Integrated Weed Management Technologies for the Control of Annual Grasses and Broadleaf Weeds in Wheat in South Eastern Ethiopia

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Abstract
A study was conducted at Bekoji Negeso, Huruba Wolkite and Boru chilalo farmer's field during 2016/17 and 2017/18 main cropping seasons to evaluate and validate effective and economical integrated weed management package for the control of annual grasses and broad leaf weeds in wheat. Pyroxsulam 0.5 lit/ha applied at 25-30 days after sowing, Pyroxsulam 0.5 lit/ha applied at 25-30 DAS followed by one hand weeding at 55-60 DAS, Clodinafop-propargyl 1 lit/ha + 2, 4-D 1 lit/ha applied at 25-30 DAS, Clodinafop-propargyl 1 lit/ha + 2, 4-D 1 lit/ha applied at 25-30 DAS followed by one hand weeding at 55-60 DAS, twice hand weeding at 30-35 and 55-60 DAS as standard check and weedy check for comparison purpose were treatments laid out in split plot design based on RCBD arrangement with three replications. The highest weed control efficiency of 86-100% was recorded in Pyroxulam + one hand weeding combined with four ploughing in controlling annual grasses(*Snowdenia polystachya, Avena fatua, Bromus pectinatus)* and broad leaf weeds (*Gizotia scabra, Galinsoga parviflora* and *Polygonum nepalense)* followed by Pyroxulam only(80-100%) and twice hand weeding(75-100%). The minimum weed control efficiency (0%) was recorded in weedy check treatment. Similarly, the highest grain yield of 4109 kg/ha was achieved by Pyroxulam + one hand weeding combined with four ploughings which was followed by Pyroxulam only (3841 kg/ha), twice hand weeding (3650 kg/ha), Clodinafop-propargyl + 2,4-D + one hand weeding (3590 kg/ha) and Clodinafop-propargyl + 2,4-D (3306 kg/ha) whereas weedy Check (1763 kg/ha) performed the least in yield. Hence, Pyroxulam as post-emergence application + one hand weeding combined with four ploughings was effective and the best integrated weed management package for controlling annual grasses and broad leaf weeds in wheat fields.
Keywords: Clodinafop-propargyl, Evaluation, Integrated Weed Management**,** Pyroxsulam, Wheat fields
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1. INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the most important cereal crops globally and is a staple food for about one third of the world's population [1] It is fourth in area coverage (1.69 million ha) following *tef*, maize and sorghum and fourth in total production (4.64 million tons) following maize, *tef,* and sorghum with a productivity of 27.36 q/ha in Ethiopia [2] which makes the country the largest wheat producer in sub-Saharan Africa. It is one of the major cereal crops in the Ethiopian highlands that lie between latitude of 6º and 16ºN and longitude of 35º and 42º E and is widely grown from 1500 to 3000 meters above sea level. Moreover, it is one of the major cereal crops of choice in Ethiopia, dominating food habits and dietary practices, and is known to be a major source of energy and protein in the country [3].

Weeds are the most underestimated pest in tropical agriculture, but they have influenced human activities more than other crop pests. Weeds compete with wheat for soil moisture, nutrients, light, carbon dioxide and space, thus reducing the yield and quality of produce. The major problem under high input wheat production system is interference of weeds which alone cause drastic reduction in yield. The reduction in productivity depends upon the type of weed flora and weed density. Although crop yield losses from weeds vary from crop to crop and region to region, because of biotic and a biotic factors, it has been estimated that weeds cause a yield loss of about 10% in the less developed countries and 25% in the least developed countries [4]. Wheat infested by multifarious weed flora comprising both grassy as well as broad leaf weeds causing yield reduction of 15-40 % depending upon type and intensity of their infestation [5]. In Ethiopia too, a yield loss of above 36.3% was recorded in wheat due to uncontrolled weed growth [6]. Similarly, in a competition study of *Avena abyssinica*, *Lolium temulentum* L., *Snowdenia polystachya* and *Phalaris paradoxa* L. with bread wheat, a yield loss of 48-86% were recorded by the maximum weed density of 320 weed seedlings/m^2 [7].

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[8]. 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 [9].

Although herbicide-based systems have benefitted the agricultural community in many ways, the heavy reliance on herbicides creates an environment favorable for weed resistance to herbicides, weed population shifts, and off-site movement of herbicides. The current challenge for producers is to manage herbicides and other inputs in a manner that prevents adapted species from reaching troublesome proportions.

Cultural, chemical and biological weed control activities can exert a strong selective influence on the weed populations [10]. Thus, knowledge of the weed community structure is an important component of weed management, and is essential in setting priorities for both weed management and research. A farming system that utilizes an array of inter-dependent cultural, biological and herbicidal weed control practices is implementing Integrated Weed Management (IWM). The principal aim of IWM is to improve the health and vigor of crops so that they may out-compete weeds emerging in the stand. Integrated weed management (IWM) systems essentially mean the integration of several practices, including herbicides, to reduce the negative impact of weeds on crops and the amount of seed produced by the weeds [11]. Malik *et al*. [12] and Jarwar *et al*. [13] observed that chemical weed control method was more effective when integrated with cultural methods of weed control.

Therefore, the study was designed with the objective to evaluate and validate effective and economical integrated weed management package for the control of annual grasses and broad leaf weeds in wheat and to improve the livelihood of wheat dependent communities.

2. MATERIALS AND METHODS

2.1 Description of the Study Areas

The activity was conducted at Bekoji Negeso, Huruba Wolkite and Boru chilalo farmer's field, Arsi zone during the main cropping seasons of 2016/17 and 2017/18 for two years. Bekoji (7°32′37"N and 39°15′21" E, 2780 meters above sea level(masl), average rainfall of 1066 mm, mean minimum and maximum temperature is 9.6°C and 24°C, respectively, and soil texture of luvisol) found in Arsi zone. Asasa is found at 7^0 07′ 23″ N Latitude and 39^0 11′ 95″ E Longitude with an altitude of 2378 m.a.s.l. Kulumsa is situated in the main wheat belt of Ethiopia at an altitude of 2200 m.a.s.l located in the north periphery of Asella town which is about 168 km South East of Addis Ababa. It is found at $8^0$01′10" N Latitude and $39^0$09′11" E Longitude and receives an average rainfall of 832 mm. The mean minimum and maximum temperature is 10^0c and 23^0c respectively. Dominant soils in these areas are Luvisol and Nitosol respectively. Bekoji and Asasa are 61km and 110km away from Asella town respectively.

2.2 Treatments and Experimental Design

The experimental design was a split plot based on Randomized Complete Block Design (RCBD) arrangement with three replications. Main plots consisted of tillage practices (Three ploughings and four ploughings-fine seedbed) while sub-plots consisted of popular post-emergence herbicides and check plots (standard and weedy check) treatments. Pyroxsylam 0.5 lit/ha applied at 25–30 days after sowing (DAS), Pyroxsylam 0.5 lit/ha applied at 25-30 DAS followed by one hand weeding at 55-60 DAS, Clodinafop-propargyl 1 lit/ha + 2, 4-D 1 lit/ha applied at 25-30 DAS, Clodinafop-propargyl 1 lit/ha + 2, 4-D 1 lit/ha applied at 25-30 DAS followed by one hand weeding at 55-60 DAS, twice hand weeding as standard check (30-35 and 55-60 DAS) and weedy check for comparison purpose were the treatments of the activity.

The testing sites were selected after field observation on the availability of naturally infested heavy and wide population of broadleaf and grass weeds i.e., a hot spot for the major broadleaf and grass weeds. The required quantity of the herbicide was calculated and measured out into manual knapsack sprayer with a water volume of 200 lit/ha for each herbicide treatments and each herbicide were applied separately and under non windy and sunny conditions. Herbicides were applied post-emergence at 25-30 days after sowing (DAS) and hand weeding was done 30-35 and 55-60 DAS.

Kakaba (Picaflor) wheat variety was used for the trials at different locations at a seeding rate of 150 kg/ha by row planting method of sowing in drill system and 121 kg/ha mixture of nitrogen, phosphorus and sulfur (NPS) and 100 kg/ha Urea fertilizers were applied at the time of sowing for all the treatments in a plot size of 5m by 4m at a spacing of one-meter width between plots for road. All the necessary agronomic practices were applied equally for all treatments.

2.3 Data Collection

2.3.1 Agronomic Data: The necessary agronomic data of the crop (plant height, number of tillers per plant, spike length, thousand kernel weight (TKW), hectoliter weight (HLW), crop biomass and grain yield) and the weed (weed count before, two and four weeks after herbicide application using 1 m^2 quadrat, weed biomass, general weed control score in 1-5 scale, (where 1= Complete eradication; 2= Effective destruction; 3=Proper reduction in growth and population; 4= Reduced growth and population and 5= no effect on weed control) were collected. The general weed control score was based on Rezene *et al.* [14]. Efficacy of herbicides was calculated using the following formula:

$$\frac{Weed\ count\ before\ herbicide\ application - \ Weed\ count\ after\ herbicde\ application}{Weed\ count\ before\ herbicide\ application} x100$$

Crop yield and yield components and weed biomass data was collected at time of harvest to supplement field observation.

2.3.2 Data analysis

Finally all yield and yield components data were subjected to analysis of variance using the general linear model procedure (Proc GLM) of SAS statistical package version 9.0 [15]. Mean separation was done using least significant difference test at 5% level of probability.

3. RESULT AND DISCUSION

3.1 Weed Control Efficiency

All the weed control methods showed significant ($P<0.05$) difference between treatments in terms of weed control efficiency. Efficiency result over locations indicated that Pyroxulam only 0.5 lit/ha, Pyroxulam 0.5 lit/ha + one hand weeding and twice hand weeding performed better in controlling target annual grass weeds like *Snowdenia polystachya, Avena fatua, Bromus pectinatus* and broad leaf weeds like *Gizotia scabra, Galinsoga parviflora* and *Polygonum nepalense* at efficacy rate between 75-100%. Pyroxulam + one hand weeding combined with four ploughing has showed better control of annual grasses and broad leaf weeds than Pyroxulam only, twice hand weeding, Clodinafop-propargyl + 2,4-D applied at 25-30 DAS + one hand weeding, Clodinafop-propargyl + 2,4-D (25-30 DAS). The highest weed control efficiency of 86-100% was recorded in Pyroxulam + one hand weeding combined with four ploughing followed by Pyroxulam only (80-100%) and two hand weeding (75-100%) whereas the minimum weeds control efficiency (0%) was recorded in weedy check treatment (Table 1 and 2).

Combined effect of two hand weeding with four ploughing has performed better in controlling *Snowdenia polystachya* and *Bromus pectinatus* (75-100%) than two hand weeding combined with three ploughing (73-100%) and controlled broad leaf weeds (*Gizotia scabra*, *Gallium spurium, Galinsoga parviflora* and *Polygonum nepalense*) at efficacy rate between 86-100% (Table 1 and 2). Both the weed control methods (Pyroxulam + one hand weeding, Pyroxulam only and two hand weeding) were statistically different with each other and extensively differed from the rest of the weed control methods. This shows that additional ploughing has reduced emerging weeds and weed seed bank than three ploughing. This result was in line with the works of Singh and Ali [16] who reported that the lowest weed control efficiency (0%) was observed under unweeded control because there is greater weed competition stress.

Both narrow and broad leaf weeds were controlled by application of broad spectrum herbicides as compared to grass weed killer or broad leaf herbicide used alone and ultimately increased grain yield. Among herbicides, minimum grass and broad leaf weeds were recorded in broad-spectrum herbicide treated plots, which might be due to efficient control of grass and broad leaf weeds. These findings are in agreement with the work of Singh *et al*. [17] who reported that maximum weed control efficiency was obtained with the use of herbicides + one hand weeding in wheat. Similarly, these results are in accordance with the works of Marwat [18], Marwat *et al.* [19] and Azad *et al*. [20] who reported that post-emergence application of isoproturon + 2,4-D was found to be the best treatment combination in reducing dry matter of weeds and producing the greatest straw and grain yield compared to control treatment. These results are also correlated with the study of Hossain *et al*. [21] who documented that application of post emergence herbicides reduced the weed dry weight and consequently increased weed control efficiency. These findings are also in agreement with the finding of Amare *et al*. [22] who reported that application of isoproturon @ 1.00kg a.i. ha^{-1} significantly reduced the weed dry biomass, which ultimately increased the weed control efficiency in wheat. The works of Rezene *et al.* [23] indicated that Propoxycarbozone-sodium (Attribut 70WG) was effective against *Bromus pectinatus* and gave satisfactory suppression of *Snowdenia polystachya* constantly across all locations of the experimental sites. On the other hand, Shambel *et al*. [24] reported that the herbicidal chemical sulfosulforol and ethiozin exhibited significant potential to control problematic grass weeds including Brome grass in the wheat growing areas of Ethiopia. In hand weeding, the weed population was reduced due to periodicity disturbances of soil by removal of weeds using hand weeding. The negative values in the efficacy of the applied herbicides were resulted from the increasingly late emergence of the weeds after herbicide applications.

Table 1 Weed count data and efficacy of herbicides at three locations 2017/18 – Three ploughing

Location	Type of weed species	Pyroxulam			Pyroxulam + one hand weeding			Clodinafop-propargyl + 2,4-D			Clodinafop-propargyl + 2,4-D + one hand weeding			Two hand weeding			Weedy Check		
		Before application	After application	Efficacy %	Before application	After application	Efficacy %	Before application	After application	Efficacy %	Before application	After application	Efficacy %	Before application	After application	Efficacy %	1st weed count	2nd Weed count	Result %
Bekoji Negeso	*Avena fatua*	3	0	100	2	0	100	4	0	100	11	4	64	4	0	100	10	10	0
	Gallium spurium	4	0	100	3	0	100	5	4	20	2	4	-50	3	0	100	4	4	0
	Gizotia scabra	4	0	100	5	0	100	6	0	100	6	0	100	6	0	100	4	4	0
	Galinsoga parviflora	0	0	0	1	0	100	1	0	100	1	0	100	0	0	0	0	0	0
	Polygonum nepalense	8	0	100	11	0	100	11	0	100	12	0	100	10	0	100	11	11	0
Huruba Wolkite	*Snowdenia polystachya*	17	4	76	6	1	83	11	7	36	16	14	12.5	15	4	73	14	17	-18
	Bromus pectinatus	4	0	100	4	0	100	6	11	-45	4	10	-60	5	1	80	6	6	0
	Gallium spurium	2	0	100	4	0	100	0	0	0	1	0	100	1	0	100	1	1	0
	Gizotia scabra	3	0	100	4	0	100	0	0	0	3	0	100	3	0	100	0	0	0
	Galinsoga parviflora	2	0	100	0	0	0	0	0	0	1	0	100	2	0	100	0	0	0
	Polygonum nepalense	6	0	100	4	0	100	6	0	100	4	1	75	0	0	0	7	7	0
Boru Chilalo	*Snowdenia polystachya*	4	1	75	4	0	100	4	1	75	4	1	75	4	0	100	5	5	0
	Bromus pectinatus	11	1	91	7	0	100	9	3	67	10	1	90	13	2	85	8	8	0
	Gizotia scabra	7	0	100	7	0	100	7	0	100	4	0	100	4	0	100	6	6	0
	Polygonum nepalense	5	0	100	3	0	100	6	1	83	3	0	100	5	1	80	5	5	0

Table 2 Weed count data and efficacy of herbicides at three locations 2017/18 –Four ploughing

Location	Type of weed species	Pyroxulam			Pyroxulam + one hand weeding			Clodinafop-propargyl + 2,4-D			Clodinafop-propargyl + 2,4-D + one hand weeding			Two hand weeding			Weedy Check		
		Before application	After application	Efficacy %	Before application	After application	Efficacy %	Before application	After application	Efficacy %	Before application	After application	Efficacy %	Before application	After application	Efficacy %	1st weed count	2nd Weed count	Result %
Bekoji Negeso	*Bromus pectinatus*	5	0	100	7	0	100	3	0	100	5	0	100	5	0	100	6	6	0
	Gallium spurium	4	0	100	6	0	100	3	2	33	5	1	80	4	0	100	5	5	0
	Gizotia scabra	7	0	100	5	0	100	4	0	100	4	0	100	5	0	100	4	4	0
	Galinsoga parviflora	0	0	0	0	0	0	2	0	100	1	0	100	2	0	100	2	2	0
	Polygonum nepalense	14	0	100	13	0	100	10	0	100	16	0	100	14	0	100	14	14	0
Huruba Wolkite	*Snowdenia polystachya*	11	2	82	14	2	86	12	12	0	13	4	69	12	3	75	12	14	-14
	Bromus pectinatus	4	0	100	4	0	100	5	5	0	4	3	25	4	1	75	4	5	-20
	Gallium spurium	1	0	100	0	0	0	1	1	0	1	1	0	2	0	100	1	1	0
	Gizotia scabra	3	0	100	2	0	100	2	0	100	2	0	100	3	0	100	1	1	0
	Galinsoga parviflora	0	0	0	1	0	100	0	0	0	1	0	100	0	0	0	0	0	0
	Polygonum nepalense	0	0	0	4	0	100	1	0	100	2	0	100	0	0	0	5	5	0
Boru Chilalo	*Snowdenia polystachya*	5	1	80	3	0	100	3	2	33	4	0	100	5	1	80	3	3	0
	Bromus pectinatus	10	0	100	10	0	100	10	3	70	7	0	100	12	3	75	9	9	0
	Gizotia scabra	6	0	100	5	0	100	5	0	100	5	0	100	4	0	100	5	5	0
	Polygonum nepalense	6	0	100	4	0	100	7	0	100	7	0	100	7	1	86	6	6	0

3.2 Yield and Yield Components

3.2.1 Grain Yield

Combined analysis over locations for the year 2017/18 showed that there is a significant ($P<0.05$) difference between treatments in terms of grain yield(GY), crop biomass(CB), dry weed biomass(DWB), hectoliter weight (HLW) and plant height(PH) due to Pyroxulam + one hand weeding (55-60 DAS), Pyroxulam only, Clodinafop-propargyl + 2,4-D + one hand weeding (55-60 DAS), twice hand weeding (30-35 & 55-60 DAS) and Clodinafop-propargyl + 2,4-D. Main plot treatment effects showed no significant difference between tillage practices; four ploughing (3377 kg ha^{-1}) and three ploughings (3376 kg ha^{-1}). On the other hand, all the weed control methods showed statistically significant ($P<0.05$) difference between treatments in terms of grain yield of wheat. The highest grain yield of 4109 kg ha^{-1} was achieved in experimental treatment that received Pyroxulam + one hand weeding combined with four ploughing followed by Pyroxulam only (3841 kg ha^{-1}), twice hand weeding (3650 kg ha^{-1}), Clodinafop-propargyl + 2,4-D + one hand weeding (3590 kg h^{-1}) and

Clodinafop-propargyl + 2,4-D (3306 kg h^{-1}). The lowest grain yield of 1763 kg ha^{-1} was recorded in weedy check treatment. It has also a yield advantage over Pyroxulam only, twice hand weeding, Clodinafop-propargyl + 2, 4-D + one hand weeding, Clodinafop-propargyl + 2, 4-D and weedy check treatment by 6.5%, 11%, 13%, 20% and 57% respectively (Table 3). The highest grain yield may be due to the suppression of weeds by herbicides combined with hand weeding that favors wheat growth with the consequences of less weed-crop competition for nutrient and soil moisture and ultimately increase wheat productivity. The results are in line with the works of Akhtar *et al*. [25] who reported that application of grassy and broad leaf herbicides increased grain yield and yield components. These results are also correlated with the finding of Khalil et *al.* [26] who reported that the application of buctril super significantly increased the grain yield of wheat. The results are also in consistent with the work of Amare *et al*. [22] who documented that increases in grain yield with the application of isoproturon for weed management.

Combined analysis over three locations for the year 2016/17 showed that there is a significant ($P<0.05$) difference between treatments in terms of grain yield, crop biomass, dry weed biomass, number of tillers and plant height due to Pyroxulam only, Pyroxulam + one hand weeding, Clodinafop-propargyl + 2,4-D, Clodinafop-propargyl + 2,4-D + one hand weeding and twice hand weeding. Most of the weed control methods showed statistically significant differences in terms of grain yield. The highest grain yield of 3968 kg ha^{-1} was achieved in Pyroxulam + one hand weeding followed by twice hand weeding (3700 kg ha^{-1}), Pyroxulam only (3619 kg ha^{-1}), Clodinafop-propargyl + 2,4-D + one hand weeding (3346 kg h^{-1}) and Clodinafop-propargyl + 2,4-D (2887 kg h^{-1}). The lowest grain yield of 2269 kg ha^{-1} was recorded in weedy check treatment. It has also a yield advantage over twice hand weeding, Pyroxulam only, Clodinafop-propargyl + 2,4-D + one hand weeding, Clodinafop-propargyl + 2,4-D and weedy check by 6.7%, 9%, 15.7%, 27% and 43% respectively (Table 4). Higher yields were attributed due to increase in growth and yield parameters thus favored accumulation of more sink which ultimately increased the yield. The result was in line with the work of Shahida *et al*. [27] that different herbicidal treatments had a significant effect on grain yield of wheat. The greatest reduction of yield was occurred when no herbicide was applied [28]. It is also in agreement with the findings of [29] and [30]. The improvement in yield parameters due to application of Pyroxulam + one hand weeding at 25 DAS is attributed to reduction in competitiveness of weeds with the crop for the desired inputs like nutrient, moisture, light and space which ultimately provided better environment for crop growth and development.

3.2.2 Dry Weed Biomass (DWB)

Statistical analysis of data over the locations indicated that dry weed biomass of wheat was significantly ($P<0.05$) affected by the weed control methods. The lowest dry weed biomass was recorded in Pyroxulam + one hand weeding (52 kg ha^{-1}) followed by Clodinafop-propargyl + 2, 4-D + one hand weeding (97 kg ha^{-1}), Pyroxulam only (194 kg ha^{-1}), twice hand weeding (472 kg ha^{-1}) and Clodinafop-propargyl + 2,4-D (1208 kg ha^{-1}), while the highest (3361 kg ha^{-1}) was recorded in untreated weedy check treatment (Table 3). This result coincides with the works of Ahmad *et al*. [31] who reported that integration of herbicides and hand weeding decreased dry weight of weeds significantly compared to dry weight in non-treated plots. Similarly, the result was in agreement with the works of Patil and Dhonde [32] who reported that weed intensity and dry matter of weeds at harvest were significantly lower in weed free followed by pendimethalin pre emergence @ 1.0 kg^{-1} + one hand weeding and was maximum in weedy check treatment. It is also supported by the works of Rathi *et al*. [33] who reported that integration of isoproturon @ 0.75 kg/ha +2,4-D @0.5 kg^{-1} with one intercultural at 30 DAS was the best treatment in terms of reducing weed population and dry weight at different stage of crop growth.

3.2.3 Thousand Kernel Weight (TKW)

Even though there is no significant difference between tillage practices (three and four ploughing), statistical analysis of data over the locations indicated that thousand grain weight of wheat was significantly ($P<0.05$) affected by the weed control methods. The maximum thousand grain weight of 54.66g was recorded in experimental plot where Clodinafop-propargyl + 2, 4-D + one hand weeding combined with four ploughing was applied and followed by Pyroxulam + one hand weeding(51.05g), Pyroxulam only(49.83g), twice hand weeding(47.72g) and weedy check (45.77g), respectively (Table 3). The possible reason behind the highest thousand grain weight might be that the decline in weed infestation provided suitable environmental conditions for crop growth and development. Thus the increased thousand grain weight in Clodinafop-propargyl + 2, 4-D + one hand weeding may be attributed to the increased availability of resources to the wheat crop due to weed control. This result was in agreement with the works of Hassan *et al.* [34], who reported that herbicide application increased thousand grain weights significantly as compared to the weedy check. The results are also coordinated with the study of Mushtaq *et al*. [35], who documented that thousand grain weight was increased with the minimum weed invasion.

Table 3 Agronomic data and grain yield (kg/ha) combined analysis for three locations 2017/18

Treatments	PH (cm)	NT	DWB (kg/ha)	CB (kg/ha)	GY (kg/ha)	TKW(g)	TKW
Main plot							
Three Ploughing	91.68b	3.53a	847.22b	8453.70b	3375.98a	72.18	
Four Ploughing	93.12a	3.66a	949.07a	8793.52a	3377.25a	72.17	
Mean	92.40	3.6	898.14	8623.61	3376.61	72.18	
LSD	1.56	0.5	249.73	894.98	243.67	1.64	
CV	4.13	17.6	74.5	9.9	10.43	3.36	
Pyroxulam	90.94cd	3.72a	194bc	9708.33ab	3841ab	72.29a	49.83c
Pyroxulam + one hand weeding	93.08ab	3.65a	52c	10299.24a	4109a	73.18a	51.05b
Clodinafop-propargyl + 2,4-D	92.05bc	3.38a	1208b	8333.33c	3306c	72.36a	41.83f
Clodinafop-propargyl + 2,4-D + one hand weeding	90.61d	3.7a	97bc	8847.22bc	3590bc	72.70a	54.66a
Two hand weeding	93.61a	3.72a	472bc	9172.22abc	3650bc	73.21a	47.72d
Weedy check	94.13a	3.38a	3361a	5444.44d	1763d	69.13b	45.77e
Mean	92.4	3.6	898.14	8623.61	3376.62	72.23	47.19
LSD	3.27	0.56	664.63	1603.13	481.38	3.16	5.05
CV(%)	3.4	14.9	70.6	17.7	13.6	5	28.6

PH=Plant height, NT= number of tillers, GWB= general weed biomass, CB= crop biomass, GY= grain yield, TKW= thousand kernel weight, HLW= hectoliter weight

Table 4. Agronomic data and grain yield (kg/ha) combined analysis for three locations 2016/17

Treatments	PH (cm)	NT	DWB (kg/ha)	CB (kg/ha)	GY(kg/ha)
Main plot					
2 Ploughing	101.90a	7.25a	541.66b	4849.53a	3291.71a
3 Ploughing	101.59a	7.24a	569.44a	4810.18a	3292.3a
Mean	101.74	7.24	555.55	4829.85	3291.33
LSD	1.59	0.63	414.74	828.02	389
CV	2.96	11.06	74.5	53.8	32.5
Sub-plot					
Pyroxulam	101.27c	7.11bc	583.33b	5263.88a	3619ab
Pyroxulam + one hand weeding	101.05c	7.75a	236.11b	5006.94a	3968a
Clodinafop-propargyl + 2,4-D	101.18c	7.24bc	534.72b	4368.05b	2887bc
Clodinafop-propargyl + 2,4-D + one hand weeding	100.92c	7.05bc	173.61b	4979.16a	3346ab
Two hand weeding	103.43a	7.37ab	500b	5236.11a	3700a
Weedy check	102.63b	6.95c	1305.55a	4124.99b	2269c
Mean	101.75	7.25	555.55	4829.85	3291.33
LSD	4.16	1.65	1082.47	2161.11	1015.47
CV (%)	2.4	15	106.53	25.73	21

4. CONCLUSION AND RECOMMENDATION

Most of the target annual grass weeds like *Snowdenia polystachya, Avena fatua, Bromus pectinatus* and broad leaf weeds like *Gizotia scabra, Galinsoga parviflora* and *Polygonum nepalense* were controlled by Pyroxulam + one hand weeding combined with four ploughings in all of the tested locations at efficacy rate between 86-100% and performed the highest grain yield. Hence, it can be recommended that Pyroxulam as post-emergence application + one hand weeding combined with four ploughings was effective and the best integrated weed management(IWM) package for controlling annual grasses and broad leaf weeds in wheat.

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