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Evaluation of frontline demonstration of herbicide (Pyroxsulam) for weed control in bread wheat in Tigray, Northern Ethiopia

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Frontline demonstration of herbicide was conducted in four districts of Tigray Region with objective of improving productivity of unit area and enhancing the income of farming community. Technology demonstration followed by perception assessment survey was conducted on the direct beneficiaries of the technology. A total of 40 farmers were selected purposively. The herbicide and improved bread wheat was offered. Yield, production cost and perception data were collected. To measure the attitude of farmers towards the improved technology, a five-point Likert scale were used. The data was analyzed using t-test and statistical analytical techniques such as descriptive, frequency, percentage and partial budget analysis. The result of this activity shows that in the four districts, an average of 2236, 2050, 3025 and 2712 kg ha^{-1} of grain yield were harvested from Pyroxsulam application, whereas, an average of 1689, 1356, 2127 and 1832 kg ha^{-1} grain yield were harvested from hand weeding, respectively. This can show us that farmers from the districts had an increment of yield by 32.39, 51.18, 42.22 and 48.03% in Hintalo-Wajirat, Enderta, Saesie Tsaeda-Emba and Glomahda districts, respectively. The t-test result also showed that there is statistically significant mean difference between the two groups at less than 5%. The average marginal rate of return of the four districts was 259% and shows greater than the minimum acceptable rate of return (100%). Hence, further scale up need to be made concerning rural institutions.

Key words: Demonstration, hand weeding, herbicide, improved wheat, profitability, pyroxsulam.

INTRODUCTION

Ethiopia is the largest wheat producer in sub-Saharan Africa. In Ethiopia, wheat is the most important cereal crop in terms of the area of land allocated, volume produced, and the number of farmers engaged in its production. About 4.7 million farmer households are involved in the production of about 3.9 million tons of

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wheat across 1.6 million hectares of land, with an average productivity of 2.4 t ha^{-1} (Central Statistics Authority - CSA, 2012).

Although efforts are being made by the government and other development partners, such as United States Agency for International Development (USAID), the wheat supply does not meet the national demand; the estimated annual deficit is about 25 to 30%, which is filled by imported grain from other countries (United States Agency for International Development - USAID, 2014). One of the most limiting factors in the production of wheat in Ethiopia in general, and Tigray region in particular is grassy and broad-leaved weeds.

Wheat is among the major cereal crops grown in Tigray region which accounts for 30% of the total production (CSA, 2012). Wheat production in the region is highly threatened by numerous production constraints, among which weeds are frequently occurring production constraints in which its effect is aggravated by traditional cultural methods that the farmers are practiced. Crop-weed competition trials conducted on various farmers field indicated that uncontrolled weed growth resulted to a regional yield reduction of 31% (Agronomy Progress Report, 2012). Though both grasses and broad leaved weeds are responsible for the reduction of yields, the wheat production areas showed similarities in that the grassy weeds particularly wild oat, had become a serious problem.

This is attributed to cereal-based cropping system, insufficient or late weeding and use of local seed which is not clean. The traditional method of sowing makes weed virtually impossible to distinguish and manually removed sufficiently early to reduce yield losses; consequently, weeding remains a neglected problem. Though the farmers practiced fertilizer use in wheat, experiments elsewhere indicated that in uncontrolled weed growth, wild oat utilized nitrogen better than wheat. Therefore, insufficient weeding, which is the common phenomenon of the region, resulted to low fertilizer use efficiency. Thus, the full benefits from increased usage of fertilizer may not be realized without the application of improved weed control technology, increasing crop yield as well as improved product quality by suppressing weed growth (Ferdous et al., 2017). Based on this, herbicide chemical (Pyroxsulam) was tested in different mandate areas giving promising result in reduction and removing of wild oat and broad-leaved weeds. Pyroxsulam was more effective on controlling broadleaved weeds which reduced the weed population as compared to other herbicides and can also control serious grassy weeds on wheat (Muhammad et al., 2013).

However, demonstration, social and economic importance of this herbicide on farmers' field is not done widely in order to popularize and promote the technology in the area. Hence, addressing this knowledge and development gap is of paramount importance in order to enhance their production and improve their income which is capable of bringing about significant development impacts.

MATERIALS AND METHODS

Description of the study area

The Tigray National Regional State is situated between 12° 15' and 14° 57' N latitude and 36° 27' and 39° 59' E longitude. It is bordered to the North by Eritrea; to the West by the Sudan, to the South by Amhara and to the East by Afar Regional States. It covers a total of 53,638 km^2 surface area and belongs to the African dry lands, which are often called the Sudano-Sahelian Region (Emiru et al., 2011). The region is divided into six administrative zones which has 54 districts and nearly 800 peasant associations (CSA, 2010). The study was done on two zones of Tigray region by selecting four districts in regard to their weed coverage. The districts are named Gulomahda and Saeisi Tsaedaemba (Eastern zone) and Enderta and Hintalo Wajirat (South-eastern zone).

Enderta and Hintalo Wajirat are found in South Eastern Tigray Zone. Enderta is one of the four districts in the Southeastern administrative zone of Tigray. It is located at 13° 15`0" N and 39° 30`30" E with an altitude ranging from 1500 to 2000 m above sea level and shares borders with Kilte`Awlaelo district in the north, Hintalo Wajirat in the south, Afar Regional State in the east and the district of Degu'a Tembien in the west. The district covers a total area of 89,812 km^2 of which 30,062 ha is cultivable land. The total population size is 114,277 according to the 2010 population census of the CSA (2010). The agro-climatic state of the district is mainly (96%) warm mild climate, with remaining 3 and 1% hot low land climate and temperate climate respectively. Annual average rainfall ranges from 450 to 550 mm. In concurrence to the agro-climatic state of the district, smallholder mixed farming remains the single largest tributary to the livelihoods of the population. Major crops grown in the district include teff, wheat, barley, sorghum, millet, oil seeds, pulse seeds, horticultural crops and vegetables. Hintalo-Wajirat district is found in the south eastern zone of the Tigray Regional State. The district covering a total land mass of 193,309 km^2 is bordered by the Afar Regional State in the east, Raya Azebo district in the south east, Alaje district in the south, Saharti-Samre district in the west and Enderta district in the North. The district is found at an elevation which ranges from the lowest 1825 m to the highest 2625 masl. Climate classifications of the area comprise 22.5% kola, 63.75% weina-dega and 13.75% dega. Teff, wheat, barley, sorghum and vegetables are the most common types of crops growing in many places of the district. The district receives an average rainfall that ranges from the lowest 336 mm to the highest 933.75 mm per annum. The total population of the district is 180739 of which 88,950 are males and 91,789 are females (Hintalo-wajerat district Plan and Finance Development office - HWPFD, 2013).

The two districts of the study area, Saesi-Tsaeda-Imba and Gulomahda, are found in Eastern Tigray Zone. Saesie-Tsaeda-Imba is located in the eastern zone of Tigray region on which the capital Firewoyni is located 60 km far from Mekelle, on the way from Mekelle to Adigrat. It has a total area of about 933.12 km^2 and is divided into 24 administrative PAs of which 22 are rural and two Kebeles are town administration. Gulomahda district is found at 915 km north of Addis Ababa (Gebrehiwot and Fekadu, 2012). It is located at 14° 30' to 14° 50' N and 39° 20' to 39° 35' E and has an altitude of 1500 to 3200 ma.s.l. It is bordered on the south by Ganta-Afeshum district, on the west by the Central Zone, on the north by Eritrea and on the east by Erob district (Agricultural and Rural Development Office of Erob District - ARDOED, 2013).

According to the CSA estimation as of July 2010, the total population was estimated to be 139,191 and 84,236 for Saesie-Tsaeda-Imba and Gulomahda (CSA, 2010). The climate of the study districts is generally sub-tropical with an extended dry period of nine to ten months and a maximum effective rainy season of 50 to 60 days. The rainfall pattern is predominantly uni-modal (June to early September) (Belete et al., 2002).

Sampling and experimental design

The activity was conducted in the above mentioned four districts (Enderta, Hintalo-Wajirat, Saesie Tsaeda-Emba and Gulomahda) in two demonstration plots (Pyroxsulam and hand weeding) side by side. One kebelle from each of the four districts which were invaded by weeds were selected purposively. Besides, from the respective kebelles 10 farmers who were willing and able to participate in the new technology were purposively selected. The activity was carried out in collaboration with District Office of Agricultural and Rural Development staffs and development agents of the respective kebelle. Plot size of 10 m × 10 m for each Pyroxsulam (45 OD) and hand weeding treatment were applied. The herbicide was mostly used and effective for controlling grass and broad leaf weeds in wheat and teff. Herbicide treatment (Pyroxsulam 45 OD) was applied at 0.5 L/ha for wheat. Besides, the amount of water required 200 L/ha for both wheat. The herbicide was applied at early stage (25 to 30 days after emergence) and T-jet\Flat fan type of spray nozzle was used during the application. The wheat variety 'Picaflor' was used uniformly for all treatment and participating farmers. The seed rate of 125 kg\ha was used and sowing date was first week of July.

Data collection

Qualitative and quantitative data were collected from the demonstration trial. Qualitative data was collected through focus group discussion and informal discussion with farmers and development agents (DAs). Qualitative data was used to fill the gap in quantitative data which was then collected through personal interview using interview schedule. Sample yield data were also collected from demonstration plots and plots where farmers use his conventional practices. Production cost and benefits were collected to see the profitability difference of the treatments. Farmers' point of view on the attributes of the variety based on the composite indicators of yield and yield components were also collected using Likert scale method, a format that this is preferred by Derrick and White (2017).

Data analysis

The data were analyzed using t-test and statistical analytical techniques such as descriptive, frequency, percentage and graphs in line with Ferdous et al. (2016). Economic analysis was made using partial budget analysis which was done to determine the economic feasibility of the weed control methods. It was calculated by taking into account the additional input costs (variable costs) involved and the gross returns obtained from weed control treatments. The variable cost also included the labor cost involved in harvesting, threshing and winnowing as their cost varied according to the yield obtained in a particular treatment (CIMMYT, 1988). Besides, different parameters as suggested by Yadav et al. (2004) were used for calculating gap analysis. Technology gap, extension gap and technology index were calculated using the following formulas

Technology gap = Potential Yield – Demonstration Yield (1)

Extension gap = Demonstration Yield – Yield under farmers practice (2)

Technology index (%) = [(Potential Yield – Demonstration Yield) / Potential Yield] × 100 (3)

RESULTS AND DISSCUSION

The grain yield of the Pyroxsulam treatment was higher than the hand weeding treatment in all districts which could be due to the effectiveness of the herbicide in reducing weed competition at all stage of the crop. The herbicide was applied at early stage (25 to 30 days after emergence) which was effective in weed reduction than the hand weeding which started lately and even not weeded as required. Similarly, the straw yield of the Pyroxsulam (45 OD) treatment was better than the hand weeding in all participated districts.

As can be seen from Figure 1, in Hintalo-Wajirat, an average grain and biomass yield of 2236 and 4095 kg ha^{-1} were harvested from Pyroxsulam (45 OD) applied; whereas, an average of 1689 and 3212 kg ha^{-1} grain and biomass yield were harvested from hand weeding respectively. In Enderta district, an average of 2050 and 3765 kg ha^{-1} of grain and biomass yield were harvested from the improved practice (Pyroxsulam 45 OD), whereas 1356 and 3085 kg ha^{-1} of grain and biomass yield were harvested from hand weeding, respectively. Besides, in Saesie Tsaeda Emba and Gulomahda district the average yield obtained from the Pyroxsulam (45 OD) was 3025 and 2712 kg ha^{-1}; whereas, in the districts the average yield that farmer obtained from the local in the same production season was 2127 and 1832 kg ha^{-1}, respectively. Similar results were also observed by Sharma and Choudhary (2014).

In addition, the result reveals that the improved practice gave a percentage yield increment of 32.39, 51.18, 42.22 and 48.03 in Hintalo-Wajirat, Enderta, Saesie Tsaeda Emba and Gulomahda districts, respectively. This would imply that the improved practice (herbicide) can play significant roles in enhancing the productivity of wheat as well as improving the food security status of small holder farmers.

Yield of the demonstration trials and potential yield of the crop due to the herbicide was compared to estimate the yield gaps which were further categorized into technology index. The technology gap shows the gap in the demonstration yield over potential yield, and in all districts technology gap were 1564, 175, 777 and 1088 kg ha^{-1}, respectively. The observed technology gap may be attributed to dissimilarities in soil fertility, salinity and erratic rainfall and other vagaries of weather conditions in the area. Hence, to narrow down the gap between the yields of different varieties, location specific recommendation appears to be necessary. Technology index shows the feasibility of the technology at the

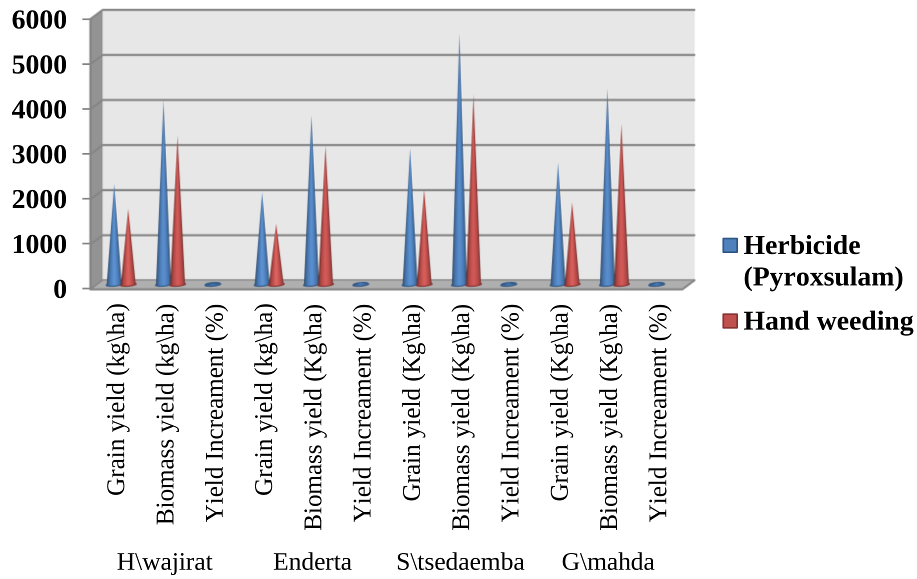

Figure 1. Grain and biomass yield of the demonstration of herbicide and hand weeding.

Table 1. Yield, technology gap and technology index of demonstration.

Districts	Practices	Yield (kg ha^{-1})	Yield increment (%)	Technology gap (kg ha^{-1})	Technology index (%)
H\wajirat	Pyroxsulam	2236	32.39	1564	41
	Hand Weeding	1689			
Enderta	Pyroxsulam	2050	51.18	1750	46
	Hand Weeding	1356			
Saesie Tsaeda Emba	Pyroxsulam	3025	42.22	777	20.44
	Hand Weeding	2127			
Gulomahda	Pyroxsulam	2712	48.03	1088	28.6
	Hand Weeding	1832			

Table 2. Main effect of herbicides on weeds and crop growth.

Attribute	Weeding	N	Mean	t	SEM*	df	P-value
Grain yield	Hand Weeding	20	1751	-2.053	261.19	38	0.04
	Pyroxsulam	20	2506		259.33		

*SEM- Standard error difference.

farmer's field. The lower the value of technology index, the more is the feasibility. Table 1 revealed that the technology index values were 41, 46, 20.44 and 28.6%, respectively. The findings of the study are in line with the findings of Sawardekar et al. (2003), and Hiremath and Nagaraju (2009).

Moreover, the analysis of data concerning grain yield revealed significant differences among the hand weeding and pallas 45 OD (Pyroxsulam) as presented in Table 2. Chemical weed control in wheat was best in producing higher grain yield than hand weeding. Akhtar et al. (1991) found that application of grassy and broad leaf herbicides

Table 3. Partial budget analysis.

Attribute	H/Wajrat		Enderta		S/T/Emba		G/Mahda		Average	
	Hand weeding	Herbicide	Hand weeding	Herbicide	Hand weeding	Herbicide	Hand weeding	Herbicide	Hand weeding	Herbicide
Yield (kg ha^{-1})	1689	2236	1356	2050	2127	3025	1832	2710	1751	2505
Straw yield (kg ha^{-1})	2270	2800	3085	3933	4233	5500	3570	4350	3289	4146
Gross field benefit (grain)	16045.5	21242	12882	19475	20206.5	28737.5	17404	25745	16634.5	23799.875
Gross field benefit (straw)	2837.5	3500	3856.25	4916.25	5291.25	6875	4462.5	5437.5	4355.625	5182.1875
Total gross benefit (Birr ha^{-1})	18883	24742	16738.25	24391.25	25497.75	35612.5	21866.5	31182.5	20746.375	28982.0625
Cost of weeding (Birr ha^{-1})	4500		5800		6700		6250		58125	
Cost of food for weeding (Birr ha^{-1})	0		700		1100		500		766.67	
Cost of pallas chemical (Birr ha^{-1})	0	1000		1000		1000		1000		1000
Cost of spraying (Birr ha^{-1})	0	150		150		150		150		150
Total variable costs (Birr ha^{-1})	4500	1150	6500	1150	7800	1150	6750	1150	6387.5	1150
Net benefit (Birr ha^{-1})	14383	23592	10238.25	23241.25	17697.75	34462.5	15116.5	30032.5	14358.88	27,832
Change in variable cost (Birr ha^{-1})		3350		5350		6650		5600		5,238
Change in net benefit (Birr ha^{-1})		9209		13003		16764.75		14916		13,473
MRR		2.75 ($64.1 USD)		2.43 (56.64 US USD)		2.52 ($58.74 USD)		2.66 ($62 USD)		**2.59** ($60.37 USD)

increased grain yield and yield components. An independent sample t-test was conducted to compare the mean difference between hand weeding and herbicide with respect to grain yield. The t-test result also showed that there is statistically significant mean difference between the two groups at less than 5% probability level (t=-2.05).

Partial budget analysis of the Pyroxsulam herbicide and hand weeding

The partial budget analysis which was expressed in hectare is shown in Table 3. The variable cost in hand weeding among the target farmers of the kebelle occurred mostly due to the frequency of weeding they practiced. The farmers of Saesie Tsaeda Emba demonstration area invested more of their time on weeding to the extent of eliminating the oats. On the contrary, farmers from H/Wajirat did not invest their time on weeding the oats.

In all, target farmers of the districts application of Pyroxsulam herbicide was profitable than hand weeding. In both Kebelles, wheat yield of the Pyroxsulam treatment were better than the hand weeding and more cost were incurred in hand weeding. The marginal rate of return (MRR) of 275, 243, 252 and 266% at H/Wajirat, Enderta, S/T/Emba and G/mahda, respectively shows that the application of Pyroxsulam herbicide was beneficial. The average MRR of the four districts (259%) shows greater than the minimum acceptable rate of return (100%). For every one Birr[1] investment in Pyroxsulam herbicide for wheat production there would be 2.59 Birr ($ 60.37 USD) return based on the demonstration conducted. This indicates that using improved technology can bring additional benefit to the farming community.

[1] Birr in this text is an Ethiopian currency and the current exchange rate of $1 USD is 23.31 Ethiopian Birr.

Major weed flora observed in the farmers' field

In the study area, different weeds were observed on farmers' field. Moreover the demonstration plot was infested with several broad leaf and grass weed species. The flora in the experimental fields indicated that the weeds belonged to 17 families which are eliminated by the herbicide (Table 4).

Plots treated by herbicide were free from most problematic weed species mentioned in the table and others. Besides, as the farmers said and from our observation, most of the weeds were eliminated by the Pyroxsulam. However, to some

Table 4. The major infesting weeds species observed through the demonstration season at study area.

Botanical name of weed species
Grass weeds
Avena fatua
Lolium temulentum L.
Snowdenia polystachya
Phalaris paradoxa L.
Bromus pectinatus
Setaria pumila
Cyperus rotundus L.
Broad leave weeds
Plantago lanceolata
Polygonum nepalense
Scorpirus muscata
Guizotia scabra
Galinsoga parviflora
Gallium spurium
Rumex abyssinica
Datura stromonium
Chenopodium album L.
Raphanusraphanixtrum L.

extent *Cynodon dactylon* and Convolvulus escaped and lately emerged since these weeds are hard and possess perennial characteristics, so it needs further study for these individual species.

Farmers' perception

In order to get essential information and insight into farmers' perception of the technology, looking at their perception on each attributes to which they are employing is quite important. Hence, knowledge of farmers' evaluative perception on technology attributes in the study area is an appropriate issue to be answered. Here under, the percentage scores of farmers' response to the perception statements of each attributes that relate to perceived technological characteristics are given in Table 5.

As presented in Table-5 the perception level of the farmers towards the pre and post-harvest attributes were putted as good and very good. Besides, most of the sample beneficiaries appreciated the herbicide. However, some farmers (38%) have negative\poor perception on straw yield. In general on the rest of the pre and post-harvest attributes of the variety due to Pyroxsulam majority of the host communities had positive perception.

As observed from Table 6, all of the respondent farmers from Enderta and Saesie Tsaeda Emba districts were highly satisfied on training (100%) followed by farmers from Gulomahda (80%); whereas 80% of farmers from Hintalo-Wajirat district had medium level of satisfaction. An average of 75% of respondent farmers was highly satisfied on supply of input, whereas a very few (25%) of respondents expressed medium level of satisfaction on supply of inputs. Moreover, most of the respondent farmers (80%) were highly satisfied on timeliness of input followed by medium level of satisfaction (20%). The level of satisfaction with respect to services rendered, linkage with farmers, and technologies demonstrated etc. indicate stronger conviction, physical and mental involvement in the demonstration, which in turn would lead to higher adoption. This finding meant that farmers were satisfied both with Pyroxsulam and existing extension approaches that has been deployed to disseminate the herbicide and innovations.

CONCLUSION AND RECOMMENDATIONS

Demonstration conducted under the close supervision of scientists is one of the most important tools of extension to demonstrate crop management practices at farmers' field under different agro-climatic regions and farming situations. As a result the activity was conducted in the moisture stressed areas of the eastern and south eastern zones of the Tigray Regional State. From the yield analysis and farmers evaluation, the grain yield of the Pyroxsulam treatment was higher than the hand weeding treatment in all districts, which is an indication that the above mentioned weeds competition reduces using the Pyroxsulam herbicide having the existing weed practice of the farming community. In all districts, wheat yield of the Pyroxsulam treatment were better than the hand weeding and more cost were incurred in hand weeding. The farmers also expressed medium to high level of satisfaction for extension services under demonstrations. The average MRR of the four districts (259%) shows greater than the minimum acceptable rate of return (100%). For every one birr investment in Pyroxsulam chemical for wheat production, there would be 2.59 Birr ($ 60.37 USD) return based on the experiments. Based on the findings, the following recommendations are forwarded so as to improve the wheat production and productivity:

i) The herbicide Pyroxsulam should be popularized in more target farmers and larger area to help farmers on its practicality at large.
ii) The herbicide Pyroxsulam utilization should be supported by practical training, technical backstopping and safety considerations to be sustainable.

Table 5. Perception of farmers on pre and post-harvest attributes.

Characteristics	Perception level (%)				
	V. poor	Poor	Neutral	Good	Very good
Effect of Pyroxsulam on vegetative period	-	-	-	13	87
Effect of Pyroxsulam on growth of the crop	-	-	-		100
Tiller number	-	-	-	76.2	23.8
Vegetative performance	-	-	-	90	10
Head size	-	4.8	-	85.7	9.5
Threshability	-	5		90	5
Seed weight	-	4.8	-	95.2	-
Seed uniformity	-	4.8	-	90.5	4.8
Seed size	-	4.8	-	90.5	4.8
Seed color	-	4.8	-	90.5	4.8
Purity	-	-	-	90.5	9.5
Yield	-	4.8	-	90.5	4.8
Straw yield	-	38.1	-	61.9	-
Straw palatability	-	20	-	80	-

Table 6. Satisfaction of the sample respondents on the Pyroxsulam demonstrating trail.

Service	Satisfaction level	District				Average
		Enderta	H/Wajirat	Saesie Tsaeda Emba	Gulomahda	
Training	High	100	20	100	80	75
	Medium	-	80	-	20	25
	Low	-	-	-	-	
Supply of inputs	High	70	50	80	100	75
	Medium	30	50	20	-	25
	Low	-	-	-	-	
Timeliness	High	60	80	100	80	80
	Medium	40	20	-	20	20
	Low	-	-	-	-	

iii) Office of Agriculture and Rural Development of the respective districts should jointly work in the popularization and own the work for further scaling up of the pallas herbicide.

iv) The reasons that could have hindered the sustainable use of the pallas herbicide like cost, technical knowhow and safety issues should be addressed in the popularization.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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