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Broad-spectrum weed management in wheat through differential wheat varieties and herbicide mixtures

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Abstract

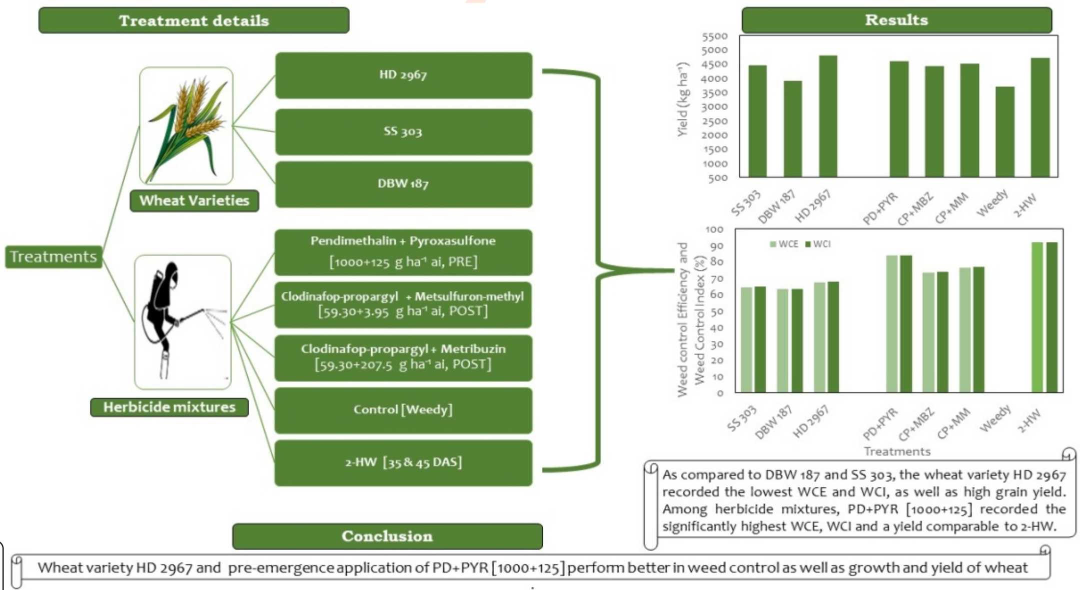
Aim: This research work was conducted to study the response of wheat varieties and herbicide mixtures on weed suppression as well as growth and yield of wheat.

Methodology: An experiment was conducted in a split-plot design, in which the main plot comprised of three wheat varieties (HD 2967, DBW 187 and SS 303), and the subplots factor consisted of three herbicide mixtures, *i.e.*, pendimethalin + pyroxasulfone (1000 + 125 g a.i. ha^{-1}), clodinafop-propargyl (CP) + metsulfuron-methyl (59.3 + 39.53 g a.i. ha^{-1}), CP + metribuzin (59.3 + 39.53 g a.i. ha^{-1}) in comparison with 2-hand weedings (35 and 45 DAS) and control [weedy check].

Results: The results showed that wheat variety HD 2967 and pre-emergence application of pendimethalin + pyroxasulfone (1000 + 125 g a.i. ha^{-1}) recorded significantly highest crop dry matter, test weight and grain yield, simultaneously recorded the lowest density, biomass of broad-leafed weeds, highest weed control efficiency and weed control index.

Interpretation: Wheat variety 'HD 2967' and pre-emergence application of pendimethalin + pyroxasulfone (1000+125 g a.i.ha^{-1}) was effective in the management of weeds and, recorded highest growth parameters and yield.

Key words: Herbicide mixtures, Weed control efficiency, Wheat cultivars



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Introduction

Globally, wheat (*Triticum aestivum* L.) is a major grain crop grown in several continents under different environments (Khan *et al.,* 2020). After China, India is the second-largest producer of wheat in the world, producing 103.6 million tonnes in 2019 (Devi *et al.,* 2021). As India is a developing country, it is difficult to ensure food security as well as maintain affordable price to the majority of population. As per estimate, by 2050, India alone will need more than 140 million tons of wheat to feed an estimated population of 1.73 billion (Bhardwaj *et al.,* 2019). Thus, the major challenge in front of researchers is to enhance wheat productivity. Wheat production suffers from several biotic and abiotic constraints (Salem *et al.,* 2022). Among the biotic factors, weeds significantly reduce the wheat yield up to 23 per cent globally (Abbas *et al.,* 2016). Discovery of selective herbicides coupled with scarcity of manual labour favours chemical weed control as a preferred tool for weed management by farmers (Silva *et al.,* 2010). Eventually farmers become more dependent on chemicals for controling weeds. In general, herbicides developed during the early stage of development possess a narrow spectrum of weed control *i.e.* control specific types of weed. Injudicious application of narrow spectrum herbicide provides ineffective control of broad spectrum weed flora that would lead to weed shift (Asadi *et al.,* 2020). Furthermore, repeated use of narrow spectrum herbicide favours the development of herbicide resistance weeds in many crops, including wheat, for example *Phalaris minor* developed resistance against isoproturon (Malik and Singh, 1995).

As weeds develop resistance against herbicides, the concept of herbicide mixtures is gaining popularity among farmers. Herbicide mixtures have advantage over sole application, foremost it is easy to apply and provides effective control against broad spectrum weed flora (Teotia *et al.,* 2024). Moreover, application of herbicide mixtures also retards the process of herbicide resistance development. On the other hand, researchers have evaluated the competitiveness of wheat variety against weeds (Mani *et al.,* 2016a). Competitiveness in wheat varieties depends upon the vegetative growth traits, like, plant height (Singh *et al.,* 2013), dry matter accumulation (Mani *et al.,* 2016b) and resource use ability of wheat plant. By using the competitive advantage of wheat varieties, it is possible to minimize the yield reduction caused by weeds. A literature review conducted over the past five years revealed a limited research on the evaluation of new wheat varieties and herbicide mixtures for effective weed management and improved crop performance. Keeping this in view, a study was conducted to find out the best herbicide mixture and wheat variety to minimize the yield losses caused by weeds.

Materials and Methods

Field research was conducted at the Agricultural Research Farm (25°15'19.4"N 82°59'35.3"E), Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during the winter season, 2020-2021. Experimental soil was neutral (pH 7.24), low organic carbon (0.45%), low available nitrogen (210 kg N ha^{-1}), intermediate available phosphorus and potassium content (20.96 kg P_2O_5 ha^{-1}, 130 kg K_2O ha^{-1}). The experimental crop received 37.2 mm rainfall, whereas, maximum and minimum temperature (Fig. 1) varied from 17.4–38.8°C and 7.3–22°C, respectively. The total sunshine hours received during the crop season ranged between 0.2 to 9.1 hr per day.

The experiment was laid out in a split plot design having fifteen treatments, replicated thrice. The main plot constituted three wheat varieties [Directorate bread wheat (DBW) 187, Hybrid Delhi (HD)2967 and Shriram Super (SS) 303] whereas the sub-plots comprised of three herbicide mixtures, *viz.,* tank-mix pendimethalin (PD) + pyroxasulfone (PYR) [1000+125 g a.i. ha^{-1}], pre-mixed formulation of clodinafop-propargyl (CP)+ metsulfuron-methyl (MM) [59.3+39.53 g a.i. ha^{-1}, and CP+ metribuzin (MBZ) [59.3+39.53 g a.i. ha^{-1} compared with 2-hand weeding [35 and 45 (DAS) and control [weedy check]. DBW 187 also known as 'Karan Vandana', was released by ICAR-Indian Institute of Wheat and Barley Research, Karnal in 2018 for irrigated timely sown conditions of North eastern Plains Zones, comprising of Eastern Plains Zones (mainly Eastern UP, Bihar, Jharkhand, Assam and West Bengal).HD 2967 also known as 'Pusa Sindhu Ganga', a high yielding double-dwarf wheat variety was released by Indian Agricultural Research Institute, New Delhi in 2014, and recommended for timely sown conditions of Eastern Plain zone of Uttar Pradesh. Shriram Super 303 was released by Shriram Fertilisers and Chemicals, New Delhi- a Unit of DCM Shriram Ltd.

Tank mix and pre-mixed formulations of herbicide mixture were used for the experiment. Chemically pendimethalin belongs to dinitroaniline group of herbicides, whereas, pyroxasulfone belongs to isoxazoline herbicide group. Pendimethalin inhibit microtubule assembly, more specifically, the cell fail to proceed prometaphase of mitosis. It provides broad-spectrum weed control (Rao, 2019). However, pyroxasulfone inhibits the elongation step of very-long chain fatty acid (VLCFA) synthesis (Cutulle *et al.,* 2019). It provides excellent control against grasses and broadleaf weeds (BLWs) (Nakatani *et al.,* 2016). Clodinafop-propargyl belongs to aryloxyphenoxypropionate (AOPP) group of herbicide, which inhibits plastidic enzyme acetyl-CoA carboxylase (ACCase), which disrupt lipid synthesis in plants (Hirai *et al*., 2002). It is used as a post-emergence herbicide to control grassy weeds in wheat (Baltazar and De Datta, 2023). Metribuzin belongs to class 1, 2, 4-triazines systemic selective post-emergence herbicide, it acts via both leaves and soil and inhibits the Hill reaction and photosynthetic electrons in Photosystem II. It provides broad spectrum activity against annual broadleaf weeds and certain annual grasses (Rao, 2019). Metsulfuron-methyl belong to sulfonylurea group, and acts through acetolactate synthase (ALS), blocking the synthesis of branched-chain amino acids (valine, leucine and isoleucine) ultimately affecting the plant cell division and growth of broadleaf weeds (Chaudhary *et al.,* 2021b).

Crop was sown manually in a furrow opened with single row drill, on 4th Dec 2020, at a spacing of 22.5 cm. After placing the seeds in furrows, the seeds were covered with soil. The herbicide

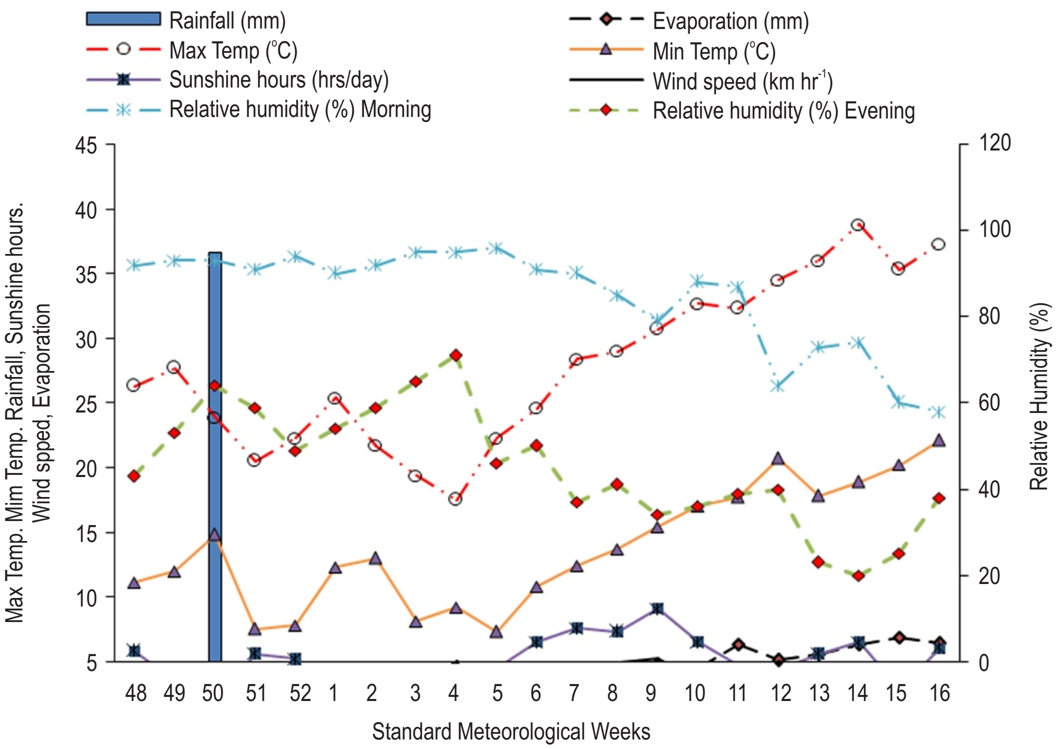

Fig. 1: Mean week-wise meteorological data during experimental crop season 2020-21.

mixtures were applied as follows: PD+PYR [1000+125] was applied as pre emergence [PRE (one day after sowing)], *i.e.,* 5th Dec 2020 whereas CP+MM and CL+MBM were applied as POST at 35 DAS (8th Jan 2021). Before spraying, the herbicide mixtures were dissolved in water @ of 500 l ha^{-1} and sprayed with a knapsack sprayer fitted with a flat-fan nozzle. Two hand-weeding was done at 35 and 45 DAS. All the agricultural operations were performed as per standard package of practice recommended for the crop (Kumar *et al*., 2014). The crop was manually harvested on 12th April 2021.

At harvest (physiological maturity), data were collected on plant growth parameters (plant height and dry matter accumulation) and 1000-grain weight, grain yield, straw yield and biological yield were recorded at harvest. To minimize experimental error due to border effect, the grain and straw yield were recorded from the net plot area, excluding a 50 cm margin from all the borders. In wheat, critical-period of crop-weed competition varies between 30 to 45 days (Chhokar *et al.,* 2012). Uncontrolled weed growth during critical period greatly reduces the grain yield of wheat. Therefore, to study the performance of weed control treatment, weed density and biomass, weed control efficiency (WCE), and weed control index (WCI) data were collected at 60 DAS. The density and dry biomass of each weed species was calculated following the method of Singh and Saini (2008), and the weeds were divided into grasses, sedges, and broadleaf weeds. Total weed density and dry biomass were calculated by summing the density and dry weight of all individual weed species. WCE and WCI were calculated by the formula given by Singh *et al.* (2021).

Statistical analyses: Heterogeneous weed data (density and biomass) were subjected to square-root transformation to make a near-normal distribution. However, original data were also presented in parenthesis. After testing for homogeneity, the data was statistically analysed for analysis of variance as per the procedure suggested by Sahu (2016), and mean separation was accomplished by the least significant difference (LSD) at the ($p>0.05$) 5% level of probability.

Results and Discussion

The experimental crop was infested with eleven weed species. Eight weeds belonged to the broadleaf weeds group (dicot) whereas two weeds belonged to grassy and one sedge. More than seventy percent of weeds belonged to C3 photosynthetic pathway (eight weed species), followed by C4 (eighteen percent; two weed species) and intermediate C3-C4 pathway (nine percent; one weed species) photosynthetic pathway. The relative composition of weeds at 30 DAS revealed a predominance of broadleaf weeds (67.5 to 82.89 percent), followed by grasses (9.30 to 12.55 percent) and sedges (7.57 to 20.45 percent). Among the broadleaf weeds, the dominant weed species were in the order: *Chenopodium album* L. (common

Table 1: Influence of varieties and herbicide mixtures on density and biomass of weeds, weed control efficiency and weed control index in wheat

Treatments	Grasses		Broad leafed weeds (BLWs)		Sedges		WCE (%)	WCI (%)
	Density (No m^{-2})	Biomass (g m^{-2})	Density (No m^{-2})	Biomass (g m^{-2})	Density (No m^{-2})	Biomass (g m^{-2})		
Varieties								
SS 303	2.33 (5.80)	1.89 (3.55)	5.76 (40.80)^{a}	4.40 (23.03)^{a}	2.19 (5.53)	1.57 (2.40)	64.47	64.66
DBW 187	2.56 (7.13)	2.06 (4.37)	6.32 (48.13)^{a}	4.82 (27.49)^{a}	2.51 (7.13)	1.76 (3.09)	63.22	63.48
HD 2967	2.28 (5.60)	1.85 (3.43)	5.00 (32.47)^{b}	3.82 (17.88)^{b}	1.98 (4.67)	1.50 (2.17)	67.26	67.70
SEm±	0.21	0.15	0.17	0.13	0.16	0.14		
CD (P=0.05)	NS	NS	0.67	0.51	NS	NS		
Herbicide mixtures								
PD+PYR [1000+125]*	1.74 (3.22)^{c}	1.45 (1.97)^{c}	4.24 (17.66)^{d}	3.23 (10.08)^{c}	1.79 (3.11)^{c}	1.31 (1.35)^{b}	83.77	84.05
CP+MBZ[59.30+207.5]*	2.51 (6.11)^{b}	2.02 (3.74)^{b}	5.51 (31.22)^{b}	4.18 (17.78)^{b}	2.45 (6.11)^{b}	1.72 (2.65)^{b}	73.17	73.77
CP+MM [59.30+3.95]*	2.33 (5.00)^{b}	1.88 (3.06)^{b}	5.15 (26.56)^{c}	3.92 (15.21)^{b}	1.90 (3.89)^{c}	1.49 (1.92)^{b}	76.28	76.77
Control [Weedy]	3.84 (14.44)^{a}	3.03 (8.85)^{a}	10.59 (112.56)^{a}	8.09 (65.50)^{a}	3.76 (14.11)^{a}	2.53 (6.11)^{a}	0.00	0.00
2-HW [35 & 45 DAS]	1.54 (2.11)^{c}	1.29 (1.29)^{c}	2.98 (9.44)^{e}	2.31 (5.43)^{d}	1.23 (1.67)^{d}	1.00 (0.72)^{c}	91.70	91.82
SEm±	0.20	0.15	2.98	0.18	0.18	0.16		
CD (P=0.05)	0.58	0.43	0.25	0.53	0.51	0.48		

PD = Pendimethalin, PYR= Pyroxasulfone, CP= Clodinafop-propargyl, MBZ= Metribuzin, MM= Metsulfuron-methyl, HW= Hand weeding, WCE= Weed control efficiency, WCE= Weed control index, Data are subjected to square root transformation $\sqrt{0+0.5}$ and non-transformed data is mentioned in the parenthesis. DAS= Days After Sowing, *= g a.i. ha^{-1}

lambsquarter)>*Melilotus alba* Medik (white sweet clover)>*Rumex dentatus* L. (sour duck)> *Anagallis arvensis* L. (scarlet pimpernel). *Cynodon dactylon* (L.) Pers. (Bermuda grass) and *Cyperus rotundus* L. (yellow nutsedge) were the predominant grass and sedge. At this location, infestation of similar floral compositions of weeds in wheat were reported by Singh *et al.* (2015) and Mani *et al.* (2016a,b).

The wheat variety HD 2967 recorded the lowest density and biomass of broadleaf weeds and achieved the highest weed control efficiency and weed control index, followed by SS 303 and DBW 187. Furthermore, HD 2967 recorded the tallest plant stature and highest dry matter accumulation, which was at par with DBW 187 and SS 303, respectively. Additionally, HD 2967 also recorded significantly highest test weight and grain yield. However, straw yield was non-significant among varieties. The superior performance of HD 2967 can be attributed to its genetic traits, namely taller plant height and greater dry matter accumulation, which provide a competitive edge over weeds. These traits enabled HD 2967 to smother weeds effectively, particularly broadleaf weeds, which constituted over 70% of the total weed population. This resulted in the lowest density and biomass of broadleaf weeds (Table 1) and better resource allocation, culminating in higher grain yields (Table 2). These findings align with reports of Jha *et al.* (2017), who noted that taller wheat varieties with vigorous dry matter accumulation outcompete weeds. Similarly, Mason *et al.* (2007) also recorded that the lowest weed biomass was attributed to taller plant height and higher plant vigour of wheat variety 'Preston'.

Among the herbicide mixtures, the pre-emergence application of PD +PYR [1000 + 125g a.i. ha^{-1}] recorded the lowest density and biomass of grasses, broadleaf weeds and sedges, except for sedge biomass, which did not differ significantly among the herbicide mixtures. Herbicide mixtures CP + MM [59.3 + 39.53g a.i. ha^{-1}] and CP + MBZ [59.30 + 207.5g a.i. ha^{-1}] recorded statistically similar densities of grasses and biomass of grasses and BLWs. Wheat crop showed statistically similar plant height and crop dry matter accumulation under herbicide mixtures and 2-HW. Further, the highest 1000-grain weight and grain yield were recorded under PD + PYR [1000 + 125g a.i. ha^{-1}] and were statistically at par with CP + MM [59.3 + 39.53g a.i. ha^{-1}], followed by CP + MBZ [59.30 + 207.5g a.i. ha^{-1}]. Moreover, all three herbicide mixtures recorded statistically similar straw yields.

From the experimental findings, it was evident that the combination of PD + PYR [1000 +125g a.i. ha^{-1}] forms a synergistic combination that effectively manages the broad spectrum of weeds for prolonged duration. It is hypothesized that enhanced efficacy of PD + PYR might be associated with its longer persistence period; for example, PYR persists in soil for 16–69 days (Szimigielski *et al.,* 2014); however, PD persists for nearly 75 days (Maheshwari and Ramesh, 2019). This prolonged persistence helps in managing weeds during critical period of crop-weed competition, thus positively influencing crop growth and yield. Aligning with the findings of this study, Chhokar and Sharma (2023) and Samota *et al.* (2024) reported that a ready-mix formulation of pyroxasulfone and pendimethalin (1000 + 125 g a.i. ha^{-1}) demonstrated broad-spectrum weed control and resulted in higher grain yields. Addtionally, they highlighted that the combination effectively controls the narrow-leaved weeds, explicitly *Phalaris minor* and *Avena ludoviciana* and broad-leaved weeds, *Rumex dentatus* (Chhokar and Sharma, 2023; Samota *et al.,* 2024). However, the mixture showed limited efficacy in managing *Medicago denticulata* (Chhokar and Sharma, 2023).

Table 2: Influence of varieties and herbicide mixtures on growth, yield attributes and yield of wheat

Treatments		Plant height (cm)	Dry matter accumulation (g m^{-2})	1000-grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Varieties						
SS 303		97.00^{b}	947.65^{a}	42.53^{b}	4443.27^{b}	6990.36
DBW 187		102.93^{a}	894.16^{b}	41.23^{c}	3886.83^{c}	6636.54
HD 2967		104.60^{a}	957.47^{a}	43.02^{a}	4783.35^{a}	7101.92
	SEm±	1.36	6.21	0.01	36.44	146.49
	CD (P=0.05)	5.35	24.39	0.04	143.09	NS
Herbicide mixtures						
PD+PYR (1000+125)*		104.56^{a}	952.36^{a}	42.88^{a}	4593.31^{a}	7089.22^{b}
CP+MBZ (59.30+207.5)*		100.33^{a}	935.78^{a}	41.94^{c}	4404.67^{b}	6824.23^{b}
CP+MM (59.30+3.95)*		103.33^{a}	943.05^{a}	42.47^{b}	4486.28^{b}	6956.43^{b}
Control (Weedy)		94.67^{b}	872.24^{b}	40.48^{c}	3679.56^{c}	6125.03^{c}
2-HW (35 and 45 DAS)		104.67^{a}	962.04^{a}	43.52^{a}	4691.94^{a}	7553.11^{a}
	SEm±	1.75	9.35	0.01	39.70	126.35
	CD (P=0.05)	5.10	27.30	0.04	115.88	368.79

PD = Pendimethalin, PYR= Pyroxasulfone, CP= Clodinafop-propargyl, MBZ= Metribuzin, MM= Metsulfuron-methyl, HW= Hand weeding, DAS= Days After sowing, *= g a.i. ha^{-1}.

However, both the herbicide mixtures CP + MM [59.3 + 3.95g a.i. ha^{-1}] and CP + MBZ [59.30 + 207.5 g a.i. ha^{-1}] were statistically similar to grass density and biomass of grasses and broadleaf weeds. Similarly, Chaudhary *et al.* (2021a) reported that POST application of CP + MM (60 + 4 g a.i. ha^{-1}) and CP + MBZ (60 +105 g a.i. ha^{-1}), recorded statistically similar dry biomass of broadleaf weeds. Poor performance of CP + MM [59.3 + 3.95 g a.i. ha^{-1}] and CP + MBZ [59.30 + 207.5g a.i. ha^{-1}] might be attributed to three reasons: the first reason may be, as these herbicides were applied to the foliage at 30 DAS; it is likely that a significant quantity of herbicide was retained on the wheat crop canopy and did not reach the targeted weeds beneath the canopy. Kim *et al.* (2011) was also of the opinion that a well-established canopy on winter wheat restricted light penetration into the lower layers and reduced herbicide deposition on the intended target weeds beneath it. Second reason may be during POST herbicide application, a barrier for absorption and translocation is posed by leaf cuticles with waxes and VLCFA derivatives. In general, most of the products perform best against young weed stages, usually in two to four-leaf stages (Krehmer *et al.,* 2021). Similarly, in our study, the weeds had produced more than 4-5 leaves and had surpassed the optimal growth stage for effective control with POST herbicide application. Third reason is on analyzing agro-meteorological data (January 1–28, 2021) (Fig. 1) revealed that low sunshine hours (0.2–3.3 hours) coupled with low temperature might have disrupted leaf stomatal opening and poor absorption and translocation of herbicide. Further, in line with our experimental findings, Singh *et al.* (2018) also reported that the application of CP + MM (60 + 4 g a.i. ha^{-1}) and CP + MBZ (60 + 105 g a.i. ha^{-1}) recorded statistically similar dry matter accumulation, grain yield and straw yield of in wheat.

Hence, it can be concluded from this study that under the agro-climatic conditions of the Eastern Indo-Gangetic Plain, the performance of wheat variety HD 2967 was found highly efficient in smothering the weeds and also achieving a higher test weight and grain yield of wheat, followed by Shriram Super 303. Further, pre-emergence application of pendimethalin+pyroxasulfone (1000 + 125 g a.i. ha^{-1}) provided effective control of weeds and recorded highest grain yield, followed by POST application of clodinafop-propargyl + metsulfuron-methyl (59.3 + 3.95g a.i. ha^{-1}) and clodinafop-propargyl + metribuzin (59.30 + 207.5g a.i. ha^{-1}) and this combination can be recommended for efficient weed management in wheat.

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