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Multiple solutions for rice farmers' production constraints in Ethiopia: Cost efficient methods of sheath rot disease management

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Rice sheath rot disease is one of the obstacles in Fogera plain of rain-fed rice production system. A cultivar called *X-Jigna* has been used by small scale farmers based on mono-cropping system for over two decades. This production system contributed to the disease occurrence and adversely impacted the production and productivity. So far, there were no any effective measures taken as research remedies in the rain-fed production areas. Since the disease is seed-borne, recently, effective seed treatment methods were identified and evaluated at farmers' fields. Partial budget analysis was employed to estimate economic costs and benefits to realize the seed treatment methods were economically viable or not. The yield responses from fungicide and hot water treatments were higher than the control check. Marginal rate of return of hot water and fungicide treatment methods were higher than untreated production. Sensitivity analysis was used to evaluate the resistance and responses to the changes in prices and yields of new production method. The result shows that marginal rate of return was declining with an increasing price change of fungicide. Marginal rate of return was highly sensitive to decreasing level of yields but not strongly sensitive to the different level of price changes of fungicide. When farmers change their production method from use of untreated to treated seed, the yield loses could be dramatically decreased and marginal rate of return were considerably increased. The result ascertained that seed treatment methods were found to be effective, economically feasible and highly recommended for rice producing farmers.

Key words: Break-even price, break-even yield, cost-benefit, marginal rate of return, partial budget analysis, seed treatment, sensitivity analysis, sheath rot disease.

INTRODUCTION

Sheath rot caused by *Sarocladium oryzae* (Sawada) is one of the major diseases of rice. The disease is gaining importance due to its effect on economic loses and widespread occurrence in almost all rice growing areas of

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the world including Bangladesh, Cameroon, India, Korea, Japan, Peru, Philippines, South East Asia, Taiwan, Thailand, Venezuela, Vietnam and USA. It is one of the most serious and devastating rice diseases in wetland rice growing regions and has caused 20−85% yield loss in Taiwan, and 30−80% in Vietnam, the Philippines, and India. In Japan, affected areas range from 51,000-122,000 ha and annual losses are estimated to be 16,000-35,000 tons (Birhanu et al., 2020). The disease occurs on uppermost leaf sheath enclosing the young panicles. The lesions appear as oblong or somewhat irregular spots with brown margins and grey centers which enlarge-and cover most of the leaf sheath, resulting in un-emerged or partially emerged panicles having unfilled or partially filled grains. The disease severely affects the leaf sheath and panicle and causes substantial yield losses depending upon the environmental conditions and genetic make-up of the cultivar and the pathogen (Pak et al, 2016; Ram et al., 1995). In Ethiopia, nowadays, sheath rot have become one of the devastating obstacles and major rice disease especially in Fogera plains of the wetland rice production system. It has prevalence, incidence and severity of 100, 47 and 44%, respectively in the area. Due to mono-cropping type of production over the last 20-30 years based on one cultivar called *X-Jigina,* the disease was triggered to appear and expanded quickly. Therefore, unless effective management measure is taken, the disease will cause tremendous yield loss consequently leading to rice crop being out of production in the area. Thus, the disease needs great attention to test and develop better management methods that alleviate the problem (Berhan et al., 2020; Mutiga et al., 2019).

Improvement in agricultural production technology is necessary for agricultural development. Agricultural scientists develop new production technologies to improve farmers' welfare. Farmers adopt new production technology that is economically superior to the existing ones. Agricultural growth requires continuous improvement of crop production technology at the farm level. Agricultural research and extension help develop and transfer appropriate new technologies to farmers. Some new technologies developed on experiment stations are not adopted by farmers because of lack of economic advantage over current production methods Partial budget analysis (PBA) provides useful information for making decisions in the research-extension-adoption process. Partial budget analysis can be used for comparing the impact of a technological change on farm costs and returns. It does not include all fixed or common production costs, but only those which change or vary between the farmer's current production practices and the proposed one(s) (Douglas, 1982; Hadian et al, 2017).

Farmers are constantly making adjustments in their farms for smooth operations and profitability. Many times, these choices involve actions to enhance the financial return of the farm, while other times these decisions are taken out of necessity to minimize the effects of unfavourable conditions or events such as drought or changes in the market conditions. Some of these decisions are relatively simple requiring making choices among alternatives within an enterprise while others are complex involving a total overhaul of the business and its enterprises. Alternative choices within an individual enterprise can have a differential impact on farm profitability. Therefore, making the best decision may make the difference between profit and loss for that enterprise. Partial budgeting is very useful in making such changes in a farm. It is a tool used to assess the costs and benefits associated with a specific change in a farm. This tool specifically focuses on the implications of the intended change in a business operation by comparing the benefits and costs resulting from implementing the alternative with respect to the current practice. Partial budgeting is a planning and decision-making framework that is used to compare the costs and benefits of alternatives faced by a farm business (Alimi and Alofe, 1992).

Different management methods were tested against this disease by Fogera National Rice Research and Training Center (FNRRTC) in different times and promising results were obtained. From several independent sets of experiments, two effective seed treatment methods along with control check were demonstrated at farmers' field and economically evaluated using partial budget analysis. Based on this finding, further demonstration at farmers' field has been conducted to evaluate the validity, economic feasibility and productivity of the technology. Therefore, this paper intends to address performance evaluation of different seed treatments methods and thereby recommend a better one that is economically viable, environmentally friendly and socially acceptable to smallholder rice producers.

Specific objectives

i) To evaluate yield performance of application of different seed treatment methods on X-Jigna rice cultivar against rice sheath rot disease.
ii) To analyse the economic feasibility of application of different seed treatment methods on X-Jigna rice cultivar against rice sheath rot disease.

MATERIALS AND METHODS

Site and farmers selection criteria

Six on-farm demonstration trials were conducted purposively based on occurrence and severity of the disease, representativeness of the fields, model farmers, and experiences of production, their willingness to allocate their plots of land and accessibility for follow-up and evaluation. It was conducted in two demo locations in Fogera plain (*Dera* and *Libokemkem* districts). Three *kebeles (sub-*

sites), Kokit, *Shina* and *Wanzaye* were selected due to intensive occurrence of sheath rot disease in these areas. Per farmer, 3 treatments (seed treated by Apron-Star and hot water, control check), 10×10 m^2 for one treatment, 300 m^2 were used for 3 treatments. A cultivar called *X-Jigna* highly susceptible for the disease was used.

Data collection

Data were collected and recorded intensively through direct field observation/measurement, detail records of costs and returns, feedbacks about the technology from those used, on the parameters of yield, demand on technologies and disease occurrence (the treatments were arranged in randomized complete block design with three replications). Disease incidence and severity data were recorded before maturity of the crop in 0-9 scale).

Data analysis framework

Concepts and terminologies in partial budget analysis for simplicity

Recommendation domain: Is a group of small-scale rice producing farmers who had similar production circumstances and did not apply improved seed treatment methods against sheath rot disease. It is a group to whom improved and economically feasible seed treatment methods could be recommended.

Total variable input costs (TVIC): Are a sum of all variable input costs and varies from one treatment to another (Kassa et al., 2018; Alcido, 2001).

Total fixed input cost (TFC): Fixed input cost is a cost of fixed resources which did not change regardless of the level of input, treatment or technology. Fixed input cost is not relevant in analysis of partial budget analysis; it should however be included in any enterprise budget analysis (CIMMYT, 1988; Douglas, 1982).

Opportunity cost: Is the value of a forgone alternative or the price of the input in its best alternative use (Alimi and Manyong, 2000).

Adjusted yield: Scaling down of the yield obtained in the experiment might be necessary by some proportion (up to 10%) in some circumstances to approximate the yield gaps between the experiment and farmers' practice as if the management level is intensive in the experiment than farmers' practice (Alimi and Manyong, 2000; Douglas, 1982). However, in the case of on-farm demonstration, management level is usually having similar and close management circumstances with farmers' practice. Hence there is no need to make adjustment of the yield in this case.

Farm gate price of output (p): The market price of output less marketing costs (usually transportation), e.g. if the market price of rice is 18 ETB/kg, and transportation cost from farms to market is 3.5 ETB/kg then farm gate price would be 18-3.5 (ETB) =14.5 ETB/kg.

Farm gate price of input: It is price of input at farm gate including transportation costs from market to farms.

Gross farm gate benefit (GB): Gross farm gate benefit is the product of farm gate price of output and adjusted yield (Soha, 2014).

Net benefit (NB): The difference between gross farm gate benefit and total variable input costs (Ehui et al., 1992; Douglas, 1982; Alimi and Manyong, 2000).

Dominance analysis: The process of eliminating dominated treatments in further analysis steps based on the value of net benefit and total variable input costs. A dominated treatment has less or equal benefits than other treatments which have lower variable input costs. In other words, in dominated treatment higher variable input costs are incurred to earn less or the same net benefit as compared with other treatments.

Partial budget analysis and marginal rate of return

Partial budget analysis and marginal rate of return were estimated considering variable input costs that vary across the treatments. Fixed input costs for all treatments were not included in the computation as described by CIMMYT (1988).

Marginal rate of return (MRR): The marginal rate of return (MRR) is the ration of the change in net benefits to change in total variable input costs between treatments (Jose and Lawrence, 2001). In other words, MRR measures the net return on additional capital invested in a new technology, compared to the farmer's present one. If the alternative technology is more costly, the rate of return (R) must be; -higher than those of other possible investments, and high enough to cover risks associated with adoption (Soha, 2014).

The marginal rate of return is estimated from the slope of the curve. The steeper the curve, the higher MRR. Net benefit curve is the relationship of the net benefits and total variable cost.

Acceptable minimum rate of return (AMRR): It is the minimum return that farmers expect from the enterprise, technology or improved production methods. It is sum of the return to management and cost of capital.

Return to management: The return to management is the benefit that farmers expect to the devotion of their time and efforts.

Cost of capital: Cost of capital is the benefit forgone in allocating working capital in one enterprise rather than in other enterprise. It might be interest or rent for money and land, respectively (Alimi and Manyong, 2000).

RESULTS AND DISCUSSION

Processing procedure of seed treatments

Seed of *X.jigna* cultivar was collected from farmers' production areas where the disease prevalence, incidence and severity were relatively intensive. After seed collection, germination test was undertaken to confirm the seed germination capability, followed by application of effective seed treatment methods. The first seed treatment method was soaking of the seed into hot water with 60°C for ten minutes and soaking it again in cold water for 5 min to ensure cooling of seed to keep its germination capability from entire damage. This mechanism was able to kill or deactivate the disease carrier (pathogen) available in the seed prior to planting. The second treatment was seed dressing using recommended fungicide (Apron-Star), and drying it evenly in shaded area. Also, control check was used

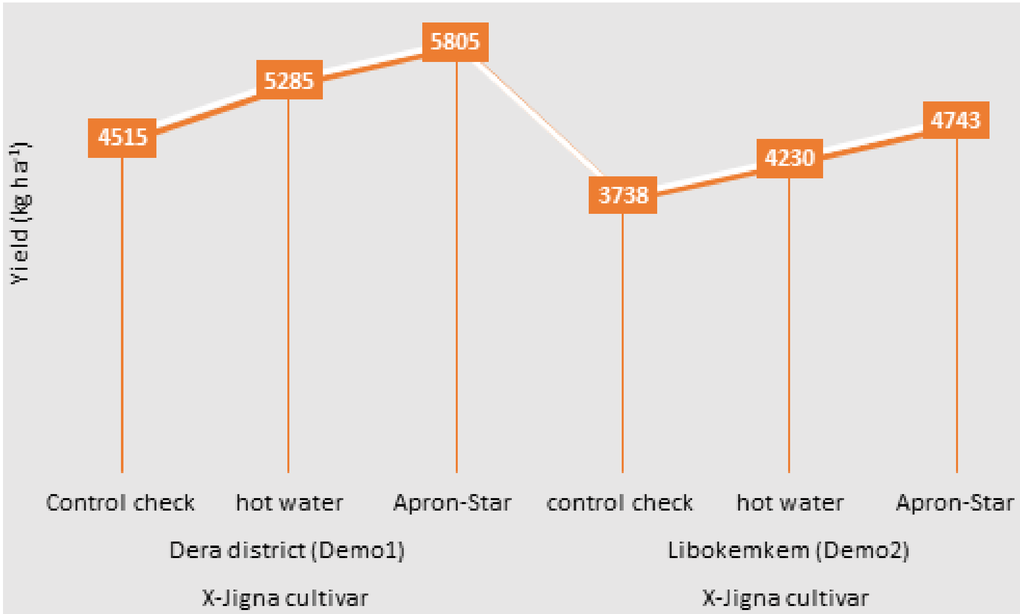

Figure 1. Effect of seed treatments on yield's performance.

similar with farmers existing production circumstances for comparison purpose for each seed treatment method.

Effect of seed treatments over existing farmers' practices in terms of grain productivity

The yield loss was decreased through application of effective seed treatment methods. Average grain yields of control check, hot water and fungicide were 4715, 5285 and 5805 kg/ha, respectively in *Dera* district (*Demonstration location 1*), (Figure 1). On the other hand, the mean yield of control check, hot water and fungicide treatment methods were 3738, 4230 and 4743 kg, respectively in *Libokemkem* district (*Demonstration location 2*). The productivity of the cultivar treated by fungicide was higher than hot water treatment which in turn is higher than the control check. The relative yield advantage was estimated using the following simplified formula. Treatment of the seed by fungicide had 23.2% relative yield advantage over control check and hot water treatment had 12.1% yield advantage over control check in *Dera* district (Demo location 1). And in *Libo kemekem* district (Demo location 2), fungicide treatment had 26.9% relative yield advantage over control check and hot water treatment had 13.2% yield advantage over control check. Fungicide treatment had 9.84% relative yield advantage over hot water treatment in *Dera* district. Seed treatment by fungicide had 12.13% relative yield advantage over hot water treatment in *Libo kemkem* district.

$$\text{Yield advantage (\%)} = \frac{\text{Yield of from seed treated} - \text{Yield of control check}}{\text{Yield of control check}} \times 100$$

Effect of seed treatments on net profit in Dera district (Demo Location 1)

Farmers who applied fungicide chemical could increase their profit by **88.7%** (14,310 ETB) than those who did not apply. Also, farmers who applied hot water seed treatment could increase their profit by **49.7%** (8,025 ETB) than those who did not apply it. Hence, fungicide treatment method had **26%** (6285 ETB) relative economic return advantage over hot water seed treatment (Table 1).

$$\text{RPA (\%)} = \frac{\text{Profit earned from seed treated} - \text{Profit from untreated seed}}{\text{Profit from untreated seed}} \times 100$$

Effect of seed treatments on net profit in *Libokemkem* district (Demo location 2)

The use of fungicide for seed treatment prior to planting had a relative profit advantage of 663% (13,077 ETB) over those farmers who did not apply this method. Also, this treatment had relative profit advantage of 67.9% over hot water seed treatment. Further, hot water seed treatment had a relative profit advantage of 350% over those who did not apply it (Table 2)

Partial budget analysis and marginal rate of return

Three treatments were set up to evaluate the performance of seed treatment options against rice sheath rot disease which intensively resulted in higher

Table 1. Records of input costs and benefits in *Dera* district (Demo 1).

Costs and benefits	Control check	Hot water treatment	Fungicide treatment
Hectare (ha)	0.01	0.01	0.01
Yield (kg ha^{-1})(Y)	4715	5285	5805
Price (p)	14.50	14.50	14.50
TR=Y x P	68367.5	76632.5	84172.5
Variable Input costs (VIC)			
Labor (birr ha^{-1})	19771.99	20011.99	19891.99
Chemical (birr ha^{-1})	0	0	1375
Total variable input costs (TVIC)	19771.99	20011.99	21266.99
Fixed input costs			
Cost of land/rent	28000	28000	28000
Seed (birr ha^{-1})	1800	1800	1800
Fertilizers (birr ha^{-1})	2658	2658	2658
Total fixed costs (TFC)	32458	32458	32458
TC=TVIC+TFC	52229.99	52469.99	53724.99
Net Profit =TR-TC	16138	24163	30448

Table 2. Records of input costs and benefits in *Libo kemkem* district (Demo 2).

Costs and benefits	Control check	Hot water treatment	Fungicide treatment
Hectare (ha)	0.01	0.01	0.01
Yield (kg ha^{-1}) (Y)	3738	4230	4743
Price (p)	14.5	14.50	14.50
TR=Y x P	54201	61335	68773.5
Variable input costs			
Labor (birr ha^{-1})	19771.99	20011.99	19891.99
Chemical (birr ha^{-1})	0	0	1375
Total variable Input costs (TVIC)	19771.99	20011.99	21266.99
Fixed costs			
Cost of land	28000	28000	28000
Seed (birr ha^{-1})	1800	1800	1800
Fertilizers (birr ha^{-1})	2658	2658	2658
Total fixed costs (TFC)	32458	32458	32458
TC=TVIC+TFC	52229.99	52469.99	53724.99
Net profit =TR-TC	1971.01	8865.01	15048.51

loss of grain yield. Farm gate price of output was taken into account in this experiment. Gross benefit **(GB)** is the product of gross yield and farm gate price of the output. Gross benefits of 68397, 76299 and 84172.5 ETB ha^{-1} were obtained from control check, hot water, and Apron-Star treatments, respectively in demonstration location 1 (*Dera* district) (Table 3). On the other hand, gross benefits of 54201, 61335 and 68774 ETB ha^{-1} were obtained from similar treatments, respectively in demonstration location 2 (*Libokemkem* district) (Table 4).

Table 3. An enterprise budget of rice production at different seed treatment methods against rice sheath rot disease in *Dera* district.

Costs and benefits of Production	Control check	Hot water	Apron-Star
Average grain yield (kg $ha^{-1)}$ = Y	4715	5285	5805
Price (birr ha^{-1}) =P	14.5	14.5	14.5
Goss farm gate benefit = (Y*P) = GB	68397	76299	84172.5
Total variable input costs = TVIC	19771.99	20011.99	21266.99
Net benefit = *GB-TVIC* = NB	48625.01	56287.01	62905.51
Change in net benefits between two consecutive treatments = ΔNB		7662	6618.5
Change in total variable input costs between two consecutive treatments = ΔTVIC		240	1255
Marginal rate of return =MRR		31.925	5.27

Change in net benefits (ETB ha^{-1}) between hot water and control check = NB (hot water) – NB (control check), ΔNB= 56287.01-48625.01 = 7662
Change in net benefit (ETB ha^{-1}) between Apron-Star and hot water = NB (Apron-Star) – NB (hot water), ΔNB= 62905.51 - 56287.01 = 6618.5
Change in net benefit (ETB ha^{-1}) between Apron-Star and control check = NB (Apron-Star) – NB (Control check), ΔNB= 62905.51 - 48625.01 = 14280.5; Change in total variable input costs (ETB ha^{-1}) between hot water and control check =TVIC (hot water) - TVIC (control check), ΔTVIC= 20011.99-19771.99 =240; Change in total variable input cost (ETB ha^{-1}) between Apron-Star and hot water =TVIC (Apron-Star) - TVIC (hot water), ΔTVIC= 21266.99- 20011.99= 1255; Change in total variable cost (ETB ha^{-1}) between Apron-Star and control check =TVIC (Apron-Star) - TVIC (control check), ΔTVIC= 21266.99-19771.99 =1495; ETB* = Ethiopian birr (local currency)

Table 4. An enterprise budget of rice production at different seed treatment methods against sheath rot disease in ***Libokemkem*** district (*Demo 2*).

Costs/benefits of Production	Control check	Hot water	Apron-Star
Average grain yield (kg $ha^{-1)}$ = Y	3738	4230	4743
Price (birr ha^{-1}) =**P**	14.5	14.5	14.5
Goss farm gate benefit = (Y*P) = **GB**	54201	61335	68773.5
Total variable input costs = **TVIC**	19771.99	20011.99	21266.99
Net benefit = (*GB-TVIC*) = **NB**	34429.01	41323.01	47506.51
Change in net benefits between two consecutive treatments = **ΔNB**		6894	6183.5
Change in total variable input costs between two consecutive treatments = **ΔTVIC**		240	1255
Marginal rate of return =**MRR**		28.725	4.927

Change in net benefits between hot water and control check = NB (hot water) – NB (control check), ΔNB= 41323.01- 34429.01= 6894 ETB ha^{-1}
Change in net benefit between Apron-Star and hot water = NB (Apron-Star) – NB (hot water), ΔNB= 47506.51 - 41323.01 = 6183.5 ETB ha^{-1}
Change in net benefit between Apron-Star and control check = NB (Apron-Star) – NB (control check), ΔNB= 47506.51 - 34429.01 = 13077.5 ETB ha^{-1}; Change in total variable input cost between hot water and control check = TVIC (hot water) - TVIC (control check), ΔTVIC=20011.99 - 19771.99 =240 ETB ha^{-1}; Change in total variable input cost between Apron-Star and hot water = TVIC (Apron-Star) - TVIC (hot water), ΔTVIC= 21266.99- 20011.99 = 1255 ETB ha^{-1}; Change in total variable cost between Apron-Star and control check = TVIC (Apron-Star) - TVIC (control check), ΔTVIC= 21266.99-19771.99 =1495 ETB ha^{-1}.

In both locations, seed treatment by fungicide known as Apron-Star generated the highest gross return than hot water and farmers' practice (Control check). Total variable input costs of control check, hot water and Apron-Star treatments were estimated as 19771.99, 20011.99 and 21266.99 ETB ha^{-1}, respectively in both demo locations 1 (*Dera* and *Libokemkem* districts). The net benefits of control check, hot water and Apron-Star treatments were estimated 48625.01, 56287.01 and 62905.51 ETB ha^{-1}, respectively in demo location 1 (*Dera* district); on the other hand, in demo location 2 (*Libokemkem* district), 34429.01, 41323.01 and 47506.51 ETB ha^{-1} were obtained from control check, hot water and Apron-star treatments, respectively. Apron-star fungicide was the highest in terms of generating net benefit among treatments in both demo locations. The change in net benefit between hot water treatment and control check which can be considered as farmers' practice was 7662 and 6618.5 ETB ha^{-1} and was estimated between Apron-Star treatment and hot water treatment. On the other side of demo (*Libokemkem* district), the change in net benefit between hot water treatment and control check was 6894 and 6183.5 ETB ha^{-1} between Apron-Star treatment and hot water treatment. Change in total variable input cost in both locations between hot water treatment and control check was 240 and 1255 ETB ha^{-1} between Apron-Star treatment and hot water treatment. A marginal rate of return between hot water treatment and control check was 31.925 which is to mean an investment or extra cost of one ETB in hot water seed treatment could generate additional net economic return of 31.925 birr and an investment on seed treatment using Apron-Star could

Table 5. The effect of alternative application of seed treatment methods on MRR and decision making.

When change of use from	Demonstration Location 1 (*Dera* district)		Demonstration Location 2 (*Libokemkem* district)		Decision
	MRR (%)	AMRR (%)	MRR (%)	AMRR (%)	
Control check to hot water	3192.5	178	2872.5	178	Economically feasible and recommended
Hot water to Apron-star	527	178	492.7	178	Economically feasible and recommended
Control check to Apron-Star	955.2	178	874.7	178	Economically feasible and recommended

MRR > AMRR.

generate net return of 5.27 ETB, in demonstration location 1 (*Dera* district). Nevertheless, additional cost of investment on hot water and Apron-Star seed treatments could release net economic returns of 28.275 and 4.927 ETB, respectively for smallholder farmers in demonstration location 2 (*Libokemkem* district).

Decision based on marginal rate of return and acceptable minimum rate of return

The equality or greater value of marginal rate of return in comparison with farmers' acceptable minimum rate of return was used as criterion for decision making and recommendation of new seed treatment methods for users. The calculated value of marginal rate of return (MRR) was greater than estimated value of acceptable minimum rate of return (AMRR) (Table 5). Acceptable minimum rate of return was estimated relying on the expectation that farmers to earn just for their management and cost of capital. The result indicates the seed treatment methods were found to be economically feasible, superior and recommended for farmers. When farmers changed their own practice to improved production method, applying hot water seed treatment could give marginal rate of return of 3192.5 and 2872.5% in *Dera* and *Libokemkem* districts, respectively. These values were found to be greater than farmers' acceptable minimum rate of return (178%). A shift from farmers' own practice (control check) to fungicide treatment method (Apron-Star) in *Dera* and *Libokemkem* districts resulted in a marginal rate of return of 955.2 and 874.7% which were also higher than the value of acceptable minimum rate of return of 178%. When farmers can change their method of production from hot water seed treatment to Apron-Star seed treatment, it could generate marginal rate of return of 527 and 492.7% in both districts. The results evidenced that both values of marginal rate of return were greater than the calculated value of acceptable minimum rate of return. Therefore, hot water and fungicide seed treatment methods were recommended for rice producers and they were assured economically feasible and superior over the use of untreated seed of X-Jigna cultivar in rice production. However, the use of hot water seed treatment method was highly recommended over the use of fungicide based on analysis of marginal rate of return since the value of marginal rate of return in both districts were greater than application of other alternative seed treatment methods. Furthermore, hot water seed treatment method is relatively eco-friendly and environmentally sounds.

Net benefit curves and MRR

The net benefit curves in two locations indicate that a shift from use of untreated seed to the use of seed treated by hot water and from hot water seed treatment to seed treatment by Apron-Star increased gain of farmers' net benefit. The slope of the curve gives us marginal rate of return which becomes steeper when shifting from control check to the use of seed treated by hot water. However, the slope of the curve between hot water treatment and usage of fungicide treatment method had relatively flattered. Therefore, the steeper the slope of net benefit curve implies value of the marginal rate of return become higher. On the other hand, the flatter the slope of the net benefit curve indicates lower marginal rate of return. Generally, on Figure 2 of both locations in *Dera* and *Libokemkem* districts, net benefits of seed treatments and slopes of the curves had similar characteristics.

Decision and recommendation based on criteria of analysis of residuals

The value obtained when acceptable minimum return was subtracted from net benefit of seed treatments is called residual value of the treatment. Then based on this calculation, the treatment with the highest value of residual tends to be recommended (Table 6). Hence, Apron-Star seed treatment was recommended in the case of both *Dera* and *Libokemkem* districts.

Dominance analysis among seed treatment methods

This analysis is a simplification of the stochastic dominance analysis, and is used to select the treatments

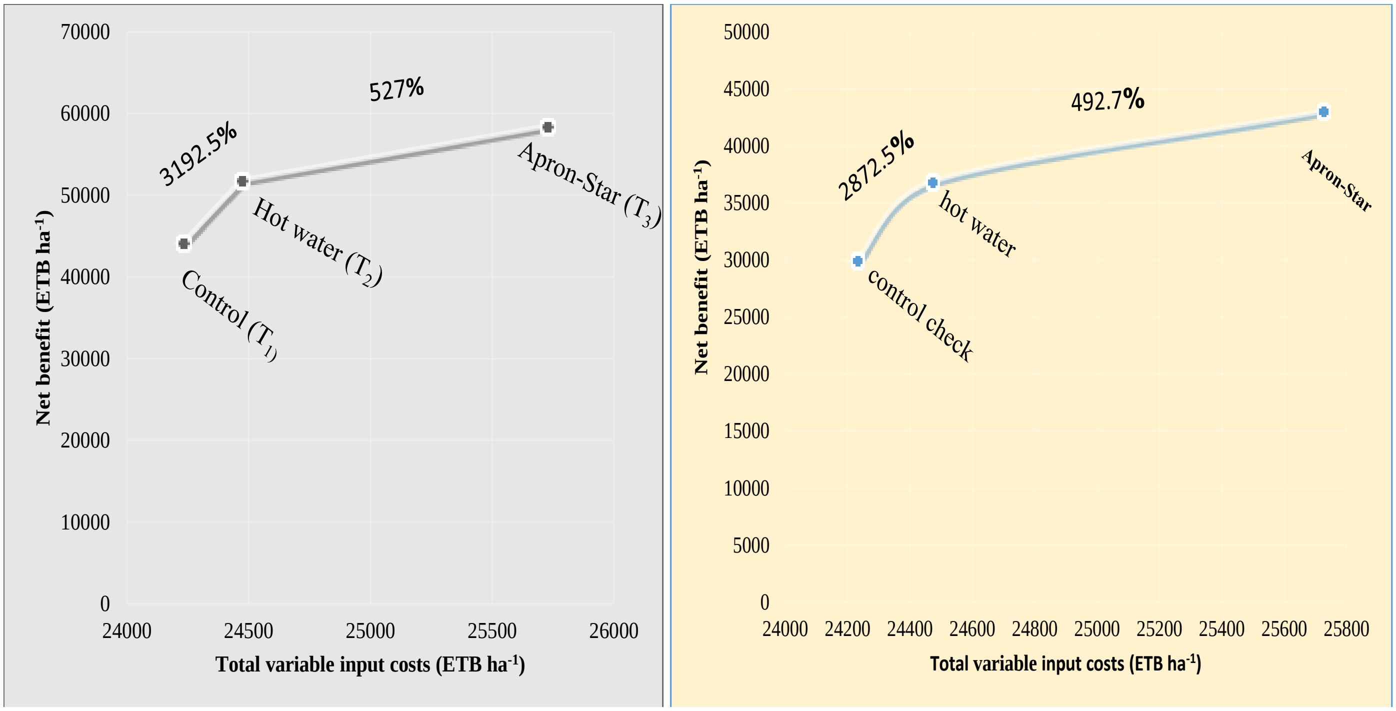

Figure 2. Net benefit curve and marginal rate of return of seed treatment methods in Dera and Libokemkem districts (Left: Dera and Right: Libokemkem).

Table 6. Estimated residual values of seed treatments.

Description	*Dera district*			*Libokemkem district*		
	CC*	HW*	AS*	CC*	HW*	AS*
Net benefit (ETB/ha), NB	48625.01	56287.01	62905.51	34429.01	41323.01	47506.51
Total variable input costs (ETB/ha), (TVIC)	19771.99	20011.99	21266.99	19771.99	20011.99	21266.99
Acceptable minimum return (ETB/ha), (AMR*)	35194.14	35621.34	37855.24	35194.14	35621.34	37855.24
Residuals (ETB/ha), (R*)	13430.87	20665.67	25050.27	-765.14	5701.67	9651.27

CC*= Control check, HW* = hot water seed treatment, AS* = Apron-Star seed treatment; R* = NB-AMR, AMR*= TVIC×178 /100.

Table 7. Dominance analysis on seed treatments.

Costs/benefits	Dera district			Libokemkem district		
	Treatments					
	CC	HW	AS	CC	HW	AS
Total variable input costs (ETB/ha)	19771.99	20011.99	21266.99	19771.99	20011.99	21266.99
Net benefit (ETB/ha)	48625.01	56287.01	62905.51	34429.01	41323.01	47506.51

that in terms of earnings offer the possibility of being chosen to be recommended to farmers. A treatment is said to be dominated when as a result of an increase in costs, its use does not lead to an increase in net benefits. It is dominated because at least there is a treatment of lesser or equal cost that generates greater benefits (Reyes-Hernández, 2001). Based on the dominance analysis on Table 7, the result shows that none of the treatment had lower or the same net benefit with relatively higher total variable input costs as compared with other treatments. Cost of control check was less than cost of hot water treatment which was less than cost of Apron-Star treatment method. Net benefit of control check was less than hot water treatment and Apron-Star treatment method. This is logically acceptable and economically feasible since there was no treatment with

Table 8. Sensitivity analysis on Apron-star seed treatment in the situation of price change of fungicide in *Dera* district (Location 1).

Description of parameter	CC (0 kg/ha)	AS (0.25 kg/ha)	Sensitivity analysis on apron-star treatment			
			Price of apron-star increased by			
			+100%	+200%	+400%	+600%
Price of Apron-Star (ETB /kg)	-	5500	11000	16500	27500	38500
Increase in Apron-Star price (%)	0	0	100	200	400	600
Average yield (kg $ha^{-1)}$ (Y)	4715	5805	5805	5805	5805	5805
Price of output (P)	14.5	14.5	14.5	14.5	14.5	14.5
(Y*P) = (GB)	68367.5	84172.5	84172.5	84172.5	84172.5	84172.5
Cost of Apron-Star/ha	0	1375	2750	4125	6875	9625
Other variable input costs (ETB/ha)	19771.99	19891.99	19891.99	19891.99	19891.99	19891.99
Total variable input costs (TVIC), ETB/ha	19771.99	21266.99	22641.99	24016.99	26766.99	29516.99
Net benefit (GB-TVIC) = (NB)	48595.51	62905.51	61530.51	60155.51	57405.51	54655.51
ΔTVIC		1495	2870	4245	6995	9745
ΔNB		14310	12935	11560	8810	6060
MRR		**9.57**	**4.5**	**2.72**	**1.26**	**0.62**

higher cost and less benefit as compared with other seed treatments. Therefore, it is unlikely to eliminate any of the treatments in this experiment.

Sensitivity analysis in change of price of Apron-Star (fungicide) and break-even price

Sensitivity analysis is a framework to visualize risk of uncertainty and is used to test a proposed technology's ability to withstand price and yield changes. Sensitivity analysis uses different prices or yields to determine what would happen to the net benefits and the choice of proposed technology if it were to occur in different price or yield conditions to those expected (Alimi and Manyong, 2000). When price policies change, inflation and other factors might influence price of variable inputs. These are some of the factors which are out of control of farmers, increases costs and that are adversely affecting the net benefits. Assuming the price of output, average yield obtained from the treatment and gross benefit were constant, the result of sensitivity analysis shows that the marginal rate of return was strongly resistant to seasonal changes or uncertainties to increasing price of fungicide. The range of recommendation is widely based on sensitivity analysis. The new practice of seed treatment method could be recommended between the range of 0 to 200% of cost of fungicide. Marginal rate of return of fungicide treatment method was greater than the acceptable minimum rate of return between this range of cost of fungicide (0 - 200%). However, if cost of fungicide was increased, the marginal rate of return would become less than the acceptable minimum rate of return. The break-even price of fungicide existed between the range of 200 - 300% and that was estimated approximately as 6544 ETB/0.25 kg. The point at which the curve of marginal rate of return intersects the line of acceptable minimum rate of return is the break-even price of fungicide. Proceeding beyond the point of intersection, the line of acceptable minimum rate of return would be above the curve of marginal rate of return. As a result, it was not recommended that fungicide seed treatment method be used above this point since it was not economically feasible and no-longer better than farmers' own practice (Table 8 and Figure 3). Break-even price of fungicide can be estimated using the following simplified formula

$$BEP_{\text{apron-star}} = \frac{\dfrac{\Delta NB}{AMRR} - \Delta TVIC_{x1}}{\Delta x}$$

ΔNB = Change in net benefit between Apron-Star treatment and control check. $\Delta TVIC_{x1}$ = Change in total variable input costs. AMRR = Acceptable minimum rate of return. ΔX = Change in quantity of *Apron-Star* fungicide (kg).BEP= Break-even price of fungicide above which the technology is not economically feasible and recommendable.

$$BEP = \frac{\dfrac{14310}{1.78} - 1495}{0.25} = 6544 \text{ ETB/0.25 kg}$$

Sensitivity analysis was also undertaken in *Libokemkem* district. If price of Apron-Star is above the break-even price, it would be no longer economically feasible and better than farmers' own practice. Therefore, the seed treatment method using Apron-Star was recommended for farmers as long as the price of fungicide is less than

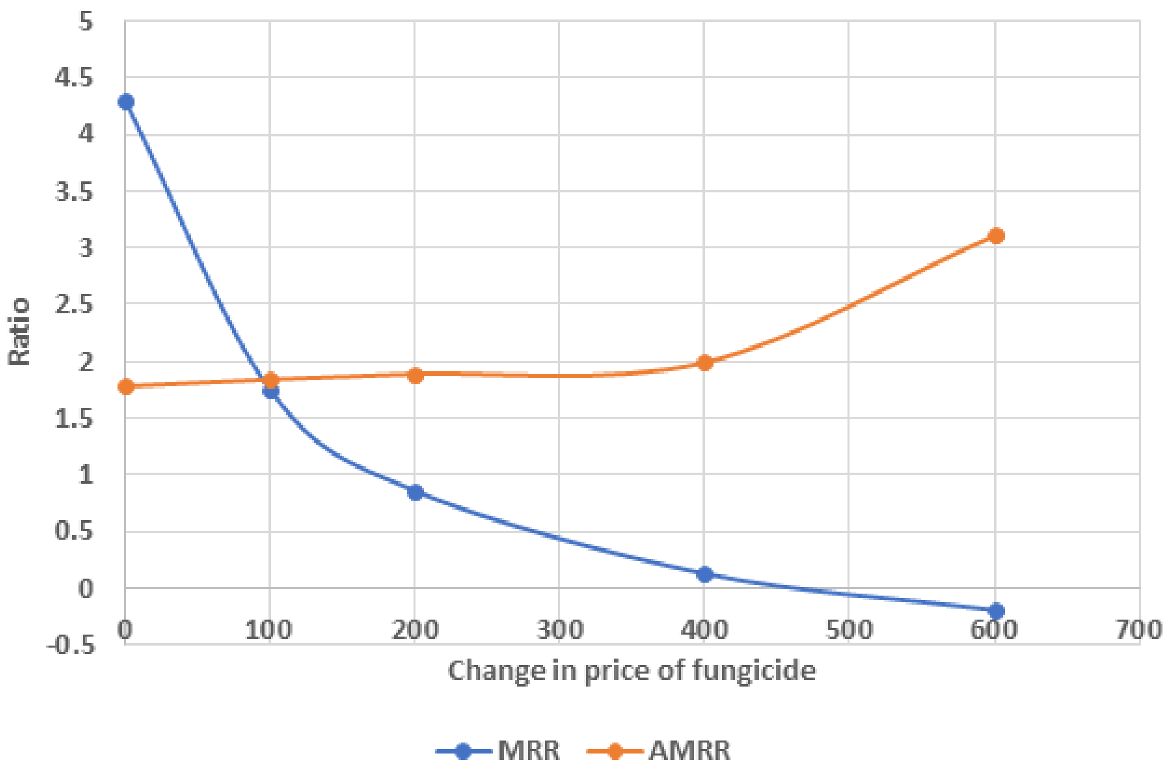

Figure 3. Sensitivity analysis in change of fungicide price and its effect on Marginal rate of return and acceptable minimum rate of return in *Dera* district (Location 1).

Table 9. Sensitivity analysis on Apron-Star in the situation of price change of fungicide in *Libo kemkem* district (location 2).

Description of parameters	CC (0 kg/ha)	AS (0.25 kg/ha)	Sensitivity analysis on Apron-Star seed treatment			
			Price of fungicide increased by			
			+100%	+200%	+400%	+600%
Average yield (kg ha$^{-1)}$ (Y)	3738	4743	4743	4743	4743	4743
Price of output (P)	14.5	14.5	14.5	14.5	14.5	14.5
(Y*P) = (GB)	54201	68773.5	68773.5	68773.5	68773.5	68773.5
Cost of Apron-Star	0	1375	2750	4125	6875	9625
Other variable input costs (ETB/ha)	19771.99	19891.99	19891.99	19891.99	19891.99	19891.99
Total variable input costs (TVIC), ETB/ha	19771.99	21266.99	22641.99	24016.99	26766.99	29516.99
Net benefit (GB-TVIC) = (NB)	34429.01	47506.51	46131.51	44756.51	42006.51	39256.51
ΔTVIC		1495	2870	4245	6995	9745
ΔNB		13077.5	11702.5	10327.5	7577.5	4827.5
MRR		**8.75**	**4.08**	**2.43**	**1.08**	**0.49**

5852 ETB/0.25 kg (Table 9 and Figure 4).

$$BEP_{apron\text{-}star} = \frac{\frac{\Delta NB}{AMRR} - \Delta TVIC_{,}}{\Delta x}$$

ΔNB = Change in net benefit between Apron-Star treatment and control check. ΔTVC_{x1} = Change in total variable input costs. AMRR = Acceptable minimum rate of return. ΔX = Change in quantity of *Apron-star* fungicide (kg).BEP= Break-even price of Apron-Star above which the technology is not economically feasible and recommendable.

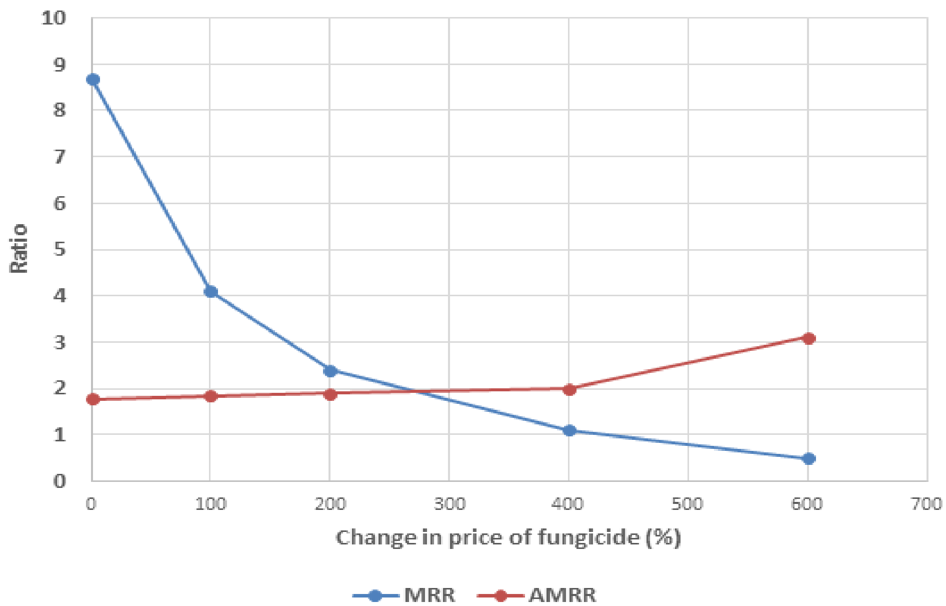

Figure 4. Sensitivity analysis in change of fungicide price and its effects on Marginal rate of return and acceptable minimum rate of return in *Libo kemkem* district (Location 2).

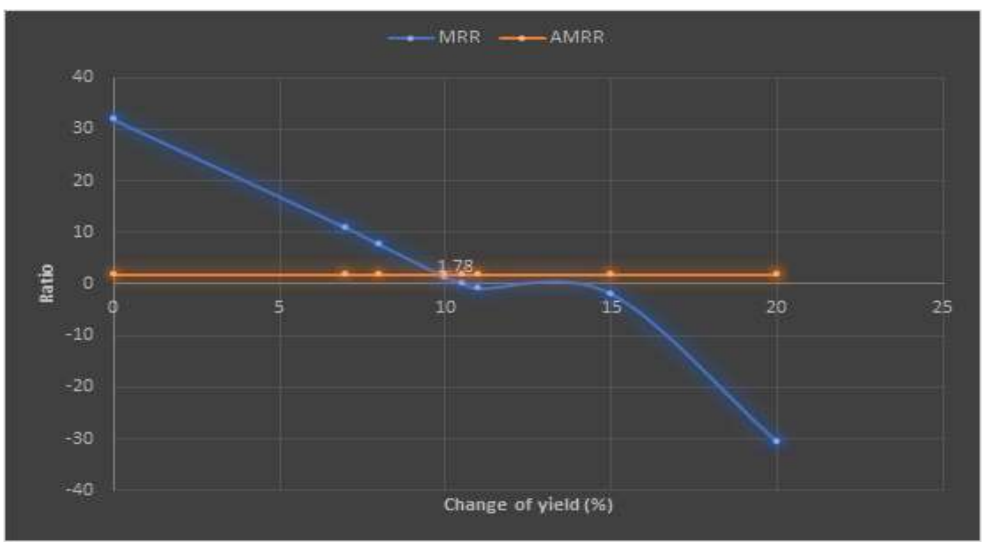

Figure 5. Sensitivity analysis in change of yield and its effect on MRR in Libokemkem district.

$$BEP = \frac{\frac{13078}{1.78} - 120}{0.25} = 5852 \text{ ETB/0.25 kg}$$

Sensitivity analysis in decreasing change of yield and calculating break-even yield

Calculating break-even yield

Estimation of break-even yield on seed treatment methods is very crucial in partial budget analysis. The break-even yield is the limit below which the new seed treatment method was not able to be recommended and economically not feasible (Figure 5). The break-even yield was estimated as 4763 kg. At this point, farmers can cover their costs of production by the revenue obtained from sale of 4763 kg. Production less than this amount is not profitable for the farmers. This implies that new practices, methods or innovations are no longer better than farmers' practices. As a result, it couldn't be economically feasible to proceed less than this point. On

Table 10. Sensitivity analysis in the situation of changing yield on hot water seed treatment in *Dera* district.

Description of parameter	Sensitivity analysis in different yield levels on hot water seed treatment								
	Treatment		Yield decreased by						
	CC	HW	-7%	-8%	-10%	-10. 5	-11%	-15%	-20%
Average yield (kg ha$^{-1)}$ (Y)	4715	5285	4915	4862	4757	4730	4703	4492	4228
Price of output (P)	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
(Y*P) = (GB)	68397	76299	71268	70499	68969	68585	68194	65134	61306
Total variable input costs (TVIC)	19771.99	20011.99	20011.99	20011.99	20011.99	20011.99	20011.99	20011.99	20011.99
Net benefit (GB-TVIC) = (NB)	48625.01	56287.01	51256.01	50487.01	48957.01	48573.01	48182.01	45122.01	41294.01
ΔTVIC		240	240	240	240	240	240	240	240
ΔNB between hot water and control check		7662	2631	1862	332	-52	-203	-443	-7331
MRR		**31.9**	**10.96**	**7.76**	**1.38**	**0.23**	**-0.85**	**-1.85**	**-30.5**

the other hand, for demonstration location 2 or in *Libokemkem* district, the break-even yield was 3784 kg, which the new seed treatment method using hot water was no longer economically feasible. We can reach this point when the yield decreased approximately by 10.5% in the production using hot water seed treatment method.

$$Q = \frac{(\Delta TVIC \times AMRR) + TVIC_{hw} + NB_{cc}}{P}$$

Q = Break-even yield below which the new seed treatment method could not be economical.
P = Price of output.
ΔTVIC = Change in total variable input costs between control check and hot water seed treatment;
TVIC = Total variable input cost of hot water treatment;
NB_{cc} = Net benefit of control check.
AMRR = Acceptable minimum rate of return;
P = 14.5 ETB;
ΔTVIC = 240 ETB;
TVIC = 20011.99 ETB
NB_{cc} = 48625.01 ETB for location 1 and
NB_{cc} = 34429.01 ETB for location 2.
AMRR = 1.78

$$Q1 = \frac{(240 \times 1.78) + 20011.99 + 48625.01}{14.5} = 4763 \text{ kg in (location 1)}$$

$$Q2 = \frac{(240 \times 1.78) + 20011.99 + 34429.01}{14.5} = 3784 \text{ kg in (location 2)}$$

Sensitivity analysis in decreasing change of yield

Yield might be decreased due to uncertainties. Natural phenomena and environmental factors such as drought, flood, rainfall distribution, temperature etc can impact on yield and net benefits of new proposed technology or new production techniques or practices. In this case, sensitivity analysis needs to be done to determine the sensitivity of marginal rate of return. If the yield changes by different levels on hot water treatment due to uncertainties, the marginal rate of return start declining. Marginal rate of return is sensitive to yield reduction in this case. Break-even yield was attained when the yield reduction could be undertaken by almost 10% (Table 10).

On the other hand, for demonstration location 2 or in *Libokemkem* district, the break-even yield was 3784 kg which the new seed treatment method using hot water was no longer economically feasible. We can reach this point when the yield decreased approximately by 10.5% in the production using hot water seed treatment method. Therefore, marginal rate of return in hot water seed treatment is relatively sensitive to yield reduction compared with Dera district (Table 11).

An increasing yield reduction would negatively affect marginal rate of return in rice production using improved seed treatment method. The figure shows when yield of rice production expected to decrease by different levels of percentages, marginal rate of return dramatically starts declining, finally crossed the horizontal axis and passed to the negative axis if the level of yield

Table 11. Sensitivity analysis in the situation of changing yield on hot water treatment in *Libokemkem* district.

Description of parameter	Sensitivity analysis on hot water seed treatment								
	Treatment		Yield decreased by						
	CC	HW	-7%	-8%	-10%	-10.5%	-11%	-15%	-20%
Average yield (kg ha^{-1}) (Y)	3738	4230	3934	3892	3807	3786	3765	3596	3384
Price of output (P)	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
(Y*P) = (GB)	54201	61335	57042	56428	55202	54896	54588	52135	49068
Total variable input costs (TVIC)	19771.99	20011.99	20011.99	20011.99	20011.99	20011.99	20011.99	20011.99	20011.99
Net benefit (GB-TVIC) = (NB)	34429.01	41323.01	37030.01	36416.01	35190.01	34884.01	34576.01	32123.01	29056.01
ΔTVIC		240	240	240	240	240	240	240	240
ΔNB between hot water and control check		6894	2601	1987	761	455	142.2	-2306	-5373
MRR		**28.7**	**10.83**	**8.28**	**3.2**	**1.89**	**0.59**	**-9.6**	**-22.39**

reduction is increasing.

CONCLUSION AND RECOMMENDATIONS

Adoptions of seed treatments methods were economically feasible at smallholder rice producing farmers and easily applicable at farmers' production circumstances. Seed treatment of *X.Jigna* cultivar using hot water and seed dressing method using Apron-star impacted higher yield performance and relative profit advantages over farmers' own production conditions which were considered as control checks. The results of marginal rate of return for both seed treatments (Apron-star and hot water) were found to be greater than farmers' acceptable minimum rate of return. This implies that both treatments were economically feasible and recommendable for rice producing farmers. Apart from application of these simple, effective and efficient seed treatment methods, it is also recommended for farmers to use newly released varieties which are well known as resistant to the disease. As it is a seed-borne disease, checking the quality of seeds involves using healthy seeds. Fungicides are recommended for the management of rice sheath rot disease which is ecofriendly to the environment and can be achieved by the use of integrated disease management. In spite of several new rice varieties released and available in the production areas with better characteristics and traits such as disease resistance, cold tolerance, better productivity and biomass, however, the grain color of those newly released varieties matters to farmers in their market acceptability and consumers' preference. This situation drives farmers to stick with using *X.Jigna* cultivar in their production for long decades. However, since productivity performance of new varieties and grain weights are better than *X-Jigna* cultivar, it could compensate farmers' benefits obtained from sales at their local markets. To strengthen demonstration of these seed treatment methods, creation of awareness and capacity building activities need to be expanded by respective entities towards untouched areas and ensure its sustainable use of these methods in major rice producing and hot spot areas of Ethiopia.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Alcido EW (2001). Economic analysis of farm change using the partial budget, Brazilian Agricultural Research Corporation (EMPRABA).

Alimi T, Alofe CO (1992). Profitability response of improved open pollinated maize varieties to Nitrogen fertilizer levels. Journal of Agriculture and Rural Development 5(1):42-47.

Alimi T, Manyong VM (2000). Partial budget analysis for on farm research. International institute of tropical agriculture (IITA), IITA Research Guide 65, Information service and Training, Nigeria.

Berhan M, Yalew D, Zeleke T (2020). Evaluation of fungicides efficacy against rice sheath rot Disease (Sarocladium oryzae) in rain fed low land rice (*Oryzae sativa* L.) in Fogera hub. International Journal of Agriculture and Biosciences 9(5):221-225.

Birhanu B, Takele N, Shashitu B, Getachew A, Gashaw A, Mohammed Y (2020). Results of Plant Protection Research.

Proceedings of the Completed Plant Protection Research Activities, 2018. Addis Abeba, Ethiopia. http://197.156.72.153:8080/xmlui/handle/123456789/3560

CIMMYT (1988). From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, D.F. International Maize and Wheat Improvement Centre.

Douglas H (1982). Partial Budget Analysis for On-Farm Potato Research. Technical Information Bulletin. International Potato Center (CIP).

Ehui S, Rey B (1992). Partial budget analysis for on-station and on-farm small ruminant production systems research: Method and data requirements. Small ruminant research and development in Africa: Proceedings of the First Biennial Conference of the African Small Ruminant Research Network: ILRAD. Nairobi, Kenya: ILCA.

Hadian P, Kazumasa M, Megumi K, Tetsuya Y, Motoki K (2017). Screening of Japanese Rice Cultivars for Seeds with Heat Stress Tolerance under Hot Water Disinfection Method. Asian Journal of Plant Sciences 16(4):211-220.

Jose A, Lawrence E (2001). The economic potential of silicon for integrated management and sustainable rice production. University of Florida-IFAS, Everglades Research and Education Centre, Belle Glade, FL 33430 USA, Crop Protection

Kassa M, Wassu M, Gebre H (2018). On farm partial budget analysis of pepper (*Capsicum annuum* L.) to the application of NP fertilizer and farmyard manure in Raya Azebo District, Northern Ethiopia.

Mutiga S, Mwongera D, Kirigua V, Otipa M, Kimani J, Mugambi C, Ngari B, Ochieng V, Wasike V, Wandera F, Wasilwa L, Too A, Nyongesa O, Zhou B, Mitchell T, Wang GL, Ouedraogo I, Rotich F, Correll JC, Talbot NJ (2019). Sheath rots disease, E-Guide for Rice Production in East Africa. IRRI, Africa Rice.

Pak D, You MP, Lanoiselet V (2016). Reservoir of cultivated rice pathogens in wild rice in Australia. European Journal of Plant Pathology 147:295-311. Available at : https://doi.org/10.1007/s10658-016-1002-y

Ram S, Dodan DS (1995). Sheath rot of rice, CCSHA U, Rice Research Station, Kaul - 132 021, Haryana, India. International Journal of Tropical Plant Diseases 13:139-152.

Reyes Hernández M (2001). Análisis económico de experimentos agrícolas con presupuestos parciales: Re-enseñando el uso de este enfoque. Boletín Ciagros. Guatemala: Universidad de San Carlos de Guatemala.

Soha M (2014). The partial budget analysis for sorghum farm in Sinai Peninsula, Egypt. Annals of Agricultural Sciences. http://dx.doi.org/10.1016/j.aoas.2014.06.011