

Bio-efficacy of metribuzin based herbicide mixtures on weeds and productivity of wheat

SARITA RANI¹, SURESH KUMAR², V.S. HOODA³ AND SATISH KUMAR⁴

Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana 125 004

Received: December 2020; Revised accepted: December 2021

ABSTRACT

A field experiment was conducted during 2014–15 and 2015–16 at Hisar, Haryana, to study bioefficacy of metribuzin-based herbicide mixture on weeds and productivity of wheat (*Triticum aestivum* L.). The experiment was conducted in a split-plot design comprising 5 wheat varieties 'WH 1105', 'HD 2967', 'DPW 621-50', 'WH 1124' and 'DBW 17' in main plots and 6 weed-management practices, viz. metribuzin (210 g/ha), metribuzin + fenoxaprop (150 + 100 g/ha), metribuzin + pinoxaden (150 + 40 g/ha) metribuzin + clodinafop (150 + 45 g/ha), weed-free and weedy check, in subplots, each replicated thrice. The wheat varieties did not affect the weed density and weed dry-matter accumulation. Wheat variety 'WH 1105' resulted in the maximum grain, straw and biological yields, being statistically at par with 'HD 2967' and 'DPW 621-50', but significantly better over 'DBW 17' and 'WH 1124'. Among the herbicides, the density of grassy and total weeds and their dry-matter accumulation at all stages were observed minimum with metribuzin + fenoxaprop which remained at par with other 2 combinations of metribuzin, whereas density and dry matter of broad-leaf weeds were found minimum with metribuzin alone (210 g/ha). Alone application of metribuzin resulted in the lowest grain yield of wheat as compared to all the other herbicidal treatments.

Key words: Wheat, Metribuzin, Herbicide mixture, Clodinafop, Fenoxaprop, Pinoxaden, Weed control efficiency

Wheat is one of the most important cereal crops and staple food in India after rice. Its assured production and supply are necessary for food security in the country. The annual wheat production has been estimated at 107.59 million tonnes and registering an all-time highest productivity of 3.51 t/ha (ICAR-IIWBR, 2020). In Haryana, wheat is grown over an area of about 2.55 million ha with production of 12.57 million tonnes and productivity of 4.92 t/ha (DESA, Haryana, 2020). The productivity of wheat in most of the northern states, i.e. Punjab, Haryana, Uttar Pradesh has almost stagnated. There are many factors responsible for the stagnation of wheat productivity, and contribution of weeds is a major factor among them. If agronomic practices are fine-tuned and weeds are managed properly, the wheat productivity can be enhanced further, so as to tap the potential productivity of the modern varieties.

Weeds are a major impediment to crop production and are accountable for maximum losses caused by all the pests. They compete with crop plants for moisture, nutrients, light and space, thereby depriving the crop of vital inputs. Wheat is generally infested with both grassy and broad-leaf weeds, depending on environmental conditions like humidity, temperature and moisture availability, type of soil, cultural practices and crop rotation adopted. Among the weed-control measures, herbicidal control plays an important role in close row crops, where manual or mechanical weeding is not feasible. The large-scale failure of isoproturon, danger of development of rapid resistance and cross-resistance against alternate herbicides due to their continuous use, non-adoption of herbicides like pendimethalin by farmers because of its high cost and requirement for high moisture at the time of spray, phytotoxicity due to high doses of metribuzin and proportionate changes in weed flora in cereal crops necessitates use of herbicide mixtures (Jain *et al.*, 2020).

Different varieties of a crop differ in their competitive ability against different weeds. Crop cultivars possessing traits such as fast germination, quick growth, high biomass and large leaf area have a competitive advantage over

Corresponding author's Email: srajotia@gmail.com

¹Technical Consultant, National Rainfed Area Authority (NRAA), NASC Complex, PUSA, New Delhi; ²Assistant Scientist, ³Assistant Scientist, ⁴Principal Scientist, Department of Agronomy, CCS HAU, Hisar, Haryana 125 004

weeds. Careful selections of a competitive crop/ genotype can potentially suppress weed growth without sacrificing crop yield (Ramesh *et al.*, 2017). Cultivars of several crops including winter wheat differ considerably in their tolerance to metribuzin, and it is desirable to determine varietal sensitivity to metribuzin and herbicide mixtures of metribuzin before use in field conditions (Yadav *et al.*, 2016). Keeping these points in view, present study was planned with wheat varieties and metribuzin-based herbicide mixtures.

MATERIALS AND METHODS

A field experiment was conducted during 2014–15 and 2015–16 at Agronomy Research Farm of the Chaudhary Charan Singh Haryana Agricultural University, Hisar (29°16'N', 75°7'E' 215.2 m above the mean sea-level) in north-west part of India. The climate of Hisar is semi-arid, characterized by dryness, extremes of temperature with the average annual rainfall of 429 mm (16.9 in). The maximum daytime temperature during the summer varies between 40 and 46°C, while during the winter it ranges between 1.5 and 4°C. Relative humidity varies from 5 to 100%. The soil of the experimental field was sandy loam with low organic carbon and nitrogen, medium available phosphorus, high potassium and slightly alkaline (pH 8.3). Sowing of wheat was done on 27 November 2014 during first year and 5 December 2015 during second year by seed-cum-fertilizer drill, with a spacing of 20 cm from line to line at 5–6 cm depth using 120 kg seed/ha. The crop was harvested on 4 April 2015 during the first year and 19 April, 2016 during the second year. The experiment was laid in a split-plot design comprising 5 wheat varieties 'WH 1105', 'HD 2967', 'DPW 621-50', 'WH 1124' and 'DBW 17' in main plots and 6 weed management practices, *viz.* metribuzin (210 g/ha), metribuzin + fenoxaprop (150 + 100 g/ha), metribuzin + pinoxaden (150 + 40 g/ha), metribuzin + clodinafop (150 + 45 g/ha), weed-free and weedy check in subplots, each replicated thrice and were applied 35 days after sowing of the crop. Observations for total weed density were recorded by randomly placing quadrat (0.25 m²) in each plot at different intervals. Major weed flora in experiment included *Phalaris minor*, *Avena ludoviciana*, *Rumex dentatus*, *Chenopodium album*, *Melilotus indicus*, *Convolvulus arvensis*, *Anagallis arvensis*, *Coronopus didymus*, *Cirsium arvense*, *Vicia sativa* and *Lathyrus aphaca* during both the years. *Phalaris minor* was the major weed observed among grassy weeds and plants of *Avena ludoviciana* were also observed at some places. All other weeds were collectively classified as broad-leaf weeds. For calculating dry-matter accumulation of weeds, the weeds taken with a quadrat were oven-dried at 65 ± 5°C, till they attained constant weight. The dried samples were weighed

and expressed as (g/m²). Weed-control efficiency (WCE) was calculated with the help of formula:

$$\text{WCE (\%)} = \frac{W_2 - W_1}{W_2} \times 100$$

where, W₂, Dry weight of weeds in weedy check plot and W₁, Dry weight of weeds in treatment plot.

Number of tillers were counted at 60, 90 and 120 days after sowing (DAS) from 1 m row length at 3 places/plot and converted into per meter square. Leaves were separated from 5 randomly harvested plants to measure leaf area (cm²/plant) with the help of LI 3000 area meter (LICOR Ltd., Nebraska, USA) at 60, 90 and 120 DAS. The leaf-area index (LAI) was worked out with the help of following formula:

$$\text{LAI} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Land area (cm}^2\text{)}}$$

After harvesting the net area of individual plots, the bundles were sun-dried for 4-5 days and weighed before threshing, which was recorded separately as biological yield after converting into kg/ha. The biomass obtained for individual net plot after sun-drying (biological yield) was threshed and weighed for grain yield (kg/ha). The grain yield so obtained was deducted from the biomass of the harvested crop to compute the straw yield. Harvest index, a ratio between grain yield and biological yield was worked out by following expression.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

The experimental data were statistically analyzed using standard methods of analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Weed density, their dry weight and weed control efficiency:

The results revealed that, the density of grassy and broad-leaf weeds and their dry weight were affected by various wheat varieties up to some extent, but the differences were not significant at any growth stage of wheat (Tables 1 and 2). Varieties 'WH 1105' and 'HD 2967' recorded less number of weeds than dwarf variety DBW 17, but difference was found to be non-significant. Similarly dry-matter accumulation of grassy and broad-leaf weeds varied among varieties, the differences were not significant and hence none of the varieties contributed towards reduction in dry matter of weeds. However, Ramesh *et al.* (2017) have reported the effect of different varieties affecting the density of weeds.

All herbicidal treatments effectively controlled population of weeds (Table 1) as compared to weedy check plots at all the crop growth stages during both the years. Metribuzin resulted in effective control of grassy as well as

broad-leaf weeds when applied alone or in mixture forms as compared to weedy check at all the stages of wheat crop during both the years, confirming the findings of Kumar *et al.* (2017). Metribuzin + fenoxaprop (150 + 100 g/ha) was found to be at par with metribuzin + pinoxaden (150 + 40 g/ha) and metribuzin + clodinafop (150 + 45 g/ha) in controlling number of grassy weeds (Table 1). Alone application of metribuzin was found better than weedy check in controlling number of grassy weeds but was inferior to mixture of metribuzin with rest of the herbicides. Density of broad-leaf weeds was significantly lower in plots with application of metribuzin at all the stages of crop (Table 1). Application of metribuzin at 210 g/ha alone was proved to be best among all the herbicidal treatments in controlling the broad-leaf weeds and it differed significantly from all the herbicidal treatments as well as weedy check. Combinations of metribuzin + fenoxaprop (150 + 100 g/ha), metribuzin + pinoxaden (150 + 40 g/ha) and metribuzin + clodinafop (150 + 45 g/ha) resulted in statistically at par population of broad-leaf weeds. The results are in conformity with the findings of Kumari *et al.* (2013).

All the herbicidal treatments significantly reduced the dry-matter of grassy and broad-leaf weeds (Table 2). Among the herbicidal treatments, combination of metribuzin with fenoxaprop resulted in the highest reduction in dry-matter accumulation by grassy weeds at all the crop growth stages and it differed significantly with weedy check, but was at par with metribuzin in combination with pinoxaden and clodinafop. Metribuzin alone significantly reduced the dry matter accumulation by grassy weeds than

the weedy check, but the dry-matter under this treatment was significantly higher than that obtained in plots treated with other herbicide combinations. Our results confirm the findings of Yadav *et al.* (2016). The herbicidal treatment of metribuzin when applied alone resulted in significant decrease in dry-matter accumulated by broad-leaf weeds in comparison to all other treatments where metribuzin was applied in combination during both the years. Herbicide combinations metribuzin + fenoxaprop (150 + 100 g/ha), metribuzin + pinoxaden (150 + 40 g/ha) and metribuzin + clodinafop (150 + 45 g/ha) being at par with each other, reduced the dry-matter accumulation of broad leaf weeds compared to weedy check, but they were inferior to application of metribuzin alone.

On average basis, the highest weed-control efficiency (WCE) for grassy weeds was observed in 'DBW 17' variety and for broad-leaf weeds in 'DPW 621-50' (Table 2). Season-long weed-free plots exhibited the highest WCE in all grassy and broad-leaf weeds during both the years. Among the herbicidal treatments, combination of metribuzin and fenoxaprop proved the best and resulted in the highest WCE in grassy weeds (96.2%) and application of metribuzin 210 g/ha resulted in the lowest WCE in grassy weeds. Application of metribuzin alone was found to be superior to all other herbicidal treatments with highest WCE (97.4%) in broad-leaf weeds. Yadav *et al.* (2016) also observed the similar trend in WCE in their experiment.

Crop growth

Among the wheat varieties, 'WH 1105' showed the

Table 1. Effect of varieties and weed-management practices on weed density in wheat (pooled data of 2 years)

Treatment	Grassy weed density (Number/m ²)		Broad-leaf weed density (Number/m ²)	
	60 DAS	120 DAS	60 DAS	120 DAS
<i>Varieties</i>				
WH 1105	3.5 (17.9)	3 (13)	4.8 (39.5)	4.2 (30.4)
HD 2967	3.5 (17.5)	3 (13.4)	4.8 (38.8)	4.2 (29.5)
DPW 621-50	3.5 (18.1)	3.1 (13.7)	4.8 (40.7)	4.3 (31.8)
WH 1124	3.5 (18.1)	3.1 (13.9)	4.8 (40.2)	4.2 (31.1)
DBW 17	3.6 (18.5)	3.1 (14.3)	4.9 (42.1)	4.4 (32.5)
SEm±	0.1	0.1	0.1	0.1
CD (P=0.05)	NS	NS	NS	NS
<i>Weed management</i>				
MBZ 210 g/ha	4.6 (19.9)	4 (14.8)	2.5 (5.6)	2.1 (3.5)
MBZ + CDF (150 + 45) g/ha	2.4 (4.8)	2 (3)	3.7 (13)	3.5 (11)
MBZ + PDN (150 + 40) g/ha	2.2 (4.1)	2 (2.9)	3.9 (14)	3.5 (11.3)
MBZ + FNP (150 + 100) g/ha	2.2 (3.8)	1.8 (2.3)	3.7 (13)	3.4 (10.3)
Weed-free	1 (0)	1 (0)	1 (0)	1 (0)
Weedy-check	8.7 (75.6)	7.7 (59.1)	14 (196)	12.3 (150.2)
SEm±	0.3	0.2	0.3	0.2
CD (P=0.05)	0.8	0.6	0.8	0.4

MBZ, Metribuzin 70 wp; CDF, clodinafop propargyl 15 wp; PDN, pinoxaden 5.1 ec; FNP, fenoxaprop ethyl 10 ec; DAS, days after sowing
Original data are given in parentheses were subjected to square root $\sqrt{(x + 1)}$ transformation before analysis

Table 2. Effect of varieties and weed-management practices on dry-matter (DM) accumulation by weeds and weed-control efficiency in wheat (pooled data of 2 years)

Treatment	Dry-matter accumulation by grassy weeds (g/m ²)		Dry-matter accumulation by broadleaf weeds (g/m ²)		Weed-control efficiency (%)	
	60 DAS	120 DAS	60 DAS	120 DAS	Grassy weeds	Broad leaf weeds
<i>Varieties</i>						
WH 1105	3 (11.5)	5 (36.8)	3.2 (14)	4.4 (30.1)	75.9	78.8
HD 2967	2.8 (10.1)	4.9 (37.1)	3 (12.9)	4.3 (30.6)	75.8	79.3
DPW 621-50	2.8 (10.1)	4.3 (33.9)	3 (12.6)	3.8 (27.5)	76.7	79.9
WH 1124	2.7 (9.6)	5 (38.1)	2.9 (12.3)	4.4 (30.7)	76.3	79.3
DBW 17	2.8 (10.2)	4.8 (36.9)	3.1 (12.9)	4.2 (30.8)	77.5	79.7
SEm±	0.1	0.1	0.1	0.1	-	-
CD (P=0.05)	NS	NS	NS	NS	-	-
<i>Weed management</i>						
MBZ 210 g/ha	3.5 (11.4)	6.6 (42.6)	1.9 (2.7)	2.2 (4.1)	73.4	97.4
MBZ + CDF (150 + 45) g/ha	2.1 (3.3)	3.1 (8.7)	2.6 (5.7)	3.4 (10.6)	94.3	92.8
MBZ + PDN (150 + 40) g/ha	2 (3)	3.1 (8.6)	2.6 (6)	3.4 (10.9)	94.8	92.8
MBZ + FNP (150 + 100) g/ha	1.9 (2.7)	2.6 (6)	2.5 (5.5)	3.3 (9.9)	96.2	93.4
Weed-free	1 (0)	1 (0)	1 (0)	1 (0)	100.0	100.0
Weedy-check	6.5 (41.6)	12.4 (153.5)	7.6 (57.7)	12 (144)	0.0	0.0
SEm±	0.1	0.2	0.2	0.1	-	-
CD (P=0.05)	0.4	0.6	0.5	0.4	-	-

MBZ, Metribuzin 70 WP; CDF, clodinafop propargyl 15 WP; PDN, pinoxaden 5.1 EC; FNP, fenoxaprop ethyl 10 EC; DAS, days after sowing
Original data are given in parentheses were subjected to square root $\sqrt{(x + 1)}$ transformation before analysis

maximum number of tillers, being statistically at par with 'HD 2967', but markedly higher than 'WH 1124' and 'DBW 17' (Table 3). Minimum number of tillers were recorded in 'WH 1124', which was statistically at par with 'DBW 17' and 'DPW 621-50' at 60, 90 and 120 DAS and with 'HD 2967' at 120 DAS. Singh *et al.* (2015) also reported similar findings for number of tillers of wheat. Leaf-area index (LAI), that determines the capacity of the crop to trap solar energy for photosynthesis, was found maximum in 'WH 1105' variety at 60 DAS and in 'HD 2967' variety at 90 DAS and 120 DAS; however, they were statistically at par with each other (Table 3). Wheat variety 'WH 1124' revealed the lowest LAI and it was statistically at par with 'DBW 17'. Kaur and Gill (2015) also observed differences in LAI among the varieties.

The maximum number of tillers and LAI of wheat were observed in the weed-free plots which were significantly superior to weedy check and metribuzin (210 g/ha). Combination of metribuzin with fenoxaprop proved the best treatment and it was statistically at par with weed-free plots as well as treatments having combination of metribuzin with other herbicides except for LAI at 60 DAS with metribuzin and clodinafop. The combination differed significantly with metribuzin applied alone and weedy check. Alone application of metribuzin was found inferior to its combinations and significantly lower number of tillers and LAI of wheat were recorded. Season-long weed-infested

plot (weedy check) resulted in significantly less number of tillers and LAI of wheat as compared to all the herbicidal treatments during both years. Our results confirm those of Kamboj *et al.* (2017).

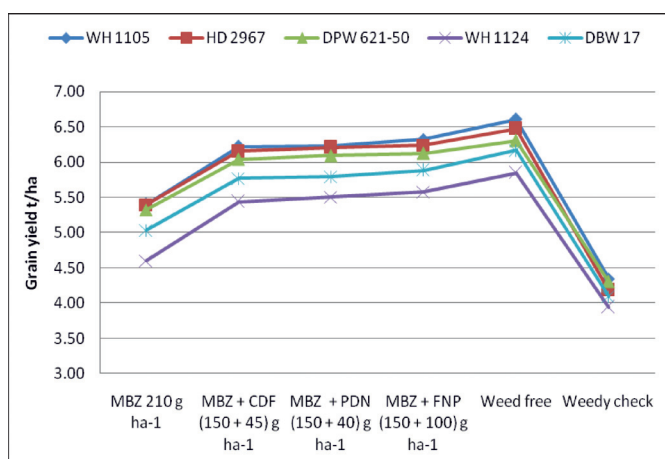
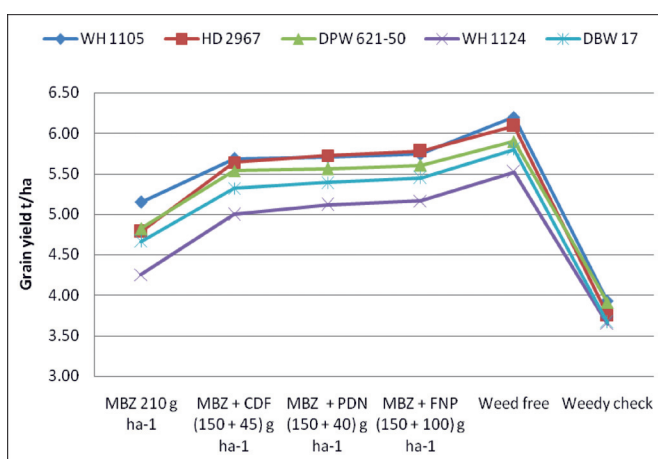
Wheat yield

Of the wheat varieties, 'WH 1105' proved the best, as this variety gave the highest grain (5.63 t/ha), straw (8.83 t/ha) and biological yield (14.46 t/ha), which remained at par with 'HD 2967' and was significantly better than 'WH 1124' and 'DBW 17' (Table 4). This may be owing to better growth of plants of these varieties in terms of number of tillers. Similar findings of differences in yield of wheat were reported by Mauriya *et al.* (2015) and Khatik *et al.* (2021). All the weed-management practices significantly affected grain, straw and biological yields during both the years. Maximum and minimum values for grain, straw and biological yield were recorded under season-long weed-free plots and weedy check plots respectively (Table 4). Among the herbicidal treatments, mixture of metribuzin with fenoxaprop remained statistically superior to the weedy check plots as well as metribuzin alone. Tomar and Tomar (2014) reported similar trend of increase in yield of wheat. The interaction effect between varieties and weed-control treatments on grain yield was found to be non-significant during both the years (Figs. 1 and 2). The highest value for harvest index was observed in variety 'DPW 621-

Table 3. Effect of varieties and weed-management practices on number of tillers and leaf-area index of wheat (pooled data of 2 years)

Treatment	Number of tillers/m ²			Leaf-area index		
	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS
<i>Varieties</i>						
WH 1105	521.0	509.3	496.8	1.94	3.45	2.95
HD 2967	513.3	504.4	488.6	1.91	3.52	3.02
DPW 621-50	510.0	500.1	484.7	1.82	3.37	2.85
WH 1124	500.2	491.5	475.9	1.55	3.16	2.66
DBW 17	508.7	497.0	482.6	1.68	3.26	2.71
SEm±	4.1	4.2	4.4	0.05	0.05	0.06
CD (P=0.05)	12.2	11.5	13.7	0.13	0.17	0.18
<i>Weed management</i>						
MBZ 210 g/ha	493.4	482.9	465.3	1.63	3.23	2.70
MBZ + CDF (150 + 45) g/ha	518.5	503.9	495.0	1.73	3.41	2.89
MBZ + PDN (150 + 40) g/ha	525.7	518.2	502.2	1.91	3.47	2.95
MBZ + FNP (150 + 100) g/ha	533.8	526.9	512.4	1.96	3.50	2.97
Weed-free	538.6	531.1	516.7	2.04	3.56	3.00
Weedy-check	453.8	439.7	422.7	1.41	2.95	2.51
SEm±	8.7	9.7	9.2	0.07	0.08	0.06
CD (P=0.05)	24.9	27.5	26.3	0.21	0.23	0.16

MBZ, Metribuzin 70 WP; CDF, clodinafop propargyl 15 WP; PDN, pinoxaden 5.1 EC; FNP, fenoxaprop ethyl 10 EC; DAS, DAYS AFTER SOWING

**Fig. 1.** Effect of varieties and weed management practices on grain yield of wheat (2014–15)**Fig. 2.** Effect of varieties and weed-management practices on grain yield of wheat (2015–16)

50' and weed-free plots (among weed-management practices) but neither varieties nor weed-management practices showed significant difference for this (Table 4). The highest benefit: cost (B:C) ratio was observed in variety 'WH 1105' and combination of metribuzin with fenoxaprop among weed management practices. Any of the herbicide treatments did not exhibit serious phytotoxicity to wheat crop (data not given, Rani *et al.*, 2018) as well as residual toxicity to succeeding fodder maize (data not given, Rani *et al.*, 2017).

From this study it may be concluded that the wheat varieties did not affect the weed density and weed dry matter accumulation and variety 'WH 1105' being at par with 'WH 2967' proved the best by giving the highest grain,

straw and biological yields. Among the herbicides, minimum density of grassy and total weeds and dry-matter accumulation by them at all stages was observed with combination of metribuzin (150 g/ha) with fenoxaprop (100 g/ha), being statistically at par with its combinations with pinoxaden (40 g/ha) and clodinafop (45 g/ha), whereas density and dry-matter of broad leaf weeds were minimum with metribuzin alone (210 g/ha). Alone application of metribuzin resulted in the lowest grain yield of wheat as compared to all the other herbicidal treatments.

REFERENCES

- DESA, Haryana. 2020. *Economic Survey of Haryana 2019–20*. Department of Economic and Statistical Analysis, Haryana, India.

Table 4. Effect of varieties and weed-management practices on yields, harvest index and benefit: cost ratio of wheat (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	Benefit: cost ratio
<i>Varieties</i>					
WH 1105	5.63	8.83	14.46	38.9	1.77
HD 2967	5.54	8.73	14.27	38.7	1.74
DPW 621-50	5.46	8.10	13.56	40.25	1.69
WH 1124	4.97	7.55	12.52	39.7	1.55
DBW 17	5.26	8.00	13.26	39.65	1.64
SEm±	0.08	0.09	0.11	0.6	-
CD (P=0.05)	0.24	0.30	0.37	NS	-
<i>Weed management</i>					
MBZ 210 g/ha	4.94	7.51	12.45	39.7	1.61
MBZ + CDF (150 + 45) g/ha	5.69	8.78	14.46	39.3	1.85
MBZ + PDN (150 + 40) g/ha	5.74	8.86	14.59	39.25	1.84
MBZ + FNP (150 + 100) g/ha	5.79	8.89	14.68	39.45	1.88
Weed-free	6.09	8.96	15.05	40.5	1.54
Weedy-check	3.98	6.47	10.44	38.1	1.35
SEm±	0.16	0.12	0.19	0.8	-
CD (P=0.05)	0.44	0.34	0.55	NS	-

MBZ, Metribuzin 70 wp; CDF, clodinafop propargyl 15 wp; PDN, pinoxaden 5.1 EC; FNP, fenoxaprop ethyl 10 EC; DAS, DAYS AFTER SOWING

ICAR-IIWBR. 2020. *Annual Report 2020*, ICAR-Indian Institute of Wheat and Barley Research, Karnal, Haryana, India.

Jain, Lokesh Kumar, Ram, Moola and Parewa, Hanuman Prasad. 2020. Chemical weed control in wheat (*Triticum aestivum*) and its residual effects on greengram (*Vigna radiata*). *Indian Journal of Agronomy* **65**(2): 231–234.

Kamboj, N.K., Hooda, V.S., Gupta, G. Devi, S. and Jinger, D. 2017. Performance of wheat under different planting methods and weed management practices. *Annals of Agricultural Research–New Series* **38**(1): 31–37.

Kaur, N. and Gill, K.K. 2015. Crop growth analysis of wheat cultivars under different hydrothermal regimes. *Annals of Agricultural Research–New Series* **36**(2): 144–151.

Khatik, Pappu, Yadav, L.R., Gupta, A.K., Prajapat, O.P. and Verma, H.P. 2021. Performance of bread wheat (*Triticum aestivum*) varieties for productivity, profitability and nutrient uptake under different sowing dates and nitrogen levels. *Indian Journal of Agronomy* **66**(2): 163–169.

Kumar, N., Hooda V.S., Gupta, G. and Sangwan, M. 2017. Weed management studies in wheat (*Triticum aestivum*) with herbicides under different planting methods. *International Journal of Current Microbiology and Applied Science* **6**(2): 1–8.

Kumari, A., Kumar, S., Singh, B. and Dhaka, A. 2013. Evaluation of herbicide alone and in combination for weed control in wheat. *Indian Journal of Weed Science* **45**(3): 210–213.

Mauriya, A.K., Maurya, D.C., Maurya, V.K and Verma, R.K. 2015. Effect of zinc application methods on yield attributes, yield and nutrient uptake in wheat (*Triticum aestivum*) varieties

under sodic soil. *Indian Journal of Agronomy* **60**(1): 82–86.

Ramesh, K., Rao, A.N. and Chauhan, B.S. 2017. Role of crop competition in managing weeds in rice, wheat, and maize in India: A review. *Crop Protection* **95**: 14–21.

Rani Sarita, Kumar, Suresh and Hooda, V.S. 2017. Residual toxicity of metribuzin based herbicide mixtures applied in wheat on succeeding fodder maize. *Forage Research* **43**(2): 136–140.

Rani, Sarita, Kumar, Suresh, Hooda, V.S. and Parshad, Jagdish. 2018. Influence of varieties and herbicide mixtures on wheat based cropping system in relation to phytotoxicity and residual soil nutrients. *International Journal of Current Microbiology and Applied Sciences* **7**(6): 3,573–3,581.

Singh V., Singh, B., Panwar, I.P., Verma, S.R., Dalal, M.S., Saharan, R.P., Solanki, Y.S., Bishnoi, O.P. and Karwasra, S.S. 2015. ‘WH 1124’: A new wheat variety for late sown irrigated conditions in North-West plain zone of India. *Journal of Wheat Research* **7**(1): 79.

Tomar, S.K. and Tomar, T.S. 2014. Effect of herbicides and their tank-mixture on weed dynamics and yield of zero-tilled wheat (*Triticum aestivum*) under rice–wheat cropping system of eastern Uttar Pradesh. *Indian Journal of Agronomy* **59**(4): 624–628.

Yadav, D.B., Yadav, A., Punia, S.S. and Chauhan, B.S. 2016. Management of herbicide-resistant *Phalaris minor* in wheat by sequential or tank-mix applications of pre- and post-emergence herbicides in North-Western Indo-Gangetic Plains. *Crop Protection* **89**: 239–247.