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Effect of weed management methods on weeds and wheat (*Triticum aestivum* L.) yield

Tesfay Amare

Department of Plant Sciences and Horticulture, College of Agriculture and Veterinary Science, Ambo University, P.O.Box 19, Ambo, Ethiopia.

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An experiment was conducted at Holetta Agricultural Research Center to study the effect of weed management practices on weeds and yield of wheat (*Triticum aestivum* L.) during 2010 to 2011 crop seasons in randomized complete block design with three replications. The experiment comprised of twelve weed management practices as treatments. The crop was infested with *Avena fatua* L. *Cynodon dactylon* (L) Pers, *Digitaria abbisinica* (A. Rich) Stapt and *Phalaris paradoxa* L. among grass weeds and *Amaranthus spinosus L., Caylusea abyssinica* (Feresen.) fisch and May, *C. trigyna* L., *Conolvulus arvenesis L., Chenopodium album* L., *Chenopodom nobile L., Corrigoala capensis* Willd., *Galinsoga parviflora Cov. Guizotia scabra* (Vis.) Chiov., *Medicago polymorpha L., Oxalis latifolia* H.B.K., *Polygonum nepalense* L., *Plantago lanceolata L., Raphanus raphanistrum* L., *Spergula arvensis* L. and *Tagetes minuta* L. were among broad leaf weeds. The results showed that broadleaved, grass and total weed density as well as dry weight were significantly influenced by weed management practices. Hand weeding + 15 cm row spacing followed isoproturon at 1.5 kg ha^{-1} + 15 cm row spacing significantly reduced density and dry weight of weeds. Among herbicides, isoproturon + 15 cm row spacing provided better control of broadleaved and total weeds, whereas; clodinafop-propargyl + 15 cm row spacing proved better than isoproturon at 1.50 kg ha^{-1}and hand weeding + 15 cm row spacing in controlling grass weeds. Highest grain yield (2289.4 kg ha^{-1}) in was recorded in hand weeding + 15 cm row spacing followed by isoproturon at 1.50 kg ha^{-1} + 15 cm row spacing (2177.3 kg ha^{-1}). Maximum N uptake was also recorded in these treatments. Uncontrolled weed growth throughout the crop growth caused a yield reduction 57.6 to 73.2%. Post emergence herbicides (isoproturon at 1.50 kg/ha) and /or hand weeding and hoeing at tillering + narrow spacing (15 cm) can further enhance the weed suppressive effect of the crop.

Key words: Wheat, weeds, weed management methods, yield loss.

INTRODUCTION

Wheat is one of the major cereal crops grown in the Ethiopian highlands (Hailu, 2003*)*. Despite its importance in Ethiopia, the mean national yield is 1.3 tons ha^{-1} which is 24% below the mean yield of Africa and 48% below the global mean yield of wheat. It ranks 5th after teff, maize, barley and sorghum in area of production, but in terms of productivity, wheat ranks 2nd next to maize (Hailu, 2003)*.* Low yield of wheat in country is mainly caused by declining soil fertility, soil erosion, insect pests, disease and problematic weeds (Bekelle, 2004).

*Corresponding author. E-mail: tesfaalemamare@yahoo.com

Wheat crop usually suffers from stress created by weeds through competition for water, nutrients, space and sunlight (Anderson, 1983) along with interference caused by releasing toxic substances into the rhizosphere of the crop plants (Rice, 1984). Apart from increasing the production cost, they also intensify the disease and insect pest problem by serving as alternative hosts (Marwat et al., 2008). Weeds cause yield reduction up to 70% in some wheat growing areas (Tanner and Giref, 1991). To properly address the weed problem in wheat, there is a dire need of developing a package of weed control technology for the wheat growers (Marwat et al., 2008).

Manual and mechanical methods are laborious, tiresome and expensive due to increasing cost of labor, draft animals and implements and weeds cannot effectively be managed merely due to crop mimicry. Therefore, the use chemical weed control has become necessary (Marwat et al., 2008). Chemical weed control method are most ideal, practical, effective, up-to-date, time saving and economical means of reducing early weed competition and crop production losses (Ashiq et al., 2007). But, the exclusive reliance on herbicides has resulted in pollution of the environment and some weed species becoming resistant and inter- and intra-specific shifts, integrating the chemical with cultural is an excellent option for the weed control (Hassan and Marwat, 2001). Manipulating row spacing in crops that are generally planted as row crops has potential to affect weed control. The ground is shaded sooner in narrow rows and weed development is suppressed (Lyon et al., 2006). In view of these facts the present study was designed with the objectives to find out the effect of different weed managements practices on wheat yield and weeds and to assess the effect of weeds on yield attributes and yield of wheat.

MATERIALS AND METHODS

The experiment was conducted at Holleta Agricultural Research Center which is located 34 km to the west of Addis Ababa. The mean total annual rainfall is 1100 mm with mean maximum and minimum air temperature of 22.2°C and 6.13°C, respectively (EIAR, 2008).

The soil of the experiment was clay loam in texture with pH 6.65, organic carbon 2.26%, available P 14.17 mg kg^{-1} soil, total nitrogen 0.12% and cation exchange capacity, 17 Cmol kg^{-1} soils. The experiment comprised twelve treatments of three row spacing combined with two herbicides, one hand weeding at tillering and weedy check (clodinafop-propargyl at 0.105 kg ha^{-1}+ 15 cm, clodinafop-propargyl at 0.105 kg ha^{-1} + 20 cm, clodinafop-propargyl at 0.105 kg ha^{-1} + 25 cm, isoproturon at 1.50 kg ha^{-1} +15 cm, isoproturon at 1.50 kg ha^{-1} +20 cm, isoproturon at 1.50 kg ha^{-1} +25 cm, hand weeding + 15 cm, hand weeding + 20 cm, hand weeding + 25 cm at tillering, weedy check + 15 cm, weedy check + 20 cm and weedy check + 25 cm). The experiment was laid out in a randomized complete block design with three replications.

Herbicides were applied as post-emergence at crop tillering stage that is, about 32 days after planting. Wheat variety HAR 604 was planted at recommended seed rate (150 kg ha^{-1}) in plots. Fertilizer was used at the rate of 64 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} through diammonium phosphate (DAP) and urea. Half of nitrogen and full amount of phosphorus was drilled in rows at the time of sowing and the remaining N through urea was applied at shoot elongation stage of crop.

Weed population and total above ground weed dry matter were recorded. Weed control efficiency (WCE) was determined by the following formula;

$$WCE = \frac{WDC - WDT}{WDC} \text{X } 100$$

Where, WDC = weed dry mass from the control plot (untreated), WDT = weed dry matter from treated plot (Devasenapathy et al., 2008).

Tillers number m^{-2}, plant height (cm), grains per spike (g), thousand kernel weights (g), grain and straw yield (kg ha^{-1}) were recorded.

Harvest index (%) was calculated by the following formula;

$$HI = \frac{Grain\ yield}{Total\ aboveground\ dry\ biomass\ yield} \text{X}100$$

Total nitrogen uptake by the wheat crop and associated weed was determined by Kjeldhal digestion method (Jackson, 1958). The uptake of nitrogen (kg ha^{-1}) was calculated as:

$$Uptake\ of\ N = \frac{N(\%)\ in\ the\ material\ \text{X}\ dry\ weight\left({kg}/{ha} \right)}{100}$$

Crop yield loss due to weeds was calculated as follows:

$$Yield\ loss = \frac{MY - YT}{MY} \text{X } 100$$

Where, MY= maximum yield from a treatment, YT = yield from a particular treatment.

Weed count were subjected to square root transformation, $\left(\sqrt{(X+0.5)}\right)$ to have normal distribution of the data. Analysis of variance and mean separation tests were applied following the randomized complete block design procedure as described by Gomez and Gomez (1984) using the SAS computer software package version 9.2.

RESULTS AND DISCUSSION

Weed composition of the experimental site

The crop was infested with *Avena fatua* L. *Cynodon dactlylon* (L) Pers, *Digitaria abbisinica* (A. Rich) Stapt and *Phalaris paradoxa* L. among grass weeds and *Amaranthus spinosus L. Caylusea abyssinica (*Feresen.) fisch and May*, C. trigyna* L.*, Conolvulus arvenesis L., Chenopodium album* L.*, Chenopodom nobile L., Corrigoala capensis* Willd.*, Galinsoga parviflora Cov. Guizotia scabra* (Vis.) Chiov.*, Medicago polymorpha L., Oxalis latifolia* H.B.K.*, Polygonum nepalense* L.*, Plantago*

Table 1. Effect of weed management practices on density (m^{-2}) broadleaved, grass and total weeds.

Weed management practices	Wee density (m^{-2})		
	Broad	Grass	Total
Clodinafop-propargyl 0.105 kg ha^{-1} + 15 cm	5.58(30.67)	0.70(0.00)	5.58(30.67)
Clodinafop-propargyl 0.105 kg ha^{-1} + 20 cm	6.96 (48.00)	1.86(4.00)	7.17(52)
Clodinafop-propargyl 0.105 kg ha^{-1} + 25 cm	8.29 (68.33)	2.47(5.67)	8.63(74)
Isoproturon 1.50 kg ha^{-1} + 15 cm	2.27 (4.67)	1.86 (3.00)	2.85(7.67)
Isoproturon 1.50 kg ha^{-1} + 20 cm	3.08 (9.00)	2.40(5.33)	3.85(14.33)
Isoproturon 1.50 kg ha^{-1} + 25 cm	4.62 (21.00)	3.34(10.68)	5.67(31.68)
Hand weeding at tillering +15 cm	1.94 (3.33)	2.03(3.67)	2.72(7.00)
Hand weeding at tillering + 20 cm	2.34 (5.00)	2.20(4.33)	3.13(9.33)
Hand weeding at tillering + 25 cm	2.96 (8.33)	2.86(7.69)	4.06(16.00)
Weedy check + 15 cm	5.77 (33.00)	3.39(11.00)	6.66(44.00)
Weedy check + 20 cm	7.10 (50.00)	4.29(18.00)	8.27(68.00)
Weedy check + 25 cm	8.23(67.34)	5.11(25.67)	9.67(83.00)
LSD (0.05)	0.44	0.308	0.42
CV(%)	5.21	6.71	4.39

Figures in parenthesis are the original values, LSD =least significant difference, CV =coefficient of variation.

lanceolata L., Raphanus raphanistrum L., *Spergula arvensis* L. and *Tagetes minuta* L. were among broad leaf weeds. Out of total weeds present in the experimental field 80% were broadleaved while 20% were grasses.

Weed density

The data (Table 1) showed a significant difference in broadleaved, grass and total weed density due to weed management practices. The lowest broadleaved weeds density (3.33 m^{-2}) was recorded when wheat was sown at 15 cm row spacing + hand weeded followed isoproturon at 1.50 kg ha^{-1} + row spacing of 15 cm (4.67 m^{-2}) and 20 cm row spacing + hand weeding (2.34 m^{-2}) but no significance difference were observed among them whereas, the highest number of broadleaved weeds (67.34 m^{-2}) was observed when wheat was sown in 25 row spacing without controlling weeds (Table 1). However, application of clodinafop-propargyl 0.105 kg ha^{-1} failed to reduce significantly as compared to weedy check at the same row spacing. These findings are in agreement with the work of Marwat et al. (2008) and Ashrafi (2009) who reported that integration of closer row spacing with broad spectrum herbicides reduce weed population as compared to weedy check.

Unlike broadleaved weeds, the results in Table 1 revealed that application of clodinafop-propargyl at 0.105 kg ha^{-1} + 15 cm row spacing had no grass weeds whereas, the highest (25.67 m^{-2}) grass weeds density was recorded in 25 cm row spacing without controlling the weeds. In general, application of clodinafop-propargyl + 15 cm row spacing proved more effective in reducing the grass weed density. These finding are in agreement with the work of Jamil et al. (2003) who reported that herbicide application with narrow row spacing suppressed weeds population more effectively than of weedy check with wider spacing.

Moreover, a minimum total weeds density (7.00 m^{-2}), observed in plots having 15 row spacing and hand weeded followed by isoproturon at 1.50 kg ha^{-1} + 15 cm row spacing (2.85m^{-2}) and hand weeded + 20 cm row spaced (9.33 m^{-2})(Table 1) but no significant difference was recorded among them. The better control of both broadleaved and grassy weeds through hand weeding + 15 cm row spacing and isoproturon at 1.50 kg ha^{-1} + 15 cm row spacing resulted in lower total weed density. These finding are in agreement with the work of Jamil et al. (2003) who reported that broad spectrum herbicide with narrow row spacing suppressed weeds population more effectively than weedy check with wider spacing.

Weeds dry weight

Significant variation in weed dry weight existed between treatments (Table 2). The significantly lowest (4.07g m^{-2}) weed dry weight resulted from hand weeding and isoproturon at 1.50 kg ha^{-1} + 15 cm row spacing (4.10 g m^{-2}) as compared to other treatments however, no significance difference between them. Minimum total weed dry weight recorded in the combination of 15 cm row spacing and hand weeding and isoproturon at 1.50 kg ha^{-1} might be due to hand weeding and broad spectrum (broadleaved and grassy weeds) weed control

Table 2. Effect weed management practices on total weed dry weight (g m^{-2}) and weed control efficiency (%).

Weed management practices	Dry weight	WCE (%)
Clodinafop-propargyl 0.105 kg ha^{-1} + 15 cm	8.03	67.1
Clodinafop-propargyl 0.105 kg ha^{-1} + 20 cm	14.23	41.7
Clodinafop-propargyl 0.105 kg ha^{-1} + 25 cm	19.87	18.6
Isoproturon 1.50 kg ha^{-1} + 15 cm	4.10	83.4
Isoproturon 1.50 kg ha^{-1} + 20 cm	6.33	65.8
Isoproturon 1.50 kg ha^{-1} + 25 cm	13.03	46.6
Hand weeding at tillering +15 cm	4.07	83.2
Hand weeding at tillering + 20 cm	8.27	66.1
Hand weeding at tillering + 25 cm	11.47	52.9
Weedy check + 15 cm	10.37	57.5
Weedy check + 20 cm	16.30	33.2
Weedy check + 25 cm	24.40	0.0
LSD (0.05)	1.14	4.62
CV(%)	5.69	5.31

LSD =least significant difference, CV =coefficient of variation.

that resulted plus less space for weed development, better competition of wheat crop for development resource, crop growth rate, early space covering, and light interception in narrow row as compare to wide row spacing. These results were in agreement with the work of Iqbal (2002) who verified that combination of closer spacing with broad spectrum herbicide that reduced the weed dry weight as compared to narrow spectrum herbicide and weedy check.

Weed control efficiency

Effect of weed management practices on weed control efficiency was significant (Table 2). The highest weed control efficacy (83.2%) was recorded in hand weeding followed by isoproturon at 1.50 kg ha^{-1} (83.4 %) + 15 cm row spacing whereas, the lowest (0%) was recorded in weedy check + 25 row spacing. This might be due the collective effect of hand weeding and/isoproturon at 1.50 kg ha^{-1} and narrow spacing (15 cm).

Yield and yields attributes

Effect of weed management practices on tiller number m^{-2} and grains per spike (g) were significance however, plant height was not significance influenced by different weed management methods. The results (Table 3) revealed that maximum tillers were recorded in hand weeding + 15 cm row spacing followed by isoproturon at 1.50 kg ha^{-1}+ 15 cm row spacing whereas minimum number of tillers were recorded in weedy check + 25 cm row spacing. Furthermore, the highest grains per spike (23.73 g) were recorded in hand weeding + row spacing of 15 cm followed by isoproturon at 1.50 kg ha^{-1} + 15 cm row spacing (22.40 g) whereas, the minimum was observed in weedy check + 25 cm row spacing (5.5 g).

Similarly, effect of weed management practices on 1000 kernel weight, grain and straw yield were significant. Contrary, the combination of isoproturon at 1.50 kg ha^{-1} and hand weeding + 25 cm gave higher thousand kernel weights and might be due to effective weed control and more space available for better light interception that helped to improve the photosynthetic efficiency of the crop thus more availability of assimilates for the crop/ grain development as compared to narrow row spacing and lower grain per spike that resulted in heavier grain. Similar result was also reported by Iqbal (2003).

The overall grain yield in the experiment was low (Table 4) due to severe infestation of yellow rust in the crop. Results given in Table 4 showed that, the highest grain yield (2289.4 kg ha^{-1}) was recorded in hand weeding + 15 cm row spacing followed by isoproturon at 1.5 kg ha^{-1} + 15 cm row spacing (2177.3 kg ha^{-1}) whereas the lowest was recorded in control treatment + 25 cm row spacing (614.4 kg ha^{-1}). This might be due to effective weed control in plots treated with hand weeding and broad spectrum herbicides in conjunction with narrow row spacing wherein; the cumulative effect resulted in increased number of tillers and grains per spike which contributed to increased yield, despite reduced 1000 grain yield.

Similar to the effect on grain yield, the straw yield was also significantly affected by weed management practices. Effect of weed management practices on harvest index, nitrogen uptake by crop (grain and straw) and associated weeds (broad and grass) were significant. The highest harvest index was recorded in a plot treated

Table 3. Effect of weed management practices on plant height (cm), tiller number (m^{-2}) and grain per spike (g).

Weed management practices	Height (cm)	Tiller (m^{-2})	Gain per spike (g)
Clodinafop-propargyl 0.105 kg ha^{-1} + 15 cm	106.7	211.0	14.1
Clodinafop-propargyl 0.105 kg ha^{-1} + 20 cm	103.7	197.0	12.5
Clodinafop-propargyl 0.105 kg ha^{-1} + 25 cm	98.3	184.0	10.7
Isoproturon 1.50 kg ha^{-1} + 15 cm	104.0	238.3	22.4
Isoproturon 1.50 kg ha^{-1} + 20 cm	103.0	218.0	20.4
Isoproturon 1.50 kg ha^{-1} + 25 cm	104.3	204.3	17.5
Hand weeding at tillering +15 cm	102.0	247.0	23.7
Hand weeding at tillering + 20 cm	102.7	225.7	21.5
Hand weeding at tillering + 25 cm	105.3	207.3	18.6
Weedy check + 15 cm	99.2	184.3	8.5
Weedy check + 20 cm	103.0	166.0	7.3
Weedy check + 25 cm	97.667	149.0	5.5
LSD (0.05)	NS	6.11	0.75
CV(%)	6.16	1.78	2.90

LSD = least significant difference, CV =coefficient of variation.

Table 4. Effect of weed management practices on 1000 kernel weight (g) grain and straw yield (kg ha^{-1}).

Weed management practices	1000 kernel weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Clodinafop-propargyl 0.105 kg ha^{-1} + 15 cm	23.30	1413.00	3878.7
Clodinafop-propargyl 0.105 kg ha^{-1} + 20 cm	28.53	1310.50	3728.9
Clodinafop-propargyl 0.105 kg ha^{-1} + 25 cm	31.10	1171.93	3552.2
Isoproturon 1.50 kg ha^{-1} + 15 cm	27.30	2177.30	5481.9
Isoproturon 1.50 kg ha^{-1} + 20 cm	31.33	2007.43	5287.4
Isoproturon 1.50 kg ha^{-1} + 25 cm	34.83	1896.47	5117.2
Hand weeding at tillering +15 cm	30.53	2289.40	5698.2
Hand weeding at tillering + 20 cm	33.27	2107.83	5355.9
Hand weeding at tillering + 25 cm	36.60	1910.10	5241.0
Weedy check + 15 cm	17.50	970.87	3195.9
Weedy check + 20 cm	18.20	872.30	3110.2
Weedy check + 25 cm	23.93	614.37	2472.7
LSD (0.05)	1.48	51.07	266.4
CV(%)	3.12	1.93	3.62

LSD =least significant difference, CV =coefficient of variation.

with hand weeding (28.66%), isoproturon at 1.50 kg ha^{-1} in + (15 cm) row spacing whereas, the lowest was in weed check plot with wider (25 cm) row spacing (Table 5).

The maximum N uptake (115.67 kg ha^{-1}) was recorded with the combination of hand weeding + 15 cm row spacing followed by isoproturon at 1.50 kg ha^{-1} + 15 cm row spacing (109.34 kg ha^{-1}) whereas; it was minimum (34.33 kg ha^{-1}) in weedy check + 25 cm row spacing (Table 5). The significant variation in N uptake by wheat crop might be due to better control of weeds that enhanced growth and development of the crop. Thus, the reduced weed competition for nutrients favored the crop against weeds resulting in increased N uptake. These findings are in agreement with the work of Nadeem et al. (2006) who reported weed management practices reduced the N-uptake by weeds in wheat. Similarly, Kumar and Agarwal (2010) also reported higher N uptake in weed management treated plots. Moreover, the weed management practices were also significantly affected N uptake by weeds. These finding are in agreement with the work of Abouziena et al. (2008) and Kumar and Agarwal (2010) who observed that weeds compete very effectively with the crop for available nitrogen to the point that the reduction in yields from weed competition were generally accompanied by reduction in protein content as well. Maximum (13.34 kg ha^{-1}) was recorded in control treatment + 25cm row spacing (Table 5) which might be

Table 5. Effect of row spacing and weed management practices on harvest index (%), Nitrogen uptake by crop and its associated weeds (kg ha^{-1}).

Weed management practices	HI (%)	N uptake by crop (kg ha^{-1})	N uptake by weeds (kg ha^{-1})
Clodinafop-propargyl 0.105 kg ha^{-1} + 15 cm	26.71	71.33	6.07
Clodinafop-propargyl 0.105 kg ha^{-1} + 20 cm	26.01	64.33	7.07
Clodinafop-propargyl 0.105 kg ha^{-1} + 25 cm	24.82	57.33	8.10
Isoproturon 1.50 kg ha^{-1} + 15 cm	28.43	109.34	3.67
Isoproturon 1.50 kg ha^{-1} + 20 cm	27.53	91.35	4.93
Isoproturon 1.50 kg ha^{-1} + 25 cm	27.04	80.33	5.53
Hand weeding at tillering +15 cm	28.66	115.67	2.87
Hand weeding at tillering + 20 cm	28.25	99.67	3.53
Hand weeding at tillering + 25 cm	26.73	89.67	4.40
Weedy check + 15 cm	23.30	49.67	8.47
Weedy check + 20 cm	21.91	41.33	10.93
Weedy check + 25 cm	19.96	34.33	13.43
LSD (0.05)	1.06	6.03	1.04
CV(%)	2.42	4.72	9.33

LSD = Least Significant Difference, CV = Coefficient of variation.

Table 6. Effect of weeds on yield of wheat crop under different weed management practices.

Weed management practices	Relative yield loss (%)
Clodinafop-propargyl 0.105 kg ha^{-1} + 15 cm	38.3
Clodinafop-propargyl 0.105 kg ha^{-1} + 20 cm	42.8
Clodinafop-propargyl 0.105 kg ha^{-1} + 25 cm	48.8
Isoproturon 1.50 kg ha^{-1} + 15 cm	4.9
Isoproturon 1.50 kg ha^{-1} + 20 cm	12.3
Isoproturon 1.50 kg ha^{-1} + 25 cm	17.2
Hand weeding at tillering +15 cm	0.0
Hand weeding at tillering + 20 cm	7.9
Hand weeding at tillering + 25 cm	16.6
Weedy check + 15 cm	57.6
Weedy check + 20 cm	61.9
Weedy check + 25 cm	73.1

due to higher weed population in control treatment and the avialability of wider space for weed development.

Effect of weeds on yield loss in wheat

While comparing the loss in yield due to the weed management practices, the lowest loss in yield (4.9%) was recorded in isoroturon at 1.50 kg ha^{-1} + 15 cm row spacing as compared to the highest yield obtained in hand weeding done + 15 cm spaced crop. This was followed by hand weeding + 20 cm row spacing (7.9%) and isoroturon at 1.25 kg ha^{-1} (12.3%) whereas; it was highest (73.2%) in weedy check with 25 cm row spacing (Table 6).

Conclusions

Combination of hand weeding + 15 cm row spacing reduced broadleaved weed density, total weed density and dry weight of weeds followed by isoproturon at 1.50 kg ha^{-1} with 15 cm row spacing. However density of grassy weeds was lower in plot treated with clodinafop-propagyl at 0.105 kg ha^{-1} + 15 cm row spacing. These treatments also increased yield and yield attributes and uptake of nitrogen of wheat significantly. Uncontrolled weed growth throughout the crop growth caused a yield reduction 57.6 to 73.2%. Post emergence herbicides (isoproturon at 1.50 kg/ha) and /or hand weeding and hoeing at tillering + narrow spacing (15 cm) further enhanced the weed suppressive effect of the crop.

However, because of the agro ecology and seasonal variation, further research is necessary in order to provide more accurate recommendation.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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