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Vinita Parte
College of Agriculture, Ganjbasoda, Vidisha, JNKVV, Jabalpur, Madhya Pradesh, India

PK Mishra
Dean, College of Agriculture Powarkheda, JNKVV, Jabalpur, Madhya Pradesh, India

Corresponding Author:
Vinita Parte
College of Agriculture, Ganjbasoda, Vidisha, JNKVV, Jabalpur, Madhya Pradesh, India

Growth parameters and yield of wheat as influenced by thermal environments and herbicidal mixtures

Vinita Parte and PK Mishra

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Abstract
A field experiment was conducted during *rabi* season of 2023-24 and 2024-25 to study the influence of thermal environments and herbicidal mixture on growth parameters of wheat at the Farm B, College of Agriculture, GanjBasoda, District Vidisha (M.P.). The experiment was conducted in split plot design with three thermal environments (15th November, 30th November and 15th December) and 6 weed control treatments (W_1: Fenoxaprop-p-ethyl + Metribuzin, W_2: Clodinafop-propargyl + Metsulfuron methyl, W_3: Sulfosulfuron + Metsulfuron methyl, W_4: Metribuzin + 2,4-D, W_5: single hand weeding at 30 DAS and W_6: Weedy check) with three replications. Results revealed that maximum growth parameters (Leaf area index, Crop growth rate and Relative growth rate) and yield was under the crop sown on 15th November as compare to other sowing dates. Among the weed control treatments, Sulfosulfuron + Metsulfuron Methyl recorded maximum growth indices (LAI, CGR and RGR) and yield.

Keywords: Thermal environments, herbicidal mixtures, leaf area index, crop growth rate and relative growth rate

Introduction
Wheat is essential crop for the food security and eliminates poverty in rural areas which also improves the livelihoods of Indian farmers. It acts as the good source of protein and carbohydrates for human diet and also superior in protein content as compared to maize and rice crops as well as other major cereals. Thermal environment is also the most significant factor that administrates the phenological growth of the crop as well as the biomass conversion in to economic yield. Wheat production is indirectly impacted by the weeds via competition for nutrients, space, water, light and other resource, harboring crop pests, reducing the grain yield, grain quality and increase in cost of processing (Zimdahl, 2018) [12].Mostly wheat farmers depending on the herbicides due to its effectiveness and easy application as compare to the manual weeding. Presently, weeds are being controlled mainly by herbicides. Therefore, the present study aimed to determine the effect of thermal environments and herbicidal mixture on wheat.

Materials and Methods
The field experiment was carried out during the *rabi* season of 2023-24 and 2024-25 at the Farm B, College of Agriculture, GanjBasoda, District Vidisha (M.P.). The climate in the GanjBasoda region is usually sub-humid with hot dry summers and cool dry winters. GanjBasoda is located at 23051'North latitude and 770 55' East longitude, at an elevation of 416.66 metres above mean sea level. According to National Agriculture Research Project standards, it is classified as part of the "Vindhya Plateau" agro-climatic zone. The soil in the GanjBasoda district Vidisha region is classed as Vertisol. The depth ranges from medium to deep and the colour is black. The soil of the experimental field is infested with a variety of weeds, depending on the season, crop grown and management strategies utilized throughout the research. The experiment was conducted in split plot design with three thermal environments (15th November, 30th November and 15th December) and 6 weed control treatments (W_1:Fenoxaprop-p-ethyl + Metribuzin, W_2: Clodinafop-propargyl + Metsulfuron Methyl, W_3:Sulfosulfuron + Metsulfuron Methyl, W_4: Metribuzin + 2,4-D, W_5: single hand weeding at 30 DAS and W_6: Weedy check) with three

replications.

Results and Discussion

Leaf area index

The LAI of wheat crop was recorded under each treatment at 60DAS and the pooled values after statistical analysis are summarized in Table 1 and depicted in Fig. 1.Leaf Area Index (LAI) showed the degree of a crop's photosynthetic surface, Therefore, a superior leaf area index results in advanced crop growth and superior crop yield. In this study, the 15th November sowing environment recorded the highest LAI (3.85), outperformed the late sown thermal environment crops. The elevated LAI under the 15th November was due to optimal environmental conditions that supported the synthesis of growth-enhancing compounds in the plant system, leading to an increased number of leaves and finally, greater LAI. Delayed sowing beyond November 15 lead crops to higher temperatures during the vegetative stage of the crop, rising transpiration rates and restraining cell expansion, which reduced leaf area. This aligns with findings by Thorat (2015) [11], who noted similar effects of delayed sowing on LAI. The highest LAI was obtained by herbicidal mixtures over the weedy check. The highest LAI was recorded by Sulfosulfuron + Metsulfuron methyl (3.87) and the lowest by weedy check treatment at 60 DAS among the herbicidal treatments. The present investigation clearly indicated that this herbicidal mixture treatment effectively controlled narrow as well as broad leaf weeds and thus helps the wheat crop to grow better with higher leaf expansion, finally resulting in higher values for leaf area index. Similarly, Kumar *et al*. (2018) [6] also reported higher LAI by Sulfosulfuron + Metsulfuron methyl herbicidal mixture.

Table 1: Effect of thermal environments and weed control treatments on Leaf area index of wheat at 60 DAS

Treatments	LAI at 60 DAS		
	2023-24	2024-25	Pooled
Main plot-Thermal environments			
E_1	3.82	3.88	3.85
E_2	3.75	3.80	3.78
E_3	3.59	3.64	3.62
S.Em±	0.04	0.02	0.03
CD(p=0.05)	0.15	0.09	0.10
Sub plot-Weed control treatments			
W_1	3.69	3.74	3.72
W_2	3.79	3.86	3.83
W_3	3.83	3.91	3.87
W_4	3.75	3.80	3.77
W_5	3.68	3.73	3.70
W_6	3.58	3.61	3.60
S.Em±	0.05	0.06	0.04
CD(p=0.05)	0.13	0.17	0.12

Note: E: Thermal environments, E_1: 15th November, E_2: 30th November, E_3: 15th December, W: Weed control treatments, W_1: Fenoxaprop-p-ethyl + Metribuzin, W_2: Clodinafop-propargyl + MetsulfuronMethyl, W_3: Sulfosulfuron + Metsulfuron Methyl, W_4: Metribuzin + 2,4-D, W_5: Hand weeding at 30 DAS, W_6: Weedy check, NS = non-significant.

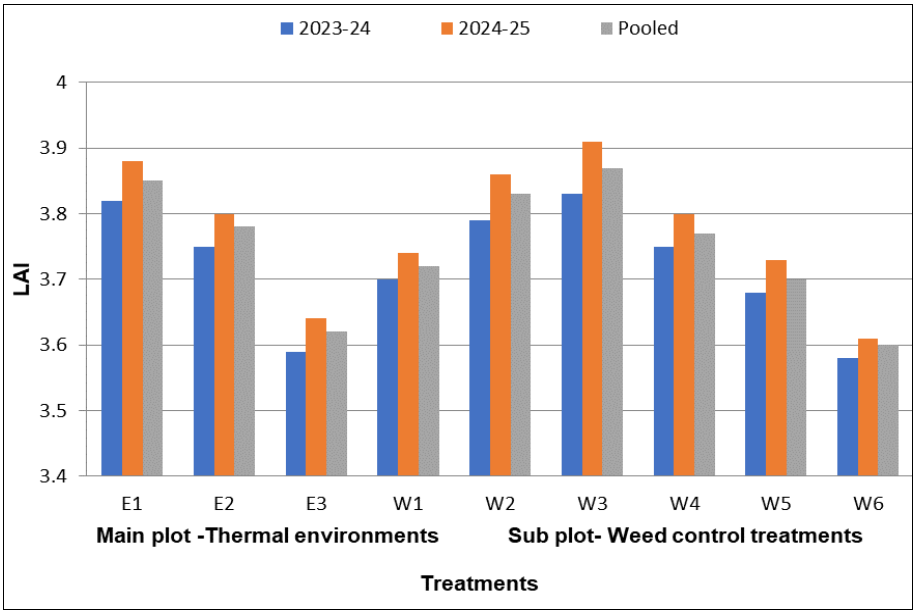

Fig 1: LAI of wheat at 60 DAS under various treatments

Crop Growth Rate (CGR)

The CGR of wheat was computed under every treatment at different growth intervals and the pooled values after statistical analysis are depicted in Table 2 and exhibited through Fig. 2.The Crop Growth Rate (CGR) under the 15th November (9.05 and 17.07$gm^{-2}day^{-1}$ at 30-60 DAS and 60-90 DAS respectively) sowing environment was higher than that of the later sown thermal environments. The 15th November sown crop recorded superior CGR due to favorable temperatures, which extended the growth period and enhanced dry matter accumulation over a longer duration compared to later sowings. In contrast, the 15th December environment crop experienced shorter growth periods and prior maturity, leading to accelerated dry matter accumulation within a compressed timeframe. These findings are corroborated with Haider (2007) [4], who reported that timely sown crops achieved higher CGR compared to late-sown ones. Among the weed control treatments, Sulfosulfuron + Metsulfuron methyl recorded highest value of CGR(8.88 and 17.16 $gm^{-2}day^{-1}$ at 30-60 DAS and 60-90 DAS respectively).The improved CGR in these treatments could be attributed to reduced weed interference and a comparatively higher Leaf Area Index (LAI), which facilitated better growth. In contrast, the minimum CGR was recorded in the Weedy check (W_6) due to restricted lateral tiller development, deprived synthesis of assimilates, and reduced dry matter accumulation. Similar outcomes have also been documented by Sarita *et al*. (2021) [10].

Table 2: Effect of thermal environments and weed control treatments on crop growth rate of wheat at different time intervals

Treatments	CGR($gm^{-2}day^{-1}$)					
	30-60 DAS			60-90DAS		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
Main plot-Thermal environments						
E_1	8.84	9.265	9.05	16.65	17.49	17.07
E_2	8.48	8.905	8.69	15.90	16.73	16.31
E_3	7.44	7.844	7.64	13.87	14.74	14.31
S.Em±	0.03	0.01	0.02	0.22	0.20	0.21
CD(p=0.05)	0.10	0.05	0.07	0.85	0.78	0.81
Sub plot-Weed control treatments						
W_1	8.18	8.600	8.38	15.14	15.98	15.56
W_2	8.54	8.965	8.75	16.42	17.27	16.84
W_3	8.67	9.094	8.88	16.74	17.59	17.16
W_4	8.34	8.761	8.54	15.59	16.44	16.01
W_5	8.03	8.431	8.23	14.74	15.59	15.17
W_6	7.77	8.176	7.97	14.21	15.06	14.63
S.Em±	0.07	0.06	0.06	0.15	0.16	0.15
CD(p=0.05)	0.19	0.16	0.17	0.42	0.47	0.44

Note: E: Thermal environments, E_1: 15th November, E_2: 30th November, E_3: 15th December, W: Weed control treatments, W_1: Fenoxaprop-p-ethyl + Metribuzin, W_2: Clodinafop-propargyl + Metsulfuron Methyl, W_3: Sulfosulfuron + Metsulfuron Methyl, W_4: Metribuzin + 2,4-D, W_5: Hand weeding at 30 DAS, W_6: Weedy check, NS = non-significant.

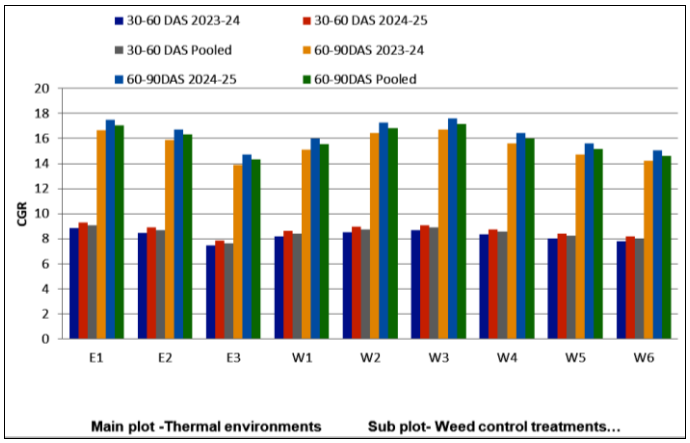

Fig 2: CGR of wheat at periodical intervals under various treatments

Relative Growth Rate (RGR)

The RGR of wheat was calculated under each treatment at different growth intervals and the pooled values, after statistical analysis is highlighted in Table 3 and illustrated through Fig.3. The November 15 sowing recorded a significantly higher RGR (0.0468 and 0.0295 $gg^{-1}day^{-1}$at 30-60 DAS and 60-90 DAS respectively) than the late sown crops. RGR was generally enhanced during early growth stages and declined as crop age increased among all environments, might be due to mutual leaf shading, which reduced dry matter accumulation and increased respiration rates. The higher relative growth rate in the November 15 sowing was due to extended growth duration, fostering overall crop development. These results corroborate findings by Kumar and Sharma (2003) [7], Baloch *et al.* (2010) [3], Ahmed *et al.* (2013) [1], Alam*et al.* (2013) [2], Jat*et al.* (2013) [5] and Pankaj *et al.* (2015) [8].Among the herbicidal combinations, the treatment with Sulfosulfuron + Metsulfuron methyl (W_3) obtained the highest relative growth rate (0.0468 and 0.0300 $gg^{-1}day^{-1}$at 30-60 DAS and 60-90 DAS respectively). This superior RGR could be because of effective control of both narrow-leaved and broad-leaved weeds under these treatments, as also reported by Sahu (2019) [9].

Table 3: Effect of thermal environment and weed control treatments on relative growth rate (gg-1day-1) of wheat at different time intervals

Treatments	RGR ($gg^{-1}day^{-1}$)					
	30-60 DAS			60-90DAS		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
Main plot-Thermal environments						
E_1	0.0466	0.0471	0.0468	0.0294	0.0296	0.0295
E_2	0.0464	0.0469	0.0467	0.0293	0.0294	0.0294
E_3	0.0459	0.0462	0.0461	0.0291	0.0293	0.0292
S.Em±	0.0002	0.0002	0.0001	0.0003	0.0003	0.0003
CD(p=0.05)	NS	0.0006	0.0005	NS	0.0010	0.0011
Sub plot-Weed control treatments						
W_1	0.0463	0.0468	0.0465	0.0290	0.0292	0.0291
W_2	0.0465	0.0470	0.0467	0.0298	0.0299	0.0298
W_3	0.0466	0.0471	0.0468	0.0299	0.0300	0.0300
W_4	0.0464	0.0469	0.0466	0.0292	0.0294	0.0293
W_5	0.0462	0.0465	0.0464	0.0289	0.0291	0.0290
W_6	0.0459	0.0462	0.0461	0.0287	0.0289	0.0288
S.Em±	0.0003	0.0002	0.0001	0.0002	0.0003	0.0003
CD(p=0.05)	NS	0.0005	0.0003	0.0007	0.0008	0.0007

Note: E: Thermal environments, E_1: 15th November, E_2: 30th November, E_3: 15th December, W: Weed control treatments, W_1: Fenoxaprop-p-ethyl + Metribuzin, W_2: Clodinafop-propargyl + Metsulfuron Methyl, W_3: Sulfosulfuron + Metsulfuron Methyl, W_4: Metribuzin + 2,4-D, W_5: Hand weeding at 30 DAS, W_6: Weedy check, NS = non-significant.

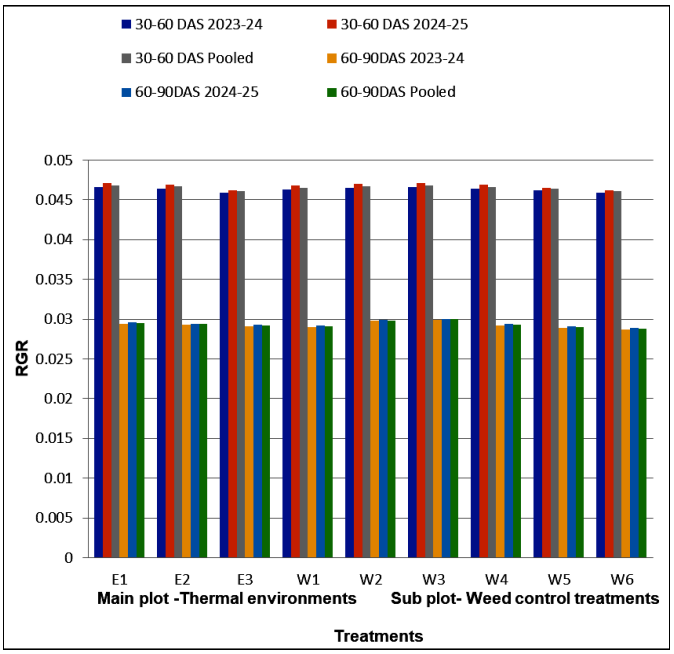

Fig 3: RGR of wheat at periodical intervals under various treatments

Yield

Data pertaining to grain yield as influenced by the thermal environments and weed control treatments are presented in Table 4 and graphically depicted through in Fig.4. Crop sown on 15th November recorded significantly highest grain yield (4623.03 kg ha^{-1}) which was at par with 30th November (4562.97 kg ha^{-1}). Among the weed control treatments, W_3 (Sulfosulfuron + Metsulfuron methyl) brought about 4549.44 kg ha^{-1} which was found significantly superior over all the weed control treatments but also statistically at par with the treatment W_2 (Clodinafop-propargyl + Metsulfuron methyl) producing grain upto 4511.17 kg ha^{-1}.

Table 4: Effect of thermal environments and weed control treatments on grain yield of wheat.

Treatments	Grain yield (kgha^{-1})
Main plot-Thermal environments	
E_1	4623.03
E_2	4562.97
E_3	3490.14
S.Em±	33.40
CD(p=0.05)	131.16
Sub plot- Weed control treatments	
W_1	4204.44
W_2	4511.17
W_3	4549.44
W_4	4375.28
W_5	4001.00
W_6	3710.94
S.Em±	21.62
CD(p=0.05)	62.45

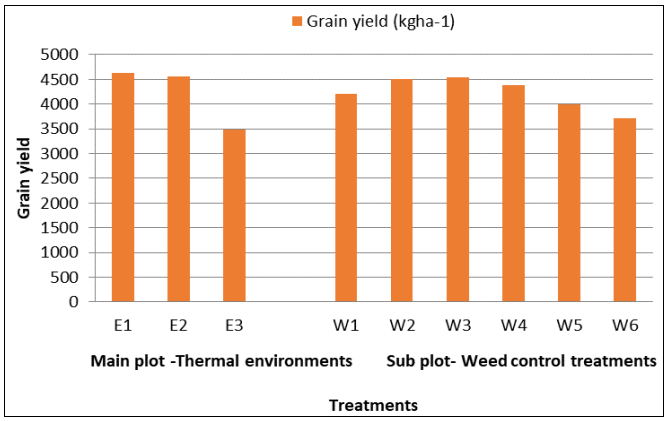

Fig 4: Grain yield (kg ha^{-1}) of wheat (pooled of two years)

Conclusion

From the present investigation it is concluded that for obtaining higher yield of wheat, crop should be sown on 15th November and weed should be controlled by the post emergence application of Sulfosulfuron + Metsulfuron methyl which was found to be the best treatment among the different treatments with maximum growth indices (LAI, CGR and RGR).

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