

## PERCEPTIONS, IMPACTS, AND REWARDS OF ROW PLANTING

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**T**eff is Ethiopia's most important staple crop, but the crop is characterized by low yields. This low teff yield is seemingly explained by the limited knowledge about possible avenues for improving teff productivity, combined with problems inherent to teff botany. Teff research has received limited national and international attention—the latter presumably because of its localized importance in Ethiopia (Berhane et al. 2011; Fufa et al. 2011). Moreover, teff yields are low because of agronomic constraints that include lodging, low modern input use, small seeds, and high postharvest losses (Habtegebrial, Singh, and Haile 2007; Berhe et al. 2011; Fufa et al. 2011). Recently it has been argued that the traditional sowing technology is a major constraint to increasing teff productivity (Berhe et al. 2011). Farmers typically plant teff by broadcasting—that is, scattering teff seed by hand at a high seed rate. Alternative planting methods, such as row planting seeds or transplanting seedlings, in which the seed rate is reduced and more space between plants is given, are seen as being superior to traditional broadcasting (Berhe et al. 2011; Fufa et al. 2011). Experiments on these alternative planting methods in controlled settings have shown large and positive impacts on teff yields (Berhe et al. 2011; Fufa et al. 2011). As a consequence, the Ethiopian government rolled out a nationwide campaign in 2013 to promote the use of row planting, aiming to scale up its adoption to almost 2.5 million teff farmers.

However, the impacts of the widespread promotion campaign of row planting of teff in particular on land and labor productivity are unknown. This is mainly due to a lack of reliable and objective farm-level data. Moreover, no systematic effort has yet been put into examining farmers' perceptions after they experimented with the new sowing techniques. The contribution of this chapter is to analyze the impact of the promotion campaign of row planting of teff and to infer farmers' perception about the new planting technique and the promotion thereof. To do so, data were collected during the "pre-scale-up"

phase of the promotion campaign in 2012/2013 by surveying farmers from 40 villages exposed to the promotion campaign. Data was collected by means of a large-scale randomized control trial (RCT), randomly assigning teff farmers to implement either row planting or broadcasting of teff seed on an experimental plot. The effect of receiving a promotion campaign for sowing teff seeds in rows, together with a reduced seed rate (this combination is referred to as row planting), was measured on teff farmers' land, as well as on labor productivity.

The promotion program of row planting was not found to significantly increase teff yields at farm level. These disappointing results conflict with the yield benefits realized in well-managed on-station research trials and on demonstration plots (ATA 2013a) and were lower than expected by farmers. Moreover, labor requirement increased when adopting row planting, and there was a substantial drop in labor productivity for row-planting farmers compared with the traditional broadcast planting. These results suggest why most farmers exposed to row planting of teff continued row planting in the year afterward, but only on a small part of their teff lands. In addition, the sensitivity of the yield findings with regard to the effects of "learning by doing" (that is, experienced farmers) were analyzed as well as examining scenarios where mechanized row planters would reduce labor requirements. In such scenarios, adopting of row planting would become more beneficial for farmers.

## **Reduced Seed Rate Technologies**

Traditionally, farmers broadcast teff seed using a high seed rate of between 25 and 50 kilograms per hectare (ATA 2013a). It is argued that this practice reduces yield because the uneven distribution of seed increases competition between teff plants for water, light, and nutrients, and makes weeding more difficult once the plants have matured (Fufa et al. 2011). As a solution, it is recommended to reduce the seed rates and to plant in rows or, alternatively, to transplant seedlings from a nursery plot. Reducing the seed rate to 2.5–3.0 kilograms per hectare reduces competition between seedlings and allows for optimal tillering or branching out of the plants. By row planting or transplanting, land management and especially weeding can be done more easily. The incidence of lodging is also found to be reduced, as the stem of row-planted teff is better able to support the weight of the filled head of grain (Berhe et al. 2011; also see Chapter 3 in this book).

On-station agronomic research has resulted in the belief that the reduced seed rate technologies will increase teff productivity. Experiments on-station

showed that when teff was planted in rows and appropriate types of fertilizer were used, teff yields were on average three times higher than yields obtained from traditional broadcasting (Berhe et al. 2011; ATA 2012). Given these positive results, programs to promote the technologies to teff farmers at a large scale were rolled out by the government (ATA 2013b). These programs, presented in the form of a technology package, were promoted to farmers. They included planting of seed or transplanting seedlings in rows, a reduction of the seed rate to 5 kilograms per hectare, a sowing depth of 2–3 centimeters, use of improved seed (Quncho variety), and the application of recommended levels of chemical fertilizer (DAP and urea).

In 2011 the Ministry of Agriculture (MoA), with the support of the Agricultural Transformation Agency (ATA), provided this package and extension to 1,400 farmers. On-farm experiments were done in 90 Farm Training Centers (FTC) at the local kebele administrative level in Ethiopia's four main teff-producing regions: Amhara, Oromia, Tigray, and the Southern Nations, Nationalities, and Peoples' (SNNP) region. The results of this promotion campaign showed an increase of 75 percent in teff yield (ATA 2013a). In 2012 this experiment was extended to almost 70,000 farmers from 1,337 FTCs. Data collected from 15,800 households that participated in this “pre-scale-up” phase indicated that teff yields had increased by 70 percent over the national average (Berhe et al. 2011; ATA 2013a). In 2013 the program was rolled out nationwide to reach 2.5 million farmers (ATA 2013a).<sup>1</sup>

## Design of the Intervention

### Design and Methodology

The experiment evaluated the impact of the “pre-scale-up” program of promotion of teff row planting implemented in 2012 through which the reduced seed rate technologies—as part of a package—were extended to a selected number of farmers. The design of the evaluation was in line with the rollout of the program by MoA in that year. However, some modifications were made to the rollout to ensure that the selection of farmers to be studied was completed

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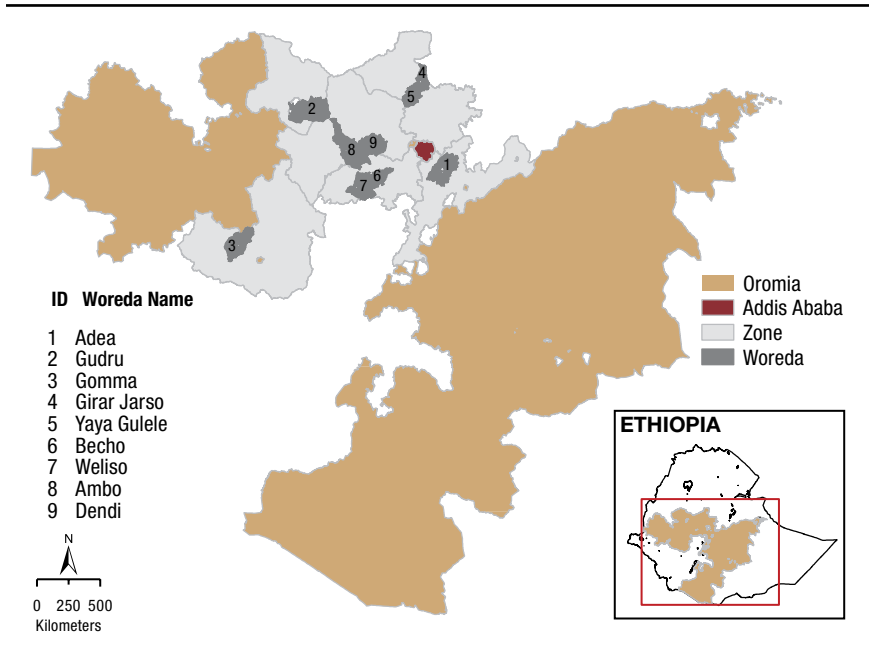
1 Overall, agronomic research tends to find positive effects of row planting (even if it is scaled up), but several small-scale trials with farmers showed lower effects that were sometimes statistically not significant. Moreover, the results from agronomic research conducted by the Ethiopian Institute of Agricultural Research (EIAR) showed that yield increases from implementing row planting were small and that changing seed rates, planting depths, and plant spacing did not affect teff yields significantly (see [Chapter 3](#) in this book).

randomly. Furthermore, farmers that implemented the traditional broadcasting technology were included in the experiment to create an appropriate control group. The sample design followed a two-stage randomization approach. First, from the 23 Agricultural Growth Program (AGP) woredas (district-level administrative unit) in the Oromia region, 10 woredas were randomly selected (Figure 5.1).<sup>2</sup> Four FTCs were then randomly selected out of all FTCs within the selected woredas. From a total of 60 randomly selected farmers in each FTC, 20 farmers were randomly selected to be interviewed for the survey.<sup>3</sup> In the second stage, farmers were randomly allocated to treatment and control groups for the study, and 10 farmers were selected to do either row planting or broadcasting. The farmers in the sample were all progressive, so-called model farmers with whom agricultural extension agents, the development agents (DA), had worked with relatively closely.

There was close cooperation with the local DAs in each FTC for selecting, training, and assisting farmers who participated in the experiment. As the objective was to evaluate the impact of the program in the field, no additional assistance to DAs was provided, but extra training was received on the inclusion of control farmers into the study. DAs instructed all farmers to grow teff using the allocated sowing technology on a small experimental plot of 300 square meters. Farmers assigned to the row-planting treatment group received 150 grams (5 kilograms per hectare) of improved teff seed (Quncho) for free, while farmers in the control group received 900 grams (30 kilograms per hectare) of the same seed, also for free. Finally, all groups received at no cost identical fertilizer packages (3 kilograms of both urea and DAP) to ensure that the same amount of inputs was used on the designated experimental plot for each farmer involved in the study.

The selected farmers in the survey area were visited three times. First, the baseline survey of October 2012 collected data on the experimental plot characteristics and teff production for the production year of 2011/2012. Second,

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- 2 AGP is a five-year program aimed at reducing poverty by increasing agricultural productivity and improving market access for smallholders in 83 woredas in Amhara, Oromia, SNNP, and Tigray (Berhane, Paulos, and Tafere 2011).
  - 3 While randomization ensures the accuracy of the estimated effect, the precision of the estimation depends on the sample size. Vandercasteelen et al. (2016) provides a detailed explanation of the sample-size calculations and randomization approach. Ex ante power calculations showed an optimal sample size of about 570 farmers in the experiment, which allows a size effect of about 0.2 metric tons of changes in teff yield due to row planting. However, in anticipation of potential survey implementation problems, this sample size was increased to 800 farmers (that is, 20 farmers in each village).

**FIGURE 5.1** Map of the intervention woredas

**Source:** Authors' illustrations, based on official maps.

**Note:** One of the selected woredas withdrew and is not indicated on the map.

farmers were revisited just before harvesting between November 2012 and January 2013 by enumerators from Ethiopia's Central Statistical Agency (CSA) to measure teff output from the experimental plot. Finally, an impact survey was fielded after the teff harvest in February 2013, similar to the baseline survey, with additional information collected on teff production and management practices on the experimental plot. This quantitative information was further complemented with qualitative investigations, plus a community questionnaire, administered at the same time as the impact survey, to understand the perceptions held of these new technologies by participating and nonparticipating farmers.

However, there were several issues in implementing the survey. First, one woreda did not follow the MoA's recommendations during the promotion campaign and was therefore dropped out of the experiment. Second, despite clear instructions, the assignment of farmers to the different technologies by the DAs was not implemented randomly everywhere. As a consequence, we only use the randomized data for 19 FTCs where technology assignment was

done randomly.<sup>4</sup> Finally, in some of these “random” villages, the actual number of farmers interviewed was not equal to the target number of 20. Some of the selected farmers did not prepare their experimental plot in line with the MoA’s recommendations—for example, experimental plots were too large or too small, or seed rates applied were not appropriate. The DA randomly replaced these selected farmers with other farmers from the remaining group of 40 in the village but failed to gather a total of 20 farmers in some villages. It proved difficult to engage additional broadcasting farmers in the experiment. Enumerators identified these “nonvisited” farmers in the random villages and revisited them afterward. As a consequence, the random sample consists of 537 farmers, which included both initially selected farmers (410) as well as replacement farmers (127).

Of interest in this research is the effect of implementing row planting on teff productivity for an individual farmer ( $i$ ) in the sample.  $T_i$  is defined as the treatment variable:  $T_i = 1$  for a row-planting farmer and 0 otherwise.  $Y_i(T_i)$  indicates teff productivity (either land or labor) given the treatment:  $Y_i(1)$  is teff productivity when a farmer implements row planting, while  $Y_i(0)$  is teff productivity when the farmer uses traditional broadcasting to plant teff seed. The impact of implementing row planting on the teff productivity of the experimental plot of a farmer  $i$  is then the difference in teff productivity between the treatments:  $\Delta_i = Y_i(1) - Y_i(0)$ . This effect is measured by the Average Treatment effect on the Treated (ATT), the average gain in teff productivity a farmer realizes from using row planting for row planters:

$$E\{\Delta_i\} = E\{Y_i(1)\} - E\{Y_i(0)\}$$

In general, the yield a row-planting farmer would obtain from implementing traditional broadcasting (the counterfactual) is not observed for row-planting farmers as they were assigned to row planting only. However, the random assignment of farmers to different sowing practices and the identical input distribution implies that all farmers in the sample were statistically identical in their characteristics relevant to teff production. Hence, the observed teff productivity from traditional broadcasters could be used to identify the counterfactual of row planters. Randomization ensures that the difference in teff yield between the traditional broadcasting and row-planting farmers could be attributed solely to the sowing method. As a consequence, by taking the

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4 See Vandecasteele et al. (2013) for a complete overview of the survey implementation problems and results of analysis on nonrandomly collected data.

**TABLE 5.1** Sample setup

Farmers in the sample	Broadcasting	Row planting	Total
Target of experimental sample	400	400	800
Outcome of impact survey	342	556	898
Sample of random farmers	195	342	537
Sample of random farmers with nonmissing self-reported output	193	338	531
Sample of random farmers with nonmissing crop-cut output	154	249	403

**Source:** Authors' calculations.

expected mean difference between the two groups, this gave an estimate of the effect of row planting on teff yield.

The implementation of row planting on the experimental plot could not be enforced, and potentially some initially assigned row-planting farmers may have shifted to the traditional broadcasting technology (or vice versa). This presents a problem in the experiment if selection occurs on the expected gains (that is, higher returns) to row planting, where adopting farmers systematically differ from those that refuse or are unable to adopt row planting. During the impact survey, careful compliance checks were made, and from the “nonvisited” farmers in the random sample, 20 farmers were identified who refused to take up the assigned technology and instead shifted to the opposite technology (18 farmers shifted from row planting to broadcasting and 2 farmers did the opposite). Even though this “one-sided noncompliance” rate is small (only 4 percent), these noncompliance issues are taken into account by comparing farmers based on their initial random assignment of ( $S_i$ ). The Intention-to-Treat (ITT) framework measures the effect of row planting on teff yield for those farmers who were initially selected to participate in the experiment, irrespective of the actual implementation of the assigned technology on their experimental plot. [Table 5.1](#) gives an overview of the sample numbers that are explained in more detail below.

### Characteristics of Farmers Participating in the Experiment

First, the farmers who took part in the experiment—that is, the 537 farmers, which consist of 195 control farmers and 342 treated (row-planting) farmers—are described. [Table 5.2](#) shows the general characteristics of the interviewed farmers as well as characteristics of the experimental plots. The sample was dominated by males (99 percent) who were literate (68 percent) and on average 44 years old. The surveyed households had on average seven household

members who lived half an hour away from the nearest FTC. The assigned technology was implemented on an experimental plot with an average size of 719 square meters. This is larger than the instructed size of 300 square meters because some farmers used an experimental plot that was too large. This plot was plowed on average five times and weeded twice. Most farmers did not use organic inputs, nor did they apply manure (90 percent), but all relied on the urea and DAP inorganic fertilizer that was provided for free by the DA. The teff seed provided to almost all was of the Quncho variety, obtained for free from the DA, indicating that the rollout of the distribution of that input worked well. Most farmers did not suffer from insects or other pests, plant diseases, late input supply, or problems with rain on their experimental plot.

The effect of row planting could only be directly estimated if the two groups could be shown to be balanced in the characteristics that determine teff yield (that is, education, household assets, and so on). Therefore, balancedness tests were performed by comparing the means of each variable for both groups and looking for statistically significant differences in characteristics. The balancedness property can only be tested on variables that are not affected by the treatment (that is, variables measured during the baseline) and is performed based on a regression model. In this case, the characteristics of the farmer and the experimental plot were the dependent variables and the treatment variable was the independent variable. [Table 5.2](#) indicates that both groups of farmers were indeed similar in age, literacy, education, household size, and nonfarm income, as shown by insignificant t-values for most of the coefficients.

In [Table 5.2](#) the difference in mean values between row planting and broadcasting farmers for variables that potentially affected the treatment status (that is, plot level variables) are reported. In general, farmers in both groups had fairly similar experimental plot characteristics, input usage (except for urea), and production practices and experienced similar shocks during the teff production period. This indicated that the only (observable) difference between both groups of farmers was the sowing technology. However, the rate of urea (grams per square meters) usage is larger for row-planting farmers, although these farmers are less likely to use herbicides compared with broadcasting farmers. Also, by design, the seed rate applied is reduced in row-planting technology. The imbalance between control and treated farmers are covered further below.

Additional qualitative information was collected from both participating and nonparticipating farmers in the experiment from all 36 villages in

**TABLE 5.2** Characteristics and balancedness of control versus treated farmers

Household (head) and experimental characteristics	Control (n = 195)	Difference	Treated (n = 342)
	Mean		t-value
Age (years)	44.00	-1.04	-0.84
Gender (male = 1)	99.40	-2.79	-1.89*
Can write (yes = 1)	31.80	-6.42	-1.22
Literacy (yes = 1)	68.20	5.59	1.04
Primary education (yes = 1)	77.10	1.96	0.43
Distance to Farmer Training Center (minutes)	33.90	-0.40	-0.16
Household size (members)	7.13	-0.22	-1.06
Total agricultural assets value (ln of birr)	6.79	-0.02	-0.16
Total assets value (ln of birr)	7.25	0.09	0.44
Total land owned by household (hectares)	5.87	-0.12	-1.05
Income from other activities (yes = 1)	75.40	-7.54	-0.83
Household asked for loan (yes = 1)	14.00	4.47	1.49
Member of Iqub group (yes = 1)	35.80	0.28	0.06
Area (square meters)	719.00	-111.00	-0.99
Distance to plot from house (minutes)	11.10	0.33	0.19
Sloped plot (yes = 1)	17.30	-2.51	-0.85
High soil quality (yes = 1)	36.30	0.00	0
Number of plows (number)	4.98	-0.01	-0.06
Number of weeding (number)	1.88	0.08	0.46
Seed rate used (kilograms per hectare)	27.52	-17.00	15.30***
Organic input used (yes = 1)	11.20	-2.23	-0.71
Inorganic fertilizer used (yes = 1)	99.40	-0.28	-0.36
Manure used (yes = 1)	10.10	-3.35	-1.08
Rate of manure used (grams per square meter)	0.12	0.45	1.02
Urea used (yes = 1)	96.10	1.12	0.80
Rate of urea used (grams per square meter)	0.09	0.01	2.18**
DAP used (yes = 1)	98.90	0.00	0
Rate of DAP used (grams per square meter)	0.12	0.01	0.92
Herbicides used (yes = 1)	77.70	-8.66	-2.22**
Rate of herbicides used (100 Ethiopian birr per square meter)	0.02	0.00	-0.55
Problems of pests (yes = 1)	22.90	2.79	0.87
Problems of diseases (yes = 1)	11.20	-2.23	-0.89

(continued)

TABLE 5.2 Continued

Household (head) and experimental characteristics	Control (n = 195)	Difference	Treated (n = 342)
	Mean		t-value
Problems of late inputs (yes = 1)	22.30	-5.59	-0.96
Days of training received on technologies (number)	2.20	-0.03	0
Visits by expert on experimental plot (number)	2.21	0.05	0

**Source:** Authors' calculations.

**Note:** Asterisks represent level of statistical significance: \* (10 percent significance), \*\* (5 percent significance), \*\*\* (1 percent significance).

community questionnaires.<sup>5</sup> All of the surveyed farmers (teff farmers and community respondents) were model farmers, as they were the target of the “pre-scale-up” phase of the teff technology promotion program. Model farmers tended to be more educated and better-off farmers, making them not representative of all teff farmers in Oromia. However, this did not affect the program evaluation as these model farmers were specifically targeted by the government to adopt the new technologies first (ATA 2013c).

### Regression Models

The survey design described above provided a robust framework within which the impact of row planting on teff productivity could be measured. The ITT is measured by estimating the following regression:

$$Y_i = \alpha + \beta * S_i + \varepsilon_i$$

$\beta$  measures the effect of being assigned to row planting, irrespective of what technology farmers actually implemented on their experimental plot. Two robustness tests are performed to assess the sensitivity of the results. First, the characteristics in which control and treated farmers differ are included as additional control variables in the regression model. These are the variables that are significantly different as shown in Table 5.2, and include gender, seed rate, rate of urea applied, and a dummy for herbicide use. Second, as the selection of farmers to be included in the experiment was done at the village level, village fixed effects are also included in the model. By including the village dummies, this enables control for differences in village level characteristics

5 Note that the RCT used data from the 19 random FTCs, while the community questionnaire used data from all FTCs.

that might affect any teff outcome. For both models the coefficient of the ITT is only reported in the results section to ease representation.

Here, different outcomes of interest are examined. Teff yield is measured in metric tons per hectare, obtained by dividing output by area. While there is reliance on the area measured during the crop-cut survey, there are two measurements of output.<sup>6</sup> First, when farmers harvested and threshed output from their experimental plots, enumerators measured the teff output for the whole plot after drying using a digital balance (“yield from crop-cut”). Second, at the time of the impact survey, after the harvesting, drying, and threshing operations were completed, all farmers were asked to estimate the teff output of the experimental plot (“reported yield after harvest”).<sup>7</sup> For both output measures, there are some missing values (see [Table 5.2](#)). For the random sample, there are six farmers for which the self-reported output is missing. There are more missing values for the crop-cut output (134), which restricts the sample to 410 farmers. In Vandercasteelen et al. (2016) the attrition in the crop-cut data is described in more detail. Additional analysis shows that attrition is not related to treatment and that our results remain once we weight the regressions with the inverse of the probability to have a nonmissing observation of crop-cut output.

## Perceptions on Reduced Seed Technologies

### Farmers' Perceptions

[Table 5.3](#) shows the stated perceptions of teff farmers on broadcasting versus reduced seed rate technologies. All of these data on perceptions were inferred after farmers experimented with the new sowing technology and were collected during the impact survey. In the year the experiment was rolled out (production year 2012), traditional broadcasting was believed to yield about 0.9 metric tons per hectare and 28 bales of straw per hectare. Teff farmers believed that higher teff yields were primarily constrained by the price of

6 Area was measured during the baseline survey using ropes and tapes, and during the crop-cut survey using a compass and ropes. The two measures are strongly correlated (88 percent). Primarily the latter was used, relying only on the area measured during the baseline survey if the other area measure was missing.

7 Measurement errors might occur in area and output variables, complicating yield measures (De Groot and Traoré 2005; Carletto, Savastano, and Zezza 2013). Moreover, it is not straightforward to assess the most appropriate teff yield measure as each of these measures has its own benefits and drawbacks. See Vandercasteelen et al. (2013) for a further description of the yield measures and their correlation.

**TABLE 5.3** Farmers' perception on teff production and row planting

	Number of observations	Percentage or unit stated
What is the teff yield (in metric tons per hectare) you can obtain from:		
Traditional broadcasting?	537	0.9
Broadcasting at reduced seed rate?	367	1.5
Row planting?	451	1.8
Transplanting?	165	1.8
What is the straw yield (in bales per hectare) you can obtain from:		
Traditional broadcasting?	537	28
Broadcasting at reduced seed rate?	306	27
Row planting?	448	27
Transplanting?	159	21
The most limiting factor of higher teff yields is:		
Price of chemical fertilizer	537	36
Unfavorable weather conditions		17
Declining soil quality		13
Access to improved seeds		10
Traditional sowing technique		2
The labor requirement will increase when implementing (yes = 1):		
Broadcasting at reduced seed rate?	537	12
Row planting?		95
Transplanting?		77
Are there benefits of reduced seed rate technologies (yes = 1)?		
The main benefit of reduced seed rate technologies is:	537	87
Saving seeds	466	100
Better weeding		83
Higher productivity		97

**Source:** Authors' calculations.

chemical fertilizer (36 percent), unfavorable weather conditions (17 percent), and declining soil quality (13 percent). Interestingly, the traditional way of sowing was generally not considered as a major limitation, but 90 percent of the teff farmers believed that the reduced seed technologies would improve teff production.<sup>8</sup> For those who believed these positive impacts, the new technologies were expected to save seed (100 percent), make weeding easier

<sup>8</sup> Only 2 percent of the teff farmers responded that the sowing technique was the most important constraint on teff yields, and only 7 percent of the farmers mentioned it as one of the top three

(83 percent), and improve productivity (97 percent). [Table 5.3](#) further reports the high yield increases expected by teff farmers when implementing row planting (93 percent higher), broadcasting at reduced seed rate (63 percent higher), and transplanting (93 percent higher).

The results reported above reflect farmers' overall beliefs on reduced teff seed rate technologies. These beliefs refer to advantages and disadvantages of reduced seed rate technologies in general and do not necessarily represent the experience of farmers on their own experimental plot. When asked about general beliefs, farmers took into account the observed results as displayed on the teff fields of other (often more successful) farmers in the village. Farmers' opinions might also be influenced by information received from extension agents, media, and training. In all instances, farmers were told that it was possible to achieve large yield increases if the reduced seed rate technologies were implemented correctly.

To induce farmers to disclose their own experiences, opinions, and implementation problems with the reduced seed rate technologies, specific perception questions about teff production on their experimental plot were asked as well ([Table 5.4](#)).<sup>9</sup> In this case, 87 percent of the farmers stated that teff production with row planting on their experimental plot would increase production compared with traditional broadcasting by, on average, 29 kilograms (that is, 0.7 metric tons per hectare), with all inputs (improved seed and fertilizer) being equal. While this was slightly lower than general expectations (when not referring solely to their experimental plot) of 0.9 metric tons per hectare, these numbers still illustrated the high expectations farmers had of improved teff productivity with the use of row planting. However, this also indicated that farmers had experienced lower benefits on their experimental plots personally, possibly related to implementation problems. A major concern mentioned was the increase in labor requirements associated with the use of row planting: the majority of farmers assessed the labor inputs with the planting technique to be significantly higher for men, women, and children by, on average, 1, 3, and 2 person-hours, respectively, for the experimental plot as a whole ([Table 5.4](#)).<sup>10</sup>

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constraints, compared to 69 percent and 56 percent for the price of chemical fertilizer and unfavorable weather conditions, respectively (not reported in [Table 5.3](#)).

9 Note that these questions were only asked to farmers who had implemented the reduced seed rate technology.

10 For females, 50 percent of the farmers thought that labor input would increase (by an average of three person-hours); while for children, 62 percent of the farmers expect labor input to increase (by an average of two person-hours).

**TABLE 5.4** Questions on farmers' perceptions of the effect of row planting on the experimental plot

Perceptions	Number of observations	Percentage or unit stated
Compared to traditional broadcasting and using the same seed type, inputs, etc.		
Teff production would be higher (yes = 1)?	339	87
How much (in metric tons per hectare)?	335	29
Straw production would be higher (yes = 1)?	339	55
How much (in bales per hectare)?	305	3
Compared to traditional broadcasting, labor increased (yes = 1)?	339	92
What would be the increase in labor (in hours) for:		
Male	332	1
Female	331	3
Children	326	2

**Source:** Authors' calculations.

### Community Focus Groups' Perceptions

Given the farmers' beliefs that (1) traditional broadcasting limits teff yield and (2) reduced seed rate technologies benefit teff production, all but one community focus group expected row planting to increase teff yields (Table 5.5).<sup>11</sup> The sowing technique was generally not considered as a major limiting factor of teff production, but when explicitly asked whether traditional broadcasting constrained teff production, 86 percent of the community focus groups agreed that the traditional practice of broadcasting seed impeded teff productivity. When asked about the advantages of reduced seed rate technologies, all community focus groups mentioned higher teff yields, while two-thirds of the community focus groups considered the lower seed rate to be the major advantage of row planting (this was similar for broadcasting at a reduced seed rate and for transplanting).<sup>12</sup>

As reduced seed rate techniques are expected to bring about teff productivity benefits, community respondents were further asked to assess

11 Similar results hold for broadcasting at reduced seed rate (61 percent) and transplanting (69 percent).

12 Community respondents were asked to give the top three major advantages of the reduced seed rate technologies. A list of nine possible answers was provided: higher teff yields, higher straw yields, lower seed rate, less wastage of fertilizer, less weeding, reduced crop damage during weeding, good branching out of plants, less labor needed, and other (specify).

**TABLE 5.5** Community focus groups' perception of teff production and row planting

Perceptions	Percentage or unit stated
The most limiting factor of higher teff yields is:	
Price of chemical fertilizer	47
Unfavorable weather conditions	33
Declining soil quality	3
Access to improved seeds	3
Traditional sowing technique	3
Traditional broadcasting impedes teff production	86
Teff yield would increase when using:	
Broadcasting at reduced seed rate?	61
Row planting?	97
Transplanting?	69
What is the teff yield (metric tons per hectare) you can obtain using:	
Traditional broadcasting?	0.8
Broadcasting at reduced seed rate?	1.9
Row planting?	2.0
Transplanting?	2.2
The major advantage of doing row planting (top three) is:	
Higher productivity	100
Saving seed	66
Higher straw yield	46
The major disadvantage of doing row planting (top three) is:	
Too much additional labor	100
Difficulty of doing row planting after rain	42
Sensitivity of seedlings to shortage of rains	22
<b>Observations</b>	<b>36</b>

**Source:** Authors' calculations.

the magnitude of the potential yield levels that were expected (Table 5.5). Compared with the anticipated 0.8 metric tons per hectare that could be obtained when using broadcasting, row planting was expected to increase yield on average by 136 percent to a level of 2.0 metric tons per hectare. Broadcasting at reduced seed rate was expected to increase yield by 124 percent (1.9 metric tons per hectare) and transplanting by 163 percent

(2.2 metric tons per hectare). A similar assessment was requested with respect to straw yield changes. Compared with the 28 bales of straw per hectare that could be obtained from traditional broadcasting, only transplanting was expected to decrease straw yield (by 31 percent). Teff farmers expected straw yield to be the same for broadcasting at a reduced seed rate and for row planting.

Despite the yield benefit expected by farmers, concerns were also raised about the negative effects of the new technology. The major disadvantage of both row planting and transplanting reported in all community focus groups was the large labor requirement.<sup>13</sup> Individual teff farmers were also asked to assess how labor needs would change when implementing the new reduced seed rate techniques (Table 5.4). Nearly all farmers feared that the labor input for row planting would increase. For example, 77 percent of the farmers thought that labor would increase significantly in the case of transplanting. Other problems mentioned by these community focus groups were the difficulty of implementing row planting after rain and the sensitivity of transplanted seedlings to a shortage of rain.

### Farmers' Adoption Plans

This review of the qualitative results is concluded by examining the adoption plans with respect to row planting of farmers who implemented row planting experimental plots. Table 5.6 shows that the majority of such farmers were planning to continue to experiment with reduced seed rate technologies the year after exposure to the promotion campaign.<sup>14</sup> The table shows that 72 percent of the farmers reported that they planned to allocate some of their teff area to row planting, while 7 percent would implement transplanting. Farmers who were planning to implement row planting in the coming year stated that they expected higher teff yields (100 percent of the farmers), lower seed use (83 percent), and less wastage of fertilizer (30 percent) by doing so.

Yet the share of land that farmers were planning to allocate to row planting was limited. Farmers planned to plant the largest part (80 percent) of their teff

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13 Community focus groups were asked to give the top three disadvantages of the reduced seed rate technology. The six possible disadvantages included too much additional labor, much harder to control the weeds, it does not give higher yields, sensitivity of seedlings to shortage of rains, difficulty of doing row planting/transplanting after rain, and other (specify).

14 Teff farmers were instructed to report the area of land they were planning to allocate to teff production in the next production season, and then they had to divide this teff production land in different parts according to the sowing technology they were planning to assign on each part. This allowed for a calculation of the average (over all teff farmers) shares of land teff farmers were going to allocate to the different sowing technologies.

**TABLE 5.6** Farmers' planning strategies for the next production year

Strategies	Number of observations	Percentage
Will you allocate some part of your teff area to (yes = 1):	537	
Traditional broadcasting?		76
Broadcasting at reduced seed rate?		55
Row planting?		72
Transplanting?		7
Share of total teff production land allocated to:	526	
Traditional broadcasting?		53
Broadcasting at reduced seed rate?		27
Row planting?		19
Transplanting?		1
Total		100
The major reason for not doing row planting next year (top three) is:	155	
Too much additional labor		96
Difficulty of doing row planting after rain		25
It does not give higher yields		16
The major reason for doing row planting next year (top three) is:	378	
Higher productivity		98
Saving seed		83
Less wastage of fertilizer		30
Would you do row planting if inputs (teff seeds and fertilizer) were:	537	
Not given for free?		73
Given at a discounted price?		78
Given for free?		83
Not given for free but you had access to a row planter?		72

Source: Authors' calculations.

lands using broadcasting (that is, just over half of their teff area using traditional broadcasting and 27 percent using broadcasting at a reduced seed rate). Only 19 percent of these farmers' teff area would be allocated to row planting and 1 percent to transplanting. When all of the teff farmers that were reluctant to implement row planting or transplanting were asked why, they stated that row planting required too much additional labor, while 25 percent of the farmers responded that implementing the technology was too difficult after rainfall. These findings reinforce the conclusion of the previous section. It seems that farmers were willing to continue to experiment with row planting

but only on a relatively small part of their teff land. While farmers believed in the general yield-increasing potential of row planting teff, they restricted their adoption of the planting technique to small areas.

Finally, given that inputs were provided for free during the experiment, it is possible that the composition of the provided package, or part of it, drove the decision of farmers to adopt row planting in the next year. That is, it is not certain whether it was the technology itself or the other elements in the package that caused farmers to be willing to experiment with the technology in the following year. Farmers were therefore asked if they would do row planting the year after, upon a potential change in the condition of the proposed technology package (teff seed and fertilizer) provided. If inputs were given at a discounted price or for free, more than 78 percent of the farmers indicated that they would do row planting next year (Table 5.6). If inputs were not given for free, still three-quarters of the farmers indicated that they would implement row planting the next season. Surprisingly, having access to a row-planting machine seemingly did not give an extra incentive to implement row planting. This might have been because few of the farmers had been exposed to such a machine at the time of the survey.

## **Impact of the Promotion Campaign of Row Planting of Teff**

In the previous section, the qualitative data were reported on farmers' perceptions about the newly promoted reduced seed rate technologies for teff. This section presents the results of the quantitative analysis of the productivity impacts from being exposed to the promotion campaign.

### **Impact on Teff Yield**

Given the widespread belief in the yield benefit of row planting, the first step in the analysis was to estimate the effect of row planting on teff yield using production data from the experimental plots. Table 5.7 reports the effect of the promotion of row planting on teff land productivity measured in the RCT. Two different yield measures are presented, the crop-cut yield and the reported yield after harvest. The third column measures the average yield attained by traditional broadcasters (the "control"), ranging between 1.10 metric tons per hectare (measured during crop-cut) and 1.13 metric tons per hectare (reported after harvest). The reported yield measure is, on average for all farmers, only 3 percent higher than the crop-cut measure of yield, possibly indicating overoptimism in output assessment by farmers. However, there is

**TABLE 5.7** Effect of the promotion of row planting on teff land productivity, metric tons per hectare

Yield	Number of observations	Control (average teff yield from traditional broadcasting)	ITT	ITT with controls	ITT with village fixed effects
Yield from crop-cut	403	1.096	0.016 (0.083)	-0.092 (0.082)	-0.103 (0.062)
Yield reported after harvest	531	1.131	0.107 (0.115)	0.044 (0.137)	0.005 (0.084)

**Source:** Authors' calculations.

**Note:** ITT = yield increase obtained from row planting measured through the Intention-To-Treat (ITT) program. The column headed "ITT" reports the simple ITT coefficient of the regression of the outcome of interest on the assignment to row planting dummy. ITT with controls = adds control variables to this regression. ITT with village fixed effects = adds village fixed effects to this regression. Robust standard errors are clustered at the village level and reported in parentheses.

no evidence that row planters overestimated yields more than control farmers, as might have been done to impress enumerators or DAs.

Columns 4 through 6 report the point estimate of the treatment effect (ITT) on teff yield for the three different regression models. When focusing on the crop-cut data, the simple ITT model (column 4) shows no significant impact of the row-planting promotion program on teff yield. Implementing row planting on the experimental plot increased farmers' yield by 20 kilograms per hectare, but this effect is not statistically different from 0. The regression model that controls for the "imbalanced" characteristics between row planting and broadcasting farmers (column 5) also finds no significant impact of row planting on crop-cut yields. Similarly, the model that controls for village fixed effects (column 6) does not find significant treatment effects of row planting. In the case of reported yields just after harvest, a slightly higher effect of row planting is found, but the effect remains insignificant at the 10 percent level. Farmers who planted teff using the traditional broadcasted technique had a teff yield of 1.1 metric tons per hectare, while those who implemented row planting were able, on average, to harvest per unit area 10 percent more, resulting in a gain of 0.12 metric tons per hectare of teff. The two robustness checks in column 5 and 6 also find no significant effect of the adoption of row planting on self-reported yields.

One concern is that there are spillover effects from farmers implementing row planting (information) on the traditional broadcasting farmers. Control farmers might become aware of the agronomic benefit of using a reduced seed rate and therefore apply a lower seed rate to the traditional broadcasting sowing method. However, [Table 5.3](#) in the previous section showed that broadcasting farmers on average applied a seed rate of 27 kilograms per hectare,

which is close to the recommended “traditional” seed rate of 25 kilograms per hectare (an F-test does not indicate a significant difference). If anything, it seems that most row-planting farmers did not apply the recommended reduced seed rate of 5 kilograms per hectare. This could undermine the agronomic benefit of row planting and influence the treatment effect of row planting on teff yield. However, when controlling for the seed rate used on the experimental plot in column 5 of [Table 5.7](#), the results are robust.

In short, no evidence is found that shows that row planting (that is, the combination of planting seeds in rows and using a reduced seed rate) improves teff yield, which is in contrast with the yield increases found in research and demonstration settings.

### **Impact on Labor Input and Productivity**

The main complaint raised by teff farmers when implementing row planting in the qualitative section was the increased labor requirements associated with row planting teff. The impact of the adoption of row planting on labor use on the experimental plot is discussed below. “Labor requirement” is defined as total person-hours needed to grow teff on one hectare of land. This investigation of labor considers: (1) labor requirement for the different activities during teff production and (2) total labor productivity.<sup>15</sup> The following changes in labor input are anticipated, based on the nature of the row-planting technique: (1) Row planting requires additional tilling and farmers need to construct rows and carefully sow the seeds in them. Hence, an increase is expected in labor requirement for land preparation (small) and sowing (large). (2) Farmers were instructed to apply the fertilizer together with the seeds in the rows, and it is therefore expected that the labor requirement for applying fertilizer will increase as well. (3) The labor input for weeding is expected to decrease as row planting should make weeding easier (ATA 2012). (4) Any significant effect on the labor requirement for harvesting or threshing is not expected. (5) Depending on how the labor allocated for each of these individual activities is altered, an increase or decrease in total labor inputs is expected.

Using the detailed data collected from the experimental plots, the third column in [Table 5.8](#) shows the labor requirement for broadcasting farmers per activity (“control”) in person-hours per hectare, while (similarly to [Table 5.7](#))

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<sup>15</sup> See Vandercasteelen et al. (2016) for a detailed impact assessment of row planting on the inter-household and intrahousehold allocation of labor in teff production. We find that even though more labor is used from all interhousehold sources, exchange and hired labor is used relatively more, and hence households with access to exchange or hired labor seem to be in a better position to adopt row planting.

**TABLE 5.8** Effect of the promotion of row planting on labor requirement and productivity

Inputs and productivity	Number of observations	Control (average teff yield from traditional broadcasting)	ITT	ITT with controls	ITT with village fixed effects
<b>Labor input (person-hours per hectare)</b>					
Land preparation	537	109.1	4.0 (5.8)	0.7 (5.4)	1.6 (6.4)
Planting	537	42.2	138.7*** (14.8)	138.4*** (14.1)	145.4*** (15.3)
Fertilizer application	537	14.6	40.6*** (5.8)	38.9*** (6.0)	41.6*** (5.9)
Weeding	537	265.8	34.8* (20.7)	28.8 (20.4)	37.4 (22.1)
Harvesting	537	175.7	-0.0 (9.9)	-5.2 (9.2)	-4.2 (9.5)
Threshing	537	217.2	-2.0 (12.6)	-9.6 (11.6)	-7.8 (13.6)
Total	537	884.2	255.3*** (48.7)	227.9*** (45.2)	266.0*** (50.7)
<b>Labor productivity (kilograms per person-hour)</b>					
Output from crop-cut	403	1.568	-0.445*** (0.130)	-0.588*** (0.137)	-0.558*** (0.098)
Output reported after harvest	531	1.643	-0.358** (0.164)	-0.373** (0.172)	-0.474** (0.121)

**Source:** Authors' calculations.

**Note:** ITT = yield increase obtained from row planting measured through the Intention-To-Treat (ITT) program. The column headed ITT reports the simple ITT coefficient of the regression of the outcome of interest on the assignment to row planting dummy; column 5 adds control variables to this regression; and column 6 adds village fixed effects to this regression. Robust standard errors are clustered at the village level and reported in parentheses. Asterisks represent level of statistical significance at 10 percent (\*), 5 percent (\*\*), and 1 percent (\*\*\*).

the next columns report the ITT of row planting, measured in the three regression models. For simplicity, we only discuss the results of the simple ITT regression (column 4), but results are found to be robust in the two other regressions. As expected, there was an increase in labor input for land preparation (but not significant), especially for the sowing operation. While broadcasting one hectare of teff on average only took 42 person-hours, row planting required an additional 139 person-hours (or about 20 person-days extra per hectare). The labor requirement for applying fertilizer also increased significantly. Surprisingly, the labor requirement for weeding also increased, in contrast to expectations (that is, row planting was expected to make weeding easier). This finding may confirm statements from some farmers that high teff seeding rates help in controlling weeds. The labor input for harvesting and threshing did not change.

As a consequence of all these changes in labor inputs by activity, the total labor requirements for row planting were significantly higher than for broadcasting. The total labor input to produce a teff crop when the seed is broadcast is estimated to be 884 person-hours of labor, while implementing row planting is estimated to require an additional total labor input of 255 person-hours. This corresponds to 126 and 163 person-days per hectare, respectively, representing an increase in labor of 29 percent when row planting is used. Note that these assessments were done on a relatively small plot, and while care was taken in the data-collection process, collection of accurate labor data are notoriously difficult. Caution in interpretation of such data is therefore required.

The same procedure for assessing land productivity was used to assess the change in labor productivity using different output measurements. Labor productivity is measured as total teff output (in kilograms) divided by total labor input (in person-hours) for producing teff. This allows an estimate to be made of the effect of row planting on respectively “labor productivity from crop-cut” and “reported labor productivity after harvest” in the last two rows of [Table 5.8](#). The ITT measured in column 3 shows that row planting has a strong and highly significant negative effect on labor productivity. Using the traditional broadcasting practice, farmers were able to produce 1.6 kilograms of teff for each person-hour of labor. When implementing row planting, this is reduced to between 1.1 and 1.3 kilograms per person-hour. Therefore, row planting is found to decrease labor productivity by between 22 and 28 percent. Similar conclusions are drawn from the regressions with controls for additional variables (column 5) or village fixed effects (column 6), and the effect of row planting is found to be even greater in magnitude.

## **Toward Understanding the Determinants of Farmers' Adoption of Row Planting**

### **Cost-Benefit Analysis of Row Planting Versus Broadcasting**

Farmers will switch from traditional broadcasting to row planting of teff only if the benefit of doing so outweighs the costs. Implementing row planting tends to have a positive (yet moderate) yield effect, but it also requires substantially more labor. Both effects can be combined in a simple cost-benefit-analysis (CBA) framework to analyze whether it is profitable for the farmers in this sample to adopt row planting or not. This was done by comparing profits (benefits minus costs) in each scenario. As claimed in the promotion

**TABLE 5.9** Cost-benefit analysis of implementing row planting versus traditional broadcasting for teff farmers on one hectare of teff land

Type of changes	Quantity			Monetary value (birr)		
	Price (birr)	Traditional broadcasting	Change for row planting	Traditional broadcasting	Row planting	Change for row planting
<b>Changes in benefits</b>						
Teff output (metric tons)	10,700	1.131	0.107	12,102	13,247	1,145
<b>Changes in costs</b>						
<b>Labor (person-days)</b>						
Land preparation	28.0	15.6	0.6	430.2	445.9	-15.8
Sowing	28.0	6.0	19.8	169.4	726.2	-556.8
Applying fertilizer	27.0	2.1	5.8	55.7	210.5	-154.9
Weeding	29.0	38.0	5.0	1,097.4	1,241.0	-143.7
Harvesting	26.0	25.1	0.0	660.1	660.1	0.0
Threshing	30.0	31.0	-0.3	924.7	916.1	8.5
<b>Seed (kilograms)</b>						
Quncho	11.0	30.0	25.0	321.0	53.5	267.5
<b>Total changes in cost-benefit analysis</b>						
Difference in profits when adopting row planting (birr per hectare)						550

**Source:** Authors' calculations.

campaign, the benefits of row planting are increased yield and reduced seed cost, while our empirical assessment shows that labor costs are higher. It is assumed that the use of other inputs (such as fertilizer) is the same when implementing either row planting or broadcasting. The first column of [Table 5.9](#) gives an overview of the different changes in benefits and costs that are considered in this CBA. The output is valued at the market prices of teff in Ethiopian birr.<sup>16</sup> Farmers using row planting and those using traditional broadcasting face different costs associated with different levels of use of labor and seed.

To measure profits in monetary values, information was collected on the input and output prices from the AGP community questionnaires for the AGP villages in Oromia. Average prices in Ethiopian birr (per unit stated) across the different villages in the AGP survey are presented in column 2. Teff prices refer to the price of one metric ton of white teff during the year prior to the survey, while wages are average daily wages for each production activity

<sup>16</sup> In February 2013, US\$1.00 = 18.40 birr.

during the same year over all villages. As prices were reported in person-days, the unit of labor input was converted into person-days (by assuming a work-day of seven hours). As no information on the price of Quncho seed was collected at the time of planting, this was estimated to be 11 birr (based on the average CSA producer price data collected at that time of year).

The changes in monetary value of teff production were calculated for both sowing technologies for one hectare of land. To do so, [Table 5.9](#) reports the quantities of output obtained and input needed in teff production when using the traditional broadcasting and row-planting technologies, respectively. Output and labor data are the observed average values, taken from [Table 5.7](#) and [Table 5.8](#). The reported yield after harvest is used, along with the yield benefit measured by the simple ITT in column 3 of [Table 5.7](#). The seed rate for farmers who broadcast is fixed at 30 kilograms per hectare and for those who use row planting at 5 kilograms per hectare. The final column of [Table 5.9](#) then reports the difference in birr for each benefit or cost associated with teff production when row planting rather than traditional broadcasting, by multiplying prices by quantities.

The results in [Table 5.9](#) show that, given the costs in teff production considered here, and assuming a farmer reported a yield increase of 10 percent, the adoption of row planting is profitable for teff farmers. The implementation of row planting on the experimental plot resulted in an additional profit of 550 birr in teff production. This is because the increase in the monetary value of output sales (1,145 birr) combined with seed saving (268 birr) compensates for the costs associated with the additional labor (863 birr) required when implementing row planting.

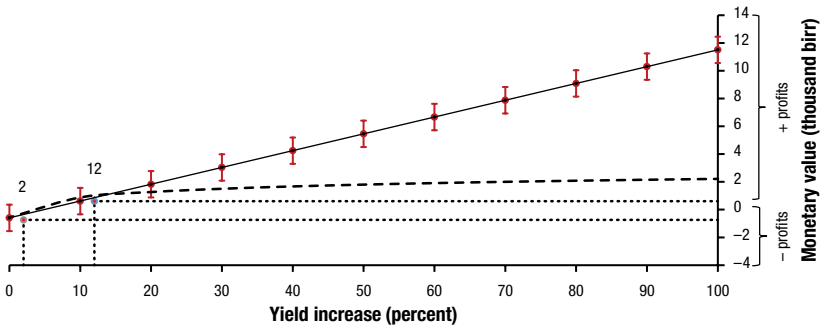
However, when this analysis is undertaken using the alternative yield data from the experimental plots that were obtained using crop-cuts, for which the average yield difference between the two planting techniques is much less, row planting is shown not to be beneficial for teff farmers. Farmers using row planting would actually incur a loss of more than 424 birr per hectare. Using the crop-cut yield data on teff output, the labor cost of row planting (816 birr) outweighs the benefits of row planting associated with slightly higher output sales (171 birr) and seed saving (268 birr). Hence, the yield increase achieved by farmers using row planting together with the labor requirements for doing so determine whether row planting is more profitable for teff farmers than the traditional broadcast method of planting. Therefore, the following sections examine two potential interventions that might make the adoption of row planting more assuredly beneficial to teff farmers by means of a sensitivity analysis of the above CBA.

## Learning by Doing

When farmers adopt new technologies, it is their familiarization and learning over time that is required for such technologies to be implemented efficiently, and this ultimately leads to higher yield benefits and lower labor costs over time. This could explain why studies of various teff planting techniques in more supervised and controlled settings (McGuire 2013) found teff yield increases under row planting of at least twice those obtained when traditional broadcasting was used. In such studies, farmers were more intensively trained and assisted by private extension agents on the correct implementation of the row-planting technology. To illustrate the effects of differential yield increases because of such effects, [Figure 5.2](#) shows a sensitivity analysis of the rewards (in birr) from changes to row planting from traditional broadcasting for different yield benefits (measured in percentage) from row planting. This analysis assumes that learning by doing does not affect labor productivity. As there is a certain degree of inaccuracy (variance) in this estimated yield effect, this also leads to a variance in expected profits. The estimated yield effect in the reported data after harvest has an estimated standard deviation of 0.075. Therefore, [Figure 5.2](#) also shows the variance in profits for each yield increase as a vertical line (the error band).<sup>17</sup>

[Figure 5.2](#) illustrates that if yield gains from row planting compared with broadcasting increase, profits per unit land will increase as well. The solid line assumes that learning increases linearly—that is, each year farmers are able to achieve the same yield gain of 10 percent. The benefits of row planting start to outweigh the costs only if the yield increases are larger than 8 percent. As described in the CBA, switching from traditional broadcasting to row planting is respectively loss making (based on the 2 percent yield increase in the crop-cut yield data) or beneficial (based on the 10 percent yield increase in the reported yield data). But if yields were to increase well beyond the break-even point of the 8 percent, implementing row planting would become considerably more profitable for teff producers. If, for example, a yield increase of 75 percent is achieved (ATA 2013b), farmers who adopted row planting could realize a profit of 8,000 birr, exceeding that which would be obtained through the traditional broadcasting technique. The dashed line in [Figure 5.2](#) is a logarithmic curve, illustrating the case of when teff farmers learn about row

17 This error band is constructed by respectively adding and subtracting the standard error of 0.075 (per hectare more or less, which is about 6 percent) to the estimated yield effect of 10 percent and calculating the associated profits.

**FIGURE 5.2** Sensitivity of profits with respect to yield improvements associated with use of new technology

**Source:** Authors' calculations.

**Note:** Benefits to the farmer when producing teff over 1 hectare of land under row planting compared with broadcasting for different specified yield levels (given that labor productivity and seed cost remain the same). The solid line assumes linear increasing learning over time, while the dashed line assumes a logarithmic (more stagnating) pattern of learning. Vertical lines represent the yield effect as measured in the experimental plot data (crop-cuts and reported yield after harvest).

planting, implying that yield benefits decrease after a while, and the increase in monetary value slows down (around 2,000 birr).

## Mechanization

A second solution to improve the profitability of row planting at farm level, given the increased requirement for labor, is to promote the mechanization of teff row sowing. Row planters are either human or animal-drawn machines that allow for opening and closing the furrows (rows), drilling the seed, and in some cases the application of fertilizer. Two types of row planters are currently being tested at the Ethiopian Institute of Agricultural Research (EIAR): the basic Type One row planter and the more advanced Type Two row planter. Both prototypes feature a dual hopper with four rows that allow for furrow opening, seeding, and furrow closing. The Type Two prototype also allows for simultaneous application of fertilizer in the furrows.

Row planters are believed to improve both the land and the labor productivity of row planting. The planters allow for a more precise adjustment for the (lower) seed rate and a uniform seed distribution, possibly leading to positive yield effects. The proper construction of furrows eases land preparation and the creation of rows as well as the sowing activity itself (Ayele 2013). Moreover, the mechanization might reduce weed infestation and drive down the cost of weeding (ATA 2013c). Temesgen (1999) found that an animal-drawn, open-furrow row planter saved labor input by one-third and by

two-thirds if a closed-furrow row planter was used, while it increased yield by 30 percent.

To assess the profitability of adopting a mechanical row planter, the internal rate of return (IRR) of investment is calculated. The IRR refers to the discount rate at which the net present value (NPV) of the benefits equalize the NPV of all cost associated with adopting the mechanical row planter. The higher the IRR, the more profitable and hence the more desirable an investment in a row planter. To calculate the IRR, the benefits and costs were taken into account as presented in [Table 5.9](#), but additionally the associated purchase costs of the row planter was factored in (the cost associated with the use of fertilizer was also included, as per agronomic recommendations). An individual farmer could choose to adopt the cheaper Type One or more expensive Type Two row planter priced at 5,000 birr and 8,000 birr, respectively. Both types are assumed to achieve (at least) the same yield increase over broadcast seeding of 2 or 10 percent—that is, the same yield increment from implementing row planting by hand.<sup>18</sup> As the main benefit of row planting by machine is the reduction in workload and labor cost compared with row planting by hand, the effect of the row planter on IRR is presented for different levels of labor input savings—that is, the number of person-hours that can be saved when using a mechanical row planter instead of doing row planting by hand.<sup>19</sup>

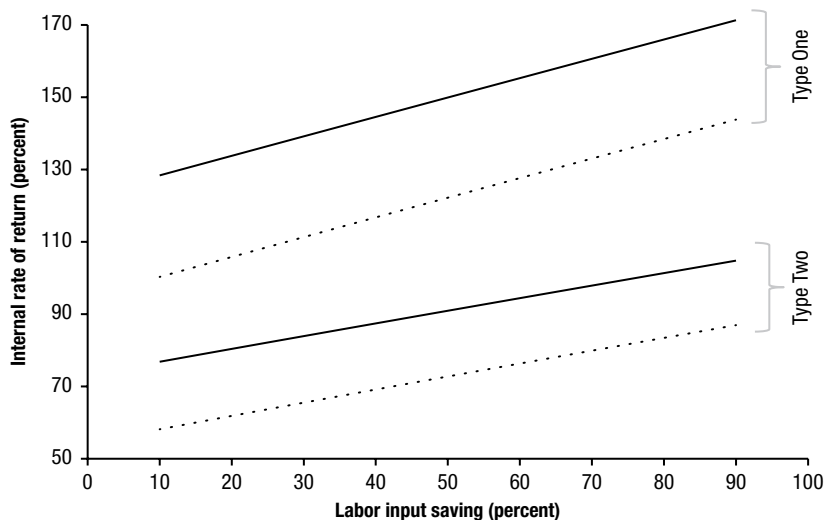
[Figure 5.3](#) shows the high IRR that farmers can achieve when adopting a row planter for different labor use inputs (in percentages). [Figure 5.3](#) distinguishes between the Type One and Type Two row planter and between the two increases in yield measured in the data.<sup>20</sup> Due to its lower initial cost, the Type One row planter has a higher IRR than the Type Two. If a labor input reduction of 50 percent is achieved and the row planter has a timespan of five years, the IRR for the Type One row planter is 150 percent while the IRR for

18 This is likely an underestimation of the yield effect of the row planter, as it should allow for additional yield improvements over row planting by hand. Moreover, the Type Two row planter allows for simultaneous application of seeds and fertilizer and should therefore have additional yield and labor effects. [Figure 5.2](#) illustrates the effect of different yield levels on the profitability of a row planter, including those much higher than 2 or 10 percent. As the row planter is expected to achieve higher yield levels than 2 or 10 percent, these numbers can be interpreted as lower bounds for assessing the actual profitability of the row planters.

19 The labor-saving effect of the row planting should be expressed in constructing the rows as well as weeding and applying fertilizer. It is thereby assumed that the row planter affects both planting and land preparation and general cultivation, but not weeding, harvesting, and postharvesting. For simplicity, it is assumed that the row planter affects both activities in the same way (for example, a 10 percent increase in labor input corresponds to 30 person-hours fewer for sowing and 36 person-hours fewer for cultivation).

20 A depreciation rate of five years is assumed. Assuming a depreciation rate of ten years has a small positive effect on the IRR (about 2 percent).

**FIGURE 5.3** Sensitivity of internal rate of return (IRR) with respect to row planter type and labor-input saving when buying a row planter



**Source:** Authors' calculations.

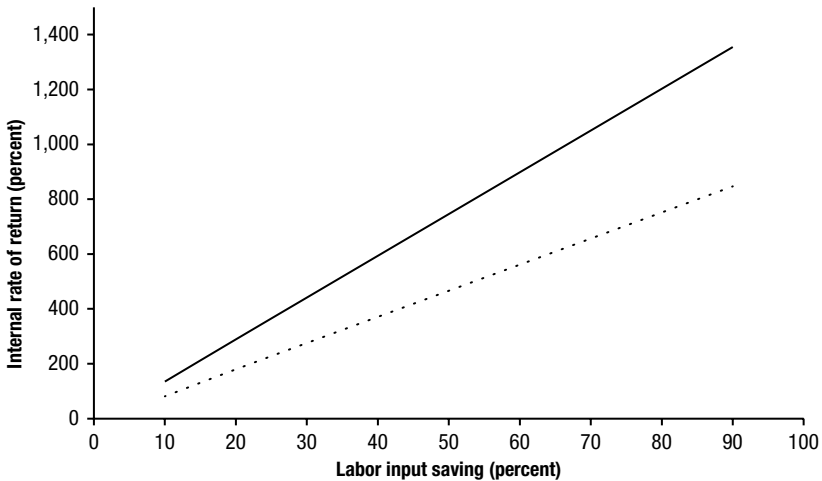
**Note:** IRR for the farmer when buying a Type One row planter (at 5,000 birr: above two lines) or a Type Two row planter (at 8,000 birr: below two lines) when farming 1 hectare of teff under row planting. For each type, the upper (solid) line assumes the yield increase of 10 percent measured in the reported yield data, while the lower (dashed) line assumes a yield increase of 2 percent as measured in the crop-cut yield data. Different levels of input saving are assumed as well as a depreciation rate of five years.

the Type Two row planter is 91 percent. Figure 5.3 also shows that the IRR increases if the adoption of the row planter achieves a higher reduction in labor input. Finally, the effect of higher yield levels is illustrated by comparing the IRR based on both the yield increases measured in the crop-cut and reported yield data. As expected, the higher yield increase measured in the reported data implies a higher IRR for the row planters.

An alternative solution to promote mechanical row planter adoption by farmers is to allow farmers to share a row-planting machine. Sharing a technology is an attractive possibility as it would allow the costs to decrease, such as in the case of the nondivisible row planter.<sup>21</sup> If farmers are assumed to adopt a row-planting machine in a group of ten persons with an average of 1 hectare of teff per farmer, and where each farmer pays an equal share in the purchase cost (that is, 10 percent of the initial purchase cost), Figure 5.4 reports that the IRR for the two row planters over different levels of labor input saving

21 The teff farmers in the sample cultivate on average half a hectare of teff land.

**FIGURE 5.4** Sensitivity of internal rate of return (IRR) with respect to labor input saving when sharing a row planter



**Source:** Authors' calculations.

**Note:** IRR for the farmer when sharing a Type One row planter (initial cost of 500 birr: upper [solid] line) or Type Two row planter (initial cost of 800 birr: lower [dashed] line) with five-year depreciation for 1 hectare of teff under row planting.

changes quickly. Figure 5.4 differs from Figure 5.3 by a lower initial cost as well as an additional variable cost of renting the row planter (assuming 100 birr a day). Figure 5.4 shows that the scenario of sharing the row planter leads to much higher IRR levels and hence the row planter becomes a more profitable investment. Similarly, if half of the labor input is saved, the Type One row planter has an IRR of 911 percent; while the Type Two row planter achieves an IRR of 569 percent.

High returns are found in the adoption of row planters. While research on the field performance of the different row planter prototypes is currently under way, many challenges to adoption need to be considered. First, the row planter machine is a nondivisible and capital-intensive technology with an initial high liquidity requirement for purchase that some farmers might not be able to manage upfront. Partial adoption is impossible and, unless rental markets develop, smaller and credit-constrained farmers will be less likely to adopt the planters. Second, the suitability and performance of the row planter depends on the agroecological conditions (for example, row planters are difficult to use in vertisols), and significant research efforts toward developing suitable prototypes are required. Finally, the supply of mechanized technologies requires local production, infrastructure, and maintenance. These elements

associated with the use of the row-planting machines are currently assessed as being underdeveloped in Ethiopia (Ayele 2013).

## **Conclusion**

Given the limits on suitable arable land and a rapidly growing population, Ethiopia will need to scale up the adoption of yield-increasing technical innovations to ensure continued agricultural growth and to safeguard national food security. This study of row planting of teff in Ethiopia has sought to gain more insights into how the promotion of improved technologies can possibly increase farmers' teff production. Teff is Ethiopia's most important staple crop, but the national yield levels are low. Traditionally teff seed is broadcasted at high seed rates (typically 30 kilograms per hectare). It is believed that this impedes teff production because the uneven seed distribution makes weeding more difficult and increases competition between seedlings. By planting seed in rows at a low seed rate instead, yields have been shown to improve significantly in agronomic trials conducted on research stations. Field demonstrations of row planting showed that teff yields increased on average by 70 percent compared with the national average (ATA 2013a). As a consequence, these new technologies have been promoted to Ethiopian teff farmers on a large scale. However, there is a lack of reliable and objective data to measure the impact of widespread promotion campaigns of such improved teff technologies. The goal of this analysis was to fill this gap and provide evidence on the impact of the promotion of row planting of teff at the farm level. With quantitative and qualitative data combined, the effect of the promotion campaign on teff farmers was assessed. The main findings are as follows: First, exposed farmers were found to have a positive attitude toward row planting (and reduced seed rates in general) and believed that row planting had a large yield-increasing potential. Many plan to adopt row planting but only on a relatively small part of their plots, seemingly indicating that the farmers were concerned with the labor requirement and that more knowledge and experience was needed in implementing the technology.

Second, by implementing row planting, farmers experienced an increase in teff yield of between 2 and 10 percent, on average, but the effect is not found to be significantly different from 0. These results therefore contrast with the larger impacts measured in more controlled settings (Abayu 2012; Tolosa 2012; ATA 2013c; McGuire 2013) or with farmers' expectations. The results reported here cannot be directly compared to other sources, but they seem to be in line with farmers' perceptions in the field (K. Assefa, EIAR, personal

communication, October 10, 2013). An intensive support program to significantly raise teff yields with use of the new technologies, as provided in the experimental settings, would require public resources that are not readily available. As such, the results of this impact evaluation are likely to reflect the outcome that would be achieved if a national program were to be rolled out along these lines.

The difference in magnitude of the estimated and claimed yield effect of row planting of teff is seemingly related to farmer field conditions and the design of the experiment. The high yield benefits claimed by the promotion campaign were measured at research stations or on demonstration plots, while this study's yield benefits reflect the effect of a promotion program at farm level, which considers farm-level realities and possible deficiencies in the extension program. Farmers might face different constraints in implementing new technologies on their farms than in research settings, and they might lack technical support resulting from implementation problems with the promotion campaign. The yield benefits from this study further measured the direct effect of row planting by being able to separate the sowing effect from other benefits related to the package or other factors that may have confounded the effect of row planting. In contrast with other assessments, farm-level data were further collected by independent enumerators; the row-planting treatment was randomized over similar farmers, all participating farmers received the same inputs; and safeguards were put in place to control farmers' inaccurate yield assessment, exaggerated expectations, and possible influence by extension agents and media.

Third, a substantial increase is found in labor input in the case of row planting. As expected, additional labor input is needed for sowing the seeds in rows and applying the fertilizer. The total person-hours needed to row plant 1 hectare of teff is more than one-third higher than in the case of traditional broadcasting, and it is estimated that row planting requires about 36 person-days of extra work per hectare compared to traditional broadcasting. It is also found that row planting not only increases total labor requirements but also significantly decreases labor productivity by between 22 percent and 28 percent. This implies that farmers need to invest more labor in teff production to obtain the same output that they would have got from broadcasting. This finding is crucial, as the most important yardstick for farmers' adoption is not increased land productivity but labor productivity (Moser and Barrett 2006).

Fourth, both the land and labor productivity effects have been combined in a cost-benefit analysis (CBA) for a comparison of the adoption of row planting

with traditional broadcasting. As the cost of the additional labor requirement is compensated by the benefits teff farmers receive from implementing row planting, they earn 550 birr in the self-reported yield data and incur a loss of 424 birr in the crop-cut data. The CBA showed that the increase in teff yield outweighed the cost of the extra labor in the first year of adoption if yields increased by more than 8 percent and therefore made the investments worthwhile. Moreover, the results also suggested that the adoption of suitable and functional row planters had high returns to investments and that farmers with access to such row planters would be able to reduce their labor requirements for the implementation of row planting (and possibly have an additional yield-increasing effect as well).

This study points to a number of policy recommendations. First, while the agronomic superiority of the row-planting technology cannot be disproved, the results indicate that to achieve the desired adoption effects, significant effort should be put into the design and implementation of more effective promotion campaigns for such improved technologies. There is often a big gap between the supply of new technologies and their efficient adoption, since innovations spread slowly and require different management skills (Moser and Barrett 2006; Duflo, Kremer, and Robinson 2008; Collier and Dercon 2014). Farmers need to be allowed to learn, therefore continuous efforts in the extension of field assistance to farmers are needed. Correct implementation of the technology is expected to bring about larger yield increases, as illustrated by the agronomic research results in controlled settings (and the CBA). Second, it seems that the extra cost of labor requirements is not sufficiently taken into account in the current program design. The development of a suitably adapted mechanical row planter to stimulate the adoption of row planting should have large rates of return and lead to higher adoption rates. Third, on-farm constraints toward adoption should be further assessed with careful monitoring, learning, and evaluation—all of which are required to improve extension approaches for successful scaling up of adoption of the row-planting technology for teff.

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