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IMPACT OF SOWING TIMING AND INTEGRATED WEED MANAGEMENT STRATEGIES ON WHEAT CROP GROWTH, PRODUCTIVITY AND MONETARY BENEFITS

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ABSTRACT

A field experiment was conducted during the *rabi* seasons of 2020–2021 and 2021–2022 at the research farm of S.D.J. Post Graduate College Chandeswar in Azamgarh (U.P.) to study the effects of sowing dates and weed management practices on the productivity of wheat (*Triticum aestivum* L.). Among the sowing dates, the crop sown on the 25th of October recorded the highest weed control efficiency and the lowest weed index compared to crops sown later. Similarly, wheat sown on the 25th of October achieved greater growth, productivity, and monetary benefits. Significantly, the highest growth parameters of the wheat crop were observed with one-hand weeding at 20 DAS in conjunction with a combination of Sulfosulfuron at 25 g a.i. and Metsulfuron methyl at 6 g a.i. The maximum yield and monetary advantages of the wheat crop were also noted under the same conditions of one-hand weeding at 20 DAS alongside the combination of Sulfosulfuron at 25 g a.i. and Metsulfuron methyl at 6 g a.i. Thus, wheat sown on the 25th of October, along with one-hand weeding at 20 DAS in combination with Sulfosulfuron at 25 g a.i. and Metsulfuron methyl at 6 g a.i., demonstrated superior weed control efficiency and enhanced growth and productivity for wheat cultivation.

Key words : IWM, Sowing, Tiller, Weed, Wheat, Yield.

Introduction

Wheat, the most important staple food crop in India, provides food security to about 77 per cent of the country's population. Wheat, alongside rice, is a principal source of protein and caloric intake in least-developed and middle-income nations. In India, wheat is grown during the Rabi season, which involves sowing in November and harvesting from March to April, aligning with the country's climatic patterns and agricultural practices. The area under wheat cultivation has reached approximately 31.4 million hectares, representing 14% of the global wheat area, yielding an unprecedented output of 110.55 million metric tonnes, or 13.64% of world production, with an average productivity of 3521 kg/ha (MOA and FW, 2023). This represents a notable increase in cultivated area from 29.04 million hectares, reflecting a net gain of 1.5 million hectares (5%). The distribution of cultivated land in India shows a high level of concentration, with Uttar Pradesh holding the largest proportion at 9.75 million hectares, which amounts to 32% of the total.

Moreover, the challenges of wheat production are exacerbated by the timing of sowing and the persistent pest pressures stemming from repetitive wheat-rice cropping systems in the same fields, heightening vulnerability and complicating sustainable agricultural practices (ICAR, 2015).

Timely sowing of wheat is critical for maximizing yields and overall productivity (Mukherjee, 2012). Delays in planting lead to significant grain yield losses, primarily due to intensified competition between crops and weeds, adverse weather conditions that favour problematic weed growth, and suboptimal vegetative development of the wheat itself (Singh *et al.*, 2017). The much lower number of spikes per m^2, the lower number of grains per spike, and the 1000-grain weight may all be related to the declining trend in grain output brought on by delayed planting (Mishri and Kailash, 2005). Besides the sowing time, weeds impose competition for nutrients, solar radiation, and water, and they set in at the early crop growth stages, where their relative density plays a significant role in reducing the yield of crops.

The introduction of high-yielding dwarf varieties, which comparatively require large amounts of water and fertiliser, has created favourable conditions for the invasion as well as the luxuriant growth of weeds. In wheat cultivation, the primary weed species encountered include *Phalaris minor*, *Avena ludoviciana*, *Chenopodium album*, *Medicago denticulata*, *Melilotus alba*, *Melilotus indica*, *Fumaria parviflora*, *Vicia hirsuta*, *Vicia sativa*, *Coronopus didymus* and *Rumex acetosella*. These species can significantly compete with wheat for resources, affecting crop yield and management practices. Yield reduction due to weeds in wheat ranges from 15–50%, depending upon the weed density and type of weed flora (Jat *et al.*, 2003). Phalaris minor is one of the very serious problems in wheat. Due to the severe infestation of weeds, a significant reduction in wheat yield ranging from 18–73% has been reported by Pandey and Verma (2004).

Continuous and indiscriminate use of single herbicides may lead to many problems, such as resistance in weeds, residue in crops and soil, pollution hazards and health hazards to non-target organisms (Singh *et al*., 2012). Herbicides have provided effective control of weeds. However, due to the continuous use of Isoproturon, *Phalaris minor* has become resistant to this herbicide (Malik and Singh, 1995). To overcome this problem, three alternate herbicides—Fenoxaprop-p-ethyl, Clodinafop-propargyl, and Sulfosulfuron—have been recommended for the control of Isoproturon-resistant *Phalaris minor* in rice-wheat growing areas (Chhokar and Malik, 2002). The continuous application of these herbicides has led to a substantial increase in the density of several broad-leaved species.

Hence, the identification of an ideal weed management strategy needs to be developed for effective weed control in wheat crops. Therefore, the present investigation entitled “Effect of date of sowing and integrated weed management practices on weed control efficiency, wheat growth, yield and productivity in the eastern region of Uttar Pradesh” was planned at SDJ Postgraduate College in Chandeshwar, Azamgarh.

Materials and Methods

A field experiment was conducted during *rabi* 2020–2021 and 2021–2022 at the research farm of S.D.J. Post Graduate College Chandeswar, Azamgarh (U.P.) (26°40’N and 83°1’E at an altitude of 77.36 m AMSL). The soil was sandy clay loam in texture, slightly alkaline in reaction (pH 7.81) with electrical conductivity of 0.63 dS/m, low in organic carbon (0.46%), nitrogen (219.76 kg/ha) and phosphorous (11.28 kg/ha) and medium in available potassium (193.82 kg/ha).

The experiment was laid out in a split-plot design with three replications. The treatments consisted of three sowing dates, *viz*. 25th October and 1st November and 7th November. The four weed management practices include HW at 20 DAS + Sulfosulfuron @ 25 g a.i./ha on 35 DAS, HW at 20 DAS + Metsulfuron methyl @ 6g a.i./ha on 35 DAS, HW at 20 DAS + Mixture of Sulfosulfuron @ 25 g a.i./ha + Metsulfuron methyl @ 6g a.i./ha on 35 DAS weed free and weedy check.

Wheat cultivar ‘HD 2967’ was sown at a row-to-row spacing of 20 cm. The crop was fertilized with 120:60:40 kg of N-P_2O_5-K_2O/ha. Full doses of phosphorus and potassium, along with one-third of nitrogen, were applied as basal dose at the time of sowing. The remaining half of nitrogen was applied in two equal splits – at the crown root initiation stage and just before the ear initiation stage. All the herbicides were sprayed at 30 DAS by knapsack sprayer fitted with flat fan T-jet nozzle using a spray volume of 500 l/ha. Weedy check plots remained infested with the native population of weeds till harvest. The weed count and weed dry matter accumulation were recorded using a quadrate of 1 m^2 size. The wheat crop growth and yield characteristics were observed following the standard measures.

The data on weed count and weed dry weight were subjected to square root transformation ($\sqrt{X+1}$) to normalize their distribution (Gomez and Gomez, 1984). Weed control efficiency (WCE) and weed index (WI) were worked out by the formula given by Mishra and Mishra (2016) and Walia (2010). The net returns were computed by deducting the total cost of cultivation from the gross returns, and the Benefit: Cost ratio was calculated by dividing the net returns by the cost of cultivation.

Results and Discussion

Weed Control efficiency

The study indicates that sowing the wheat crop earlier, specifically on October 25th, could greatly enhance weed control efficiency (Table 1). This improvement in management practices can be attributed to the accelerated growth rate of the wheat plants, which allows them to establish themselves before the weeds have a

Table 1 : Effect of date of sowing and weed management practices on weed control efficiency (%) at different stages of wheat and weed index (%) in 2020-21 and 2021-22.

Treatment	Weed Control Efficiency (%)						Weed Index %	
	30 DAS		60 DAS		90 DAS		2020-21	2021-22
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22		
A. Date of sowing								
D_1 – October 25	59.85	61.61	67.08	71.15	75.79	76.08	6.26	6.65
D_2 – November 01	50.80	54.17	63.85	65.88	75.44	75.47	6.39	6.74
D_3 – November 07	46.97	49.26	59.79	64.06	74.12	74.01	6.47	6.80
B. Weed management practices*								
W_1 - Sulfosulfuron @ 25 g a.i./ha on 35 DAS	44.53	47.16	63.69	68.14	79.37	78.99	7.43	6.94
W_2 - Metsulfuron methyl @ 6g a.i./ha on 35 DAS	48.57	52.44	56.38	62.89	77.06	76.69	4.67	5.16
W_3 - Mixture of W_1 and W_2	52.64	56.38	69.07	72.66	79.77	80.97	0.81	2.36
W_4 - Weed free	100.00	100.00	100.00	100.00	100.00	100.00	0.00	0.00
W_5 - Weedy check	0.00	0.00	0.00	0.00	0.00	0.00	18.95	19.18

* One hand weeding was done on 20 DAS in all the treatments except the Weedy check.

chance to proliferate. Typically, most weed species emerge around the second week of November. By sowing the wheat crop earlier in October, farmers enable the wheat plants to grow robustly and cover the soil adequately before the weeds start to sprout. Consequently, this early planting strategy not only promotes healthier wheat development but also minimizes the opportunities for weeds to thrive in the field, leading to more effective overall weed management.

This study focused on effective weed management and observed that the highest weed control efficiency was observed with one-hand weeding at 20 DAS *fb* application of a mixture of post-emergence application of Sulfosulfuron combined with Metsulfuron methyl. This herbicide mixture was particularly notable for its ability to reduce weed dry weight substantially compared to other treatments. The reduced weed biomass demonstrated by this combination suggests a strong herbicidal activity, which aligns with findings from previous research conducted by Meena and Singh (2011), Li *et al*. (2016), and Tomar and Tomar (2014). Their studies support the efficacy of these herbicides in managing weed populations effectively.

Weed Index

The weed index serves as a critical metric for assessing the impact of weed infestation on crop yield, specifically reflecting the extent of yield reduction attributable to the presence of weeds. This index is closely correlated with two primary factors: weed density and the dry matter of the weeds present in the area. A lower weed index signifies a higher degree of benefit for the crop, indicating less competition from weeds and consequently, better potential yields.

Research suggests that sowing wheat crops on October 25th can lead to increased grain yields while simultaneously reducing the weed index (Table 1). This phenomenon may be attributed to the fact that earlier sowing allows wheat crops to establish themselves before weeds can proliferate, thereby creating a weed-free environment. Such conditions promote optimal growth, enabling the wheat plants to flourish and ultimately produce a higher yield.

One-hand weeding at 20 DAS *fb* application of a herbicide mixture, consisting of Sulfosulfuron @ 25 grams of active ingredient (a.i.) and Metsulfuron methyl @ 6 grams a.i., resulted in a strikingly low weed index, highlighting the effectiveness of these herbicides in controlling and suppressing unwanted weed growth. In stark contrast, the control group, which received no intervention for weed management, exhibited alarmingly high weed indices. This significant disparity underscores the vital role that herbicide application plays in maintaining healthy plant growth by effectively managing weed populations. The lowest weed index in efficient herbicidal treatments can probably be ascribed to minimized weed density but also averted weed dry matter and reduction

Table 2 : Effect of date of sowing and weed management practices on plant height (cm) at different stages of wheat in 2020-21 and 2021-22.

Treatment	30 DAS		60 DAS		90 DAS		At harvest	
	2020-21	**2021-22**	**2020-21**	**2021-22**	**2020-21**	**2021-22**	**2020-21**	**2021-22**
A. Date of sowing								
D_1 – October 25	28.33	27.13	60.12	59.18	85.92	85.24	98.29	94.02
D_2 – November 01	27.43	26.95	59.53	58.86	84.35	83.76	96.69	92.51
D_3 – November 07	27.28	26.34	58.68	58.69	83.66	83.37	95.21	92.08
SE(m)±	*0.11*	*0.17*	*0.14*	*0.16*	*0.28*	*0.35*	*2.46*	*2.82*
CD (p=0.05)	*0.43*	*NS*	*0.31*	*0.37*	*1.11*	*1.42*	*NS*	*NS*
B. Weed management practices*								
W_1 - Sulfosulfuron @ 25 g a.i./ha on 35 DAS	27.38	26.86	58.77	57.98	83.96	83.62	96.72	93.20
W_2 - Metsulfuron methyl @ 6g a.i./ha on 35 DAS	27.58	26.94	59.36	59.62	84.94	84.84	97.43	93.78
W_3 - Mixture of W_1 and W_2	28.35	27.26	60.64	60.16	86.94	86.57	99.80	95.92
W_4 - Weed free	28.47	27.46	62.56	61.88	87.55	87.95	103.12	98.65
W_5 - Weedy check	26.60	25.51	55.90	54.92	79.83	77.64	86.58	82.81
SEM±	*0.31*	*0.21*	*0.63*	*0.47*	*0.91*	*0.71*	*2.94*	*4.04*
CD (p=0.05)	*0.92*	*0.63*	*1.85*	*1.38*	*2.66*	*2.07*	*8.63*	*11.85*
Interaction A × B								
Factor(B) at same level of A: SEM±	*0.24*	*0.38*	*0.85*	*0.57*	*0.62*	*0.79*	*5.50*	*6.30*
Factor(B) at same level of A: CD (p=0.05)	*NS*	*NS*	*2.47*	*1.62*	*1.13*	*2.65*	*NS*	*13.48*
Factor(A) at same level of B: SEM±	*0.50*	*0.37*	*0.45*	*0.77*	*1.43*	*1.15*	*5.18*	*6.86*
Factor(A) at same level of B: CD (p=0.05)	*NS*	*NS*	*1.28*	*NS*	*NS*	*NS*	*NS*	*NS*

*One hand weeding was done on 20 DAS in all the treatments except Weedy check.

in crop-weed competition. These results conformed with the findings of Jat *et al*. (2013) and Bhullar *et al*. (2012).

Plant height

The timing of sowing and the implementation of effective weed management practices have a significant impact on the height of wheat plants (Table 2). This study indicates that sowing the seeds earlier in the growing season is likely to promote greater plant height across both observed years. A noticeable inverse relationship was established between the date of sowing and plant height, with a marked decrease in height associated with later sowing dates. Specifically, the shortest plants were recorded for those sown on November 7th. This reduction in plant height can be attributed to the favourable climatic conditions present during earlier sowing periods, which are conducive to optimal growth and development. In contrast, crops sown later tend to exhibit slower growth rates, likely due to lower temperatures that prevail during that time, negatively affecting their overall development. Support for these findings can be found in the research conducted by Mahajan *et al*. (2018), which corroborates the observation that maximum plant height is attained when wheat is sown on earlier dates.

In the course of the experimentation, it was observed that the tallest plants consistently thrived in weed-free plots at every growth stage across both years. The one-hand weeding at 20 DAS *fb* combination of Sulfosulfuron at a rate of 25 grams of active ingredient (a.i.) and Metsulfuron methyl at 6 grams a.i. emerged as the most effective treatment for promoting plant height, closely followed by one-hand weeding at 20 DAS *fb* application of Metsulfuron methyl alone at the same concentration. Conversely, when one-handed weeding at 20 DAS *fb* Sulfosulfuron was applied by itself at 25 grams a.i., the plants exhibited reduced height throughout all growth stages during the two-year study.

Table 3 : Effect of date of sowing and weed management practices on number of tillers (No. m^{-2}) at different stages of wheat in 2020-21 and 2021-22.

Treatment		30 DAS		60 DAS		90 DAS		At harvest	
		2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
A. Date of sowing									
D_1 – October 25		230.65	221.17	377.72	368.59	451.02	440.02	396.64	382.01
D_2 – November 01		226.50	219.32	365.52	358.69	442.12	425.37	395.34	379.81
D_3 – November 07		225.60	215.82	359.37	349.84	438.47	420.77	391.64	378.16
SE(m)±		*1.17*	*1.69*	*1.88*	*3.02*	*1.39*	*2.35*	*1.99*	*3.68*
CD (p=0.05)		*NS*	*NS*	*7.59*	*12.16*	*5.59*	*9.49*	*NS*	*NS*
B. Weed management practices*									
W_1 - Sulfosulfuron @ 25 g a.i./ha on 35 DAS		226.93	216.20	370.52	361.75	450.00	435.30	389.55	376.13
W_2 - Metsulfuron methyl @ 6g a.i./ha on 35 DAS		228.38	220.10	373.27	365.45	455.55	438.45	396.90	380.98
W_3 - Mixture of W_1 and W_2		231.18	223.35	379.32	373.50	464.30	450.70	416.60	400.53
W_4 - Weed free		232.53	225.55	392.72	380.80	473.35	456.80	422.20	406.98
W_5 - Weedy check		218.88	208.65	321.87	313.70	376.15	362.35	347.45	335.33
SEM±		*1.72*	*1.78*	*3.26*	*2.84*	*3.48*	*2.87*	*3.20*	*3.78*
CD (p=0.05)		*5.05*	*5.24*	*9.58*	*8.35*	*10.23*	*8.43*	*9.41*	*11.10*
Interaction A × B									
Factor(B) at same level of A	SEM±	*2.61*	*3.78*	*4.21*	*6.74*	*3.10*	*5.26*	*4.45*	*8.23*
	CD (p=0.05)	*NS*	*NS*	*12.89*	*14.91*	*9.74*	*14.61*	*NS*	*NS*
Factor(A) at same level of B	SEM±	*2.91*	*3.24*	*5.40*	*5.34*	*5.57*	*5.03*	*5.35*	*6.92*
	CD (p=0.05)	*NS*	*NS*	*13.86*	*NS*	*NS*	*NS*	*NS*	*NS*

*One hand weeding was done on 20 DAS in all the treatments except Weedy check.

The dramatic height advantages observed in weed-free plots can likely be attributed to reduced competition between crops and weeds, which in turn allows for greater access to essential resources such as water and nutrients. Consequently, significant increases in plant height were documented across various treatments that minimized weed interference. In stark contrast, the weedy check plots displayed considerably lower plant heights and decreased dry matter of wheat, primarily due to intense competition from surrounding weeds. These findings were consistent with similar research conducted by Singh *et al*. (2019), further validating the importance of managing weed presence for optimal crop growth.

No. of Tillers per m^2

A gradual increase in the number of tillers was observed as the crop matured, with notable growth across all treatments up to 90 DAS during both years of the study (Table 3). The results indicated that wheat sown on October 25 yielded the highest density of tillers per square meter throughout various growth stages. This trend was particularly prominent at the 60-day mark and 90 DAS, where the tiller count was significantly greater compared to other sowing dates. The enhanced performance of this treatment can be attributed to the more favourable climatic conditions experienced during the early stages of crop development, which provided an optimal environment for growth. This conducive setting ultimately led to an increase in tillering, a critical factor for overall yield. The late planting resulted in diminished tillering success due to the unfavourable low temperatures typically encountered during this period. This finding aligns with research conducted by Mahajan *et al*. (2018), which also highlighted the adverse effects of late sowing on tiller development in wheat.

The combination of one-hand weeding at 20 DAS *fb* Sulfosulfuron at a rate of 25 grams of active ingredient per hectare, alongside Metsulfuron methyl at 6 grams of

Table 4 : Yield attributes of wheat as influenced by different date of sowing and weed management practices in wheat crop during 2020-21 and 2021-22.

Treatment		Grain: Straw Ratio		Spike length (cm)		No. of spikes m^{-2}		No. of grains $spike^{-1}$		1000 grain weight (g)	
		2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
A. Date of sowing											
D_1 – October 25		0.704	0.697	10.188	9.814	373.190	359.940	40.744	39.936	10.188	9.814
D_2 – November 01		0.694	0.687	9.953	9.634	370.840	354.740	39.539	38.711	9.953	9.634
D_3 – November 07		0.689	0.677	9.658	9.354	366.240	353.040	38.329	37.381	9.658	9.354
SE(m)±		*0.005*	*0.008*	*0.059*	*0.052*	*2.297*	*3.062*	*0.233*	*0.382*	*0.252*	*0.203*
CD (p=0.05)		*NS*	*NS*	*0.238*	*0.209*	*NS*	*NS*	*0.939*	*1.540*	*1.014*	*0.819*
B. Weed management practices*											
W_1 - Sulfosulfuron @ 25 g a.i./ha on 35 DAS		0.692	0.685	9.745	9.267	372.500	353.467	39.273	38.495	40.312	39.457
W_2 - Metsulfuron methyl @ 6g a.i./ha on 35 DAS		0.702	0.690	10.065	9.477	375.150	361.367	39.808	38.835	40.967	40.317
W_3 - Mixture of W_1 and W_2		0.707	0.700	10.385	10.197	385.500	373.317	40.998	39.975	42.172	41.492
W_4 - Weed free		0.722	0.715	10.780	10.527	391.950	378.617	42.338	41.390	42.732	42.017
W_5 - Weedy check		0.657	0.645	8.690	8.537	325.350	312.767	35.268	34.685	38.637	37.697
SEM±		*0.006*	*0.007*	*0.094*	*0.073*	*3.419*	*2.859*	*0.341*	*0.381*	*0.396*	*0.298*
CD (p=0.05)		*0.017*	*0.021*	*0.276*	*0.213*	*10.037*	*8.393*	*1.002*	*1.119*	*1.163*	*0.876*
Interaction A × B											
Factor(B) at same level of A	SEM±	*0.011*	*0.017*	*0.132*	*0.116*	*5.137*	*6.846*	*0.521*	*0.854*	*0.562*	*0.454*
	CD (p=0.05)	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*1.23*	*2.391*	*1.379*	*1.381*
Factor(A) at same level of B	SEM±	*0.010*	*0.013*	*0.157*	*0.124*	*5.773*	*5.384*	*0.578*	*0.703*	*0.663*	*0.505*
	CD (p=0.05)	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*1.44*	*2.174*	*1.794*	*1.617*

*One hand weeding was done on 20 DAS in all the treatments except Weedy check.

Table 5 : Yield of wheat as influenced by different date of sowing and weed management practices in wheat crop during 2020-21 and 2021-22.

Treatment		Grain yield (q ha^{-1})		Straw yield (q ha^{-1})		Biological yield (q ha^{-1})		Harvest Index	
		2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
A. Date of sowing									
D_1 – October 25		48.52	46.98	68.68	67.19	117.20	114.17	41.29	41.05
D_2 – November 01		47.44	46.28	68.16	67.17	115.60	113.44	40.95	40.70
D_3 – November 07		46.80	45.85	67.73	67.55	114.54	113.39	40.78	40.35
SE(m)±		0.37	0.12	0.68	0.73	0.99	0.75	0.18	0.27
CD (p=0.05)		0.78	0.47	NS	NS	NS	NS	NS	NS
B. Weed management practices*									
W_1 - Sulfosulfuron @ 25 g a.i./ha on 35 DAS		47.05	46.26	67.99	67.53	115.04	113.79	40.89	40.65
W_2 - Metsulfuron methyl @ 6g a.i./ha on 35 DAS		48.46	47.15	69.05	68.33	117.50	115.48	41.24	40.83
W_3 - Mixture of W_1 and W_2		50.42	48.54	71.33	69.35	121.74	117.89	41.41	41.17
W_4 - Weed free		50.83	49.71	70.40	69.51	121.22	119.22	41.91	41.68
W_5 - Weedy check		41.20	40.18	62.20	61.80	103.39	101.97	39.59	39.16
SEM±		0.24	0.43	0.80	0.79	1.11	1.07	0.19	0.26
CD (p=0.05)		0.63	1.26	2.34	2.32	3.25	3.15	0.56	0.75
Interaction A × B									
Factor(B) at same level of A	SEM±	0.89	0.26	1.51	1.64	2.20	1.69	0.41	0.61
	CD (p=0.05)	2.49	0.63	3.83	NS	4.51	3.53	1.37	NS
Factor(A) at same level of B	SEM±	0.70	0.68	1.41	1.43	1.98	1.83	0.35	0.48
	CD (p=0.05)	2.22	*1.84*	NS	NS	NS	NS	0.94	NS

*One hand weeding was done on 20 DAS in all the treatments except Weedy check.

active ingredient per hectare, demonstrated a remarkable enhancement in the number of tillers produced per square meter across all stages of crop growth. This significant increase can largely be attributed to the effective weed control provided by the herbicide mixture, which in turn diminished the competition between crops and weeds. As a result, this led to greater nutrient availability for the crops, ultimately fostering the development of a higher number of tillers. In contrast, the weedy control plots exhibited the lowest tiller counts, a situation exacerbated by unfavourable weather conditions and intensified competition from weeds. These findings align with previous studies conducted by Punia *et al.* (2013), Mohammad and Ismail (2018), and Singh *et al.* (2019), which similarly highlighted the benefits of herbicide application in crop yield enhancement.

Yield attributes

Wheat that is sown on October 25th has demonstrated superior performance in terms of these yield-attributing characteristics compared to wheat sown on later dates (Table 4). This improved performance can be attributed to the favourable cool weather conditions that prevail for an extended period following the earlier sowing date. Such conditions are ideal for the development of wheat plants, allowing for enhanced vegetative growth and reproductive success. Supporting this observation, Ali *et al.* (2018) provided evidence that crops planted earlier in the season tend to yield better results than those sown later.

This study demonstrated that a combination of one-hand weeding at 20 DAS *fb* herbicides Sulfosulfuron at 25 grams of a.i. and Metsulfuron methyl at 6 grams of a.i., was particularly effective. The herbicide mixture outperformed other weed management practices in terms of all measured yield-attributing characteristics, indicating its superiority. Moreover, the study highlighted that the highest values for all yield-contributing parameters were observed in weed-free plots. This superior performance can likely be attributed to the enhanced availability of essential resources such as nutrients, moisture, space, and light. When weeds are effectively managed or eliminated, crops experience reduced competition, which fosters improved growth and development. These findings align with previous research conducted by Singh *et al*. (2011) and Chand and Punia (2017), who reported similar trends and underscored the importance of effective weed management strategies in agricultural practices.

Yield characters

The yield characteristics of wheat crops, specifically grain yield, straw yield, and overall biological yield, are significantly affected by both the timing of sowing and the management practices employed to control weed growth. Data analysis reveals a clear trend: as the sowing date is postponed, there is a marked decrease in grain yield (Table 5). Each sowing date results in significantly different grain yields when compared to one another. In this context, the optimal time for sowing wheat appears to be around 25th October, as crops sown on this date achieved the highest recorded grain yield. Following closely, the crops sown on 1st November also yielded well. In contrast, the lowest grain yield was recorded for wheat sown on 7th November, indicating the detrimental effects of sowing later in the season. The underlying reason for this decline in yield associated with delayed sowing can be attributed to the exposure of the crop's reproductive phase to elevated temperatures. When sowing is delayed, plants face higher temperatures during critical growth stages, which forces them to shorten their vegetative growth periods. This shortening leads to a reduced duration for both grain filling and the overall grain development phase. Consequently, the result is a significant drop in both grain yield and straw yield when compared to crops sown under more favourable thermal conditions. Furthermore, the phenomenon of forced maturity due to high temperatures during the grain-filling period, particularly for crops sown on 7th November, exacerbates the issue, leading to an even greater reduction in grain yield.

Among the various herbicidal treatments evaluated in the study, one-hand weeding at 20 DAS *fb* the usage of a combination of Sulfosulfuron at 25 g/ha and Metsulfuron at 6 g/ha as post-emergence herbicides resulted in the significantly highest grain yield. This impressive outcome can be attributed to the broad-spectrum nature of these herbicides, which effectively inhibited the growth of a wide variety of weeds. By controlling weed populations, these treatments minimise crop-weed competition, thereby creating a more favourable environment for the growth and development of the crop. Similar results were documented in previous studies by Chaudhray and Iqbal (2013) and Dev *et al*. (2013), both highlighting the positive impact of effective

Table 6 : Monetary benefits of wheat cultivation under different date of sowing and weed management practices during 2020-21 and 2021-22.

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})		Net Return (Rs. ha^{-1})		B:C ratio	
		2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
A. Date of sowing							
D_1 – October 25	38729	110383	106880	71654	68151	2.85	2.76
D_2 – November 01	38729	107926	105287	69197	66558	2.79	2.72
D_3 – November 07	38729	106470	104309	67741	65580	2.75	2.69
B. Weed management practices*							
W_1 - Sulfosulfuron @ 25 g a.i./ha on 35 DAS	39669	107039	105242	67370	65573	2.70	2.65
W_2 - Metsulfuron methyl @ 6g a.i./ha on 35 DAS	39879	110247	107266	70368	67387	2.76	2.69
W_3 - Mixture of W_1 and W_2	40819	114706	110429	73887	69610	2.81	2.71
W_4 - Weed free	43698	115638	113090	71940	69392	2.65	2.59
W_5 - Weedy check	38729	93730	91410	55001	52681	2.42	2.36

*One hand weeding was done on 20 DAS in all the treatments except Weedy check.

weed management on crop yield. Additionally, the findings of Kumar *et al.* (2018) and Singh *et al.* (2019) also corroborate the notion that strategic herbicide applications contribute significantly to enhancing agricultural productivity by reducing weed interference.

Monetary benefits

During the study, it was noted that the overall cost of cultivation remained constant regardless of the sowing date. Nonetheless, variations in the cost of cultivation were evident across different weed management strategies, primarily due to the various herbicide formulations employed throughout the research (Table 6). Specifically, the highest cultivation costs were recorded in plots that were left weedy, serving as the control group. Among the weed management techniques evaluated, the combination of one-hand weeding performed at 20 DAS followed by the application of Sulfosulfuron (25 g/ha) and Metsulfuron (6 g/ha) resulted in the highest expenses.

In terms of crop performance, wheat sown on October 25 yielded the maximum gross and net returns, with the second-best results coming from sowing on November 1. Conversely, plots sown on November 7 displayed the lowest returns, likely attributable to the diminished crop yield associated with this delayed planting date. The early sowing on October 25 facilitated optimal growth conditions, resulting in increased grain production and consequently, the highest financial returns for the crop.

When assessing the effectiveness of various weed management practices, the most substantial economic returns were achieved through the one-hand weeding treatment implemented at 20 DAS in conjunction with the selected herbicides (Sulfosulfuron and Metsulfuron). The weedy check plots, on the other hand, yielded the lowest financial returns due to uncontrolled weed competition.

Furthermore, the benefit-to-cost (B: C) ratio paralleled the trends in returns, reinforcing the economic advantages of targeted weed management approaches. It was observed that maintaining a weed-free environment was not cost-effective compared to employing herbicidal treatments, as the substantial expenses associated with manual weeding and control measures outweighed the benefits. The herbicide treatments demonstrated significantly better net returns and returns per rupee invested, primarily because they incurred less incremental cost compared to the weed-free plots, showcasing the effectiveness of these management practices in optimizing both yields and financial outcomes.

Conclusion

Based on two years of study, it was concluded that wheat crop sown on 25th October along with One-hand weeding at 20 DAS *fb* application of a herbicide mixture, consisting of Sulfosulfuron @ 25 grams of active ingredient (a.i.) and Metsulfuron methyl @ 6 grams a.i., was found effective in achieving better weed control efficiency and wheat crop growth and productivity. Concurrently, this treatment shows more monetary benefits.

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