*Original Research Article*

# Effects of herbicides and nano urea mixture on weeds, yield attributes and yield of wheat (*Triticum aestivum*)


## Abstract

Wheat (*Triticum aestivum*) is second most important staple crop in India after rice. Weeds have emerged as the major biotic stress in wheat. Post-emergence herbicidal combinations are used widely to control the complex weed flora in wheat crops. A field experiment was carried out to study the "**Effects of herbicides and nano urea mixture on weeds, yield attributes and yield of wheat (*Triticum aestivum*)".** The experiment was performed in randomized blocked design with three replications and fourteen treatments in *Rabi* season 2022-23 at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar. Significantly minimum weed count (1.52 $m^{-2}$) and dry weight (1.49 g $m^{-2}$) and maximum weed control efficiency **(**88.6%**)** of *Phalaris minor* and broadleaved weeds (87%) was recorded with application of clodinafop + metribuzin 60 + 210 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ followed by clodinafop + metribuzin 60 + 210 g $ha^{-1}$ at 90 DAS. In case of yield attributes i.e. number of effective tillers per meter row length (92.5), spike length (11.4 cm), number of grains $spike^{-1}$ (55.9) and 1000-grain weight (43.8) were higher with application of clodinafop + metribuzin 60 + 210 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ followed by clodinafop + metribuzin 60 + 210 g $ha^{-1}$. Grain yield (5876 kg $ha^{-1}$) and B:C (1.94) was recorded higher with application of clodinafop + metribuzin 60 + 210 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ followed by clodinafop + metribuzin 60 + 210 g $ha^{-1}$ which was significantly higher than weedy check but at par with the weed free treatment.



**Keywords:** Post-emergence, herbicides, weed, economics, nano urea, wheat


## 1. Introduction

Wheat (*Triticum aestivum* L.) is one of the world's major cereal food crops and has a very important role in attaining food security. Wheat is a staple crop for many countries and is a significant source of dietary energy, protein and essential nutrients for a large portion of the global population (Rueda *et al*., 2011, Khan *et al*., 2023c). Weeds compete with wheat plants for resources such as sunlight, water, nutrients, and space, which can significantly impact crop growth and reduce yields if not properly managed (Nadeem et al., 2022, Maqbool et al., 2022). The main biological constraint limiting the potential yield of any crop is weed (Rao and Wani, 2015). Weeds are one of the crucial factors accountable for lower yield, declining productivity by 15-40% or even higher, and also for lowering grain quality (Singh *et al*., 1999, Khan et al., 2022a; Khan et al 2022b). In extreme case, losses due to weeds resulted in complete crop failure (Chhokar *et al*., 2007; Singh *et al*., 1999). Wheat production increased significantly during and after the green revolution due to the use of larger fertiliser dosages, assured irrigation, dwarf and high yielding cultivars (Choudhary *et al*., 2016). The high nutrient and water requirements along with less competitive nature of these high yielding dwarf varieties have provided the suitable environment for increased weed infestation. Due to the introduction of these high yielding dwarf wheat varieties, the spectrum of weed flora changed from the dominance of broadleaved weeds in the 1960s to grassy weeds in the early 1970s, specifically *Phalaris minor*, regarded as most notorious to crop production and account for about one third of total losses caused by all the pests. Thus, by the late 1970s, chemical weed management became a necessity. Wheat fields are susceptible to infestation by both grassy and broadleaved weeds. Crop rotation, soil type, meteorological conditions including temperature and humidity, soil moisture availability, cultural practises, and varieties utilised all play a significant role in the composition of these weeds (Chhokar *et al.*, 2007, 2012; Singh *et al*., 1995 Khan et al., 2022b). Among grassy weeds, *Phalaris minor*, *Avena ludoviciana* and among broad leaved weeds *Rumex dentatus*, *Chenopodium album, Chenopodium murale, Fumaria parviflora* and *Medicago denticulata* are of major concern in irrigated wheat under rice-wheat system in India (Singh and Singh, 2020; Khan et al., 2022a,). Littleseed canary grass (*Phalaris minor* Retz.), an invasive weed native to the Mediterranean area, present on all continents with the exception of the polar regions. Weeds are generally controlled manually. However, manual weeding is time consuming and expensive, thus chemical weed management is the most straightforward and effective alternative method. Herbicides offer most ideal, practical, effective and economical means of reducing early weed competition and crop production losses (Khan et al., 2023a; Khan et al., 2022a). Continuous use of herbicides, *P. minor* populations have developed multiple herbicide resistance (MHR) (Dhawan *et al*., 2012; Singh *et al*., 2021; Khan et al., 2022b), making it the most prevalent weed species that restricts wheat productivity in N-W IGPs of India. Additionally, a few of the biotypes became resistant to a couple of novel herbicides, including pinoxaden and mesosulfuron + iodosulfuron. Even now, multiple herbicide resistances have been developed in *Phalaris minor* (Dhawan *et al*., 2012; Rasool *et al*., 2017; Khan et al., 2023c). Earlier in India, the herbicide resistance problem was limited to only *Phalaris minor*, but with the intensive use of metsulfuron-methyl to control broad leaf weeds, it has now resulted in the aggravation of the resistance problem with the addition of one more case of *Rumex dentatus* (Chaudhary *et al*., 2021; Javaid *et al*., 2022). Nano urea is potential component of 4R stewardship as it promotes precision sustainable agriculture. IFFCO nano urea liquid contains 40,000 ppm of nitrogen in 500 ml bottle which is equivalent to the impact of nitrogen provided by the one bag of conventional urea. So keeping this in view, the present experiment was carried out to study the herbicides bioefficacy in combination with nano urea against different weeds in wheat.

## 2. Material and Methods

The field experiment was conducted at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar (Haryana) (29°8’56.62"N latitude and 75°41’4.24"E longitude) with an elevation of 215.2 m above mean sea level in winter season 2022-23 in the Haryana State of India to assess the “**Effects of herbicides and nano urea mixture on weeds, yield attributes and yield of wheat (*Triticum aestivum*)”**. During the crop season 2022-23, the range of maximum and minimum temperature varied between 14.6-38.1°C and 4.4-19.3°C, respectively. The total rainfall received during the crop growing period was 26.9 mm and the highest amount of rainfall received under $11^{th}$ standard meteorological weeks ($12^{th}$ March-$18^{th}$ March) was 5.4 mm. The soil of the experimental site was sandy loam in texture, slightly alkaline in reaction (pH 8.2) and normal electrical conductivity (0.30 dS $m^{-1}$). Organic carbon (0.36%) and nitrogen (137.98 kg $ha^{-1}$) were determined to be low in the soil with medium phosphorus (15.11 kg $ha^{-1}$) and potassium content (240.79 kg $ha^{-1}$). The wheat variety HD 3086 was sown in a regularly tilled seed bed using 100 kg seed $ha^{-1}$ in rows 20 cm apart. The experiment was conducted in randomized complete block design with three replications. Different herbicides treatments were: $T_{1:}$ pinoxaden 50 g $ha^{-1}$, $T_2$: pinoxaden 50 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$, $T_3$: metribuzin 175 g $ha^{-1}$, $T_4$: metribuzin 175 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$, $T_5$: clodinafop 60 g $ha^{-1}$, $T_6$: clodinafop 60 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$, $T_7$: sulfosulfuron + metsulfuron (RM) 33 g $ha^{-1}$, $T_8$: sulfosulfuron + metsulfuron (RM) 33 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$, $T_9$: mesosulfuron + iodosulfuron (RM) 14.4 g $ha^{-1}$, $T_{10}$: mesosulfuron + iodosulfuron (RM) 14.4 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$, $T_{11}$: clodinafop + metribuzin (RM) (60 + 210 g $ha^{-1}$), $T_{12}$: clodinafop + metribuzin (RM) 60 + 210 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$, $T_{13}$: weedy check and $T_{14}$: weed free. The densities and dry weight of grassy and broadleaved weeds were measured using a quadrat (0.5 x 0.5 m), weed samples were collected from two randomly chosen locations in each plot. Each weed sample was divided into the following groups: grassy and broadleaved weeds. *Grassy weed* i.e. *Phalaris minor* and broadleaved weeds were counted in each sample and the density was expressed as a number $m^{-2}$. *Phalaris minor* and broadleaved weeds from each quadrat were sun-dried before being placed in oven to obtain a constant weight at $65^0$C. The weight of the dried weed samples was measured g $m^{-2}$. The weed control efficiency was determined by comparing the percentage of weed dry weight under different treatments to weedy conditions. The weed control efficiency (WCE) was calculated using the formula as given below:

$$\text{WCE (\%)} = \frac{\text{Weed dry weight in control plot (g m}^{-2}\text{)} - \text{Weed dry weight in treated plot (g m}^{-2}\text{)}}{\text{Weed dry weight in control plot (g m}^{-2}\text{)}} \times 100$$

Three rows each of one metre in length were randomly chosen from each plot for the purpose of calculating the number of effective tillers per metre row length and the mean was taken. Based on prevailing market price of inputs on hectare basis, economics of each treatment was calculated. The data was analysed using the OP STAT software from CCS HAU, Hisar.

**Table 1:** Effect of different herbicides on weed count (No. $m^{-2}$) and dry wight of grassy and broadleaved weeds in wheat at 90 DAS

| **Treatments** | *P. minor* | *M. denticul* | *R. dentatu* | *L. aphaca* | *C. album* | Dry weight (g $m^{-2}$) |
|---|---|---|---|---|---|---|

| | | *ata* | *s* | | | Grassy | BLW |
|---|---|---|---|---|---|---|---|
| Pinoxaden 50 g $ha^{-1}$ | 2.23 (4.0) | 4.39 (18.3) | 3.87 (14.0) | 4.86 (22.5) | 2.88 (7.3) | 2.29 (4.3) | 6.00 (35.0) |
| Pinoxaden 50 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ | 2.06 (3.3) | 4.43 (18.6) | 3.82 (13.6) | 4.83 (22.3) | 3.20 (9.3) | 2.27 (4.2) | 6.00 (35.0) |
| Metribuzin 175 g $ha^{-1}$ | 2.36 (4.6) | 2.73 (2.0) | 2.15 (3.6) | 3.54 (11.6) | 1.00 (0.0) | 2.11 (3.5) | 3.04 (8.4) |
| Metribuzin 175 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ | 2.23 (4.0) | 1.81 (2.3) | 1.89 (2.6) | 3.30 (10.0) | 1.00 (0.0) | 2.16 (3.7) | 3.17 (9.1) |
| Clodinafop 60 g $ha^{-1}$ | 2.82 (7.0) | 4.46 (19.0) | 4.03 (15.3) | 4.60 (20.3) | 3.08 (8.6) | 2.87 (7.3) | 6.00 (35.0) |
| Clodinafop 60 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ | 2.60 (6.0) | 4.43 (18.6) | 3.87 (14.0) | 4.82 (22.3) | 2.98 (7.9) | 2.80 (6.9) | 6.00 (35.0) |
| Sulfosulfuron+metsulfuron (RM) 33 g $ha^{-1}$ | 2.54 (5.6) | 2.94 (7.6) | 1.71 (2.0) | 3.57 (12.3) | 2.23 (4.0) | 2.65 (6.1) | 3.38 (10.5) |
| Sulfosulfuron+metsulfuron (RM) 33 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ | 2.43 (5.0) | 2.88 (7.3) | 2.62 (6.0) | 3.34 (12.0) | 2.15 (3.6) | 2.58 (5.7) | 3.41 (10.8) |
| Mesosulfuron + iodosulfuron (RM) 14.4 g $ha^{-1}$ | 1.89 (2.6) | 2.88 (7.3) | 2.81 (7.0) | 3.60 (12.3) | 1.71 (2.0) | 1.88 (2.6) | 4.14 (16.3) |
| Mesosulfuron + iodosulfuron (RM) 14.4 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ | 2.00 (3.0) | 3.00 (8.0) | 2.62 (6.0) | 3.60 (12.3) | 1.98 (2.9) | 2.02 (3.1) | 4.35 (18.0) |
| Clodinafop + metribuzin (RM) 60 + 210 g $ha^{-1}$ | 1.61 (1.6) | 1.73 (2.0) | 1.50 (1.3) | 3.16 (9.0) | 1.71 (2.0) | 1.52 (1.4) | 2.44 (5.1) |
| Clodinafop + metribuzin (RM) 60 + 210 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ | 1.52 (1.3) | 1.62 (1.6) | 1.24 (0.7) | 3.10 (8.6) | 1.61 (1.6) | 1.49 (1.3) | 2.34 (4.5) |
| Weedy check | 3.46 (11.0) | 4.61 (20.3) | 4.12 (16.0) | 4.85 (22.6) | 3.20 (9.3) | 3.47 (11.1) | 6.00 (35.0) |
| Weedy free | 1.00 (0.0) | 1.00 (0.0) | 1.00 (0.0) | 1.00 (0.0) | 1.00 (0.0) | 1.00 (0.0) | 1.00 (0.0) |
| SEm ± | 0.17 | 0.10 | 0.27 | 0.21 | 0.15 | 0.11 | 0.18 |
| C.D. (p=0.05) | 0.49 | 0.30 | 0.56 | 0.64 | 0.44 | 0.32 | 0.54 |

Original data given in parenthesis was subjected to square root ($\sqrt{x}$ + 1) transformation before analysis

## 3. Results and Discussion

### 3.1. Weed flora

The major grassy weed of the experimental field was *Phalaris minor and* among broadleaved weeds *Chenopodium album, Lathyrus aphaca*, *Medicago denticulate, Rumex dentatus, Convonvulus arvensis and Anagallis arvensis* were dominant.

### 3.2. Density of *Phalaris minor* (No. $m^{-2}$)

The weed control treatments at 90 DAS (days after sowing) had significant effects on the weed densities. As weed growth was luxuriant and uninterrupted in the absence of any weed control practise throughout the crop growing season, the highest population of grassy weeds was observed in case of weedy check at 90 DAS, and it was significantly higher than other weed control treatments. Among all the herbicide treatments, clodinafop + metribuzin (RM) 60 + 210 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ found most effective to reduce the density of weed, which was statistically at par with clodinafop + metribuzin (RM) 60 + 210 g $ha^{-1}$, mesosulfuron + iodosulfuron (RM) 14.4 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ and mesosulfuron + iodosulfuron (RM) 14.4 g $ha^{-1}$. Clodinafop + metribuzin (RM) 60 + 210 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ and mesosulfuron + iodosulfuron (RM) 14.4 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$ treated plots had lower weed density, which was due to the broad-spectrum activity of herbicides. Similar results were reported by Singh *et al.*, 2011 with ready-mix application of fenoxaprop and metribuzin (Accord Plus). Khan et al., 2023c reported that the maximum density of *P. minor* (18.33 and 19.33 $m^{-2}$) was recorded in plots treated with no dose of clodinofop-propargyl and fenoxaprop-P-ethyl nanoparticles (control) in both experimental years. However, with application of nanoparticles of clodinofop-propargyl and fenoxaprop-P-ethyl at recommended dose of normal herbicide resulted in minimum density (0.00 $m^{-2}$) of weed under investigation *P. minor*.

### 3.3. Density of broadleaved weeds (No. $m^{-2}$)

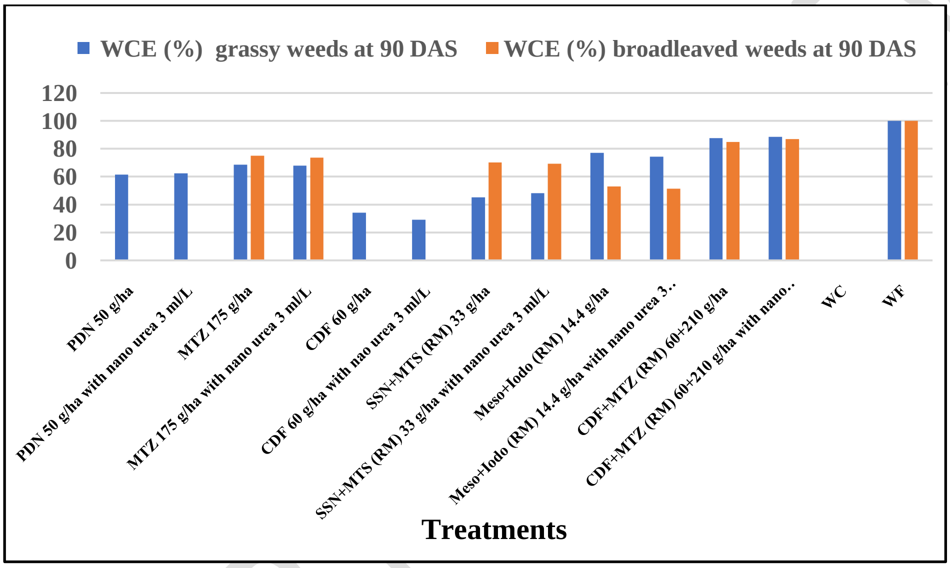
The minimum weed density at 90 DAS was recorded under weed free treatment which was followed by ready mix application of clodinafop + metribuzin 60 + 210 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$, which was at par with clodinafop + metribuzin 60 + 210 g $ha^{-1}$ but significantly superior over other treatments at 90 DAS. These results are in conformity with Singh *et al.* (2019) who reported that application of the tank mixed herbicides reduced broad leaf and narrow leaf weeds to a varying degree sometimes approaching to 100%.

### 3.4. Weed dry weight ($gm^{-2}$)

All herbicide treatments caused significant reduction in weed biomass as compared to weedy check at 90 DAS. Among the herbicidal treatments, the lowest weed biomass was recorded by the application of clodinafop + metribuzin 60 + 210 g $ha^{-1}$ with nano urea 3 ml $L^{-1}$, which was at par clodinafop + metribuzin 60 + 210 g $ha^{-1}$ but significantly superior over other treatments at 90 DAS. Weed biomass accumulation was reduced in treatments using post-emergence herbicides because of the minimum density of weeds. These results are in line with Qazizada *et al*. (2022); Yadav *et al.* (2016) and Shoeran *et al*. (2013) Khan et al., 2023c).

### 3.5. Weed control efficiency (%)

The weed control efficiency of herbicides was measured based on weed biomass, and it showed that the weed-free plot had the maximum efficiency of grassy weeds (100%) at 90 DAS. Among the herbicidal treatments, application of clodinafop + metribuzin 60 + 210 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ recorded highest weed control efficiency of grassy weeds (88.6%), which was followed by the clodinafop + metribuzin 60 + 210 g ha$^{-1}$ (87.7%) as in Fig. 1. Weed control efficiency of broadleaved was higher (87%) under clodinafop + metribuzin 60 + 210 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ *fb* clodinafop + metribuzin 60 + 210 g ha$^{-1}$ (85%) at 90 DAS. It might be due to better weed control as reflected in associated weed density and dry weight. Among herbicide treatments, minimum WCE of broadleaved weed was recorded under pinoxaden 50 g ha$^{-1}$ and clodinafop 60 g ha$^{-1}$ with and without nano urea, because these herbicides are grass killers. Lower weed control efficiency with these herbicides also reported by Singh *et al*. (2019). Khan *et a*l., (2022b)




PDN- pinoxaden, MTZ- metrivuzin, CDF- clodinafop, SSN- sulfosulfuron, MTS- metsulfuron, Meso- mesosulfuron, Iodo- iodosulfuron, WF-weed free and WC- weedy check

**Fig 1: Effect of weed control treatments on WCE (%) of grassy and broadleaved weeds**

### 3.6. Yield

The effective tillers were significantly influenced by different weed control treatments (Table-2). The data revealed that maximum effective tillers were found in weed free treatment (95.6) which was statistically at par with clodinafop + metribuzin 60 + 210 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$, with clodinafop + metribuzin 60 + 210 g ha$^{-1}$, metribuzin 175 g ha$^{-1}$ with and without nano urea but significantly superior over rest of the herbicide and weedy check. Among the herbicides, the highest effective tillers mrl$^{-1}$ were recorded in ready mix application of with clodinafop + metribuzin 60 + 210 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ (92.5), followed by clodinafop + metribuzin 60 + 210 g ha$^{-1}$ (90.2). The lowest number of effective tillers was recorded in weedy check (71.1). Mahmood *et al*. (2013) reported that the number of tillers caused by herbicides may be due to greater weed management, decrease of crop weed competition for nutrients, moisture, light and improved crop utilisation of resources.

**Table 2:** Effect of different weed control treatments on yield attributes and yield of wheat

| Treatments | Number of effective tillers (mrl$^{-1}$) | Length of spike (cm) | Grains spike$^{-1}$ | Test weight (g) | Grain yield (kg ha$^{-1}$) | B-C ratio |
|---|---|---|---|---|---|---|
| Pinoxaden 50 g ha$^{-1}$ | 81.1 | 8.9 | 52.4 | 41.5 | 5191 | 1.68 |
| Pinoxaden 50 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ | 79.5 | 8.6 | 53.0 | 40.1 | 5072 | 1.64 |
| Metribuzin 175 g ha$^{-1}$ | 86.0 | 9.0 | 53.3 | 42.7 | 5596 | 1.83 |
| Metribuzin 175 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ | 87.0 | 9.2 | 53.4 | 42.6 | 5632 | 1.82 |
| Clodinafop 60 g ha$^{-1}$ | 76.2 | 8.5 | 45.8 | 40.6 | 4905 | 1.63 |
| Clodinafop 60 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ | 78.5 | 8.6 | 45.8 | 40.7 | 4844 | 1.57 |
| Sulfosulfuron+metsulfuron (RM) 33 g ha$^{-1}$ | 81.0 | 8.8 | 52.0 | 42.2 | 5342 | 1.74 |
| Sulfosulfuron+metsulfuron (RM) 33 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ | 80.7 | 9.0 | 53.7 | 42.7 | 5275 | 1.71 |
| Mesosulfuron + iodosulfuron (RM) 14.4 g ha$^{-1}$ | 81.3 | 8.8 | 52.2 | 42.3 | 5363 | 1.74 |
| Mesosulfuron + iodosulfuron (RM) 14.4 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ | 82.3 | 9.0 | 52.4 | 42.1 | 5430 | 1.75 |
| Clodinafop + metribuzin (RM) 60 + 210 g ha$^{-1}$ | 90.2 | 10.8 | 53.5 | 43.7 | 5806 | 1.89 |
| Clodinafop + metribuzin (RM) 60 + 210 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ | 92.5 | 11.4 | 55.9 | 43.8 | 5876 | 1.94 |
| Weedy check | 71.1 | 8.3 | 44.8 | 40.2 | 4448 | 1.52 |
| Weedy free | 95.6 | 11.5 | 57.4 | 44.0 | 6033 | 1.60 |
| SEm ± | 4.0 | 0.5 | 2.3 | 2.2 | 190 | |
| C.D. (p=0.05) | 11.6 | 1.4 | 6.8 | NS | 557 | |



Length of spike (cm) and Number of grains spike$^{-1}$ are another important component of grain yield (Table 2). Maximum length of spike was recorded under weed free (11.5 cm) followed by clodinafop + metribuzin (RM) 60 + 210 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ (11.4 cm) and clodinafop + metribuzin (RM) 60 + 210 g ha$^{-1}$ (10.8 cm). Among the herbicide treatments maximum and minimum number of grains spike$^{-1}$ recorded with application of clodinafop + metribuzin (RM) 60 + 210 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ (55.9) and Clodinafop 60 g ha$^{-1}$ (45.8), respectively. All herbicidal treatment having higher number of grains spike$^{-1}$ than weedy check. Mahmood *et al.* (2013) better weed control, the elimination of weed crop competition for nutrients, moisture, light and improved agricultural resource utilisation may be responsible for the increase in the number of grains spike$^{-1}$.

Data in Table-2 indicated that the 1000-grain weight was not influenced significantly by different weed control treatments. All herbicidal treatment possesses numerically higher 1000 grain weight (g) than weedy check. Maximum 1000-grain weight recorded in weed free treatment (44 g), which followed by clodinafop + metribuzin (RM) 60 + 210 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ (43.8 g) and clodinafop + metribuzin (RM) 60 + 210 g ha$^{-1}$ (43.7). The lowest 1000 grain weight was recorded in weedy check (40.2). These findings are corroborated by Singh *et al.* (2015), which showed that weedy check plots had the lowest 1000-grain weight and those treated with a mixture of herbicides had the highest. Chhokar *et al*. (2015), also reported that the herbicide-treated plots attained higher 1000-grain weights than the weedy plots.

### 3.7. Grain yield (kg ha$^{-1}$)

Perusal data in table-2 exhibited that all herbicide treatments significantly influence the grain yield and maximum grain yield was recorded in weed free treatment (6033 kg ha$^{-1}$), which was statistically at par with clodinafop + metribuzin (RM) 60 + 210 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ (5876 kg ha$^{-1}$), clodinafop + metribuzin (RM) 60 + 210 g ha$^{-1}$ (5806 kg ha$^{-1}$), metribuzin 175 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ (5632 kg ha$^{-1}$) and metribuzin 175 g ha$^{-1}$ (5596 kg ha$^{-1}$) but significantly higher than other treatments. Minimum grain yield was recorded in weedy check plots (4448 kg ha$^{-1}$), which was significantly lower than all the herbicide treatments except clodinafop. The presence of weeds throughout the growing season resulted in a significant reduction in grain yield. Specifically, the grain yield was reduced by 26.27% in weedy check compared to weed-free conditions. This indicates that weeds had a substantial negative impact on the overall productivity of the crop during the growing season. The findings reported by Sheoran *et al*. (2013) and Singh *et al*. (2019) are consistent with the observation that the presence of weeds throughout the growing season can lead to a significant reduction in grain yield. Kumari *et al*. (2013), found that the ready-mix application of sulfosulfuron + metsulfuron 32 g ha$^{-1}$ resulted in the highest grain yield among the different herbicide treatments they tested. The specific grain yield achieved with this treatment was reported to be 6.42 tons per hectare (t ha$^{-1}$). Almost similar findings were reported by Chand and Puniya (2017) that the pre-mix application of clodinafop + metribuzin (60+210 g ha$^{-1}$) followed by sulfosulfuron + metsulfuron (32 g/ha) and pinoxaden+ metribuzin (40+210 g ha$^{-1}$), gave higher yields and better weed control than other treatments. Khan et al., 2023c reported that the maximum grain yield of wheat crop was recoded with application of nanoparticles of clodinofop-propargyl and fenoxaprop-P-ethyl nanoparticles as compared to control in both experimental years.

## 4. B-C ratio

To examine the economic feasibility and viability of different treatments under investigation economics of wheat production in terms B-C ratio. The B-C ratio is a financial indicator that compares the total benefits generated from an investment or activity to the total costs incurred. Among the different herbicidal treatments higher B-C ratio was recorded by clodinafop + metribuzin (RM) 60 + 210 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ (1.94) *fb* clodinafop + metribuzin (RM) 60 + 210 g ha$^{-1}$ (1.89) and metribuzin 175 g ha$^{-1}$ (1.83). Lowest B:C was reported from weedy check (1.52). The low B-C ratio from the weedy check treatment indicate that the presence of weeds had a substantial negative impact on wheat yield and overall profitability. These findings are consistent with the findings of Qazizada *et al*. (2022) that the application of pendimethalin 1000 g ha$^{-1}$ (just after sowing) *fb* pinoxaden + metribuzin as a tank mix 50 + 105 g ha$^{-1}$. The economic benefits can be attributed to improved crop productivity, enhanced quality and potentially reduced costs associated with weed management. Herbicide treatment led to a higher B-C ratio, as reported by Kumar *et al.* (2013).

## 5. Conclusion

Amongst herbicides treatments highest grain yield was recorded with the ready mixed application of clodinafop + metribuzin 60 + 210 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ (5876 kg ha$^{-1}$) followed by clodinafop + metribuzin 60 + 210 g ha$^{-1}$ (5806 kg ha$^{-1}$), metribuzin 175 g ha$^{-1}$ with nano urea 3 ml L$^{-1}$ (5632 kg ha$^{-1}$) and metribuzin 175 g ha$^{-1}$ (5596 kg ha$^{-1}$). The improved grain yield can be attributed to several factors, including reduced weed density, lower dry matter of weeds, lower weed index, and improved yield attributes. Specifically, the grain yield was reduced by 26.27% in weedy check compared to weed-free conditions.

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