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# Bio-efficacy of promising post-emergence herbicides alone and in combination against major weeds in soybean

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**Abstract**
A field experiment was conducted during *Kharif* season of 2015 at Agriculture Research Station, Kasbe Digraj, Sangli, Mahatma Phule Agricultural University, Maharashtra, India. The dominant broad-leaved weeds in the field were *Commelina benghalensis*, *Acalypha indica*, *Digera arvensis*, *Parthenium hysterophorus*, *Amaranthus viridis* and *Euphorbia geniculata*. Grassy weeds were *Echinochloa colonum*, *Brachiaria reptans*, *Dinebra arabica*, *Digitaria longiflora* and *Cynadon dactylon* and *Cyperus rotundus* as sedge. Results revealed that, post-emergence application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ recorded significantly lower weed density and total weed dry weight at 45 DAS. Higher weed control efficiency (86.36%) was recorded with post-emergence application Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$. Post-emergence application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ recorded significantly higher seed yield (1776.00 kg $ha^{-1}$) and which was at a par with application of Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$ as post-emergence and weed free check with highest B:C ratio.

**Keywords:** Herbicides, fluazifop-p-butyl, fomesafen, imazethapyr, quizalofop-ethyl, soybean, weeds

## Introduction

Soybean (*Glycine max* L.) is mostly grown for oil (20%) and protein (40%) around the world. In India, it is cultivated over 10.84 million hectares area with a production and productivity of 14.68 million tones and 1.35 t $ha^{-1}$, respectively. In Maharashtra, it is grown over an area of 3.22 million hectares with a production and productivity of 4.67 million tones and 1.45 t $ha^{-1}$, respectively (Anonymous 2013) [2]. The national productivity of soybean (1.3 t $ha^{-1}$) is low as compared to world average 2.4 t $ha^{-1}$ (Agarwal *et al.* 2013) [1]. One of the major reasons for lower productivity is abiotic and biotic factors encountered during crop season. Weeds are the major biotic factor responsible for poor soybean yield. Weeds alone are responsible for reduction in seed yield of soybean to the range of 25 to 70% depending upon the weed flora and intensity. Therefore, it is important to keep the soybean crop weed free as far as possible, so as to get higher seed yield (Kewat *et al*. 2000) [7]. Malik *et al*. (2006) [9] have reported 55% soybean yield reduction with broad-leaved weeds (80%), grasses and sedges (20%) infestation throughout the crop season. Hand-weeding is a traditional and effective method of weed control, but it is time consuming and difficult due to unavailability of laborers during peak period of demand. Hence, the only alternative that needs to be explored is the use of herbicide. Farmers are mostly using pre-plant incorporated or pre-emergence herbicides for weed control in soybean, but their efficacy is reduced due to variation in climatic and edaphic factors (Singh *et al.* 2013) [12]. Newer molecules of post-emergence herbicides are promising for control of monocotyledonous or dicotyledonous weeds. Further, herbicide mixtures may broaden the window of weed management by broad spectrum weed control (Bineet *et al.* 2001) [3]. Therefore, the present investigation was initiated to assess bio-efficacy of post-emergence herbicides alone and in combination for effective management of weeds and higher productivity of soybean.

## Materials and Methods

A field experiment was conducted at Agriculture Research Station (ARS), Kasbe Digraj, Sangli, Mahatma Phule Agricultural University, Maharashtra, India during *Kharif* season of 2015.

Average rainfall of the station is 692.4 mm in 49 rainy days. The experiment was laid out in medium deep black soil (0 - 45 cm depth) which was low in available nitrogen (167 kg $ha^{-1}$) and phosphorus (11.50 kg $ha^{-1}$) content, and high in available potash content (632 kg $ha^{-1}$) with pH 8.27. The experiment consisted of eight treatments *viz.*, Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$ as PoE, Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ as PoE, Imazethapyr @ 100 g a.i. $ha^{-1}$ as PoE, Quizalofop-ethyl @ 75 g a.i. $ha^{-1}$ as PoE, Fluazifop-p-butyl @ 125 g a.i. $ha^{-1}$ as PoE, Fomesafen @ 175 g a.i. $ha^{-1}$ as PoE, weed free and a weedy check which were replicated thrice in a randomized block design. The gross and net plot size of the experiment were 5 m x 3.6 m and 4.5 x 2.7 m, respectively. Soybean seed (75 kg $ha^{-1}$) of variety *'KDS-344'* was sown on 01 July, 2015 at 45 x 5 cm spacing. Crop was applied with recommended dose of fertilizer i.e. 75:50:0 N: $P_2O_5$:$K_2O$ kg $ha^{-1}$. Before sowing, the seeds were treated with Carbendazim at 2.0 g $kg^{-1}$ of seed followed by inoculation with *Rhizobium japonicum* culture at 5 g $kg^{-1}$ of seed. All the herbicides were applied as post-emergence at 2-5 leaf stage of weed with knapsack sprayer fitted with flat-fan nozzle using 500 litres of water per hectare.

Data on species wise weed density at 45 days after sowing (DAS) was recorded using a quadrant of 1m × 1m from three random spots per plot and was reported as weed density ($m^{-2}$). The weeds were oven dried and total weed dry weight was recorded at 45 DAS and expressed as (g $m^{-2}$). Data of both weed density and total weed dry weight was analyzed statistically using suitable square root transformation. Weed control efficiency measures the efficiency of any weed control treatment in comparison to weedy treatment. To adjudge the efficiency of weed control treatments, weed control efficiency (WCE) was calculated (Das, 2008) [4] as follows:

$$\text{WCE (\%)} = \frac{\text{DWC-DWT}}{\text{DWC}} \times 100$$

(Where, WCE = Weed control efficiency in percent, DWC = Dry weight of weeds in control plot and DWT = Dry weight of weeds in treated plot)

Weed index is defined as the per cent reduction in the seed yield under a particular treatment due to the presence of weeds in comparison to the seed yield obtained in weed free plot as suggested by Gill and Kumar (1969) [5]. It is expressed in percentage and was determined with the help of following formula:

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

(Where, X = yield from weed free plot and Y = yield from treated plot)

Crop was harvested at physiological maturity on 18 October, 2015. After the harvest, threshing was done and seed yield of each treatment was recorded and expressed as kg $ha^{-1}$. The yield attributes *viz.*, number of pods $plants^{-1}$; number of seeds $pod^{-1}$ and 100 seed weight (g) were recorded. Gross returns, net returns as well as B:C ratio were worked out using prevailing prices of inputs and outputs. The data of each year was analyzed separately. MSTAT was used for statistical analysis of data and means were separated using critical difference (CD) at P=0.05.

## Results and Discussion

**Effect on weeds:** The experimental field at 45 days after sowing (DAS) was infested with broad-leaved weeds (46.12%). The predominant broad-leaved weeds in the field were *Commelina benghalensis*, *Acalypha indica*, *Digera arvensis*, *Parthenium hysterophorus*, *Amaranthus viridis* and *Euphorbia geniculata*. All the herbicide treatments caused significant reduction in broad-leaved weed density at 45 DAS as compared to weedy check. Application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ as post-emergence recorded significantly lower broad-leaved weed density compared to other herbicide treatments and was on-par with post-emergence application of Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$. Further, weedy check recorded significantly higher weed population of broad-leaved weeds (31.67 $m^{-2}$) at 45 DAS (Table 1).

The experimental field was infested with grassy weeds (38.34%) at 45 DAS. The predominant grassy weeds in field were *Echinochloa colonum*, *Brachiaria reptans*, *Dinebra arabica*, *Digitaria longiflora* and *Cynadon dactylon*. Among the different herbicide treatments, application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ as post-emergence recorded significantly lowest population of grassy weeds (7.67 $m^{-2}$) compared to other herbicide treatments and was on-par with post-emergence application of Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$. Highest population of grassy weeds (26.33 $m^{-2}$) was recorded in weedy check at 45 DAS.

**Table 1:** Effect of weed control treatments on weed density, total weed dry weight, weed control efficiency and weed index in soybean at 45 DAS

| Treatment | Weed density ($m^{-2}$) | | | Total weed dry weight (g $m^{-2}$) | WCE (%) | Weed index (%) |
|---|---|---|---|---|---|---|
| | Broad-leaved weeds | Grasses | Sedges | | | |
| $T_1$- Imazethapyr + Quizalofop-ethyl @ 175 g a.i./ha | 3.82 (13.67) | 3.26 (9.67) | 2.44 (5.00) | 4.18 (16.42) | 81.68 | 15.93 |
| $T_2$- Fluazifop-p-butyl + Fomesafen @ 300 g a.i./ha | 3.55 (11.67) | 2.94 (7.67) | 2.23 (4.00) | 3.63 (12.30) | 86.36 | 10.00 |
| $T_3$- Imazethapyr @ 100 g a.i./ha | 4.12 (16.00) | 4.57 (20.00) | 3.05 (8.33) | 4.65 (20.70) | 77.05 | 23.22 |
| $T_4$- Quizalofop-ethyl @ 75 g a.i./ha | 5.03 (24.33) | 3.64 (12.33) | 2.88 (7.33) | 5.83 (33.10) | 63.30 | 31.36 |
| $T_5$- Fluazifop-p-butyl @ 125 g a.i./ha | 4.72 (21.33) | 3.46 (11.00) | 2.57 (5.67) | 5.41 (28.40) | 68.51 | 28.81 |
| $T_6$- Fomesafen @ 175 g a.i./ha | 4.03 (15.33) | 4.43 (18.67) | 2.94 (7.67) | 4.82 (22.43) | 75.12 | 25.42 |
| $T_7$- Weed free | 1.00 (0.00) | 1.00 (0.00) | 1.00 (0.00) | 1.00 (0.00) | 100.00 | 0.00 |
| $T_8$- Weedy check | 5.71 (31.67) | 5.22 (26.33) | 3.41 (10.67) | 9.95 (90.18) | 0.00 | 56.27 |
| SEm ± | 0.11 | 0.15 | 0.10 | 0.18 | - | - |
| CD (P=0.05) | 0.34 | 0.46 | 0.29 | 0.55 | - | - |

Data in parentheses are original weed density and total weed dry weight values; Data was subjected to square root transformation ($\sqrt{x+1}$).
DAS: Days after sowing

The experimental field was infested with sedges (15.54%) at 45 DAS. Among the different herbicide treatments, post-emergence application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ and Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$ were found equally efficient in controlling the sedges in soybean. Weedy check recorded significantly higher sedges population (10.67 $m^{-2}$) as compared to other weed controlling treatments at 45 DAS. These results were in conformity with the findings of Singh *et al.* (2014) [11] who reported significantly lower weed density of grasses and non-grassy weeds with application of post-emergence herbicide Fluazifop-p-butyl + Fomesafen. Further, Prachand *et al.* (2015) [10] reported significantly lowest density of monocot and dicot weeds in soybean with post-emergence application of Imazethapyr 0.100 kg $ha^{-1}$ +Quizalofop-ethyl 0.075 kg $ha^{-1}$. Post-emergence application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ found to be significantly superior over rest of the herbicide treatments in controlling the weeds and recorded least total dry weight of weeds (12.30 g $m^{-2}$) at 45 DAS and was on-par with post-emergence application of Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$ (Table 1). Further, weedy check recorded significantly higher total dry weight of weeds (90.18 g $m^{-2}$) as compared to other weed control treatments. Among different herbicide treatments, application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ as post-emergence recorded highest weed control efficiency (86.36%) at 45 DAS and it was followed by post-emergence application of Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$. These results were in conformity with the findings of Singh *et al.* (2014) [11] and Thakare *et al.* (2015) [13]. Weed index indicates the reduction in yield due to weed competition as compared to the maximum attained seed yield. Lowest weed index (10.00%) was recorded with post-emergence application Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ followed by application of Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$ as post-emergence. The maximum weed index (56.27%) was recorded under weedy check where no weed management practices were applied ultimately caused reduction in seed yield. Similar results were also reported by Kushwah and Vyas (2005) [8] and Jha *et al.* (2014) [6].

**Yield attributes and economics:** Highest seed yield (1972.00 kg $ha^{-1}$) was recorded in weed free plot which was significantly higher over rest of the treatments and was on-par with post-emergence application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ and Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$ (Table 2). Singh *et al.* (2014) [11] reported significantly highest seed yield of soybean in weed free treatment and which was at par with application of Fluazifop-p-butyl + Fomesafen as post-emergence. The yield enhancement due to weed control treatments was to the tune of 56.98 to 128.68% over weedy check. The seed yield was increased with post-emergence application of Fluazifop-p-butyl + Fomesafen by 105.81% over weedy check. This might be due to effective control of weeds which reduced the competition of crop with weeds for space, air, sunlight, moisture and nutrients. Further, weedy check recorded significantly lowest seed yield (865.33 kg $ha^{-1}$) as compared to other weed control treatments.

**Table 2.** Yield attributes and economics of soybean as influenced by various treatments

| Treatment | Number of podsplant$^{-1}$ | Number of seeds pod$^{-1}$ | 100 seed weight (g) | Seed yield (kg ha$^{-1}$) | Gross returns (Rs. ha$^{-1}$) | B:C ratio |
|---|---|---|---|---|---|---|
| $T_1$- Imazethapyr + Quizalofop-ethyl @ 175 g a.i./ha | 47.67 | 3.33 | 13.29 | 1669.67 | 57641.81 | 2.33 |
| $T_2$- Fluazifop-p-butyl + Fomesafen @ 300 g a.i./ha | 49.00 | 3.67 | 13.63 | 1776.00 | 62049.12 | 2.52 |
| $T_3$- Imazethapyr @ 100 g a.i./ha | 45.33 | 3.33 | 12.31 | 1512.67 | 52548.00 | 2.18 |
| $T_4$- Quizalofop-ethyl @ 75 g a.i./ha | 38.33 | 3.33 | 12.60 | 1356.00 | 46807.20 | 1.93 |
| $T_5$- Fluazifop-p-butyl @ 125 g a.i./ha | 42.67 | 3.00 | 12.52 | 1403.33 | 48675.20 | 2.02 |
| $T_6$- Fomesafen @ 175 g a.i./ha | 44.67 | 3.33 | 12.90 | 1472.67 | 50946.13 | 2.11 |
| $T_7$- Weed free | 50.33 | 3.33 | 14.32 | 1972.00 | 69069.33 | 1.99 |
| $T_8$- Weedy check | 29.67 | 2.67 | 10.92 | 865.33 | 29240.00 | 1.28 |
| SEm ± | 1.41 | 0.32 | 0.42 | 111.79 | - | - |
| CD (P=0.05) | 4.27 | NS | 1.28 | 339.12 | - | - |

Number of pods plant$^{-1}$ was highest (50.33) in weed free plot and was on-par with post-emergence application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ and Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$. Lowest pods plant$^{-1}$ was recorded in weedy check plot. Number of seeds pod$^{-1}$ was not significantly different among treatments. 100 seed weight was highest (14.32 g) in weed free plot and was on-par with post-emergence application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ and Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$. Lowest 100 seed weight (g) was recorded in weedy check plot.

Maximum gross returns were realized under weed free check and it was followed by post-emergence application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ and Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$. However, among the different weed control treatments, post-emergence application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ recorded the highest B:C ratio (2.52) followed by application of Imazethapyr + Quizalofop-ethyl @ 175 g a.i. $ha^{-1}$ as post-emergence.

## Conclusion

It may be concluded that post-emergence application of Fluazifop-p-butyl + Fomesafen @ 300 g a.i. $ha^{-1}$ was found most effective for control of major weeds in soybean with higher yield and monetary returns.

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