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# Comparative efficacy of tank mixture of post emergence herbicides for the control of mixed weed flora in wheat

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**Abstract**
To find out the comparative efficacy of herbicides for the control of mixed weed flora of wheat (*Triticum aestivum* L.), an experiment was conducted at Research Farm of CCS Haryana Agricultural University, Hisar during *Rabi* 2011-12 and 2012-13. The experiment comprised of 14 treatments *viz.*, metribuzin (210 g/ha), clodinafop (60 g/ha), pinoxaden (40 g/ha), sulfosulfuron (25 g/ha), tank mixture of metribuzin with clodinafop (210+60 g/ha), Pinoxaden (210+40 g/ha), sulfosulfuron (210+25 g/ha) and fenoxaprop (210+120 g/ha), tank mixture of sulfosulfuron + metsulfuron (32 g/ha), mesosulfuron + iodosulfuron (14.4 g/ha), clodinafop + metsulfuron (60+4 g/ha), isoproturon + 2,4-D (1000+500 g/ha), weedy check and weed free. The experiment was laid out in randomized block design with three replications. For effective weed control, weed free treatment and sulfosulfuron + metsulfuron @ 32 g/ha, proved to be the best treatment with minimum weed density and dry weight of weeds; maximum weed densities and weed dry weight were recorded in weedy check. The highest grain yield of wheat was recorded in weed free plot (64.7 and 49.1 q/ha), which was similar to tank mixture of sulfosulfuron + metsulfuron @ 32 g/ha (64.4 and 48.4 q/ha) and these were significantly higher than individual application of herbicides but at pat with other tank mixed herbicides during 2011-12 and 2012-13, respectively. Sulfosulfuron + metsulfuron was also proved to be effective in yield parameters *viz.* effective tillers (452 and 449 $m^{-2}$) and 1000-grain weight (42.0 and 40.4 g) during 2011-12 and 2012-13, respectively. In the light of this study the weed free followed by the tank mixture of sulfosulfuron + metsulfuron provided better results for controlling weeds in the wheat. Presence of weeds throughout the growing season brought about 36.0 and 33.6% reduction in grain yield as compared to weed free during 2011-12 and 2012-13, respectively.

**Keywords:** wheat, weed, weed control, herbicides, yield

## Introduction
Wheat is the most important and widely cultivated food crop of the world. In India, its production increased from a mere 11.0 mt during 1960-61 to 93.5 mt during 2015-16 (Anonymous, 2016). This increment was mainly due to the adoption of high yielding dwarf varieties, increased fertilizers use, irrigation and herbicide uses. The high nutrient and water requirements along with less competitive nature of these high yielding dwarf varieties have provided conducive environment for increased weed infestation (Chhokar *et al*., 2012) [5]. Weed infestation is one of the major biotic constraints in wheat production. Wheat is infested with diverse type of weed flora like *Phalaris minor, Avena ludoviciana, Convolvulus arvensis, Chenopodium album, Melilotus indica, Melilotus alba, Lathyrus aphaca, Anagallis arvensis, Vicia sativa, Medicago denticulata, Fumaria parviflora* and *Circium arvensis etc.* (Singh *et al*., 1995) [25]. Wheat infested by multifarious weed flora comprising both grassy as well as broad leaf weeds causing yield reduction of 15-40% depending upon type and intensity of their infestation (Singh *et al.*, 2013) [11]. If the weeds are not controlled at the critical stages of crop, they may cause reduction in yield up to 66% (Singh *et al*., 2005; Kumar *et al*., 2009 and Kumar *et al*., 2011) [26, 9, 10]. Chemical weed control is a preferred practice due to scarce and costly labour as well as lesser feasibility of mechanical or manual weeding especially in broadcast wheat. Singh *et al*. (2015) [6] reported that unchecked weed growth reduced grain yield of wheat by 43% when compared with metribuzin + clodinafop-propargyl 600 g/ha. All the herbicides decreased weed population and significantly increased the yield and yield components of wheat as compared to control. For control of diverse weed flora in wheat combination of herbicides either as tank mixture, if compatible or as sequential, if not compatible are required. Herbicides have provided effective control of weeds; however, increased use of isoproturon led to the evolution of resistant *Phalaris minor* Retz. biotypes and shift in weed flora (Malik and Singh, 1993) [14]. To overcome this problem, fenoxaprop-p-ethyl, sufosulfuron and clodinafop-propargyl have been recommended (Chhokar and

Malik, 2002) [4]. Fenoxaprop-p-ethyl and clodinafop-propargyl are specific to *Phalaris minor* and *Avena ludoviciana* but are ineffective against broad-leaved weeds. Earlier studies conducted on cross resistance in Punjab and Haryana of isoproturon and alternate herbicides (clodinafop, fenoxaprop and sulfosulfuron) revealed that efficacy of clodinafop has decreased from 100% during 2004-05 to 78.1% during 2006-07 (Walia *et al.*, 2007) [28]. The herbicide pinoxaden 5 EC at 40 - 50 g/ha was found very effective and recommended for the control of grassy weeds in wheat especially against clodinafop resistant *P. minor* biotypes without any residual toxicity to succeeding rice and sorghum crops (Walia *et al*., 2007, Punia *et al*., 2008, Punia and Yadav, 2010) [28, 21, 30]. Sulfosulfuron is also not effective against some of the broad-leaved weeds like *Rumex* spp. and *Convolvulus arvensis* Linn. (Chhokar *et al*., 2007) [3]. Continuous use of these herbicides have resulted in tremendous increase in density of broadleaved species like *Rumex dentatus, Medicago denticulata, Chenopodium album, Melilotus indica, Vicia sativa* and *Fumaria parviflora*. Tank mix application of 2,4- D with clodinafop and fenoxaprop gave less control of grassy weeds because of antagonism between 2,4- D and these grass weed killers (Punia *et al*., 2004; Yadav *et al*., 2009a) [18, 29]. Malik *et al*. (2007) [15] reported that sulfosulfuron + metsulfuron (15 + 4 g/ha) proved effective against all weeds and reduced the total weed dry weight to the extent of 87-96%. So there is a need to evaluate alternative herbicides with different mode of action for the control of complex weed flora in wheat. In view of the weeds problem in wheat crop, a study was conducted to investigate the comparative efficacy of herbicides alone and in combination to control complex weed flora of wheat crop at Hisar condition during 2011-12 and 2012-13, respectively.

## Materials and Methods

An experiment to evaluate the efficacy of different post emergence herbicides alone and in combination to control the complex weed flora of wheat was conducted during *Rabi* season of 2011-12 and 2012-13 at Research Farm of Wheat and Barley Section, Chaudhary Charan Singh Haryana Agricultural University, Hisar (India) located in Indo-Gangetic plains of North-West India with latitude of $29^0$10' North and longitude of $75^0$46' East at 215.2 meters above mean sea level. The experimental soil was sandy loam with 61% sand, 22.1% silt and 19.1% clay, slightly alkaline in pH (7.9), low in organic carbon, poor in available nitrogen and medium in available phosphorus and available potassium. Wheat variety WH 711 was sown manually with hand plough on 7th November and 18th November in 2011-12 and 2012-13, respectively by using seed rate of 100 kg/ha. The experiment was arranged in randomized block design and was replicated thrice with fourteen weed control treatments comprised of individual application of metribuzin, clodinafop, pinoxaden, sulfosulfuron, tank mixture of metribuzin with clodinafop/pinoxaden/ sulfosulfuron or fenoxaprop, tank mixture of sulfosulfuron + metsulfuron, mesosulfuronn + iodosulfuron, clodinafop + metsulfuron, isoproturon + 2,4-D, weedy check and weed free. 150 kg N + 60 kg $P_2O_5$ $ha^{-1}$ were applied through urea and DAP. Half of N and full dose of P were applied as basal dose. Remaining half of nitrogen was top dressed at 1st irrigation. The crop was raised with all other recommended Package of Practices. All herbicides alone and in combination were applied as post emergence between 30-35 DAS as per treatment with knapsack power sprayer using flat fan nozzle in 500 litres of water $ha^{-1}$. Observations for weed population and their dry matter accumulation were recorded at 60 and 120 DAS with the help of random quadrate (0.5 x 0.5 m) at four places in a plot and then converted into per $m^2$. This data was subjected to square root ($\sqrt{x+1}$) transformation to normalize their distribution before analysis.

The weed control efficiency was worked out on the basis of weed dry matter production (Mallikarjun *et al.*, 2014) [16].

$$\text{WCE (\%)} = \left(\frac{\text{DMC}-\text{DMT}}{\text{DMC}}\right) \times 100$$

Where,
WCE = weed control efficiency (%)
DMC = dry matter of weeds in unweeded plot ($gm^{-2}$)
DMT = dry matter of weeds in treated plot ($gm^{-2}$)
Weed index was calculated by using the formula suggested by Gill and Vijaya Kumar (1966).

$$\text{Weed index (\%)} = \left(\frac{X-Y}{X}\right) \times 100$$

Where,
X = Grain yield of weed free plot
Y = Grain yield from treated plot
Crop was harvested on 10th April and 12th April during 2011-12 and 2012-13, respectively. Wheat grain yield and yield attributes were recorded at harvest which was statistically analyzed using analysis of variance.

## Results and Discussion

### Effects on weed

### Weed flora

The major weed species observed in the experiment field were *Phalaris minor, Avena ludoviciana, Convolvulus arvensis, Chenopodium album, Melilotus indica, Melilotus alba, Lathyrus aphaca, Anagallis arvensis, Vicia sativa, Rumex dentatus, Medicago denticulate, Fumaria parviflora and Circium arvensis* in both the experimental year.

### Weed density

The weeds densities were remarkably influenced by weed control treatments at 60 and 120 DAS (days after sowing) (Table 1). The minimum weed density was recorded under weed free treatment which was followed by tank mixture application of sulfosulfuron + metsulfuron and sulfosulfuron + metribuzin, which was at par with clodinafop+metribuzin, pinoxaden + metribuzin, mesosulfuron + iodosulfuron and clodinafop + metsulfuron but significantly superior over isoproturon + 2,4-D and alone application of metribuzin, clodinafop, pinoxaden and sulfosulfuron at 60 and 120 DAS. Highest weed density was recorded in weedy check treatment at 60 and 120 DAS. These results are in conformity with Khan *et al*. (2003) [8] who reported that application of the tank mixed herbicides reduced broad leaf and narrow leaf weeds to a varying degree sometimes approaching to 100%. The variability in weeds population in different treatments can be attributed to the fact that some herbicides are more effective for weed control than the others. Chhokar *et al.* (2007) [3] also reported that the mixture of herbicides effectively controlled weed flora than alone application.

### Weed dry matter ($gm^{-2}$)

All herbicides treatments caused significant reduction in weed biomass as compared to weedy check at 60 and 120 DAS (Table 1). The pooled mean of two years revealed that significantly lowest weed biomass was recorded in weed free treatment at 60 and 120 DAS. Among the herbicidal treatments, the lowest weed biomass was recorded in tank mixture of sulfosulfuron + metsulfuron @ 32 g/ha which was statistically at par with herbicide combination of sulfosulfuron + metribuzin @ 25 + 210 g/ha, clodinafop + metribuzin @ 60 + 210 g/ha, pinoxaden + metribuzin @ 40 + 210 g/ha, clodinafop + metsulfuron @ 60 + 4 g/ha but significantly superior over individual application of herbicides at 60 and 120 DAS. Malekian *et al*. (2013) [13] reported that metsulfuron-methyl plus sulfosulfuron reduced weed dry matter by 98 % compared with weedy check. It is mainly because sulfosulfuron is a selective, systemic sulfonyl urea herbicide, absorbed through both roots and leaves. It translocates throughout the plant and acts as an inhibitor of amino acid biosynthesis, hence stopping cell division and plant growth, whereas, metsulfuron is also a systematic sulfonyl urea herbicide, its mode of action is by inhibiting cell division in the shoots and roots of the plant. Both of these herbicides when applied in combination, the effect on weeds are more lethal than their application as alone.

**Weed control efficiency (%)**

The efficacy of herbicides estimated on the basis of weed biomass (Table 1) indicated that highest efficiency was recorded in weed free plot (100%) at 60 and 120 DAS. Among the herbicidal treatments, application of tank mixture sulfosulfuron + metsulfuron recorded highest weed control efficiency of 85.8% and 92.4% which was followed by the sulfosulfuron + metribuzin (83.5% and 91.8%) at 60 and 120 DAS, respectively. It might be due to better weed control as reflected in associated weed density and dry weight. Minimum efficiency was recorded in alone application of all herbicide. It indicated that tank mixture of herbicides provided better weed control efficiency than alone application of herbicide. Meena and Singh (2013) [17] and Tomar and Tomar (2014) [27] also recorded higher weed-control efficiency with tank-mix application of herbicides over their alone application.

**Table 1:** Effect of weed control treatments on weed density, dry weight, weed control efficiency and weed index of wheat crop (Pooled means of 2011-12 and 2012-13 data)

| Treatments | | Weed density ($m^2$) | | Weed dry weight ($gm^{-2}$) | | Weed control efficiency (%) | | Weed index (%) |
|---|---|---|---|---|---|---|---|---|
| Herbicide | Dose (g/ha) | 60 DAS | 120 DAS | 60 DAS | 120 DAS | 60 DAS | 120 DAS | |
| Metribuzin | 210 | 4.86 (22.7) | 4.28 (17.3) | 4.08 (15.6) | 5.86 (33.6) | 66.2 | 75.9 | 16.34 |
| Clodinafop | 60 | 5.80 (32.7) | 4.79 (22.0) | 5.01 (24.1) | 7.06 (49.0) | 47.7 | 64.9 | 20.03 |
| Pinoxaden | 40 | 5.63 (30.7) | 4.93 (23.3) | 4.88 (22.9) | 7.23 (51.3) | 50.3 | 63.5 | 19.33 |
| Sulfosulfuron | 25+S | 4.85 (22.7) | 4.36 (18.0) | 4.26 (17.1) | 5.89 (33.8) | 72.1 | 75.8 | 13.70 |
| Clodinafop+ Metribuzin | 60 + 210 | 3.32 (10.0) | 2.99 (8.0) | 2.90 (7.5) | 4.03 (15.3) | 83.7 | 89.1 | 4.57 |
| Pinoxaden+ Metribuzin | 40 + 210 | 3.40 (10.7) | 2.65 (6.3) | 2.95 (7.8) | 3.83 (14.0) | 83.1 | 89.9 | 4.21 |
| Sulfosulfuron +Metribuzin | 25 + 210+S | 2.94 (7.7) | 2.63 (6.0) | 2.92 (7.6) | 3.53 (11.6) | 83.5 | 91.8 | 1.58 |
| Accord Plus (Fenoxaprop+Metribuzin) | 120 + 210 | 3.87 (14.0) | 3.21 (9.3) | 3.56 (11.7) | 4.60 (20.3) | 74.6 | 85.6 | 7.38 |
| Total (Sulfosulfuron+metsulfuron) | 32+S | 2.94 (7.7) | 2.63 (6.0) | 2.78 (6.7) | 3.40 (10.6) | 85.8 | 92.4 | 1.05 |
| Atlantis (Mesosulfuron+Iodosulfuron) | 14.4+S | 3.50 (11.3) | 2.68 (6.3) | 3.28 (9.8) | 4.04 (15.7) | 78.7 | 88.7 | 6.15 |
| Vesta (Clodinafop+metsulfuron) | 60+4+S | 3.46 (11.3) | 3.08 (8.7) | 2.96 (8.0) | 4.06 (15.8) | 82.6 | 88.8 | 5.97 |
| Isoproturon+2,4-D | 1000 + 500 | 3.70 (12.7) | 3.32 (10.0) | 3.40 (10.6) | 4.76 (21.6) | 77.0 | 84.5 | 7.73 |
| Weedy check | - | 9.57 (90.7) | 8.42 (70.3) | 6.86 (46.1) | 11.90 (140.7) | | | 35.0 |
| Weed free | - | 1.00 (0.0) | 1.00 (0.0) | 1.00 (0.0) | 1.00 (0.0) | 100 | 100 | |
| SE (m)± | | 0.19 | 0.23 | 0.14 | 0.25 | | | |
| CD at 5% | | 0.56 | 0.68 | 0.42 | 0.73 | | | |

Surfactant for Sulfosulfuron is 1250 $mlha^{-1}$ and 500 $mlha^{-1}$ for Atlantis.
Original values given in parenthesis were square root transformed for statistical analysis.

**Effect on crop**

**Effective tillers $m^{-2}$**

The effective tillers were significantly influenced by weed control treatments during both the years (Table 2). Pooled mean of two years revealed that maximum effective tillers were found in weed free treatment (459) which was statistically at par with all tank mixed herbicides but significantly superior over individual application of herbicide and weedy check. Among the herbicides, the highest effective tillers $m^{-2}$ were recorded in tank mixture of sulfosulfuron + metsulfuron (450) followed by sulfosulfuron + metribuzin (446). The lowest number of productive tillers was recorded in weedy check (346). Mahmood *et al*. (2013) [12] reported that the increase in number of tillers, 1000-grain weight, number of grains $spike^{-1}$ by herbicides may be attributed to better weed control and elimination of weed crop competition for nutrients, moisture and light and better utilization of available resources by the crop.

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

| Treatments | | Effective Tillers $m^{-2}$ | | | Grains $spike^{-1}$ | | | 1000-grain weight (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Herbicide | Herbicide Dose (g/ha) | 2011-12 | 2012-13 | pooled | 2011-12 | 2012-13 | pooled | 2011-12 | 2012-13 | pooled |
| Metribuzin | 210 | 383 | 396 | 390 | 33.9 | 27.7 | 30.8 | 41.1 | 38.1 | 39.6 |
| Clodinafop | 60 | 376 | 386 | 381 | 32.5 | 27.6 | 30.0 | 41.6 | 37.8 | 39.7 |
| Pinoxaden | 40 | 378 | 394 | 386 | 34.2 | 28.6 | 31.4 | 40.1 | 35.8 | 38.0 |
| Sulfosulfuron | 25+S | 402 | 394 | 398 | 34.2 | 27.9 | 31.0 | 41.6 | 37.6 | 39.6 |
| Clodinafop+ Metribuzin | 60 + 210 | 440 | 441 | 441 | 33.9 | 26.3 | 30.1 | 41.9 | 39.8 | 40.8 |
| Pinoxaden+ Metribuzin | 40 + 210 | 444 | 431 | 437 | 34.3 | 27.2 | 30.8 | 41.6 | 39.2 | 40.4 |
| Sulfosulfuron +Metribuzin | 25 + 210+S | 450 | 442 | 446 | 34.0 | 27.2 | 30.6 | 41.9 | 39.9 | 40.9 |
| Accord Plus (Fenoxaprop+Metribuzin) | 120 + 210 | 433 | 412 | 423 | 34.0 | 27.6 | 30.8 | 41.9 | 38.6 | 40.3 |
| Total (Sulfosulfuron+metsulfuron) | 32+S | 452 | 449 | 450 | 33.9 | 26.7 | 30.3 | 42.0 | 40.4 | 41.2 |
| Atlantis (Mesosulfuron+Iodosulfuron) | 14.4+S | 435 | 434 | 435 | 34.0 | 26.4 | 30.2 | 41.9 | 39.1 | 40.5 |
| Vesta (Clodinafop+metsulfuron) | 60+4+S | 422 | 443 | 433 | 34.7 | 26.2 | 30.4 | 41.4 | 40.3 | 40.8 |
| Isoproturon+2,4-D | 1000 + 500 | 425 | 423 | 424 | 34.4 | 26.9 | 30.7 | 41.6 | 38.9 | 40.3 |
| Weedy check | - | 332 | 360 | 346 | 32.0 | 27.4 | 29.7 | 39.0 | 33.2 | 36.1 |
| Weed free | - | 454 | 464 | 459 | 33.8 | 26.7 | 30.3 | 42.2 | 40.3 | 41.2 |
| SE (m)± | | 16 | 18 | 12.7 | 0.94 | 1.32 | 0.66 | 0.73 | 1.19 | 0.74 |
| CD at 5% | | 45 | 53 | 37.1 | 2.74 | 3.84 | NS | 2.11 | 3.45 | 2.15 |

**Grains $spike^{-1}$**

Number of grains $spike^{-1}$ is another important component of grain yield (Table 2). Pooled mean of two years indicated that grains $spike^{-1}$ was not influenced by different weed control treatments. Although maximum and minimum number of grains $spike^{-1}$ recorded with individual application of pinoxaden (31.4) and weedy check (29.7), respectively. All herbicidal treatment possesses numerically higher number of grains $spike^{-1}$ than weedy check. Mahmood *et al*. (2013) [!2] reported that the increase in number of grains $spike^{-1}$ may be attributed to better weed control and elimination of weed crop competition for nutrients, moisture and light and better utilization of available resources by the crop.

**1000-grain weight (g)**

The analysis of the data showed that the different treatments significantly affected 1000-grain weight (Table 2). Pooled data mean of 2011-12 and 2012-13 resulted that maximum 1000-grain weight recorded in weed free treatment (41.2 g), which were statistically at par with all herbicide treatments except individual application of pinoxaden and weedy check. The lowest 1000 grain weight was recorded in weedy check (36.1 g). Among the herbicidal treatment maximum 1000-grain weight was recorded by tank mixture of sulfosulfuron + metsulfuron @ 32 g/ha (41.2 g) followed by sulfosulfuron + metribuzin (40.9 g), clodinafop + metribuzin (40.8 g). These results are corroborated with the results of Singh *et al*. (2015) [24] who concluded that maximum 1000-grain weight was recorded in those plots which were treated with the mixture of herbicides while minimum in weedy check plots. Chhokar *et al*. (2015) have also reported that herbicide treated plots given higher 1000-grain weight than the weedy check plots.

**Grain yield ($qha^{-1}$)**

Different herbicidal treatments had a significant effect on the grain yield during both the years of study (Table 3). Perusal of the data exhibited that the maximum grain yield was recorded in weed free treatment (64.7 and 49.1 $qha^{-1}$), which was very near about to tank mix application of sulfosulfuron + metsulfuron (64.2 and 48.4 $qha^{-1}$) during 2011-12 and 2012-13, respectively. Among the herbicides treatments, tank mix application of sulfosulfuron + metsulfuron @ 32 g/ha produced significantly higher grain yield than individual application of different herbicide and weedy check but statistically at par with other tank mixed herbicides during both years. Minimum grain yield was recorded in weedy check plots (41.4 and 32.6 $qha^{-1}$), which was significantly lower to all herbicidal treatments. Presence of weeds throughout the growing season brought about 36.0 and 33.6% reduction in grain yield as compared to weed free during 2011-12 and 2012-13, respectively. Similar findings were reported by Sheoran *et al*. (2013) and Singh *et al*. (2015) [24] who concluded that herbicide application and hand weeding increased grain yield of wheat as compared to weedy check. Meena and Singh (2013) [17] and Tomar and Tomar (2014) [27] recorded higher grain yield with tank-mix application of herbicides over their alone application. Increased grain yield in herbicide mixture (sulfosulfuron + metsulfuron) could be ascribed to poor weed growth, weed dry matter and more number of grains $spike^{-1}$ and test weight when compared with alone application of sulfosulfuron and untreated treatment. Kumari *et al*. (2013) [11] reported that ready-mix application of sulfosulfuron + metsulfuron at 32 g/ha produced the highest grain yield (6.42 t/ha) among different herbicide treatment. Yadav *et al*. (2009b) [31] also observed that sulfosulfuron + metsulfuron and sulfosulfuron *fb* metsulfuron reduced the density and dry weight of *P. minor* and it was as good as weed-free check in respect of effective tillers and grain yield of wheat. No phytotoxicity of sulfosulfuron + metsulfuron was observed on any wheat variety with x (32 g/ha) and 2x (64 g/ha) doses (Punia *et al*., 2013) [22]. Yadav *et al*. (2010) [30] supports superiority of herbicide mixture over their alone application in improving wheat yield components and yield. Malekian *et al*. (2013) [13] also reported that post emergence application of sulfosulfuron + metsulfuron was found to be the best treatment in reducing dry weed biomass and producing more biological as well as grain yield. Enhanced grain yield in herbicide treated plots might be due to availability of more nutrients, light, moisture and space resulting in better crop growth (Mahmood *et al*., 2013) [12]. The grain yield was negatively associated with total weed density, weeds biomass and positively associated with number of tillers $m^{-2}$, no. of grains/earhead and test weight. Therefore, weeds in weedy check reduced the grain yield of wheat. More yields in herbicide treated plot might be due to effective control of weeds, less crop weed competition throughout the crop growth period which resulted in improved growth parameters of the crop (Singh *et al*., 2015) [24].

**Table 3:** Effect of weed control treatments on grain yield and harvest index of wheat

| Treatments | | Grain Yield (qha$^{-1}$) | | | Biological Yield (qha$^{-1}$) | | | Harvest Index (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Herbicide** | **Herbicide Dose (g/ha)** | **2011-12** | **2012-13** | **pooled** | **2011-12** | **2012-13** | **pooled** | **2011-12** | **2012-13** | **pooled** |
| Metribuzin | 210 | 53.5 | 41.7 | 47.6 | 134.7 | 118.9 | 126.8 | 39.7 | 35.1 | 37.4 |
| Clodinafop | 60 | 50.8 | 40.2 | 45.5 | 128.1 | 113.7 | 120.9 | 39.8 | 35.3 | 37.5 |
| Pinoxaden | 40 | 51.9 | 39.9 | 45.9 | 128.9 | 105.2 | 117.1 | 40.3 | 38.2 | 39.2 |
| Sulfosulfuron | 25+S | 57.1 | 41.2 | 49.1 | 140.3 | 103.8 | 122.1 | 40.7 | 39.8 | 40.2 |
| Clodinafop+ Metribuzin | 60 + 210 | 62.4 | 46.3 | 54.3 | 152.3 | 130.2 | 141.3 | 40.9 | 35.5 | 38.2 |
| Pinoxaden+ Metribuzin | 40 + 210 | 63.2 | 45.8 | 54.5 | 154.0 | 120.8 | 137.4 | 41.1 | 37.9 | 39.5 |
| Sulfosulfuron +Metribuzin | 25 + 210+S | 64.1 | 47.8 | 56.0 | 155.3 | 125.9 | 140.6 | 41.3 | 38.1 | 39.7 |
| Accord Plus (Fenoxaprop+Metribuzin) | 120 + 210 | 61.6 | 43.8 | 52.7 | 152.3 | 116.3 | 134.3 | 40.5 | 37.7 | 39.1 |
| Total (Sulfosulfuron+metsulfuron) | 32+S | 64.2 | 48.4 | 56.3 | 154.6 | 138.9 | 146.8 | 41.8 | 34.9 | 38.2 |
| Atlantis (Mesosulfuron+Iodosulfuron) | 14.4+S | 61.9 | 44.8 | 53.4 | 151.0 | 116.3 | 133.7 | 41.0 | 38.6 | 39.8 |
| Vesta (Clodinafop+metsulfuron) | 60+4+S | 60.4 | 46.7 | 53.5 | 147.9 | 129.3 | 138.6 | 40.8 | 36.2 | 38.5 |
| Isoproturon+2,4-D | 1000 + 500 | 60.7 | 44.3 | 52.5 | 148.5 | 118.7 | 133.6 | 40.9 | 37.4 | 39.1 |
| Weedy check | - | 41.4 | 32.6 | 37.0 | 105.9 | 94.0 | 99.9 | 39.2 | 34.7 | 37.0 |
| Weed free | - | 64.7 | 49.1 | 56.9 | 155.0 | 138.8 | 146.9 | 41.8 | 35.4 | 38.6 |
| SE (m)± | | 2.04 | 1.75 | 1.32 | 5.78 | 5.38 | 3.82 | 0.56 | 1.22 | 0.71 |
| CD at 5% | | 5.96 | 5.11 | 3.85 | 16.89 | 15.72 | 11.16 | NS | NS | NS |

**Biological yield (qha$^{-1}$)**

Different herbicidal treatments had a significant effect on the biological yield during 2011-12 and 2012-13 (Table 3). Pooled analysis resulted that maximum biological yield was recorded in weed free (146.9 qha$^{-1}$) followed by sulfosulfuron + metsulfuron (146.8 qha$^{-1}$) and minimum biological yield was recorded in weedy check (99.9 qha$^{-1}$). Increased biological yield in all herbicidal treatment was due to poor weed growth, weed dry matter and more number of grains spike$^{-1}$ and test weight as compared to weedy check. Malekian *et al*. (2013) [13] also reported that post emergence application of sulfosulfuron + metsulfuron was found to be the best treatment in reducing dry weed biomass and producing more biological yield. Enhanced biological yield in herbicide treated plots might be due to availability of more nutrients, light, moisture and space resulting in better crop growth (Mahmood *et al*., 2013) [12].

**Harvest index (%)**

Harvest index was not affected significantly by different weed control treatment (Table 3). However, individual application of sulfosulfuron perform numerically higher harvest index (40.2%) indicate its better assimilate partitioning efficiency (source sink). Minimum harvest index was recorded in weedy check (37.0%). The numerically increase in harvest index with weed control practices may be attributed to suppression of weed growth resulting in more availability of plant nutrients, soil moisture and space to wheat crop, which favored utilization of photosynthates for better grain formation (Amare *et al*., 2016) [1].

**Weed index (%)**

Weed index was minimum under sulfosulfuron + metsulfuron (1.05%), followed by sulfosulfuron + metribuzin (1.58%) and maximum under weedy check (35%). Higher weed control efficiency with lower weed index under sulfosulfuron + metsulfuron @ 32 g/ha applied plots were due to effective control of weeds as evident from lower weed population than other treatments.

**Conclusion**

Amongst herbicides the tank mixture of sulfosulfuron+metsulfuron @ 32 g/ha gave significantly higher grain yield than alone application of herbicides but statistically at par with other tank mixed herbicides application because of reduced weed density, dry matter of weed, lower weed index and higher yield attributes and weed control efficiency. It can be concluded that herbicide mixtures gave better results as compared with individually applied herbicides. Presence of weeds throughout the growing season brought about 36.0 and 33.6% reduction in grain yield as compared to weed free during 2011-12 and 2012-13, respectively.

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