4. EXPERIMENTAL RESULTS

The result of field experiment entitled “Bio-efficacy of Herbicidal Weed Control on Production Potential of Wheat (Triticum aestivum L.)”, conducted at instructional farm, Rajasthan College of Agriculture, Udaipur during Rabi 2014-15 is presented in this chapter. The data pertaining to the effects of different treatments on weeds and crop were statically analyzed and after evaluated them for test of significance, observed results have been presented in this chapter with the help of suitable tables and graphs. Analyses of variance for the data have been presented in these appendices at the end.

4.1 Weed studies

4.1.1 Weed density

4.1.1.1 At 30 DAS (before herbicides spray)

An assessment of the data (Table 4.1) reveals a homogeneous population of broadleaf, grassy and their total density were observed in the experimental plots. The density of both the categories of weeds (broadleaf and grassy) as well as the total weed density did not show any significant effect at this stage of observation.

4.1.1.2 At 60 DAS

Broadleaf weeds

Data presented in (Table 4.1) revealed that all the individual herbicides and their mixture tended to reduce the density of broadleaf weeds at 60 DAS. Amongst various weed control treatments mixture applied of herbicides observed lower in density of broadleaf weeds as compared to their applied alone. The minimum density of broadleaf weeds was observed in the plots treated with metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (2.32 m\(^2\)), however, the result was found at par with all other mixtures except 2,4-D 0.25 kg ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (3.01 m\(^2\)). Amongst sole applied herbicides the lowest density of broadleaf weeds was observed under the influence of metsulfuron 4 g ha\(^{-1}\) (3.13 m\(^2\)), which was significantly greater than other herbicides.

Grassy weeds

An assessment of data (Table 4.1) indicates that all the weed control treatments except 2,4-D 0.5 kg ha\(^{-1}\) and metsulfuron 4 g ha\(^{-1}\) significantly reduced density of grassy weeds as
against weedy check at 60 DAS. All the herbicide mixtures and sole applied of isoproturon 1.0 kg ha\textsuperscript{-1} and sulfosulfuron 25 g ha\textsuperscript{-1} were found at par and significantly superior over sole applied of 2,4-D 0.5 kg ha\textsuperscript{-1} and metsulfuron 4 g ha\textsuperscript{-1}. The lowest density of grassy weeds was observed in the plots treated with mixtures of metsulfuron 3 g ha\textsuperscript{-1} + isoproturon 0.75 kg ha\textsuperscript{-1} (3.12 m\textsuperscript{2}). Amongst sole applied of herbicides, the lowest density of grassy weeds (3.48 m\textsuperscript{2}) observed in plot treated by sulfosulfuron 25 g ha\textsuperscript{-1} closely followed by isoproturon 1.0 kg ha\textsuperscript{-1} (3.58 m\textsuperscript{2}) whereas, 2,4-D 0.5 kg ha\textsuperscript{-1} and metsulfuron 4 g ha\textsuperscript{-1} failed to reduce density of grassy weeds as compared to weedy check.

**Total weeds**

All herbicide and their tank mixtures under test were significantly superior over weedy check in term of reduction in total weed density at 60 DAS. A clear trend emerged with the mixtures performing better than herbicides applied alone. The lowest density of total weeds (4.12 m\textsuperscript{2}) was recorded in plot treated by metsulfuron 3 g ha\textsuperscript{-1} + sulfosulfuron 20 g ha\textsuperscript{-1}, however, it result was at par with all other mixtures and significantly lower than their herbicides when applied alone. Amongst the herbicides when applied alone, post emergence application of sulfosulfuron 25 g ha\textsuperscript{-1} and isoproturon 1.0 kg ha\textsuperscript{-1} resulted significant reduction in higher order in compared to 2,4-D 0.5 kg ha\textsuperscript{-1} and metsulfuron 4 g ha\textsuperscript{-1} (Table 4.1).

**4.1.1.3 At 90 DAS**

**Broadleaf weeds**

Data in Table 4.2 indicate that all the weed control treatments significantly reduced the density of broadleaf weeds as compared to weedy check. The data further indicate the minimum density of broadleaf weeds (3.09 m\textsuperscript{2}) was recorded under the plot treated by metsulfuron 3 g ha\textsuperscript{-1} + sulfosulfuron 20 g ha\textsuperscript{-1}, which was found at par with metsulfuron 3 g ha\textsuperscript{-1} + isoproturon 075 kg ha\textsuperscript{-1} (3.71 m\textsuperscript{2}). Whereas, mixture applied of 2,4-D 0.25 kg ha\textsuperscript{-1} + isoproturon 0.75 kg ha\textsuperscript{-1} and metsulfuron alone were statistically at par (3.81 m\textsuperscript{2}) closely followed by 2,4-D 0.25 kg ha\textsuperscript{-1} + sulfosulfuron 20 g ha\textsuperscript{-1} (3.94 m\textsuperscript{2}). Amongst various weed control treatments mixture applied of herbicides tended to have lower weed density od broadleaf weeds as compared to single applied ones.

**Grassy weeds**

Compared to weedy check, all the herbicide mixtures and their sole applied sulfosulfuron 25 g ha\textsuperscript{-1} and isoproturon 1.0 kg ha\textsuperscript{-1} tended to significantly reduce the density of
grassy weeds at 90 DAS. The minimum density of grassy weeds (3.11 m²) was recorded in plot treated with metsulfuron 3 g ha⁻¹ + sulfosulfuron 20 g ha⁻¹ closely followed by sulfosulfuron 25 g ha⁻¹ (3.15 m²) and metsulfuron 3 g ha⁻¹ + isoproturon 0.75 kg ha⁻¹ (3.18 m²). However, its results were at par with rest of the treatments except sole applied metsulfuron 4 g ha⁻¹ (6.86 m²) and 2,4-D 0.5 kg ha⁻¹ (6.87 m²) (Table 4.2).

**Total weeds**

An assessment of data (Table 4.2) indicates that all the weed control treatments significantly reduced density of total weeds at 90 DAS as compared to weedy check. The data further indicate that the minimum of total weeds (4.34 m²) was recorded in plot treated by metsulfuron 3 g ha⁻¹ + sulfosulfuron 20 g ha⁻¹, however, it result was at par with all other mixtures except 2,4-D 0.25 kg ha⁻¹ + sulfosulfuron 20 g ha⁻¹ (5.17 m²). Amongst sole applied of herbicides the lowest weed density of total weeds (5.75 m²) which was found at par with isoproturon 1.0 kg ha⁻¹. Whereas, applied of metsulfuron 4 g ha⁻¹ and 2,4-D 0.5 kg ha⁻¹ were at par and lagged behind in density of total weeds as compared to other treatments.

**4.1.1.4 At harvest**

**Broadleaf weeds**

Data in Table 4.2 indicate that all the weed control treatments significantly reduced the density of broadleaf weeds at harvest as compared to weedy check. The data further indicate that mixture applied herbicides tended to have lower density of broadleaf weeds as compared to their herbicides when applied alone. The lowest density of broadleaf weeds (2.96 m²) was recorded in plot treated by metsulfuron 3 g ha⁻¹ + sulfosulfuron 20 g ha⁻¹. However, it result was found at par with all other mixtures and sole applied metsulfuron 4 g ha⁻¹ (3.32 m²). Amongst sole applied of herbicides, the density of broadleaf weeds reduction under the influence of metsulfuron 4 g ha⁻¹ (3.32 m²) was significantly greater than other herbicides in this regard under test.

**Grassy weeds**

An assessment of data (Table 4.2) reveals that mixture and sole applied of isoproturon and sulfosulfuron significantly reduced the density of grassy weeds at harvest as compared to weedy check. The per cent reduction in density of grassy weeds due to affected of herbicides mixture range from 50.08 to 54.06 under different treatments as compared to weedy check.
Data further indicate that sole applied of metsulfuron 4 g ha\(^{-1}\) (7.11 m\(^{2}\)) and 2,4-D 0.5 kg h\(^{-1}\) (7.19 m\(^{2}\)) failed to reduce density of grassy weed at harvest over weedy check (7.38 m\(^{2}\)).

**Total weeds**

Data presented in (Table 4.2) revealed that all the weed control treatments significantly reduced the total density of weeds at harvest as compared to weedy check. The lowest density of total weeds (4.63 m\(^{2}\)) was recorded in plot treated by metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\). However, it result was found at par with all other mixture and significantly lower than single applied ones. Amongst sole applied of herbicides the lowest density of total weeds was recorded in plot treated by sulfosulfuron 25 g ha\(^{-1}\) (5.67 m\(^{2}\)) closely followed by isoproturon 1.0 kg ha\(^{-1}\) (5.97 m\(^{2}\)). Whereas, metsulfuron 4 g ha\(^{-1}\) and 2,4-D lagged behind in the significance in respect of total weed density at harvest.

**4.1.2 Weed dry matter**

**4.1.2.1 At 30 DAS (before herbicide spray)**

Uniform dry matter with non significant effect of broadleaf weeds, grassy weeds as well as total weeds was recorded under different treatments as evident from Table 4.3 and fig 4.1.

**4.1.2.2 At 60 DAS**

**Broadleaf weeds**

Table 4.3 and fig 4.2 revealed that all the weed management treatments significantly reduced the dry matter of broadleaf weeds at 60 DAS over weedy check. The lowest dry matter of broadleaf weeds recorded under the influence of metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (1.43 g m\(^{2}\)) closely followed by metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (1.54 g m\(^{2}\)). However, it results were found at par with all other mixtures and sole applied of metsulfuron 4 g ha\(^{-1}\) (1.62 g m\(^{2}\)) and 2,4-D 0.5 kg ha\(^{-1}\) (1.78 g m\(^{2}\)). Whereas, sole applied of isoproturon 1.0 kg ha\(^{-1}\) (2.91 g m\(^{2}\)) and sulfosulfuron 25 g ha\(^{-1}\) (3.12 g m\(^{2}\)) lagged behind in respect of dry matter of broadleaf weeds under test. Amongst various weed control treatments mixture applied of herbicides tended to have lower dry matter of broadleaf weeds as compared to these herbicides when applied alone. The per cent reduction in dry matter of broadleaf weeds varies from 21.21 to 63.88 under different treatments as compared to weedy check (3.96 g m\(^{2}\)).
Grassy weeds

An assessment of data (Table 4.3 and fig 4.2) indicates that except 2,4-D 0.5 kg ha\(^{-1}\) and metsulfuron 4 g ha\(^{-1}\) all the herbicidal weed control treatments significantly reduced dry matter of grassy weeds as compared weedy check. The lowest grassy weed dry matter accumulation (1.12 g m\(^{-2}\)) was recorded in plot treated by metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\). However, its result was found at par with all other mixtures and sole applied of sulfosulfuron 25 g ha\(^{-1}\) (1.34 g m\(^{-2}\)) and isoproturon (1.44 g m\(^{-2}\)). Whereas, sole application of 2,4-D 0.5 kg ha\(^{-1}\) (2.35 g m\(^{-2}\)) and metsulfuron 4 g ha\(^{-1}\) (2.36 g m\(^{-2}\)) failed to reduce dry matter of grassy weeds in comparison to weedy check (2.36 g m\(^{-2}\)).

Total weeds

In comparison to weedy check all the individual herbicides and their tank mixtures application under test resulted in significant decrease in total dry matter accumulation of weeds. The data revealed that the minimum dry matter (1.67 g m\(^{-2}\)) was found under the influence of metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) closely followed by metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (1.79 g m\(^{-2}\)). The next in the superiority were the mixtures comprising of 2,4-D 0.25 kg ha\(^{-1}\) with either sulfosulfuron 20 g ha\(^{-1}\) or isoproturon 0.75 kg ha\(^{-1}\) (1.89 g m\(^{-2}\) and 1.98 g m\(^{-2}\)). Amongst sole application of herbicides, the minimum dry matter of weeds was recorded under metsulfuron 4 g ha\(^{-1}\) (2.77 g m\(^{-2}\)) closely followed by 2,4-D 0.5 kg ha\(^{-1}\) (2.86 g m\(^{-2}\)) while isoproturon 1.0 kg ha\(^{-1}\) and sulfosulfuron lagged behind. All the mixtures were significantly superior to herbicides when they were applied alone and the per cent reduction in total dry matter of weeds varies from 37.28 to 63.37 under different treatments as compared to weedy check (Table 4.3 and fig 4.2).

4.1.2.3 At 90 DAS

Broadleaf weeds

A perusal of data present in Table 4.4 and Fig 4.3 revealed that all the individual herbicides and their tank mixtures significantly decreased in dry matter of broadleaf weed as compared to weedy check. All the mixtures were significantly superior to herbicides when they were applied alone. The minimum dry matter of broadleaf weeds was recorded in plots treated with metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (1.64 g m\(^{-2}\)), however, it effects was at par with all other mixtures but significant difference with these herbicides when applied alone. Amongst sole applied of herbicides, the lowest dry matter of broadleaf weeds was observed in
plots treated by metsulfuron 4 g ha\(^{-1}\) (2.04 g m\(^{-2}\)) which was closely followed by 2,4-D 0.5 kg ha\(^{-1}\) (2.23 g m\(^{-2}\)). Whereas, the effect of isoproturon 1.0 kg ha\(^{-1}\) and sulfosulfuron 25 g ha\(^{-1}\) were at par and lagged behind in this regard under test (Table 4.4 and fig 4.3)

**Grassy weeds**

Application of herbicide mixtures consisted of sulfosulfuron 25 g ha\(^{-1}\) and isoproturon 1.0 kg ha\(^{-1}\) resulted in significant drop down in dry matter of grassy weeds at 90 DAS. The data also indicated that the minimum grassy weeds dry matter (1.35 g m\(^{-2}\)) was obtained under plots treated with metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) closely followed by metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (1.38 g m\(^{-2}\)). However, its results were at par with 2,4-D 0.25 kg ha\(^{-1}\) + either sulfosulfuron 20 g ha\(^{-1}\) (1.46 g m\(^{-2}\)) or isoproturon 0.75 kg ha\(^{-1}\) (1.55 g m\(^{-2}\)) and sole applied sulfosulfuron 25 g ha\(^{-1}\) (1.59 g m\(^{-2}\)). Amongst sole application of herbicides, effect of sulfosulfuron 25 g ha\(^{-1}\) recorded the lowest dry matter of grassy weeds (1.59 g m\(^{-2}\)) closely followed by isoproturon 1.0 kg ha\(^{-1}\) (1.73 g m\(^{-2}\)). Whereas, 2,4-D 0.5 kg ha\(^{-1}\) (2.73 gm\(^{-2}\)) and metsulfuron 4 g ha\(^{-1}\) (2.74 g m\(^{-2}\)) applied individually failed to reduce the dry matter of grassy weeds as compared to weedy check (Table 4.4 and fig 4.3).

**Total weeds**

Data presented in (Table 4.4 and fig 4.3) revealed that all the individual herbicides and their tank mixtures under test resulted in significantly decreased in total weed dry matter as compared to weedy check. The lowest weed dry matter accumulation (2.01 g m\(^{-2}\)) was recorded under the influence of metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) closely followed by metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (2.09 g m\(^{-2}\)). However, its results were found at par with mixtures of 2,4-D 0.25 kg ha\(^{-1}\) + either sulfosulfuron 20 g ha\(^{-1}\) (2.21 g m\(^{-2}\)) or isoproturon 0.75 kg ha\(^{-1}\) (2.32 g m\(^{-2}\)). Amongst sole application of herbicides metsulfuron 4 g ha\(^{-1}\) recorded the minimum dry matter of total weeds (3.36 g m\(^{-2}\)) which was found at par with each other under test. Amongst various weed control treatments mixture applied of herbicides tended to have lower weed dry matter as compared to single applied ones.

**4.1.2.4 At harvest**

**Broadleaf weeds**

An assessment of the data (Table 4.4 and fig 4.4) revealed that all the herbicidal weed control treatments significantly reduced the dry matter of broadleaf weeds at harvest as
compared to weedy check. Overall the range of decrease was 40.66 to 73.19 per cent under different treatments in comparison to weedy check. The data further indicated that the lowest dry matter of broadleaf weeds recorded in plot treated by metsulfuron 3 g ha$^{-1}$ + sulfosulfuron 20 g ha$^{-1}$, which was found at par with all other mixture. Amongst sole applied of herbicides the lowest dry matter of broadleaf weeds (1.81 g m$^{-2}$) observed in plot treated by metsulfuron 4 g ha$^{-1}$, however, it was found at par with 2,4-D 0.5 kg ha$^{-1}$ (2.01 g m$^{-2}$). Whereas, isoproturon 1.0 kg ha$^{-1}$ and sulfosulfuron 25 g ha$^{-1}$ lagged behind in this regard under test.

**Grassy weeds**

The data explicitly indicate that all the weed management treatments significantly reduced the dry matter of grassy weeds in comparison to weedy check. data further indicate that the lowest dry matter accumulation of grassy weed was recorded in plot treated by metsulfuron 3 g ha$^{-1}$ + isoproturon 0.75 kg ha$^{-1}$ (1.43 g m$^{-2}$) closely followed by metsulfuron 3 g ha$^{-1}$ + sulfosulfuron 20 g ha$^{-1}$ (1.45 g m$^{-2}$). However, its results were at par with all other mixture and sole applied of sulfosulfuron 25 g ha$^{-1}$ (1.66 g m$^{-2}$) and isoproturon 1.0 kg ha$^{-1}$ (1.77 g m$^{-2}$). Whereas, sole applied metsulfuron 4 g ha$^{-1}$ (2.78 g m$^{-2}$) and 2,4-D 0.5 kg ha$^{-1}$ (2.80 g m$^{-2}$) lagged behind in this regard as compared to weedy check under test. Amongst various weed control treatments mixture applied of herbicides tended to give lower dry matter of grassy weed at harvest as compared to single applied ones (Table 4.4 and fig 4.4).

**Total weeds**

An assessment of the data (Table 4.4 and fig 4.4) showed that all the weed control treatments significantly reduced the total weed dry matter at harvest. The per cent reduction in dry matter of total weed varies from 43.38 to 69.22 as compared to weedy check under different treatments. The lowest dry matter of weed (1.93 g m$^{-2}$) was recorded when metsulfuron 3 g ha$^{-1}$ + sulfosulfuron 20 g ha$^{-1}$ were used and it was found at par with metsulfuron 3 g ha$^{-1}$ + isoproturon 0.75 kg ha$^{-1}$ (2.02 g m$^{-2}$) and all other mixture. Mixtures application of herbicides tended to have lower weed dry matter accumulation as compared to these herbicides when applied alone. Amongst sole applied herbicides, metsulfuron 4 g ha$^{-1}$ recorded the minimum weed dry matter accumulation (3.25 g m$^{-2}$), however, it was found at par with each other.
4.1.3 Weed control efficiency at harvest

**Broadleaf weeds**

A perusal of data (Table 4.5) reveals that application of various herbicides and their mixtures resulted in wide ranging weed control efficiency at harvest. The highest weed control efficiency of broadleaf weeds (94.16 per cent) was recorded under the influence of metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) followed by metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (92.84 per cent). All herbicides mixture including 2,4-D 0.5 kg ha\(^{-1}\) and metsulfuron 4 g ha\(^{-1}\) when applied alone tended to give higher weed control efficiency of broadleaf weed at harvest. Sulfosulfuron 25 g ha\(^{-1}\) and isoproturon 1.0 kg ha\(^{-1}\) were least effective in controlling broadleaf weeds, resulting poor in weed control efficiency of 65.85 and 69.60 per cent respectively.

**Grassy weeds**

The data (Table 4.5) reveals that all the herbicide mixtures and isoproturon 1.0 kg ha\(^{-1}\) and sulfosulfuron 25 g ha\(^{-1}\) when applied alone significantly increased the weed control efficiency of grassy weeds. Application mixtures of metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) gave highest weed control efficiency of grassy weed at harvest (84.02 per cent) closely followed by metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (84.44 per cent) as compared to weedy check. Sole applied 2,4-D 0.5 kg ha\(^{-1}\) and metsulfuron 4 g ha\(^{-1}\) failed to increase weed control efficiency of grassy weeds at harvest (26.28 and 25.86 per cent) as compared to weedy check.

**Total weeds**

An assessment of the data (Table 4.5) reveals that all the weed control through individual herbicides and their mixtures tended to increase weed control efficiency at harvest. Mixtures application of herbicides tended to give higher weed control efficiency as compared to single applied ones. The highest weed control efficiency (91.49 per cent) was recorded under the influence of metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) followed by metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (90.65 per cent) and other mixtures. While the minimum of weed control efficiency (68.67 per cent) under the influence of sulfosulfuron 25 g ha\(^{-1}\). Amongst various weed control treatments mixture applied of herbicides tended to have higher weed control efficiency as compared to individual herbicides when it was applied alone.
4.1.4 Weed index

An appraisal of data (Table 4.5) reveals that the highest weed index (33.60 per cent) was recorded under weedy check. Amongst the weed control treatments the lowest weed index (2.35 per cent) was recorded when metsulfuron 3 g ha$^{-1}$ + sulfosulfuron 20 g ha$^{-1}$ was applied followed by metsulfuron 3 g ha$^{-1}$ + isoproturon 0.75 kg ha$^{-1}$ (9.17 per cent). The individual applied of herbicides gave higher weed index viz. 22.77, 22.08, 21.05 and 20.75 per cent, respectively as compared to their mixtures.

4.1.5 Nutrient content in weed at harvest

4.1.5.1 Nitrogen content

Almost uniform nitrogen content with non significant effect of broadleaf weeds as well as grassy weeds was recorded under different treatments. However, it results range from 1.20 to 1.29 per cent in broadleaf weeds and from 0.96 to 1.08 per cent in grassy weeds under different treatments (Table 4.6).

4.1.5.2 Phosphorus content

An assessment of the data (Table 4.6) reveal that a homogeneous and non significant of phosphorus content in broadleaf weeds and grassy weeds recorded under different treatments. However, it results range from 0.298 to 0.338 per cent in broadleaf weeds and from 0.227 to 0.253 per cent in grassy weeds under different treatments.

4.1.6 Nutrient uptake by weeds at harvest

4.1.6.1 Nitrogen uptake

The data presented in (Table 4.7) reveal that all the weed control treatments significantly affected the uptake of nitrogen by broadleaf and grassy weeds as well as their total uptake as compared to weedy check. Data further indicate that all the herbicides mixture showed lower nitrogen uptake by weeds as compared to their individual application of herbicides. The lowest nitrogen uptake by weeds was recorded under the influence of metsulfuron 3 g ha$^{-1}$ + sulfosulfuron 20 g ha$^{-1}$ (0.34 kg ha$^{-1}$) closely followed by metsulfuron 3 g ha$^{-1}$ + isoproturon 0.75 kg ha$^{-1}$ (0.39 kg ha$^{-1}$). However, its results were at par with all other mixtures. Amongst sole application of herbicides, 2,4-D 0.5 kg ha$^{-1}$ showed the lowest of nitrogen uptake by weeds (1.14 kg ha$^{-1}$) as compared to weedy check (5.00 kg ha$^{-1}$). However, it results was at par with rest of the other treatments.
4.1.6.2 Phosphorus uptake

In comparison to weedy check, all the individual herbicides and their mixtures significantly reduced the phosphorus uptake by broadleaf and grassy weeds as well as the total weeds. The lowest phosphorus uptake by weeds (0.09 kg ha\(^{-1}\)) was recorded in the plots treated with metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\). However it was at par with all other mixtures. Amongst sole application of herbicides, the lowest phosphorus uptake by weeds (0.27 kg ha\(^{-1}\)) was recorded under plot treated with metsulfuron 4 g ha\(^{-1}\). However it was at par with rest of the treatments. Data further indicate that all the herbicide mixture showed lower of phosphorus uptake by weeds as compared to single applied ones.

4.2 CROP STUDIES

4.2.1 Plant population

4.2.1.1 At 30 DAS

An assessment of the data (Table 4.8) reveal that a homogeneous population of wheat crop was observed in the experimental plots and found non significant.

4.2.1.2 At harvest

An assessment of the data (Table 4.8) reveal a homogenous population of wheat crop was observed in the experimental plots. The plant population of wheat crop did not show any significant effect at this stage of observation.

4.2.2 Plant growth parameters

4.2.2.1 Plant height

4.2.2.1.1 At 30 DAS (before herbicide spray)

An assessment of data (Table 4.9) reveal that the plant height of wheat crop did not vary significantly at 30 DAS under various treatments because of this stage treatments were not applied.

4.2.2.1.2 At 60 DAS

An examination of data (Table 4.9) reveal that all the weed control treatments significantly improved the plant height as compared to weedy check. The maximum plant height (61.17 cm) was recorded under weed free treatment plots which was found at par with all other mixtures and statistically superior over weedy check. Amongst sole application of
herbicides, 2,4-D 0.5 kg ha\(^{-1}\) recorded maximum plant height (56.83 cm) closely followed by metsulfuron 4 g ha\(^{-1}\) (56.67 cm). However, its results were at par with isoproturon 1.0 kg ha\(^{-1}\) (55.83 cm) and sulfosulfuron 25 g ha\(^{-1}\) (55.17 cm). The per cent increase in plant height due to sole applied of herbicides ranges from 17.81 to 21.35 under different treatments as compared to weedy check. Amongst various weed control treatments, mixture applied of herbicides tended to have higher plant height as compared to individual herbicides when these applied alone.

4.2.2.1.3 At 90 DAS

The data (Table 4.9) show that all the weed control treatments including weed free significantly increased the plant height of wheat at 90 DAS as compared to weedy check. The data further indicated that mixture application of herbicides tended to have higher of wheat plant than individual herbicides when these applied alone. Out of weed free treatment (96.33 cm) the highest plant height was recorded under metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (94.50 cm) closely followed by metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (93.67 cm). However, its results were at par with rest of the treatments. The per cent increase in plant height ranges from 10.05 to 17.58 under different treatments as compared to weedy check.

4.2.2.1.4 At harvest

An assessment of data (Table 4.9) indicated statistical superiority of all the weed control treatments including weed free in respect of plant height at harvest. The per cent increase in plant height ranges from 14.17 to 23.42 under different treatment as compared to weedy check. Out of with free treatment (104.50 cm), metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) recorded the highest plant height (103.67 cm) closely followed by metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\). However, its results were at par with rest of the treatment but significant different in comparison to weedy check.

4.2.2.2 Dry matter accumulation by wheat crop

4.2.2.2.1 At 30 DAS

An examination of data (Table 4.10) reveal that weed control treatments could not significantly affect dry matter accumulation in wheat plant as observation was taken prior to application of weed control treatments.
4.2.2.2 At 60 DAS

A perusal of the data (Table 4.10 and Fig. 4.5) indicate that all weed control treatments except sole applied isoproturon 1.0 kg ha\(^{-1}\) significantly increased dry matter accumulation of wheat plants as compared to weedy check. After weed free (187.18 g m\(^{-1}\)) the maximum dry matter accumulation (185.93 g m\(^{-1}\)) was recorded in plots treated with metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (185.93 g m\(^{-1}\)) closely followed by metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (183.50 g m\(^{-1}\)). However, its results were at par to all other treatments except sole applied of isoproturon (158.40 g m\(^{-1}\)). The per cent increase in dry matter accumulation of wheat plant ranges from 12.47 to 32.01 under different treatments as compared to weedy check.

4.2.2.2.3 At 90 DAS

The data (Table 4.10 and Fig 4.5) reveal that all the weed control treatments except sole applied isoproturon 1.0 kg ha\(^{-1}\) significantly increased dry matter accumulation of wheat plants in comparison to weedy check. The data further indicate that all the herbicides mixtures tended to have higher dry matter accumulation of wheat as compared to single applied ones. After weed free (377.69 g m\(^{-1}\)) the maximum dry matter (374.56 g m\(^{-1}\)) was recorded under metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) followed by metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (367.86 g m\(^{-1}\)). However, its results were at par with all other treatment except sole applied of isoproturon (322.01 g m\(^{-1}\)). The per cent increase in wheat dry matter accumulation ranges from 12.68 to 31.07 under different treatments as compared to weedy check.

4.2.2.2.4 At harvest

Dry matter accumulation of wheat crop at harvest was significantly increased by all weed control treatments including weed free as compared to weedy check. After weed free (441.58 g m\(^{-1}\)) the highest plant dry matter accumulation was recorded under plots treated by metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (437.62 g m\(^{-1}\)), however, it results were at par with all the remaining treatments under test. The per cent increase in plant dry matter accumulation ranges from 32.35 to 49.99 under different treatments as compared to weedy check (Table 4.10 and Fig. 4.5)

4.2.3 Yield attributes

4.2.3.1 Effective tillers m\(^{-1}\) row length

An assessment of data (Table 4.11) indicate that all the weed control treatments significantly increased the effective tillers m\(^{-1}\) row length of wheat crop over weedy check. After weed free (126.67 m\(^{-1}\) row length), the highest effective tillers m\(^{-1}\) row length was observed under plots treated by metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (125.00 m\(^{-1}\) row
length) closely followed by metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (124.33 m\(^{-1}\) row length). However, its results were at par with rest of the treatments under test. Amongst various weed control treatments mixture applied of herbicides tended to give higher effective tiller m\(^{-1}\) row length than single applied ones. The per cent increase in effective tiller m\(^{-1}\) row length ranges from 18.26 to 29.31 under different treatments in comparison to weedy check.

### 4.2.3.2 Ear length (cm)

An assessment of data (Table 4.11) indicates that all the weed control treatments did not have any significant effect on ear length (cm) of wheat crop.

### 4.2.3.3 Grains ear\(^{-1}\)

Data (Table 4.11) show that all weed control treatments except sole applied of isoproturon 1.0 kg ha\(^{-1}\) and sulfosulfuron 25 g ha\(^{-1}\) significantly increased the number of grains per ear as compared to weedy check. After weed free (47.80), the highest number of grain ear\(^{-1}\) was recorded in plots treated with 2,4-D 0.25 kg ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (47.05), however, it was found at par with rest of the treatments except sole applied isoproturon (43.44) under test. The per cent increase in grain ear\(^{-1}\) varies from 5.74 to 14.53 under different treatments over weedy check.

### 4.2.3.4 1000 grain weight (g)

Data (Table 4.11) show that tank mixture applied of herbicides significantly increased the 1000 grain weight of wheat crop over un-weeded control. Whereas, sole applied of herbicides do not show any significant increase in 1000 grain weight of wheat crop as compared to weedy check. After weed free (48.17 g) the maximum 1000 grain weight (47.26 g) was recorded under metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) closely followed by 2,4-D 0.25 kg ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (46.64 g) and rest of the treatments under test. The per cent increase in 1000 grain weight ranges from 6.33 to 19.22 under different treatments in comparison to weedy check.

### 4.2.4 Yield and harvest index

#### 4.2.4.1 Grain yield (kg ha\(^{-1}\))

An examination of data (Table 4.12 and Fig. 4.6) reveal that all the weed control treatments tended to give higher grain yield as compared to weedy check. Data further indicate that tank mixture applied of herbicides significantly increased in grain yield of wheat crop as compared to weedy check, whereas, sole applied of herbicides do not show any significant increase in grain yield of wheat crop in comparison to weedy check. The per cent increase in
grain yield of wheat crop due to weed control treatments varies from 16.44 to 47.22 under different treatments over weedy check. After free weed (5350 kg ha\(^{-1}\)) the highest grain yield (5222 kg ha\(^{-1}\)) was recorded under metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\), it was found at par with all other mixtures of herbicides. Amongst sole application of herbicides sulfosulfuron 25 g ha\(^{-1}\) was recorded the highest grain yield (4240 kg ha\(^{-1}\)) followed by rest of the treatments under test.

4.2.4.2 Straw yield (kg ha\(^{-1}\))

It is clear from the data (Table 4.12 and Fig. 4.6) reveal that all the weed control treatments significantly increased straw yield of wheat crop as compared to weedy check. The data further indicate that the effect of all the herbicidal treatments were significantly superior over that of weedy check and all of these treatments including weed free are statistically at par in this regard. The highest straw yield of wheat crop was recorded under weed free treatment (7174 kg ha\(^{-1}\)) while the lowest was recorded under weedy check (5698 kg ha\(^{-1}\)). The increase in straw yield of wheat crop varies from 812 kg to 1476 kg under different treatments over weedy check.

4.2.4.3 Biological yield (kg ha\(^{-1}\))

Data (Table 4.12 and Fig 4.6) reveal that all the weed control treatments significantly increased the biological yield of wheat crop in comparison to un-controlled weeds. The per cent increase in biological yield of wheat crop ranges from 15.51 to 35.47 under different treatments over weedy check. After weed free treatment (12524 kg ha\(^{-1}\)) mixture applied metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) recorded the highest biological yield (12333 kg ha\(^{-1}\)). However, it results was at par with metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (11872 kg ha\(^{-1}\)) and significance different with rest of the treatments under test. Amongst sole applied of herbicides the highest biological yield (11039 kg ha\(^{-1}\)) was recorded in plots treated with sulfosulfuron 25 g ha\(^{-1}\), however, it was found at par with rest of the treatments under test.

4.2.4.4 Harvest index (%)

An appraisal of data (Table 4.12) reveal that individual herbicides and their tank mixtures including weed free treatment tended to give higher harvest index of wheat crop in comparison to weedy check. Data further indicate that tank mixture applied of herbicides significantly increased the harvest index of wheat crop as compared to weedy check, whereas, these herbicides do not show any significant increase in harvest index over weedy check when
applied alone. After weed free (42.76 %) the highest harvest index was recorded in plots treated with metsulfuron 3 g ha$^{-1}$ + sulfosulfuron 20 g ha$^{-1}$ (42.34 %), however, it results was found at par with all other mixtures under test. Amongst sole applied of herbicide the highest of harvest index was recorded under 2,4-D 0.5 kg ha$^{-1}$ (39.78 %) closely followed by rest of the treatments under test.

4.2.5 Biochemical analysis

4.2.5.1 Nutrient content in wheat crop

4.2.5.1.1 Nitrogen content

An assessment of the data (Table 4.13) reveal that all the weed control treatments could not significant affect of nitrogen content in grain as well as in straw of wheat crop. However, it results range from 1.74 to 1.85 per cent in grain and from 0.35 to 0.38 per cent in straw under different treatments.

4.2.5.1.2 Phosphorus content

An assessment of the data (Table 4.13) indicate that all the weed control treatments did not have any significant effect on phosphorus content in grain as well as in straw of wheat plant. However, it results range from 0.297 to 0.327 per cent in grain and from 0.203 to 0.227 per cent in straw under different treatments.

4.2.5.2 Nutrient uptake by wheat crop

4.2.5.2.1 Nitrogen uptake (kg ha$^{-1}$)

(i) Grain

An appraisal of the data (Table 4.14 and Fig. 4.7) show that mixture applied of herbicides recoded significant increase in nitrogen uptake by wheat grain as compared to weedy check, whereas, individual herbicides do not show any significant increase in nitrogen uptake by wheat grain in comparison over weedy check. Data further indicate that after weed free treatment (98.98 kg ha$^{-1}$) the highest of nitrogen uptake (96.16 kg ha$^{-1}$) was recorded in plots treated with metsulfuron 3 g ha$^{-1}$ + sulfosulfuron 20 g ha$^{-1}$. However, it results was found at par with all other mixtures except 2,4-D 0.25 kg ha$^{-1}$ + sulfosulfuron 20 g ha$^{-1}$ (80.21 kg ha$^{-1}$). The increase in nitrogen uptake by wheat grain ranges from 9.84 to 36.35 kg ha$^{-1}$ under different treatments including weed free as compared to weedy check.
(ii) Straw

In comparison to weedy check, all the weed control treatments significantly increased nitrogen uptake by wheat straw at harvest. The highest nitrogen uptake by wheat straw was recorded under metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (26.84 kg ha\(^{-1}\)), which was found at par with all other treatments except 2,4-D 0.5 kg ha\(^{-1}\) (22.26 kg ha\(^{-1}\)). The increase in nitrogen uptake by wheat straw ranges from 3.82 kg to 7.99 kg ha\(^{-1}\) under different treatments as compared to weedy check (Table 4.14 and Fig. 4.7).

(iii) Total

An assessment of data (Table 4.14 Fig. 4.7) reveal that all the herbicide mixtures including sole application sulfosulfuron 25 g ha\(^{-1}\) significantly increased nitrogen uptake in wheat crop at harvest as compared to weedy check. The maximum nitrogen uptake in wheat plant (125.41 kg ha\(^{-1}\)) was estimated under weed free closely followed by metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (122.99 kg ha\(^{-1}\)). However, its results were at par with mixtures of metsulfuron 3 g ha\(^{-1}\) + isoproturon 0.75 kg ha\(^{-1}\) (115.87 kg ha\(^{-1}\)). Amongst sole application of herbicides the highest nitrogen uptake by wheat plant was recorded under sulfosulfuron 25 g ha\(^{-1}\) (99.51 kg ha\(^{-1}\)) but it did not show any significance different with rest of the treatments and weedy check under test.

4.2.5.2.2 Phosphorus uptake (kg ha\(^{-1}\))

(i) Grain

Data (Table 4.14 and Fig. 4.8) show that all the herbicide mixtures except 2,4-D 0.25 kg ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) significantly increased phosphorus uptake by wheat grain in comparison over weedy check, whereas, sole applied of herbicides do not show any significant increase in nitrogen uptake by wheat grain as compared to weedy check. After weed free (17.47 kg ha\(^{-1}\)) the highest phosphorus uptake by wheat grain was estimated in plots treated with metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (16.18 kg ha\(^{-1}\)). However, it was found at par with all other mixtures. The increase in phosphorus uptake by wheat grain ranges from 1.85 to 6.83 kg ha\(^{-1}\) under different treatments including weed free as compared to weedy check.

(ii) Straw

An assessment of the data (Table 4.14 and Fig. 4.8) show that all the individual herbicides and their tank mixtures including weed free recorded significantly increased
phosphorus uptake by wheat straw in comparison over weedy check. The per cent increase in phosphorus uptake ranges from 18.94 to 41.22 under different treatments as compared to weedy check. After weed free (17.01 kg ha\(^{-1}\)) the highest phosphorus uptake by wheat straw was recorded under metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (15.21 kg ha\(^{-1}\)), which was found at par with all other mixtures and sole applied sulfosulfuron 25 g ha\(^{-1}\) (13.75 kg ha\(^{-1}\)). Amongst various weed control treatments, mixtures application of herbicides tended to have higher phosphorus uptake by wheat straw as compared to single applied ones.

(iii) Total

Data (Table 4.14 and Fig. 4.8) reveal that all the weed control treatments significantly increased phosphorus uptake by wheat plant in comparison to weedy check. Data further indicate that mixtures application of herbicides recoded higher of phosphorus uptake by wheat plant in comparison to single applied ones. After weed free treatment (34.48 kg ha\(^{-1}\)) mixtures applied metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (31.40 kg ha\(^{-1}\)) recorded the highest phosphorus uptake by wheat plant, however, it results was at par with all other mixtures except 2,4-D 0.25 kg ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (27.10 kg ha\(^{-1}\)). Amongst sole application of herbicides sulfosulfuron 25 g ha\(^{-1}\) recoded maximum phosphorus uptake by wheat plant (26.58 kg ha\(^{-1}\)), which was found at par with rest of the treatments under test.

4.2.5.3 Protein content in seed (%)

An examination of data (Table 4.15) reveal that all the weed control treatments could not show any significant increase protein content in wheat grain. The protein content in wheat grain ranges from a minimum of 10.90 per cent to maximum of 11.18 per cent under different treatments.

4.2.5.4 Protein yield (kg ha\(^{-1}\))

Data (Table 4.15) reveal individual and tank mixtures applied of herbicides tended to have higher protein yield in comparison to weedy check. The protein yield increase ranges from 66.24 to 208.7 kg ha\(^{-1}\) under different treatments including weed free as compared to weedy check. Data further indicate that tank mixture applied of herbicides significantly increased protein yield as compared to weedy check, whereas, sole applied of herbicides do not show any significant increase in protein yield over weedy check. After weed free treatment (595.40 kg ha\(^{-1}\)) the highest of protein yield was recorded in plots treated with metsulfuron 3 g
ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\) (581.37 kg ha\(^{-1}\)). However, it results was at par with all other mixtures and significantly superiority over rest of the treatments.

4.3 Economics

Data pertaining to net return and benefit cost ratio as influenced by different treatments are summarized in (Table 4.16).

4.3.1 Net returns

In comparison to wheat crop facing stress on account of un-controlled weeds, weed control through different herbicides and their mixtures including weed free enhance net returns of the experimentation. Amongst various weed control treatments isoproturon 1.0 kg ha\(^{-1}\) was least effective by giving the minimum net returns of ₹37695 ha\(^{-1}\) in comparison to weedy check (₹30908 ha\(^{-1}\)). The maximum net returns of ₹52603 ha\(^{-1}\) was recorded under metsulfuron 3 g ha\(^{-1}\) + sulfosulfuron 20 g ha\(^{-1}\), however, it results was found at par with all other mixtures including weed free treatment (₹52359 ha\(^{-1}\)) and significant superiority to rest of treatments under test. Amongst sole application of herbicides the highest net returns (₹39814 ha\(^{-1}\)) was recorded in plots treated with sulfosulfuron 25 g ha\(^{-1}\) which was found at par with each other but did not show significant difference as compared to weedy check (Table 4.16 and Fig. 4.9).

4.3.2 B-C ratio

Data presented in (Table 4.16) reveal that all the weed control treatments tended to give higher BC ratio than weedy check. The per cent increase in BC ratio ranges from 14.96 to 60.63 under different treatments as compared to weedy check. Data further indicate that mixture applied of metsulfuron 3 g ha\(^{-1}\) + either sulfosulfuron 20 g ha\(^{-1}\) (2.04) or isoproturon 0.75 kg ha\(^{-1}\) (1.85) significantly increased BC ratio as compared to weedy check. whereas, mixture of 2,4-D 0.25 kg ha\(^{-1}\) + either isoproturon 0.75 kg ha\(^{-1}\) (1.69) or sulfosulfuron 20 g ha\(^{-1}\) (1.60) and these herbicides when applied alone do not show any significant increase in BC ratio over weedy check. Amongst various weed control treatments mixture applied of herbicides tended to give higher BC ratio than single applies ones.