural transformation agency (MoA, 2012) investigated that crop planting with space starts with growing seedlings in a garden center and planting these in the field with sufficient and equal spacing between each seedling. On the other hand, seed grain can be sown in rows with enough spacing between the seeds and rows simultaneously and started since 2011 to 2012. It’s antonymous to the traditional broadcasting sowing method manually by hand that contributes positively to the lower agricultural produce.

Sowing wheat crops in rows at low rate instead of scattering seeds by hand recommendations were introduced to about 400,000 wheat farmers in 200 kebeles located in the four main wheat belt regions of Ethiopia: Amhara, Oromia, SNNP, and Tigrai (Gashaw et al., 2014; Sarah, 2014). Using a reduced-seed rate through row planting is a major piece of the package. However, small farm households were convinced that 50 kilograms (Kg) of the advised seed per hectare was not enough because they traditionally use 75 kg per half hectare. Farmers were very skeptical of the recommendation; some of them even applied additional wheat seed on top of the recommended doze. Small farm households who sow with the recommended amount of seed have got impressive yield (a deviation of 75 to 80 percent per hectare) (Sarah, 2014).

The process of adoption is the change that takes place within individual in relation to innovation starting from adopters initially aware of the innovation to the last decision whether or not to adopt that new technology. Despite, Ray (2001) has defined that adoption does not necessarily follow the stages that starts from awareness creation to adoption of that new technology. Enough spacing between the plants and sowing of two seed grains at one point facilitates needed moisture, aeration, nutrition, and light to the crop roots, as a result; helps faster growth of plants and productivity as well (Ram and Prashanta, 2011). In general speaking, there are two main systems of wheat intensification (SWI) principles of crop production. First, principles of root development and the second one is principle of intensive care.

Principles of root development: For the sake of proper growth of crop plant, it must be well established from its rooting system. It’s a fact that root development is the first stage of healthy growth of any plant. To be achieved requires enough food and space around the plant. From this principle, then conclude that distance between plants and nourishment are decisive things for the better growth and development of crop plants for that matter enhances outputs. Principles of intensive care: Intensification, here is contrary to the high number of plant density per unit space meaning it’s proper space maintenance takes care of plants very closely. Finally, so as to increase wheat yield it needs intensive care in each stage plant development including management of weed, insect, disease, irrigation, and organic manure (Ram and Prashanta, 2011).

“The prevalent system of wheat cultivation requires more chemical fertilizers and nearly 120 to 180 kg of seed per hectare. However, system of wheat intensification (SWI) uses only 20 to 30 kg of improved seed in one hectare” (Ram and Prashanta, 2011). For its effectiveness 20 to 25 cm spacing between rows, use of manure, improved seed and organic seed treatment ensures more yield of wheat.

Technology concepts

Rogers (1995; P. 12) often uses “innovation” and “technology” synonymously. He describes as follows: “technology is a design for instrumental action that reduces the uncertainty in the cause effect relationships involved in achieving a desired outcome”. Enos and Park (1988) defined technology as “the general knowledge or information that permits some tasks to be accomplished, some service rendered, or some products manufactured”. Rogers (1995; P. 5) conceptualized that “diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system” provided that decisions are not authoritative or collective, each member of the social system faces his or her own innovation decision following a five stage processes.

The innovation decision process is the process through which an individual (other decision making unit) passes from first knowledge of an innovation forming an attitude toward the innovation, to a decision of adopt or reject, to implementation of the new idea, and to confirmation of
this decision”-(Rogers, 1995; P. 20 to 21). New technology adoption takes place within the mind of an individual or other decision making unit, however, diffusion occurs among the units in a social system. Finally, there are five main stages in new technology adoption process stated as follows:

1. Knowledge: A decision making individual becomes aware of an innovation and has some idea of how it works is the main idea of this stage. As decision making persons first exposed to an innovation, however; lack information about the innovation and even have no desire to find extra information about the innovation.

2. Persuasion: This stage takes place when an individual decision unit creates a favorable or unfavorable attitude toward the innovation. Individual decision unit become interested in innovation and actively seeks information regarding to the new technology.

3. Decision: In this stage an individual typically is attracted to seek innovation-evaluation information, which is the reduction in uncertainty about an innovation’s expected out comes. Questions like innovation’s consequences, advantages and disadvantages be in my situation are usually answered by most individuals from their peers whose subjective opinion of the innovation is most convincing. Though this stage is most difficult to endorse by empirical evidence, individuals focus in activities that lead to a choice either to adopt or reject the innovation in weighing the advantages and disadvantages of adopting the innovation.

4. Implementation: Takes place when persons put an innovation in to use. Injunction to that an individual determines the usefulness of innovation as well. When that adopted new technologies give utility to him/her will continue to use the innovation and otherwise.

5. Confirmation: A person evaluates the results of an innovation-decision already made. As a result, individual decision unit decided to use the innovation even up to the fullest capacity.

Types of adoptors in new technology adoption process

Rogers (1995: 246 to 250) conducted a research on ‘innovation adoption’ stated that in the new technology adoption process there are five adopter categories. These are:

1. Innovators (Venture some): This category of adopters is very eager to try new ideas and leads them out of a local circle of peer networks and into more modern social relationships. Generally, the adopters of the innovation category are risk takers, under youngest age brackets, have higher social status, nearest to scientific sources, and interact with other technology innovators.

2. Early adopters (Respectable): Characterized by greatest degree of opinion leadership in most social systems, younger in age, have more financial variability, have higher social status, advanced education, greater social relationships, and greater exposure to different mass-media channels.

3. Early majority (Deliberate): Adopt new ideas before the average number of a social system. Similarly, they interact repeatedly with their peers and sometimes hold leadership positions. The innovation-decision period of early majority adopter is relatively longer as compared to innovator and the early adopter.

4. Late majority (Skeptical): Individual decision unit in late majority category characterized by adopting an innovation after the average member of the society adopts the innovation because these are with high degree of skepticism.

5. Laggards (Traditional): Laggards or individual decision unit who falls behind peers are the last category to adopt an innovation. Furthermore, laggards behave as they do have more isolated in social networks, lowest social status, and lowest financial changeability up to the extent little opinion leadership over the average number of a social system (Rogers, 1995: 247).

Previous researches

Bola et al. (2012), used a local average treatment effect (LATE) method to examine “the impact of improved agricultural technology adoption on sustainable rice productivity and rural farmers’ welfare in Nigeria”; using a cross sectional data of 481 rice producers stated that the decision of small farm households to adopt improved rice varieties were determined by the different socio-economic /demographic and institutional variables such as number of years of residence in the village, access to media, mobile phone, vocational training, livestock ownership, access to improved seed, and income from other crop production significantly increased the probability of adoption. As a result, adopters received more 3.6 quintals of rice additions per hectare.

A research output revealed that farmers who has adopted selected wheat seed, a lower seeding density, row planting, fertilizer recommendations, and marketing assistance as full-package obtained 12 to 13% higher wheat yields as compared to non users (Gashaw et al., 2014). Mamudu et al. (2012) made a research entitled “adaptation of modern agricultural production technologies by farm households in Ghana” using logit model as a tool over 300 farmers who found that, plot size, expected returns from technology adoption, access to credit, and extension services are the factors that significantly affect technology adoption decisions of small farm households in the west district area of that country. Debela (2011), agricultural growth can be achieved through better small farm management practices and increased adoption of improved agricultural technologies such as chemical
fertilizers, improved seed varieties, pesticides, and organic minerals. Among other important variables age of the household head, family size, number of oxen, access to credit, and off-farm activities positively affect the probability of participation in an agricultural extension program. Of which age, education level, and access to credit, affects significantly.

Yaron et al. (1998) and Harper et al. (1998) found that small farm households have a negative correlation between adoption of new technology and land size of small farm households. Bola et al. (2012) revealed that technology complexity has a negative impact on adoption of technologies and this bottle neck could only be solved through education. Ibrahim (2013) on his ‘constraints to agricultural technology adoption in Uganda’ panel data using probit model, shows that small farm heads with low educational level and small land holdings are less likely to adopt improved seed and fertilizer technologies. Adoption of improved wheat varieties on small farm households increases food security and small farm households that did not adopt that technology would also have benefited sufficiently had they adopted improved seed (Bekele et al., 2013). Tsegaye and Bekele (2012) conducted a study on the ‘impacts of adoption of improved wheat technologies on households’ food consumption in South eastern Ethiopia’ using a propensity score matching (PSM) over randomly selected 200 farmers stated that improved wheat seed varieties grew based on a recommended planting space (row) which had a robust and positive impact on small farm household level of food consumption. The average treatment effect on the treated (ATT) revealed that 377.37 to 603.16 calories per day increment came on the adopters of row planting method thereby improving household’s income. Variables like age, education, farm experience, off-farm activities, access to credit, extension contact, and livestock holding affected adoption of wheat technology. Lastly, these reviewed literatures aforementioned have helped for this research to design the potential socioeconomic and demographic factors related to the good quality consideration that support to explain the impact of row planting technology adoption on small farm households wheat yield.

MATERIALS AND METHODS

Description of the study area

Southern Tigrai is one of the seven administrative zones of the Tigrai regional state of Ethiopia. It holds eight Woredas under and is found about 167 km south of Mekelle city. Ofila lies between 12°31’ North Latitude and 39°33’ East Longitude and bordered by Woreda Endamokini to the North, Raya Azebo to the East, Alamata to the South, and Amhara regional administrative state to the west. It lies at an altitude range of 1500 to 2800 m.a.s.l. The average annual temperature of the Woreda is 22.3°C as well. However, its annual temperature ranges from 14.6°C to 30°C. Mean annual rainfall of the Woreda also ranges from 450 to 800 mm in the main summer season (June to September) and 180 to 250 mm in the Belg season (December to April). Besides, it has 21 administrative Tabias under it. The agro climatic condition of the area is Dega (highland), Weynadega (mid-highland), and Kolla (lowland). Nevertheless, the Dega holds 42% largest proportion which is conducive to wheat crop production, and 29% weynadega and kola, respectively. Ofila Woreda with the total population of 147,000 is the second largest populated rural Woreda in Tigrai. Of the total, 49.7% are male and the remaining 50.3% are female. From this total population, 16% are economically active labor. Total numbers of households of the Woreda are estimated 33,943 of which 69% are male headed and the rest 31% are female headed households. Growth rate of the Woreda's population is estimated to be 2.2% per annum. The study area accounts for about 144,220 hectare of land meter area. Of the total hectare of land 22,851 hectare is arable and 44,635 hectare is covered by forests while the remaining was covered by grazing, area not under use, settlement and others. 40% landscape of the Woreda is sloppy, 20% flat plain, and 25% flat, and the remaining 15% is guiley and valleys. It's potential wheat producer woreda. The dominant economic base of that Woreda's rural community is agricultural economic sector. It accounts for 97% of the total population livelihoods (Ibid).

Sources and methods of data collection

A multi-stage sampling technique was applied so as to reach at the selection of a sample of smallholder farm households in the study. In the first stage, out of the total five rural Woredas of south zone, Ofia woreda were purposively selected because of its high potential of wheat and there is a practice of row planting (sowing in line). In the second stage, of the total 21 Tabias of Ofia Woreda administration, four Tabias (Hashenge, Adi-golo, Menkere, and Wenberet) were selected purposively. Similarly, the selected Tabias consisted of both large number of row planting technology adopter households and represent the agro ecological zone as compared to the remaining Tabias. A total sample of 300 smallholder farmers has been therefore selected in the third stage (Table 1). Random sampling technique was applied in each stratum to select both the treated and control groups. In the fourth stage, of these total sample size, a total of 99 smallholder wheat row planting adopter households from the treatment group and 201 non-adopter households from the control group were surveyed. Finally, the 99 adopter smallholder farmers and 201 non adopters were selected randomly and proportional to the total household heads in the four Tabias. Lists of all respondents were found from the administration centers (Kebelles).

Data type and source

The research was conducted using primary (cross sectional) data. Due to the nature of small farm households, primary data source is dominantly used. In the primary data, a well designed and organized questionnaire was prepared in order to collect all relevant data from the smallholder farmers in the study area. The socioeconomic aspects of the representative farms have been collected. A total of ten data enumerators were selected on the basis of their level of education. And they qualify equivalent to degree, data collection experience, and proficiency on the local language Tigrigna. Next, the selected enumerators were trained well on the detail contents of the questionnaire and techniques of data collection include how to approach households and discuss face to face. In order to develop, check the validity of the instrument

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2 Tabia (K’ebelle) in this context is a rural administrative structure of governance next to Woreda level.
Table 1. Sample size of agricultural technology participants and non participant smallholder farm heads on wheat yield (2014) production year.

<table>
<thead>
<tr>
<th>Name of tabia</th>
<th>Row planting adoptors</th>
<th>Non adoptors</th>
<th>Total number of household heads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adigolo</td>
<td>492</td>
<td>1,573</td>
<td>2,065</td>
</tr>
<tr>
<td>Hashenge</td>
<td>918</td>
<td>1,371</td>
<td>2,289</td>
</tr>
<tr>
<td>Menkere</td>
<td>5,80</td>
<td>1,033</td>
<td>1,613</td>
</tr>
<tr>
<td>Wenberet</td>
<td>453</td>
<td>884</td>
<td>1,337</td>
</tr>
<tr>
<td>Total</td>
<td>2,443</td>
<td>4,861</td>
<td>7,304</td>
</tr>
</tbody>
</table>

Source: BoARD of OfIla, 2014.

and to make some amendments when necessary, a pilot survey using some randomly selected households was conducted. Therefore, the main sources of data for the research were collected mainly from sample smallholder farmers, agricultural development agents; agricultural inputs supply expertise, and administrators of the study area.

Econometric method of data analysis

Propensity Score Matching (PSM) method was applied to estimate the robust impact of row planting technology adoption on wheat yield at household level. In evaluating the impact of row planting technology adoption on wheat yield of adopter households (treated group) and non-adopters (control group), it is obvious that a researcher faces selection bias estimation problem. Thus, to evaluate the impact of a treatment on performance indicators, it is indeed to draw a counter factual group that can serve as a comparison group. Heckman et al. (1997) suggested that the counter factual can be compared with the treated group to evaluate the impact of the treatment on the performance indicators. In the context of this study, the treated groups counterpart factual would be the situation where wheat is produced in the absence of the participation in row planting. However, in reality a household cannot hold both a treatment and control group status at a time.

As a result, counter factual for the treated is possible by constructing a treatment factual group that resembles the treatment group in the absence of treatment. In order to eliminate selection bias, there is a need to compare the performance levels of both treated and control groups which are statistically comparable (Rosenbaum and Rubin, 1985; Khandker et al., 2010). Consequently, in dealing with selection bias problem the implementation of propensity score matching (PSM) is advised.

Model specification

A binary choice model is applied to estimate the smallholder farmers’ probability of participation in row planting technology adoption that is, \( Y=1 \) decision of households to adopt wheat line sowing, \( 0=\text{otherwise} \) on observable characteristics.

As emphasized by Caliendo and Kopeinig (2008), since PSM is a conditional probability estimator, any discrete choice model such as logit or probit can be used equally so long as they give almost the same output. The two discrete choice models are different only on their distribution; the logit model is based on the cumulative standard logistic distribution and the probit model is based on cumulative standard normal distribution. The logit model is a non-linear regression (LR) and is applicable when the dependent variable, like in the study, is binary (dummy); which takes values of either 0 or 1. It is implemented to estimate household’s probability of participation of row planting technology. Gujarati (2004) stated that the logit model estimates the probability of the dependent variable to be 1. The specification of the logit model in this study is specified as:

\[
P(Yi=1/X) = p(\text{adoption}) = \frac{1}{1+e^{-\beta x}}
\]

Where,

\[
\beta = \text{a vector of logit index (Coefficient)} \quad e = \text{the stochastic (error or disturbance) term.}
\]

Propensity Score Matching (PSM)

PSM initially coined by Rosenbaum and Rubin (1985) has been applied in many program evaluations. PSM matches groups based on their conditional probability of receiving a treatment given pre-treatment characteristics (ibid). As far as this impact of agricultural technologies is concerned the impact of both row-planting and improved wheat seed technology is found by comparing the average wheat yield of adopter and non-adopter households. The correct evaluation of impact of technologies requires identifying the "average treatment effect on the treated" (ATT). ATT is the difference between the outcome variables of being treated and its counter factual (outcome of a beneficiary if s/he had not been part of both row-planting and improved wheat seed technology). The average treatment effect on the treated (ATT) is given as:

\[
\text{ATT} = \mathbb{E}(Y_{1/D=1}) - \mathbb{E}(Y_{0/D=1})
\]

Where,

\[
\mathbb{E}(Y_{1/D=1}) = \text{the production levels of the adopters before they adopt row planting and it is reasonably approximated by the output level of non-adopters during data collection.}
\]

\[
\mathbb{E}(Y_{0/D=0}) = \text{is a counter factual and is not observed.}
\]

\[
D = \text{dummy variable that takes the value 1 if the individual is treated 0 otherwise}
\]

Using the mean outcome of non-beneficiaries, which is more likely to be observed in most cases, can’t solve the problem of the society provided that there is a possibility that the variables that determine the treatment decision also affect the outcome variables. Now, the outcome of treated and non- treated individuals might differ leading to selection bias. To clarify the mean outcome of a program, we can further specify ATT as:
\[ \text{ATT} = \{E[ Y_1 / D = 1 ] - E[ Y_0 / D = 0 ] \} - \{E[ Y_0 / D = 1 ] - E[ Y_0 / D = 0 ] \} \]  

Where, \( E[ Y_1 / D = 1 ] - E[ Y_0 / D = 0 ] \) is the selection bias which will be equal to zero, if the program was given randomly and at the event where adopter and non-adopters did not differ before the program implementation. The validity of the result of the PSM method depends on the satisfaction. The two assumptions are:

1. Conditional Independence Assumption (CIA): meaning outcomes of the adopters and non-adopters are independent of the treatment status or after controlling for observable characteristics. The treatment assignment is "as good as random", and specified as:

\[ Y_0, Y_1 \perp D \mid X \]  

2. Common support condition (CSC): Entails the existence of sufficient overlap in the characteristics of the treated and untreated units to find adequate matches (common support). To provide a robust result of the PSM, we use four methods of matching. Namely: Nearest Neighbor matching (NNM), radius, Kernel, and stratified matching (Caliendo and Kopeinig 2005). According to Rosenbaum and Rubin (1983) a standardized difference greater than 20% should be considered too large, and an indication of the matching has failed. Additionally, the pseudo R² should be lower and the joint significance of covariates should be rejected, or the p-values of the likelihood logit values should be insignificant which is advised by Sianesi (2004).

**Sensitivity analysis**

Caliendo and Kopeinig (2008) contend that PSM only controls the observed variables, included in the propensity score, to match both the treated and control groups of the households. Un observable characteristics are left out of consideration. As cited in (Menale et al., 2010) it was stated that before interpreting the base line estimates as evidences of a true causal effect of the treatment, testing the presence of unobserved variable is of great importance, which can be done using a sensitivity analysis. Sensitivity analysis is applicable mainly to check whether and to what extent the estimated average treatment effects are robust to possible deviations from the conditional independence assumption (CIA) (Ichino et al., 2008). Although, the CIA is a basic assumption to identify the true treatment effect in the ATT estimation strategy, the validity of the CIA cannot be tested using non-experimental data (Crino, 2011). One of the prime assumptions of the sensitivity analysis is that assignment to treatment may be confounded provided that the set of observable variables, that is, the common support assumption (CSA) no longer holds. But, it is assumed that the CIA is uncompounded given observed X and an unobserved binary variable, U.

\[ Y_0 = D(X, U) \]  

U is not observed, as a result, the outcome of the controls cannot be credibly used to estimate the counter factual outcome of the treated.

\[ E \left( \frac{Y_0}{D=1}, X, U \right) = E \left( \frac{Y_0}{D=0}, X, U \right) \]  

On the other hand, knowing U (together with the observable covariates X) would be enough to consistently estimate the ATT, hence:

\[ \Pr \left[ D = 1 / Y_1^c, Y_0^c, X, U \right] = \Pr \left[ D = 1 / X, U \right] \]  

The above equation assumes the basic assumption CIA to be violated by the incidence of an unobserved binary variable U \( \epsilon [0, 1] \). It tries to assess the sensitivity of the point estimate of the ATT to changes in a small set of parameters that characterize the relationship of U with treatment and outcome variable.

The distribution of the unobserved binary confounding variable U can be derived by specifying the parameters clearly as:

\[ P_i \equiv \Pr \left[ U = 1 / D = i, Y = j \right] = \Pr \left[ U = 1 / D = i, Y = j \right] \]  

With \( i, j \in \{0, 1\} \) that give the probability value U=1 in each of the four groups defined by the treatment status, the outcome value, and then a value of U is attributed to each unit. As far as the conditions mentioned below holds true; Ichino et al. (2008) found that by simply choosing the parameters \( P_i \) it is possible to simulate a "dangerous" confounder or a confounder whose existence might give rise to a positive and significant ATT estimate even in the absence of a true causal effect. Thus,

\[ P_{01} > P_{00} \Rightarrow \Pr \left[ Y_c^c = 1 / D = 0, U = 1, X \right] > \Pr \left[ Y_c^c = 1 / D = 0, U = 0, X \right] \]  

\[ P_{10} > P_{00} \Rightarrow \Pr \left[ D = 1 / U = 1, X \right] > \Pr \left[ D = 1 / U = 0, X \right] \]  

Consequently, considering the simplest assumption of \( P_{01} > P_{00} \) and \( P_{10} > P_{00} \) it is possible to simulate a confounding factor that has a positive effect on the untreated outcome \( Y_0 \) and on the treatment assignment conditioning on X respectively can be simulated. The sensitivity analysis approach finally boils and reach to easily interpretable measures of association (both the outcome effect and selection effect) are estimated by the average odds ratios as specified here after. The "outcome effect of the simulated confounder is given by:

\[ \mu = \sum_{i=1}^{k} \frac{1}{R} \left( \Pr \left[ Y = 1 / D = 0, U = 1, X \right] - \Pr \left[ Y = 1 / D = 1, X \right] \right) + \Pr \left[ Y = 0 / D = 0, U = 0, X \right] / \Pr \left[ Y = 1 / D = 0, U = 0, X \right] \]

On the same fashion, the logit model of \( \Pr \left[ Y = 1 / U, X \right] \) is also estimated at every iteration and the average odds ratio of U is reported as the "selection effect" of the simulated confounder here:

\[ \nu = \Pr \left[ D = 1 / U = 1, X \right] * \Pr \left[ D = 0 / U = 0, X \right] / \Pr \left[ D = 1 / U = 0, X \right] * \Pr \left[ D = 0 / U = 0, X \right] \]

Where, \( R \) indicates the number of replications \( \mu = \) represents the outcome effect and \( \nu = \) represents the selection effect. It has been argued that if U is simulated under the assumptions that \( P_{01} > P_{00} \) and \( P_{10} > P_{00} \), both the outcome and selection effects must be larger than unity. Therefore, sensitivity analysis in this paper is incorporated and applied mainly to assure whether the inference taken about the impact of both row-planting and improved wheat seed new technologies adoption have better wheat yield increment over the treated small scale households is reliable or not. As a result, sensitivity analysis supports the robustness of estimated results of the intervention as it can be seen later.

**Description of important variables used in the analysis**

Caliendo and Kopeinig (2005) clearly investigated that in estimating propensity score matching, only variables that affect the participation decision of households and the outcome variable simultaneously are unaffected by participation to a program or the participation must be incorporated in the logit model. In doing so, different literatures has been reviewed, expertise ideas were
incorporated, knowledge and experience of the researcher were
even employed so as to differentiate the determinant factors of the
assigned outcome variables used in the study (Table 2).

RESULTS AND DISCUSSION

Descriptive analysis

This part presents the results that were obtained from the
sample respondents. The paper applied both descriptive
and econometric methods of data analysis. In the first part
the descriptive analysis was found. The descriptive
analysis is clearly carried out using the tools like mean,
percentages, standard deviation, and frequency
distribution over both demographic and socio-economic
household characteristics. Hence, it is an auxiliary tool to
have strong econometric output.

Demographic characteristics of row planting adopter
households

Based on the result, about 19% of the sample
households were headed by females and the remaining
81% were headed by males. Besides, out of the 100% row
planting adopter household heads, 18.2% were
female headed unlike to 81.8% male headed households
(Table 3). As it can be seen from Table 4, approximately
68.3% of the sample households were found to be non-
educated; whereas about 31.7% of the total sampled
household heads attained some educational level that
ranges from grade 1 to 8. Comparisons by the level of
wheat row planting participation reveal that 99 (33% participants) and 201 (67% non-participants) were found
educated and non-educated, respectively. Similarly, the
sex ratio of educated adopter to non adopter is almost
the same. The level of education ranges from non-
educated to eighth grade.

About 27.7% from the adopter household heads and
5.3% non adopter sampled households have had a
chance to see demonstration agricultural sites organized
by their local government either in their neighbours or
outside of their Woreda. According to the survey result,
above 67% of the respondents did not get a chance to
participate in field visit days and keeps them away from
gaining best agricultural practices (Table 5). As a result, a
household who had participated on field visit days adopts
agricultural technology as compared to those who do not.
As indicated in Table 6, the average age of the adopter and
non adopter smallholder farm head is 48 and 46 years consecutively. Particularly, age of the adopter and
non adopter exhibits as there exists a relationship with
the probability of adoption of the row planting. Concisely,
age of the household head is considered as a proxy for
experience. Definitely, education plays a great role in
adoption of row planting and other technologies. It assists
both adopter and non adopters as a crucial way of
collecting information with regard to row planting
technology as well. The t-test revealed that significant at
1% probability level is of significance. From Table 6, it
can be said that sex of the smallholder farm were
statistically significant at (p < 0.05). On the other hand, it
reveals that male headed households have more
probability of participating in row planting technology
unlike females. This might be because of the fact that
more physical effort is expected to exert on agriculture.
Moreover, a field visit day has an influence on the
probability of wheat row planting use. Households with
more chance to participate in field visit days were more
likely to engage in row planting use than that of their
counterparts. It's also significant at (p < 0.01) probability
level of significance. Hence, it serves as easy way to own
best technical knowledge and trust more in regard to the
benefits of that new technique in their plots. From Table 7
above it can be said that around 34, 20, and 13% of the
respondents from the survey replied that the main
reasons for not participating in row planting were due to
lack of working labor availability, infertility of farmland
ownership and lack of awareness regarding to the
benefits of adopting row planting technology. Moreover, a
shortage of working labor by smallholder farms caused
largely mistrusts on that technology and leads to not
adopting it. And that was partly misperceived simply in
observing the high labor demand during wheat sowing
season.

Table 2. Summary of explanatory variables and their expected signs used in the model.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description of Variables</th>
<th>Type of the Variable</th>
<th>Expected Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent</td>
<td>A household head who has adopted row planting on wheat on his/her farm since last year</td>
<td>Dummy (1= if a household adopts</td>
<td>±</td>
</tr>
<tr>
<td>Variable</td>
<td>(2013), otherwise (0)</td>
<td>wheat row planting, 0 = otherwise)</td>
<td></td>
</tr>
<tr>
<td>Age of hh</td>
<td>Age of the household head in Years</td>
<td>Continuous</td>
<td>±</td>
</tr>
<tr>
<td>Sex of hh</td>
<td>Sex of the household head</td>
<td>Dummy(1=Male,0= Female)</td>
<td>±</td>
</tr>
<tr>
<td>Education of hh</td>
<td>Education level of the household</td>
<td>Continuous</td>
<td>+</td>
</tr>
<tr>
<td>Fie Field visit days</td>
<td>If a household ever get a chance and see row planted demonstration</td>
<td>Dummy (1=Yes,0=No)</td>
<td>+</td>
</tr>
</tbody>
</table>

From Table 2.

Table 3.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description of Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent</td>
<td>A household head who has adopted row planting on wheat on his/her farm since last year</td>
</tr>
<tr>
<td>Variable</td>
<td>(2013), otherwise (0)</td>
</tr>
<tr>
<td>Age of hh</td>
<td>Age of the household head in Years</td>
</tr>
<tr>
<td>Sex of hh</td>
<td>Sex of the household head</td>
</tr>
<tr>
<td>Education of hh</td>
<td>Education level of the household</td>
</tr>
<tr>
<td>Fie Field visit days</td>
<td>If a household ever get a chance and see row planted demonstration</td>
</tr>
</tbody>
</table>


Table 3. Sex of the household head.

<table>
<thead>
<tr>
<th>Description</th>
<th>Sample HH</th>
<th>%</th>
<th>Adopter</th>
<th>%</th>
<th>Non-adopter</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>57</td>
<td>19</td>
<td>18</td>
<td>18.2</td>
<td>39</td>
<td>19.4</td>
</tr>
<tr>
<td>Male</td>
<td>243</td>
<td>81</td>
<td>81</td>
<td>81.8</td>
<td>162</td>
<td>80.6</td>
</tr>
<tr>
<td>Total</td>
<td>300</td>
<td>100</td>
<td>99</td>
<td>100</td>
<td>201</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Computed from own survey, 2014.

Table 4. Education level of household head.

<table>
<thead>
<tr>
<th>Description</th>
<th>Non-educated HH</th>
<th>Educated (1 to 8th grade)</th>
<th>Adopter</th>
<th>%</th>
<th>Non adopter</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>41</td>
<td>16</td>
<td>49</td>
<td>16.3</td>
<td>46</td>
<td>15.3</td>
</tr>
<tr>
<td>Male</td>
<td>164</td>
<td>79</td>
<td>50</td>
<td>16.7</td>
<td>155</td>
<td>51.7</td>
</tr>
<tr>
<td>Total</td>
<td>205</td>
<td>95</td>
<td>99</td>
<td>33.0</td>
<td>201</td>
<td>67.0</td>
</tr>
</tbody>
</table>

Source: Computed from own survey, 2014.

Table 5. Access to field visit days.

<table>
<thead>
<tr>
<th>Description</th>
<th>Sample HH</th>
<th>%</th>
<th>Adopter</th>
<th>%</th>
<th>Non adopter</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>201</td>
<td>33</td>
<td>16</td>
<td>5.3</td>
<td>185</td>
<td>61.7</td>
</tr>
<tr>
<td>Yes</td>
<td>99</td>
<td>67</td>
<td>83</td>
<td>27.7</td>
<td>16</td>
<td>5.3</td>
</tr>
<tr>
<td>Total</td>
<td>300</td>
<td>100</td>
<td>99</td>
<td>33.0</td>
<td>201</td>
<td>67.0</td>
</tr>
</tbody>
</table>

Source: Computed from own survey, 2014.

Table 6. Summary of statistics for variables of the smallholder farm characteristics of row planting adoption.

<table>
<thead>
<tr>
<th>Variables</th>
<th>adopters = 99</th>
<th>Non adopters= 201</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Err</td>
<td>Mean</td>
</tr>
<tr>
<td>Age</td>
<td>48</td>
<td>0.83</td>
<td>46</td>
</tr>
<tr>
<td>Education</td>
<td>1.83</td>
<td>0.1068</td>
<td>0.87</td>
</tr>
<tr>
<td>Sex</td>
<td>0.8181</td>
<td>0.0389</td>
<td>0.8059</td>
</tr>
<tr>
<td>M</td>
<td>1.757</td>
<td>0.2419</td>
<td>0.5174</td>
</tr>
<tr>
<td>Field visit days</td>
<td>0.8383</td>
<td>0.3718</td>
<td>0.0796</td>
</tr>
</tbody>
</table>

Source: Computed from own survey, 2014. **significant at 5%, *** significant at 1% probability of significance level.

Table 7. Reasons for not adopting wheat row planting technology on their farm.

<table>
<thead>
<tr>
<th>Description</th>
<th>Sample households</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adopter</td>
<td>101</td>
<td>33.0</td>
</tr>
<tr>
<td>Labor consuming</td>
<td>97</td>
<td>34.0</td>
</tr>
<tr>
<td>Lack of awareness</td>
<td>42</td>
<td>13.0</td>
</tr>
<tr>
<td>Cultivable land infertility</td>
<td>60</td>
<td>20.0</td>
</tr>
<tr>
<td>Total</td>
<td>300</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Own survey, 2014.

Econometric analysis

To estimate the impact of adopting wheat row planting, newly introduced technology on wheat production of small scale households was employed using different ATT estimation algorithms. Lastly, the sensitivity analysis
has been implemented to test the robustness of estimated ATTs in the PSM. In dealing with all these econometric estimates, STATA 12 version has been employed.

In order to estimate the propensity scores to match the outcomes of adopter, non adopter households logistic estimation model was also applied. The marginal effects results are provided below in Table 8. The pseudo R-squared is found about 0.5782, meaning all the explanatory (independent) important variables included in the model do exactly explain 58% of the probability of households row planting technology adoption. The overall model is proven as it's statistically significant at 1% probability level of significance. Farm field visit day programs are 78% higher than other factors among household heads. Again, it’s statistically significant at 1% probability level of significance.

Indeed, a farm field visit day participation plays a great role in obtaining experience and skill in different ways. Therefore, households who participate in farm field visit day programs are 78% higher to adopt row planting new technology than non participant households, (ceteris paribus). Those results are consistent to the researches that had been done before (Tsegaye and Bekelle, 2012; Bola et al., 2012; Ibrahim, 2011; and Mamudu et al., 2012). As household’s age increase (getting older and older) by one year, the probability of adopting row planting decrease by almost 0.5%, (ceteris paribus). This might be due to the fact that old households might oppose the new technology unlike to youngster farmers.

### Table 8. Logit estimate for propensity score for the study area.

| Variables      | Coefficient | P>|Z|  | Marginal effect dy/dx | P>|Z|  |
|----------------|-------------|-----|----------------------|-----|
| Sexhh**        | -1.583      | 0.018 | -3.442               | 0.027 |
| Agehh***       | 0.4986      | 0.007 | 0.091                | 0.009 |
| Educ_hh        | 0.3933      | 0.347 | 0.071                | 0.350 |
| Fieldvi_days***| 4.289       | 0.000 | 0.776                | 0.000 |
| M              | 0.5505      | 0.197 | 0.1                   | 0.198 |
| Age_squar**    | -0.0043     | 0.018 | -0.001               | 0.021 |
| _cons          | -15.812     | 0.000 |                      |     |

Number of obs = 300; Logistic Regression; Wald chi² (6) = 220.01; Log likelihood = 80.25; Prob > chi² = 0.0000; M = Sexhh*Educ_hh; Pseudo R² = 0.58; The region of common support point is [0.01803602; 0.99981767].

***, ** and* are statistically significant at 1, 5 and 10%, respectively. Figures in parenthesis are standard errors. Source: Own survey, 2014.

The marginal effect estimates of Table 8, shows that keeping other factors constant, a 1 year increase in the age of the household head, increases households’ probability of adopting row planting technology on wheat by 9%. This seems almost the same in adopting row planting by all age groups other than other factors among household heads. Again, it’s statistically significant at 1% probability level of significance.

The result for the logit estimates of households’ probability of adopting row planting technology is presented in Table 8. At the bottom of the table we see 300 observations in the data set that were used in the analysis. The Pseudo R² is the measure of goodness of fit, which is 0.58. This implies that 58% of the variation in the households’ probability of adopting the technology is explained by the independent variables in the model. The Wald chi² (6) 220.01 with a p-value (Prob>chi²) 0.0000 also tells that the logit model as a whole is statistically significant as compared to the model with no predictors. As reported in the same table, the coefficients for the row planting technology adoption such as sex, age, field visit days, and age square are significant at 1 and 5% probability level of significance. Besides, those explanatory variables have the expected negative and positive signs.

### Interpretations of the marginal effects of wheat row planting adoption

The marginal effect estimates of Table 8, shows that keeping other factors constant, a 1 year increase in the age of the household head, increases households’ probability of adopting row planting technology on wheat by 9%. This seems almost the same in adopting row planting by all age groups other than other factors among household heads. Again, it’s statistically significant at 1% probability level of significance.

Indeed, a farm field visit day is statistically significant at 1% probability level of significance. Farm field visit day participation plays a great role in obtaining experience and skill in different ways. Therefore, households who participate in farm field visit day programs are 78% higher to adopt row planting new technology than non participant households, (ceteris paribus). Those results are consistent to the researches that had been done before (Tsegaye and Bekelle, 2012; Bola et al., 2012; Ibrahim, 2011; and Mamudu et al., 2012). As household’s age increase (getting older and older) by one year, the probability of adopting row planting decrease by almost 0.5%, (ceteris paribus). This might be due to the fact that old households might oppose the new technology unlike to youngster farmers.

### Impact estimation of ATT for row planting technology adoption on wheat produce

After the propensity score is estimated, the next task is to
match the treated with the control groups based on their scores. This can also be done using different matching methods like NNM, Radius, Kernel, and the Stratification matching methods. Although, it was worthy enough to deploy only one PSM matching method to show the impact of adoption of row planting production enhancing technology, for the sake of transparency and to exhibit accuracy of the evidence four of the above matching algorithms were implemented. The results illustrated that adoption of new technology have a positive and significant impact on enhancing wheat produce from the ATTs estimations of Stratification, Radius, Kernel, and NNM matching methods.

As one can see from Table 9, the results of the matching techniques are statistically significant at (p <0.01) probability level of significance. Similarly, the ATT result lies between 9.7 quintal in the stratification and 15.844 quintal per “Tsimdi” or 0.25 ha a year in the remaining three matching algorithms. Undeniably, the smallholder farms who had adopted row planting technology on their marginal farm land on average has obtained 14 quintal of wheat yield per “Tsimdi” at a cost of sowing around 1,200 ETB greater (40 quintal to 60 quintal per hectare) than that of non adopters in a single production year. However, the matched control group on average has obtained below four and half quintal of wheat per “Tsimdi” at an average cost of sowing 900 ETB (less than 20 quintal per hectare) on the same single production year. Therefore, adopting row planting technology on wheat as a package (row and spacing, improved seed, fertilizer rates /and or compost, early hand weeding and hoeing, tilling repeatedly) is vital.

As can be seen, adopters of row planting technology on wheat as a package increase their wheat yield 50 to 80% as compared to non adopters. The wheat yield increase obtained in this paper is consistent with the previous research outputs (Gashaw et al., 2014; Tsegaye and Bekelle, 2012; Bola et al., 2012; Ibrahim, 2011; and Mamudu et al., 2012). Lastly but not the least, narrowing the gap between adoptors and non adoptor is indispensable in order to enhance wheat yield and get food secured soon in the specified area.

**Estimation results of the Sensitivity Analysis**

Indeed, in order to check the robustness of the estimated results aforementioned, sensitivity analysis has been undertaken. In case the CIA fails in PSM it can easily solve the pitfall using the comparison between the simulated and baseline ATTs estimates. As it can be seen from Table 10, though U is associated with a large outcome effects (μ >1) and selection effects (V>1) for the NNH, Kernel, and Radius matching algorithms, the overall simulated ATTs of each adopter of both row-planting and improved wheat yield technology are still too much closer to the baseline ATTs. Hence, both values of outcome effect and selection effects are larger than unity.
each, and also the difference in percentage between the baseline ATTs and simulated ATTs are below 10% which makes it stronger in the credibility of our estimated ATTs as well.

The simulated ATT of each of the household wheat produce is too close to the baseline estimate. Obviously, this implies that it is only when U is simulated to provide incredibly large outcome effect; the ATT can be driven far from the baseline estimates or even closer to zero. Over all, the results estimated support strengthens the robustness of the matching analysis which is the reliable conclusion.

CONCLUSIONS AND POLICY IMPLICATION

The research was motivated to examine the impact of wheat row planting adoption on households wheat produce in Ofila wheat belt district of Tigray regional state of Ethiopia. It also intended to examine the potential factors that affect smallholder farms decision on whether to participate in row planting or not. Undeniably, the smallholder farms who had adopted wheat row planting technology on their marginal farm land on average had obtained 14 quintal (1.4 tone) of wheat yield per “Tsimdi” or 0.25 ha at a sowing cost of around 1,200 ETB larger (40 to 60 quintal per hectare) than that of non adoptors (use broadcasting) in a single production year. As it can be seen adopter households of wheat row planting technology were increased in their wheat yield 50 to 80%more as compared to non adoptor households. However, the matched control group on average has obtained below four and half quintal of wheat per “Tsimdi” at an average cost of sowing 900 ETB (less than 20 quintal per hectare) on the same single production year. Therefore, the research recommended that adopting wheat row planting technology as a package (row and spacing, improved seed, fertilizer rates and or compost, early hand weeding and hoeing, tilling repeatedly) is vital in enhancing wheat yield on the marginal farm lands. Complementary agricultural technology adoption best yield results when they are taken up as a complete package together, rather than in the individual elements to give high wheat yield.

Conflict of Interests

The author has not declared any conflict of interests.

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