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Integrated weed management in wheat (*Triticum aestivum* L.)

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Abstract
An experiment was laid out to study the effect of integrated weed management practices for weed management in wheat during *Rabi* seasons of the year 2021-2022 in Randomized Block Design at Post Graduate Research Farm, Agronomy Section, College of Agriculture, Dhule. Experiment consisted of nine treatments with three replications. The results revealed that weed intensity and weed dry weight were found significantly lower in weed free (T_2) treatment which was statistically at par with treatment T_5 *i.e.* pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* two HW at 20 and 40 DAS and treatment T_9 *i.e.* pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS. Weed free also showed significantly higher weed control efficiency throughout the crop growth period. The highest benefit: cost ratio was recorded under treatment T_9 *i.e.* pendimethalin 30% EC 1.0kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS followed by weed free and treatment T_5 (2.51, 2.40 and 2.37. respectively). Hence, it can be concluded that treatment T_9 *i.e.* pendimethalin 30% EC 1.0kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS were comparable with weed free and suitable for weed control in wheat crop.

Keywords: IWM, pendimethalin, metsulphuron methy and wheat

Introduction
The wheat (*Triticum aestivum* L.) crop belongs to the family "Poaceae" and genus "Triticum". It is India's second-most significant cereal crop, and it plays a crucial role in the country's food and nutritional security. Wheat is a major source of carbohydrates, but it also provides significant amounts of protein, vitamins (particularly B vitamins), dietary fiber, and phytochemicals, all of which are needed or beneficial to human health. One of the key causes of low wheat productivity is weed infestation during the early phases of crop growth. Weeds compete with crops for moisture, nutrients, space, and light and provide a safe haven for harmful insect pests, resulting in poorer yields. Weeds can reduce yields up to 50%, depending on the quantity and flora of the weeds. The critical period of crop weed competition is 30-45 days after the crop emerges (Chaudhary *et al*., 2008) [2]. Wheat grain yields have been found to be reduced by up to 66 percent due to poor weed management or uncontrolled weeds (Angiras *et al*. 2008) [1]. Weeds reduce yield, degrade product quality, and increase harvesting, threshing, and cleaning costs. The crop is heavily infested with narrow and broad-leaved weeds such as *Parthenium hysterophorus, Portulaca oleracea, Euphorbia mollis, Amaranthus viridis, Convolvulus arvensis, Commelina benghalensis, Chenopodium album, Cyperus rotundus,* and *Sonchus arvensis* among others, which appear on a regular basis due to intensive cultivation with frequent irrigation.

The untimely and poor weed management adversely affects proper growth and yield of wheat. Integration of weed controls methods are effective and workable practices that may be used ecologically and economically viable to the farmer. Frequently applied herbicides, on the other hand, promote an environment conducive to herbicide resistance, alter weed flora, and facilitate herbicide movement off-site. Hand weeding is laborious, time consuming, energy intensive and only possible on small scale and effective on annual weeds. Raising cost of labour and their non-availability lead to the search for alternative methods such as herbicide use either alone or in combination with hand weeding. The challenge for weed scientists is to develop innovative, effective, economical and environmentally safe IWM systems that can be integrated into current and future cropping systems to bring a more diverse and integrated approach to weed management.

Material and Methods

The field experiment was conducted at the Post Graduate Research Farm, Department of Agronomy, College of Agriculture, Dhule during the *Rabi* season of year 2021. Climatologically, this area falls in the sub-tropical region at the North. Generally, monsoon commences by third week of June and retreats at the end of September with the average annual rainfall of 607 mm. Experiment consisted of nine treatments laid out in randomized block design with three replications. The treatments consist with weedy check (T_1), weed free (T_2), farmers practices (Two hand weeding's at 20 and 40 DAS) (T_3), pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* one HW at 20 DAS (T_4), pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* two HW at 20 and 40 DAS (T_5), pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* clodinafop 15% 60 g *A.I.* ha^{-1} (PoE) (T_6), pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl 20% WP 4 g *A.I.* ha^{-1} (PoE) (T_7), pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* clodinafop (PoE) + one HW at 40 DAS (T_8), pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS (T_9).

The wheat variety Phule Samadhan (NIAW-1994) was sown at row spacing of 20 cm on 22nd Nov, 2021 and harvesting was completed on 21st march, 2022. The plot sizes were adopted 4.50m x 3.60m for gross and 4.10m x 2.80m for net plot. Soil of the experimental plot was clayey in texture and slightly alkaline in reaction. The soil was low in available nitrogen, moderate in phosphorus and very high in available potassium. Fertilizers were applied uniformly at the rate of 120kg N and 60 kg P_2O_5 and 40 kg K_2O ha^{-1}. Species wise weed flora of each plot was recorded from randomly selected 1m x 1m quadrant area at 30, 60 and 90 DAS. Randomly five plants were selected from each plot and regular biometric observations of crop. To establish the significance of differences between treatment means, critical difference values of $p = 0.05$ were frequently utilized.

Weed control efficiency

Weed control efficiency of each mechanical and chemical treatment was worked out by using formula proposed by Gautam *et al*. (1975) [4].

$$WCE\ (\%) = \frac{WPC - WPT}{WPC} \times 100$$

WCE = Weed control efficiency
WPC = Weed population in control plot
WPT = Weed population in treated plot

Weed index

Weed index is an index expressing the reduction in yield due to presence of weeds in comparison with weed free situation. Weed index was calculated by the formula proposed by Gill and Kumar (1969) [5].

$$WI\ (\%) = \frac{X - Y}{X} \times 100$$

WI = Weed index
X = Grain yield from the weed free plot
Y = Grain yield from the treated plot for which weed index is to be worked out

Result and Discussion

Weed control efficiency

The weed control efficiency (WCE) indicates the comparative magnitude of reduction in weed dry matter by different weed control treatments. At 90 DAS, the greater WCE was recorded with weed free treatment (T_2) compared to rest of the treatments (Table 1). Among integrated weed management treatments pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* two HW at 20 and 40 DAS showed maximum weed control efficiency (82.95%) followed by treatment pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS (78.53%). Among various weed control treatments significantly lowest weed control efficiency was found in weedy check treatment. These findings corroborate the findings of the previous study reported by Pisal and Sagarka (2013) [8], Chokkar *et al.*, (2014) [10] and Kumar *et al.*, (2022) [11].

Weed index

The weed index is based on comparison of yield obtained in different treatments with the weed free check. It clearly indicates the relative efficiency of herbicides and weeding. Among all the weed control treatments, weed free treatment produced zero weed index (WI) and the application pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* two HW at 20 and 40 DAS produced significantly lower weed index (1.93%) and followed by treatment pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS (3.75%). Maximum weed index was found under weedy check treatment (38.02%). These results were similar to those reported by Bhoir *et al.*, (2016) [12], Mukharjee *et al.*, (2019) [3] and Meena *et al.*, (2019) [14].

Weed intensity

Weed intensity consists of grasses, sedges and broad leaves collected per meter square area which shows overall view of abundance of weeds in the crop field. Pre-emergence application of pendimethalin resulted efficient control of monocot and dicot weeds, whereas post-emergence application of clodinafop resulted excellent control of monocot weeds and post-emergence application of metsulfuron-methyl control dicot weeds efficiently. At 90 DAS, weed free treatment recorded significantly minimum weed intensity per m^2 (0.71). Among other integrated weed management treatments pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* two HW at 20 and 40 DAS (3.52) which was at par with pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS (3.94) proved more effective in reducing the weed density at harvest as compared to other treatments. Whereas weedy check exhibited maximum weed intensity per m^2 (8.39). These results were similar to those reported by Pisal *et al.*, (2013) [9], Patro *et al.*, (2016) [6] and Meena *et al.*, (2019) [14].

Dry weight of weeds (At harvest)

The total dry weight of weed at harvest was influenced by different integrated weed control treatments. Weed free noted remarkably the lowest dry weight of weeds. Among other integrated weed management treatments, pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* two HW at 20 and 40 DAS (11.25 g) recorded smaller number of weed dry weight which was at

par with treatment pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS (13.56 g). Significantly more dry weight of weeds was recorded in weedy check treatment due to more population of weeds (59.76 g).

It is clearly revealed that various weed management treatments considerably reduced the dry weight of weeds over weedy check plot at harvest. The lowest uptake of nutrients by weeds was associated with the lowest dry weight of weeds under these treatments. Lower weed dry mass in pendimethalin + two HW at 20 and 40 DAS plot is due to slower pace of growth of first flush of weeds at 25 days after sowing and thereafter emergence of new flush of weeds could not attain the full growth under shade of the crop canopy. These results were similar to those reported by Pisal *et al.* (2013) [9], Patil *et al.*, (2018) [13] and Kumar *et al*., (2022) [11]

Table 1: Effect of different weed management treatments on weed intensity, dry weight of weeds, weed index and weed control efficiency

Treatment Details	Weed intensity (No./m^2)	Weed dry weight (g m^{-2})	Weed control efficiency (%)	Weed index (%)
T_1 - Weedy check	8.39(69.99)	59.76	00	38.02
T_2 - Weed free	0.71(00)	00	100	0.00
T_3 - Farmers Practices (Two hand weedings at 20 and 40 DAS)	4.68(21.43)	18.56	69.38	14.41
T_4 - Pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* one HW at 20	5.25(27.16)	28.53	61.19	22.03
T_5 - Pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* two HW at 20 and 40 DAS	3.52(11.93)	11.25	82.95	1.93
T_6 - Pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* clodinafop 15% 60 g *A.I.* ha^{-1} (PoE)	5.84(33.67)	36.73	51.89	29.47
T_7 - Pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl 20% WP 4 g *A.I.* ha^{-1} (PoE)	5.41(28.81)	30.36	58.84	22.22
T_8 - Pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* clodinafop (PoE) + one HW at 40 DAS	4.41(18.95)	16.72	72.92	12.69
T_9 - Pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS	3.94(15.03)	13.56	78.53	3.75
S.E. m±	0.14	0.83	1.05	1.86
C. D. @ 5%	0.43	2.48	3.17	5.57
General mean	4.68	23.94	66.74	16.05

Economics

Highest gross monetary returns were observed in weed free treatment (₹ 125447 ha^{-1}) and found at par with treatment pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* two HW at 20 and 40 DAS (₹ 122674 ha^{-1}) and treatment pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS (₹ 120751 ha^{-1}). Highest net monetary returns were recorded in weed free treatment (₹73219 ha^{-1}) and at par with treatment pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS (₹ 72716 ha^{-1}). The highest benefit cost ratio was obtained in application of pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS (2.51) followed by weed free treatment (2.40). Lowest benefit: cost ratio (1.90) was found under weedy check. These findings are consistent with Similar results were reported by Pisal and Sagarka (2013) [8], Patil *et al*., (2021) [13] and Kumar *et al.*, (2022) [11].

Table 2: Effect of integrated weed management on economics of wheat

Treatment Details	Total cost of Cultivation (₹ ha-1)	Gross Returns (₹ ha-1)	Net Returns (₹ ha-1)	B:C Ratio
T1 - Weedy check	38228	72751	34523	1.90
T2 - Weed free	52228	125447	73219	2.40
T3 - Farmers Practices (Two hand weeding (20 and 40 DAS)	48228	107265	59037	2.22
T_4 - Pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* one HW at 20	46835	97821	50986	2.09
T5 - Pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* two HW at 20 and 40 DAS	51835	122674	70839	2.37
T6 - Pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* Clodinofop 15% 60 g *A.I.* ha^{-1} (PoE)	43985	88461	44476	2.01
T7 - Pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* Metsulphuron methyl 20% WP 4 g *A.I.* ha^{-1} (PoE)	43035	97113	54078	2.26
T8 - Pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* Clodinofop (PoE) + one HW at 40 DAS	48985	109359	60374	2.23
T9 - Pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* Metsulphuron methyl (PoE) + one HW at 40 DAS	48035	120751	72716	2.51
S.E. (m) ±	-	3035.17	1700.59	-
C.D. @ 5%	-	9099.84	5098.60	-
General mean	46822	104627	64365	2.22

Conclusion

It can be concluded from the present investigation that to get the higher growth, yield and net and gross monetary returns, wheat crop should be kept weed free. Weed free treatment control the weeds most efficiently, it reduced the weed dry matter resulted in increase in weed control efficiency. But from economic point of view weed free treatment is not feasible to the farmers because of having a greater number of labours and high cost of cultivation which results in less benefit cost ratio. Whereas, among integrated weed management treatment pendimethalin 30% EC 1.0 kg *A.I.* ha^{-1} (PE) *fb* metsulphuron methyl (PoE) + one HW at 40 DAS effective with higher benefit: cost ratio and can be used in wheat crop.

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