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# Assessment of post-emergence weed management in direct-seeded rice

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## ABSTRACT

The present study was carried out at G.B. Pant University of Agriculture and Technology, Pantnagar during rainy seasons 2014 and 2015 to determine the efficacy of post-emergence application of cyhalofop-butyl in managing weeds in direct-seeded rice. Eight treatments, *viz*. cyhalofop-butyl 10% EC at 65, 75, 80 and 90 g/ha, cyhalofop-butyl 10% EC at 75 and 80 g/ha, hand weeding twice at 20 and 40 DAS and untreated control were laid out in a randomized block design with three replications. Application of cyhalofop-butyl controlled grassy weeds better than the non-grassy weeds and recorded maximum weed control efficiency, higher yield attributes and yield. Application of cyhalofop-butyl in rice did not show any phytotoxic effect on succeeding wheat.

**Key words:** Cyhalofop-butyl, Herbicide, Herbicide efficiency index, Weed control efficiency, Yield

Rice (*Oryza sativa*) is a major cereal crop and staple food for more than half of the world's population. About 90% of the world's rice is produced and consumed in Asia (FAO 2014). The world's total rice area is 168 Mha and production is about 722 M tons with the productivity of 4.29 t/ha (FAOSTAT 2012). Puddling for transplanted rice cause to dispersion of soil particles and consequent compaction of the soil and is labour intensive (Chauhan *et al.* 2012). The direct-seeded rice (DSR) cultivation, which does not need puddling and transplanting was found as feasible alternative to save water and labour (Ghosh *et al.* 2016). DSR is a cost effective rice establishment method where dry seed is drilled into the non-puddled soil. This provides opportunities of saving irrigation water by 12-35%, labor up to 60% and provides higher net returns (US$ 30-50/ha) with similar or slightly lower yield of rice (Kumar and Ladha 2011). Despite multiple benefits of dry DSR, weed control remains one of the major challenges for its success in South Asia (Kumar and Ladha 2011, Rao *et al*. 2007, Singh *et al*. 2008). Since the concept of aerobic rice is new (Belder *et al.* 2005) growing rice under aerobic conditions on raised beds or flat land would require suitable, effective and economic weed-control methods. Both pre-emergence and post-emergence herbicides can be used in aerobic rice fields and they are effective, if properly used (De Datta and Baltazar 1996, Singh *et al*. 2006). In spite of use of different chemicals as pre-emergence and post-emergence, certain weeds like *Leptochloa chinensis* and other grassy weeds are still not controlled. Hence, the present study was undertaken to determine the efficacy of cyhalofop-butyl as post-emergence application against grassy weeds in direct-seeded rice.

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## MATERIALS AND METHODS

The field experiment was conducted at GBPUA&T, Pantagar (29$^0$N latitude, 27.3$^0$E longitude and at an altitude of 243.8 m above the mean sea level) during the rainy season of 2014 and 2015. The climate of Pantnagar is very hot in summers and cold in winters. The hottest months are May and June, when the maximum temperature reaches 40$^0$C, whereas during December and January, the coldest month of the year, the minimum temperature often remains below 10$^0$C and may reach to 1$^0$C. The average rainfall is 1450 mm, 80% of which is received through the monsoon from June to September.

The experiment was laid out in a randomized block design with three replications. Eight treatment combinations were made up with different herbicides, hand weeding and weedy check as follows: Cyhalofop-butyl 10% EC at 65 g/ha, cyhalofop-butyl 10% EC at 75 g/ha, cyhalofop-butyl 10% EC at 80 g/ha, cyhalofop-butyl 10% EC at 90 g/ha, cyhalofop-butyl 10% EC (standard check) at 75 g/ha, cyhalofop-butyl 10% EC (std. check) at 80 g/ha, two hand weeding (20 and 40 days after sowing;

DAS) and weedy check. Herbicides were applied using a power operated knapsack sprayer fitted with a flat fan nozzle and water as a carrier at 500 liter/ha. In the weedy check, no weeding was done. For phytotoxicity study, cyhalofop-butyl 10% EC (std. check) was applied at 160 g/ha in direct-seeded rice. Rice ('*Sarjoo 52*') was seeded manually in line on 13th June, 2014 and 11th June, 2015 using seed rate of 50 kg/ha. Row to row spacing was 20 cm with continuous rice plants in a row. Thinning was done manually at 15 DAS to maintain plant population. Irrigation was applied in the field as per requirement. The soil was loamy, medium in organic matter (0.67%), available nitrogen (210 kg/ha), phosphorus (17.5 kg/ha) and potassium (181.2 kg/ha) with pH 7.5. Half of nitrogen, full dose of phosphorous and potash were applied as basal and remaining half of nitrogen was applied in two split doses first at active tillering and second at panicle initiation stage in all treatments. Observations were taken on density and biomass of weeds, weed control efficiency (WCE), herbicide efficiency index (HEI) and weed persistence index at 45 DAS by placing a quadrate of 0.25 $m^2$ at four randomly selected places. Removed weed flora was oven dried at $70^0C$ for 72 hours. Crop was harvested on October 27, 2014 and October 25, 2015 and left in the field for 5-7 days for sun drying. The number of panicles/$m^2$, grains/panicle, 1000 grain weight, grain yield, straw yield and grain straw ratio was recorded. Data were analyzed by using standard statistical techniques (STPR package). Phytotoxic symptoms were recorded in direct-seeded rice on 3, 7, 14, 21 and 28 days after herbicide application at a dose of 80 and 160 g/ha of cyhalofop-butyl by comparing it with weedy check. Carry over effect of applied herbicides also observed on succeeding wheat crop.

## RESULTS AND DISCUSSION

### Relative weed density

At 45 days after herbicide application (DAA) the experimental area of direct-seeded rice crop was infested with different grassy and non-grassy weeds during both the years of experimentation. Among grassy weeds *Echinochloa colona*, *E. crus-galli* and *Leptochloa chinensis* were dominant and among non-grassy weeds *Alternanthera sesillis*, *Caesulia axillaris*, *Cyperus iria* and *Cyperus rotundus* were major weeds. *Echinochloa colona*, *E. crus-galli*, *L. chinensis* and non-grassy weeds accounted 7.7, 7.7, 9.5 and 75.1% during 2014 and 4.1, 7.6, 4.7 and 83.6% relative weed density during 2015, respectively in weedy check plot (**Table 1**).

### Density and dry biomass of weeds

During 2014, the minimum density and biomass of *E. colona* and *E. crus-galli* was recorded with the application of cyhalofop-butyl at 90 g/ha, which was comparable with its lower dose applied at 80 (both sponsor sample and std. check) and 75 g/ha while during 2015, all the herbicidal treatments except cyhalofop-butyl at 65 g/ha completely eliminated *E. colona* whereas the density as well as dry biomass of *E. crus-galli* was found minimum with the application of cyhalofop-butyl at 90 g/ha, which was at par with its lower dose applied at 75 and 80 g/ha. All the doses of cyhalofop-butyl except its lower dose at 65 g/ha recorded complete elimination of *L. chinensis* during both the years of experimentation while during 2015, std. check of cyhalofop-butyl at 75 g/ha also not achieved complete control over its density and dry biomass. None of the herbicidal treatments was found effective in controlling the density and dry biomass of non-grassy weeds over the weedy check treatment. Minimum density of grassy weeds is due to selectivity of herbicide. This herbicide was more effective against the grassy weeds as compared to broad leaf weeds and sedges and lowest dry biomass of grassy weeds might be due to low density of grasses as compared to non-grassy weeds.

### Total weed dry biomass, WCE, HEI and WPI

Minimum total dry biomass of weeds was recorded with the post-emergence application of cyhalofop-butyl at 90 g/ha which was significantly superior to rest of the treatments except twice hand weeding at 20 and 40 DAS during 2014 while during 2015, cyhalofop-butyl applied at 90 g/ha as post-emergence was comparable with rest of the weed management practices except with the application of cyhalofop-butyl at 65 g/ha. Among different herbicidal treatments, application of cyhalofop-butyl at 90 g/ha as post-emergence recorded maximum weed control efficiency (WCE) of 70.2 and 74.0% during 2014 and 2015, respectively (**Table 3**).

Maximum herbicide efficiency index (HEI) was attained (21.7 and 13.9%) with the application of cyhalofop at 90 g/ha during 2014 and 2015, respectively, which was followed by its lower dose applied at 80 g/ha. During 2014, application of cyhalofop-butyl at 90 g/ha obtained minimum weed persistence index (WPI) (0.42%) that was followed by cyhalofop-butyl (std. check) at 80 g/ha, whereas, during 2015, cyhalofop-butyl (std. check) at 75 g/ha recorded lowest weed persistence index (0.32%), which was followed by cyhalofop-butyl at 90 g/ha

(**Figure 1**).Thus, with the increase in herbicide efficiency index, weed persistence index is decreases. As compared to 2015, in 2014 greater herbicide efficiency index as well as weed persistence index was recorded.

## Yield attributes

All yield attributing characters of rice crop, *viz.* number of panicles/m$^2$, grains/panicle and 1000 grain weight were significantly influenced by different weed control treatments during both the years of study except 1000-grain weight during 2014 (**Table 4**). Yield attributes data depicted highest value under twice hand weeding at 20 and 40 DAS during both the years. Within herbicidal treatments, application of cyhalofop-butyl at 90 g/ha achieved maximum panicles number of 232 and 253/m$^2$ during 2014 and 2015, respectively, which was at par with rest of the herbicidal treatments except cyhalofop-butyl applied at 65 g/ha. During 2014, cyhalofop-butyl applied at 90 g/ha and during 2015 application of cyhalofop-butyl at 80 g/ha obtained highest number of grains/ panicle, which was comparable to rest of the treatments. 1000-grain weight was maximum (24.5 g) with the application of cyhalofop-butyl at 80 g/ha which was significantly superior to cyhalofop-butyl applied at 65 g/ha. This might be due to less density and biomass of weeds, less crop weed competition during critical period, better environment for rice

**Table 1. Effect of treatment on weed density (no./m$^2$) at 45 days after herbicide application**

| Treatment | Grasses | | | | | | Non grassy weeds | |
|---|---|---|---|---|---|---|---|---|
| | *E. colona* | | *E. crus-galli* | | *L. chinensis* | | | |
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| Cyhalofop-butyl (65 g/ha) | 3.2(9.3) | 1.7(2.0) | 3.0(8.0) | 2.4(4.7) | 2.5(5.3) | 4.7(2.4) | 14.5(210.7) | 13.4(179.3) |
| Cyhalofop-butyl (75 g/ha) | 2.1(3.3) | 1.0(0.0) | 2.0(3.0) | 1.5(1.3) | 1.0(0.0) | 1.0(0.0) | 13.3(178.7) | 13.2(174.7) |
| Cyhalofop-butyl (80 g/ha) | 1.9(2.7) | 1.0(0.0) | 1.9(2.7) | 1.2(0.7) | 1.0(0.0) | 1.0(0.0) | 12.2(150.7) | 13.0(168.7) |
| Cyhalofop-butyl (90 g/ha) | 1.5(1.3) | 1.0(0.0) | 1.5(1.3) | 1.0(0.0) | 1.0(0.0) | 1.0(0.0) | 12.6(158.0) | 13.4(178.7) |
| Cyhalofop-butyl (std. check) (75 g/ha) | 2.5(5.3) | 1.0(0.0) | 2.5(5.3) | 2.2(4.0) | 1.0(0.0) | 1.9(2.7) | 12.0(142.7) | 13.9(191.0) |
| Cyhalofop-butyl (std. check) (80 g/ha) | 1.9(2.7) | 1.0(0.0) | 1.9(2.7) | 1.9(2.7) | 1.0(0.0) | 1.0(0.0) | 12.8(162.7) | 13.2(174.7) |
| Hand weeding 20 and 40 DAS | 2.5(5.3) | 1.5(1.3) | 2.2(4.0) | 1.9(2.7) | 3.2(9.3) | 1.5(1.3) | 7.9(62.7) | 10.4(108.0) |
| Weedy check | 4.3(17.3) | 3.2(9.3) | 4.3(17.3) | 4.3(17.3) | 4.7(21.3) | 3.4(10.7) | 13.0(168.7) | 13.8(190.7) |
| LSD (p=0.05) | 0.60 | 0.3 | 0.50 | 0.6 | 0.31 | 0.40 | 2.1 | 1.24 |

Value in parentheses was original and transformed to square root $(\sqrt{x+1})$ for analysis, DAS- Days after sowing

**Table 2. Effect of treatment on weed dry biomass (g/m$^2$) at 45 days after herbicide application**

| Treatment | Grasses | | | | | | Non grassy weeds | |
|---|---|---|---|---|---|---|---|---|
| | *E. colona* | | *E. crus-galli* | | *L. chinensis* | | | |
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| Cyhalofop-butyl (65 g/ha) | 5.2(26.7) | 2.6(5.8) | 5.0(24.0) | 3.1(8.5) | 3.5(11.4) | 2.1(3.4) | 8.6(73.0) | 8.1(65.2) |
| Cyhalofop-butyl (75 g/ha) | 3.1(8.7) | 1.0(0.0) | 2.8(7.3) | 1.7(2.0) | 1.0(0.0) | 1.0(0.0) | 7.9(61.9) | 8.0(63.5) |
| Cyhalofop-butyl (80 g/ha) | 3.0(8.3) | 1.0(0.0) | 2.8(7.0) | 1.3(0.8) | 1.0(0.0) | 1.0(0.0) | 7.8(60.4) | 7.8(60.1) |
| Cyhalofop-butyl (90 g/ha) | 2.1(3.9) | 1.0(0.0) | 2.0(3.7) | 1.0(0.0) | 1.0(0.0) | 1.0(0.0) | 7.6(57.3) | 7.7(59.0) |
| Cyhalofop-butyl (std. check) (75 g/ha) | 4.1(16.2) | 1.0(0.0) | 4.0(14.9) | 2.0(3.2) | 1.0(0.0) | 1.8(2.1) | 7.5(55.5) | 7.7(58.1) |
| Cyhalofop-butyl (std. check) (80 g/ha) | 3.1(8.8) | 1.0(0.0) | 2.82(7.7) | 1.9(2.7) | 1.0(0.0) | 1.0(0.0) | 7.8(59.9) | 7.6(57.7) |
| Hand weeding 20 and 40 DAS | 4.2(16.6) | 2.6(6.9) | 3.6(12.3) | 1.9(2.8) | 4.2(16.4) | 1.7(2.1) | 4.8(22.3) | 5.2(26.6) |
| Weedy check | 7.8(60.3) | 8.3(67.6) | 7.1(49.2) | 9.8(95.3) | 6.7(44.5) | 3.4(10.9) | 8.0(63.5) | 7.3(53.1) |
| LSD (p=0.05) | 1.0 | 0.9 | 0.82 | 0.70 | 0.27 | 0.43 | 0.83 | 0.85 |

Value in parentheses was original and transformed to square root $(\sqrt{x+1})$ for analysis, DAS- Days after sowing

**Table 3. Effect of treatments on total weed dry biomass and WCE at 45 DAA**

| Treatment | Total weed dry biomass(g/m$^2$) | | Weed control efficiency (%) | |
|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 |
| Cyhalofop-butyl (65 g/ha) | 11.7(135) | 9.1(83) | 37.9 | 63.5 |
| Cyhalofop-butyl (75 g/ha) | 9.4(87) | 8.1(65) | 60.0 | 71.1 |
| Cyhalofop-butyl (80 g/ha) | 8.8(77) | 7.9(61) | 64.7 | 73.2 |
| Cyhalofop-butyl (90 g/ha) | 8.1(65) | 7.7(59) | 70.2 | 74.0 |
| Cyhalofop-butyl (std. check) (75 g/ha) | 9.4(87) | 8.0(63.4) | 60.2 | 72.1 |
| Cyhalofop-butyl (std. check) (80 g/ha) | 8.8(76) | 7.8(60) | 64.8 | 73.4 |
| Hand weeding 20 and 40 DAS | 8.3(67) | 6.3(38) | 68.9 | 83.1 |
| Weedy check | 14.8(218) | 15.1(227) | - | - |
| LSD (p=0.05) | 0.40 | 0.77 | - | - |

Value in parentheses was original and transformed to square root $(\sqrt{x+1})$ for analysis, DAS- days after sowing, DAA- days after herbicide application and WCE- weed control efficiency.

growth at higher doses of cyhalofop-butyl, which in turn resulted in highest value for yield attributes of rice crop.

### Grain and straw yield

The highest grain yield (4.21 and 4.29 t/ha) was found with the application of cyhalofop-butyl at 90 g/ha which was comparable with rest of the herbicidal treatments except with its lower dose applied at 65 g/ha (**Table 4**). The grassy weeds dominant at critical period of weed competition stage (**Table 1 and 2**) were well managed by cyhalofop-butyl. Menono *et al.* (2014) also reported that maximum rice yield with application of cyhalofop-butyl either applied as alone or in combination. The highest straw yield was recorded with the application of cyhalofop-butyl at 80

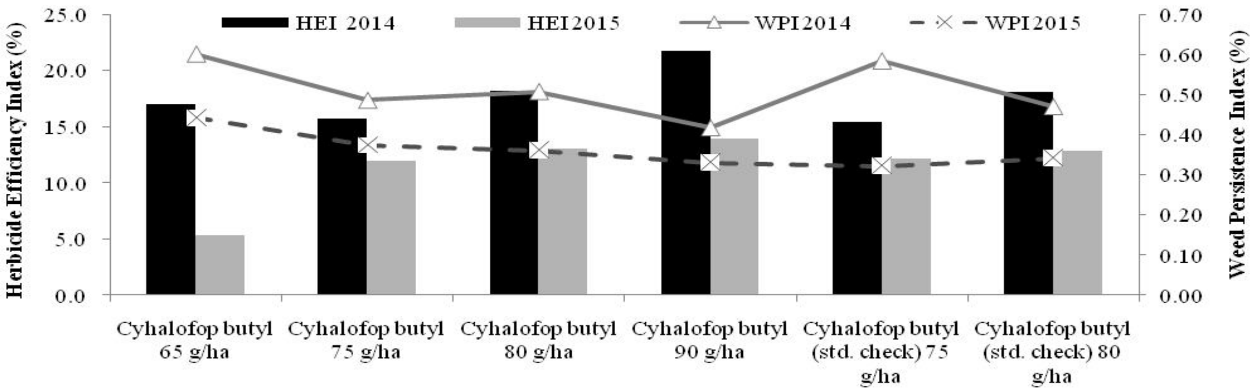


**Figure 1. Effect of treatments on herbicide efficiency index (HEI) and weed persistence index duing (WPI) 2014 and 2015**

**Table 4. Rice yield and yield attributing characters of direct-seeded rice as affected by treatments**

| Treatment | Panicles (no./m²) | | Grains/ panicle | | 1000 grain weight (g) | | Grain yield (t/ha) | | Straw yield (t/ha) | | Grain: Straw | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| Cyhalofop-butyl(65 g/ha) | 134 | 223 | 92.7 | 94.5 | 23.9 | 23.0 | 2.97 | 3.50 | 4.31 | 6.30 | 0.69 | 0.55 |
| Cyhalofop-butyl (75 g/ha) | 225 | 251 | 97.7 | 104.5 | 24.2 | 24.3 | 4.07 | 4.10 | 7.36 | 7.38 | 0.55 | 0.56 |
| Cyhalofop-butyl (80 g/ha) | 229 | 252 | 98.0 | 106.7 | 24.2 | 24.5 | 4.17 | 4.16 | 7.46 | 7.48 | 0.56 | 0.56 |
| Cyhalofop-butyl (90 g/ha) | 232 | 253 | 99.3 | 104.5 | 24.3 | 24.1 | 4.21 | 4.29 | 7.29 | 7.73 | 0.58 | 0.56 |
| Cyhalofop-butyl (std. check)(75g/ha) | 225 | 238 | 97.7 | 103.5 | 24.1 | 23.9 | 4.00 | 4.02 | 7.19 | 7.24 | 0.57 | 0.55 |
| Cyhalofop-butyl (std. check)(80g/ha) | 227 | 247 | 98.7 | 105.1 | 24.3 | 24.4 | 4.12 | 4.07 | 5.99 | 7.44 | 0.69 | 0.55 |
| Hand weeding 20 and 40 DAS | 246 | 265 | 109.3 | 111.3 | 24.1 | 24.7 | 4.25 | 4.34 | 6.67 | 7.81 | 0.64 | 0.56 |
| Weedy check | 112 | 138 | 54.0 | 67.0 | 23.6 | 22.2 | 0.65 | 1.19 | 1.17 | 2.13 | 0.56 | 0.56 |
| LSD (p=0.05) | 30.5 | 27.3 | 6.6 | 14.2 | NS | 1.36 | 0.38 | 0.29 | 0.48 | 0.50 | - | - |

DAS- days after sowing

**Table 5. Effect of various doses of cyhalofop-butyl applied in rice on the succeeding wheat crop, *Rabi* season**

| Treatment | Plant population (m²) | | Spikes (no/m²) | | Grains/spike | | 1000 grain weight (g) | | Grain yield (t/ha) | | Straw yield (t/ha) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 |
| Cyhalofop-butyl(65 g/ha) | 262 | 229 | 296 | 329 | 42.6 | 41.3 | 44.4 | 39.4 | 4.39 | 4.02 | 6.41 | 6.90 |
| Cyhalofop-butyl (75 g/ha) | 256 | 224 | 285 | 307 | 43.1 | 40.5 | 44.4 | 40.2 | 4.30 | 4.20 | 6.47 | 7.14 |
| Cyhalofop-butyl (80 g/ha) | 256 | 225 | 273 | 309 | 43.0 | 41.5 | 44.2 | 39.0 | 4.46 | 4.20 | 6.36 | 7.15 |
| Cyhalofop-butyl (90 g/ha) | 234 | 230 | 292 | 275 | 41.6 | 40.5 | 43.5 | 40.3 | 4.14 | 4.01 | 6.52 | 6.81 |
| Cyhalofop-butyl (std. check)(75g/ha) | 245 | 223 | 304 | 304 | 42.7 | 41.0 | 45.1 | 39.1 | 4.52 | 4.14 | 6.46 | 6.98 |
| Cyhalofop-butyl (std. check)(80g/ha) | 241 | 225 | 288 | 298 | 42.4 | 40.4 | 45.7 | 39.5 | 4.10 | 4.10 | 7.05 | 6.97 |
| Hand weeding 20 and 40 DAS | 267 | 222 | 286 | 284 | 42.7 | 40.7 | 45.0 | 39.5 | 4.18 | 3.95 | 6.63 | 6.72 |
| Weedy check | 269 | 224 | 280 | 328 | 42.1 | 41.4 | 45.4 | 39.5 | 4.30 | 4.02 | 6.74 | 6.80 |
| LSD (p=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

DAS- days after sowing, NS- non significant g/ha in 2014 and 90 g/ha during 2015, which were significantly superior to cyhalofop-butyl applied at 65 g/ha. The highest grain yield of rice was obtained with cyhalofop-butyl at 90 g/ha due to better control of grassy weeds. Maximum grain: straw ratio was recorded with cyhalofop-butyl at 65 g/ha and cyhalofop-butyl (std. check) at 80 g/ha (0.69) during 2014 and with application of cyhalofop-butyl at 75, 80 and 90 g/ha as well as twice hand weeding at 20 and 40 (0.56) during 2015.

### Phytotoxicity

No phytotoxic symptoms were seen in direct-seeded rice crop due to application of cyhalofop-butyl at different doses on 3, 7, 14, 21 and 28 days after herbicide application during both the years.

### Carryover effect

In succeeding wheat crop, the plant population at harvest as well as wheat yield and yield attributing characters were not influenced significantly due to various weed control treatments applied during preceding rice crop and they were statistically similar to each other. This concludes that post emergence application of cyhalofop-butyl against weeds in direct-seeded rice crop during rainy season was very safe for growing wheat crop during winter season (**Table 5**).

It was concluded that cyhalofop-butyl should be applied at 75 and 80 g/ha for better control of grassy weeds and maximum rice grain yield. The succeeding wheat crop had no phytotoxic effect due to application of cyhalofop-butyl.

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# Efficacy of pre-emergence herbicides for control of complex weed flora in transplanted rice

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## ABSTRACT

A field experiment was conducted at Chiplima, Sambalpur, Odisha during the rainy season of 2014 and 2015 to study the effect of sand-mix application of pre-emergence herbicides on weed population yield and economics of transplanted rice (*Oryza sativa* L.). Application of chlorimuron + metsulfuron 4 g/ha, bensulfuron 60 g/ha and pyrazosulfuron 16 g/ha alone was selectively effective on broad-leaf weeds while pretilachlor 500 g/ha was effective on grasses. Pre-emergence application of pyrazosulfuron with pretilachlor (16 + 500 g/ha) was more effective in minimizing the density (10/$m^2$), biomass (4.8 g/$m^2$) of weeds and enhancing the weed control efficiency (89.3%), grain yield (6.14 t/ha), net returns (` 53.2 x $10^3$/ha) and benefit: cost ratio (1.37) than pretilachlor alone.

**Key words**: Bensulfuron-methyl, Chlorimuron-ethyl + metsulfuron-methyl, Herbicide mixture, Pretilachlor, Pyrazosulfuron-ethyl, Transpalnted rice, Weed control

Weed management is one of the important factors affecting rice yield. Uncontrolled weeds cause 35-55% reduction in grain yield under transplanted conditions (Manhas *et al.* 2012 and Rao and Chauhan 2015). Therefore, timely weed control is imperative for realizing desired level of productivity. Weed shift from grasses to broad-leaf weeds and sedges is being observed in transplanted rice fields due to continuous use of pretilachlor, butachlor or oxadiargyl in major rice growing areas of the country (Singh *et al.* 2004, Sunil *et al.* 2010). This undesirable ecological change in weed species is to be checked to avoid crop losses due to weeds. Such changes beyond a certain level may become unmanageable. Therefore, to widen weed control spectrum, there is necessity to combine the pretilachlor, which is being widely used as pre-emergence herbicide in transplanted rice with other broad-leaf weeds controlling herbicides. Bensulfuron-methyl + pretilachlor herbicide combination at 3 days after transplanting (DAT) was reported to provide effective control of broad-leaf weeds, sedges and grasses without any phytotoxic effect on rice (Rao *et al.* 2015, Bhat *et al.* 2017). Therefore, present study was undertaken to find suitable broad-leaf controlling herbicides to use with pretilachlor for widening the weed control spectrum in transplanted rice during *Kharif* season.

## MATERIALS AND METHODS

The study was undertaken at Regional Research and Technology Transfer Station, Orissa University of Agriculture and Technology, Chiplima, Sambalpur, Odisha during *Kharif* 2014 and 2015. The soil of the experimental field was sandy clay loam with pH 6.6, organic carbon 0.43% and available N ($KMnO_4$ method), P (Olsen) and K ($NH_4OHC$ method) content of 268, 13.4 and 132 kg/ha, respectively. The experiment was laid out in randomized block design with 3 replications and 9 treatments. The treatments consisted of pretilachlor 500 g/ha, bensulfuron methyl 60 g/ha, pyrazosulfuron-ethyl 16 g/ha, chlorimuron-ethyl + metsulfuron-methyl 4 g/ha, pretilachlor 500 g/ha + chlorimuron-ethyl + metsulfuron-methyl 4 g/ha, pretilachlor 500 g/ha + pyrazosulfuron-ethyl 16 g/ha, pretilachlor 500 g/ha + bensulfuron-methyl 60 g/ha, weed-free and weedy-check. All the herbicides were applied as sand – mix at 3 days after transplanting (DAT). Herbicide was mixed with 50 kg of sand per hectare on the day of application and applied uniformly to the field in 2.5 cm depth of water. Water was not drained for 2 days from the field and fresh irrigation was not given. Rice cultivar '*MTU 1001*' of 135 days duration was transplanted at spacing of 20 x 15 cm on July 27, 2014 and August 8, 2015. A common fertilizer dose of 80, 40 and 40 kg of N, $P_2O_5$ and $K_2O$/ha, respectively was applied. Full dose of $P_2O_5$ and $K_2O$ and half dose of N were applied as basal and remaining N was top-dressed in 2 equal splits, at maximum tillering and panicle-initiation stages of the crop. Plant protection measures and irrigation was provided as and when required. Weed density (no./$m^2$) and weed biomass (g/$m^2$) were measured by sampling randomly at 2

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places using 0.25 $m^2$ quadrate at 40 DAT. Weed density data was analyzed after subjecting to square root transformation. Yield and yield attributes of rice were recorded at crop harvest. Weed control efficiency was also calculated on the basis of dry matter production of weeds.

$$\text{Weed control efficiency (WCE)} = \frac{(WDc - WDt)}{WDc} \times 100$$

Where, WDc is the biomass of weeds in weedy plots, WDt is the biomass of weeds in treated plots

Economics was computed using the prevailing market prices for inputs and outputs such as rice grain (` 14,100/t), rice straw (` 800/t) and manual labour (` 200/day).

## RESULTS AND DISCUSSION

### Effect on weeds

The major weed flora in the experimental field comprised of grasses *Digitaria sanguinalis* (L.) Scop., *Echinochloa crus-galli* (L.), *Echinochloa colonum* (L.) Link, *Panicum repens* (L.), *Leptochloa chinensis* (L.); sedges *Cyperus difformis* (L.), *Cyperus iria* (L.), *Fimbristylis miliacea* (L.) Vahal and broad-leaved weeds (BLW) *Ammania baccifera* (L.), *Ludwigia paraviflora* (L.), *Eclipta prostrata* (L.), *Eclipta alba* (L.), *Lippa nodiflora* Nich, *Marsilea quadrifolium* (L.), *Sphenoclea zeylanica* Gaertn., *Commelina benghalensis* (L.). The composition of grasses, sedges and broad-leaf weeds in weedy check plot was 48.6, 30.4 and 20.9%, respectively. Emergence of BLW was noticed earlier as compared to sedges and grasses.

Sole application of pretilachlor was the best in controlling grasses (18/$m^2$), while pyrazosulfuron, bensulfuron and chlorimuron + metsulfuron were most effective in controlling sedges and broad-leaf weeds (**Table 1**). Grassy weed population was more (36/$m^2$) in the plot treated with chlorimuron + metsulfuron as compared to pretilachlor alone. This may be due to differential selectivity of herbicides towards grassy and broad-leaf weeds. The results are in agreement with (Singh *et al.* 2004).

Mixed application of pretilachlor and pyrazosulfuron was more effective than pretilachlor alone. Sedges could be completely controlled with combined application of pretilachlor with any of the 3 herbicides. All the combinations were significantly superior to the sole application of the herbicide and over weedy check. Bhat *et al.* (2017) also recorded lower weed density with ready mix application of pretilachlor with pyrazosufuron and bensulfuron.

Total weed biomass (**Table 1**) ranged between 17.7 to 23.3 g/$m^2$ with sole application of herbicides, whereas weed biomass of herbicide mixture varied between 4.8 to 9.2 g/$m^2$, the lowest being with pretilachlor + pyrazosulfuron. The highest weed control efficiency (89.3%) was found with pretilachlor + pyrazosulfuron followed by pretilachlor + bensulfuron (85.5%) and pretilachlor + chlorimuron + metsulfuron (79.5%). This showed that all the herbicide combinations tested in this experiment were compatible with higher efficiency over sole application without any phytotoxic effect causing adversity.

### Effect on crop

Plant height was not affected by any of the tested treatments. But the herbicide treatments increased the yield attributing parameters of rice. Effective tillers/$m^2$ (363), grains/panicle (127), panicle length (26.6 cm) and test weight (24.1 g) were the highest with pretilachlor + pyrazosulfuron and were at par with weed free treatment (**Table 2**). The complex weed flora comprised of grasses, sedges and broad-leaf weeds caused 40.6% rice grain yield reduction in the weedy check compared to weed free treatment (6.33 t/ha). Sole application of pyrazo-sulfuron, bensulfuron and chlorimuron + metsulfuron

**Table 1. Effect of herbicides on weed density, weed biomass and weed control efficiency at 40 days after transplanting in rice (mean data of 2 years)**

| Treatment | Weed density (no./$m^2$) | | | | Weed biomass (g/$m^2$) | | | | WCE (%) |
|---|---|---|---|---|---|---|---|---|---|
| | Grasses | Sedges | BLWs | Total | Grasses | Sedges | BLWs | Total | |
| Pretilachlor | 18(4.4) | 16(4.1) | 8(3.0) | 42(6.6) | 8.7(3.1) | 6.4(2.7) | 2.6(1.9) | 17.7(4.3) | 60.5 |
| Bensulfuron | 34(5.9) | 9(3.2) | 6(2.6) | 49(7.1) | 16.5(4.2) | 3.6(2.1) | 1.9(1.7) | 22.0(4.8) | 50.8 |
| Pyrazosulfuron | 32(5.7) | 8(3.0) | 4(2.2) | 44(6.7) | 15.5(4.1) | 3.2(2.0) | 1.3(1.5) | 20.0(4.6) | 55.4 |
| Chlorimuron + metsulfuron | 36(6.1) | 10(3.3) | 6(2.6) | 52(7.3) | 17.4(4.3) | 4.0(2.2) | 1.9(1.7) | 23.3(4.9) | 47.9 |
| Pretilachlor + chlorimuron + metsulfuron | 17(4.2) | 0(1.0) | 3(2.0) | 20(4.6) | 8.3(3.0) | 0(1.0) | 0.9(1.4) | 9.2(3.2) | 79.5 |
| Pretilachlor + pyrazosulfuron | 10(3.3) | 0(1.0) | 0(1.0) | 10(3.3) | 4.8(2.4) | 0(1.0) | 0(1.0) | 4.8(2.4) | 89.3 |
| Pretilachlor + bensulfuron | 12(3.6) | 0(1.0) | 2(1.7) | 14(3.9) | 5.8(2.6) | 0(1.0) | 0.7(1.3) | 6.5(2.7) | 85.5 |
| Weed-free | 0(1.0) | 0(1.0) | 0(1.0) | 0(1.0) | 0(1.0) | 0(1.0) | 0(1.0) | 0(1.0) | 100 |
| Weedy check | 51(7.2) | 32(5.7) | 22(4.8) | 105(10.3) | 24.7(5.1) | 12.8(3.7) | 7.3(2.9) | 44.8(6.8) | 0 |
| LSD (p=0.05) | 1.4 | 1.5 | 0.2 | 2.7 | 0.1 | 0.3 | 0.2 | 1.7 | - |

($\sqrt{x+1}$) transformed values are given in parentheses, BLW- Broad-leaf weeds, WCE-Weed control efficiency

**Table 2. Effect of herbicides on yield attributes, yield and economics of rice (mean data of 2 years)**

| Treatment | Plant height (cm) | Effective tillers (no./$m^2$) | Panicle length (cm) | Grains/ panicle | Test weight (g) | Grain yield (t/ha) | Straw yield (t/ha) | Cost of cultivation (x$10^3$ `/ha) | Net returns (x$10^3$ `/ha) | Benefit : cost ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| Pretilachlor | 117.4 | 353 | 26.2 | 124 | 23.7 | 4.97 | 5.96 | 38.4 | 36.5 | 0.95 |
| Bensulfuron | 103.4 | 340 | 25.1 | 120 | 23.1 | 4.35 | 5.22 | 38.5 | 27.1 | 0.70 |
| Pyrazosulfuron | 111.6 | 338 | 25.3 | 123 | 23.1 | 4.87 | 5.84 | 38.2 | 35.1 | 0.92 |
| Chlorimuron + metsulfuron | 116.8 | 295 | 24.4 | 113 | 22.6 | 4.05 | 4.86 | 38.3 | 22.7 | 0.59 |
| Pretilachlor + chlorimuron + metsulfuron | 120.1 | 342 | 25.7 | 125 | 29.9 | 5.53 | 6.08 | 38.8 | 44.5 | 1.13 |
| Pretilachlor + pyrazosulfuron | 118.7 | 363 | 26.6 | 127 | 24.1 | 6.14 | 6.25 | 38.8 | 53.2 | 1.37 |
| Pretilachlor + bensulfuron | 116.4 | 357 | 26.6 | 126 | 23.9 | 5.68 | 6.24 | 39.0 | 46.0 | 1.18 |
| Weed-free | 122.1 | 368 | 26.9 | 128 | 24.3 | 6.33 | 6.96 | 47.6 | 47.2 | 0.99 |
| Weedy check | 108.3 | 203 | 23.3 | 112 | 22.4 | 3.76 | 4.88 | 37.6 | 19.3 | 0.51 |
| LSD (p=0.05) | NS | 27.4 | 2.3 | 10 | 1.1 | 1.77 | 1.84 | - | - | - |

recorded lower grain yield as compared to their sand-mix application with pretilachlor due to their ineffectiveness in controlling grassy weeds, resulting lower weed control efficiency (**Table 1** and **2**). Singh *et al.* (2004) also reported that pretilachlor did not provide any control of sedges and broad-leaf weeds.

Among the herbicides combinations, the highest grain yield (6.14 t/ha) was recorded with pretilachlor + pyrazosulfuron, which was at par with weed free treatment. Pyrazosulfuron, bensulfuron and chlorimuron + metsulfuron application in combination with pretilachlor resulted in an average increase of 38.7, 33.8 and 32%, respectively in the grain yield as compared to weedy check. Combined application of pretilachlor with pyrazosulfuron, bensulfuron and chlorimuron + metsulfuron resulted in significantly higher yield than their sole application due to better control of all grasses, sedges and broad-leaf weeds. Pyrazosulfuron, bensulfuron and chlorimuron + metsulfuron were compatible with pretilachlor, as their site of action is different in the plant. Pyrazosulfuron, bensulfuron and chlorimuron + metsulfuron inhibits the plant enzyme acetolactate synthase (ALS), which is essential for the synthesis of branched chain amino acids. Inhibition of amino acid production subsequently inhibits cell division. Pretilachlor belongs to chloroacetamide group which inhibits cell division. Bhat *et al.* (2017) observed that pre-emergence application of pretilachlor with bensulfuron or pyrazosulfuron was as effective as weed free treatment. None of the treatments had any toxicity on the rice crop in terms of crop stand, crop growth, yellowing, necrosis, scorching, epinasty and hyponasty.

All the herbicides applied in combination with pretilachlor recorded higher monetary returns than their sole application and weedy check (**Table 2**). Among the tested treatments, pretilachlor + pyrazosulfuron gave the maximum net return (` 53.2 x $10^3$/ha) and benefit:cost ratio (1.37), followed by pretilachlor + bensulfuron owing to low cost and high grain yield as compared to other pre-emergence herbicides. Kaur *et al.* (2016) also reported similar findings with tank mix application of herbicides. Weed free treatment though registered higher grain yield (6.33 t/ha), recorded lower monetary returns (` 47.2 x $10^3$/ha) than application of pretilachlor + pyrazosulfuron mixture, due to high cost incurred in manual weeding to keep the crop weed free.

It can be concluded that pyrazosulfuron, bensulfuron and chlorimuron + metsulfuron were compatible with pretilachlor and there was no adverse effect on crop growth. Their combination successfully controlled the complex weed flora in rice. Pretilachlor with pyrazosulfuron was the most remunerative and effective herbicide mixtures for controlling the complex weed flora in transplanted rice.

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# Weed management effect on growth and yield of wet direct-seeded rice in Cauvery command area of Karnataka

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## ABSTRACT

Field experiment was conducted during rainy seasons of 2014 and 2015 to study the effect on weed management practices in wet direct-seeded rice (*Oryza sativa* L.) in Cauvery command area of Karnataka under irrigated condition with eight treatments replicated thrice. Pre-emergence application of bensulfuron-methyl + pretilachlor GR (Londax Power) at 660 g/ha *fb* bispyribac-sodium (Nominee Gold) at 25 g/ha at 20 days after sowing (DAS) significantly reduced weed growth and recorded the higher seed yield (4.80 t/ha), net monetary returns (` 25631/ha) and B:C ratio (1.62) and it was at par with other sequential treatments, *viz.* pre-emergence application of pendimethalin at 1.0 kg/ha (Stomp) *fb* post-emergence application of bispyribac-sodium, pre-emergence application of bensulfuron-methyl + pretilachlor, application of pendimethalin as pre-emergence *fb* 1 HW. Uncontrolled weed growth caused 55.2% reduction in seed yield of wet seeded rice.

**Key words:** Direct-seeded rice, Economics, Pre- and post-emergence herbicides, Sequential application

Rice is the world's most important crop and is a staple food for more than half of the world's population. About 90% of the world's rice is grown and produced in Asia. India is the second largest rice producing country in the world with an area of 43.4 Mha and produced 104.3 Mt of rice with a productivity of 2404 kg/ha (Anonoymus 2016). In many parts of the country traditional transplanting of rice seedlings in the puddled field is a major practice. However, in recent years, traditional transplanted rice is being replaced by the direct seeding of rice because of its lower labour, seeds and water requirement with 10-12 days early maturity. Though direct-seeded rice (DSR) yields comparable with transplanted crop, increased weed infestation is major drawback of this system.

Success of DSR is mainly depends on effective weed control with all the possible means. The yield loss in DSR is as high as 50-60% due to simultaneous germination of both crop and weeds seeds (Pinjari *et al.* 2016). Though the hand weeding has been found effective, but it is very expensive. Moreover, heavy demand of labour during peak period and its scarcity necessitates the use of alternate weed control measures. Chemical weed control by using pre-emergence herbicides being cost effective and less labour dependent is recommended to overcome this constraint under DSR. Broad spectrum of weed flora may not be controlled by spraying pre-emergence herbicides alone, as flushes of weeds come up at different growth stages. Hence, use of sequential application of pre- *fb* post-emergence herbicides or pre-emergence herbicides *fb* manual weeding could be more convenient in containing the weed menace. By keeping above information in view, the present investigation was carried out to study the effect of weed management practices on wet direct seeded rice in Cauvery command area of Karnataka.

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## MATERIALS AND METHODS

The experiment was conducted during rainy seasons of 2014 and 2015, at Zonal Agricultural Research Station, V.C. Farm, Mandya. The soil of experimental site was red sandy loams with bulk density and particle density of 1.15 g/cc and 2.65 g/cc, respectively. The soil pH was 6.5 (neutral in reaction). It was low in available nitrogen and phosphorus and high in potassium. Eight treatments, *viz.* bensulfuron-methyl + pretilachlor 660 g/ha (pre-emergence; PE) + one HW, pendimethalin 1.0 kg/ha (PE) + one HW, bensulfuron-methyl + pretilachlor 660 g/ha (PE) *fb* bispyribac-sodium 25 g/ha (post-emergence; PoE), pendimethalin 1.0 kg/ha (PE) *fb* bispyribac-sodium 25 g/ha (PoE) and bispyribac-sodium 25 g/ha (early PoE) were take. These weed control treatments were compared with hand weeding thrice at 20, 40 and 60 DAS, weedy and weed free check. These eight treatments were laid out in complete randomized block design with three replications.

Pre-germinated seeds of medium duration rice variety '*MTU 1001*' were broadcasted on well puddled and leveled field in June 2014 and 2015 with a seed rate of 62.5 kg/ha. The crop was fertilized with 100:50:50 kg N:$P_2O_5$:$K_2O$/ha and 50% nitrogen, entire dose of phosphorous and potassium was applied as basal in addition to zinc sulphate 25 kg/ha. The remaining 50% of the nitrogen was top dressed at two equal splits at tillering and panicle initiation stage. Pre-emergence herbicides were mixed with sand 100 kg/ha and applied uniformly in the field on 5 DAS. A thin film of water was maintained at the time of pre-emergence herbicide application. The post-emergence herbicides were sprayed at 3-4 leaf stage of weeds by using knapsack sprayer fitted with deflector nozzle mixed with water 750 liter/ha. Hand weeding was carried out as per the treatment schedule. All other agronomic and plant protection measures were adopted as per the recommended packages of UAS, Bangalore.

The data on weed density and weed dry weight (at 60 DAS) were recorded with the help of quadrate (0.5 x 0.5 m). The normality of distribution was not seen in case of observation on weeds hence, the values were subjected to square root transformation ($\sqrt{x+0.5}$) prior to statistical analysis to normalize their distribution. Data on plant height (at harvest) and yield attributes like number of productive tillers, grain weight/panicle, 100 seed weight and grain yield were recorded. The weed control efficiency was worked out on the basis of weed dry matter production using the formula suggested by Mani *et al.* (1973) and weed index was calculated by using the formula suggested by Gill and Vijayakumar (1966).

All the data obtained in the study were statistically analyzed using F-test, the procedure given by Gomez and Gomez (1984), critical difference values at p=0.05 were used to determine the significance of differences between means.

## RESULTS AND DISCUSSION

### Weed flora

The important weeds observed in the experimental fields were; *Echinochloa colona, Cynodon dactylon, Paspalum conjugatum* and *Leptochloa chinensis* among grasses; *Eclipta alba, Ludwigia parviflora, Ammania baccifera, Euphorbia hirta* and *Bergia capensis* among broad-leaved weeds (BLW) and *Cyperus rotundus, Cyperus iria* and *Scripus* spp. among sedges.

### Effect on weeds

All the weed control treatments significantly reduced the density and dry weight of grasses, BLW, sedges and total weeds as compared to unweeded check (**Table 1 and 2**). Among the weed control treatments, hand weeding thrice at 20, 40 and 60 DAS recorded significantly lower weed density (11.62, 7.63, 4.35 and 23.60/$m^2$ of grasses, BLW, sedges and total weeds, respectively) and weed dry matter production (3.66, 2.04, 0.50 and 6.20 g/$m^2$ of grasses, BLW, sedges and total weeds, respectively) as compared to other treatments. However, it was at par with pre-emergence application of bensulfuron-methyl + pretilachlor 660 g/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha (18.36, 12.52, 7.11 and 37.99/$m^2$ density of grasses, BLW, sedges and total weeds, respectively) and (4.80, 2.69, 0.66 and 8.15 g/$m^2$ dry weight of grasses, BLW, sedges and total weeds, respectively). While, the lowest weed density and dry weight of weeds were observed in weed free check and the highest was recorded in weedy check. These results were in conformity with the findings of Walia *et al.* (2012) who reported that sequential application of bispyribac-sodium after pre-emergence herbicide found effective in control of weeds in direct-seeded rice. The crop yield was directly proportional to weed control efficiency. The weed control efficiency at 60

**Table 1. Density of weeds (no. /$m^2$) as influenced by weed management practices in wet direct-seeded rice at 60 DAS (pooled data of two years)**

| Treatment | Grasses | BLW | Sedges | Total |
|---|---|---|---|---|
| Bensulfuron-methyl + pretilachlor 660 g/ha (PE) *fb* one HW | 4.60(20.72) | 4.00(15.51) | 3.09(9.04) | 6.76(45.26) |
| Pendimethalin 1 kg/ha (PE) v one HW | 5.33(27.91) | 4.49(19.68) | 3.47(11.55) | 7.72(59.14) |
| Bensulfuron-methyl + pretilachlor 660 g/ha (PE) *fb* bispyribac-sodium 25 g/ha (PoE) | 4.34(18.36) | 3.61(12.52) | 2.76(7.11) | 6.20(37.99) |
| Pendimethalin 1 kg/ha (PE) *fb* bispyribac-sodium 25 g/ha (PoE) | 5.04(24.90) | 3.96(15.22) | 3.21(9.79) | 7.10(49.91) |
| Bispyribac-sodium 25 g/ha (early PoE) | 6.01(35.72) | 4.96(24.13) | 3.91(14.82) | 8.67(74.67) |
| Hand weeding thrice at 20, 40 and 60 DAS | 3.47(11.62) | 2.85(7.63) | 2.20(4.35) | 4.90(23.60) |
| Weed free check | 0.71(0.00) | 0.71(0.00) | 0.71(0.00) | 0.71(0.00) |
| Weedy check | 8.15(65.93) | 6.64(43.61) | 5.16(26.14) | 11.67(135.7) |
| LSD (p=0.05) | 0.33 | 0.23 | 0.12 | 0.27 |

Square root ($\sqrt{x+0.5}$) transformed values. Values in the parentheses are original values; PE - pre-emergence; PoE - post-emergence

DAS was maximum in hand weeding thrice at 20, 40 and 60 DAS (87.2%) and pre-emergence application of bensulfuron-methyl + pretilachlor 660 g/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha was the best treatment among the herbicides in terms of higher WCE (83.1%). These results were in agreement with Walia *et al.* (2012) and Naseeruddin and Subramanyam (2013). Among the herbicides tested, pendimethalin found toxic and hinders germination of rice seeds lead to reduced plant population. A similar phytotoxic effect caused by pendimethalin on rice crop was observed by Rana *et al.* (2016). While, application of pre-emergence herbicide *fb* one hand weeding failed to control the all types of weeds due to emergence of second flush weeds.

### Effect on crop

All the herbicide treatments produced significantly higher seed yield (3.19-4.80 t/ha) compared to weedy check (2.34 t/ha). Unweeded check registered 55.2% reduction in seed yield compared to weed free check owing to sever competition offered by uncontrolled weeds for nutrients, soil moisture, space and light. Among the weed control treatments, significantly higher seed yield (5.22 t/ha) was obtained with season long weed free check as compared to weedy check (**Table 3**). However, it was at par with pre-emergence application of bensulfuron methyl + pretilachlor 660 g/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha (4.80 t/ha) and hand weeding thrice at 20, 40 and 60 DAS (5.14 t/ha). The superior performance of these treatments were mainly attributed to enhanced yield parameters, *viz.* number of productive tillers/plant, grain weight/panicle and 100 seed weight. These increased yield parameters in turn due to growth parameters, *viz.* plant height and total dry matter production, was due to effective control of weeds during critical period of paddy growth. These results were in conformity with earlier findings of Brar and Bullar (2012), Singh and Singh (2014), Kaur and Singh (2015) and Pinjari *et al.* (2016). Pre-emergence application of bensulfuron-methyl 0.6% + pretilachlor 6% GR 10 kg/ha or pendimethalin *fb* one hand weeding failed to enhance

**Table 2. Dry weight of weeds (g/m$^2$) and weed control efficiency as influenced by weed management practices in wet direct seeded rice at 60 DAS (pooled data of two years)**

| Treatment | Grasses | BLW | Sedges | Total | WCE (%) |
|---|---|---|---|---|---|
| Bensulfuron-methyl + pretilachlor 660 g/ha (PE) *fb* 1 HW | 2.62(6.40) | 2.02(3.57) | 1.18(0.88) | 3.37(10.85) | 77.5 |
| Pendimethalin 1 kg/ha (PE) *fb* one HW | 2.82(7.46) | 2.16(4.17) | 1.23(1.02) | 3.63(12.65) | 73.8 |
| Bensulfuron-methyl + pretilachlor 660 g/ha (PE) *fb* bispyribac-sodium 25 g/ha (PoE) | 2.30(4.80) | 1.78(2.69) | 1.08(0.66) | 2.94(8.15) | 83.1 |
| Pendimethalin 1 kg/ha (PE) *fb* bispyribac-sodium 25 g/ha (PoE) | 2.61(6.34) | 2.01(3.54) | 1.17(0.87) | 3.35(10.75) | 77.7 |
| Bispyribac-sodium 25 g/ha (early PoE) | 3.70(13.17) | 2.81(7.38) | 1.52(1.80) | 4.78(22.35) | 53.7 |
| Hand weeding thrice at 20, 40 and 60 DAS | 2.04(3.66) | 1.59(2.04) | 1.00(0.50) | 2.59(6.20) | 87.2 |
| Weed free check | 0.71(0.00) | 0.71(0.00) | 0.71(0.00) | 0.71(0.00) | 100.0 |
| Weedy check | 5.40(28.70) | 4.15(16.71) | 1.84(2.87) | 6.98(48.28) | 0.0 |
| LSD (p=0.05) | 0.12 | 0.23 | 0.18 | 0.15 | - |

Square root ($\sqrt{x+0.5}$) transformed values. Values in the parentheses are original values

**Table 3. Growth and yield of wet direct seeded rice as influenced by weed management practices (pooled data of two years)**

| Treatment | Plant height at harvest (cm) | No. of productive tillers per hill at harvest | Grain weight/ panicle (g) | 100-seed weight (g) | Per cent choppiness | Grain yield (t/ha) | Weed index (%) | Net returns (x10$^3$ `/ha) | B:C ratio |
|---|---|---|---|---|---|---|---|---|---|
| Bensulfuron-methyl + pretilachlor 660 g/ha (PE) *fb* 1 HW | 55.3 | 12.0 | 2.06 | 1.29 | 19.7 | 3.67 | 29.7 | 12.37 | 1.32 |
| Pendimethalin 1 kg/ha (PE) *fb* one HW | 53.6 | 10.7 | 1.78 | 0.99 | 22.2 | 3.49 | 33.1 | 9.99 | 1.26 |
| Bensulfuron-methyl + pretilachlor 660 g/ha (PE) *fb* bispyribac-sodium 25 g/ha (PoE) | 58.3 | 13.3 | 2.34 | 1.54 | 15.5 | 4.80 | 8.0 | 27.63 | 1.65 |
| Pendimethalin 1 kg/ha (PE) *fb* bispyribac-sodium 25 g/ha (PoE) | 51.8 | 11.0 | 1.95 | 1.15 | 24.8 | 3.87 | 25.8 | 12.71 | 1.31 |
| Bispyribac-sodium 25 g/ha (early PoE) | 50.3 | 10.2 | 1.56 | 1.11 | 28.4 | 3.19 | 39.0 | 5.24 | 1.13 |
| Hand weeding thrice at 20, 40 and 60 DAS | 62.0 | 13.2 | 2.57 | 1.78 | 11.9 | 5.14 | 1.5 | 25.72 | 1.49 |
| Weed free check | 63.6 | 14.6 | 2.60 | 1.79 | 10.9 | 5.22 | 0.0 | 23.34 | 1.50 |
| Weedy check | 43.3 | 8.8 | 1.49 | 1.08 | 54.7 | 2.34 | 55.2 | -3.98 | 0.89 |
| LSD (p=0.05) | 5.9 | 2.9 | 0.26 | 0.15 | 3.9 | 0.47 | - | - | - |

the paddy grain yield significantly owing to severe weed competition. The treatments, which received pre-emergence application of pendimethalin also failed to enhance the paddy grain yield significantly because of its toxicity.

### Economics

The highest net returns (` 27,631/ha) and B:C ratio (1.65) were recorded in pre-emergence application of bensulfuron-methyl + pretilachlor 660 g/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha. The increased monetary benefits in this treatment were mainly attributed to higher grain yield and reduced labour cost. While, the lowest net returns (` -3976/ha) and B:C ratio (0.89) was observed in weedy check (**Table 3**). Similar results of higher net returns and B:C ratio in direct-seeded rice due to sequential application of herbicides were also reported by Pinjari *et al.* (2016) and Ghosh *et al.* (2016).

On the basis of pooled data of two years, it was concluded that pre-emergence application of bensulfuron-methyl + pretilachlor 660 g/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha found most effective and economical in controlling the weeds in direct seeded wet sown rice in Cauvery Command Area of Karnataka.

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# Control of canarygrass in wheat with pre-mixture of pinoxaden plus clodinafop-propargyl

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**ABSTRACT**

The field efficacy of pre-mixture of pinoxaden plus clodinafop for control of *Phalaris minor* Retz. in wheat was evaluated in winter 2011-12 and 2012-13 on Research Farm, Department of Agronomy at Punjab Agricultural University, Ludhiana. The study comprised of pre-mixture of pinoxaden plus clodinafop 40, 50 and 60 g/ha, clodinafop 60 g/ha, pinoxaden 50 g/ha and unsprayed control. The results revealed that post-emergence application of pre-mixture of pinoxaden plus clodinafop at 50-60 g/ha recorded effective control of *P. minor* and recorded the highest effective tillers/m$^2$, spike length and wheat grain yield and was significantly better than its application at 40 g/ha and clodinafop during both the years and pinoxaden alone in one year.

**Key words**: Clodinafop, Fenoxaprop, Pinoxaden, Tank mix, Weed management, Wheat

Wheat (*T. aestivum*) is the most important food crop of India after rice. It is the staple food of millions of Indians, particularly in the northern and North-Western parts. *Phalaris minor* and *Avena ludoviciana* are major problematic grass weeds causing large scale reductions in wheat grain yield (Chhokar *et al.* 2012). Due to the strong competitiveness, these weeds can cause yield reduction in the range of 15 to 100% in wheat (Walia and Brar 2001). Many herbicides have been recommended for the control of grassy weeds in wheat. Clodinafop-propargyl, an ACCase inhibitor, has been extensively used for post-emergence control of both these grassy weeds in wheat fields in the region. After 8-10 years of continuous use of these herbicides, complaints regarding their efficacy also started to emerge. *P. minor* populations have evolved resistance against clodinafop in wheat fields especially in Northern states of Punjab and Haryana (Brar *et al.* 2002, Yadav *et al.* 2002). Pinoxaden, which belongs to phenylpyrazolin group was then introduced to tackle the problem of herbicide resistance in *P. minor*. Pinoxaden at 40-50 g/ha provided effective control of clodinafop resistant *P. minor* (Punia *et al.* 2008, Punia and Yadav 2010) during early years of its introduction. The resistance against pinoxaden among *P. minor* populations from Punjab has been confirmed (Kaur *et al.* 2016). Both clodinafop and pinoxaden are absorbed through foliage and have no residual herbicidal activity in soil (Campagna and Rueegg 2006). Herbicide pre-mixture and tank mixtures have been known to provide better weed control than use of single herbicide. Moreover herbicide mixtures will also help in managing and delaying herbicide resistance. The present study investigated the efficacy of pre-mixture of pinoxaden and clodinafop-propargyl for control of herbicide resistant *P. minor* in wheat, and how this combination influences succeeding crop in rotation.

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## MATERIALS AND METHODS

A field experiment was conducted at Punjab Agricultural University, Ludhiana during winter 2011-12 and 2012-13. The experimental soil was sandy loam and having pH 7.1. Wheat variety '*PBW 550*' and '*HD 2967*' was sown in mid-November of 2011 and 2012. The plot size was 7.00 x 2.25 m. Six treatments namely pre-mixture of pinoxaden plus clodinafop-propargyl at 40, 50, 60 g/ha, clodinafop-propargyl (clodinafop) 60 g/ha, pinoxaden 50 g/ha and unsprayed control were replicated four times in randomized block design. Pinoxaden plus clodinafop at 120 g/ha was also kept with an objective to study the residual effect on the following crop. All the herbicides were applied at 30 days after sowing, after first irrigation, when *P. minor* plants were at 3-4 leaf stage. The herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle by dissolving in 375 L water/ha. The broad-leaf weeds in all plots were controlled by metsulfuron at 4 g/ha applied at 30-35 days after wheat sowing. *P. minor* plants were counted from two representative sites per plot by using 45 x 45 cm quadrat at 60 days after sowing. *P. minor* plants from these two quadrats were cut from the soil level and dry biomass was recorded. The crop was raised as per standard package and was harvested in mid-April in 2012 and 2013. The data on wheat yield and yield attributes were recorded at harvest. All data were statistically analyzed by using statistical procedures and comparisons were made at 5% level of significance. The weed data were square root transformed before analysis.

## RESULTS AND DISCUSSION

### Effect on *P. minor*

All the herbicide treatments recorded significantly lower population and biomass of *P. minor* as compared to unsprayed control during both the years. Among herbicide treatments, pre-mixture of pinoxaden plus clodinafop at 60 g/ha recorded the lowest density and biomass of *P. minor* during both the years. The weed density under this treatment was at par to its lower dose of 50 g/ha in both the years and pinoxaden 50 g/ha in 2011-12. Clodinafop recorded good control of *P. minor* in 2011-12, however the control was poor in 2012-13 (<75%). The poor control with pinoxaden and clodinafop alone particularly in year 2012-13 indicated the development of resistance in *P. minor* populations against these herbicides. The result also indicated that pre-mixture of both these herbicides may provide temporary relief in the areas infested with *P. minor* populations resistant to both these herbicides. The weed biomass recorded a trend to that of weed density.

### Effect on crop

The effective control of *P. minor* with pre-mixture of pinoxaden plus clodinafop at 50-60 g/ha resulted in higher effective tillers density, longer spikes and taller plants compared to other herbicide treatments and unsprayed control. The pre-mixture of pinoxaden plus clodinafop at 50-60 g/ha recorded the highest wheat grain yield which was significantly higher than its lower dose of 40 g/ha, pinoxaden and clodinafop applied alone in 2012-13, and similar to pinoxaden alone in 2011-12. All the herbicide treatments recorded significantly higher wheat grain yield and yield attributes than unsprayed control. The wheat grain and straw yield differences among different treatments were reflected in differential efficacy against *P. minor*, the treatments which gave the best efficacy recorded the highest grain yield and vice-versa.

Grozi (2016) also reported that herbicides Foxtrot, Axial, Topic and pre-mixture of pinoxaden plus clodinafop increased the grain yield and the increase was the highest by pre-mixture of pinoxaden plus clodinafop *i.e.* 8.5%. The increase in grain yield was greatest with the pre-mix because it controlled a large number of grassy weeds including *Bromus arvensis*. Ibrahim *et al.* (2015) also reported the high effectiveness of clodinafop and pinoxaden + clodinafop herbicide treatments against wheat annual grass weeds. Singh *et al.* (2015) reported that pre-mixture of pinoxaden plus clodinafop 60 g/ha provided lower dry weight of grassy weeds, higher tillers and wheat grain yield compared to its lower

**Table 1. Effect of different weed control treatments on density and biomass of *P. minor* at 60 days after sowing in wheat**

| Treatment | Weed density (no./$m^2$) | | Weed biomass (g/$m^2$) | |
|---|---|---|---|---|
| | 2011-12 | 2012-13 | 2011-12 | 2012-13 |
| Pinoxaden plus clodinafop 40 g/ha | 7.0 (48)* | 6.1 (36) | 11.8 (139) | 17.5 (304) |
| Pinoxaden plus clodinafop 50 g/ha | 5.9 (34) | 5.2 (27) | 12.0 (144) | 16.5 (273) |
| Pinoxaden plus clodinafop 60 g/ha | 5.0 (24) | 4.0 (15) | 11.4 (129) | 13.6 (184) |
| Pinoxaden 50 g/ha | 6.1 (36) | 5.1 (25) | 12.1 (145) | 15.2 (231) |
| Clodinafop 60 g/ha | 7.2 (52) | 8.7 (75) | 12.5 (156) | 18.4 (336) |
| Unsprayed control | 12.7 (159) | 9.7 (93) | 34.5 (1191) | 41.2 (1707) |
| LSD (p=0.05) | 0.7 | 0.6 | 0.5 | 0.7 |

**Table 2. Effect of different weed control treatments on plant growth, yield attributes and yield of wheat**

| Treatment | Plant height (cm) | | Spike length (cm) | | Effective tillers (no./$m^2$) | | Grain yield (t/ha) | | Straw yield (t/ha) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2011-12 | 2012-13 | 2011-12 | 2012-13 | 2011-12 | 2012-13 | 2011-12 | 2012-13 | 2011-12 | 2012-13 |
| Pinoxaden plus clodinafop 40 g/ha | 70 | 90 | 10.6 | 10.5 | 340 | 320 | 4.00 | 3.72 | 5.82 | 6.38 |
| Pinoxaden plus clodinafop 50 g/ha | 72 | 91 | 11.0 | 10.6 | 354 | 342 | 4.31 | 4.28 | 5.98 | 6.84 |
| Pinoxaden plus clodinafop 60 g/ha | 73 | 91 | 11.0 | 10.6 | 354 | 343 | 4.44 | 4.35 | 6.18 | 6.85 |
| Pinoxaden 50 g/ha | 74 | 90 | 10.6 | 10.3 | 339 | 322 | 4.05 | 3.78 | 5.89 | 6.46 |
| Clodinafop 60 g/ha | 72 | 90 | 10.8 | 10.4 | 270 | 320 | 3.77 | 3.81 | 5.38 | 6.05 |
| Unsprayed control | 67 | 85 | 8.3 | 8.5 | 264 | 253 | 3.72 | 2.50 | 4.73 | 4.84 |
| LSD (p=0.05) | 5 | 5 | 0.8 | 0.1 | 11 | 20 | 0.28 | 0.16 | 0.19 | 0.31 |

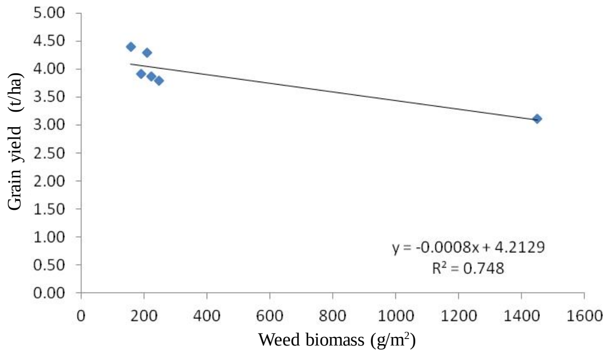


**Figure 1. Relationship of grain yield and weed biomass (mean of two years data)**

dose 40 g/ha, but was statistically similar to pinoxaden, clodinafop and fenoxaprop. Chopra *et al.* (2015) also reported that sole application of pinoxaden both at 50 and 75 g/ha and clodinafop at 60 g/ha were found to be effective only on grasses. Application of pinoxaden at 30–35 g/ha provided effective control of *P. minor* in wheat and wheat yields in pinoxaden were similar to weed-free yields (Chhokar *et al.* 2008). Post-emergence application of pinoxaden at 40-50 g/ha provided excellent control of *P. minor* and *Avena ludoviciana* (Kumar 2010). Pinoxaden 40-60 g/ha is very effective against *Avena ludoviciana* and *P. minor* without any phytotoxicity, but is ineffective against broadleaf weeds (Singh and Punia 2007, Chhokar *et al.* 2008).

Regression analysis indicated that there was significant negative linear relationship between grain yield and weed biomass in wheat. In regression analysis, the equations Y = -0.0008 x +4.2129 **(Figure 1)** were found to be fit for the wheat grain yield and biomass of weeds where Y is grain yield and X is weed biomass. Correlation between grain yield and weed biomass was $R^2$ = 0.748 (**Figure 1**). It indicated a high degree of negative correlation between weed biomass and grain yield. Results indicated that as the weed biomass increased, wheat grain yield decreased.

### Residual effect of pre-mixture of pinoxaden plus clodinafop on succeeding greengram crop

No phytotoxicity on residual greengram crop was observed in already treated plots of pre-mixture of pinoxaden plus clodinafop. Pre-mix of pinoxaden plus clodinafop at 40, 50, 60 and 120 g/ha and other recommended herbicides did not effect the plant height of succeeding greengram crop indicating the safety of this herbicide.

The results of this study concluded that pre-mixture of pinoxaden and clodinafop could provide temporary relief to farmers for management of *P. minor* in wheat.

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# Tillage and weed management effect on productivity of wheat under soybean-wheat-greengram cropping system in conservation agriculture

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**ABSTRACT**

The effect of tillage and weed management practices on density and biomass of *Medicago denticulata*, *Chenopodium album* and *Phalaris minor* as well as productivity of wheat in soybean-wheat-greengram cropping system was evaluated during 2013-14 and 2014-15 at ICAR-DWR, Jabalpur. The density and biomass of weeds were reduced to maximum when conventional tillage was done in wheat under CT-CT-fallow system followed by conventional tillage in wheat under CT-ZT-ZT system. While, weed density and biomass were minimum with zero tillage in wheat in the presence of residues of preceding soybean under ZT+R-ZT+R-ZT+R system followed by ZT-ZT+R-ZT+R system, which recorded higher grain and straw yields as well as gross and net monetary returns. Metsulfuron + clodinafop (4 + 60 g/ha) ready mixture applied at 25 DAS recorded the lowest weed density as well as biomass and higher crop yield and monetary returns. The interaction indicated that metsulfuron + clodinafop (4 + 60 g/ha) applied in wheat with zero tillage in presence of residues of preceding soybean under ZT+R-ZT+R-ZT+R and ZT-ZT+R-ZT+R system has resulted in lower weed density and biomass with higher weed control efficiency, grain and straw yields, higher gross and net monetary returns including B:C ratio than other combinations.

**Key words:** Conventional tillage, Economics, Productivity, Weed management, Wheat, Zero tillage

Soybean-wheat cropping system is commonly practiced in the semi-arid to sub-humid tropical regions of Malwa, Vindhyan plateau and some part of Kymore plateau and Satpura hill zones of Madhya Pradesh on 4.5 Mha area, and contributes nearly 57.6 and 8.8% of the total soybean and wheat production in the country respectively (Monsefi *et al.* 2011). Tillage has been found an essential component of wheat however, intensive tillage has been found to have adverse effect on soil structure leading to soil erosion and carbon loss. Besides, concentration of greenhouse gases in the atmosphere is increasing due to burning of preceding rice residues and in turn helping in global warming. Therefore, many countries switching towards conservation agriculture in which minimum or zero soil disturbance and retention of crop residues is done on soil surface, and legumes are included in crop rotation. The conventional practices of intensive tillage, involving 6-8 tillage operations, consume a high proportion (25-30%) of total operational energy used in crop production (Sindhu *et al.* 2004). Conservation tillage practices, such as no tillage combined with previous crop residues may offset production costs and other constraints associated with land preparation (Hobbs 2001). The potential benefits of no tillage can be fully realized only when it is practiced continuously and soil surface remain covered with previous crop residues (Sindhu *et al.* 2007). Despite lower energy requirement for tillage and more efficient energy use under zero tillage conditions, the input requirement especially of fertilizers and weed control either manually or through herbicides affect crop growth (Gajri *et al.* 1992). In conventional-tilled farming of wheat in soybean-wheat cropping system, weeds are effectively controlled by tillage, due to better uprooting of weeds and their deep burial into the soil. But lack of tillage, promotes weeds growth in conservation agriculture, if effective weed control measures are not followed in nick of time. Weed control in conservation agriculture is a greater challenge because weed seed burial by tillage operations and soil applied herbicides are not incorporated well, resulting in reduced efficiency of herbicides (Chauhan and Johanson 2009). Besides this, the presence of crop residues over the soil surface, may intercept and bind the herbicides before reaching the soil surface. Henceforth, post-emergence herbicides are becoming potent tool for control of weeds in conservation agriculture. Keeping aforesaid facts in view, the comprehensive study was undertaken to see the effect of tillage and weed control practices on weeds, yields and economics of wheat in soybean-wheat-greengram cropping system.

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## MATERIALS AND METHODS

The field experiment was conducted at Research Farm, ICAR- Directorate of Weed Research, Maharajpur Jabalpur (M.P.), situated at $23^0$ 09' North latitude and $79^0$ 58' East longitudes with an altitude of 411.78 meters above the mean sea level during *Rabi* season 2013-14 and 2014-15. The soil was clayey loam in texture, neutral in pH (7.2) with bulk density of 1.12 Mg/$m^3$. It was medium in organic carbon content (0.6%), available nitrogen (251.0 kg/ha), phosphorus (18.5 kg/ ha) and high in available potassium (289.7 kg/ ha). The total rainfall of the area was 116.4 and 218.3 cm during the year 2013-14 and 2014-15 respectively.

A split plot design with three replications was used. Fifteen treatments were tested with five tillage treatments in the main plots *viz*. conventional tillage in soybean-conventional tillage in wheat and fallow in summer (CT-CT-fallow), conventional tillage in soybean-zero tillage in wheat-zero tillage in greengram (CT-ZT-ZT tillage system), zero tillage with preceding crop residues in soybean - zero tillage in wheat- zero tillage with preceding crop residues in greengram (ZT+R-ZT-ZT+R tillage system), zero tillage in soybean- zero tillage with preceding crop residues in wheat-zero tillage with preceding crop residues in greengram (ZT-ZT+R-ZT+R tillage system), zero tillage with preceding crop residues in soybean- zero tillage with preceding crop residues in wheat- zero tillage with preceding crop residues in greengram (ZT+R-ZT+R-ZT+R tillage system) and three weed management treatments in sub plots, *viz*. weedy check in all crops, pendimethalin 750 g/ha *fb* imazethapyr 100 g/ha in soybean - mesosulfuron 12 g/ha + iodosulfuron 2.4 g/ha (Atlantis) in wheat - pendimethalin 750 g/ha in greengram, metribuzin 500 g/ha + 1 HW at 25 DAS in soybean - metsulfuron 4 g/ ha + clodinafop 60 g/ha (Vesta) in wheat-pendimethalin 750 g/ha + 1 HW in greengram. Observation were recorded on density and biomass of weeds at 60 DAS by quadrate count method and yields of wheat. The weed density and biomass were subjected to square root transformation to normalize their distribution. WCE was calculated by using the formulae suggested by Gomez and Gomez (1984). Economic analysis was done as per the prevailing cost of inputs and selling price of output.

## RESULTS AND DISCUSSION

### Weed density and biomass

The higher density and biomass of *Medicago denticulata*, *Chenopodium album* and *Phalaris minor* were recorded when conventional tillage was done in wheat under CT-CT tillage system followed by CT-ZT-ZT tillage system being minimum when zero tillage was done in presence of residue of preceding soybean crop in wheat under ZT+R-ZT+R-ZT+R tillage system (**Table 1**). Higher density and biomass of *M. denticulata* and *P. minor* were observed under conventional tillage in wheat because of soil disturbance caused by tillage may have brought the deep buried weed seeds near to soil surface, where favourable environment, in terms of better availability of light, oxygen and moisture facilitated the germination and emergence of weed seeds. Besides, tillage caused abrasion/rapture of seed coat of weed seeds and thus facilitated germination of weed seeds and in turns had more density and biomass of former weeds. Chhokar *et al.* (2009) found that density of *P. minor* was higher under conventional tillage. But, the infestation of broad-leaved weeds like *Rumex dentatus* and *M. denticulata* was maximum under zero tillage condition. However, the density and biomass of *C. album* was maximum when conventional tillage was done in wheat under CT-CT tillage system. Seed germination of *C. album* also manifested by absolute light requirement. Deep buried weed seeds remain inactive for germination due to absence of red light. After tillage, deep buried weed seeds come up to the upper layer of soil surface and exposure to red light after by phytochrome (pr), later convert into Pfr (active form) and series of physiological events leads to germination of *C. album* (Gallagher and Cardina 1998). The lower density and biomass of all weeds under zero tillage in presence of residues of soybean in wheat (ZT+R-ZT+R-ZT+R tillage system) was due to fact that seed buried deeper, tends to enhance seed dormancy and led to less emergence (Eltiti 2003 and Colbach *et al.* 2005). In addition to this, deep buried smaller seeds and weed seedlings either died due to deep burial or lack of oxygen in plough sole layer on account of zero soil manipulation/disturbance and resulted in lower density and biomass of former weeds (Hakansson 2003). In an another study, surface residues retention supports a wide variety of surface invertebrates and insects including carabit beetles and spiders. Carabid beetles shown to have considerable preference for seed of some weed species (Eltiti 2003).

Ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha (Atlantis) was found more effective in controlling grasses as well as broad-leaved weeds as compared to ready mixture of metsulfuron + clodinafop 4 + 60 g/ha. Das (2008) found that tank mixture of alternative herbicides metsulfuron and clodinafop showed antagonism and decreasd the efficiency of herbicide mixture but sequential application of both these herbicides curtailed the density and biomass of weeds.

Density and biomass were maximum when no weed control was done after conventional tillage in wheat under CT-CT tillage system followed by no weed control after zero tillage in wheat under CT-ZT-ZT tillage system. Hossain and Begum (2015) also observed that soil disturbance with tillage expose weed seed to a flash of light that releases seeds from dormancy. The identical reduction in weed density as well as biomass in plots receiving ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha after zero tillage in presence of residues of soybean in wheat under ZT+R-ZT+R-ZT+R tillage system followed by ZT-ZT+R-ZT+R tillage system was observed. No soil disturbance under zero tillage also encourages higher predator populations. No tilled fields increase the number, diversity or activity of seed consuming fauna as compared to conventionally tilled fields (Blubaugh and Kaplan 2015).

## Weed control efficiency in wheat

Weed control efficiency was minimum when conventional tillage was done in wheat under CT-CT tillage system because of more weed biomass production being higher in zero tillage in wheat under CT-ZT-ZT tillage system (**Table 2**). Whereas, weed control efficiency was maximum when zero tillage was done in presence of residues of preceding soybean in wheat under ZT+R-ZT+R-ZT+R tillage system. Lower weed biomass production due to better control of weeds increased the weed control efficiency. Besides, weed seed germination and emergence were hampered by thick layer of residues of preceding crop. Khaliq *et al.* (2013) also endorsed similar views from their studies.

Ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha attained higher weed control efficiency than ready mixture of metsulfuron +clodinafop 4+60 g/ha. Walia *et al.* (2005) also found that mesosulfuron + iodosulfuron provided effective control of grasses and broad-leaved weeds.

Interaction of tillage and weed control practices caused identical variation on weed control efficiency. Weed control efficiency was minimum when no weed control was done after conventional tillage in wheat under CT-CT tillage system. This may be attributed to the fact that tillage brought the deep buried weed seeds near to soil surface, where favourable conditions in soil facilitated germination and emergence of weed seeds (maximum weed seeds were found at the 5-10 cm soil depth under conventional tillage). In addition to this, no weed control measures were adopted in weedy check plots, which in turn had more dry matter of all weeds and finally lower weed control efficiency. However, it was higher when no weed control was done after zero tillage in presence of residues of preceding soybean in wheat under ZT+R-ZT+R-ZT+R tillage system being maximum when ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha was applied after zero tillage in presence of residues of preceding soybean in wheat under ZT+R-ZT+R-ZT+R tillage system. It was observed that weed seeds were not germinated in plots where soil surface was covered by preceding crop residues and does not provided congenial condition for germination and emerged weeds were effectively controlled by ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha.

## Grain and straw yields of wheat

The grain and straw yields (5.24 and 5.54 t/ha) were minimum when conventional tillage was done in wheat under CT-CT tillage system being at par to zero tillage in wheat under CT-ZT-ZT (5.28 and 5.95 t/ha) and ZT+R -ZT-ZT+R (5.46 and 6.23t/ha) tillage

**Table 1. Density and biomass (no./m$^2$) of *Medicago denticulata, Chenopodium album* and *Phalaris minor* in wheat as affected by tillage and weed control practices at 60 DAS (mean of two years)**

| Treatment | *Medicago denticulata* | | *Chenopodium album* | | *Phalaris minor* | |
|---|---|---|---|---|---|---|
| | Weed density | Weed biomass | Weed density | Weed biomass | Weed density | Weed biomass |
| *Tillage* | | | | | | |
| CT-CT | 6.8(45.5) | 3.3(10.6) | 2.5(5.9) | 1.27(1.12) | 1.60(2.06) | 1.04(0.59) |
| CT-ZT-ZT | 5.8(32.9) | 3.1(8.9) | 2.0(3.6) | 1.12(0.76) | 1.25(1.07) | 0.96(0.42) |
| ZT+R-ZT-ZT+R | 5.5(29.7) | 3.0(8.5) | 1.5(1.7) | 0.96(0.42) | 1.06(0.62) | 0.83(0.19) |
| ZT-ZT+R-ZT+R | 5.1(25.9) | 2.8(7.2) | 1.3(1.3) | 0.87(0.26) | 0.97(0.44) | 0.85(0.22) |
| ZT+R-ZT+R-ZT+R | 4.9(23.8) | 2.6(6.4) | 1.3(1.3) | 0.87(0.25) | 0.91(0.32) | 0.79(0.12) |
| LSD (p=0.05) | 0.47 | 0.26 | 0.18 | 0.11 | 0.33 | 0.11 |
| *Weed management* | | | | | | |
| Mesosulfuron + iodosulfuron 12 + 2.4 g/ha | 2.8(7.4) | 0.9(0.4) | 0.9(0.4) | 0.83(0.19) | 0.72(0.41) | 0.79(0.12) |
| Metsulfuron + clodinafop 4 + 60 g/ha | 3.4(11.1) | 1.3(1.2) | 1.4(1.4) | 0.90(0.30) | 0.74(0.48) | 0.82(0.17) |
| Weedy check | 10.6(112.9) | 6.6(43.4) | 2.9(8.12) | 1.33(1.26) | 1.38(1.84) | 1.07(0.65) |
| LSD (p=0.05) | 0.32 | 0.18 | 0.13 | 0.09 | 0.16 | 0.08 |

systems (**Table 2**). However, maximum grain and straw yields (5.78 and 6.73 t/ha) were recorded when zero tillage was done in presence of residues of preceding soybean in wheat under ZT+R-ZT+R-ZT+R tillage system and proved significantly superior over other tillage system but at par to zero tillage in presence of residues of preceding soybean in wheat under ZT-ZT+R-ZT+R tillage system (5.63 and 6.23 t/ha, respectively). Lesser yields of wheat in case of conventional tillage attributed to poor availability of growth resources on account of more weeds, which affected the growth and developments of crop plants and finally had inferior values of yield attributing traits. Superior yield attributes in wheat were recorded due to availability of more space, light and nutrients for optimum growth and development of crop plants due to zero/least interspecies competition as plants were equally spaced under zero tillage in presence of residues of soybean in wheat under ZT+R-ZT+R-ZT+R tillage system.

The present findings corroborated with the results of Singh (2014). The lowest grain and straw yields (4.49 and 4.62 t/ha) were recorded in weedy check plots where no weed control was done. Grains yield was appreciably increased (5.37and 5.63 t /ha) in plots receiving ready mixture of metsulfuron + clodinafop 4 + 60 g /ha being maximum (5.98 and 6.38 t/ha) when ready mixture of mesosulfuron + iodosulfuron 12 + 2.4 g/ha was applied in experimental plots and both herbicidal treatments were superior as both caused 33.18 and 38.09% increase in grain and straw yields over weedy check plots (4.49 and 4.62 t/ha). Singh *et al.* (2003) also reported mesosulfuron + iodosulfuron 12+2.4 g/ha had produced grain yields similar to weed free plots.

Interaction of tillage and weed control practices caused significant variation on grain and straw yields of wheat. Both were minimum when no weed control was done after conventional tillage in wheat under CT-CT tillage system. However, higher grain and straw yields were recorded when no weed control was done after zero tillage in presence of preceding crop residues of soybean in wheat under ZT+R-ZT+R-ZT+R tillage system and proved significantly superior over no weeding after conventional tillage in wheat under CT-CT tillage system and zero tillage in wheat under CT-ZT-ZT tillage system but at par to no weed control after zero tillage in presence of residues of preceding soybean in wheat under ZT-ZT+R-ZT+R tillage system and no weed control after zero tillage in wheat under ZT+R-ZT-ZT+R tillage system in soybean-wheat-greengram cropping system. However, grain and straw yields of wheat were further increased under metsulfuron + clodinafop 4+60 g/ha after all tillage systems being the maximum when ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha was applied after zero tillage in presence of residues of preceding soybean in wheat under ZT+R-ZT+R-ZT+R tillage system and proved significantly superior over ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha after conventional tillage in wheat under CT-CT tillage system, zero tillage in wheat under CT-ZT-ZT and ZT+R-ZT-ZT+R tillage systems but at par to ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha applied after zero tillage in presence of residues of preceding soybean in wheat under ZT-ZT+R-ZT+R tillage system. Singh *et al*. (2010), Singh *et al*. (2017) also reported higher grain yield of wheat under zero tillage system after use of post-emergence herbicides.

**Economics**

The minimum cost of cultivation was recorded when zero tillage was done in wheat under CT-ZT-ZT tillage system followed by zero tillage in wheat under ZT+R-ZT-ZT+R tillage system, zero tillage in presence of residues of preceding soybean in wheat under ZT+R-ZT+R-ZT+R tillage system being maximum when conventional tillage was done in wheat under CT-CT tillage system (**Table 2**). Due to more number of tillage operations in conventional tilled plots, the cost of cultivation was higher under conventional tillage than zero tilled plots. GMRs, NMRs and B:C ratio were maximum in plots receiving zero tillage in presence of previous crop residues in case of wheat under ZT+R-ZT+R-ZT+R and ZT-ZT+R-ZT+R tillage (Bullock 2004). Reverse trends was observed in case of gross, net monetary returns and B:C ratio in other tillage systems. Higher cost of cultivation was recorded with ready mixture of metsulfuron + clodinafop 4+60g/ha in wheat followed by ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha in wheat relative to weedy check. But GMRs, NMRs and B:C ratio were higher when ready mixture of mesosulfuron + iodosulfuron 12+2.4 g/ha was applied in wheat. Interaction between tillage and weed control practices also caused marked influence on economics of wheat. The GMRs, NMRs and B:C ratio were lower in plots where weed control practices were not adopted after each tillage. However, these were higher when ready mixture of mesosulfuron + iodosulfuron (12+2.4 g/ha) was applied after zero tillage in wheat in presence of previous crop residues of soybean under ZT+R-ZT+R-ZT+R and ZT+R-ZT+R-ZT+R than other combinations.

Thus, it was concluded that zero tillage in presence of residues of soybean in wheat along with PoE application of mesosulfuron + iodosulfuron

**Table 2. Weed control efficiency, grain and straw yields as affected by tillage and weed control practices in wheat (mean of two years)**

| Treatment | Weed control efficiency (%) | Grain yield (t/ha) | Straw yield (t/ha) | Cost of cultivation (x$10^3$ `/ha) | Gross monetary returns (x$10^3$ `/ha) | Net monetary returns (x$10^3$ `/ha) | B:C ratio |
|---|---|---|---|---|---|---|---|
| *Tillage* | | | | | | | |
| CT-CT | 64.22 | 5.24 | 5.54 | 33.12 | 101.70 | 68.58 | 3.07 |
| CT-ZT-ZT | 69.32 | 5.28 | 5.95 | 32.47 | 103.58 | 71.11 | 3.18 |
| ZT+R-ZT-ZT+R | 71.35 | 5.46 | 6.23 | 32.47 | 107.41 | 74.94 | 3.30 |
| ZT-ZT+R-ZT+R | 75.91 | 5.63 | 6.32 | 32.87 | 110.52 | 77.66 | 3.35 |
| ZT+R-ZT+R-ZT+R | 79.38 | 5.78 | 6.73 | 32.87 | 114.13 | 81.26 | 3.46 |
| LSD (p=0.05) | - | 0.22 | 0.86 | - | - | - | - |
| *Weed management* | | | | | | | |
| Mesosulfuron + iodosulfuron 12 + 2.4 g/ha | 98.68 | 5.98 | 6.38 | 33.06 | 121.71 | 88.65 | 3.68 |
| Metsulfuron + clodinafop 4 + 60 g/ha | 96.70 | 5.37 | 5.63 | 33.46 | 112.19 | 78.72 | 3.35 |
| Weedy check | 20.73 | 4.36 | 4.62 | 31.75 | 88.50 | 56.75 | 2.79 |
| LSD (p=0.05) | - | 0.27 | 0.61 | - | - | - | - |

12+2.4 g/ha found effective for control weeds in wheat and attained higher productivity and profitability of wheat.

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# Effect of different pre- and post-emergence herbicides on weed control, productivity and economics of maize

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**ABSTRACT**

A field experiment was conducted at Agricultural Research Station, Vizianagaram, Andhra Pradesh during rainy seasons of 2015 and 2016 to find out the best chemical weed management practices in maize (*Zea mays* L.). Twelve treatments were tested in randomized block design with three replications. Treatments consisted of pre-emergence (PE) and post-emergence (PoE) herbicides applications along with weed free check and weedy check. Experimental results indicated that PoE of tank mix formulation of tembotrione 50 g/ha + atrazine 0.5 kg/ha at 15-20 days after seeding (DAS) has recorded highest weed control efficiency (93.6 and 96.9%, respectively during 2015 and 2016) followed by hand weeding twice at 20 and 40 DAS (90.1 and 95.6%, respectively). Grain yield was significantly higher (9.79 t/ha and 8.70 t/ha, respectively) with hand weeding twice at 20 and 40 DAS, and it was closely followed by PoE of tembotrione 50 g/ha + atrazine 0.5 kg/ha (9.65 t/ha and 8.61 t/ha respectively). Net monetary returns (` 104357 and ` 97985, respectively) and B:C ratio (2.94 and 3.14, respectively) were also significantly high with PoE application of tembotrione 50 g/ha + atrazine 0.5 kg/ha.

**Key words**: Grain Yield, Maize, Pre- and post-emergence herbicides, Weed control efficiency

Maize (corn) along with wheat and rice is one of the world's most important food crops. Maize provides food to the human beings and feed to the cattle. During recent years, maize is being increasingly used as a feedstock and for the production of bio ethanol. Protecting maize from weeds, pests and diseases is very much essential to avoid heavy losses caused by them in maize yield and gain quality. Weed control is usually most important, as weed interference is a severe problem in corn, especially in the early part of the growing season due to its initial slow growth rate and wider row spacing. Yield losses due to weed infestation vary from 28-93% depending on the type of weed flora and their intensity, stage, nature and duration of crop weed competition (Sharma and Thakur 1998). The critical period of crop weed competition in corn range from 1 to 8 weeks after sowing. In order to realize the maximum yield potential of maize, weed management becomes indispensable during this period. Chemical weed management by using pre- or post-emergence herbicides can lead to the efficient and cost effective control of weeds during critical period of crop weed competition, which may not be possible in manual or mechanical weeding due to its high cost of cultivation. Hence, there is an immense need to find out the best chemical for effective weed management in maize and hence this study was undertaken to identify the best chemical weed management practices in maize (*Zea mays* L.)

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## MATERIALS AND METHODS

A field experiment was conducted at Agricultural Research Station, Vizianagaram, Andhra Pradesh during rainy seasons of 2015 and 2016. The soil of the experimental site was sandy clay loam in texture with neutral soil reaction (pH-7.0), electric conductivity-0.13dS/m and low in organic carbon content (0.36%). Availability of nitrogen, phosphorus and potassium in the experimental site were low (198.4 kg/ha), high (70.5 kg/ha) and medium (230.2 kg/ha), respectively. Total rainfall received during crop season was 455.8 and 709.4 mm, respectively with mean maximum (31.6 $^0$C and 30.3 $^0$C, respectively) and mean minimum temperatures (28.0 $^0$C and 28.3 $^0$C, respectively) during 2015 and 2016.

Experiment was conducted in randomized block design with three replications. Treatments include atrazine 1.0 kg/ha as pre-emergence application (PE), pendimethalin 1.0 kg/ha as PE, alachlor 1.0 kg/ha as PE, atrazine 0.5 kg/ha + alachlor 0.5 kg/ha as PE, 2,4-D sodium salt 1.0 kg/ha at 15-25 days after seeding (DAS), 2,4-D amine salt 0.58 kg/ha at 15-20DAS, atrazine 1.0 kg/ha at 15-20 DAS, 2,4-D ethyl ester 0.9 kg/ha at 15-20 DAS, tembotrione 100 g/ha at 15-20 DAS, tembotrione 50 g/ha + atrazine 0.5 kg/ha at 15-20 DAS, hand weeding twice at 20 and 40 DAS unweeded check (control).

Maize hybrid "*DHM-117*" was sown on 21.07.2015 and 12.07.2016, during 2015 and 2016, respectively at 60 x 20 cm spacing. Before sowing, field was thoroughly ploughed and levelled. The crop was fertilized evenly irrespective of treatments with 180-200:60:50 kg NPK/ha with N in three equal split doses at the time of sowing, 30 DAS and 50 DAS. Pre-emergence herbicides were applied within two days after sowing. Post-emergence herbicides were applied at 15-20 DAS. All the herbicides were used after making the spray volume of 500 L/ha. Phytotoxic effect on crop was recorded at 3rd and 10th day after application of herbicides. Weed density was recorded at 20 DAS and 40 DAS by using a quadrate of 100 x 100 cm (1 $m^2$) size from the centre of the plot. The entire weeds inside the quadrate were uprooted and cut close to the transition of root and shoot in each plot and collected for dry matter accumulation (biomass). The samples were first dried in sun and then kept in oven at 70 ± 2°C. The dried samples were weighed and expressed as biomass (g/$m^2$). Cost of cultivation, gross returns, net monetary returns and benefit cost ratio for each treatment were calculated by taking into consideration of total costs incurred and returns obtained. Square root transformation was done for weed density and weed biomass by using the formula $\sqrt{x+0.5}$. Weed control efficiency (WCE), weed index (WI) and herbicide efficiency index (HEI) were calculated using formulae as suggested by Gill and Vijayakumar (1969), Mani *et al.* (1973), Krishnamurthy *et al.* (1995).

## RESULTS AND DISCUSSION

### Weed flora

Among the weeds, grasses and sedges were dominant in the experimental site compared to the broad-leaved weeds (**Table 1**). *Echinochloa colona* (L.) Link., *Eleusine indica* (L.), *Dactyloctenium aegyptium* (L.) Willd. , *Digitaria sanguinalis* (L.) Scop. were the major grassy weeds and *Cyperus rotundus* (L.) was the dominant sedge weed. *Trianthema portulacastrum* (L.), *Digera arvensis* Forsskal, *Cleome viscosa* (L.), *Commelina benghalensis* (L.), *Euphorbia hirta* (L.), *Tridax procumbence* (L.) and *Phyllanthus niruri* (L.) *etc.* were the major broad-leaved weed species during both the years of study.

**Table 1. Major weeds density (no./$m^2$) in the experimental plot**

| Treatment | 2015 | | | | | | 2016 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 DAS | | | 40 DAS | | | 20 DAS | | | 40 DAS | | |
| | Grasses | Sedges | BLW | Grasses | Sedges | BLW | Grasses | Sedges | BLW | Grasses | Sedges | BLW |
| Atrazine 1000 g/ha as PE | 5.6 | 5.7 | 2.7 | 7.5 | 4.1 | 1.8 | 2.5 | 4.4 | 1.8 | 7.4 | 3.9 | 3.3 |
| | (30.7) | (32.0) | (6.7) | (56.0) | (16.0) | (2.7) | (6.0) | (18.7) | (2.7) | (54.7) | (14.7) | (10.7) |
| Pendimethalin 1000 g/ha as PE | 6.2 | 5.6 | 3.7 | 6.6 | 4.8 | 2.1 | 2.5 | 5.6 | 2.1 | 7.3 | 5.1 | 4.2 |
| | (37.3) | (30.7) | (13.3) | (42.7) | (22.7) | (4.0) | (6.0) | (30.7) | (4.0) | (53.3) | (25.3) | (17.3) |
| Alachlor 1000 g/ha as PE | 5.9 | 7.0 | 2.9 | 4.8 | 6.8 | 1.8 | 2.3 | 5.9 | 2.4 | 7.5 | 5.3 | 4.2 |
| | (34.7) | (48.0) | (8.0) | (22.7) | (45.3) | (2.7) | (4.7) | (34.7) | (5.3) | (56.0) | (28.0) | (17.3) |
| Atrazine 500 g/ha + alachlor 500 g/ha as PE | 3.7 | 7.2 | 1.4 | 3.5 | 7.9 | 2.1 | 1.8 | 4.6 | 2.0 | 7.3 | 4.8 | 2.9 |
| | (13.3) | (50.7) | (1.3) | (12.0) | (61.3) | (4.0) | (2.7) | (20.7) | (3.3) | (53.3) | (22.7) | (8.0) |
| 2,4-D sodium salt 1000 g/ha at 15-25 DAS | 11.3 | 6.4 | 2.9 | 10.4 | 4.5 | 0.7 | 9.3 | 5.7 | 3.6 | 10.4 | 4.8 | 0.7 |
| | (126.7) | (40.0) | (8.0) | (106.7) | (20.0) | (0.0) | (86.7) | (32.0) | (12.7) | (108.0) | (22.7) | (0.0) |
| 2,4-D amine salt 580 g/ha at 15-20 DAS | 14.3 | 4.8 | 2.4 | 9.3 | 6.7 | 0.7 | 9.5 | 5.6 | 3.4 | 9.8 | 5.3 | 2.1 |
| | (204.0) | (22.7) | (5.3) | (85.3) | (44.0) | (0.0) | (89.3) | (30.7) | (11.3) | (94.7) | (28.0) | (4.0) |
| Atrazine 1000 g/ha at 15-20 DAS | 13.2 | 5.6 | 2.7 | 9.3 | 5.5 | 2.9 | 9.1 | 5.6 | 3.3 | 9.1 | 5.6 | 4.4 |
| | (174.7) | (30.7) | (6.7) | (86.7) | (29.3) | (8.0) | (82.0) | (31.3) | (10.7) | (82.7) | (30.7) | (18.7) |
| 2,4-D ethyl ester 900 g/ha at 15-20 DAS | 13.7 | 5.8 | 3.1 | 9.2 | 6.2 | 1.8 | 9.2 | 5.5 | 3.0 | 9.9 | 4.9 | 2.9 |
| | (188.0) | (33.3) | (9.3) | (84.0) | (37.3) | (2.7) | (83.3) | (29.3) | (8.7) | (97.3) | (24.0) | (8.0) |
| Tembotrione 100 g/ha at 15-20 DAS | 15.7 | 3.5 | 1.8 | 3.7 | 3.7 | 1.8 | 11.1 | 5.3 | 3.4 | 3.3 | 4.5 | 0.7 |
| | (245.3) | (12.0) | (2.7) | (13.3) | (13.3) | (2.7) | (122.0) | (28.0) | (11.3) | (10.7) | (20.0) | (0.0) |
| Tembotrione 50 g/ha + atrazine 500 g/ha at 15-20 DAS | 13.3 | 4.5 | 2.9 | 1.8 | 3.5 | 1.4 | 10.9 | 5.6 | 3.7 | 1.8 | 3.1 | 0.7 |
| | (176.0) | (20.0) | (8.0) | (2.7) | (12.0) | (1.3) | (118.7) | (31.3) | (13.3) | (2.7) | (9.3) | (0.0) |
| Hand weeding twice at 20 and 40 DAS | 12.1 | 6.4 | 3.5 | 3.5 | 3.3 | 0.7 | 11.1 | 5.6 | 3.8 | 2.7 | 3.1 | 2.1 |
| | (145.3) | (40.0) | (12.) | (12.0) | (10.7) | (0.0) | (122.7) | (30.7) | (14.0) | (6.7) | (9.3) | (4.0) |
| Unweeded check (control) | 15.1 | 5.1 | 3.1 | 11.1 | 7.5 | 3.5 | 11.7 | 5.1 | 4.0 | 12.0 | 6.0 | 5.5 |
| | (226.7) | (25.3) | (9.3) | (122.7) | (56.0) | (12.0) | (136.7) | (25.3) | (15.3) | (144.0) | (36.0) | (29.3) |
| LSD (p=0.05) | 2.03 | 2.06 | 0.73 | 1.61 | 1.46 | 0.86 | 0.58 | 0.58 | 0.44 | 0.79 | 0.77 | 0.59 |

DAS=Days after seeding; Values in the parentheses are original values; Subject to square root transformation

**Phytotoxicity on crop and weed**

No phytotoxic symptoms were observed on maize due to herbicidal treatments. Tembotrione 100 g/ha at 15-20 DAS and tembotrione 50 g/ha + atrazine 0.5 kg/ha at 15-20 DAS, caused complete chlorosis of all weeds including grasses, sedges and broad-leaved weeds. After that weeds were withered and died. But, the sedges were again re-germinated from the underground corm within 15-20 days after application of herbicide. Meanwhile, maize grew rapidly and covered the entire space.

**Effect on weeds**

At 20 DAS, weed growth was found significantly low in PE herbicide treated plots and among them PE of atrazine 0.5 kg/ha + alachlor 0.5 kg/ha and atrazine 1.0 kg/ha recorded lowest weed density during both the years. Deshmukh *et al.* (2009) reported similar results of lowest weed population and weed biomass at 30 DAS with atrazine 1.0 kg/ha as PE. At 40 DAS, significantly lowest weed density was noticed in the treatment tembotrione 50 g/ha + atrazine 0.5 kg/ha at 15-20 DAS. It was 29.5% and 40.0% lower weed density over hand weeding twice at 20 and 40 DAS during 2015 and 2016, respectively (**Table 2**).

Weed biomass was significantly low with atrazine 1.0 kg/ha PE followed by atrazine 0.5 kg/ha + alachlor 0.5 kg/ha and pendimethalin 1.0 kg/ha compared to other treatments at 20 DAS. Chopra and Angiras (2008) also reported that atrazine1.5 kg/ha as PE was found promising in reducing weed biomass over other treatments. However at 40 DAS, weed biomass in tembotrione 50 g/ha + atrazine 0.5 kg/ha at 15-20 DAS treatment was significantly low (12.6 and 10.3 g/m$^2$) and it was closely followed by hand weeding twice at 20 and 40 DAS (19.6 and 14.7 g/m$^2$) (**Table 2**). During both the years, weed biomass was significantly high in weedy check.

Among the PE herbicide treatments, higher weed control efficiency (WCE) at 20 DAS was observed with atrazine 1.0 kg/ha followed by atrazine 0.5 kg/ha + alachlor 0.5 kg/ha (**Table 3**). Deshmukh *et al.* (2009) reported that PE application of atrazine 1.0 kg/ha has shown highest WCE at 30 DAS. Patel *et al.* (2006) was achieved maximum WCE with PE of atrazine + alachlor each applied at 0.5 kg/ha. At 40 DAS, WCE of tembotrione 50 g/ha + atrazine 0.5 kg/ha as PoE was significantly higher (93.6 and 96.9% respectively) over other treatments and it was closely followed by hand weeding twice at 20 and 40 DAS (90.1 and 95.6% respectively). Similarly Martin *et al.* (2011) observed improved control of individual weed species by 5 to 45% with tank mix application of tembotrione with atrazine 31 + 370 g/ha at four to five-collar leaf stage of corn. Joseph *et al.* (2008) reported that tank mix application of tembotrione and atrazine 92+560 g/ha as post-emergence in maize resulted in excellent control of grassy weeds. Jonathon *et al.* (2013) noticed 95% of weed control with the tank mix application of HPPD inhibiting herbicide tembotrione along with atrazine.

Weed index was significantly high in weedy check (53.3% and 49.2% in 2015 and 2016, respectively) whereas, it was significantly low in tembotrione 50 g/ha + atrazine 0.5 kg/ha (1.3% and 1.0% respectively) (**Table 3**). Similarly herbicide efficiency index was also high for tembotrione 50 g/ha + atrazine 0.5 kg/ha (138.7 and 94.8% during 2015 and 2016 respectively) (**Table 3**).

**Table 2. Effect of different pre- and post-emergence herbicides on weed density and weed biomass**

| Treatment | Weed density (no/m$^2$)* | | | | Weed biomass(g/m$^2$) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | 2015 | | 2016 | |
| | 20 DAS | 40 DAS | 20 DAS | 40 DAS | 20 DAS | 40 DAS | 20 DAS | 40 DAS |
| Atrazine 1000 g/ha as PE | 8.3(69.3) | 8.7(74.7) | 5.3(27.3) | 9.0 (80.0) | 45.9 | 48.7 | 35.9 | 53.8 |
| Pendimethalin 1000 g/ha as PE | 9.0(81.3) | 8.4(69.3) | 6.4 (40.7) | 9.8 (96.0) | 49.2 | 43.3 | 49.1 | 65.1 |
| Alachlor 1000 g/ha as PE | 9.5(90.7) | 8.4(70.7) | 6.7 (44.7) | 10.1 (101.3) | 59.2 | 57.7 | 61.6 | 66.1 |
| Atrazine 500 g/ha + alachlor 500 g/ha as PE | 8.1(65.3) | 8.8(77.3) | 5.2 (26.7) | 9.2 (84.0) | 47.6 | 55.6 | 40.9 | 62.6 |
| 2,4-D sodium salt 1000 g/ha at 15-25 DAS | 13.2(174.7) | 11.2(126.7) | 11.5 (131.3) | 11.4 (130.7) | 117.8 | 115.1 | 151.0 | 143.5 |
| 2,4-D amine salt 580 g/ha at 15-20 DAS | 15.2(232.0) | 11.4(129.3) | 11.4 (131.3) | 11.3 (126.7) | 159.7 | 111.8 | 145.8 | 143 |
| Atrazine 1000 g/ha at 15-20 DAS | 14.5(212.0) | 11.1(124.0) | 11.1 (124.0) | 11.5 (132.0) | 164.5 | 112.9 | 163.5 | 154.7 |
| 2,4-D ethyl ester 900 g/ha at 15-20 DAS | 15.2(230.7) | 11.2(124.0) | 11.0 (121.3) | 11.4 (129.3) | 159.1 | 130.3 | 149.2 | 153.7 |
| Tembotrione 100 g/ha at 15-20 DAS | 16.0(260.0) | 5.4(29.3) | 12.7 (161.3) | 5.6 (30.7) | 165.8 | 28.9 | 219.6 | 31.6 |
| Tembotrione 50 g/ha + atrazine 500 g/ha at 15-20 DAS | 14.2(204.0) | 4.0(16.0) | 12.8 (163.3) | 3.5 (12.0) | 171.7 | 12.6 | 219.6 | 10.3 |
| Hand weeding twice at 20 and 40 DAS | 14.0(197.3) | 4.8(22.7) | 12.9 (167.3) | 4.5 (20.0) | 159.4 | 19.6 | 233.6 | 14.7 |
| Unweeded check (control) | 16.2(261.3) | 13.8(190.7) | 13.3 (177.3) | 14.3 (209.3) | 175.0 | 198.0 | 239.1 | 332.4 |
| LSD (p=0.05) | 1.23 | 0.68 | 0.54 | 0.55 | 22.84 | 12.62 | 15.6 | 23.60 |

*Original figures in parentheses were subjected to square root transformation before statistical analysis

## Effect on crop

Weed control treatments significantly affected the growth and yield attributing characters of maize over the weedy check. Plant height, cob length, cob diameter and number of rows per cob were significantly high in hand weeding twice at 20 and 40 DAS *fb* tembotrione 50 g/ha + atrazine 0.5 kg/ha, tembotrione 100 g/ha at 15-20 DAS and also in four PE herbicide treatments (**Table 4**). Martin *et al.* (2011) observed that yield attributes of sweet corn were higher when atrazine was applied along with tembotrione as PoE. Cob diameter was found significantly high in the treatment tembotrione 50 g/ha + atrazine 0.5 kg/ha *fb* hand weeding twice at 20 and 40 DAS during 2015. Highest 1000-grain weight was recorded in hand weeding twice at 20 and 40 DAS (278.2 and 251.0 g in 2015 and 2016, respectively) while, it was low in weedy check compared to other treatments (**Table 4**). Shelling per cent was significantly high in hand weeding twice at 20 and 40 DAS followed by tembotrione 50 g/ha + atrazine 0.5 kg/ha.

Grain and stover yields were significantly affected by different weed control treatments. Grain yields were more during 2015 compared to 2016 (**Table 5**). Heavy rainfall during crop season badly affected the yield during 2016. During both the years grain yields were significantly high with hand weeding twice at 20 and 40 DAS (9.79 and 8.70 t/ha, respectively) *fb* tembotrione 50 g/ha + atrazine 0.5 kg/ha (9.65 and 8.61 t/ha in 2015 and 2016, respectively). These results were in inconformity with the results obtained by Swetha (2015). The next best treatment was tembotrione 100 g/ha at 15-20 DAS. The grain and straw yields in weedy check were significantly low in both years. Straw yield was significantly high with hand weeding twice at 20 and 40 DAS *fb* tembotrione 50 g/ha + atrazine 0.5 kg/ha during 2015 and 2016 respectively. Harvest index (HI) was maximum in the treatments hand weeding twice at 20 and 40 DAS, tembotrione 50 g/ha + atrazine 0.5 kg/ha and tembotrione 100 g/ha at 15-20 DAS, while it was minimum in weedy check (36.2 and 37.0% in 2015 and 2016, respectively).

**Table 3. Weed control efficiency and weed index as affected by pre- and post-emergence herbicides**

| Treatment | Weed control efficiency (%) 2015 | | Weed control efficiency (%) 2016 | | Weed index (%) | | Herbicide efficiency index (%) | |
|---|---|---|---|---|---|---|---|---|
| | 20 DAS | 40 DAS | 20 DAS | 40 DAS | 2015 | 2016 | 2015 | 2016 |
| Atrazine 1000 g/ha as PE | 73.8 | 75.4 | 85.0 | 83.8 | 17.6 | 8.3 | 99.7 | 80.4 |
| Pendimethalin 1000 g/ha as PE | 71.9 | 78.2 | 79.5 | 80.4 | 19.4 | 11.6 | 95.3 | 73.9 |
| Alachlor 1000 g/ha as PE | 66.1 | 70.8 | 74.2 | 80.1 | 19.2 | 11.9 | 95.8 | 73.4 |
| Atrazine 500 g/ha + alachlor 500 g/ha as PE | 72.8 | 71.9 | 82.9 | 81.2 | 16.9 | 9.8 | 101.4 | 77.4 |
| 2,4-D sodium salt 1000 g/ha at 15-25 DAS | - | 41.9 | - | 56.8 | 35.6 | 17.5 | 56.1 | 62.3 |
| 2,4-D amine salt 580 g/ha at 15-20 DAS | - | 43.5 | - | 57.0 | 38.4 | 31.9 | 49.2 | 33.9 |
| Atrazine 1000 g/ha at 15-20 DAS | - | 43.0 | - | 53.4 | 41.1 | 30.0 | 42.8 | 37.7 |
| 2,4-D ethyl ester 900 g/ha at 15-20 DAS | - | 34.2 | - | 53.8 | 39.5 | 26.8 | 46.6 | 44.0 |
| Tembotrione 100 g/ha at 15-20 DAS | - | 85.4 | - | 90.5 | 9.3 | 9.6 | 119.8 | 77.9 |
| Tembotrione 50 g/ha + atrazine 500 g/ha at 15-20 DAS | - | 93.6 | - | 96.9 | 1.5 | 1.0 | 138.7 | 94.8 |
| Hand weeding twice at 20 and 40 DAS | - | 90.1 | - | 95.6 | | - | - | - |
| Unweeded check (control) | - | - | - | - | 58.7 | 49.2 | - | - |

**Table 4. Effect of pre- and post-emergence herbicides on growth and yield attributes of maize**

| Treatment | Plant height (cm) | | Cob length (cm) | | Cob diameter (cm) | | No of rows/cob | | Test wt (g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Atrazine 1000 g/ha as PE | 255.6 | 245.7 | 17.5 | 16.2 | 15.5 | 16.1 | 15.6 | 14.5 | 259.0 | 218.2 |
| Pendimethalin 1000 g/ha as PE | 255.5 | 243.5 | 16.7 | 16.1 | 15.1 | 16.0 | 15.2 | 14.4 | 247.9 | 215.3 |
| Alachlor 1000 g/ha as PE | 258.5 | 241.1 | 17.0 | 15.9 | 15.1 | 16.1 | 14.8 | 14.3 | 254.7 | 213.7 |
| Atrazine 500 g/ha + alachlor 500 g/ha as PE | 256.8 | 244.5 | 17.4 | 16.1 | 15.5 | 16.0 | 15.5 | 14.6 | 258.2 | 217.5 |
| 2,4-D sodium salt 1000 g/ha at 15-25 DAS | 238.5 | 217.7 | 15.5 | 14.9 | 14.7 | 14.3 | 14.3 | 13.8 | 245.8 | 194.9 |
| 2,4-D amine salt 580 g/ha at 15-20 DAS | 235.9 | 219.1 | 15.1 | 14.8 | 13.6 | 14.6 | 14.3 | 13.3 | 251.6 | 199.5 |
| Atrazine 1000 g/ha at 15-20 DAS | 242.5 | 216.2 | 15.6 | 14.7 | 13.9 | 14.6 | 13.8 | 13.4 | 248.3 | 199.4 |
| 2,4-D ethyl ester 900 g/ha at 15-20 DAS | 238.4 | 216.2 | 15.4 | 14.6 | 14.3 | 14.7 | 14.1 | 13.1 | 248.1 | 194.3 |
| Tembotrione 100 g/ha at 15-20 DAS | 261.1 | 238.3 | 17.0 | 16.2 | 15.9 | 15.7 | 16.2 | 14.5 | 261.2 | 218.9 |
| Tembotrione 50 g/ha + atrazine 500 g/ha at 15-20 DAS | 260.3 | 249.2 | 17.5 | 16.9 | 16.6 | 16.2 | 14.4 | 15.3 | 258.7 | 232.5 |
| Hand weeding twice at 20 and 40 DAS | 268.7 | 252.5 | 18.0 | 17.1 | 16.5 | 16.4 | 16.0 | 15.4 | 278.2 | 251.0 |
| Unweeded check (control) | 218.7 | 206.5 | 14.8 | 14.1 | 12.6 | 14.0 | 13.0 | 12.6 | 225.0 | 193.3 |
| LSD (p=0.05) | 15.91 | 16.95 | 1.25 | 1.10 | 1.26 | 0.96 | 1.07 | 0.96 | 12.31 | 12.60 |

**Table 5. Effect of pre- and post-emergence herbicides on yield and economics of maize**

| Treatment | Shelling (%) | | Grain yield (t/ha) | | Stover yield (t/ha) | | HI (%) | | Net monetary returns (`/ha) | | B:C | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Atrazine 1000 g/ha as PE | 67.3 | 70.9 | 8.07 | 7.98 | 11.23 | 10.78 | 41.8 | 42.6 | 82865 | 89808 | 2.43 | 3.01 |
| Pendimethalin 1000 g/ha as PE | 69.9 | 64.6 | 7.89 | 7.69 | 10.95 | 10.43 | 41.8 | 42.4 | 79655 | 84847 | 2.29 | 2.78 |
| Alachlor 1000 g/ha as PE | 67.4 | 65.6 | 7.91 | 7.67 | 10.44 | 10.27 | 43.1 | 42.7 | 80355 | 84937 | 2.34 | 2.83 |
| Atrazine 500 g/ha + alachlor 500 g/ha as PE | 68.5 | 69.9 | 8.14 | 7.85 | 11.24 | 10.60 | 42.0 | 42.6 | 83728 | 87706 | 2.44 | 2.93 |
| 2,4-D sodium salt 1000 g/ha at 15-25 DAS | 70.9 | 50.1 | 6.31 | 7.18 | 9.54 | 9.65 | 39.6 | 42.6 | 57816 | 77827 | 1.72 | 2.61 |
| 2,4-D amine salt 580 g/ha at 15-20 DAS | 71.7 | 51.2 | 6.03 | 5.92 | 8.94 | 8.57 | 40.3 | 40.8 | 53731 | 58928 | 1.59 | 1.97 |
| Atrazine 1000 g/ha at 15-20 DAS | 67.8 | 56.3 | 5.77 | 6.09 | 9.26 | 8.42 | 38.3 | 42.0 | 49515 | 61474 | 1.45 | 2.06 |
| 2,4-D ethyl ester 900 g/ha at 15-20 DAS | 69.2 | 52.9 | 5.92 | 6.37 | 9.01 | 9.22 | 39.7 | 40.9 | 51357 | 65141 | 1.49 | 2.15 |
| Tembotrione 100 g/ha at 15-20 DAS | 69.1 | 69.6 | 8.88 | 7.87 | 11.83 | 10.15 | 42.8 | 43.7 | 91864 | 85430 | 2.49 | 2.62 |
| Tembotrione 50 g/ha + atrazine 500 g/ha at 15-20 DAS | 71.1 | 72.4 | 9.65 | 8.61 | 12.47 | 10.79 | 43.6 | 44.4 | 104357 | 97985 | 2.94 | 3.14 |
| Hand weeding twice at 20 and 40 DAS | 71.5 | 77.4 | 9.79 | 8.70 | 12.94 | 10.87 | 43.1 | 44.5 | 104162 | 96505 | 2.76 | 2.84 |
| Unweeded check (control) | 68.4 | 47.1 | 4.04 | 4.42 | 7.12 | 7.38 | 36.2 | 37.0 | 25794 | 37338 | 0.79 | 1.29 |
| LSD (p=0.05) | 3.09 | 5.73 | 0.76 | 0.58 | 0.86 | 0.76 | 0.94 | 1.59 | - | - | - | - |

Note: Price of grain: ` 14.50/- (2015) and ` 15.00/-(2016) per kilogram

## Economic

Preference of any herbicides by the farmers mainly depends on the weed control efficiency and economics. Generally, the cost of manual weeding is much higher than the chemical weed control, which encourages many farmers for switching over to herbicides from expensive and tiresome manual weeding. Considering the economics of different treatments, net monetary returns were found to be high in the treatment tembotrione 50 g/ha + atrazine 0.5 kg/ha *fb* hand weeding twice at 20 and 40 DAS during both years. Lowest net returns were recorded in weedy check mainly because of declined yields due to excess weed growth. Further, the Benefit: Cost ratio was also significantly high for tembotrione 50 g/ha + atrazine 0.5 kg/ha during both the years (2.94 and 3.14 respectively) *fb* hand weeding twice at 20 and 40 DAS (2.76) during 2015 and PE of atrazine 1.0 kg/ha (3.01) and atrazine 0.5 kg/ha + alachlor 0.5 kg/ha (2.93) during 2016. Lowest benefit cost ratio was observed in weedy check during both years (0.79 and 1.29 respectively) (**Table 5**).

It was concluded that post emergence application of tembotrione 50 g/ha + atrazine 0.5 kg/ha at 15-20 DAS was proved effective in improving weed control, maize yield and economics. Hence, it can be recommended to the maize crop grown in the North Coastal Zone of Andhra Pradesh.

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# Management of diverse weed flora in maize under Kangra valley conditions of Himachal Pradesh

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## ABSTRACT

Twelve weed control treatments, *viz*. atrazine 1.0 kg/ha (2 days after sowing, DAS), metribuzin 0.25 kg/ha (2 DAS), oxyflourfen 0.15 kg/ha (2 DAS) alone and in integration with hoeing at 30 DAS, atrazine 1.0 kg/ha (2 DAS) followed by (*fb*) atrazine 0.5 kg/ha (30 DAS), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (2 DAS), intercropping of cowpea and mung bean, hand weeding thrice (15, 30 and 45 DAS) and weedy check were tested in maize during 2012 and 2013 under Kangra valley conditions of Himachal Pradesh. Herbicides alone, in combination with hoeing and sequential application significantly reduced the count and dry weight of weeds and increased number of cobs, 100-grain weight and grain yield of maize over the intercropping treatments. Maize grain yield was negatively associated with weed count (r= -0.819**) and weed dry weight (r = -0.791**) and positively correlated with cobs number (r = 0.950**), cob length (r = 0.879**) and 100-seed weight (r = 0.836**). With unit increase in weed count, the grain yield of maize decreased by 75.5 kg/ha. Un-checked weed growth reduced the grain yield of maize by 60.7%. Based on the results, metribuzin 0.250 kg/ha, atrazine 1.00 kg/ha, atrazine 1.0 kg/ha *fb* atrazine 0.5 kg/ha (30 DAS), oxyflourfen 0.15 kg/ha, atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha and metribuzin 0.25 kg/ha *fb* hoeing (30 DAS) were recommended for effective management of diverse weed flora in maize under Kangra valley conditions of Himachal Pradesh.

**Key words:** Dry weight, Economic thresholds, Grain yield, Impact assessment, Maize, Weed management

Maize is grown at wider row spacing which results in greater infestation of weeds in the early stages. Diverse weed flora are composed of grasses, sedges and broad-leaved species. Atrazine is the most popular herbicide for controlling weeds in maize. The repeated application of atrazine has resulted in increased frequency of *Ageratum*, *Commelina* and *Brachiaria* (Kumar *et al*. 2012). In order to optimize weed control efficacy and minimize the application costs, the use of combinations of pre- and post-emergence herbicides as well as herbicide mixtures has been advocated for season-long weed control. Intercropping has also been recognized as an effective tool to suppress weeds in maize (Sood *et al*. 2016). In view of the above, the present investigation was carried out to develop practices for diverse weed flora management in maize.

## MATERIALS AND METHODS

A field trial was conducted during the *Kharif* seasons of 2012 and 2013 at Shivalik Agricultural Research and Extension Centre, Kangra (32$^{o}$092 N latitude, 76$^{o}$222 E longitude and 615 m altitude). The site lies in warm sub-humid zone of Himachal Pradesh (NARP zone II), which is characterized by mild summers and severe winters. The average total annual rainfall was 1539 mm, out of which 1216 mm was received during SW monsoon. The soil of the experimental site was silty clay loam in texture, neutral in reaction (pH 6.8) and medium in available N (335 kg/ha), P (20 kg/ha) and K (201 kg/ha). Twelve weed control treatments *viz*. atrazine 1.0 kg/ha (2 days after sowing, DAS), metribuzin 0.25 kg/ha (2 DAS), oxyflourfen 0.15 kg/ha (2 DAS) alone and in integration with hoeing at 30 DAS, atrazine 1.0 kg/ha (2 Das) followed by (*fb*) atrazine 0.5 kg/ha (30 DAS), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (2 DAS), cowpea and mung bean intercrops, hand weeding thrice (15, 30 and 45 DAS) and weedy check were tested in randomized block design with three replications. Seed of maize hybrid '*Pro Agro 4640*' was sown at 20 kg/ha on 5$^{th}$ June 2012 and 1$^{st}$ June 2013 keeping row to row spacing of 60 cm and plant to plant spacing of 20 cm. The crop was fertilized with 120 kg N, 60 kg $P_2O_5$ and 40 kg $K_2O$/ha through urea, single super phosphate and muriate of potash, respectively. The required quantity of half N and whole $P_2O_5$ and 40 kg $K_2O$ was drilled at sowing. The remaining half N was band placed in two equal splits

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at knee high and tasseling stages. Herbicides as per treatment were applied with backpack power sprayer using 600 litre water/ha.

Weed dry weight (60 DAS and at harvest) was recorded using a quadrate of 50 x 50 cm. Yields were harvested from net plot area (4.5 x 3.6 m). The data were subjected to statistical analysis by analysis of variance (ANOVA) for the randomized block design to test the significance of the overall differences among the treatments by the "F" test and conclusion was drawn at 5% probability level.

Economic threshold (=economic injury levels), the weed density at which the cost of treatment equals the economic benefit obtained from that treatment, was calculated after Uygur & Mennan (1995) and Stone and Pedigo (1972).

Uygur and Mennan:

$Y = [\{(100/He*Hc)+A_C\}/(Gp*Yg)]*100$

where, Y is percent yield losses at a different weed density; He, herbicide efficiency; Hc, herbicide cost; Ac, application cost of herbicide; Gp, grain price and Ywf, yield of weed free.

Stone and Pedigo:

Economic threshold = Gain threshold/ Regression coefficient

where, gain threshold = Cost of weed control (Hc+Ac)/Price of produce (Gp), and regression coefficient (b) is the outcome of simple linear relationship between yield (Y) and weed density/ biomass (x), Y = a + bx.

The different impact indices were worked out after Rana and Kumar (2014).

Additionally, 'overall impact index' was determined, by calculating firstly the 'unit value' where the value under a particular treatment of a parameter was divided by the respective arithmetic mean of treatments for that parameter as given below:

$$U_{ij} = \frac{V_{ij}}{AM_j}$$

where Uij is the unit value for ith treatment corresponding to jth parameter, Vij is the actual measured value for ith treatment and jth parameter and AMj is the arithmetic mean value for jth parameter.

Secondly, the overall performance index was calculated as an average of unit values (Uij) of all the parameters under consideration:

$$OI_i = \frac{1}{N}\sum_{i=1}^{N} U_{ij}$$

where OIi is the overall impact index for ith treatment and N is the number of parameters used in deriving overall impact index.

## RESULTS AND DISCUSSION

### Weed count and dry weight

Major weeds of the experimental field were *Echinochloa colona*, *Cyperus iria*, *Equisetum arvense*, *Setaria glauca*, *Paspalum* sp, *Ageratum conyzoides* and *Bidens pilosa*. All treatments were significantly superior to weedy check in reducing the count and dry weight of weeds both at 60 DAS and at harvest (**Table 1**). The lowest count and dry weight of weeds were recorded under hand weeding thrice. The herbicides alone and in combination with hoeing were superior to intercropping treatments in reducing count and dry weight of weeds. Superiority of atrazine (Hawaldar and Agastimani 2012), metribuzin (Patel *et al*. 2006), oxyflourfen alone and in integration with hand weeding/hoeing (Hawaldar and Agastimani 2012) and as a sequential application (Kumar *et al*. 2012) in maize is well established.

### Yield

Growth and yield of maize differed significantly due to weed control treatments (**Table 2**). Uninterrupted competition by weeds significantly reduced the effective maize plant population. Cowpea vines trailed around the maize and brought down the effective maize population. Similarly, effective population of maize under maize + mungbean intercropping was significantly lower than hand weeding. Plant height was significantly more in treatments than the weedy check. Intercropping of cowpea and mungbean, oxyflourfen, oxyflourfen *fb* hoeing and atrazine *fb* atrazine had shorter plants than hand weeding. Number of cobs was significantly more in herbicidal treatments and hand weeding. Number of cobs under cowpea intercropping was lower than the weedy check. All treatments were significantly superior to weedy check in increasing the 100-grain weight. Atrazine + pendimethalin, metribuzin *fb* hoeing and atrazine had higher 100-grain weight than the other treatments. All treatments except intercropping of cowpea and mungbean had higher maize grain yield over weedy check. All herbicidal treatments were comparable to hand weeding thrice in increasing the yield.

Maize grain yield was found to be negatively associated with weed count (r = -0.819**) and weed dry weight (r = -0.791**) and was positively associated with plant population (r = 0.874**), cobs number (r = 0.950**), cob length (r = 0.879**) and 100-seed weight (r = 0.836**). The increases in yield attributes and yield due to effective control of weeds with herbicides alone, in combination and herbicides + interculture/hand weeding are documented (Rana *et al*. 1998, Hawaldar and Agastimani 2012, Kumar *et al*. 2011, 2012). The linear relationship between weed count and dry weight at 60 DAS (x, almost the end of critical period of crop weed competition and grain yield (Y) of maize is given here as under:-

Weed count

Y = 7997 – 75.5x ($R^2$= 0.671)...................(1)

Weed dry weight

Y = 7885 – 75.1x ($R^2$= 0.626).....................(2)

Equation 1 and 2 explain that over 60% of the variation in grain of maize due to count and dry weight of weeds during the critical period of crop-weed competition could be explained by these regression equations. With unit increase in weed count/$m^2$ or weed dry weight (g/$m^2$), the grain yield of maize reduced by 75 kg/ha.

## Economic threshold

The economic threshold levels of weeds at the current prices of treatment application and the crop production on the basis of weed infestation during the time of critical period of competition in maize have been given in **Table 3**. The economic threshold levels varied from 7.8 – 85/$m^2$ and 7.6-90.3 g/$m^2$ when determined after Stone and Pedigo and 2.1 to 25.7 after Uygur and Mennan. It indicates that any increase in cost of weed control would lead to higher values of economic threshold, whereas an increase in price of crop produce would result in lowering the

**Table 1. Effect of treatments on count and dry weight of weeds in maize at 60 DAS**

| Treatment | Dose (kg/ha) | Time (DAS) | Weed count (no./$m^2$) | | Weed dry weight (g/$m^2$) | |
|---|---|---|---|---|---|---|
| | | | 2012 | 2013 | 2012 | 2013 |
| Atrazine | 1 | 2 | 5.3(27.3) | 5.3(27.3) | 5.3(28.2) | 5.2(27.0) |
| Metribuzin | 0.25 | 2 | 4.7(23.0) | 5.1(26.7) | 5.3(30.9) | 5.0(25.6) |
| Oxyflourfen | 0.15 | 2 | 5.2(27.0) | 5.5(29.7) | 5.9(35.0) | 5.5(29.4) |
| Atrazine *fb* atrazine | 1.0 *fb* 0.5 | 2 *fb* 25-30 | 5.4(28.3) | 5.4(28.7) | 5.5(29.7) | 5.4(28.5) |
| Atrazine *fb* hoeing | 1 | 2 *fb* 25-30 | 6.1(36.3) | 6.4(40.0) | 5.9(34.9) | 6.1(37.2) |
| Metribuzin *fb* hoeing | 0.25 | 2 *fb* 25-30 | 5.7(32.3) | 6.0(35.3) | 4.6(21.1) | 6.3(39.0) |
| Oxyflourfen *fb* hoeing | 0.15 | 2 *fb* 25-30 | 5.1(26.0) | 5.2(26.7) | 5.0(25.0) | 5.4(28.9) |
| Atrazine + pendimethalin | 1.0 + 0.5 | 2 | 6.3(40.3) | 6.2(37.7) | 5.6(31.6) | 6.2(38.5) |
| Cowpea inter-cropping | - | | 7.4(56.0) | 7.8(61.0) | 7.0(49.0) | 8.0(63.4) |
| Mungbean inter-cropping | - | | 7.1(53.7) | 7.9(61.7) | 6.3(40.4) | 7.9(62.4) |
| Hand weeding | | 15, 30, 45 | 3.0(8.7) | 3.5(12.0) | 1.8(2.9) | 3.0(8.8) |
| Weedy | | | 9.2(83.7) | 9.3(86.7) | 9.1(81.6) | 9.3(86.7) |
| LSD (p=0.05) | | | 1.9 | 0.8 | 1.5 | 0.7 |

Data transformed to square root transformation; Values given in parentheses are the means of original data

**Table 2. Effect of treatments on growth, yield attributes and yield of maize**

| Treatment | Dose (kg/ha) | Plant population (x$10^3$/ha) | | Plant height (cm) | | Cobs (x$10^3$/ha) | | Cob length (cm) | | 100-grain weight (g) | | Grain yield (t/ha) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 |
| Atrazine | *1* | 71.1 | 71.1 | 206.7 | 219.7 | 63.7 | 65.9 | 23.8 | 22.8 | 40.5 | 39.4 | 5.83 | 5.74 |
| Metribuzin | 0.25 | 73.7 | 72.2 | 200.7 | 216.7 | 69.3 | 68.1 | 24.3 | 22.9 | 36.3 | 38.4 | 6.60 | 6.16 |
| Oxyflourfen | 0.15 | 71.9 | 71.5 | 162.0 | 192.0 | 64.8 | 67.8 | 22.2 | 23.1 | 36.1 | 35.9 | 6.02 | 5.82 |
| Atrazine *fb* atrazine | 1.0 *fb* 0.5 | 74.1 | 72.6 | 165.7 | 178.3 | 67.8 | 71.5 | 22.9 | 22.9 | 31.9 | 31.6 | 6.24 | 6.00 |
| Atrazine *fb* hoeing | 1 | 70.4 | 69.6 | 185.7 | 197.0 | 63.0 | 67.8 | 23.5 | 23.1 | 33.0 | 37.7 | 6.09 | 6.05 |
| Metribuzin *fb* hoeing | 0.25 | 71.5 | 70.4 | 201.3 | 204.3 | 61.1 | 67.4 | 25.6 | 22.8 | 42.3 | 41.5 | 6.54 | 6.33 |
| Oxyflourfen *fb* hoeing | 0.15 | 72.6 | 74.1 | 160.3 | 164.7 | 65.2 | 64.4 | 22.5 | 23.6 | 31.6 | 31.3 | 6.00 | 5.93 |
| Atrazine + pendimethalin | 1.0 + 0.5 | 66.7 | 73.7 | 203.7 | 206.0 | 61.1 | 67.4 | 24.5 | 23.3 | 40.8 | 40.2 | 6.51 | 6.08 |
| Cowpea inter-cropping | - | 47.4 | 44.8 | 174.3 | 174.3 | 18.1 | 28.9 | 23.1 | 20.0 | 24.2 | 24.0 | 1.35 | 1.24 |
| Mungbean inter-cropping | - | 65.9 | 69.6 | 171.3 | 169.3 | 31.5 | 67.4 | 21.7 | 19.7 | 29.1 | 27.7 | 2.74 | 2.25 |
| Hand weeding | - | 75.2 | 73.7 | 195.0 | 200.0 | 63.0 | 69.6 | 22.9 | 22.6 | 34.2 | 32.4 | 6.10 | 6.08 |
| Weedy check | - | 51.1 | 48.1 | 151.0 | 147.0 | 24.4 | 38.5 | 20.7 | 20.2 | 21.9 | 20.6 | 2.58 | 2.48 |
| LSD (p=0.05) | | 4.6 | 3.5 | 13.4 | 16.0 | 5.1 | 3.0 | 1.9 | 1.4 | 3.7 | 2.1 | 0.50 | 0.22 |

economic threshold. Hand weeding had higher values of economic threshold than the herbicidal treatments due to higher wages. The lowest application cost was under metribuzin alone and thus the lowest values of economic threshold.

**Economics**

Due to higher grain and stover yield, gross returns under hand weeding thrice and herbicidal treatments were significantly more over weedy check (**Table 3**). However, due to low yield of maize and intercrop, intercropping did not significantly increase total gross returns over weedy check. Integrated weed control treatments were more or less similar to hand weeding thrice, but due to higher cost under the latter, net returns over weedy check (NRwc) were more. The highest net returns due to weed control (NRwc) were accrued under metribuzin followed by atrazine + pendimethalin, metribuzin *fb* hoeing and atrazine *fb* atrazine. MBCR was also highest under metribuzin 0.25 kg/ha followed by atrazine, oxyflourfen, atrazine + pendimethalin and atrazine *fb* atrazine. The results indicated that hoeing in combination with herbicides increased the cost of treatment and thus lowered marginal benefit: cost ratio.

**Impact assessment**

Hand weeding thrice resulted in highest weed control efficiency due to effective frequent removal (**Table 4**). All herbicidal treatments were superior to intercropping of cowpea and mungbean in increasing weed control efficiency. Weed persistence index (WPI) was lowest and crop resistance index (CRI) was highest under the hand weeding thrice. Since maize + legume intercropping system was grown

**Table 3. Economics of weed control and economic threshold of weeds**

| Treatment | Dose | Gt | Et (S and P) Count | Et (S and P) Weight | Et (U and M) | CWC | GRwc | NRwc | MBCR |
|---|---|---|---|---|---|---|---|---|---|
| Atrazine | *1* | 94 | 7.8 | 8.3 | 3.6 | 1404 | 62470 | 61066 | 43.49 |
| Metribuzin | 0.25 | 86 | 7.2 | 7.6 | 2.1 | 1287 | 73899 | 72612 | 56.41 |
| Oxyflourfen | 0.15 | 133 | 11.1 | 11.8 | 3.4 | 1995 | 65016 | 63021 | 31.60 |
| atrazine *fb* atrazine | 1.0 *fb* 0.5 | 174 | 14.5 | 15.4 | 6.7 | 2616 | 68965 | 66349 | 25.36 |
| Atrazine *fb* hoeing | 1 | 377 | 31.4 | 33.4 | 7.5 | 5654 | 67973 | 62319 | 11.02 |
| Metribuzin *fb* hoeing | 0.25 | 369 | 30.8 | 32.7 | 6.1 | 5537 | 74992 | 69455 | 12.54 |
| Oxyflourfen *fb* hoeing | 0.15 | 416 | 34.7 | 36.8 | 8.0 | 6245 | 65940 | 59695 | 9.56 |
| Atrazine + pendimethalin | 1.0 + 0.5 | 171 | 14.3 | 15.1 | 4.8 | 2567 | 72304 | 69738 | 27.17 |
| Cowpea inter-cropping | - | 233 | 19.4 | 20.6 | 25.7 | 3500 | 4376 | 876 | 0.25 |
| Mungbean inter-cropping | - | 233 | 19.4 | 20.6 | 21.8 | 3500 | 7070 | 3570 | 1.02 |
| Hand weeding | | 1020 | 85.0 | 90.3 | 16.8 | 15300 | 68304 | 53004 | 3.46 |
| Weedy check | | 0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | - |

Gt - gain threshold; Et - Economic threshold; Et - (S and P) - economic threshold after Stone and Pedigo; Et (U and M) - Economic threshold after Uyger and Mennan; GRwc - Gross return over weedy check (INR/ha); CWC - cost of weed control (INR/ha); NRwc - Net return over weedy check; MBCR - marginal benefit cost ratio;

**Table 4. Impact assessment indices**

| Treatment | Dose (kg/ha) | WCE | WPI | CRI | WMI | AMI | IWMI | HEI | WI | Win | Cin | OIi |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Atrazine | 1.00 | 67.5 | 1.02 | 6.97 | 3.40 | 2.40 | 2.90 | 3.92 | 5.0 | 79.4 | 20.6 | 1.18 |
| Metribuzin | 0.25 | 68.6 | 1.15 | 7.51 | 3.80 | 2.80 | 3.30 | 4.53 | -4.8 | 77.3 | 22.7 | 1.34 |
| Oxyflourfen | 0.15 | 64.3 | 1.15 | 6.12 | 3.79 | 2.79 | 3.29 | 3.50 | 2.8 | 79.8 | 20.2 | 1.16 |
| Atrazine *fb* atrazine | 1.0 *fb* 0.5 | 66.0 | 1.03 | 7.00 | 3.70 | 2.70 | 3.20 | 4.11 | -0.6 | 79.5 | 20.5 | 1.17 |
| Atrazine *fb* hoeing | 1.00 | 56.2 | 0.96 | 5.60 | 4.20 | 3.20 | 3.70 | 3.27 | 0.3 | 84.5 | 15.5 | 1.07 |
| metribuzin *fb* hoeing | 0.25 | 62.3 | 0.90 | 7.13 | 3.96 | 2.96 | 3.46 | 4.33 | -5.7 | 82.7 | 17.3 | 1.14 |
| Oxyflourfen *fb* hoeing | 0.15 | 68.5 | 1.04 | 7.37 | 3.47 | 2.47 | 2.97 | 4.24 | 2.0 | 78.2 | 21.8 | 1.09 |
| Atrazine + pendimethalin | 1.00 + 0.50 | 56.3 | 0.91 | 5.98 | 4.26 | 3.26 | 3.76 | 3.58 | -3.4 | 84.7 | 15.3 | 1.16 |
| Cowpea inter-cropping | - | 32.3 | 0.97 | 0.77 | 1.54 | 0.54 | 1.04 | -0.73 | 78.7 | 92.7 | 7.3 | 0.30 |
| Mungbean inter-cropping | - | 35.6 | 0.90 | 1.61 | 2.54 | 1.54 | 2.04 | -0.02 | 59.0 | 89.5 | 10.5 | 0.50 |
| Hand weeding | | 90.5 | 0.57 | 34.72 | 2.59 | 1.59 | 2.09 | 20.29 | 0.0 | 58.1 | 41.9 | 1.67 |
| Weedy check | | 0.0 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 58.5 | 94.5 | 5.5 | 0.23 |

WCE - weed control efficiency (%); WPI - Weed persistence index; CRI - Crop resistance index; WMI - Weed management index; AMI - Agronomic management index; IWMI - Integrated Weed management index; HEI - Treatment/Herbicide efficiency index; WI - weed index; Win - Weed intensity; Cin - Crop intensity; OIi - overall impact index without any herbicidal/manual control, crop resistance index (CRI) due to poor control of the weeds were lower than all the herbicidal/IWM treatments. Weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IWMI) were higher in herbicidal/IWM treatments than the hand weeding and intercropping treatments. Highest WMI, AMI and IWMI were found under atrazine + pendimethalin and lowest under cowpea intercropping. Treatment/ herbicidal efficiency index was highest under hand weeding thrice followed by metribuzin, metribuzin *fb* hand weeding, oxyflourfen *fb* hoeing. Intercropping gave negative values of TEI/HEI and thereby maximum reduction in yield in comparison to weed free/hand weeding thrice. Weed intensity was lowest and crop intensity was more in hand weeding thrice than other treatments. Highest weed intensity and lowest crop intensity were recorded in weedy check. Overall impact index (OIi), which was drawn taking together different indices as well as per cent control of weeds, yield and economic parameters to have a valid inference and conclusion. The OIi was highest under hand weeding thrice followed by metribuzin, atrazine, atrazine *fb* atrazine, oxyflourfen, atrazine + pendimethalin, metribuzin *fb* hand weeding, oxyflourfen *fb* hand weeding and atrazine *fb* hand weeding.

It was concluded that metribuzin 0.250 kg/ha, atrazine 1.0 kg/ha, atrazine 1.0 kg/ha *fb* atrazine 0.75 kg/ha (30 DAS), oxyflourfen 0.15 kg/ha, atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha, metribuzin 0.250 kg/ha *fb* hand weeding (30 DAS), oxyflourfen 0.15 kg/ha *fb* hand weeding (30 DAS) or atrazine 1.0 kg/ ha *fb* hand weeding (30 DAS) may be recommended for effective weed management in maize under Kangra valley conditions of Himachal Pradesh.

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# Glyphosate tolerant and insect resistant transgenic Bt maize efficacy against shoot borer, cob borer and non-target insect pests

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## ABSTRACT

Introducing Bt insect resistance genes into hybrid maize seems to be the most feasible and effective technique accessible to control the pest. Transgenic stack hybrid maize (MON 89034X NK 603) was developed by Monsanto for checking yield losses of maize crop to increase productivity. Transgenic stack hybrid maize was claimed to have both insect protection and herbicide tolerant traits to provide protection to the crop from target pests and also provide effective weed management. MON 89034X NK 603 is 2nd generation glyphosate tolerant with Bt maize technology effective against lepidopteron insect pests with "dual mode of action". A field experiment was carried out at ICAR-Directorate of Weed Research, Jabalpur for two years during *Kharif* (rainy season) 2009 and 2010 to evaluate the efficacy of transgenic stack hybrid maize (MON 89034X NK 603) against shoot borer (*Chilo partellus*), cob borer (*Helicoverpa armigera*), non-target insect pests and beneficial insects. Treatments consisted of two transgenic stacked hybrids named '*Hishell*' and '*'900M Gold*'' with two conventional hybrids namely '*Proagro-4640*' and '*'HQPM-1*''. Artificial infestation of *Chilo partelus* revealed complete absence of stem borer infestation in all the transgenic entries of *'Hishell'* and *'900M Gold'* with less than one leaf injury score (LIS), while in other conventional entries, stem borer infestation was observed and LIS was more than one. *Hlicovepa armigera* infestation was also not observed on transgenic hybrids whereas in the remaining non-transgenic maize treatment, significant attack of *Helicoverpa armigera* was observed in the range of 37 to 56%. These transgenic entries were not found resistant to aphids and grass hoppers. Beneficial insects were observed to visit transgenic Bt maize and conventional maize entries with no significant difference.


**Key words:** *Chillo partellus*, Glyphosate tolerant maize, *Heliothis armigera*, MON 89034X NK 603. Non-target insect pest, Insect resistant maize, Transgenic maize

Food security is an important political and social agenda (Anon 2010). Global population has increased four fold during the past century with current estimates of around 9.2 billion by 2050 (UN 2009). With this projected population of about 10 billion by 2052, an immediate priority for agriculture is to achieve increased crop yields in a sustainable and cost-effective way. Insecticides introduction in 1947 paved the way to increase food production. Despite an annual pesticide budget of US $30 billion, losses owing to insects, weeds and disease for eight of the world's major crops were estimated to be in the range of US $244 billion per annum, representing 43% of world production (Oerke 2006). Paoletti and Pimentel (2000) estimated that in the absence of these synthetic pesticides, losses might increase by further 30%. However, despite pesticide contribution, it has long been recognized that such chemicals pose both environmental and health concerns. Rachel Carson (1962) cautioned the world about the overuse of pesticides in her book '*Silent Spring'*. Recombinant DNA technology to produce transgenic crops (genetically modified (GM) or engineered, biotech) with enhanced tolerance to abiotic or biotic stresses can make a significant contribution to achieve food security in the world.

Herbicide tolerant and insect resistant genetically modified (GM) crop have become leading features in agro ecosystem of many of the world's agricultural regions (ISAAA 2016). When insects and herbicide tolerant crops are employed as an integrated component of insect and weed management, productivity of crop is increased. In recent years, it has become evident that insect-resistant crops expressing $\delta$-endotoxin genes from *Bacillus thuringiensis* have made a significant beneficial influence on global agriculture in terms of better

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quality of produce and pests decrease (Gatehouse *et al*. 2011, ISAAA 2016). *Bacillus thuringiensis*, commonly known as Bt, is a bacterium that occurs naturally in the soil. However, because of the potential for pest populations to evolve resistance, and owing to lack of effective control of pests, alternative strategies are being developed. Some of these are based on *Bacillus* spp. or other insect pathogens, while others are based on the use of plant and animal-derived genes. But, if such techniques are to play a beneficial role in crop security, it is desirable that they do not have a negative impact on beneficial organisms. This widely held fear over the environmental and biological impacts of GM crops has led to the extensive examination of transgene proteins on non-target and beneficial insects (John *et al*. 2001, Gatehouse 2011). The introduction of insect-resistant Bt Cotton for commercial production in 2002 turned out to be a large success, which is reflected that biotech cotton was sown globally in 22.3 million hectares of land in 2016 (ISAAA 2016). Bt cotton has reduced the dependency on chemical pest control, increased yields and profits for smallholder farmers in a sustainable way over a long period, and has thereby contributed to a positive economic and social development in India (Kathage and Qaim 2012, Qaim and Kouser 2013).

Maize (*Zea mays* L.) is considered a promising option for diversifying agriculture in upland areas of India. It now ranks as the third most important food grain crop. In India, maize is grown in a wide range of situations, extending from extreme semi-arid to sub-humid and humid regions. Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh are traditional maize growing areas while Karnataka and Andhra Pradesh are non-traditional maize areas. Maize crop is faced with some biotic and abiotic limitations to attain the target production. Proper management of pests can only make the production to the required levels. Insects and weeds are the major restraints to lower down the production. Among these, insects may cause huge yield losses in the range of 25-50%, if not managed properly. The development of insect and weed tolerant maize is a step to boost maize production. The 'insect resistant maize' in combination with "Rounup Ready (glyphosate tolerant)' have been genetically engineered to resist the attack of some problematic insects like shoot and cob borer and allow spraying of herbicide glyphosate on both crop and weeds without harming the crop but to kill all types of weeds. This dual action strategy will help to reduce cost and increase yield. Out of 60.6 million hectares of biotech maize sown in the world, comprised of 6 million hectares insect resistant (IR), 7 million hectares herbicide tolerant (HT) and 47.7 million hectares (IR/HT) insect resistant/herbicide tolerant (ISAAA 2016).

Post-emergence application of glyphosate at 900, 1800 and 3600 g/ha registered lower weed density, dry weight and higher weed control efficiency in transgenic '*Hishell*' and '*900 M Gold*' maize hybrids in the Maize Trial I and post-emergence application of glyphosate at 900 and 1800 g/ha registered lower weed density, dry weight and higher weed control efficiency in transgenic '*30V92*' and '*30B11*' hybrids in the Maize Trial II compared to their state and national checks (Chinnusamy *et al*, 2014). In our earlier study in evaluation of bioefficacy of glyphosate tolerant transgenic maize (MON 89034X NK 603) under field conditions, we found lower weed density and higher weed control efficiency (100%) in all transgenic maize hybrids at 21 DAS and at harvest and three times high yield than the normal hybrid (Dixit *et al.*, 2016). Simultaneously, another combined experiment was done to study the bioefficacy of Bt in transgenic maize (MON 89034X NK 603) against lepidopteron pests, secondary pests, non-target insect pests and on beneficial insects and its effect on conventional counterpart hybrids. This paper presents the results of efficacy of glyphosate tolerant transgenic stack maize with it, lepidopteran insect resistant Bt maize on major insect pests like *Chillo partellus, Helicoverma armigera*, non-target insect pests and beneficial insects.

## MATERIALS AND METHODS

A field experiment was conducted for consecutive two years at research farm ICAR-Directorate of Weed Research, Jabalpur, Madhya Pradesh (India) during *Kharif* (rainy season) 2009 and 2010 under Bio-safety Research Trial Level-1 for transgenic staked maize hybrids to evaluate the bio-efficacy of Bt in transgenic maize hybrids (MON 89034 X NK 603) against weeds, key maize insect pests, secondary pests, non-targeted insect pests and beneficial insects. The climate of the area was typically sub-humid and sub-tropical with an average annual rainfall of 1253 mm. The geographical location of the experiment was situated at 23°10'N latitude and 79° 57'E longitude with an altitude of 412 m above MSL in Kymore plateau and Satpura hills of Madhya Pradesh, India. The soil of the Directorate's farm is medium black (Typic Haplustert) and moderately alkaline with the organic carbon (0.9%), available N (177 kg/ha), P (8 kg/ha), K (478 kg/ha), sulphur (35 ppm), Zn (0.7 ppm), EC of saturated extract (0.18 dS/m at 25 °C) and neutral pH of 6.3. Experiment was done with 16 treatments in randomized block design (RBD) replicated thrice. The gross plot size was 18 $m^2$ (5 × 3.6 m). The spacing between the rows and plants were 60 and 25 cm, respectively. The recommended dose of 150:75:75 kg of NPK/ha were given in the form of urea, diammonium phosphate and muriate of potash. As per protocol, aerial isolation distance of 300 m was maintained in periphery of experimental area.

The transgenic staked maize hybrids '*Hishell*' (MON 89034xNK 603) and '*900 M Gold*' (MON 89034xNK 603), and conventional hybrids namely '*Proagro-4640*' and '*'HQPM-1'*' were sown on July 7 in 2009 and 2010 during *Kharif* season with university recommendation for weed and insect protection (P), no weeding from sowing to harvest with no chemical insect protection (control), and no weeding from sowing to harvest with only chemical insect protection (control), national check conventional (P), national check conventional control, local check conventional (P), and local check conventional (control).

In want of natural infestation of major pest of maize *Chilo partelus* in the area, artificial inoculation was done to assess the resistance against stem borer incidence. Eggs of *Chilo partellus* were obtained from International Crops Research Institute for the Semi-Arid Tropics (*ICRISAT*), Hyderabad (India). Egg card with 10-12 eggs were tagged in each whorl of 5 plants from border rows at randomly in each treatment after 40 days of sowing. The observations on per cent infestation of stem borer and mean leaf injury score (LIS) were taken after 15 days of inoculation. All the plants showing dead-heart formation from four inner lines were counted and their percentages was calculated on the basis of total plant stand. Such dead hearts were ascertained whether they are actually caused by stem borer or by other insects. All the plants showing symptoms of borer damage or shot holes were counted and their percentages were calculated on the basis of total plant stand. Injury scale was taken at 1 to 10 scale as follows: 1. Apparently healthy plant, 2. Plant showing slight damage pinholes on 1-2 leaves, 3. Plant showing slight damage pinholes on 3-4 leaves, 4. Plant showing injury pinholes, shot holes slit in about 1/3 total leaves, 5. Plant showing 50 % leaf damage, 6. Plant showing 2/3 total leaf injuries, 7. Plant with every type of injury almost all damaged, 8. Entire plant with complete leaf injury likely to form dead heart, 9. Complete dead heart. Mean leaf injury score/ plot was calculated based on total leaf injury score (LIS) divided by total no. of plants scored. The plants on which leaf injury was scored, were selected for calculating stem tunneling. Per cent stem tunneling was calculated at the time of harvest by calculating total borer tunneled length divided by plant height of affected plants. Average per cent stem tunneling per plot was calculated by dividing total length by no. of plants taken for tunneling observations.

There was no secondary major pest on the maize crop during experimental period, therefore to see the infestation level on transgenic and conventional entries, artificial inoculation of about 8-10 first instar larvae of *Helicoverpa armigera* (an destructive insect pests of cobs of maize) was made on each 5 plants of transgenic and conventional entries at silken stage of cobs. Per cent infestation of *Helicoverpa armigera* was recorded at 90 days after sowing. All the non-target insect species visiting the various treatments other than secondary lepidopterans and beneficial insects were recorded at 30, 45 and 60 days after sowing (DAS) from 10 plants/treatment. Population of beneficial predators, pollinators were recorded per plant at 30, 45 and 60 DAS on 10 plants/treatment. In University recommendation plots, for insect control, application of endosulfan 35 EC was done each year at 17 DAS and weed control with use of atrazine at 1.0 kg/ha as pre-emergence.

The data on various observations recorded during course of investigation were analyzed statistically by adopting the procedure described by Gomez and Gomez (1984). The data were subjected to Fisher's method of analysis of variance and the level of significance used in F test was P = 0.05. The critical differences were calculated at 5% probability level whenever F values was found to be significant. Wherever it was necessary, the original values were transformed using arc-sin transformation.

## RESULTS AND DISCUSSION

### Natural infestation

No natural infestation of insect pests was observed in transgenic treatments, but it occurred in non-transgenic treatments. There was a mild infestation up to 20 days in conventional '*900 Gold*', national check and local check ('*HQPM-1'*), which increased significantly in some of the non-transgenic treatments when crop stage advanced from 20 to 40 DAS (**Table 1**).

**Artificial infestation of *Chillo partellus***

Artificial inoculation of stem borer *Chillo partellus* was nil up to 55 DAS and leaf injury score (LIS) was less than one in all the transgenic entries of '*Hishell'* and *'900M Gold'*. In all other conventional entries, stem borer infestation was observed and the LIS was more than one. There was about 31 to 43% infestation in conventional '*900 Gold*' while in local check conventional, it was 100% (*'HQPM-1'*) followed by national check (*Proagro 4640*). Tunnel length taken at the harvest time after tearing the stems also revealed highest tunnel length in national check and local check, which correlated highest infestation per cent of stem borer after artificial inoculation (**Table 2**). The Central Compliance Committee (CCC) also visited the site of trial on 18.10.2010 and monitored the insect attack and was convinced with the results.

**Artificial infestation of *Helicoverpa armigera***

No infestation of *Helicoverpa armigera* in all transgenic entries of '*Hishell'* and *'900M Gold'* was observed. Whereas, in the remaining non-transgenic maize treatments, significantly higher infestation was observed as compared to transgenic hybrids. Significantly 36 to 71% infestation was observed in all the non-transgenic lines, which showed that transgenic entries are resistance to *Helicoverva* armigera (**Table 3**).

**Other insect pests**

A few insect species like leaf hoppers and aphids were observed at 30 and 60 days after sowing. Aphid population was observed on both transgenic and non-transgenic lines, which indicated that the transgenic lines are equally susceptible to aphids. The trend of population decline at 60 days was also same in both transgenic and non-transgenic line. Leaf hoppers were found to attack only a few non-transgenic lines at 60 days (**Table 4**).

**Beneficial insects**

Data on beneficial insects like coccinalids, spiders were taken at 30, 45 and 60 DAS. Good number of adults of predator *Coccinella septempunctata* was observed at 30 DAS in both transgenic and non-transgenic maize hybrid, which declined sharply at 60 DAS in both the lines (**Table 5**). The Syrphids were also observed on both the lines at 30 DAS. Like-wise, pollinators like honey bees were also recorded at 30, 45 and 60 DAS. The spiders were also observed at 30, 45 and 60 DAS on transgenic and non-transgenic treatments. These observations showed that beneficial insect species can thrive well on transgenic lines also in addition to conventional lines (**Table 5**).

Several species of insects that attack maize, also feed on maize pollen. Therefore, study done by

**Table 1. Natural infestation of stem borer (*Chilo partellus*) and mean leaf injury score (LIS 1-9 scale) at 20 and 40 DAS in transgenic and conventional maize hybrids**

| Treatment | Natural infestation at 20 DAS | Mean leaf injury score at 20 DAS | Natural infestation at 40 DAS | Mean leaf injury score at 40 DAS |
|---|---|---|---|---|
| *Hishell* (MON 89034xNK 603) + round up 900 g/ha | 0.71 (0.00) | 1.00 | 0.71 (0.00) | 1.00 |
| *Hishell* (MON 89034xNK 603) + round up 800 g/ha | 0.71 (0.00) | 1.00 | 0.71 (0.00) | 1.00 |
| *Hishell* (MON 89034xNK 603) + round up 3600 g/ha | 0.71 (0.00) | 1.00 | 0.71 (0.00) | 1.00 |
| *900 M Gold* (MON 89034xNK 603) + round up 900 g/ha | 0.71 (0.00) | 1.00 | 0.71 (0.00) | 1.00 |
| *900 M Gold* (MON 89034xNK 603) + round up 1800 g/ha | 0.71 (0.00) | 1.00 | 0.71 (0.00) | 1.00 |
| *900 M Gold* (MON 89034xNK 603) + round up 3600 g/ha | 0.71 (0.00) | 1.00 | 0.71 (0.00) | 1.00 |
| *Hishell* conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 250 g/ha | 0.91 (0.41) | 1.00 | 0.91 (0.41) | 1.07 |
| *Hishell* conventional (control) | 0.91 (0.41) | 1.00 | 0.91 (0.41) | 1.07 |
| *Hishell* conventional (control) + endosulfan 35 EC 1250 g/ha | 0.71 (0.00) | 1.00 | 0.71 | 1.13 |
| *900 M Gold* conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 1.39 (1.67) | 1.00 | 0.91 (0.41) | 1.07 |
| *900 M Gold* conventional (control) | 0.71 (0.00) | 1.00 | 0.71 (0.00) | 1.20 |
| *900 M* conventional (control) + endosulfan 35 EC 1250 g/ha | 1.05 (0.83) | 1.00 | 0.91 (0.41) | 1.07 |
| National check conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 1.39 (1.67) | 1.07 | 0.71 (0.00) | 1.27 |
| National check conventional control | 1.05 (0.83) | 1.00 | 0.71 (0.00) | 1.47 |
| Local check conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 1.94 (3.33) | 1.60 | 1.96 (3.35) | 2.53 |
| Local check conventional (control) | 1.36 (1.67) | 1.40 | 1.16 (1.26) | 2.07 |
| LSD (p=0.05) | 0.57 | 0.17 | 0.44 | 0.48 |

Original values are given in parentheses subjected to arc sine

**Table 2. Effect of artificial infestation of stem borer (*Chilo partelus*) and mean leaf injury score (LIS 1-9 scale) at 15 DAI (days after inoculation) in transgenic and conventional maize hybrids**

| Treatment | Infestation at 55 DAS (%) | Mean leaf injury (LIS) score at 55 DAS | Tunnel length (cm) at harvest |
|---|---|---|---|
| *Hishell* (MON 89034xNK 603) + round up 900 g/ha | 4.05 (0.00) | 1.00 | 0.00 |
| *Hishell* (MON 89034xNK 603) + round up 800 g/ha | 4.05 (0.00) | 1.00 | 0.00 |
| *Hishell* (MON 89034xNK 603) + round up 3600 g/ha | 4.05 (0.00) | 1.00 | 0.00 |
| *900 M Gold* (MON 89034xNK 603) + round up 900 g/ha | 4.05 (0.00) | 1.00 | 0.00 |
| *900 M Gold* (MON 89034xNK 603) + round up 1800 g/ha | 4.05 (0.00) | 1.00 | 0.00 |
| *900 M Gold* (MON 89034xNK 603) + round up 3600 g/ha | 4.05 (0.00) | 1.00 | 0.00 |
| *Hishell* conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 250 g/ha | 39.23 (40.00) | 3.20 | 1.63 |
| *Hishell* conventional (control) | 26.56 (20.00) | 2.13 | 2.47 |
| *Hishell* conventional (control) + endosulfan 35 EC 1250 g/ha | 30.79 (26.66) | 2.60 | 1.63 |
| *900 M Gold* conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 23.28 (20.00) | 2.67 | 1.97 |
| *900 M Gold* conventional (control) | 30.79 (26.66) | 2.73 | 1.80 |
| *900 M* conventional (control) + endosulfan 35 EC 1250 g/ha | 43.08 (46.66) | 3.33 | 2.23 |
| National check conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 35.00 (33.33) | 3.27 | 1.77 |
| National check conventional control | 39.23 (40.00) | 3.27 | 3.13 |
| Local check conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 85.94 (100.00) | 7.00 | 3.40 |
| Local check conventional (control) | 78.44 (93.33) | 5.93 | 3.63 |
| LSD (p=0.05) | 10.58 | 0.94 | 0.99 |

**Table3. Effect of artificial infestation of cob borer (*Helicoverpa armigera*) at 90 DAS in transgenic and conventional maize hybrids**

| Treatment | Natural infestation | Artificial infestation at 90 DAS (%) |
|---|---|---|
| *Hishell* (MON 89034xNK 603) + round up 900 g/ha | 0.00 | 0.71 (0.00) |
| *Hishell* (MON 89034xNK 603) + round up 800 g/ha | 0.00 | 0.71 (0.00) |
| *Hishell* (MON 89034xNK 603) + round up 3600 g/ha | 0.00 | 0.71 (0.00) |
| *900 M Gold* (MON 89034xNK 603) + round up 900 g/ha | 0.00 | 0.71 (0.00) |
| *900 M Gold* (MON 89034xNK 603) + round up 1800 g/ha | 0.00 | 0.71 (0.00) |
| *900 M Gold* (MON 89034xNK 603) + round up 3600 g/ha | 0.00 | 0.71 (0.00) |
| *Hishell* conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 250 g/ha | 0.00 | 7.98 (63.33) |
| *Hishell* conventional (control) | 0.00 | 7.31 (53.33) |
| *Hishell* conventional (control) + endosulfan 35 EC 1250 g/ha | 0.00 | 8.06 (65.00) |
| *900 M Gold* conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 0.00 | 7.34 (55.00) |
| *900 M Gold* conventional (control) | 0.00 | 6.07 (36.66) |
| *900 M* conventional (control) + endosulfan 35 EC 1250 g/ha | 0.00 | 7.53 (56.66) |
| National check conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 0.00 | 7.75 (60.00) |
| National check conventional control | 0.00 | 7.76 (60.00) |
| Local check conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 0.00 | 8.39 (70.00) |
| Local check conventional (control) | 0.00 | 8.47 (71.66) |
| LSD (p=0.05) | 0.00 | 1.08 |

Original values are given in parentheses

**Table 4. Population of other pest species on transgenic and non-transgenic lines**

| Treatment | Aphids 30 DAS | Leaf hoppers 60 DAS |
|---|---|---|
| *Hishell* (MON 89034xNK 603) + round up 900 g/ha | 1259.00 | 0.00 |
| *Hishell* (MON 89034xNK 603) + round up 800 g/ha | 586.00 | 0.00 |
| *Hishell* (MON 89034xNK 603) + round up 3600 g/ha | 978.33 | 0.00 |
| *900 M Gold* (MON 89034xNK 603) + round up 900 g/ha | 1199.33 | 0.00 |
| *900 M Gold* (MON 89034xNK 603) + round up 1800 g/ha | 1145.00 | 0.00 |
| *900 M Gold* (MON 89034xNK 603) + round up 3600 g/ha | 1073.33 | 0.00 |
| *Hishell* conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 250 g/ha | 1211.33 | 0.00 |
| *Hishell* conventional (control) | 1073.00 | 0.00 |
| *Hishell* conventional (control) + endosulfan 35 EC 1250 g/ha | 856.33 | 2.00 |
| *900 M Gold* conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 1421.66 | 1.33 |
| *900 M Gold* conventional (control) | 1342.67 | 0.67 |
| *900 M* conventional (control) + endosulfan 35 EC 1250 g/ha | 1140.00 | 1.00 |
| National check conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 1417.67 | 0.00 |
| National check conventional control | 1698.33 | 0.00 |
| Local check conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 1433.33 | 0.33 |
| Local check conventional (control) | 1533.67 | 0.00 |
| LSD (p=0.05) | NS | 0.95 |

Pilcher *et al.* (1997) showed that direct consumption of transgenic maize pollen by immature stages of three predatory species commonly found in maize fields did not affect development or survival. The mortality rate of nymphal stages of *Orius majusculus* (predator) was the same when fed a thrips species reared on Bt maize as and when the thrip were fed on non-Bt maize (Zwahlen *et al.* 2000). However, increased mortality of lacewing (*Chrysoperla carnea*) larvae was observed when the larvae fed on an artificial diet containing Bt toxin or preyed on maize borers or other lepidopteran larvae that had fed on transgenic maize (Hilbeck *et al.*1998). Resende *et al.* (2016) assessed the effect of the cultivation of genetically modified crops in Brazil on non-target insect diversity by comparing a homogeneous maize field with conventional and transgenic maize, conveying different Bt proteins in seven counties of Minas Gerais, Brazil. The results did not support the hypothesis that Bt protein affects insect biodiversity. Romeis *et al.* (2014) found that there is sufficient information available today to conclude that Bt maize containing Cry 1Ab does not harm beneficial insect predator *Chrysoperla carnea* (Neuroptera: Chrysopidae). Our observation also revealed the presence of beneficial predator on transgenic and non-transgenic entries. Therefore, one advantage of the use of GM maize would be in reduction of insecticide applications, especially of broad spectrum type (Dively 2005, Naranjo 2005). In many cases, the insect richness estimated for conventional and Bt maize fields was not significantly different or was lower than on Bt maize. Again, considering that conventional maize fields underwent insecticide spraying, it is likely that the low insect population in these fields is the result of this impact. However, although other studies have already shown that the effect of insecticide use may be stronger on insect communities than the impacts of transgenic *Bt* crops. In the present study, the estimated insect population was not significantly affected by insecticide use on the studied maize fields (Dively 2005). The use of transgenic plants may be considered as one more method for integrated pest management (IPM). Regarding community diversity, the presence of secondary pests was directly related with the richness of natural enemies. Recent literature also indicate no significant effect of Bt proteins on natural enemies.

**Table 5. Population of beneficial insects at 30, 45 and 60 days after showing (DAS)**

| Treatment | Coccinalid DAS | | | Spider DAS | | | Syrphid | | | Pollinator | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 | 45 | 60 | 30 | 45 | 60 | 30 | 45 | 60 | 30 | 45 | 60 |
| *Hishell* (MON 89034xNK 603) + round up 900 g/ha | 8.33 | 3.67 | 0.00 | 2.00 | 1.67 | 3.00 | 9.00 | 9.67 | 3.33 | 3.00 | 2.33 | 3.00 |
| *Hishell* (MON 89034xNK 603) + round up 800 g/ha | 9.33 | 4.00 | 0.00 | 0.00 | 0.67 | 2.00 | 8.00 | 8.67 | 2.33 | 2.00 | 2.00 | 1.67 |
| *Hishell* (MON 89034xNK 603) + round up 3600 g/ha | 7.33 | 2.67 | 0.00 | 0.30 | 2.67 | 2.33 | 9.00 | 17.00 | 2.00 | 1.00 | 2.00 | 1.67 |
| *900 M Gold* (MON 89034xNK 603) + round up 900 g/ha | 9.33 | 5.33 | 0.00 | 1.05 | 1.00 | 2.67 | 11.0 | 11.67 | 2.33 | 1.33 | 1.33 | 2.33 |
| *900 M Gold* (MON 89034xNK 603) + round up 1800 g/ha | 6.00 | 5.00 | 0.00 | 0.67 | 1.33 | 2.67 | 8.33 | 17.7 | 1.67 | 1.33 | 3.33 | 1.67 |
| *900 M Gold* (MON 89034xNK 603) + round up 3600 g/ha | 5.00 | 4.33 | 0.00 | 0.33 | .33 | 2.00 | 16.00 | 16.7 | 1.67 | 2.00 | 3.00 | 2.67 |
| *Hishell* conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 250 g/ha | 12.3 | 6.33 | 0.00 | 1.00 | 2.33 | 2.33 | 13.00 | 11.7 | 2.00 | 0.67 | 2.67 | 3.33 |
| *Hishell* conventional (control) | 6.33 | 3.67 | 0.67 | 1.09 | 2.00 | 1.33 | 14.33 | 11.0 | 2.67 | 0.67 | 2.00 | 2.33 |
| *Hishell* conventional (control) + endosulfan 35 EC 1250 g/ha | 10.33 | 3.67 | 0.00 | 1.67 | 1.00 | 2.67 | 12.00 | 12.3 | 2.00 | 3.33 | 1.67 | 2.67 |
| *900 M Gold* conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 9.33 | 4.67 | 0.67 | 1.22 | 2.00 | 2.33 | 19.33 | 28.7 | 2.00 | 3.67 | 3.00 | 2.67 |
| *900 M Gold* conventional (control) | 7.33 | 2.33 | 0.00 | 0.33 | 0.67 | 2.33 | 9.00 | 10.7 | 2.00 | 3.00 | 2.00 | 2.00 |
| *900 M* conventional (control) + endosulfan 35 EC 1250 g/ha | 11.33 | 4.33 | 0.67 | 0.0 | 0.33 | 2.67 | 10.00 | 9.3 | 3.33 | 3.00 | 3.33 | 2.67 |
| National check conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 11.67 | 7.67 | 0.67 | 0.0 | 2.00 | 1.67 | 11.33 | 18.3 | 1.00 | 2.00 | 3.67 | 2.33 |
| National check conventional control | 12.67 | 6.33 | 0.67 | 0.0 | 1.00 | 1.67 | 13.33 | 14.33 | 1.67 | 6.00 | 6.00 | 3.00 |
| Local check conventional (P) + atrazine 1000 g/ha and endosulfan 35 EC 1250 g/ha | 8.33 | 2.67 | 0.00 | 1.67 | 067 | 1.33 | 12.33 | 7.67 | 1.67 | 5.67 | 0.67 | 2.00 |
| Local check conventional (control) | 8.67 | 3.67 | 1.00 | 0.33 | 1.00 | 2.00 | 10.67 | 7.67 | 1.00 | 5.67 | 5.33 | 2.67 |
| LSD (p=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

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# Herbicides efficacy for managing weeds in greengram and their residual effect on succeeding mustard

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## ABSTRACT

A field experiment was conducted at Research Farm of S. K. Rajasthan Agricultural University, Bikaner during *Kharif* 2014 and 2015 to study the efficacy of pre- and post-emergence herbicides in managing weeds in greengram (*Vigna radiata*) and herbicides carryover effect on Indian mustard (*Brassica juncea*) grown during succeeding *Rabi* seasons of 2014-15 and 2015-16. Ten weed control treatments, *viz*. pendimethalin 1000 g/ha pre-emergence (PE), imazethapyr 50 and 70 g/ha (early post-emergence; PoE), imazethapyr + pendimethalin (ready mix) 800, 900, and 1000 g/ha pre-emergence (PE), imazethapyr + imazamox 60 and 70 g/ha, two hand weedings at 20 and 40 days after seeding (DAS) and weedy check were evaluated in greengram grown in three replications with randomized block design (RBD). Two hand weedings at 20 and 40 DAS resulted in lowest weed density of broad-leaf and grassy weed, total weed biomass at 60 days after sowing, significantly highest number of branches per plant, pods per plant, seeds per pod and seed and straw yield compared to other treatments. Imazethapyr + pendimethalin 800 g/ha PE was at par with two hand weedings in managing weeds and increasing greengram yield. Application of herbicides did not cause any adverse effect on succeeding mustard in both years.

**Key words**: Greengram, Imazethapyr, Mustard, Herbicide residues

Greengram (*Vigna Radiata*) is an important pulse crop of India which is cultivated in 3.35 million hectares mainly during *Kharif* (rainy) seasons (Anonymous. 2015). Besides other constraints, weed infestation is one of the major factors responsible for low productivity of greengram (512 kg/ha). Traditionally, weeds in greengram are controlled by manual weeding and hoeing at appropriate growth stages. Manual weeding is time-consuming and expensive and often not feasible due to intermittent rains during rainy season. The labour is also becoming scarce, not available in time and expensive to further increase the cost of cultivation. Under such situations, use of appropriate herbicide with suitable dose remains the pertinent choice for timely control of weeds.

The effectiveness of pendimethalin and imazethapyr on weed control and productivity of greengram/pulses was reported (Kaur *et al.* 2010). Certain effective herbicides were reported to have long persistence in soil (Das 2008) and therefore, the knowledge of their residual effect on succeeding crop in a crop sequence is essential before making any recommendation for the farmers. Greengram Indian mustard is common crop rotation in the semi-arid North-Western region of India. Hence, the present study was conducted to study the efficacy of ready-mix pre- and early post-emergence herbicides in managing weeds in greengram and to assess the herbicides carryover effect on succeeding Indian mustard.

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## MATERIALS AND METHODS

A field study was conducted for two consecutive years during 2014-15 and 2015-16 at the research farm of Agricultural Research Station, Swami Keshwanand Rajasthan Agricultural University, Bikaner. The treatments comprised of pre-emergence application PE of pendimethalin at 1000 g/ha and imazethapyr + pendimethalin ready-mix at 800, 900 and 1000 g/ha, early post-emergence application (PoE) of imazethapyr at 50 and 70 g/ha, imazethapyr + imazamox (ready-mix) at 60 and 70 g/ha, two hand weedings at 20 and 40 days after sowing (DAS) and weedy checkin greengram. These treatments were evaluated in randomized block design with three replications. The soil of experimental site was loamy sand having 0.08% organic carbon, 8.22 pH, 78, 22 and 210 kg/ha available N, P and K, respectively. Greengram '*SML-668*' was sown on 16 July 2014 and 02 July 2015 at

30 cm row to row spacing using seed rate of 20 kg/ha and was harvested on 10 October in 2014 and on 08 October in 2015. Recommended dose of fertilizers (20 kg N, 40 kg $P_2O_5$ and 40 kg $K_2O$ per ha) was applied as basal dose. The total rainfall during the season was 427.9 mm with 12 rainy days in 2014 and 394.2 mm with 18 rainy days in 2015.

Pre-emergence application of pendimethalin and imazethapyr + pendimethalin was done on the next day of sowing whereas post-emergence application of imazethapyr and imazethapyr + imazamox was made at 25 DAS (3-4 leaf stage) as per the treatments with knapsack sprayer. Weed density was recorded at 60 DAS by using quadrate of 0.25 $m^2$ in all the treatments and then expressed as a number of weeds/ $m^2$. The weeds were dried in oven till a constant weight was observed and then expressed as weed biomass (g/$m^2$). Growth, yield parameters and yield of greengram were recorded for two consecutive years.

The data on total weed density and weed biomass were subjected to square root transformation to normalize their distribution (Gomez and Gomez 1984). The residual effect of different herbicides applied in greengram was studied on the succeeding Indian mustard. All the recommended package of practices was followed to raise the mustard crop. In case of Indian mustard, plant population per unit area, plant height and yields were recorded at maturity.

## RESULTS AND DISCUSSION

### Effect on weeds

The experimental field was infested with *Amaranthus spinosus, Digera arvensis, Trianthema portulacastrum, Gisekia poredious, Mollugo verticillata, Euphorbia hirta, Aristida depressa, Portulaca oleracea, Cenchrus biflorus, Cleome viscosa, Tribulus terrestris, Corchorus tridense, Cyperus rotundus, Eleusine verticillata* and *Eragrostis tennela* during the two seasons of experimentation.

The density of both broad-leaf and grassy weeds and their biomass at 60 DAS were significantly reduced by all weed control treatments compared to weedy check (**Table 1**). However, two hand weedings recorded lowest number of broad-leaf, grassy and total weeds compared to rest of the weed control treatments. Among different herbicides, pre-emergence application of imazethapyr + pendimethalin at 1000 g/ha was the most effective in reducing the density of both broad-leaf and grassy weeds and biomass of weeds followed by its lower doses (imazethapyr + pendimethalin at 900 g/ha and 800 g/ ha) and application of imazethapyr + imazamox at 60 and 70 g/ha (**Table 1**). Application of pendimethalin at 1000 g/ha as pre-emergence was effective against grassy weeds, whereas imazethapyr at 50 and 70 g were at par with each other and significantly reduced the density of broad-leaf weeds as compare to weedy check. The present results were in close accordance with finding of Yadav *et al.* (2011).

Imazethapyr and imazethapyr + imazamox are selective herbicides and are applied as post-emergence with a view to control late emerging weeds. Results of weed density corroborate with the findings of Rao and Rao (2003) and Sasikala *et al.* (2007). Weedy check registered significantly higher weed density. Reduction in both density of grassy weeds and biomass of weeds with application of imazethapyr + imazamox might be due to the greater effectiveness of imazamox against grassy and thick broad-leaf weeds. Hand weedings twice removed the

**Table 1. Effect of tested weed management treatments on weed density and weed biomass at 60 days after sowing in greengram**

| Treatment | Weed density (no./$m^2$)* | | | | | | Weeds biomass (g/$m^2$) | |
|---|---|---|---|---|---|---|---|---|
| | Broad-leaved | | Grass | | Total | | | |
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| Pendimethalin (1000 g/ha) PE | 5.6 (31.0) | 6.0 (35.4) | 0.9 (0.3) | 0.9 (0.3) | 5.6 (31.3) | 6.0 (35.8) | 5.9 (34.0) | 5.9 (35.0) |
| Imazethapyr (50 g/ha) 3-4 leaf stage | 3.1 (9.3) | 3.4 (11.5) | 2.0 (3.7) | 2.3 (4.7) | 3.7 (13.0) | 4.1 (16.2) | 2.3 (5.0) | 2.6 (6.3) |
| Imazethapyr (70 g/ha) 3-4 leaf stage | 2.8 (7.3) | 3.1 (9.1) | 1.6 (2.0) | 1.8 (2.7) | 3.1 (9.3) | 3.5 (11.8) | 1.7 (2.7) | 2.0 (3.7) |
| Imazethapyr + pendimethalin (800 g/ha) PE | 1.9 (3.3) | 2.2 (4.6) | 0.7 (0) | 0.7 (0.0) | 1.9 (3.3) | 2.2 (4.6) | 1.2 (1.0) | 1.2 (1.0) |
| Imazethapyr + pendimethalin (900 g/ha) PE | 1.46 (1.7) | 1.8 (3.0) | 0.7 (0) | 0.7 (0.0) | 1.5 (1.7) | 1.8 (3.0) | 1.0 (0.7) | 1.0 (0.7) |
| Imazethapyr + pendimethalin (1000 g/ha) PE | 0.9 (0.3) | 0.9 (0.4) | 0.7 (0) | 0.7 (0.0) | 0.9 (0.3) | 0.9 (0.4) | 0.9 (0.3) | 0.9 (0.3) |
| Imazethapyr + imazamox (60 g/ha) 3-4 leaf stage | 2.3 (5.0) | 3.0 (8.3) | 1.0 (0.7) | 1.0 (0.7) | 2.5 (5.7) | 3.1 (9.0) | 1.9 (4.0) | 2.1 (4.3) |
| Imazethapyr + imazamox (70 g/ha) 3-4 leaf stage | 1.6 (2.0) | 1.9 (3.2) | 0.7 (0) | 0.7 (0.0) | 1.6 (2.0) | 1.9 (3.2) | 1.0 (0.7) | 1.0 (0.7) |
| Two hand weeding 20 and 40 DAS | 0.7 (0.0) | 0.8 (0.2) | 0.7 (0) | 0.7 (0.0) | 0.7 (0.0) | 0.8 (0.2) | 0.7 (0) | 0.7 (0) |
| Weedy check | 8.0 (63.7) | 8.2 (66.3) | 2.5 (5.7) | 2.5 (6.0) | 8.3 (69.3) | 8.5 (72.3) | 7.6 (56.7) | 7.7 (58.3) |
| LSD (p=0.05) | 0.67 | 0.64 | 0.32 | 0.29 | 0.67 | 0.62 | 0.81 | 0.68 |

*Square root transformed value; Actual values are given in parentheses weeds completely and created conditions, which were more favourable for crop growth and ultimately resulted in lowest density of later emerged weeds and their lowest biomass during the crop growth period. The results of study also corroborate with the finding of Punia *et al.* (2011). May be ascribed to broad spectrum activity of herbicidal combination particularly on emergence of both broad leaf and grassy weeds and their greater efficiency to retard cell division of meristems causing rapid drying of weeds. In earlier study, Kanter *et al.* (1999) reported about 84.6% control of weed biomass with application of imazethapyr in chickpea. Papierniks *et al.* (2003) also reported that imazethapyr application was effective for weed control in legumes.

### Effect on greengram

All weed management practices resulted in significant increase in number of branches per plant, number of pods per plant, seeds per pod and seed and straw yields over weedy check (**Table 2**). The highest number of branches per plant, number of pods per plant, seeds per pod and seed and straw yields recorded with two hand weedings and was at par with all doses of imazethapyr + pendimethalin (800, 900 and 1000 g/ha). This might be due to better availability of resources to the crop in absence of weeds. The lowest number of branches per plant recorded under weedy check might be due to severe competition by weeds to crop for resources. The results corroborated with the findings of Singh *et al.* (2006) and Yadav *et al.* (2014). Reduced crop weed competition during critical phase of crop growth better regulates the complex process of yield formation due to better availability of resources to the crop plant. Reduced crop-weed competition under different weed control treatments might have influenced the 'source' by virtue of higher photosynthetic and metabolic activity which in turn improved growth and consequently yield components of crop. The adverse effect of weed competition on crop performance under present investigation is clearly reflected under weedy check wherein dense population of weeds reduced crop growth compared to two hand weeding treatment as well as other treatments and ultimately resulted in reduced number of pods per plant and seeds per pod.

Among different treatments, application of imazethapyr + pendimethalin 800 g/ha resulted in higher seed and straw yield over weedy check and was at par with its higher doses, and two hand weeding (**Table 2**). Kanter *et al.* (1999) observed 63.6% higher seed yield of chickpea over unweeded check with application of imazethapyr. The reduced crop weed competition caused significant improvement in growth and yield attributes and ultimately led to higher seed yield of greengram. The significant improvement in seed as well as straw yield as a result of two hand weeding treatment and all herbicidal weed control treatments could be ascribed to the fact that yield of crop depends on several yield components which are interrelated. Under weedy situation, at early crop growth stage a greater part of resources present in soil and environment are depleted by weeds for their growth. The crop plant thus, faced stress which ultimately affected their growth, development and yield. Similar results were also reported in soybean by Upadhayay *et al.* (2013).

### Residual effect on succeeding mustard

Different weed management practices or application of different herbicides applied to greengram did not cause any adverse effect on plant population, plant height and yield of succeeding Indian mustard crop in both the years (**Table 3**).

**Table 2. Effect of weed management treatments on yield attributes and yields of greengram**

| Treatment | Branches/ plant | | Pods/plant | | Seeds/pod | | Yield (t/ha) Seed | | Yield (t/ha) Straw | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| Pendimethalin (1000 g/ha) PE | 3.53 | 3.93 | 55.7 | 58.3 | 4.68 | 5.62 | 0.76 | 0.81 | 1.51 | 1.68 |
| Imazethapyr (50 g/ha) 3-4 leaf stage | 3.33 | 3.69 | 52.7 | 54.2 | 4.26 | 5.38 | 0.76 | 0.76 | 1.58 | 1.64 |
| Imazethapyr (70 g/ha) 3-4 leaf stage | 3.42 | 3.72 | 55.0 | 54.3 | 4.37 | 5.41 | 0.75 | 0.78 | 1.59 | 1.70 |
| Imazethapyr + pendimethalin (800 g/ha) PE | 3.94 | 4.14 | 63.3 | 64.3 | 5.15 | 5.83 | 0.88 | 0.90 | 1.66 | 1.74 |
| Imazethapyr + pendimethalin (900 g/ha) PE | 3.86 | 4.10 | 61.3 | 65.5 | 4.97 | 5.79 | 0.88 | 0.93 | 1.62 | 1.78 |
| Imazethapyr + pendimethalin (1000 g/ha) PE | 3.78 | 4.04 | 60.0 | 62.4 | 4.87 | 5.73 | 0.88 | 0.89 | 1.60 | 1.71 |
| Imazethapyr + imazamox (60 g/ha) 3-4 leaf stage | 3.65 | 3.88 | 54.3 | 55.7 | 4.53 | 5.57 | 0.76 | 0.80 | 1.56 | 1.64 |
| Imazethapyr + imazamox (70 g/ha) 3-4 leaf stage | 3.62 | 3.77 | 55.7 | 56.8 | 4.41 | 5.46 | 0.77 | 0.80 | 1.58 | 1.65 |
| Two hand weeding 20 and 40 DAS | 4.14 | 4.25 | 65.3 | 68.7 | 5.32 | 5.98 | 0.94 | 1.03 | 1.59 | 1.81 |
| Weedy check | 3.05 | 2.95 | 40.0 | 43.7 | 3.94 | 4.64 | 0.61 | 0.66 | 1.13 | 1.20 |
| LSD (p=0.05) | 0.35 | 0.53 | 8.79 | 7.44 | 0.32 | 0.13 | 0.09 | 0.15 | 0.11 | 0.25 |

**Table 3. Residual effect of different herbicides and other treatments applied in greengram on succeeding mustard**

| Treatment | Plant stand/m row length at maturity | | Plant height (cm) at maturity | | Seed yield (t/ha) | | Straw yield (t/ha) | |
|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 |
| Pendimethalin (1000 g/ha) PE | 7.7 | 7.7 | 150.8 | 159.4 | 1.11 | 1.22 | 2.45 | 2.61 |
| Imazethapyr (50 g/ha) 3-4 leaf stage | 8.0 | 8.4 | 151.1 | 159.7 | 1.11 | 1.18 | 2.45 | 2.58 |
| Imazethapyr (70 g/ha) 3-4 leaf stage | 8.7 | 8.7 | 153.8 | 165.6 | 1.07 | 1.21 | 2.25 | 2.50 |
| Imazethapyr + pendimethalin (800 g/ha) PE | 8.0 | 8.3 | 151.2 | 162.9 | 1.06 | 1.15 | 2.22 | 2.54 |
| Imazethapyr + pendimethalin (900 g/ha) PE | 8.7 | 8.7 | 151.2 | 162.8 | 1.05 | 1.21 | 2.21 | 2.53 |
| Imazethapyr + pendimethalin (1000 g/ha) PE | 8.3 | 7.6 | 151.7 | 161.2 | 1.04 | 1.27 | 2.18 | 2.52 |
| Imazethapyr +imazamox (60 g/ha) 3-4 leaf stage | 8.0 | 7.9 | 152.0 | 161.4 | 1.07 | 1.16 | 2.22 | 2.57 |
| Imazethapyr + imazamox (70 g/ha) 3-4 leaf stage | 8.7 | 8.4 | 155.3 | 165.0 | 1.04 | 1.20 | 2.15 | 2.47 |
| Two hand weeding 20 and 40 DAS | 7.7 | 8.1 | 153.3 | 162.4 | 1.09 | 1.23 | 2.26 | 2.61 |
| Weedy check | 8.3 | 8.0 | 150.7 | 159.6 | 1.05 | 1.19 | 2.18 | 2.52 |
| LSD (p=0.05) | NS | NS | NS | NS | NS | NS | NS | NS |

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# Efficacy of pre- and post-emergence herbicides for weed control in greengram

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**ABSTRACT**

A field experiment was conducted during rainy seasons in 2011 and 2012 to study the efficacy of pre- and post-emergence herbicides on weeds, growth, symbiotic traits and grain yield of greengram. Pre-emergence application of pre-mix pendimethalin + imazethapyr at 1.0 kg/ha showed lowest weed index and highest weed control efficiency, followed by pre-mix pendimethalin + imazethapyr at 0.75 kg/ha and two hand weedings done at 20 and 40 days after sowing. Post-emergence application of quizalofop-ethyl at 37.5 g/ha reduced the number and dry weight of nodules/plant compared to other herbicides. Weed free treatment provided the highest grain yield, gross returns and net returns. Among the herbicides, pre-emergence application of pre-mix pendimethalin + imazethapyr at 1.0 and 0.75 kg/ha recorded higher grain yield (1.41 and 1.31 t/ha, respectively) and provided higher net returns (` 52970 and ` 48390, respectively) and B:C ratio (2.57 and 2.44, respectively) than the other treatments of herbicides due to significant reduction in the dry weight of weeds and higher weed control efficiency and consequently improving the yield attributing parameters.

**Key words:** Greengram, Imazethapyr, Nodulation, Pendimethalin, Post-emergence, Weeds

Greengram [*Vigna radiata* (L.) Wilczek], also known as mungbean, is grown in rainy season in many parts of India. Weeds are one of the most limiting factors in successful greengram production. Due to monsoon rainfall in rainy season, weeds grow luxuriantly and pose a serious threat to greengram. Weeds compete for nutrients, water, light and space with crop plants. Raising of greengram requires lot of labour due to more weeds and farmers generally do not harvest profitable yields. Weeds can cause 30-85% yield losses in greengram (Raman and Krishnamoorthy 2005, Yadav and Singh 2005, Mirjha *et al*. 2013). The effect of weed competition is greater during early growth period than the later one. Moreover, herbicides have also been reported for their negative effect on legume-*Rhizobium* interactions (Singh 2005) affecting either directly the rhizobial structure (Anderson *et al*. 2004) or indirectly reducing the photosynthate transport to the symbiotic organ ''nodules'' for $N_2$ fixation (Ahemad and Khan 2011).

Due to involvement of high cost and scarcity of labour for manual weeding, there is a need of evaluation of pre-emergence (PE) and post-emergence (PoE) herbicides in greengram for effective weed control. Therefore, an experiment was conducted to study the effect of pre- and post-emergence herbicides on weeds, growth, symbiotic traits and grain yield of greengram.

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## MATERIALS AND METHODS

A field experiment was conducted during rainy seasons 2011 and 2012 at the research farm of Punjab Agricultural University, Ludhiana (30° 54'N, 75° 48'E, altitude 247 m), Punjab. The soil of the experimental site was loamy sand, having pH (7.8), organic carbon (0.29%), available phosphorus (11.5 kg/ha) and available potassium (196 kg/ha). Ten treatments, (**Table 1)**, were arranged in a randomized block design with three replications. Quizalofop-ethyl and fenoxaprop-ethyl were sprayed at 23 and 25 days after sowing (DAS) during 2011 and 2012, respectively and pendimethalin and pre-mix pendimethalin + imazethapyr as PE (within 24 hour of sowing) with a knapsack sprayer fitted with a flat fan nozzle using 375 litres of water per hectare. In the case of two hand weedings, weeds were removed manually with a a *khurpa* (kind of hand tool) at 20 and 40 DAS. In the case of weedy check plots, weeds were allowed to grow and in weed free plots, weeds were removed with *khurpa* during the whole crop growing season.

The preceding crop was wheat. After pre-sowing irrigation, at optimum soil moisture, the field was ploughed twice followed by planking. The crop was sown on 19 July, 2011 and 11 July, 2012. The sowing of greengram variety '*PAU 911*' was done in rows 30 cm apart using a seed rate of 20 kg/ha. Each plot measured 6.0 × 2.7 m in 2011 and 5.5 x 2.1 m in 2012. Data on weed species count were recorded at

40 DAS from a randomly selected area measuring 50 x 50 cm from each plot and then converted to weed species count per $m^2$. At harvest, weeds from the whole plot were harvested, dried and data converted into kg/ha. Data on symbiotic parameter *viz*. number and dry weight of nodules were recorded at 40 DAS. Five plants per plot were randomly selected for number and dry weight of nodules, and then average worked out.

At maturity, data on plant height, branches/plant and pods/plant were recorded from randomly selected five plants from each plot, and seeds/pod from randomly selected 20 pods. Biological yield and grain yield were recorded on the basis of whole plot area and converted into kg/ha. From the produce of each plot, 100-seeds were taken for 100-seed weight data. Harvest index (HI) was also calculated. Gross returns, net returns as well as benefit:cost (B:C) ratio were worked out using prevailing prices of inputs and output. Two-year pooled data were subjected to analysis of variance (ANOVA) in a randomized block design as per the standard procedure.

## RESULTS AND DISCUSSION

### Effect on weeds

During the period of experimentation, the major weed flora emerged were *Cyperus rotundus* (nut grass), *Eleucine aegyptiacum* (crow foot grass) and *Commelina benghalensis* (day flower) (**Table 1**). In general, weedy check, fenoxaprop-ethyl and quizalofop-ethyl recorded higher weed density whereas pre-mix application of pendimethalin + imazethapyr at 0.75 and 1.0 kg/ha recorded lower weed density than other treatments.

Pre-mix application of pendimethalin + imazethapyr at 0.75 and 1.0 kg/ha caused significant reduction in the dry weight of weeds followed by two hand weedings and pendimethalin at 0.45 kg/ha + hand weeding (**Table 1**). However, application of post-emergence herbicides quizalofop-ethyl at 37.5 g/ha and fenoxaprop-ethyl at 50 g/ha did not control the weeds effectively.

Quizalofop-ethyl at 37.5 g/ha and fenoxaprop-ethyl at 50 g/ha recorded low weed control efficiency (WCE) as these treatments did not control weeds effectively (**Table 1**). PE application of pre-mix pendimethalin + imazethapyr at 0.75 and 1.0 kg/ha recorded higher WCE as compared to pendimethalin alone at the same rates of application. This could be due to better weed control owing to two different chemicals. Application of imazethapyr has been reported to provide effective control of weeds in greengram (Khairnar and Sethi 2014, Singh *et al*. 2014a, Singh *et al*. 2015, Kumar *et al*. 2016), blackgram (Aggarwal *et al*. 2014) and lentil (Singh *et al*. 2014b). Khairnar and Sethi (2014) also reported higher WCE with the application of imazethapyr. Reduction of dry matter of weeds with the application of pendimethalin has also been reported by several researchers (Sekhon *et al.* 1996, Kaur *et al.* 2010, Singh 2011, Aktar *et al.* 2015). Among different weed control treatments, PE application of pre-mix pendimethalin + imazethapyr at 1.0 kg/ha showed lowest weed index followed by pendimethalin + imazethapyr at 0.75 kg/ha and two hand weedings.

### Effect on crop

Number and dry weight of nodules were the lowest in weedy check (**Table 2**). Application of quizalofop-ethyl at 37.5 g/ha recorded lower number and dry weight of nodules/plant than the other herbicide treatments and these were significantly lower than hand weeding treatment. Ahemad and

**Table 1. Population of different weed species, dry weight, weed control efficiency and weed index as influenced by different weed control treatments in greengram (pooled data of 2 years)**

| Treatment | At 40 DAS weed count (no./m$^2$) | | | At harvest | | |
|---|---|---|---|---|---|---|
| | *Cyperus rotundus* | *Eleucine aegyptiacum* | *Commelina benghalensis* | Dry weight of weeds (kg/ha) | Weed control efficiency (%) | Weed index (%) |
| Pendimethalin at 0.45 kg/ha (PE) *fb* HW at 25-30 DAS | 4.2 (18.0) | 2.3 (5.4) | 2.2 (4.6) | 15.7 (247) | 93.1 | 26.8 |
| Pendimethalin at 0.75 kg/ha (PE) | 4.0 (16.0) | 2.0 (4.1) | 2.6 (6.6) | 22.9 (527) | 85.3 | 31.2 |
| Pendimethalin at 1.0 kg/ha (PE) | 4.1 (16.6) | 1.8 (3.4) | 2.7 (7.4) | 20.5 (420) | 88.2 | 35.7 |
| Pendimethalin + imazethapyr at 0.75 kg/ha (PE) | 2.3 (5.4) | 1.2 (1.4) | 1.0 (0) | 13.7 (189) | 94.8 | 12.7 |
| Pendimethalin + imazethapyr at 1.0 kg/ha (PE) | 2.0 (4.0) | 1.0 (0) | 1.0 (0) | 13.1 (173) | 95.2 | 5.9 |
| Quizalofop-ethyl at 37.5 kg/ha 23-25 DAS (PoE) | 5.9 (34.7) | 5.0 (25.4) | 2.7 (7.4) | 34.5 (1187) | 66.3 | 68.4 |
| Fenoxaprop-ethyl at 50 g/ha 23-25 DAS (PoE) | 6.4 (40.7) | 4.8 (22.6) | 3.1 (9.4) | 28.5 (814) | 77.0 | 56.9 |
| Weedy check | 6.6 (43.9) | 5.1 (26.0) | 2.9 (8.6) | 59.3 (3520) | - | 66.4 |
| Hand weeding (20 and 40 DAS) | 2.6 (6.6) | 2.3 (5.4) | 1.4 (2.0) | 16.6 (277) | 92.3 | 15.7 |
| Weed free | 1.0 (0.0) | 1.0 (0.0) | 1.0 (0.0) | 1.0 (0.0) | 100.0 | 0.0 |
| LSD (p=0.05) | 2.6 | 2.2 | 1.1 | 13.8 | 17.0 | 18.7 |

Figures in parentheses are means of original values and subjected to square root transformation

Khan (2010) also reported the negative effects of quizalofop-p-ethyl on the symbiosis in greengram plants and the effects enhanced gradually with the increase in dose of the herbicide.

Different treatments of weed control did not influence the plant height, branches/plant and 100-seed weight significantly (**Table 2**). Treatments of weed free, two hand weedings and pendimethalin + imazethapyr at 0.75 and 1.0 kg/ha recorded higher number of pods/plant than other treatments. Seeds/pod was the lowest in weedy check.

Weed free recorded the highest biological yield and grain yield (**Table 3**). Weedy check treatment recorded the lowest biological yield and grain yield, which might be due to more weed density and dry weight of weeds and poor nodulation. Among the herbicide treatments, application of pre-mix pendimethalin + imazethapyr at 1.0 and 0.75 kg/ha recorded significantly higher grain yield than the other treatments of herbicides. Higher grain yield in these treatments was due to more number of pods/plant, which might have been resulted due to better control of weeds by reducing the dry matter of weeds and enhancing the WCE. Harvest index was higher in those treatments where weeds were effectively controlled. Quizalofop-ethyl at 37.5 g/ha, fenoxaprop-ethyl at 50 g/ha and weedy check recorded low harvest index.

Pendimethalin improved the grain yield significantly over weedy check (**Table 3**). Pendimethalin is known to improve the grain yield of greengram (Kaur *et al.* 2010) and blackgram (Singh 2011). However, application of pre-mix pendimethalin + imazethapyr showed significant superiority over the sole application of pendimethalin, which could be due to better weed control owing to two different chemicals.

Economics of different weed control treatments (**Table 3**) showed that weed free gave the maximum gross returns and net returns, followed by pre-mix application of pendimethalin + imazethapyr at 1.0 kg/ha and 0.75 kg/ha. Pre-mix application of pendimethalin + imazethapyr 1.0 kg/ha gave the highest B:C ratio followed by pendimethalin +

**Table 2. Influence of different weed control treatments on the symbiotic traits, plant characters and yield attributes of greengram (pooled data of 2 years)**

| Treatment | Number of nodules/ plant at 40 DAS | Dry weight of nodules (mg/plant) at 40 DAS | Plant height (cm) | Branches / plant | Pods/ plant | Seeds/ pod | 100-seed weight (g) |
|---|---|---|---|---|---|---|---|
| Pendimethalin at 0.45 kg/ha (PE) *fb* HW 25-30 DAS | 31.9 | 56.1 | 62.5 | 4.8 | 19.7 | 10.6 | 3.25 |
| Pendimethalin at 0.75 kg/ha (PE) | 31.8 | 53.6 | 62.3 | 4.8 | 18.6 | 10.8 | 2.99 |
| Pendimethalin at 1.0 kg/ha (PE) | 28.6 | 51.1 | 58.6 | 4.6 | 18.7 | 10.5 | 3.05 |
| Pendimethalin + imazethapyr at 0.75 kg/ha (PE) | 31.1 | 53.1 | 63.5 | 4.9 | 21.9 | 11.3 | 3.10 |
| Pendimethalin + imazethapyr at 1.0 kg/ha (PE) | 32.3 | 58.3 | 65.3 | 4.9 | 24.1 | 11.6 | 3.22 |
| Quizalofop-ethyl at 37.5 kg/ha 23-25 DAS (PoE) | 26.4 | 45.2 | 60.5 | 4.5 | 15.8 | 10.8 | 3.08 |
| Fenoxaprop-ethyl at 50 g/ha 23-25 DAS (PoE) | 31.2 | 51.3 | 61.6 | 4.8 | 14.8 | 10.3 | 3.23 |
| Weedy check | 22.5 | 43.6 | 54.1 | 4.3 | 16.0 | 9.9 | 2.87 |
| Hand weeding (20 and 40 DAS) | 30.7 | 51.0 | 61.8 | 5.1 | 22.8 | 11.4 | 3.20 |
| Weed free | 29.0 | 57.4 | 61.5 | 5.4 | 24.3 | 11.4 | 3.27 |
| LSD (p=0.05) | 3.1 | 5.2 | NS | NS | 4.6 | 0.5 | NS |

**Table 3. Influence of different weed control treatments on biological yield, grain yield, harvest index and economics of greengram (pooled data of 2 years)**

| Treatment | Grain yield (t/ha) | Biological yield (t/ha) | Harvest index (%) | Gross returns ($x10^3$ `/ha) | Net returns ($x10^3$ `/ha) | B:C ratio |
|---|---|---|---|---|---|---|
| Pendimethalin at 0.45 kg/ha (PE) *fb* HW 25-30 DAS | 1.09 | 5.46 | 20.2 | 57.03 | 36.54 | 1.79 |
| Pendimethalin at 0.75 kg/ha (PE) | 1.03 | 4.92 | 21.6 | 53.79 | 35.01 | 1.87 |
| Pendimethalin at 1.0 kg/ha (PE) | 0.97 | 4.71 | 20.8 | 50.71 | 31.56 | 1.65 |
| Pendimethalin + imazethapyr at 0.75 kg/ha (PE) | 1.31 | 5.01 | 26.1 | 68.26 | 48.39 | 2.44 |
| Pendimethalin + imazethapyr at 1.0 kg/ha (PE) | 1.41 | 5.85 | 24.3 | 73.62 | 52.97 | 2.57 |
| Quizalofop-ethyl at 37.5 kg/ha 23-25 DAS (PoE) | 0.48 | 3.81 | 13.2 | 25.08 | 6.26 | 0.34 |
| Fenoxaprop-ethyl at 50 g/ha 23-25 DAS (PoE) | 0.66 | 4.39 | 15.0 | 34.67 | 15.57 | 0.82 |
| Weedy check | 0.51 | 3.05 | 16.6 | 26.67 | 10.75 | 0.68 |
| Hand weeding (20 and 40 DAS) | 1.26 | 5.26 | 23.9 | 65.65 | 45.72 | 2.30 |
| Weed free | 1.50 | 5.90 | 25.5 | 78.64 | 54.71 | 2.29 |
| LSD (p=0.05) | 0.23 | 1.33 | 3.9 | 11.93 | 11.93 | 0.63 |

imazethapyr 0.75 kg/ha, two hand weedings and weed free. Higher economic returns in these treatments could be due to higher grain yields as well as cost effectiveness for controlling weeds.

It was concluded that pre-mix application of pendimethain + imazethapyr at 0.75 or 1.0 kg/ha as pre-emergence effectively controlled the weeds, improved the grain yield of greengram and provided high net returns and B:C ratio.

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# Weed management with pre- and post-emergence herbicides in blackgram

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## ABSTRACT

A field experiment was conducted during rainy seasons of 2014 and 2015 at College of Agriculture, Gwalior (M.P.) to study the effect of herbicides in blackgram. The experiment was laid out with 12 treatments, *viz*. imazethapyr with four application rates 70 and 80 g/ha as pre-emergence (PE) and 70 and 80 g/ha as post-emergence (PoE); imazethapyr + imazamox (RM) 70 and 80 g/ha as PE, and 70 and 80 g/ ha as PoE, pendimethalin 1000 g/ha as PE, pendimethalin + imazethapyr (RM) 1000 g/ha PE, two hand weedings at 20 and 40 DAS (weed free) and weedy check in a randomized block design. Two hand weeding at 20 and 40 DAS were found to be very efficient in controlling the dominant grassy weeds and gave maximum seed yield (924 kg/ha) *fb* ready mix herbicides *i.e.* imazethapyr + imazamox 80 g/ha as PoE (905 kg/ha) and pendimethalin + imazethapyr 1000 g/ha as PE (879 kg/ha). Net returns and B:C ratio were the highest for the application of pendimethalin + imazethapyr (1000 g/ha PE) (3.32) *fb* application of imazethapyr + imazamox (80 g/ha PoE) (3.11).

**Key words:** Blackgram, Hand weeding, Imazethapyr, Imazamox, Pendimethalin, Weeds

Blackgram (*Vigna mungo*) is usually accompanied by luxuriant weed growth during rainy season owing to abundant rainfall received during monsoon leading to serious crop losses by weeds. Unchecked weeds have been reported to cause a considerable reduction in seed yield which in case of summer blackgram could be 46-53% (Bhandari *et al*. 2004, Kumar and Tewari 2004) whereas, in rainy season the losses could be 43.2-64.1%. (Chand *et al*. 2004, Rathi *et al*. 2004). The crop is most sensitive for weed competition during 15 to 45 days after sowing.

Imazethapyr, a broad-spectrum herbicide, has soil and foliar activity that allows flexibility in its application timing and has low mammalian toxicity (Tan *et al.* 2005). Nandan *et al*. (2011) reported that post-emergence application of imazethapyr at 25 g/ha had no adverse effect on growth characters and resulted statistically similar grain yield to that of twice hand weeding (20 and 40 DAS). Pendimethalin is basically pre-emergence herbicide. In rainfed condition, if weeds have not yet germinated, this herbicide may be effective when applied after first shower. Among different methods of weed control, the chemical method is becoming popular among farmers because of increasing labour. In order to increase the productivity of blackgram timely weed control is essential. Keeping the above facts in view, the field experiments were conducted to determine the efficacy of pre- and post-emergence herbicides against weeds in blackgram.

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## MATERIALS AND METHODS

The field experiments were conducted during rainy seasons of 2014 and 2015 at Research Farm College of Agriculture, Gwalior (M.P.) to find out the effective dose of different herbicides and their time of application. The soil texture was sandy clay loam, low in available nitrogen (234 kg/ha), medium in phosphorus (14 kg/ha) and potash (240 kg/ha). The 12 treatments replicated thrice in a completely RBD were, *viz*. imazethapyr at 70 and 80 g/ha as PE, imazethapyr 70 and 80 g/ha as PoE, imazethapyr + imazamox (RM) 70 and 80 g/ha as PE, imazethapyr + imazamox (RM) 70 and 80 g/ha as PoE, pendimethalin 1000 g/ha as PE, pendimethalin + imazethapyr (RM) 1000 g/ha PE, two hand weeding at 20 and 40 DAS (weed free) and weedy check. The blackgram variety '*T-9*' was sown on 19$^{th}$ July in 2014 and on 14$^{th}$ July in 2015 keeping row to row spacing of 30 cm with 18 kg/ha seed rate. Crop was harvested during second week of October 2014 and 2015. The recommended dose of fertilizer was 20: 50: 20 NPK kg/ha, respectively. Pre-emergence herbicides were applied within 48 hours of sowing and post-emergence herbicides were applied at 20 DAS. Observations for different weed species weed population and their dry weight were recorded at 40 DAS and at the harvest. Weed control efficiency and economics of different weed control treatments were also worked out. Since treatment effects for both years were same, so pooled analysis of data was made.

## RESULTS AND DISCUSSION

### Weed flora

The major weed flora of experimental site were *Cynodon dactylon* (1.70%), *Setaria gluaca* (2.41%), *Echinochloa crus-galli* (16.3%), *Echinochloa crusgalli* (16.3%), *Sateria gluaca* (2.4%) *Arachne racemosa* (8.8%) as grasses, and *Digera arvensis* (2.4%), *Celosia argentia* (1.0%), *Commelina benghalensis* (1.4%), *Phyllanthus niruri* (3.5%) were emerged as major broad-leaf weeds (BLWs). *Cyperus rotundus* (43.3%) was most dominating sedge among all the weeds.

### Effect on weeds

All the weed management practices significantly reduced the weed population and dry weight of weeds over the weedy check. The lowest weed population and weed dry weight were obtained with two hand weedings at 20 and 40 DAS which was significantly superior to other weed control treatments. Similar results were reported by Rajib *et al.* (2014). Among the herbicides applied alone, post-emergence application was found more effective than pre-emergence application of imazethapyr. Application of imazethapyr 80 g/ha as PoE resulted in the lowest density of grassy weeds as well as BLWs and sedges *fb* imazethapyr 70 g/ha as PoE, imazethapyr 80 g/ha as PE and imazethapyr 70 g/ha PRE. Alone application of pendimethalin 1000 g/ha as PE and imazethapyr PE was recorded less effective than other treatments but was significantly superior to weedy check. Among various ready-mix (RM) herbicides the pre-emergence application of pendimethalin + imazethapyr (pre-mix) 1000 g/ha was the most effective and recorded 92.6, 95.8 and 87.1% suppression of grassy, BLWs and sedges, respectively compared to weedy check. The application of post-emergence imazethapyr + imazamox 80 g/ha was equally effective in reducing weed density and dry weight of weeds.

Minimum weed dry matter accumulation was achieved with two hand weeding at 20 and 40 DAS. Among various pre-mix applications of herbicides, minimum weed dry matter accumulation was recorded with pendimethalin + imazethapyr applied as pre-emergence 1000 g/ha, which was at par with imazethapyr + imazamox applied as post-emergence 80 g/ha. Whereas, among alone application of imazethapyr 70 g/ha as post-emergence *fb* its respective higher dose applied 80 g/ha was found more effective in reducing the dry matter accumulation of weeds. Twice hand weeding was found most effective in reducing the dry matter accumulation of weeds. However, all the weed control treatments were proved to be significantly superior to weedy check.

The highest weed control efficiency (94.96%) was recorded with two hand weeding at 20 and 40 DAS *fb* pendimethalin + imazethapyr application 1000 g/ha as PE (85.88%) and imazethapyr + imazamox 80 g/ha as PoE (85.78%).

### Effect on yield attributes and yield

During the experimentation all the growth and yield attributing parameters *i.e.* number of plants/row length, plant height, number of pods/plant, number of seeds/pod, and seed yield were found significantly higher under weed management practices compared

**Table 1. Effect of different herbicide treatments on weed density, dry weight and weed control efficiency at 40 DAS**

| Treatment | Weed density (no./m$^2$) | | | Total weed density (no./m$^2$) | Total weed dry weight (g/m$^2$) | WCE (%) at 40 DAS |
|---|---|---|---|---|---|---|
| | Grassy | BLWs | Sedges | | | |
| Imazethapyr 70 g/ha PE | 1.17(93.0) | 1.10(73.0) | 1.33(133.0) | 1.69(299.0) | 29.40 | 69.39 |
| Imazethapyr 80 g/ha PE | 1.14(85.0) | 1.03(66.0) | 1.27(115.0) | 1.63(266.0) | 28.30 | 70.54 |
| Imazethapyr 70 g/ha PoE | 1.10(84.0) | 0.90(43.0) | 1.27(113.0) | 1.60(240.0) | 20.65 | 78.50 |
| Imazethapyr 80 g/ha PoE | 1.09(76.0) | 0.77(31.0) | 1.20(98.0) | 1.53(205.0) | 17.47 | 81.81 |
| Imazethapyr + imazamox (RM) 70 g/ha PE | 1.30(124.0) | 1.19(90.0) | 1.49(194.0) | 1.83(408.0) | 38.25 | 60.18 |
| Imazethapyr + imazamox (RM) 80 g/ha PE | 1.33(129.0) | 1.11(76.0) | 1.39(147.0) | 1.77(352.0) | 30.88 | 67.85 |
| Imazethapyr + imazamox (RM) 70 g/ha PoE | 1.16(89.0) | 0.83(38.0) | 1.13(83.0) | 1.54(210.0) | 17.20 | 82.09 |
| Imazethapyr + imazamox (RM) 80 g/ha PoE | 0.89(55.0) | 0.65(25.0) | 1.00(61.0) | 1.34(141.0) | 13.66 | 85.78 |
| Pendimethalin 1000 g/ha PE | 1.26(114.0) | 1.13(77.0) | 1.51(201.0) | 1.81(392.0) | 42.74 | 55.51 |
| Pendimethalin + imazethapyr (RM) 1000 g/ha PE | 0.87(53.0) | 0.64(22.0) | 1.01(63.0) | 1.36(138.0) | 13.56 | 85.88 |
| Two hand weeding 20 and 40 DAS | 0.51(22.0) | 0.30(8.0) | 0.69(30.0) | 0.99(60.0) | 4.84 | 94.96 |
| Weedy check | 1.74(340.0) | 1.63(254.0) | 1.68(291.0) | 2.17(885.0) | 96.06 | - |
| LSD (p=0.05) | 0.19 | 0.21 | 0.12 | 0.10 | 8.57 | - |

PE: Pre-emergence; PoE: Post-emergence; DAS - Days after sowing; Valus in parentheses were original and transformed for analysis, WCE - Weed control efficiency to weedy check. Pooled data of two years indicated that there was no significant difference between all weed control treatments except weedy check. Among different herbicide treatments, the highest pods/plant was obtained with twice hand weeding (20 and 40 DAS) *fb* pre-mix imazethapyr + imazamox 80 g/ha as post-emergence and pendimethalin + imazethapyr at 1000 g/ha as pre-emergence (**Table 2**).

Two hand weedings at 20 and 40 DAS resulted maximum number of grains/pod compared to all herbicidal treatments. These results confired the findings of Rajib *et al.* (2014). Among different pre-mix, maximum number of grains/pod was recorded with the post emergence application of imazethapyr + imazamox 80 g/ha *fb* pre-emergence pendimethalin + imazethapyr 1000 g/ha. However, among alone application of herbicides, post-emergence application of imazethapyr 70 g/ha gave the recorded number of grains/pod *fb* higher dose of imazethapyr 80 g/ha (**Table 2**).

Among different treatments, the highest seed yield as 924 kg/ha was recorded under two hand weeding at 20 and 40 DAS, but among different herbicide treatments application of imazethapyr + imazamox at 80 g/ha as PoE recorded maximum seed yield *fb* pre-emergence herbicide application of pendimethalin + imazethapyr at 1000 g/ha. The alone application of imazethapyr 80 g/ha as post-emergence resulted in higher yield compared to application of lower dose of imazethapyr 70 g/ha as post-emergence. The lowest grain yield 374 kg/ha was recorded under weedy check.

**Weed persistence index (WPI) and herbicide efficiency index (HEI)**

Weed persistence index (WPI) and herbicide efficiency index (HEI) express the tolerance of weeds to different herbicidal treatments as well as their efficacy to eradicate the weeds (**Table 2**). Among the various pre-mix combination of imazethapyr + imazamox applied 80 g/ha recorded lowest WPI (0.394%) *fb* its lowest dose applied 70 g/ha. Among all treatments, highest WPI was recorded with pendimethalin 1000 g/ha *fb* pre-emergence application of imazethapyr + imazamox 70 g/ha. Regarding HEI, pre-emergence application of imazethapyr + imazamox applied 70 g/ha produced higher HEI than all other herbicidal treatments *fb* pendimethalin + imazethapyr applied 1000 g/ha. However, twice hand weeding (20 and 40 DAS) proved to be superior to all the herbicidal treatments.

**Economics**

Aapplication of pendimethalin + imazathapyr (RM) 1000 g/ha as pre-emergence was proved economically the best treatment due to the highest B:C Ratio 2.32 *fb* imazethapyr + imazamox (RM) 80 g/ha as post-emergence with B:C ratio of 2.11. The minimum B:C ratio (0.57) was recorded under weedy check (**Table 2**).

It was concluded that two hand weeding at 20 and 40 DAS gave maximum seed yield (924 kg/ha) *fb* PoE use of imazethapyr + imazamox (RM) 80 g/ha (905 kg/ha) and pendimethalin + imazethapyr 1000 g/ha as PE can be practiced for weed control in blackgram.

**Table 2. Effect of different herbicide treatments on growth, yield attributes, yield herbicidal efficiency index, weed persistence index and B:C ratio of black gram**

| Treatment | No of Plants (in row length) | Plant height (cm) | No. of pods/ plant | No. of grains/ pod | Seed yield (kg/ha) | HEI | WPI | B:C Ratio |
|---|---|---|---|---|---|---|---|---|
| Imazethapyr 70 g/ha PE | 8.78 | 69.87 | 23.47 | 6.40 | 625 | 2.19 | 0.393 | 1.30 |
| Imazethapyr 80 g/ha PE | 8.33 | 70.40 | 23.00 | 6.47 | 690 | 2.87 | 0.392 | 1.50 |
| Imazethapyr 70 g/ha PoE | 9.33 | 72.20 | 29.53 | 6.67 | 765 | 4.86 | 0.292 | 1.79 |
| Imazethapyr 80 g/ha PoE | 9.67 | 67.53 | 30.60 | 6.60 | 859 | 7.13 | 0.258 | 2.08 |
| Imazethapyr + imazamox (RM) 70 g/ha PE | 9.33 | 68.53 | 26.00 | 6.47 | 537 | 1.09 | 0.472 | 0.91 |
| Imazethapyr + imazamox (RM) 80 g/ha PE | 9.11 | 69.07 | 29.93 | 6.67 | 557 | 1.52 | 0.394 | 0.95 |
| Imazethapyr + imazamox (RM) 70 g/ha PoE | 8.67 | 72.87 | 31.13 | 6.53 | 788 | 6.18 | 0.252 | 1.77 |
| Imazethapyr + imazamox (RM) 80 g/ha PoE | 9.33 | 74.60 | 35.73 | 6.80 | 905 | 9.98 | 0.230 | 2.11 |
| Pendimethalin 1000 g/ha PE | 8.11 | 70.73 | 25.67 | 6.40 | 521 | 0.88 | 0.533 | 0.86 |
| Pendimethalin + imazethapyr (RM) 1000 g/ha PE | 8.67 | 74.20 | 34.60 | 6.73 | 879 | 9.57 | 0.225 | 2.32 |
| Two hand weeding 20 and 40 DAS | 9.33 | 74.67 | 38.30 | 6.93 | 924 | 29.19 | 0.110 | 1.57 |
| Weedy check | 8.22 | 75.60 | 20.60 | 4.73 | 374 | - | - | 0.57 |
| LSD (p=0.05) | NS | NS | 11.95 | 0.52 | 134 | - | - | |

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# Nutrient uptake by clusterbean as influenced by weed management and sulphur nutrition

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**ABSTRACT**

A field experiment was carried out during two consecutive seasons of *Kharif* 2013 and 2014 to evaluate effect of weed management and sulphur nutrition on the nutrient uptake by weeds and crop in clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]. Minimum weed dry matter of narrow-leaved (239 kg/ha), broad-leaved (285 kg/ha) and total dry weight (524 kg/ha) was observed under hand weeding at 20 and 40 days after sowing (DAS),which was closely followed by the sequential application of pre-emergence application of pendimethalin 0.75 kg/ha followed by (*fb*) imazethapyr 0.075 kg/ha as post-emergence. The highest seed (1.22 t/ha), haulm (2.44 t/ha) and biological yields (3.66 t/ha) was registered in hand weeded twice, which was statistically at par to pendimethalin *fb* imazethapyr. Hand weeding twice and pendimethalin *fb* imazethapyr, with non-significant difference between these two, saved N and P uptake by 56, 47 and 55, 46%, respectively, compared to weedy check in combined uptake of nutrient both by weeds and crop.

**Key words:** Clusterbean, Nutrient uptake, Sulphur, Weed management, Yield

Clusterbean, popularly known as 'Guar', is being cultivated in India since ancient time for various purposes. Among leguminous crops, it is comparatively more drought hardy, which is grown during rainy season in semi-arid and arid regions of India. Being a rainy season crop, it suffers badly due to severe competition by mixed weed flora. Presence of weeds beyond the critical period of crop weed competition results in yield reductions up to 46% (Sangwan *et al*. 2016). Therefore, weed control needs to be restored to exploit the yield potential of this crop. In addition to weed management, nutrition in this crop is of paramount importance. Besides application of N and P in legumes, sulphur (S) is now required as the fourth major plant nutrient (Tandon and Messick 2007). Results of research over the years have convincingly shown that S application can bring about significant increases in crop yield. Keeping this in view, an experiment was formulated to assess the losses caused by weeds and uptake of nutrients both by crop and weeds.

## MATERIAL AND METHODS

A field experiment was conducted during the *Kharif* seasons of 2013 and 2014 at the Instructional Farm of Department of Agronomy, Rajasthan college of Agriculture, MPUAT, Udaipur. The soil was medium in available nitrogen (274.56 and 279.61 kg/ha), phosphorus (19.27 and 18.69 kg/ha), high in available potassium (318.83 and 324.17 kg/ha) and low in sulphur (9.7 and 9.6 ppm) during 2013 and 2014, respectively. The experiment consisted of eight weed management treatments, *viz*. weedy check, one hand weeding at 20 DAS, two hand weeding at 20 and 40 DAS, pre-emergence (PE) application of pendimethalin 1.0 kg/ha, post-emergence (PoE) application of imazethapyr 0.1 kg/ha, PoE application of quizalofop-ethyl 0.05 kg/ha, PE application of pendimethalin 0.75 kg/ha *fb* PoE imazethapyr 0.075 kg/ha and PE pendimethalin 0.75 kg/ha *fb* PoE quizalofop-ethyl 0.04 kg/ha and four levels of sulphur (control, 15, 30 and 45 kg/ha ) supplied through mineral gypsum, thereby making 32 treatments combinations.

The experiment constituted in a split plot design with weed management treatments assigned in main plots and sulphur levels in sub plots. All treatment combinations were replicated thrice. Clusterbean variety '*RGC-1017*' was used as the test crop and crop was raised as per package of practices recommended for sub humid Southern Plain and Aravalli hills of Rajasthan. The weeds under 0.25 $m^2$ area were removed at 75 DAS after categorizing these weeds into narrow and broad-leaved weeds and oven dried at $65^0$C temperature till a constant weight was obtained and expressed in kg/ha. The estimation of N and P both in crop and weeds was done following the procedures given by Snell and Snell (1949) and Jackson (1973), respectively. The data were

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subjected to statistical analysis by adopting appropriate methods as described by Cocharan and Cox (1967).

## RESULTS AND DISCUSSION

Clusterbean was mainly infested with mixed flora of narrow and broad-leaved weeds, *viz. Cynodon dactylon*, *Echinochloa colona*, *Cyperus rotundus*, *Brachiaria reptans*, *Dinebra retroflexa* and *Dactyloctenium aegyptium* among narrow-leaved weeds and *Amaranthus viridis*, *Commelina benghalensis*, *Digera arvensis*, *Trianthema portulacastrum* and *Physalis minima* among broad-leaved weeds.

### Weed dry matter

It was found that dry biomass of narrow-leaved, broad-leaved weeds and total weed dry weight at 75 DAS was affected significantly by all weed management treatments (**Table 1**). During both the years, two hand weeding recorded the lowest dry matter, however its effect differed non significantly with pendimethalin0.75 kg/ha *fb* imazethapyr 0.075 kg/ha. Averaged over the years, two hand weeding reduced the biomass of narrow and broad-leaved weeds by 83 and 86% compared to weedy check while the corresponding reduction in biomass of these categories of weeds under pendimethalin 0.75 kg/ha *fb* imazethapyr 0.075 kg/ha was 81 and 85%.

### Yield

Two hand weeding treatment recorded the maximum seed yield (1.22 t/ha), haulm (2.44 t/ha) and biological yields (365 kg/ha) closely followed by the sequential application of pendimethalin with imazethapyr and both of these treatments were found significantly superior over rest of treatments (**Table 2**). The improvement in yield with hand weeding have also been reported by Tiwana *et al.* (2002). Soil enrichment with 45 kg sulphur/ha showed a significant results in terms of seed, haulm and biological yields of clusterbean with the percent increase of 28, 30 and 29, respectively, compared to control.

### Nutrient uptake by weeds

The minimum N depletion by narrow-leaved (4.13 kg/ha), broad-leaved (6.02 kg/ha) and total (10.14 kg/ha) and P uptake by narrow-leaved (0.58 kg/ha), broad-leaved (0.92 kg/ha) and total (1.50 kg/ha) was found under two hand weeding which was closely followed by the sequential application of pendimethalin *fb* imazethapyr (**Table 1**). Application of different doses of sulphur had no significant impact on N uptake by narrow-leaved; however, uptake of nitrogen by broad-leaved and total uptake enhanced upto 30 kg S/ha compared to control but at par to 15 and 45 kg S/ha, however, application of 15 kg S/ha did not differ significantly compared to control. Sulphur application in various doses could not bring about a significant variation in P uptake by both categories of the weeds and thereby total uptake. The uptake of N and P by the weeds was estimated at 67 and 53%, respectively of the total removal (weeds + crop) in weedy check and only 10.8 and 6.3% N and P, respectively in the two hand weeding treatment and the corresponding N and P in pendimethalin *fb* imazethapyr treatment was 12.0 and 7.1%. Thus,

**Table 1. Weed management and sulphur nutrition on dry matter of weeds and nutrient removal at 75 DAS (pooled)**

| Treatment | Weed dry matter (t/ha) | | | Nutrient removal by weeds (kg/ha) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Nitrogen | | | Phosphorus | | |
| | Narrow-leaved | Broad-leaved | Total | Narrow-leaved | Broad-leaved | Total | Narrow-leaved | Broad-leaved | Total |
| *Weed management* | | | | | | | | | |
| Pendimethalin 1.0 kg/ha PE | 0.63 | 1.09 | 1.72 | 10.68 | 22.75 | 33.43 | 1.49 | 3.52 | 5.01 |
| Imazethapyr 0.1 kg/ha PoE | 0.47 | 0.53 | 1.00 | 8.11 | 11.09 | 19.20 | 1.13 | 1.69 | 2.83 |
| Quizalofop 0.05 kg/ha PoE | 0.58 | 1.65 | 2.23 | 9.68 | 34.37 | 44.05 | 1.37 | 5.25 | 6.62 |
| Pendimethalin 0.75 kg/ha PE *fb* imazethapyr 0.075 kg/ ha PoE | 0.27 | 0.31 | 0.58 | 4.56 | 6.53 | 11.10 | 0.64 | 1.02 | 1.66 |
| Pendimethalin 0.75 kg/ha PE *fb* quizalofop 0.04 kg/ha | 0.37 | 0.91 | 1.28 | 6.38 | 18.92 | 25.30 | 0.90 | 2.90 | 3.79 |
| One hand weeding at 20 DAS | 0.68 | 1.11 | 1.79 | 11.54 | 23.12 | 34.66 | 1.63 | 3.54 | 5.17 |
| Two hand weeding at 20 and 40 DAS | 0.24 | 0.28 | 0.52 | 4.13 | 6.02 | 10.14 | 0.58 | 0.92 | 1.50 |
| Weedy check | 1.40 | 2.04 | 3.44 | 23.38 | 41.20 | 64.58 | 3.27 | 6.42 | 9.69 |
| LSD (p=0.05) | 0.05 | 0.07 | 0.07 | 0.84 | 1.46 | 1.59 | 0.10 | 0.24 | 0.27 |
| *Sulphur* | | | | | | | | | |
| 15 kg/ha | 0.58 | 0.99 | 1.57 | 9.72 | 20.36 | 30.07 | 1.37 | 3.13 | 4.50 |
| 30 kg/ha | 0.58 | 1.00 | 1.58 | 9.94 | 20.86 | 30.80 | 1.38 | 3.19 | 4.57 |
| 45 kg/ha | 0.59 | 1.00 | 1.59 | 10.00 | 20.99 | 31.00 | 1.40 | 3.20 | 4.60 |
| Control | 0.58 | 0.98 | 1.55 | 9.57 | 19.79 | 29.36 | 1.36 | 3.11 | 4.47 |
| LSD (p=0.05) | NS | NS | NS | NS | 0.57 | 0.89 | NS | NS | NS |

**Table 2. Weed management and sulphur nutrition on yield and nutrient depletion by clusterbean (pooled)**

| Treatment | Yield (t/ha) | | | Nutrient removal (kg/ha) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Nitrogen | | | Phosphorus | | |
| | Seed | Haulm | Biological | Seed | Haulm | Total | Seed | Haulm | Total |
| *Weed management* | | | | | | | | | |
| Pendimethalin 1.0 kg/ha PE | 0.81 | 1.90 | 2.70 | 32.23 | 26.38 | 58.61 | 8.99 | 6.40 | 15.39 |
| Imazethapyr 0.1 kg/ha POE | 0.84 | 1.92 | 2.76 | 33.73 | 26.92 | 60.65 | 9.45 | 6.53 | 15.98 |
| Quizalofop 0.05 kg/ha POE | 0.67 | 1.63 | 2.30 | 26.85 | 22.63 | 49.48 | 7.46 | 5.49 | 12.94 |
| Pendimethalin 0.75 kg/ha PE *fb* imazethapyr 0.075 kg/ha PoE | 1.19 | 2.40 | 3.59 | 47.80 | 33.99 | 81.79 | 13.47 | 8.19 | 21.66 |
| Pendimethalin 0.75 kg/ha PE *fb* quizalofop 0.04 kg/ha | 1.05 | 2.25 | 3.30 | 42.01 | 31.73 | 73.74 | 11.76 | 7.63 | 19.40 |
| One hand weeding at 20 DAS | 0.77 | 1.83 | 2.60 | 30.68 | 25.38 | 56.06 | 8.63 | 6.19 | 14.82 |
| Two hand weeding at 20 and 40 DAS | 0.12 | 2.44 | 3.66 | 49.03 | 34.38 | 83.41 | 13.72 | 8.33 | 22.04 |
| Weedy check | 0.41 | 1.17 | 1.58 | 16.18 | 16.11 | 32.29 | 4.56 | 3.96 | 8.52 |
| LSD (p=0.05) | 0.05 | 0.11 | 0.11 | 1.89 | 1.77 | 2.46 | 0.53 | 0.45 | 0.62 |
| *Sulphur* | | | | | | | | | |
| 15 kg/ha | 0.85 | 1.89 | 2.74 | 33.43 | 26.13 | 59.56 | 9.49 | 6.42 | 15.91 |
| 30 kg/ha | 0.92 | 2.05 | 2.97 | 37.17 | 29.09 | 66.26 | 10.28 | 6.99 | 17.28 |
| 45 kg/ha | 0.96 | 2.16 | 3.12 | 39.49 | 30.96 | 70.45 | 10.84 | 7.36 | 18.20 |
| Control | 0.75 | 1.66 | 2.42 | 29.17 | 22.57 | 51.74 | 8.40 | 5.59 | 13.99 |
| LSD (p=0.05) | 0.03 | 0.06 | 0.07 | 1.20 | 0.85 | 1.57 | 0.33 | 0.22 | 0.42 |

savings of 56 and 47% nitrogen and phosphorus could be obtained by adoption of the two hand weeding treatment while the respective saving of nitrogen and phosphorus under the pendimethalin *fb* imazethapyr treatment was 55and 46%. Nutrient uptake by weeds is the function of per cent nutrient content and biomass, thus a similar trend in uptake and total weed biomass production was an expected outcome (Shruthi and Salakinkop 2015).

### Nutrient uptake by crop

Hand weeding twice recorded the highest N uptake by seed, haulm and total uptake (49.03, 34.08 and 83.41 kg/ha) and P uptake by seed, haulm and total uptake (13.72, 8.33 and 22.04 kg/ha) but differed non significantly with sequential application of pendimethalin with imazethapyr. Application of imazethapyr, pendimethalin and one hand weeding were found superior over quizalofop-ethyl and weedy check. It was found that increasing S levels successively increased N and P uptake by seed, haulm and total uptake. Pooled analysis reflects a significant increase in this parameter with increasing S levels up to 45 kg/ha. The highest N and P uptake by the crop was recorded with two hand weeding which might be ascribed to higher yield with this treatment as uptake of nutrient is mainly the function of crop yield. Nutrient uptake by any crop is primarily a function of yield and nutrient concentration. Thus, higher nutrient uptake by crop might be due to cop weed competition, which had concurrently increased in nutrient availability, better crop growth and higher crop biomass production coupled with more nutrient content. Such results corroborate with the findings of Yadav *et al.* (2013) and Singh *et al.* (2014). Thus, it is apparent that whenever the removal of nutrient by weeds was more, corresponding uptake by the crop was less and vice-versa. Therefore, for efficient utilization of applied nutrients, the weeds should be kept under control.

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# Weed management influence on weed dynamics and yield of summer lady's finger

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## ABSTRACT

A field experiment was conducted during the summer seasons of 2013 and 2014 in Vertisol soil to evaluate the fruit yield and weed dynamics influenced by weed management practices at the College Farm, N.M. College of Agriculture, Navsari Agricultural University, Navsari. Results showed that three hand weeding (HW) at 20, 40 and 60 days after sowing (DAS) recorded significantly higher weed control efficiency with minimum weed population. All growth and yield attributes were significantly higher under three HW at 20, 40 and 60 DAS. Consequently, higher fruit yield (16.78 t/ha) was also registered with three HW at 20, 40 and 60 DAS and remained at par with two HW at 20 and 40 DAS and pendimethalin 1.0 kg/ha as pre-emergence + quizalofop-ethyl 0.04 kg/ha at 30 DAS. For achieving higher and profitable fruit yield, two HW at 20 and 40 DAS found appropriate. However, under a scarce labour situation, application of pendimethalin 1.0 kg/ha as pre-emergence + quizalofop-ethyl 0.04 kg/ha at 30 DAS was also found remunerative.

**Key words:** lady's fingers, Oxyfluorfen, Pendimethalin, Quizalofop-ethyl, Weed management

Okra [*Abelmoschus esculentus* (L.) Moench] belongs to family Malvaceae, known as Lady's finger, is one of the most important vegetables grown in tropical and sub-tropical parts of the world. Among the problems encountered in cultivation of okra, control of weeds is of utmost importance. Weeds are the silent robbers of plant nutrients, moisture, sun light and also compete for space that would otherwise be available to the main crop. Because of the slow growth rate of okra during the initial stages, weeds take advantage of moisture, soil fertility and environmental conditions to suppress the growth of the crop. Due to this weed competition, the crop remains weak and unhealthy, which results in the reduction of yield and quality of the crop. Yield losses in okra due to weeds varied from 40 to 80% depending on the type of flora, their intensity and stages (Patel *et al.* 2004). The most critical period of crop weed competition in okra is up to 2 - 6 weeks after sowing.

In spite of enough technologies in mechanization of agriculture, farmers still practice hand weeding to keep weeds down in the field. For avoiding drudgery and expenses on labour, manual, mechanical and chemical weed management practices should tested for recommendation to the farmers. It was, therefore, considered necessary to undertake a study to find the performance of various pre-emergence as well as post-emergence herbicides applied with other weed management practices to reduce the farmers extra expenditure incurred on manual weeding.

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## MATERIALS AND METHODS

The present investigation was conducted at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari during summer 2013 and 2014. The trial was laid out in a randomized block design with ten treatments (**Table 1**) replicated thrice on okra hybrid. The soil was clay in texture, having 0.59% organic C, medium in available nitrogen (224 kg/ha) and phosphorus (40 kg/ha), fairly rich in available potassium (362 kg/ha) and slightly alkaline in reaction (pH 7.6) with normal electrical conductivity.

The field was fertilized with recommended doses of NPK at the rate of 150: 100:100 kg/ha. Common application of well decomposed FYM 10 t/ha was uniformly applied to all the experimental units before transplanting. The basal dose of fertilizers, consisting of full dose of $P_2O_5$ through SSP and $K_2O$ through MOP, half dose of N through urea as per the treatment was applied manually. The remaining dose of N was supplied at 30 days after sowing. All the recommended package of practices was adopted to raise the crop except weed control. All the herbicides were applied as pre-emergence using a knapsack sprayer fitted with a flat fan nozzle attached with the hood of sprayer by mixing in 500 L of water/ha as per treatment. Marketable size green okra fruits were picked up for yield estimation. The data on dry weed weight (g/m$^2$) at 90 DAS were collected from plots of different treatments. Fresh pod yield (t/ha) was recorded by adding the weight of pods at different pickings. The weed control efficiency was calculated as per standard method.

## RESULTS AND DISCUSSION

### Effect on weeds

Dominant weeds identified in the experimental plots during the course of investigation were *Echinochloa* spp., *Convolvulus arvensis, Trianthema portulacastrum*, *Digera arvensis*, *Physalis minima* and *Cynodon dactylon.* The crop experienced severe weed competition during investigation, which might be due to favourable environmental conditions leading to vigorous growth of weeds. All the weed management practices caused a significant reduction in weed density.

Among the treatment, HW at 20, 40 and 60 DAS, two hand weeding at 20 and 40 and among chemical method of weed control, treatment pendimethalin 1.0 kg/ha as pre-emergence + quizalofop-ethyl 0.040 kg/ha at 30 DAS and quizalofop-ethyl 0.040 kg/ha at 20 DAS + one hand weeding at 40 DAS significantly reduced the weed population and dry weight of weeds compared to weedy check. The effective control of weeds under these treatments resulted in the highest weed control efficiency and lower weed index. Effectiveness of various herbicides against different weed species in okra crop has been reported by many workers including Kumar *et al.* (2009), Singh *et al.* (2010) and Sharma and Patel (2011).

### Effect on crop

Various growth parameters, *viz*. plant height, number of leaves/main stem and number of nodes/ main stem; yield attributes, *viz*. diameter, weight and length of fruit, number of fruit/plant and fruit yield/ plant play a vital role in increasing the productivity of okra crop which were favourably influenced by various weed management treatments. However, significantly higher values of all said parameters were recorded under three HW at 20, 40 and 60 DAS, while lower was recorded with weedy check. In case of diameter, weight and length of okra fruit, found at par with treatments of two HW at 20 and 40 DAS, combination of pre- and post-emergence herbicides and integrated weed management practices. However, in most of growth and yield parameters, *viz*. plant height, numbers of leaves/plant number of nodes/main stem, stem diameter, plant dry matter accumulation; yield attributes, *viz*. diameter, weight, length of fruit, number of fruits/plant, fruit yield/plant, all the weed management practices found significantly superior than weedy check except the stale seedbed technique for weed diameter.

Growth is the function of photosynthetic activity of the okra plant and their capacity to utilize available nutrients. Thus, enhanced availability of nutrients, water, light and space resulted in increase in plant height, number of leaves and dry matter accumulation which reflected in term of higher fruit length, fruit diameter and average fruit weight. These findings were supported by Pandey and Mishra (2013) and Shivalingappa *et al.* (2014).

**Table 1. Total weed count, dry weight of weeds, weed control efficiency and wed index as influenced by weed management in summer lady's finger**

| Treatment | Total weed count/m$^2$ | | | Dry weed biomass (g/m$^2$) | Dry weed biomass (kg/ha) | WCE (%) | WI (%) |
|---|---|---|---|---|---|---|---|
| | 20 DAS | 40 DAS | At harvest | 20 DAS | 40 DAS | | |
| Stale seed bed | 7.1(49) | 9.0(80) | 10.0(98) | 30.4 | 556.0 | 45.9 | 51.3 |
| Pendimethalin 1.0 kg/ha (PE) | 7.7(59) | 8.8(77) | 9.5(89) | 29.1 | 502.8 | 51.2 | 48.7 |
| Oxyfluorfen 0.24 kg/ha (PE) | 8.8(77) | 10.2(103) | 10.8(116) | 39.2 | 649.9 | 37.2 | 49.9 |
| Pendimethalin1.0 kg/ha (PE) + quizalofop-ethyl 0.040 kg/ha at 30 DAS | 8.0(63) | 7.1(49) | 6.3(39) | 24.8 | 281.5 | 73.1 | 16.1 |
| Oxyfluorfen 0.24 kg/ha (PE) + quizalofop-ethyl 0.040 kg/ha at 30 DAS | 9.2(84) | 8.7(75) | 9.7(94) | 29.7 | 537.9 | 48.1 | 42.6 |
| Quizalofop-ethyl 0.040 kg/ha at 20 DAS + one hand weeding at 40 DAS | 10.6(113) | 8.7(74) | 7.2(51) | 30.1 | 299.6 | 70.9 | 24.8 |
| One hand weeding + straw mulch 3 t/ha at 20 DAS | 10.2(104) | 8.0(63) | 9.0(81) | 24.3 | 470.7 | 54.2 | 47.5 |
| Two hand weeding at 20 and 40 DAS | 10.6(119) | 7.5(55) | 5.3(27) | 21.6 | 183.5 | 82.1 | 14.1 |
| Weed free check (three hand weeding at 20, 40 and 60 DAS) | 10.2(103) | 6.7(43) | 4.6(20) | 17.1 | 119.4 | 88.4 | 0.0 |
| Weedy check (control) | 11.3(119) | 11.0(121) | 11.7(139) | 46.1 | 1047.1 | 0.0 | 67.0 |
| LSD (p=0.05) | 1.09 | 0.88 | 0.97 | 6.00 | 85.76 | -- | |

Data were subjected to transformation. Figures in parentheses are means of original values

**Table 2. Growth and yield attributes and yield of summer ladies' fingers at harvest as influenced by weed management**

| Treatment | Plant height (cm) | No. of leaves/ plant | No. of nodes/ main stem | Fruit | | | No. of fruit/ plant | Fruit yield/ plant (g) | Fruit yield (t/ha) | Net return (`/ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Diameter (cm) | Weight (g) | Length (cm) | | | | |
| Stale seed bed | 85.7 | 32.0 | 12.3 | 1.47 | 11.05 | 11.10 | 6.6 | 64.7 | 8.0 | 23772 |
| Pendimethalin 1.0 kg/ha (PE) | 89.3 | 33.3 | 13.3 | 1.43 | 11.23 | 11.89 | 8.7 | 91.9 | 8.5 | 29346 |
| Oxyfluorfen 0.24 kg/ha (PE) | 80.6 | 31.4 | 12.8 | 1.41 | 10.17 | 11.07 | 6.7 | 67.0 | 8.3 | 28611 |
| Pendimethalin1.0 kg/ha (PE) + quizalofop-ethyl 0.040 kg/ha at 30 DAS | 97.1 | 40.0 | 16.5 | 1.69 | 11.30 | 12.25 | 9.4 | 111.4 | 13.9 | 82277 |
| Oxyfluorfen 0.24 kg/ha (PE) + quizalofop-ethyl 0.040 kg/ha at 30 DAS | 91.1 | 34.8 | 13.2 | 1.58 | 10.38 | 12.10 | 7.1 | 79.4 | 9.6 | 39421 |
| Quizalofop-ethyl 0.040 kg/ha at 20 DAS + one hand weeding at 40 DAS | 96.5 | 37.7 | 16.2 | 1.66 | 11.23 | 12.23 | 9.2 | 110.1 | 12.5 | 66505 |
| One hand weeding + straw mulch 3 t/ha at 20 DAS | 92.4 | 35.5 | 14.9 | 1.59 | 10.87 | 11.03 | 7.3 | 80.5 | 8.7 | 23799 |
| Two hand weeding at 20 and 40 DAS | 97.6 | 42.2 | 16.8 | 1.67 | 11.51 | 12.19 | 10.3 | 126.1 | 14.3 | 83442 |
| Weed free check (three hand weeding at 20, 40 and 60 DAS) | 110.6 | 48.5 | 19.0 | 1.74 | 12.61 | 13.63 | 11.6 | 144.2 | 16.8 | 105233 |
| Weedy check (control) | 68.2 | 26.2 | 11.1 | 1.30 | 8.83 | 7.31 | 4.0 | 44.4 | 5.5 | 1303 |
| LSD (p=0.05) | 11.81 | 5.17 | 2.41 | 0.21 | 1.50 | 1.55 | 1.22 | 10.42 | 2.89 | |

| | | | |
|---|---|---|---|
| FYM: ` 1/kg | Quizalofop-ethyl: ` 1600/L | Labour: ` 150/day | Urea: ` 6.38/kg |
| Paddy straw: ` 2.25/kg | SSP: ` 7.02/kg | Pendimethalin: ` 500/L | MOP: ` 16.80/kg |
| Oxyfluorfen: ` 800 /L | Okra: ` 10.00/kg | | |

Higher fresh fruit yield (16.8, 14.3 and 13.9 t/ha, respectively) were obtained under treatment three HW at 20, 40 and 60 DAS followed by two HW at 20 and 40 DAS and pendimethalin 1.0 kg/ha as pre-emergence + quizalofop-ethyl 0.040 kg/ha at 30 DAS. This might be due to weed management treatments which controlled weeds effectively, reduced the competition from the weeds to a greater extent leading to lesser nutrient removal by weeds and higher uptake of nutrients thus helped in faster growth and development of okra crop, resulting in obtaining higher values of all yield attributing characters. The findings were in closely vicinity of those reported by Kumar *et al.* (2011) and Sharma and Patel (2011) with respect to okra yield.

## Economics

From the economics point of view, the highest net profit of ` 1,05,233/ha was obtained from treatment three HW at 20, 40 and 60 DAS followed by treatments two HW at 20 and 40 DAS (` 83442/ha) and pendimethalin 1.0 kg/ha as pre-emergence + quizalofop-ethyl 0.040 kg/ha at 30 DAS (` 82277/ha).

Thus for management of weeds in lady's finger, two hand weeding at 20 and 40 DAS found effective for achieving higher and profitable fruit yield. Alternatively, under scare labour situations, application of pendimethalin 1.0 kg/ha as pre-emergence + quizalofop-ethyl 0.04 kg/ha at 30 DAS was also found remunerative.

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# Integrated weed management in garlic

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**ABSTRACT**

A field experiment was conducted during, winter seasons 2014-15 and 2015-16 to evaluate the weed management practices in garlic. The experiment was conducted in a split plot design having straw mulch treatments in main plot (0, 5 t/ha and 10 t/ha) and weed control treatment, *viz*. pendimethalin 1.0 kg/ha (pre-emergence), oxyfluorfen 0.223 kg/ha (pre-emergence) manual weeding (2) and weedy check. Application of mulch at 10 t/ha declined the weed population and recorded significantly lower weed density and higher weed control efficiency (71.65 and 75.17%), and higher growth and yield (2.08 and 2.72 t/ha) of garlic as compared to without mulch treatment. Among the weed control measures, application of oxyfluorfen 0.223 kg/ha recorded significantly lower weed density (55.9 and 70.89 $m^2$) and higher growth and yield (2.05 and 2.53 t/ha) of garlic as compared to weedy check, but it was at par with pendimethalin 1.0 kg/ha application. Maximum BCR (1.19 and 2.18) was recorded under the paddy straw mulch applied at 10 t/ha and oxyfluorfen 0.223 kg/ha (1.11 and 2.14) as pre-emergence application.

**Key words**: Garlic, Herbicide, Straw mulch, Weed management

Garlic (*Alleum sativum* L.) is the second widely used cultivated crop after onion. India ranks second after China with respect to area and production of garlic in the world. In India, it is grown on 2.42 lakh hectares of area producing 12.28 lakh tonnes of garlic with the productivity of 5.07 t/ha (Annonymous 2015). In India, major garlic growing states are Madhya Pradesh, Gujarat, Rajasthan and Odhisa. Through the export of garlic and its products, India earns about ` 374.2 million annually (Annonymous 2015). There are certain production constraints in garlic due to which yield levels are poor. Among them, weed problem is very severe in the garlic. Besides this, garlic being non-branching habit, sparse foliage and shallow root system also become vulnarable for weeds. Garlic is a closely planted crop, manual weeding is tedious, expensive and often damages the plants. Thus, all these situations make it necessary on straw mulch and hebicides for an effective and timely control of weed in Garlic. Hence, efficacy of new herbicides needs to be tested. Information on integratred weed management methods in garlic in the agro-climatic conditions of Eastern Uttar Pradesh (India) is meagre. Hence, the present investigation was undertaken to identify effective integrated weed management options in garlic.

## MATERIALS AND METHODS

The field experiment was conducted during winter seasons 2014-15 and 2015-16 at Agronomy Research Farm of Narendra Dev University of Agriculture and Technology Kumarganj, Faizabad (UP). The soil of the experimental field was silty loam having pH 8.1, EC 0.23 dS/m, organic carbon 3.2 g/kg, available N 122 kg/ha, available P 16.2 kg/ha and abailable K 251.5 kg/ha respectively. The experiment was laid out in split-plot design and replicated thrice. In main plot mulches were placed, *viz*. without mulch, straw mulch 5 t/ha and straw mulch 10 t/ha. In sub-plot, weed management practices were imposed *viz*. pendimethalin 1.0 kg/ha pre-emergence (PE), oxyfluorfen 0.223 kg/ha PE, twice manual weeding (2) and weedy check. Garlic variety '*Yamuna Safed-1*' was planted on 6 October 2014 and 10 October 2015. The corp was fertilized with 125 kg/ha N, 60 kg/ha P and 60 kg/ha K through urea, single supper phosphate and murate of potash, respectively. Herbicides were sprayed using water 375 L/ha with a knapsack sprayer fitted with a flat fan nozzle. In case of manual weeding, weeds were removed manually with the help of a tools. In case of weedy check weeds were allowed during the whole crop growing season. Data on weed species, growth and yield attribute of garlic were also recorded.

## RESULTS AND DISCUSSION

### Effect on weed flora

The major weeds noted in the experimental field at 75 days after transplanting (DAT) in the weedy check plot consisted of different categories of weeds. *Chenopodium album, Solanum nigrum, Melilotus alba, Anagallis arvensis* and *Convolvulus arvensis*

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were of broad-leaved weeds (BLWs), while *Cynodon dactylon* and *Phalaris minor* were grassy weeds and *Cyperus rotundus* was only sedges. (**Table 1**). During 1st and 2nd year, the lowest broad-leaf weeds (2.27 and 5.19 no./m$^2$, respectively), grassy weeds (1.35 and 4.60 no./m$^2$, respectively) and sedges (31.50 and 53.25 no./m$^2$, respectively) were recorded under paddy straw at 10 t/ha treated plots.

Paddy straw mulch at 10 t/ha reduced the weed density and dry weight significantly over rest of the treatments. This might be due to effective control of the weeds under treatments (**Table 1**). However, the weed density and dry weight per unit area remained less as compared to other methods tested. Similar finding was also corroborated by Singh and Nandlal (2002). Weed control efficiency was affected substantially due to different mulch treatments. The highest weed control efficiency was recorded in 10 t/ha mulch treatment (71.65 and 75.17% during 1st and 2nd year, respectively) and lowest was found with no mulch (52.47 and 53.64% during 1st and 2nd year, respectively) during study. In mulch plots, soil was undisturbed nearby garlic plants; hence the weed seeds present in the soil did not get suitable condition for germination and resulted the highest weed control efficiency as compared to no mulched plots. Both the herbicides decreased the number of weeds, weed density and weed dry weight significantly over weedy check (**Table 1**). Oxyfluorfen 0.223 kg/ha as PE proved more effective in reducing weed density and weed dry weight as compared to pendimethalin (1.0 kg/ha as PE). This is mainly due to the fact that oxyfluorfen controlled the all group of weeds very effectively as compared to pendimethalin. Weed control efficiency was also observed better under oxyfluorfen. The results were in agreement with the finding of Vora and Mehta (1998).

**Effect on crop**

Highest plant height was recorded with the application of 10 t/ha paddy straw mulch at 75 DAP, which was significantly superior over others. Weed control treatments influenced the plant height significantly over weedy check. Both the herbicides (oxyfluorfen at 0.235 kg/ha and pendimethalin at 1.0 kg/ha) and twice hand weeding were at par and recorded taller plants as compare to weedy check during both the years (**Table 2**) . The taller plants in these might be due to less crop weed competition for light, nutrients and moisture during the crop growth period. Plant height was also affected mainly due to crop – weed competition and moisture conservation. These parameters become possible where a combination of paddy straw mulch along with herbicides was used (Rahman *et al.* 2012).

**Effect on yield attributes**

Reproductive parameters are the resultant of better vegetative development with the commencement of reproductive phase. The yield attributes like fresh weight, dry weight of bulbs and diameter of bulb (cm) were affected largely from the quantum of growth taken place before the reproductive phase consisting of various yield attributing factors. Thus, the reproductive phase was one of the major factors which governed the bulb yield. The relative contribution of these characters in respect of yield is necessary to assess in the light of treatments effect. All yield attributing characters fresh weight of bulb, dry weight of bulb, 100 cloves weight and bulb dry matter indicates that the mulch at 10 t/ha significantly increased the yield attributes over 5 t/ha and no mulch (**Table 2**).

The yield attributes were affected significantly due to application of different weed management

**Table 1. Effect of mulches and weed management practices on weed density, weed dry weight and weed control efficiency at 75 Day after planting (DAP) in garlic**

| Treatment | Broad-leaves weeds (no./m$^2$) | | Grassy weeds (no./m$^2$) | | Sedges (no./m$^2$) | | Weed density (no./ m$^2$) | | Total dry weight (g/m$^2$) | | WCE (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 |
| *Mulche* | 5.53 | 13.52 | 4.12 | 9.62 | 39.90 | 68.71 | 49.55 | 91.85 | 77.73 | 132.12 | 52.47 | 53.64 |
| Without mulch | | | | | | | | | | | | |
| Paddy straw mulch 5 t/ha | 3.36 | 9.60 | 2.78 | 6.61 | 35.42 | 57.42 | 41.56 | 73.63 | 52.90 | 73.75 | 67.65 | 74.12 |
| Paddy straw mulch 10 t/ha | 2.27 | 5.19 | 1.35 | 4.60 | 31.50 | 53.25 | 35.12 | 63.06 | 46.35 | 70.75 | 71.65 | 75.17 |
| LSD (p=0.05) | 0.85 | 1.88 | 0.63 | 1.00 | 1.22 | 1.64 | 1.98 | 1.54 | 2.65 | 2.74 | - | - |
| *Weed management* | | | | | | | | | | | | |
| Pendimethalin 1.0 kg/ha PE | 5.20 | 10.05 | 3.60 | 6.66 | 51.00 | 61.05 | 59.80 | 77.76 | 71.20 | 80.50 | 56.46 | 71.75 |
| Oxyfluorfen 0.223 kg/ha PE | 4.33 | 8.36 | 3.07 | 6.53 | 48.50 | 56.00 | 55.90 | 70.89 | 65.30 | 74.00 | 60.06 | 74.03 |
| Manual weeding (two) | 2.34 | 7.26 | 1.53 | 5.68 | 30.45 | 53.50 | 34.32 | 66.44 | 42.34 | 67.66 | 74.11 | 76.25 |
| Weedy check | 12.23 | 12.06 | 9.28 | 8.90 | 68.35 | 68.63 | 89.86 | 89.59 | 163.54 | 146.66 | - | - |
| LSD (p=0.05) | 2.37 | 3.06 | 2.07 | 2.49 | 4.62 | 3.38 | 0.68 | 2.97 | 4.72 | 4.78 | - | - |

**Table 2. Effect of mulches and weed management practices on growth, yield attributes and yield of garlic**

| Treatment | Plant height (cm) 75 DAT | | Fresh weight of bulb (g) | | Dry weight of bulb (g) | | 100-cloves weight (g) | | Bulb diameter (cm) | | Yield (t/ha) | | B:C Ratio | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 |
| *Mulche* | | | | | | | | | | | | | | |
| Without mulch | 42.27 | 60.95 | 6.82 | 6.30 | 4.98 | 5.40 | 35.82 | 48.23 | 1.77 | 1.92 | 1.66 | 1.901 | 0.96 | 1.36 |
| Paddy straw mulch 5.0 t/ha | 44.31 | 62.70 | 6.92 | 7.62 | 5.81 | 6.20 | 36.14 | 49.30 | 1.87 | 2.37 | 1.94 | 2.23 | 1.10 | 1.69 |
| Paddy straw mulch 10t/ha | 48.35 | 66.67 | 9.2 | 8.62 | 6.12 | 7.00 | 38.07 | 51.50 | 1.98 | 3.00 | 2.08 | 2.72 | 1.19 | 2.18 |
| LSD (p=0.05) | 2.40 | 2.49 | 1.30 | 2.91 | 2.53 | 0.94 | 4.61 | 2.40 | 0.66 | 0.78 | 0.28 | 0.15 | - | - |
| *Weed management* | | | | | | | | | | | | | | |
| Pendimethalin 1.0 kg/ha PE | 41.51 | 66.13 | 7.63 | 9.00 | 7.37 | 6.70 | 33.33 | 54.20 | 2.67 | 2.43 | 2.02 | 2.46 | 1.09 | 1.97 |
| Oxyfluorfen 0.223 kg/ha PE | 42.48 | 66.56 | 8.18 | 10.13 | 7.67 | 6.95 | 33.67 | 54.64 | 2.77 | 2.26 | 2.05 | 2.53 | 1.16 | 2.14 |
| Manual weeding (two) | 47.00 | 67.20 | 9.05 | 10.73 | 8.10 | 6.23 | 35.53 | 55.80 | 3.10 | 2.50 | 2.13 | 2.59 | 1.11 | 1.92 |
| Weedy check | 42.00 | 53.06 | 5.76 | 4.47 | 3.95 | 3.96 | 32.25 | 33.00 | 1.56 | 1.96 | 1.34 | 1.56 | 0.97 | 0.94 |
| LSD (p=0.05) | 4.50 | 2.77 | 1.43 | 1.83 | 1.59 | 1.94 | 4.56 | 4.84 | 1.01 | 1.31 | 0.40 | 0.23 | - | - |

treatments. The number of bulb/m$^2$ and diameter of bulb (cm) were recorded significantly higher under mulch with 10 t/ha + oxyfluorfen (0.223 kg/ha) followed by pendimethalin (1.0 kg/ha) and hand weeding twice (45 and 75 DAP) each combined with 10 t/ha paddy straw mulch over weedy check. It might be due to the fact that all the growth characters remained higher, where 10 t/ha mulch + oxyfluorfen (0.223 kg/ha) was applied. These results were also confirmed by Lawande *et al*. 2009.

The bulb weight (fresh and dry) was affected significantly due to different weed control and mulch as it was directly related to the crop-weed competition. However, highest bulb weight was recorded with 10 t/ha mulch over rest of the treatments. Among herbicide treatments, the highest bulb was recorded under 10 t/ha mulch + oxyfluorfen followed by 10 t/ha mulch + pendimethalin and 10 t/ha mulch + twice hand weeding although difference were non-significant (Singh and Nandlal 2002).

### Effect on bulb yield

The significantly higher bulb yield was recorded under 10 t/ha paddy straw mulch followed by 5 t/ha and no mulch (**Table 2**). Similarly, different weed control measures influenced the bulb yield significantly. Oxyfluorfen (0.223 kg/ha), hand weeding (45 and 75 DAP) and pendimethalin (1.0 kg/ha) along with 10 t/ha paddy straw mulch combination being at par recorded significantly higher value of bulb weight as compared to weedy check treatments. However, weedy check caused the significantly lower bulb dry weight as compare to all three treatments. This might have effectively controlled the weeds during the crop growth period especially at critical crop growth stages resulting in production of higher bulb dry matter, bulb weight and bulb diameter, which might have contributed to higher bulb yields. These results were also confirmed by Kumar *et al*. (2013). The highest benefit cost ratio (1.19 and 2.18 in 2014 and 2015, respectively) were obtained with 10 t/ha straw mulch whereas under weed management practices highest benefit cost ratio (1.16 and 2.14 in 2014 and 2015, respectively) with oxyfluorfen 0.223 kg/ha treatment.

It was concluded that oxyflurofen 0.223 kg/ha and pendimethalin 1.0 kg/ha integrated with 10 t/ha rice straw mulch being at par and recorded significantly higher garlic yield and effective control of complex weed flora.

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# Sequential use of herbicides for weed control in Egyptian clover

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## ABSTRACT

To study the effect of sequential use of herbicides for weed control in Egyptian clover (berseem) crop, a field experiment was conducted under All India Coordinated Research Project on Forage Crops and Utilization, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, during *Rabi* (winter) seasons of 2012-2013, 2013-2014 and 2014-2015. The field experiment with 10 weed control treatments was laid out in a randomized block design with three replications. Among the weed control treatments, oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.1 kg/ha applied after first cut recorded the lowest weed count and weed dry weight with higher weed control efficiency. However, it was at par with the application of imazethapyr 0.1 kg/ha after first and second cut. The green forage yield, dry matter yield, seed yield, straw yield, crude protein yield, gross monetary returns and benefit-cost ratio were significantly superior in the treatment of imazethapyr 0.1 kg/ha applied after harvest of first and second cut.

**Key words:** Berseem**,** Egyptian clover, Herbicides**,** Imazethapyr, Oxyfluorfen, Pendimethalin, Sequential use, Weed management

Egyptian clover (*Trifolium alexandrium* L.) or berseem is a potential winter forage legume, one of the most popular crop in North, North-West and Central parts of India. It is a well-known green forage crop to stimulate milk production in dairy animals. Due to its excellent and quick re-growing ability and long durational nutritious green fodder availability (November to April), the crop is grown under irrigated conditions. Because of its slow growth in the initial stages, a wide range in yield reduction in the crop on account of weeds is well documented in respect of competition for essential nutrients, light, moisture and space (Thakur *et al.* 1990). Weed competition substantially reduces the green forage yield and it causes reduction up to 30 to 40% besides deteriorating quality of green forage, if not controlled during critical period of crop-weed competition (Jain 1998). Therefore, there is need to create an environment that is detrimental to weeds and favourable to the crops. Hence, weed control need to be done during the initial period of crop growth. Hand weeding is traditional and an effective method of weed control but it is very costly, labour intensive and sometimes it is not possible due to non-availability of labour. Under such situations, chemical weed control offers a better alternative to manual weeding. So, this study was conducted to evaluate pre-and post-emergence herbicides alone and in combination, which could be alternative to the traditional hand weeding practices.

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## MATERIALS AND METHODS

The experiment was conducted under All India Coordinated Research Project on Forage Crops and Utilization, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra) during the *Rabi* (winter) seasons of 2012-13, 2013-14 and 2014-15. The soils of the experimental field were clayey in texture, low in available nitrogen (175 kg/ha), medium in available phosphorus (16.5 kg/ha) and high in available potassium (335 kg/ha). It was moderately alkaline in reaction with 0.20 dS/m electrical conductivity. The organic carbon content was 0.38%. The field experiment was laid out in a randomized block design with three replications. The experiment comprised of 10 weed control treatments *viz.* weedy check (control), pendimethalin 0.3 kg/ha, pendimethalin 0.4 kg/ha, pendimethalin 0.5 kg/ha, oxyfluorfen 0.1 kg/ha, imazethapyr 0.1 kg/ha applied after harvest of first and second cut, oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.1 kg/ha applied after harvest of first cut, pendimethalin 0.3 kg/ha *fb* imazethapyr 0.1 kg/ha applied after harvest of first cut, pendimethalin 0.4 kg/ha *fb* imazethapyr 0.1 kg/ha applied after harvest of first cut and pendimethalin 0.5 kg/ha *fb* imazethapyr 0.1 kg/ha applied after harvest of first cut. The gross and net plot size were 4 x 3 $m^2$ and 3.4 x 2.4 $m^2$, respectively.

Herbicides were sprayed with a manually operated knapsack sprayer. Pendimethalin and oxyfluorfen were used as pre-emergence, while imazethapyr as post-emergence. The pre-emergence herbicides were sprayed 3 days after sowing, prior to emergence of weeds as well as crop, which was irrigated immediately after sowing and the post-emergence herbicide was applied after first and second cut of fodder as per the treatment. The crop was fertilized with the recommended dose of fertilizer *i.e* 20 kg N, 80 kg $P_2O_5$ and 40 kg $K_2O$/ha and supplied through urea, single super phosphate and mutate of potash, respectively. The variety '*Wardan*' was sown at 30 cm using a seed rate of 30 kg/ha. First two cuts were taken for green forage purpose and after harvesting of second cut for fodder, crop was left for seed production and harvesting of seed was done in May. From each plot, a 250 g representative fresh plant sample was taken at each cut to estimate the dry matter content for computing dry matter yield of fodder. One quadrate of 1.0 x 1.0 m was placed randomly in each plot and weeds were recorded. Data were recorded on the plant population (per m row length), plant height (cm), weed count ($m^2$), dry matter of weeds ($g/m^2$), green forage yield (t/ha), straw yield (t/ha) and seed yield (t/ha). The weed control efficiency (%) was also calculated. The economics of various treatments was worked out in terms of `/ha. The data on weeds were subjected to square root transformation ($\sqrt{x+0.5}$) to normalize their distribution. The data were statistically analyzed following standard procedure

## RESULTS AND DISCUSSION

### Weed flora

Major grassy (monocot) weeds were *Cynodon dactylon, Chloris barbata, Digitaria longiflora* and *Dactyloctenium agyptium;* among broad-leaved (dicot) weeds *Amaranthus viridis, Euphorbia geniculata, Celosia argentea, Trianthema portulacastrum, Commmelina benghalensis, Corchorus aestuans, Parthenium hysterophorus, Tridax procumbens, Portulaca oleracea* and *Cichorium intybus;* and *Cyperus rotundus* from sedges.

Among the weed control treatments, 18 monocot weeds and 9 dicot weeds were recorded in the plots treated with oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.1 kg/ha applied after first cut but this treatment was at par with the application of imazethapyr 0.1 kg/ha applied after 1st and 2nd cut which recorded monocot weed density of 20 plants/$m^2$ and dicot weed density of 12 plants/$m^2$ (**Table 1**).

### Weed biomass

Weed dry weight of monocot (47 $g/m^2$) and dicot weeds (21 $g/m^2$) was recorded significantly lower in the plots treated with oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.1 kg/ha applied after first cut. However, it was at par with the application of

**Table 1. Effect of various treatments on weed count, weed biomass and weed control efficiency in berseem (pooled mean of three years)**

| Treatment | Weed Count ( $m^2$) | | | Dry weight of weeds ($g/m^2$) | | | Weed control efficiency (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Monocot | Dicot | Total (Monocot + dicot) | Monocot | Dicot | Total (Monocot + dicot) | Monocot | Dicot | Total (Monocot + dicot) |
| Pendimethalin 0.3 kg/ha | 7.72 (59) | 4.39 (18) | 11.00 (77) | 10.88(119) | 6.94(48) | 14.33 (167) | 18 | 34 | 26 |
| Pendimethalin 0.4 kg/ha | 7.75 (59) | 4.28 (18) | 11.02 (77) | 10.95(120) | 6.67(45) | 14.18 (164) | 18 | 38. | 28 |
| Pendimethalin 0.5 kg/ha | 7.50 (56) | 4.58 (21) | 11.03 (76) | 10.65(113) | 7.11(50) | 13.93 (163) | 23 | 29 | 26 |
| Oxyfluorfen 0.1 kg/ha | 5.33 (28) | 3.78 (13) | 8.30 (41) | 7.95 (64) | 5.69(32) | 11.01 (96) | 61 | 49 | 55 |
| Imazethapyr 0.1 kg/ha after first and second cut | 4.57 (20) | 3.60 (12) | 7.24 (33) | 7.40 (54) | 4.88(24) | 9.61 (78) | 72 | 56 | 64 |
| Oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.1 kg/ha after first cut | 4.29 (18) | 3.19 (9) | 6.77 (27) | 6.81 (47) | 4.62(21) | 9.33 (68) | 75 | 65 | 70 |
| Pendimethalin 0.3 kg/ha *fb* imazethapyr 0.1 kg/ha after first cut | 6.12 (37) | 4.03 (15) | 9.15 (52) | 9.05 (82) | 5.93(34) | (11.90 116) | 49 | 44 | 47 |
| Pendimethalin 0.4 kg/ha *fb* imazethapyr 0.1 kg/ha after first cut | 5.69 (32) | 3.96 (15) | 8.70 (47) | 8.78 (77) | 6.10(37) | 11.78 (113) | 56 | 47 | 52 |
| Pendimethalin 0.5 kg/ha *fb* imazethapyr 0.1 kg/ha after first cut | 5.60 (31) | 3.89 (14) | 8.57 (45) | 8.68 (74) | 6.15(38) | 11.58 (112) | 57 | 51 | 54 |
| Weedy check (control) | 8.53 (72) | 5.40 (29) | 12.67(101) | 11.85(140) | 8.17(66) | 15.61 (206) | 0 | 0 | 0 |
| LSD (p=0.05) | 0.48 | 0.40 | 0.62 | 0.66 | 0.56 | 0.69 | 7.33 | 11.24 | 6.80 |

Data were subjected to square root transformation ($\sqrt{x+0.5}$); Figures in parentheses are actual values

**Table 2. Growth parameters and yield and economics of berseem as influenced by different weed management treatments (pooled mean of three years)**

| Treatment | Plant population / meter row length | Plant height (cm) | Leaf: Stem ratio | Yield | | | Dry matter yield (t/ha) | Crude protein yield (kg/ha) | Gross monetary returns (x$10^3$`/ha) | Cost of cultivation (x$10^3$`/ha) | Net monetary returns (x$10^3$`/ha) | B:C Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Green forage (t/ha) | Seed (kg/ha) | Straw (kg/ha) | | | | | | |
| Pendimethalin 0.3 kg/ha | 91.0 | 46 | 0.7 | 25.51 | 120 | 669 | 4.10 | 764 | 60.89 | 40.60 | 20.29 | 1.54 |
| Pendimethalin 0.4 kg/ha | 83.3 | 44 | 0.6 | 24.24 | 116 | 578 | 3.85 | 734 | 58.22 | 40.43 | 17.79 | 1.47 |
| Pendimethalin 0.5 kg/ha | 81.7 | 43 | 0.7 | 23.14 | 113 | 561 | 3.63 | 685 | 56.00 | 41.04 | 14.96 | 1.39 |
| Oxyfluorfen 0.1 kg/ha | 91.3 | 44 | 0.7 | 29.56 | 143 | 858 | 4.81 | 878 | 71.35 | 42.88 | 28.47 | 1.69 |
| Imazethapyr 0.1 kg/ha after first and second cut | 118.3 | 49 | 0.6 | 41.61 | 182 | 1130 | 6.90 | 1278 | 96.52 | 47.56 | 48.97 | 2.09 |
| Oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.1 kg/ha after first cut | 94.3 | 43 | 0.6 | 33.20 | 162 | 966 | 5.49 | 1013 | 80.34 | 47.25 | 33.09 | 1.70 |
| Pendimethalin 0.3 kg/ha *fb* *i*mazethapyr 0.1 kg/ha after first cut | 87.7 | 47 | 0.6 | 28.86 | 142 | 828 | 4.67 | 851 | 70.18 | 45.55 | 24.57 | 1.58 |
| Pendimethalin 0.4 kg/ha *fb* imazethapyr 0.1 kg/ha after first cut | 85.7 | 43 | 0.6 | 27.82 | 136 | 782 | 4.38 | 786 | 67.44 | 45.28 | 22.16 | 1.52 |
| Pendimethalin 0.5 kg/ha *fb* imazethapyr 0.1 kg/ha after first cut | 83.0 | 43 | 0.7 | 26.93 | 124 | 732 | 4.14 | 766 | 63.82 | 45.05 | 18.77 | 1.45 |
| Weedy check (control) | 104.3 | 51 | 0.6 | 30.05 | 148 | 741 | 4.94 | 894 | 72.66 | 42.74 | 29.92 | 1.70 |
| LSD (p=0.05) | 10.11 | 5.06 | NS | 3.19 | 14.0 | 92.0 | 0.62 | 114.0 | 5.43 | -- | 5.75 | 0.15 |

imazethapyr 0.1 kg/ha applied after 1st and 2nd cut. The total weed control efficiency (70%) was recorded significantly higher with oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.1 kg/ha applied after first cut and was at par with the application of imazethapyr 0.1 kg/ha applied after 1st and 2nd cut (64%). The results were in accordance with the findings of Tiwana *et al.* (2002) and Pathan *et al.* (2013).

### Growth parameters

Plant population was recorded significantly higher (118.3 plants/m row length) in plots treated with imazethapyr 0.1 kg/ha after 1st and 2nd cut (**Table 2**). The plant height of berseem was recorded significantly higher in weedy check (51 cm) than remaining treatments. This might be due to the weed crop competition in this treatment resulted into higher plant height. It was followed by the application of imazethapyr 0.1 kg/ha applied after 1st and 2nd cut (49 cm). The leaf-stem ratio was found non-significant among various weed control treatments on pooled mean basis.

### Yield

The data pertaining to green forage yield, seed yield, straw yield, dry matter yield and crude protein yield (**Table 2**) revealed that application of imazethapyr 0.1 kg/ha after 1st and 2nd cut recorded significantly higher values of green forage yield (41.61 t/ha), seed yield (182 kg/ha), straw yield (1130 kg/ha), dry matter yield (6.90 t/ha) and crude protein yield (1278 kg/ha) than the rest of treatments. This might be due to the higher weed control efficiency and plant population in this treatment resulted into higher yield. While**,** lower green forage, seed, straw, dry matter and crude protein yield were recorded in the plots treated with pendimethalin 0.5 kg/ha than rest of the treatments.

### Economics

The maximum mean gross returns (` 96,520/ ha), net returns of (` 48,970/ha) and B-C ratio (2.09) were recorded due to application of imazethapyr 0.1 kg/ha after 1st and 2nd cut. This was due to reduced crop weed competition during the crop growth period which resulted in higher uptake of nutrient ultimately resulting into more accumulation of the dry matter and the yield.

On the basis of pooled data on weed dynamics, yield and economic in berseem, it can be concluded that application of imazethapyr 0.1 kg/ha applied after 1st and 2nd cut was effective for control of weeds and obtaining higher green forage, seed and straw yield with higher remunerations in berseem.

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# Weed management influence on crop-weed competition in sorghum under South Gujarat conditions

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## ABSTRACT

A field experiment was conducted at Instructional Farm, Navsari Agricultural University, Navsari during 2013-14 and 2014-15 with a view to study the crop-weed competition as influenced by different weed management practices in *Rabi* (winter season) sorghum (*Sorghum bicolor* L.). Twelve weed management treatments were evaluated in a randomized block design with four replications. Pre-emergence (PE) application of atrazine 0.5 kg/ha + pendimethalin 0.25 kg/ha as tank mixture significantly reduced weed population and weed biomass, increased the weed control efficiency at early stage, next to weed free treatment. However, at the rest of the growth stages, two HW and inter culturing (IC) at 20 and 40 DAS, atrazine 0.5 kg/ha PE + HW and IC at 20 DAS, pendimethalin 0.5 kg/ha PE + HW and IC at 20 DAS effectively controlled the weeds, reduced the weed biomass and increased the weed control efficiency. Nutrient losses by weeds were highest under unweeded control and lowest with weed free condition followed by application of atrazine 0.5 kg/ha PE + HW and IC at 20 DAS.

**Key words**: Crop-weed competition, Sorghum, Weed management

Weeds are one of the major problems in sorghum and limiting factor for productivity. It is well established that the most critical period for crop-weed competition in sorghum is 45 DAS. At initial stages, the sorghum grows slowly and is a weak competitor to most weeds; even minimal weed infestations in the early growth period reduce sorghum yields significantly (Everaarts 2003).

Chemical method of weed control has become efficient, time saving and cheaper with the introduction of herbicides. Use of pre-emergence herbicides assumes greater importance in the view of their effectiveness from initial stages, while post-emergence herbicides may help in avoiding the problem of weeds at later stages. Mulching is a diversified agronomic practice which imparts various effects in agriculture. Surface-applied mulches protect the plants against extreme changes in soil temperature and water loss and also prevent the weed growth (Mousavi 2001). However, neither herbicides nor mechanical methods are adequate for consistent and acceptable weed control.

The integration of herbicide with some cultural operations or use of pre-emergence and post-emergence herbicides in combination with mechanical methods can be more successful (Ishya *et al.* 2007). Thus, integrated weed management is gaining importance in management of weeds for preventing losses and increasing input-use efficiency.

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## MATERIALS AND METHODS

Field experiments were conducted in the Instructional Farm, during *Rabi* 2014 and 2015 Navsari Agricultural University, Navsari, which is located at 20.930 N latitude, 72.900 E longitude and at height of 9 metres above the mean sea level. The soil of experimental field was clay in texture and slightly alkaline in reaction (pH 7.8) with normal electrical conductivity (EC 0.37/dSm). The soil nutrient status showed lower availability of nitrogen (191 kg/ha), medium for phosphorus (34 kg/ha) and high value for available potassium (350 kg/ha).

Twelve weed management treatments comprising unweeded control, weed free, two hand weeding (HW) and interculturing (IC) at 20 and 40 DAS, atrazine 0.5 kg/ha as pre-emergence (PE), atrazine 0.5 kg/ha PE + HW and IC at 20 DAS, pendimethalin 0.5 kg /ha PE, pendimethalin 0.5 kg/ha PE + HW and IC at 20 DAS, pendimethalin 0.5 kg/ha PE + 2, 4-D 0.5 kg/ha post-emergence (PoE) at 20 DAS, atrazine 0.5 kg/ha PE + pendimethalin 0.25 kg/ ha PE (tank mixture), atrazine 0.5 kg/ha PE + 2, 4-D 0.5 kg/ha PoE at 20 DAS, atrazine 0.5 kg/ha PE + pyrithiobac-sodium 0.5 kg/ha PoE at 20 DAS and organic mulch (sugarcane trash 2 t/ha, after germination of crop between row) were employed in a randomized block design with four replications during both successive years of experimentation.

The weed free plot was maintained through hand weeding at every 15 days interval from 15 DAS to 75 DAS of sorghum crop (total 5 hand weeding). Pre-emergence herbicides, *viz*. atrazine and pendimethalin were sprayed uniformly in respective plots, next day after sowing of sorghum crop. However, post-emergence herbicides, *viz*. 2,4-D sodium salt and pyrithiobac-sodium were applied uniformly at 20 DAS. Hand weeding and interculturing with wheel hoe were done according to the schedule of treatments in relevant plots. Sugarcane trash 2 t/ha was used as organic mulch and was applied after germination of crop between rows.

The number of weeds present in 1 m² area in each plot was counted at 20, 40, 60 DAS and at harvest. Further, these weeds were oven dried to a constant weight at $65^0$C and the dry weight of weeds was expressed in g per m2. The data on weed count and weed dry weight showed considerable variation and hence, the data were subjected to square root transformation ($\sqrt{X + 0.5}$) before statistical analysis (Gomez and Gomez, 2010). The weed control efficiency was calculated by using the formula given by Mani *et al.* (1976).The nutrient uptake by weeds was also calculated by the following formula.

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content in weed (\%)} \times \text{Weed biomass at harvest (kg/ha)}}{100}$$

## RESULTS AND DISCUSION

### Weed flora

The dominant weed flora found in the sorghum crop during *Rabi* of 2013-14 and 2014-15 showd the presence of more varieties of broad-leaf weeds as compared to grasses and sedges. These results were in close conformity with the findings of Mishra *et al.* (2012). Grassy weeds *Echinochloa colonum* and *Digitaria sanguinalis* were observed by Mishra *et al.* (2012) at Rajendranagar, Priya and Kubsad (2013) at Dharwad in sorghum crop. Presence of *Digitaria sanguinalis* in sorghum has also been reported by Besancon *et al.* (2015) and Vincent *et al.* (2015) at North Carolina. While, *Eleusine indica* was noticed in sorghum crop by Giri and Bhosle (2001) at Parbhani and Kumar *et al.* (2012) at Pantnagar. *Echinochloa crusgalli* is a prominent weed species found in Navsari district according to Thanki *et al.* (2012).

The broad-leaf weeds, were *Portulaca oleracea, Amaranthus viridis, Acalypha indica, Ageratum conyzoides, Euphorbia geniculata, Digera arvensis, Phyllanthus niruri, Eclipta alba and Phyllanthus maderaspatensis Cyperus rotundus* was prominent weed among sedge

### Weed density, biomass and weed control efficiency

Weed count and weed biomass were found lowest in weed free treatment at 20, 40, 60 DAS and at harvest due to the manual weeding done at every 15 days interval upto 75 DAS, while the highest number of weeds and weed biomass were registered under unweeded control treatment (**Figure 1** and **2**). The non-interference in weed growth under unweeded control treatment resulted in maximum utilization of resources *i.e*. moisture, nutrient, light and space resulting in higher number of weeds and dry weed biomass. Earlier workers (Priya and Kubsad 2013 and Patel *et al.* 2014) have also reported the same for unweeded control treatment.

At 20 DAS, complete control of weeds (grassy, broad-leaf and sedges) was observed with atrazine 0.5 kg/ha + pendimethalin 0.25 kg/ha PE as tank mixture. Grichar *et al.* (2005) also reported similar results for atrazine + pendimethalin in sorghum. While at 40 DAS, atrazine 0.5 kg/ha PE + HW and IC at 20 DAS was effective against grassy and broad-leaf weeds and atrazine 0.5 kg/ha PE *fb* 2,4-D 0.5 kg/ha against sedges. Atrazine 0.5 kg/ha PE + HW and IC at 20 DAS was efficient for control of weed population at 40 DAS.

At 60 DAS, two hand weeding (HW) and interculturing (IC) at 20 and 40 DAS effectively restricted grassy weeds, broad-leaf weeds as well as sedges. Apart from this, the treatment of two HW and IC at 20 and 40 DAS successfully managed the total weed population at 60 DAS. At harvest, the treatment of two HW and IC at 20 and 40 DAS efficiently hampered the grassy and broad-leaf weeds, while sedges were limited by the treatment of atrazine 0.5 kg/ha PE + pyrithiobac-sodium 0.5 kg/ha PoE at 20 DAS. Excluding these treatments, the weed population was found lowest among the treatment of atrazine 0.5 kg/ha PE + HW and IC at 20 DAS.

The weed biomass at 20 DAS was lowest in the treatment pendimethalin 0.5 kg/ha PE during first year, whereas in second year and pooled analysis, atrazine 0.5 kg/ha + pendimethalin 0.25 kg/ha PE (tank mixture) proved superior with less weed biomass. The weed biomass at 40, 60 DAS and at harvest was consistently influenced by application of two HW and IC at 20 and 40 DAS, atrazine 0.5 kg/ha

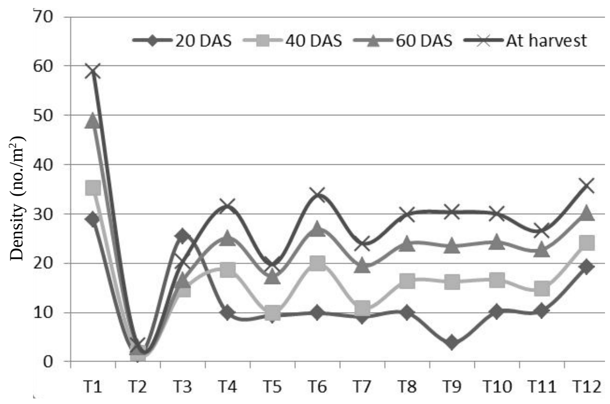



**Figure 1. Density of weeds in *Rabi* sorghum**

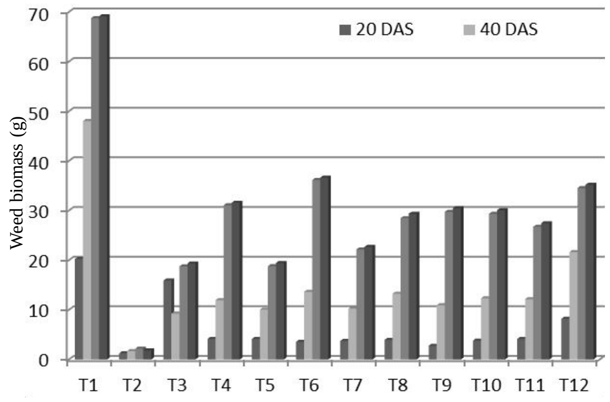
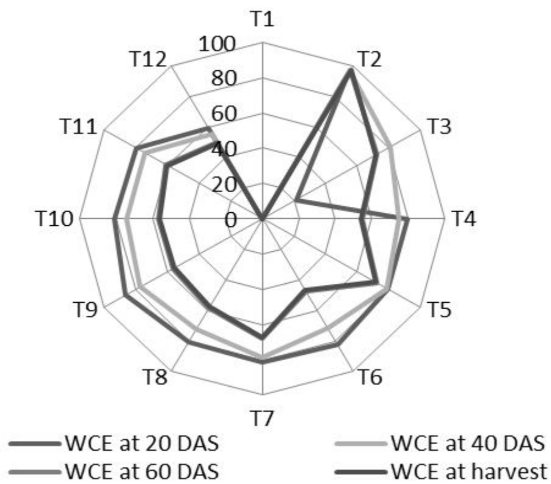



**Figure 2. Weed biomass (g) in *Rabi* sorghum**




T1 - Unweeded control; T2 - Two HW and IC at 20 and 40 DAS; T3 - Weed free; T4 - Atrazine 0.5 kg/ha PE; T5 - Atrazine 0.5 kg/ha PE + HW and IC at 20 DAS; T6 - Pendimethalin 0.5 kg/ha PE; T7 - Pendimethalin 0.5 kg/ha PE + HW and IC at 20 DAS; T8 - Pendimethalin 0.5 kg/ha PE + 2,4-D 0.5 kg/ha PoE at 20 DAS; T9 - Atrazine 0.5 kg/ha + pendimethalin 0.25 kg/ha PE (tank mixture); T10 - Atrazine 0.5 kg/ha PE + 2, 4-D 0.5 kg/ha PoE at 20 DAS; T11 - Atrazine 0.5 kg/ha PE + pyrithiobac sodium 0.5 kg/ha PoE at 20 DAS; T12 - Organic mulch (sugarcane trash 2 t/ha)

**Figure 3. Efficiency (%) of different weed management treatments in *Rabi* sorghum (based on means values)**

PE + HW and IC at 20 DAS and pendimethalin 0.5 Kg/ha PE + HW and IC at 20 DAS treatments.

The weed control efficiency at 20 DAS (**Figure 3**) was maximum during first year with the application of atrazine 0.5 kg/ha + pendimethalin 0.25 kg/ha PE (tank mixture) and pendimethalin 0.5 Kg/ha PE during second year. Whereas, at the rest of the growth stages, two HW and IC at 20 and 40 DAS had the highest weed control efficiency. The integrated weed management treatment of atrazine 0.5 kg/ha PE + HW and IC at 20 DAS closely followed the treatment two HW and IC at 20 and 40 DAS at 40, 60 DAS and at harvest for weed control efficiency on pooled basis. Patel *et al.* (2006) has justified the similar results in maize crop with the longer persistence of atrazine and pendimethalin up to harvest of crop. While, the similar efficacy of pre-emergence herbicide with one hand weeding or interculturing in sorghum are supported by Kumar *et al.* (2012), Priya and Kubsad (2013) and Patel *et al.* (2014).

**Nutrient uptake by weeds**

Minimal nutrient uptake of N, P and K in weeds was observed during both the years as well as in pooled results under weed free treatment and highest under unweeded control. Mishra *et al.* (2014) and Vijayakumar *et al.* (2014) also observed similar results for unweeded treatment.

Besides weed free treatment, Nitrogen uptake by weeds was found significantly lower with atrazine 0.5 kg/ha PE + HW and IC at 20 DAS followed by two HW and IC at 20 and 40 DAS, pendimethalin 0.5 kg/ha PE + HW and IC at 20 DAS and atrazine 0.5 kg/ha PE + pyrithiobac-sodium 0.5 kg/ha PoE at 20 DAS during 2013-14, while in 2014-15, two HW and IC at 20 and 40 DAS registered decreased N uptake by weeds followed by atrazine 0.5 kg/ha PE + HW and IC at 20 DAS and atrazine 0.5 kg/ha PE + pyrithiobac-sodium 0.5 kg/ha PoE at 20 DAS. However in pooled results, atrazine 0.5 kg/ha PE + HW and IC at 20 DAS was found to minimize the N uptake by weeds followed by two HW and IC at 20 and 40 DAS and pendimethalin 0.5 kg/ha PE + HW and IC at 20 DAS. These results were in close conformity with that of Kaushik and Shaktawat (2005).

In case of P and K uptake by weeds, atrazine 0.5 kg/ha PE + HW and IC at 20 DAS treatment was found with lowest value along with two HW and IC at 20 and 40 DAS, pendimethalin 0.5 kg/ha PE + HW and IC at 20 DAS and atrazine 0.5 kg/ha PE + pyrithiobac-sodium 0.5 kg/ha PoE at 20 DAS during

**Table 1. Effect of different weed management practices on nutrients uptake by weeds at 60 DAS**

| Treatment | N uptake (kg/ha) | | | P uptake (kg/ha) | | | K uptake (kg/ha) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2013-14 | 2014-15 | Pooled | 2013-14 | 2014-15 | Pooled | 2013-14 | 2014-15 | Pooled |
| Atrazine 0.5 kg/ha PE | 6.36 | 6.06 | 6.21 | 3.67 | 3.54 | 3.61 | 6.87 | 6.56 | 6.72 |
| Atrazine 0.5 kg/ha PE + HW and IC at 20 DAS | 4.68 | 4.53 | 4.60 | 3.03 | 2.95 | 2.99 | 5.03 | 4.77 | 4.90 |
| Pendimethalin 0.5 kg/ha PE | 7.10 | 6.78 | 6.94 | 3.93 | 3.76 | 3.85 | 7.68 | 7.32 | 7.50 |
| Pendimethalin 0.5 kg/ha PE + HW and IC at 20 DAS | 5.17 | 4.88 | 5.02 | 3.21 | 3.08 | 3.15 | 5.55 | 5.24 | 5.39 |
| Pendimethalin 0.5 kg/ha PE + 2,4-D 0.5 kg/ha PoE at 20 DAS | 5.98 | 5.83 | 5.91 | 3.56 | 3.45 | 3.51 | 6.55 | 6.24 | 6.40 |
| Atrazine 0.5 kg/ha + pendimethalin 0.25 kg/ha PE (tank mixture) | 6.21 | 5.89 | 6.05 | 3.57 | 3.48 | 3.52 | 6.69 | 6.42 | 6.55 |
| Atrazine 0.5 kg/ha PE + 2, 4-D 0.5 kg/ha PoE at 20 DAS | 6.10 | 5.79 | 5.95 | 3.53 | 3.45 | 3.49 | 6.62 | 6.34 | 6.48 |
| Atrazine 0.5 kg/ha PE + pyrithiobac sodium 0.5 kg/ha PoE at 20 DAS | 5.71 | 5.53 | 5.62 | 3.42 | 3.35 | 3.38 | 6.21 | 5.98 | 6.10 |
| Organic mulch (sugarcane trash 2 t/ha) | 7.89 | 7.49 | 7.69 | 4.81 | 4.74 | 4.77 | 8.39 | 8.13 | 8.26 |
| Two HW and IC at 20 and 40 DAS | 4.75 | 4.52 | 4.64 | 3.06 | 2.95 | 3.00 | 5.03 | 4.78 | 4.91 |
| Weed free | 1.28 | 1.22 | 1.25 | 1.11 | 1.08 | 1.10 | 1.31 | 1.24 | 1.28 |
| Unweeded control | 20.06 | 19.10 | 19.58 | 13.80 | 13.46 | 13.63 | 20.74 | 20.11 | 20.42 |
| LSD (p=0.05) | 1.23 | 1.11 | 0.81 | 0.41 | 0.41 | 0.28 | 1.21 | 1.18 | 0.83 |

both the years of investigation and pooled results. Uptake of nutrients by weeds were comparatively higher in pendimethalin and atrazine alone application compared to rest of herbicidal treatments. Similar results were obtained by Rao *et al.* (2007) in sorghum.

It was conceded that either two hand weeding and interculturing at 20 and 40 DAS or pre-emergence application of atrazine 0.5 kg/ha followed with one hand weeding and interculturing at 20 DAS should be adopted for better weed management in sorghum.

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**Short communication**

# Herbicides combinations for control of complex weed flora in transplanted rice in Lateritic belt of West Bengal

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**Key words**: Herbicide combination, Transplanted rice, Weed management, Yield

Rice (*Oryza sativa* L.) is one of the world's most important food crops (Singh and Khush 2000). Currently more than half of the world's population depends on rice for food, calories and protein, especially in developing countries. Rice is the world's most important food among all staple food crops and more than half of the world's population depends on rice for food, calories and protein, especially in developing countries. It is grown by manual transplanting of seedlings into puddled soil. Like other cereal crops, rice also suffers severely from weed competitions (Rao *et al.* 2007). Uncontrolled weeds compete with rice and cause yield losses to the tune of 50-65% under wet-seeded rice (Subbaiah and Sreedevi 2000) and up to 76% in transplanted rice (Singh *et al.* 2004). The farmers generally do hand weedings in transplanted rice. Post-emergence application of metsulfuron-methyl + chlorimuron-ethyl and early post-emergence application of ehoxysulfuron showed promising results in achieving more grain yield of transplanted rice (Pal *et al.* 2008). Pre-emergence application of pyrazosulfuron, penoxsulam (Chauhan and Seth 2013) and post-emergence bispyribac (Khaliq *et al.* 2012) herbicides were considered to be an alternative/supplement to hand weeding. Therefore, the present experiment was conducted to find out the effective herbicides or herbicide mixtures for weed control in transplanted rice.

The field trial was laid out in RBD with 12 treatments and replicated thrice in Agricultural Farm of Visva-Bharati during *Kharif*, 2014. The herbicide treatments were bispyribac-Na 25 g/ha and penoxsulam 22.5 g/ha alone, tank-mix of bispyribac-Na 25 g/ha with ethoxysulfuron 18.75 g/ha and (chlorimuron + metsulfuron ) 4 g/ha, pretilachlor 750 g/ha followed by (*fb*) ethoxysulfuron 18.75 g/ha and (chlorimuron + metsulfuron ) 4 g/ha, pyrazosulfuron 20 g/ha *fb* (chlorimuron + metsulfuron ) 4 g/ha, ready mix of penoxsulam + cyhalofop 135 g/ha, ready mix of triafamone + ethoxysulfuron 60 g/ha and pendimethalin 750 g/ha *fb* bispyribac 25 g/ha. Two hand weeding and weedy check were also included. Herbicides were applied with knapsack sprayer fitted with flat fan nozzle using 500 L/ha of water. The rice (var. *'IR-36'*) was transplanted on 26th August, 2014 and harvested on 11th November 2014. . The weed population, biomass of weed, yield attributes and yield were recorded. The weed population and biomass of weeds were subjected to square-root transformation ($\sqrt{x+0.5}$). The data were analyzed according to randomized block design by standard ANOVA at p=0.05 level of significance.

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### Weed flora

The experimental rice field was infested with 9 weed species out of which 2 were grasses, 5 were broad-leaved and 2 were sedges. The weeds species were *Cynodon dactylon*, *Echinochloa colona, Ludwigia parviflora*, *Spilanthes acmella*, *Oldenlandia corymbosa*, *Ammania multiflora, Hydrolea zeylanica, Cyperus iria* and *Fimbristylis miliacea*. The pre-dominant weed species were *Ludwigia parviflora* (48.02%) and *Fimbristylis miliacea* (38.35%).

### Effect on weeds

All the herbicidal treatments significantly controlled the complex weed flora prevailing in transplanted rice. Early post-emergence application of penoxsulam was less effective in controlling *Ludwigia parviflora* and *Fimbristylis miliacea*. Post-emergence applications of bispyribac and bispyribac + ethoxysulfuron were also found less effective in controlling *Hydrolea zeylanica*. Post-emergence application of bispyribac, penoxsulam, bispyribac + ethoxysulfuron, bispyribac + (chlorimuron + metsulfuron) ready mix of penoxsulam + cyhalofop, ready mix of triafamone of ethoxysulfuron and pendimethalin *fb* bispyribac-sodium were found most effective in controlling grass weed population. Pre-emergence application of pendimethalin *fb* bispyribac, pyrazosulfuron *fb* bispyribac and tank mix of bispyribac and chlorimuron + metsulfuron successfully controlled grass weed population. Early post-emergence application of penoxsulam + cyhalofop (ready-mix) controlled broad-leaved weeds namely, *Hydrolea zeylanica, Oldenlandia corymbosa, Ammania baccifera* and *Spilanthes acmella* successfully. With regards to suppression of sedge weeds, bispyribac-Na + ethoxysulfuron, pretilachlor *fb* ethoxysulfuron, pretilacholor *fb* chlorimuron + metsulfuron, pyrazosulfuron *fb* chlorimuron + metsulfuron, penoxsulam + cyhalofop and ready-mix of triafamone + ethoxysulfuron were found most effective. Early post-emergence application of penoxsulam + cyhalofop was found most effective in controlling total weed population. Similar trend was also observed in case of dry matter of weeds.

## Effect on yield attributes and yield

The yield attributes namely, number of effective tillers/m$^2$, number of grains/panicle and test weight differed significantly among the treatments. Early post-emergence application of penoxsulam + cyhalofop (ready-mix) recorded the highest number of effective tillers/m$^2$and number of grains/panicle. With respect to grain yield of transplanted rice, early post-emergence application of penoxsulam + cyhalofop (ready-mix) recorded the highest grain yield of transplanted rice (4.867 t/ha), which was closely followed by hand weeding twice (4.782 t/ha) and bispyribac + ethoxysulfuron (4.762 t/ha). It was noted that all the herbicidal treatment either alone or in combination produced grain yield of rice at par with the best treatment.

**Table 1. Effect of treatments on species wise weed density (no./m$^2$) in transplanted rice under herbicides combinations at 60 DAT**

| Treatment | *Cynodon dactylon* | *Echinochloa colona* | *Ludwigia parviflora* | *Spilanthes acmella* | *Oledenlandia corymbosa* | *Ammania multiflora* | *Hydrolea zeylanica* | *Fimbristlylis miliacea* | *Cyperus iria* |
|---|---|---|---|---|---|---|---|---|---|
| Bispyribac-Na | 0.7(0.0) | 0.7(0.0) | 0.0(27.7) | 0.7(0.0) | 2.6(6.3) | 1.7(2.7) | 2.7(6.7) | 3.3(10.3) | 1.8(2.7) |
| Penoxsulam | 0.7(0.0) | 0.7(0.0) | 12.0(147.3) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 5.2(27.0) | 0.7(0.0) |
| Bispyribac + ethoxysulfuron | 0.7(0.0) | 0.7(0.0) | 4.2(21.0) | 0.7(0.0) | 2.3(5.0) | 0.7(0.0) | 2.5(5.7) | 0.7(0.0) | 0.7(0.0) |
| Bispyribac + chlorimuron + metsulfuron (Almix) | 0.7(0.0) | 0.7(0.0) | 5.3(33.0) | 3.0(8.3) | 1.1(0.7) | 0.7(0.0) | 0.7(0.0) | 3.2(9.7) | 0.7(0.0) |
| Pretilachlor *fb* ethoxysulfuron | 0.7(0.0) | 1.0(0.7) | 3.3(11.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) |
| Pretilachlor *fb* chlorimuron + metsulfuron (Almix) | 2.3(4.7) | 1.1(0.7) | 4.1(17.3) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) |
| Pyrazosulfuron *fb* chlorimuron + metsulfuron (Almix) | 0.7(0.0) | 3.2(9.7) | 6.7(47.7) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) |
| Penoxsulam + cyhalofop 6% OD (RM) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) |
| Triafamone + ethoxysulfuron 30% WG (RM) | 0.7(0.0) | 0.7(0.0) | 6.3(39.3) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) |
| Pendimethalin (38.7% CS) *fb* bispyribac-sodium | 0.7(0.0) | 0.7(0.0) | 4.6(24.0) | 2.5(5.7) | 0.7(0.0) | 0.7(0.0) | 0.7(0.0) | 2.7(6.7) | 0.7(0.0) |
| Hand weeding at 25 and 45 DAT | 1.5(1.7) | 2.5(5.7) | 5.7(34.3) | 2.5(6.0) | 2.4(5.3) | 1.5(1.7) | 0.7(0.0) | 3.6(12.3) | 0.7(0.0) |
| Weedy check | 2.8(7.7) | 3.4(11.3) | 15.3(230.0) | 3.2(9.7) | 3.8(14.3) | 2.2(4.3) | 3.1(9.3) | 13.6(183.7) | 3.0(8.7) |
| LSD (p=0.05) | 0.21 | 0.41 | 1.30 | 0.27 | 0.29 | 0.26 | 0.21 | 0.32 | 0.15 |

Figures in the parentheses indicate the actual values; Transformed value = ($\sqrt{x+0.5}$); RM - Ready-mix

**Table 2. Effect of treatments on weed density and dry matter of weed in transplanted rice under herbicides combinations at 60 DAT**

| Treatment | Weed density (no./m$^2$) | | | | Dry matter of weed (g/m$^2$) | | | |
|---|---|---|---|---|---|---|---|---|
| | Grass | Broad-leaved | Sedge | Total | Grass | Broad leaved | Sedge | Total |
| Bispyribac-Na | 0.7(0.0) | 6.6(43.3) | 3.7(13.0) | 7.5(56.3) | 0.7(0.0) | 2.4(15.4) | 1.3(3.5) | 2.6(18.9) |
| Penoxsulam | 0.7(0.0) | 12.0(147.3) | 5.2(27.0) | 13.1(174.3) | 0.7(0.0) | 3.6(37.0) | 1.7(7.1) | 3.9(44.1) |
| Bispyribac + ethoxysulfuron | 0.7(0.0) | 5.7(31.7) | 0.7(0.0) | 5.7(31.7) | 0.7(0.0) | 1.9(9.4) | 0.7(0.0) | 1.9(9.4) |
| Bispyribac + chlorimuron+metsulfuron (Almix) | 0.7(0.0) | 6.5(42.0) | 3.2(9.7) | 7.2(51.7) | 0.7(0.0) | 2.1(11.7) | 1.2(3.1) | 2.3(14.8) |
| Pretilachlor *fb* ethoxysulfuron | 1.0(0.7) | 3.4(11.0) | 0.7(0.0) | 3.5(11.7) | 0.8(0.5) | 1.1(2.1) | 0.7(0.0) | 1.2(2.6) |
| Pretilachlor *fb* chlorimuron+metsulfuron (Almix) | 2.4(5.3) | 4.2(17.3) | 0.7(0.0) | 4.8(22.7) | 1.33.6) | 1.3(3.8) | 0.7(0.0) | 1.7(7.4) |
| Pyrazosulfuron *fb* chlorimuron+metsulfuron (Almix) | 3.2(9.7) | 6.9(47.7) | 0.7(0.0) | 7.6(57.3) | 2.0(10.5) | 2.1(11.5) | 0.7(0.0) | 2.8(22.0) |
| Penoxsulam+ cyhalofop 6% OD (RM) | 0.7(0.0) | 1.0(0.7) | 0.7(0.0) | 1.0(0.7) | 0.7(0.0) | 0.9(0.7) | 0.7(0.0) | 0.9(0.7) |
| Triafamone+ ethoxysulfuron 30% WG (RM) | 0.7(0.0) | 6.3(39.3) | 0.7(0.0) | 6.3(39.3) | 0.7(0.0) | 2.1(12.0) | 0.7(0.0) | 2.1(12.0) |
| Pendimethalin (38.7% CS)*fb* bispyribac-sodium | 0.7(0.0) | 5.5(29.7) | 2.7(6.7) | 6.1(36.3) | 0.7(0.0) | 1.8(7.8) | 1.1(2.0) | 1.9(9.8) |
| Hand weeding at 25 and 45 DAT | 2.8(7.3) | 6.9(47.3) | 3.6(12.3) | 8.2(67.0) | 1.3(3.5) | 2.1(11.7) | 1.3(3.3) | 2.6(18.5) |
| Weedy check | 4.4(19.0) | 16.4(267.7) | 13.9(192.3) | 21.9(479.0) | 2.5(17.6) | 5.8(98.4) | 5.8(98.8) | 8.5 (214.8) |
| LSD (p=0.05) | 0.41 | 1.25 | 0.30 | 1.22 | 0.10 | 0.21 | 0.19 | 0.16 |

Figures in the parentheses indicate the actual values; Transformed value = ($\sqrt{x+0.5}$)

**Table 3. Effect of treatments on yield attributes and grain yield of transplanted rice under herbicides combinations**

| Treatment | No. of effective tillers/m$^2$ | No. grains / panicle | Test weight (g/1000 grain) | Grain yield (t/ha) |
|---|---|---|---|---|
| Bispyribac-Na | 376.3 | 77.7 | 22.2 | 4.527 |
| Penoxsulam | 389.7 | 83.0 | 22.2 | 4.534 |
| Bispyribac + ethoxysulfuron | 399.7 | 88.0 | 22.3 | 4.762 |
| Bispyribac + chlorimuron + metsulfuron (Almix) | 392.3 | 85.3 | 22.2 | 4.722 |
| Pretilachlor *fb* ethoxysulfuron | 414.0 | 95.7 | 22.3 | 4.795 |
| Pretilachlor *fb* chlorimuron + metsulfuron (Almix) | 368.0 | 77.7 | 22.1 | 4.472 |
| Pyrazosulfuron *fb* chlorimuron + metsulfuron (Almix) | 374.3 | 75.3 | 22.1 | 4.465 |
| Penoxsulam + cyhalofop 6% OD (RM) | 426.0 | 103.3 | 22.3 | 4.867 |
| Triafamone + ethoxysulfuron 30% WG (RM) | 396.3 | 95.3 | 22.2 | 4.691 |
| Pendimethalin (38.7% CS) *fb* bispyribac-sodium | 361.3 | 92.3 | 22.1 | 4.625 |
| Hand weeding at 25 and 45 DAT | 403.3 | 95.3 | 22.2 | 4.782 |
| Weedy check | 315.3 | 67.7 | 21.6 | 3.133 |
| LSD (p=0.05) | 43.37 | 8.47 | 0.12 | 0.480 |


## SUMMARY

The field trial was laid out in RBD with 12 treatments and replicated thrice in agricultural farm of Visva-Bharati during *Kharif,* 2014. The herbicidal treatments were bispyribac and penxsulam alone; tank of bispyribac with ethoxysulfuron and (chlorimuron + metsulfuron); pretilachlor *fb* ethoxysulfuron and (chlorimuron + metsulfuron) pyrazosulfuron *fb* (chlorimuron + metsulfuron) ready mix of penoxsulam + cyhalofop, ready mix of triafamone + ethoxysulfuron and pendimethalin *fb* bispyribac. Two hand weeding and weedy check also included with an idea to find out the best herbicides / herbicide mixtures for weed control in transplanted rice. Early post-emergence application of penoxsulam + cyhalofop as ready-mix was found most effective in controlling total weed population recorded the highest number of effective tillers/m$^2$, number of grains/panicle and grain yield of transplanted rice.


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**Short communication**

# Weed management approaches in transplanted rice in Mollisols of Uttarakhand

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**Key words:** Growth attributes, Herbicides, Integrated weed management, Transplanted rice, Yield

Rice (*Oryza sativa* L.) is one of the most important cereal crops in India cultivated in 43.9 Mha area with the total production of 106.5 Mt and a productivity of 2.4 t/ha (Economic Survey, 2014-15). Rice as staple food has tremendous influence on agrarian economy of India since it contributes 45% of the total food grain production. Infestation of weeds is one of the most important causes for low yield of rice (Pandey 2009). Transplanted rice is infested with heterogeneous group of weeds comprising of grasses, broad-leaf weeds and sedges causing yield reduction up to 76% (Singh *et al.* 2004). Among different weed species, grassy weeds pose greater competition as they have an extensive and fibrous root system. Similarly, sedges grow in huge number and cause serious competition for nutrients as they dominate the surface feeding zone and obstruct nutrient flow to crop roots. Broad-leaf weeds being deep rooted explore the sub-surface zone for minerals and exert less competition for nutrients with rice (Puniya *et al.* 2007). Manual weeding is expensive, time consuming, labour intensive, tedious, back-breaking, difficult and often limited by scarcity of laborers in time. Herbicidal weed control offers an advantage to save labour and money, as a result, regarded as cost-effective (Ahmed *et al.* 2000). Application of herbicide mixture or sequential application of pre- and post-emergence herbicides or its integration with other methods of weed control may be effective for broad-spectrum management of weed flora in transplanted rice. Therefore, the present study was undertaken to quantify the effect of different weed control treatments either alone or in combination on weed abundance, growth parameters and yield performance of transplanted rice.

A field study was conducted at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during rainy season of 2012. The soil of the experimental site was silty loam with a pH of 7.3 and EC of 1.16 dS/cm, high in organic carbon content (0.86%), low in available N (226.2 kg/ha) but medium in available P (22.8 kg/ha) and K (145.4 kg/ha). The experiment was laid out in a randomized block design with three replications and twelve treatments *viz.* pre-emergence (PE) application of pretilachlor 750 g/ha, post-emergence application of bispyribac-Na 20 g/ha, penoxsulam 20, 22.5 and 25 g/ha, pre-emergence application of pretilachlor 750 g/ha *fb* one hand weeding at 45 days after transplanting (DAT), post-emergence (PoE) application of penoxsulam 22.5 g/ha *fb* one hand weeding at 45 DAT and one mechanical weeding through conoweeder at 15 DAT *fb* one hand weeding at 45 DAT, PE application of pretilachlor with no irrigation up to one week, PE application of pretilachlor with no irrigation up to one week *fb* PoE application of bispyribac-Na 20 g/ha, hand weeding twice at 20 and 40 DAT and untreated (weedy check). Pre-emergence application of pretilachlor was done at 3 DAT while PoE application of bispyribac-Na and penoxsulam was done at 14 and 20 DAT, respectively. Total five irrigations were given to the crop as and when needed. To all the treatments, irrigation was applied to saturation except PE application of pretilachlor with no irrigation up to one week and pre-emergence application of pretilachlor with no irrigation up to one week *fb* post-emergence application of bispyribac-Na 20 g/ha. In both of these treatments, irrigation was withheld up to initial one week after transplanting to provide aerobic condition that results in emergence of weeds, which were later effectively controlled by application of post-emergence herbicide. Thereafter, irrigation application was common to all the plots. The herbicide application was done as sole or sequential at the recommended rates using 500 L of water/ha for application of pre and post-emergence herbicides through knapsack sprayer fitted with a flat fan nozzle.

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Twenty five days old seedlings of rice variety "*Sarjoo 52*" were transplanted on July 6, 2012 at 20 x 10 cm apart using two seedlings per hill. All the plots (5 x 3 m) were fertilized with 120 kg N, 60 kg $P_2O_5$, 40 kg $K_2O$ and 20 kg $ZnSO_4$/ha in the form of urea, NPK mixture (12:32:16) and muriate of potash. Full dose of P and K and half dose of N were applied uniformly as basal dose at the time of transplanting. Remaining half dose of N was top dressed in two equal splits, one-fourth each at active tillering (30-35 DAT) and at panicle initiation (60-65 DAT) stage of the crop. Weed sampling in experimental plots was done from a sampling area of 1.0 $m^2$ by using 50 x 50 cm quadrant at 60 DAT as maximum weed density and dry matter were recorded at this stage compared to other crop growth stages. Weeds were identified, counted species-wise and then biomass was weighed after drying at 70±2°C in electric oven till constant dry weights. The dominant weed species was determined based on the sum dominance ratio (SDR) values expressed as a percentage, computed by using the following equation (Janiya and Moody 1989).

$$\text{SDR of a species} = \frac{\text{Relative density (RD)} + \text{Relative dry weight (RDW)}}{2}$$

Where,

$$\text{RD} = \frac{\text{Density of a given species}}{\text{Total density}} \times 100,$$

$$\text{RDW} = \frac{\text{Dry weight of a given species}}{\text{Total dry weight}} \times 100$$

Rice crop was harvested manually on November 3, 2012 with help of sickle at height of 10-15 cm from ground level to leave rice stubbles for residue incorporation into the soil.

The untreated (weedy check) plots were infested by 8 weed species representing 5 families; 4 from Poaceae, and 1 from each of Asteraceae, Cyperaceae, Lythraceae and Amaranthaceae (**Table 1**). Among the weed flora, 4 were grasses, 3 were broad-leaved weeds and 1 sedge. Based on SDR, grasses were the most dominant weeds which occupied more than 60% SDR of which *Leptochloa chinensis* (SDR 19.8%) and *Echinochloa colona* (SDR 19.1%) were the most prominent weeds. Broad-leaved weeds were next to grasses accounting for about 27.7% SDR of which *Caesulia axillaris* (SDR 13.2%) and *Ammania baccifera* (SDR 10.3%) were most dominant while Sedge was the least dominant accounting merely 12.2% SDR.

**Table 1. Sum dominance ratio (SDR) based on different weed species at 60 DAT in transplanted rice**

| Weed species | Family | Weeds type | SDR (%) |
|---|---|---|---|
| *Leptochloa chinensis* | Poaceae | Grassy | 19.8 |
| *Echinochloa colona* | Poaceae | Grassy | 19.1 |
| *Ischaemum rugosum* | Poaceae | Grassy | 14.2 |
| *Caesulia axillaris* | Asteraceae | Broad-leaf | 13.2 |
| *Cyperus difformis* | Cyperaceae | Sedge | 12.2 |
| *Ammania baccifera* | Lythraceae | Broad-leaf | 10.3 |
| *Echinochloa crus-galli* | Poaceae | Grassy | 7.2 |
| *Alternanthera sessilis* | Amaranthaceae | Broad-leaf | 4.2 |

At 30 DAT and harvest, no significant difference in plant height was observed among all the treatments due to less competition between crop and weeds (**Table 2**). At other growth stages, shorter plants were observed in weedy check compared to other integrated and alone application of herbicides. This might be due to the inter plant competition for longer period which inhibited the plants to become taller in weedy check. At 45 and 60 DAT, the maximum plant height was recorded with the PoE application of penoxsulam 22.5 g/ha *fb* one hand weeding at 45 DAT. This might be due to minimum crop-weed competition with application of penoxsulam due to broad spectrum control of weeds and greater weed control efficiency (91.4%) over rest of the treatments.

Number of shoots plays a vital role in determining grain yield in rice since it is closely related to number of panicles per unit ground area. At all the crop growth stages, no significant difference in number of shoots was observed among all the treatments except at 60 DAT (**Table 2**). In general, shoot population increased up to 45 DAT and thereafter, decreased at subsequent stages irrespective of treatments. Among weed control treatments, higher number of shoots was recorded with PE application of pretilachlor with no irrigation up to one week *fb* PoE application of bispyribac-Na 20 g/ha followed by PoE application of bispyribac-Na g/ha alone compared to other treatments. Higher number of shoots/$m^2$ with PE application of pretilachlor with no irrigation up to one week *fb* PoE application of bispyribac-Na 20 g/ha might be attributed to less crop-weed competition and better utilization of resources (nutrient, solar radiation and space) at the time of tillering due to effective control of complex weed flora. Similar result was also reported by Bhanumathy (1987). Chandra (1994) also reported that the shoot number and crop dry weight was significantly affected by various weed control treatments whereas, plant height did not reached up to the significant level.

No significant difference was observed in crop dry matter accumulation by rice at all the crop growth stages except at harvest (**Table 3**). At harvest, significantly highest dry matter accumulation was observed with PE application of pretilachlor with no irrigation up to one week *fb* PoE application of bispyribac-Na 20 g/ha, followed by PoE application of penoxsulam 22.5 g/ha supplemented with one hand weeding at 45 DAT and PoE application of bispyribac-Na 20 g/ha while significantly lower dry matter accumulation was recorded with PE application of pretilachlor with no irrigation up to one week. Higher dry matter accumulation with PE application of pretilachlor with no irrigation up to one week *fb* PoE application of bispyribac-Na 20 g/ha might be due to better weed control and higher leaf area index (LAI).

The grain and straw yield of rice was influenced significantly due to various weed control treatments. All the weed control treatments registered significantly higher rice grain and straw yield over the weedy check (**Table 3**). Among different treatments, PE application of pretilachlor with no irrigation up to one week *fb* PoE application of bispyribac-Na 20 g/ha recorded significantly higher grain and straw yield over PE application of pretilachlor 750 g/ha alone, PE application of pretilachlor 750 g/ha with no irrigation upto one week and one mechanical weeding through conoweeder at 15 DAT supplemented with one hand weeding at 45 DAT but remained at par with rest of the treatments. Pre-emergence application of pretilachlor 750 g/ha with no irrigation up to one week and one mechanical weeding through conoweeder at 15 DAT supplemented with one hand weeding at 45 DAT recorded lower straw and grain yield, respectively. Similar results were also reported by Uma *et al.* (2014). The higher straw yield might be

**Table 2. Effect of weed control treatments on number of shoots and plant height at different stages of crop growth**

| Treatment | Dose (g/ha) | Number of shoots/m$^2$ | | | | Plant height (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 30 DAT | 45 DAT | 60 DAT | At harvest | 30 DAT | 45 DAT | 60 DAT | At harvest |
| Penoxsulam | 20.0 | 174.2 | 173.3 | 170.0 | 135.8 | 61.6 | 80.3 | 97.0 | 106.2 |
| Penoxsulam | 22.5 | 179.2 | 175.8 | 176.7 | 151.7 | 64.8 | 81.6 | 99.3 | 106.4 |
| Penoxsulam | 25.0 | 186.7 | 192.5 | 177.3 | 152.5 | 63.3 | 81.3 | 98.6 | 106.5 |
| Bispyribac-Na | 20.0 | 175.8 | 188.3 | 198.3 | 129.2 | 60.9 | 79.0 | 99.5 | 112.7 |
| Pretilachlor | 750 | 165.8 | 189.2 | 161.7 | 126.7 | 59.9 | 79.3 | 97.3 | 106.9 |
| Pretilachlor *fb* 1 HW (45 DAT) | 750 | 179.2 | 180.8 | 179.2 | 131.7 | 63.6 | 79.5 | 98.7 | 106.5 |
| Penoxsulam *fb* 1 HW (45 DAT) | 22.5 | 180.8 | 202.5 | 178.3 | 135.0 | 63.5 | 81.7 | 99.8 | 107.6 |
| Pretilachlor with no irrigation up to one week | 750 | 160.0 | 162.5 | 160.0 | 130.0 | 60.3 | 78.7 | 96.1 | 106.3 |
| Pretilachlor with no irrigation up to one week *fb* bispyribac-Na | 750 *fb* 20.0 | 200.8 | 195.0 | 205.8 | 161.7 | 66.5 | 81.1 | 99.0 | 110.6 |
| One mechanical weeding through conoweeder *fb* 1 HW | 15 *fb* 45 DAT | 213.3 | 205.0 | 159.2 | 158.3 | 67.4 | 80.7 | 98.6 | 111.3 |
| Hand weeding twice | 20 and 40 DAT | 164.2 | 180.0 | 183.3 | 136.7 | 63.2 | 79.7 | 98.1 | 110.0 |
| Untreated (weedy check) | - | 161.7 | 149.2 | 124.2 | 110.0 | 58.9 | 75.3 | 94.3 | 101.1 |
| LSD (p=0.05) | - | NS | NS | 18.0 | NS | NS | 3.1 | 2.3 | NS |

**Table 3. Effect of weed control treatments on crop dry matter at different stages of crop growth, yield, HI and grain/straw ratio at harvest**

| Treatment | Dose (g/ha) | Crop dry matter (g/m$^2$) | | | | Grain yield (t/ha) | Straw yield (t/ha) | Grain/ straw ratio | HI |
|---|---|---|---|---|---|---|---|---|---|
| | | 30 DAT | 45 DAT | 60 DAT | At harvest | | | | |
| Penoxsulam | 20.0 | 14.6 | 32.8 | 112.1 | 381.4 | 4.90 | 7.24 | 0.68 | 40.44 |
| Penoxsulam | 22.5 | 20.0 | 40.2 | 117.5 | 414.8 | 5.16 | 7.45 | 0.70 | 41.05 |
| Penoxsulam | 25.0 | 21.8 | 45.4 | 128.0 | 430.8 | 5.26 | 7.50 | 0.71 | 41.38 |
| Bispyribac-Na | 20.0 | 18.6 | 37.0 | 136.9 | 436.3 | 5.62 | 7.86 | 0.72 | 41.66 |
| Pretilachlor | 750 | 20.6 | 40.0 | 106.4 | 399.1 | 4.84 | 6.82 | 0.71 | 41.53 |
| Pretilachlor *fb* 1 H.W (45 DAT) | 750 | 24.1 | 43.7 | 140.2 | 421.6 | 5.39 | 7.51 | 0.72 | 41.80 |
| Penoxsulam *fb* 1 H.W (45 DAT) | 22.5 | 21.9 | 30.9 | 139.4 | 437.7 | 5.36 | 7.56 | 0.72 | 41.59 |
| Pretilachlor with no irrigation up to one week | 750 | 20.1 | 37.6 | 111.6 | 317.1 | 4.63 | 6.50 | 0.72 | 41.64 |
| Pretilachlor with no irrigation up to one week *fb* bispyribac-Na | 750 *fb* 20.0 | 27.6 | 59.2 | 149.6 | 440.3 | 5.73 | 8.38 | 0.69 | 40.64 |
| One mechanical weeding through conoweeder *fb* 1 HW | 15 *fb* 45 DAT | 18.5 | 31.8 | 129.3 | 337.3 | 4.48 | 6.74 | 0.66 | 39.94 |
| Hand weeding twice | 20 and 40 DAT | 20.5 | 40.4 | 141.7 | 338.1 | 5.62 | 7.76 | 0.73 | 42.03 |
| Untreated (weedy check) | - | 12.9 | 23.8 | 98.2 | 295.1 | 2.29 | 3.96 | 0.59 | 36.89 |
| LSD (p=0.05) | - | NS | NS | NS | 43.4 | 0.70 | 1.22 | NS | NS |

HI - Harvest index

attributed to more plant height and dry matter accumulation due to reduced crop-weed competition. Among the different doses of penoxsulam, penoxsulam 25 g/ha applied as PoE recorded higher grain yield followed by PoE application of penoxsulam 22.5 g/ha owing to higher number of panicles/$m^2$ and grains/panicle. These findings are in conformity with the results of Khare *et al.* (2014). Post-emergence application of penoxsulam alone 22.5 and 25 g/ha was found statistically at par with PoE application of bispyribac-Na 20 g/ha. Integration of one hand weeding with pretilachlor or penoxsulam did not improve the rice grain and straw yield significantly over their sole application. The grain/straw ratio and HI were not influenced significantly due to various weed control measures (**Table 3**).

## SUMMARY

The present study was carried out during *Kharif* season of 2012 at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The dominant weed flora observed in the experimental plots were *Echinochloa colona, E. crus-galli, Leptochloa chinensis, Ischaemum rugosum* among grasses and *Ammania baccifera, Alternanthra sessilis* and *Caesulia axillaris* among broad-leaf weeds and *Cyperus difformis* among the sedges. Grasses were the most dominant weeds which occupied more than 60% of SDR followed by broad-leaved weeds (27.7%) and sedges (12.2%). Pre-emergence application of pretilachlor at 0.75 kg/ha with no irrigation up to one week *fb* PoE application of bispyribac-Na at 20 g/ha was the most promising treatment which recorded higher rice grain and straw yield as compared to other weed control treatments.

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**Short communication**

# Tank mix application of cyhalofop-butyl with selected herbicides for weed control in wet-seeded rice

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Herbicidal weed control is becoming very common in rice cultivation in India (Rao *et al.* 2007). Recently farmers are opting for use of single application of herbicide mixtures in rice fields for broad-spectrum control of weeds. Cyhalofop-butyl is a cost -effective post- emergence selective herbicide that controls grass weeds especially *Echinochloa* spp. and *Leptochloa chinensis* (Saini *et al*. 2001). As it is not effective against sedges or broad-leaf weeds, a follow up application of broad spectrum herbicides is usually recommended. However, to reduce the cost of spraying, farmers prefer tank mix application of these herbicides to have broad spectrum weed control in a single application. However, this practice often leads to herbicide antagonism though synergistic effects are also reported. So the present study was conducted to find out the best herbicide that can be tank mixed with cyhalofop-butyl, so that effective control of weeds can be achieved, while reducing the cost of cultivation.

A field experiment was conducted during *Mundakan* season (September 2015 to January 2016) in a farmer's field at Alappad Kole lands (100 31' N latitude and 76013' E longitude and 1m below mean sea level) of Thrissur district. The soil was clayey in texture with pH 4.7, medium in organic carbon (1.25%), available phosphorous (18.14 kg/ha) and potassium (183.3 kg/ha) and low in available nitrogen (151.2 kg/ha). The average maximum and minimum temperature during the crop growing season was 32.35°C and 23.63°C respectively. The experiment was laid out in randomized block design (RBD) with 16 treatments and 3 replications (**Table 1**). Rice variety '*Uma (MO 16)*' was broadcasted on Sep 23, 2015 with a seed rate of 80 kg/ha. The recommended dose of fertilizers and plant protection measures were applied. The herbicidal treatments comprised of both tank mix and sequential application of cyhalofop-butyl with selected herbicides, *viz*. Almix®, ethoxysulforun, carfentrazone-ethyl, pyrazosulfuron-ehtyl, pretilachlor, pendimethalin. The treatments were cyhalofop-butyl (80 g/ha) + Almix® (4 g/ha), cyhalofop-butyl (80 g/ha) + ethoxysulfuron (15 g/ ha), cyhalofop-butyl (80 g/ha) + carfentrazone-ethyl (20 g/ha), cyhalofop-butyl (80 g/ha) + pyrazo-sulfuron-ehtyl (30 g/ha), cyhalofop-butyl (80 g/ha) + pretilachlor (500 g/ha) and cyhalofop-butyl (80 g/ ha) + pendimethalin (1000 g/ha), cyhalofop-butyl (80 g/ha) followed by (*fb*) Almix® (4 g/ha), cyhalofop-butyl (80 g/ha) *fb* ethoxysulfuron (15 g/ha), cyhalofop-butyl (80 g/ha) *fb* carfentrazone-ethyl (20 g/ha), pyrazosulfuron-ethyl (30 g/ha) *fb* cyhalofop-butyl (80 g/ha), pretilachlor (500 g/ha) *fb* cyhalofop-butyl (80 g/ha), pendimethalin (1000 g/ha) *fb* cyhalofop-butyl (80 g/ha), bispyribac-sodium (30 g/ ha), hand weeded control, unweeded control. Pre-emergence herbicides (pyrazosulfuron-ethyl, pretilachlor and pendimethalin) were sprayed at 6 days after sowing (DAS), while all tank mix applications were sprayed at 18 DAS and follow up post-emergent herbicides at 20 DAS (*ie.* 2 days after the application of cyhalofop-butyl). Herbicide spraying was done using knapsack sprayer with flood jet nozzle and the spray volume was 250 litters/ha. Hand weeding was carried out at 20 and 40 DAS. Weed count and weed dry weight was recorded at 30, 60 DAS and at harvest using 0.25 m$^2$ quadrat. Weed control efficiency (WCE) was worked out on the basis of dry weight of weeds. Data on weed count and dry weight were subjected to square root transformation before statistical analysis to make the analysis of variance valid (Gomez and Gomez, 1984).

## Weed flora

Broad-leaf weeds were the major weeds present in the experimental area and they constituted about 52% of total weed flora, this was followed by grasses (40%) and sedges (8%) at 60 DAS. *Echinochloa stagnina*, *Ludwigia parviflora* and *Monochoria vaginalis* were the major weeds. Among broad-leaf

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weeds *Monochoria vaginalis* was the predominant one. Estorninos (1982) reported *Monochoria vaginalis* as a major weed in direct wet-seeded rice.

**Weed density and biomass**

Cyhalofop-butyl was very effective against grass weeds of rice at 30 DAS (**Table 2**). However, when cyhalofop-butyl was tank mixed with Almix®, the count of *Echinochloa stagnina* was next to that in unweeded control (**Table 1**). This clearly shows that cyhalofop-butyl losses its herbicidal when mixed with Almix®. Scott (2002) has reported reduction in cyhalofop-butyl activity when it was tank mixed with 2,4-D. At the same time, the plots treated with tank mix combination of cyhalofop-butyl with Almix® were free of sedges and broad leaf weeds at 30 DAS (**Table 2**). Hence, it can be inferred that when tank mixed with cyhalofop-butyl, Almix® do not loss its activity. Plots applied with cyhalofop-butyl alone or in sequential application with ethoxysulfuron and carfentrazone-ethyl gave complete control of *Echinochloa stagnina*.

Complete control of *Monochoria vaginalis* was obtained when Almix® was applied as both tank mix with cyhalofop-butyl and as follow up application. Follow up application of pendimethalin, bispyribac-sodium and hand weeded plot were also free of *Monochoria vaginalis* at 30 DAS. Tank mix combination of cyhalofop-butyl with ethoxysulfuron registered effective control of *M. vaginalis,* while the sequential application of these two herbicides was not so effective. Kuk *et al.* (2003) has reported occurrence of cross resistance in certain biotypes of *Monochoria vaginalis* to sulfonyl urea herbicides. Good control of *Ludwigia parviflora* was obtained in plots treated with tank mix combination of cyhalofop-butyl + Almix®, cyhalofop-butyl + carfen-trazone-ethyl, cyhalofop-butyl + pyrazosulfuron-ethyl, cyhalofop-butyl + pendimethalin. Sequential application of pyrazosulfuron-ethyl *fb* cyhalofop-butyl also gave complete control of *Ludwigia parviflora* similar to bispyribac-sodium.

At all stages of crop growth the highest weed dry matter production was registered in unweeded

**Table 1. Weeds density (no./m$^2$) at 60 days after sowing (DAS) and at harvest**

| Treatment | *Monochoria vaginalis* | | *Ludwigia parviflora* | | *Echinochloa stagnina* | | *Sacciolepis interrupta* | | *Leptochloa chinensis* | | *Cyperus difformis* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 60 DAS | At harvest | 60 DAS | At harvest | 60 DAS | At harvest | 60 DAS | At harvest | 60 DAS | At harvest | 60 DAS | At harvest |
| Cyhalofop-butyl | *4.40 | 4.93 | 4.18 | 4.40 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 1.46 | 1.94 |
| | (19.33) | (24.37) | (17.11) | (19.37) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (1.67) | (3.33) |
| Cyhalofop-butyl + Almix® | 2.24 | 2.97 | 2.48 | 2.00 | 5.13 | 5.02 | 1.87 | 0.71 | 0.71 | 0.71 | 0.71 | 2.39 |
| | (5.00) | (8.80) | (5.67) | (4.00) | (25.80) | (24.67) | (3.00) | (0.00) | (0.00) | (0.00) | (0.00) | (5.33) |
| Cyhalofop-butyl + ethoxysulfuron | 2.24 | 2.41 | 3.58 | 3.87 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 1.58 | 2.39 |
| | (5.00) | (5.80) | (12.33) | (15.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (2.00) | (5.33) |
| Cyhalofop-butyl + carfentrazone-ethyl | 3.11 | 3.27 | 2.55 | 2.83 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 1.23 | 1.65 |
| | (9.67) | (10.73) | (6.00) | (8.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (1.00) | (2.67) |
| Cyhalofop-butyl + pyrazosulfuron-ethyl | 2.16 | 2.48 | 1.63 | 1.41 | 2.92 | 2.92 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 |
| | (4.67) | (6.17) | (2.26) | (2.00) | (8.00) | (8.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Cyhalofop-butyl + pretilachlor | 4.20 | 4.36 | 3.85 | 3.74 | 1.92 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 2.39 | 0.71 |
| | (17.67) | (19.00) | (14.33) | (14.00) | (3.20) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (4.67) | (0.00) |
| Cyhalofop-butyl + pendimethalin | 2.71 | 2.65 | 2.37 | 2.75 | 3.45 | 3.85 | 1.77 | 0.71 | 0.71 | 0.71 | 0.71 | 1.92 |
| | (7.33) | (7.00) | (5.13) | (7.57) | (11.40) | (14.33) | (2.67) | (0.00) | (0.00) | (0.00) | (0.00) | (4.00) |
| Cyhalofop-butyl *fb* Almix® | 2.28 | 2.83 | 1.58 | 2.89 | 2.12 | 2.12 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 |
| | (5.23) | (8.00) | (2.00) | (8.33) | (4.00) | (4.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Cyhalofop-butyl *fb* ethoxysulfuron | 3.65 | 3.16 | 2.12 | 3.29 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 |
| | (13.33) | (10.00) | (4.00) | (10.80) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Cyhalofop-butyl *fb* carfentrazone-ethyl | 3.00 | 3.16 | 1.89 | 3.82 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 2.39 | 2.27 |
| | (9.00) | (10.00) | (3.13) | (14.57) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (5.33) | (4.67) |
| Pyrazosulfuron-ethyl *fb* Cyhalofop-butyl | 2.94 | 3.16 | 0.71 | 1.68 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 2.39 | 2.27 |
| | (8.67) | (10.00) | (0.00) | (2.80) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (5.33) | (4.67) |
| Pretilachlor *fb* cyhalofop-butyl | 2.83 | 2.92 | 2.14 | 2.45 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 2.12 | 2.12 |
| | (8.00) | (8.57) | (4.13) | (6.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (4.00) | (4.00) |
| Pendimethalin *fb* cyhalofop-butyl | 1.84 | 2.00 | 2.74 | 2.91 | 2.12 | 2.86 | 1.34 | 0.71 | 0.71 | 0.71 | 2.39 | 1.65 |
| | (3.40) | (4.00) | (7.00) | (8.48) | (4.00) | (7.67) | (1.33) | (0.00) | (0.00) | (0.00) | (5.33) | (2.67) |
| Bispyribac sodium | 2.52 | 2.49 | 1.87 | 2.24 | 0.71 | 0.71 | 0.71 | 0.71 | 1.94 | 2.41 | 0.71 | 0.71 |
| | (6.33) | (6.20) | (3.00) | (5.00) | (0.00) | (0.00) | (0.00) | (0.00) | (3.26) | (5.33) | (0.00) | (0.00) |
| Hand weeding | 1.52 | 1.73[j] | 1.87 | 1.84 | 0.71 | 1.58 | 0.71[d] | 0.71 | 0.71 | 1.05 | 0.71 | 0.71 |
| | (2.33) | (3.00) | (3.00) | (3.40) | (0.00) | (2.00) | (0.00) | (0.00) | (0.00) | (0.67) | (0.00) | (0.00) |
| Unweeded control | 5.75 | 6.21 | 3.94 | 4.36 | 4.64[b] | 4.34[b] | 2.70[a] | 0.71 | 3.08 | 3.24 | 2.65 | 3.00 |
| | (33.00) | (38.60) | (15.00) | (19.00) | (21.00) | (18.33) | (6.80) | (0.00) | (9.00) | (10.0) | (6.67) | (8.67) |
| LSD(P = 0.05) | 0.16 | 0.19 | 0.32 | 0.15 | 0.08 | 0.07 | 0.12 | 0.00 | 0.05 | 0.14 | 0.40 | 0.77 |

Almix® - (metsulfuron methyl 10% + chlorimuron ethyl 10% WP) control and it almost doubled by 60 DAS, but only a marginal increase was noted from 60 DAS to harvest. Among tank mix application of herbicides, cyhalofop-butyl + pyrazosulfuron-ethyl recorded the least weed dry matter production while among various sequential application of herbicides, the lowest weed dry matter accumulation was noted in cyhalofop-butyl *fb* Almix® at all stages of observation.

### Weed control efficiency

Cent per cent WCE was observed in hand weeded treatment at 30 DAS and even at harvest stage 93% WCE was observed. Rice grain yield was 45% higher than unweeded control. Among the herbicide treatments, tank mix combination of cyhalofop-butyl + pyrazosulfuron-ethyl recorded higher rice grain and straw yield which was at par with post-emergence application of bispyribac-sodium. The higher values under these treatments resulted from lesser crop-weed competition. It can also be inferred that either tank mix application of cyhalofop-butyl + pyrazosulfuron-ethyl or bispyribac-sodium is adequate to manage the weeds.

### Yield and economics

The lowest rice yield was recorded in unweeded control, which was due to high weed density and biomass that adversely affected all the yield parameters. Kumar *et al.* (2013) observed a yield reduction to the tune of 48% in wet-seeded rice due to severe weed competition.

Highest B:C ratio as well as net return was obtained in cyhalofop-butyl + pyrazosulfuron-ethyl (**Table 3**). This is due to high rice grain and straw yield as well as saving in cost of spraying due to tank mix application. The next best treatment with respect to net returns was bispyribac-sodium. The difference in net returns over the best treatment was ` 5000/ha. Bispyribac-sodium application per hectare costed ` 4596. For tank mix combination of cyhalofop-butyl + pyrazosulfuron-ethyl, the cost involved was only ` 2841/ha (` 1776 for 800 ml of cyhalofop-butyl and `

**Table 2. Effect of weed management treatments on weed density and biomass**

| Treatment | Weed density (no./m$^2$) | | | | | | | | | Weed biomass (kg/ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 60 DAS | | | harvest | | | | | |
| | G | S | B | G | S | B | G | S | B | 30 DAS | 60 DAS | Harvest |
| Cyhalofop-butyl | *0.7 | 1.6 | 5.1 | 0.7 | 1.5 | 6.0 | 0.7 | 1.9 | 6.4 | *17.6 | 19.9 | 20.1 |
| | (0.0) | (2.0) | (26.0) | (0.0) | (1.7) | (36.4) | (0.0) | (3.3) | (43.7) | (309.5) | (398.7) | (403.9) |
| Cyhalofop-butyl + Almix® | 4.9 | 0.7 | 0.7 | 5.4 | 0.7 | 3.3 | 5.0 | 2.4 | 3.6 | 11.6 | 16.2 | 15.2 |
| | (24.0) | (0.0) | (0.0) | (28.8) | (0.0) | (10.7) | (24.7) | (5.3) | (12.8) | (134.4) | (261.3) | (234.7) |
| Cyhalofop-butyl + ethoxysulfuron | 0.7 | 1.3 | 3.7 | 0.7 | 1.6 | 4.2 | 0.7 | 2.4 | 4.6 | 12.4 | 13.9 | 16.8 |
| | (0.0) | (1.3) | (13.3) | (0.0) | (2.0) | (17.3) | (0.0) | (5.3) | (20.8) | (153.9) | (197.3) | (282.8) |
| Cyhalofop-butyl + carfentrazone-ethyl | 0.7 | 1.5 | 3.5 | 0.7 | 1.2 | 3.9 | 0.7 | 1.7 | 4.3 | 12.5 | 11.3 | 14.7 |
| | (0.0) | (1.7) | (12.0) | (0.0) | (1.0) | (15.6) | (0.0) | (2.7) | (18.7) | (157.3) | (130.5) | (218.1) |
| Cyhalofop-butyl + pyrazosulfuron-ethyl | 2.7 | 0.7 | 2.4 | 2.9 | 0.7 | 2.6 | 2.9 | 0.7 | 2.8 | 8.7 | 9.7 | 11.2 |
| | (6.7) | (0.0) | (5.3) | (8.0) | (0.0) | (6.9) | (8.0) | (0.0) | (8.2) | (77.3) | (96.8) | (128.0) |
| Cyhalofop-butyl + pretilachlor | 1.8 | 1.5 | 5.0 | 1.7 | 2.4 | 5.7 | 0.7 | 0.7 | 5.7 | 17.5 | 17.7 | 16.7 |
| | (2.7) | (1.7) | (24.7) | (3.2) | (4.7) | (32.1) | (0.0) | (0.0) | (33.0) | (307.7) | (312.3) | (280.5) |
| Cyhalofop-butyl + pendimethalin | 3.5 | 0.7 | 3.1 | 3.9 | 0.7 | 3.5 | 3.8 | 1.9 | 3.8 | 14.9 | 13.6 | 15.3 |
| | (12.0) | (0.0) | (9.3) | (14.4) | (0.0) | (12.1) | (14.3) | (4.0) | (14.6) | (221.4) | (185.1) | (234.1) |
| Cyhalofop-butyl *fb* Almix® | 0.7 | 0.7 | 2.4 | 2.1 | 0.7 | 2.7 | 2.1 | 0.7 | 4.1 | 7.3 | 11.0 | 13.8 |
| | (0.0) | (0.0) | (5.3) | (4.0) | (0.0) | (7.3) | (4.0) | (0.0) | (16.3) | (52.9) | (121.4) | (190.4) |
| Cyhalofop-buyl *fb* ethoxysulfuron | 0.7 | 1.2 | 4.4 | 0.7 | 0.7 | 4.2 | 0.7 | 0.7 | 4.6 | 11.9 | 11.4 | 14.5 |
| | (0.0) | (1.0) | (18.7) | (0.0) | (0.0) | (17.3) | (0.0) | (0.0) | (20.8) | (100.4) | (130.0) | (212.2) |
| Cyhalofop-butyl *fb* carfentrazone-ethyl | 0.7 | 1.5 | 3.1 | 0.7 | 2.4 | 3.5 | 0.7 | 2.3 | 3.8 | 12.2 | 11.9 | 12.1 |
| | (0.0) | (1.7) | (9.3) | (0.0) | (5.3) | (12.1) | (0.0) | (4.7) | (14.6) | (150.8) | (144.9) | (148.5) |
| Pyrazosulfuron-ethyl *fb* cyhalofop-butyl | 0.7 | 0.7 | 2.7 | 0.7 | 2.4 | 2.9 | 0.7 | 2.3 | 3.6 | 10.7 | 10.9 | 11.4 |
| | (0.0) | (0.0) | (6.7) | (0.0) | (5.3) | (8.7) | (0.0) | (4.7) | (12.8) | (117.3) | (118.9) | (130.8) |
| Pretilachlor *fb* cyhalofop-butyl | 0.7 | 1.2 | 3.1 | 0.7 | 2.1 | 3.5 | 0.7 | 2.1 | 3.8 | 11.7 | 11.4 | 12.1 |
| | (0.0) | (1.0) | (9.3) | (0.0) | (4.0) | (12.1) | (0.0) | (4.0) | (14.6) | (137.3) | (131.4) | (148.5) |
| Pendimethalin *fb* cyhalofop-butyl | 1.8 | 1.5 | 2.9 | 2.4 | 2.4 | 3.2 | 2.8 | 1.7 | 3.5 | 11.7 | 12.6 | 12.3 |
| | (2.7) | (1.7) | (6.67) | (5.3) | (5.3) | (10.4) | (7.7) | (2.7) | (12.5) | (142.3) | (161.7) | (154.5) |
| Bispyribac-sodium | 0.7 | 0.7 | 0.7 | 1.7 | 0.7 | 3.0 | 2.4 | 0.7 | 3.3 | 0.7 | 9.1 | 10.6 |
| | (0.0) | (0.0) | (0.0) | (2.7) | (0.0) | (9.3) | (5.3) | (0.0) | (11.2) | (0.0) | (84.9) | (114.2) |
| Hand weeding | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 2.3 | 1.8 | 0.7 | 2.5 | 0.7 | 6.2 | 8.8 |
| | (0.0) | (0.0) | (0.0) | (0.0) | (0.0) | (5.3) | (2.7) | (0.0) | (6.4) | (0.0) | (40.0) | (80.2) |
| Unweeded control | 5.6 | 2.41 | 5.7 | 6.1 | 2.7 | 6.9 | 5.4 | 3.0 | 7.6 | 23.8 | 31.8 | 33.6 |
| | (30.7) | (5.3) | (32.0) | (36.8) | (6.7) | (48.0) | (28.3) | (8.7) | (57.6) | (566.6) | (1010.5) | (1133.2) |
| LSD(p=0.05) | 0.4 | 0.2 | 0.6 | 0.5 | 0.4 | 0.7 | 0.3 | 0.8 | 0.7 | 2.1 | 2.2 | 2.1 |

* $\sqrt{x+0.5}$ transformed values, Original values in parentheses. G- Grasses, S- Sedges, B- Broad-leaf weeds; DAS = Days after seeding

**Table 3. Economics of rice cultivation of rice as affected by weed management with various herbicides and their combinations**

| Treatment | Weed control efficiency (%) | | Grain yield (t/ha) | Straw yield (t/ha) | Total cost (x$10^3$ `) | Gross income (x$10^3$ `) | Net income (x$10^3$ `) | B:C ratio | Additional cost for weed management (x$10^3$ `) | Additional returns due to weed management (x$10^3$ `) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | | | | | | | | |
| Cyhalofop-butyl | 45.2 | 60.6 | 3.8 | 4.2 | 50.87 | 1,16.21 | 65.34 | 2.3 | 3.78 | 36.78 |
| Cyhalofop-butyl + Almix® | 76.3 | 73.8 | 3.8 | 3.8 | 51.39 | 1,15.09 | 63.70 | 2.2 | 4.29 | 35.15 |
| Cyhalofop-butyl + ethoxysulfuron | 72.8 | 85.0 | 3.7 | 3.6 | 51.41 | 1,10.34 | 58.93 | 2.1 | 4.31 | 30.38 |
| Cyhalofop-butyl + carfentrazone-ethyl | 72.4 | 87.6 | 3.9 | 3.9 | 51.41 | 1,17.26 | 65.85 | 2.3 | 4.31 | 37.30 |
| Cyhalofop-butyl + pyrazosulfuron-ethyl | 86.4 | 90.7 | 4.3 | 4.4 | 51.91 | 1,30.15 | 78.24 | 2.5 | 4.84 | 49.69 |
| Cyhalofop-butyl + pretilachlor | 45.7 | 69.6 | 3.8 | 3.9 | 53.22 | 1,13.78 | 60.55 | 2.1 | 6.13 | 32.00 |
| Cyhalofop-butyl + pendimethalin | 60.9 | 83.0 | 3.9 | 3.9 | 52.54 | 1,15.94 | 63.40 | 2.2 | 5.44 | 34.85 |
| Cyhalofop-butyl *fb* Almix® | 90.7 | 92.4 | 4.1 | 4.1 | 53.39 | 1,23.70 | 70.31 | 2.3 | 6.29 | 41.76 |
| Cyhalofop-butyl *fb* ethoxysulfuron | 75.1 | 87.0 | 4.1 | 4.1 | 53.41 | 1,23.35 | 69.94 | 2.3 | 6.31 | 41.39 |
| Cyhalofop-butyl *fb* carfentrazone-ethyl | 73.3 | 85.6 | 4.0 | 3.9 | 53.41 | 1,19.40 | 65.99 | 2.2 | 6.31 | 37.44 |
| Pyrazosulfuron-ethyl *fb* cyhalofop-butyl | 79.1 | 88.1 | 4.2 | 4.1 | 53.94 | 1,23.98 | 70.04 | 2.3 | 6.84 | 41.49 |
| Pretilachlor *fb* cyhalofop-butyl | 75.9 | 87.0 | 4.1 | 4.1 | 55.22 | 1,23.37 | 68.14 | 2.2 | 8.13 | 39.59 |
| Pendimethalin *fb* cyhalofop-butyl | 75.19[d] | 84.0 | 4.1 | 4.1 | 54.54 | 1,23.32 | 68.78 | 2.3 | 7.44 | 40.23 |
| Bispyribac sodium | 100.0 | 91.6 | 4.2 | 4.2 | 53.69 | 1,26.93 | 73.24 | 2.4 | 6.60 | 44.68 |
| Hand weeding | 100.0 | 96.1 | 4.5 | 4.6 | 74.10 | 1,35.73 | 61.63 | 1.8 | 27.00 | 33.08 |
| Unweeded control | - | - | 2.5 | 2.7 | 47.10 | 75.65 | 28.55 | 1.6 | - | - |
| LSD (p=0.05) | 8.9 | 4.6 | 0.2 | 0.3 | | | | | | |

1065 for 300 g of pyrazosulfuron-ethyl). Thus there was a saving of ` 1755/ha in cost of herbicide alone, due to this combination.

## SUMMARY

The experiment was conducted during September 2015 to January 2016 in a farmer's field one meter below of mean sea level in Thrissur district of Kerala. Tank mix application of cyhalofop-butyl (80 g/ha) with pyrazosulfuron-ethyl (30 g/ha) at 18 DAS gave effective control of mixed weed flora in wet-seeded rice. It is not advisable to tank mix cyhalofop-butyl with Almix® as it will lead to complete loss of activity of cyhalofop-butyl. Tank mixing of pre emergence herbicides with cyhalofop-butyl was found to be less effective than their sequential application.

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**Short communication**

# Nutrient uptake by rice and weeds as influenced by different weed management practices in dry-seeded rice

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Rice cultivation by direct-seeding is viewed as both cost and labor saving practice and becoming popular alternative to transplanting in some regions of Asia. Compared to transplanted rice, under direct-seeding, weeds have been found to be the biggest biological constraint because they emerge simultaneously with rice seedlings (Rao and Nagamani 2013). Ninty per cent loss in grain yield due to weeds in direct-seeded rice was reported by Zahoor *et al*. (2014). The yield losses in direct-seeded rice may range from 10 to 100% depending on type of weed flora, their density and duration of competition (Rao *et al*. 2007). In this context, the present investigation was carried out to study the effect of weed management practices on nutrient uptake of weeds and crop.

A field experiment was conducted during *Kharif*, 2014 at the Agricultural College, Naira, Andhra Pradesh. The soil was sandy loam in texture with a $p^H$ of 6.5 and EC of 0.15 dS/m, low in organic carbon (0.33%) and available nitrogen (174 kg/ha), medium in available phosphorus (38 kg/ha) and potassium (264 kg/ha). Rice variety '*Vijetha¼*' was sown by using line markers at 20 cm row spacing with solid rows with a seed rate of 75 kg/ha on 26$^{th}$ July, 2014. During the crop growing period, 723.9 mm rainfall in 36 rainy days was received. The plot size was 6 x 4 m. The experiment was laid out in randomized block design with three replications. The treatments consisted of ten weed management practices (**Table 1**), The herbicides were applied with knapsack sprayer; using spray volume of 500 l/ha. The crop was harvested on 2$^{nd}$ December, 2014.

A recommended dose of 120 kg N, 60 kg P, and 50 kg K/ha was applied through urea, single superphosphate and muriate of potash, respectively. Nitrogen was applied in three equal splits. Entire quantity of phosphorus was applied as basal at the time of sowing. Potassium was applied in two splits ½ as basal at the time of sowing and ½ at panicle initiation stage along with urea. The plant samples of rice utilized for recording dry matter production at harvest and weed samples at 60 DAS were ground in a Willey mill to pass through 40 mesh sieve. The ground material was collected in butter paper bags and later used for chemical analysis. Nitrogen and phosphorus were estimated by micro Kjeldahl's method (Jackson 1973), Vanado molybdate phosphoric yellow colour method (Jackson 1973), respectively. Potassium was determined by Flame photometer method (Jackson 1973) and it was expressed in per cent.

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## Weed flora

Eleven weed species that belong to seven different families were recorded in the experimental field. Among them, *Echinochloa colona*, *Echinochloa crus-galli* and *Cynodon dactylon* were grasses, *Cyperus rotundus, Cyperus difformis, Fimbristylis miliaceae* were sedges while, *Eclipta alba, Ludwigia parviflora, Ammania baccifera, Euphorbia hirta, Trianthema portulacastrum* were broad-leaved weeds. However, *Echinochloa colona* and *Echinochloa crus-galli* among grasses, *Cyperus rotundus* among sedges and *Eclipta alba* and *Ludwigia parviflora* among broad-leaved were dominant throughout the crop growth period.

## Effect on weeds

Pre-emergence (PE) application of pendimethalin 0.75 kg/ha *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha as post-emergence (PoE) registered the lowest total weeds biomass and was comparable with weed free check. Sequential application of pendimethalin *fb* metsulfuron-methyl + chlorimuron-ethyl was found to be highly efficacious in reducing total weed biomass at harvest (**Table 1**). Pre-emergence application of pendimethalin *fb* PoE application of metsulfuron-methyl + chlorimuron-ethyl registered the highest weed control efficiency (89.7%), which was comparable with weed free check (90.6%). The highest weed control efficiency might be attributed to successive application of two herbicides at an interval of 20 days resulting in reduction in total weed biomass which was comparable with weed free check.

Significantly lower values (0.1%) for weed index were recorded with PE application of pendimethalin 0.75 kg/ha at 3-5 DAS *fb* PoE application of metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 20-25 DAS, which was comparable with weed free check indicating its superiority compared to rest of the weed control treatments as well as weedy check. Pre-emergence application of pendimethalin 0.75 kg/ha at 3-5 DAS registered significantly higher values for weed index (44.1%) while weedy check registered the highest weed index (63.5%) among all the weed control treatments studied.

**Effect on crop yield**

Maximum grain and straw yield was obtained with the application of pendimethalin *fb* metsulfuron-methyl + chlorimuron-ethyl and was comparable with weed free check. Harvest index did not vary to a statistically perceptible magnitude. Prevalence of weed free crop growing environment might have enabled congenial conditions for higher crop growth and higher yields in PE application of pendimethalin 0.75 kg/ha *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha as PoE, on par with weed free check.

**Nutrient uptake by crop**

Among the herbicides, the highest uptake of nitrogen by grain was registered with the application of pendimethalin 0.75 kg/ha as PE *fb* metsulfuron-methyl + chlorimuron ethyl 4 g/ha as PoE and was found parity with pendimethalin 0.75 kg/ha as PE *fb* orthosulfamuron 100 g/ha as PoE application and orthosulfamuron 100 g/ha as PE application as well as weed free check. Uptake of phosphorus by grain also showed similar trend as that of the uptake of nitrogen. Uptake of potassium by grain also showed similar trend as that of the uptake of nitrogen by grain except that pendimethalin 0.75 kg/ha as PE application *fb* orthosulfamuron 100 g/ha as PoE application was comparable only with pendimethalin 0.75 kg/ha as PE application *fb* ethoxysulfuron 20 g/ha PoE application.

Among the herbicides tried, pendimethalin 0.75 kg/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha as PoE registered significantly higher nitrogen uptake by straw which was comparable with pendimethalin 0.75 kg/ha as PE at 3-5 DAS *fb* orthosulfamuron 100 g/ha as PoE at 20-25 DAS as well as weed free check. Similar trend as noticed with the uptake of nitrogen by straw was also observed with the uptake of phosphorus by straw except that weedy check was comparable with pendimethalin 0.75 kg/ha as PE, orthosulfamuron 100 g/ha and ethoxysulfuron 20 g/ha PoE application at 20-25 DAS and significantly inferior to rest of the treatments. Uptake of potassium by straw followed same trend as noticed with the uptake of phosphorus by straw.

Higher uptake of N, P and K by grain and straw comparable to weed free check was observed with pendimethalin 0.75 kg/ha as PE *fb* metsulfuron-methyl + chlorimuron ethyl 4 g/ha as PoE, pendimethalin 0.75 kg/ha as PE at 3-5 DAS *fb* orthosulfamuron 100 g/ha as PoE and orthosulfamuron 100 g/ha as pre-emergence. Higher values for the uptake of N, P and K by crop under relatively weed free crop growing conditions was also observed earlier (Sandyarani *et al.* 2013).

**Nutrient uptake by weeds**

Significantly higher quantity of nitrogen uptake by weeds was noticed in weedy check treatment

**Table 1. Effect of weed management practices on weed density, weed control efficiency, weed index and yield of semidry rice**

| Treatment | Total weed biomass (g/m) | Total weed density (no./m) | Weed control efficiency (%) | Weed index (%) | Grain yield (t/ha) | Straw yield (t/ha) |
|---|---|---|---|---|---|---|
| Pendimethalin 750 g/ha as PE at 3-5 DAS | 11.0(121.3) | 12.8(163.2) | 49.6(58.0) | 41.6(44.1) | 3.02 | 4.70 |
| Orthosulfamuron 100 g/ha as PE at 3-5 DAS | 7.1(49.7) | 7.0(48.9) | 65.7(83.1) | 17.0(8.6) | 4.94 | 6.46 |
| Orthosulfamuron 100 g/ha as PoE at 20-25 DAS | 9.3(86.6) | 12.7(160.4) | 56.2(69.1) | 36.4(35.2) | 3.50 | 5.02 |
| Ethoxysulfuron 20 g/ha PoE at 20-25 DAS | 8.8(77.3) | 12.2(149.6) | 57.7(71.4) | 30.6(26.0) | 4.00 | 5.69 |
| Metsulfuron-methyl + chlorimuron-ethyl 4 g/ha as PoE at 20-25 DAS | 8.4(69.4) | 11.7(136.6) | 61.7(77.4) | 27.7(21.7) | 4.23 | 5.71 |
| Pendimethalin 0.75 kg/ha as PE *fb* orthosulfamuron 100 g/ha as PoE | 7.4(54.9) | 7.5(55.2) | 65.6(82.9) | 20.5(12.7) | 4.71 | 6.24 |
| Pendimethalin 0.75 kg/ha as PE *fb* ethoxysulfuron 20 g/ha PoE | 7.5(56.0) | 8.1(65.2) | 62.7(78.9) | 21.4(13.3) | 4.68 | 6.28 |
| Pendimethalin 0.75 kg/ha as PE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha as PoE | 6.5(41.3) | 6.1(37.5) | 71.3(89.7) | 1.8(0.1) | 5.40 | 6.97 |
| Hand weeding twice at 20 and 40 DAS (weed free check) | 6.4(40.0) | 6.0(35.7) | 72.1(90.6) | - | 5.40 | 6.97 |
| Weedy check | 16.2(261.9) | 16.1(259.9) | - | 52.8(63.5) | 1.97 | 3.05 |
| LSD (P=0.05) | 0.4 | 2.2 | 4.5 | 4.3 | 0.345 | 0.55 |

Data were subjected to arc sine transformation. Figures in parentheses are original values; DAS - Days after sowing

**Table 2. Effect of weed management practices on uptake of N, P and K by grain, straw and weeds at 60 DAS of semi-dry rice**

| Treatment | Grain (kg/ha) | | | Straw (kg/ha) | | | Weeds at 60 DAS (kg/ha) | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | N | P | K | N | P | K |
| Pendimethalin 750 g/ha as PE at 3-5 DAS | 38.3 | 14.3 | 27.5 | 24.5 | 12.4 | 84.7 | 10.3 | 4.2 | 10.5 |
| Orthosulfamuron 100 g/ha as PE at 3-5 DAS | 51.1 | 19.6 | 37.9 | 38.8 | 19.9 | 111.0 | 3.8 | 1.7 | 4.3 |
| Orthosulfamuron 100 g/ha as PoE at 20-25 DAS | 38.8 | 14.7 | 28.2 | 24.4 | 12.8 | 86.9 | 8.4 | 3.8 | 8.2 |
| Ethoxysulfuron 20 g/ha PoE at 20-25 DAS | 42.2 | 15.9 | 30.1 | 27.1 | 13.5 | 89.9 | 7.1 | 3.3 | 7.6 |
| Metsulfuron-methyl + chlorimuron-ethyl 4 g/ha as PoE at 20-25 DAS | 44.9 | 16.7 | 31.1 | 29.5 | 15.1 | 91.6 | 5.7 | 3.0 | 6.4 |
| Pendimethalin 0.75 kg/ha as PE *fb* orthosulfamuron 100 g/ha as PoE | 49.4 | 19.1 | 35.4 | 35.5 | 18.3 | 97.8 | 4.4 | 1.9 | 4.4 |
| Pendimethalin 0.75 kg/ha as PE *fb* ethoxysulfuron 20 g/ha PoE | 45.9 | 16.9 | 32.3 | 31.6 | 15.3 | 93.5 | 4.9 | 2.3 | 5.8 |
| Pendimethalin 0.75 kg/ha as PE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha as PoE | 52.3 | 20.2 | 38.2 | 39.7 | 20.4 | 114.3 | 2.9 | 1.4 | 2.5 |
| Hand weeding twice at 20 and 40 DAS (weed free check) | 52.3 | 20.1 | 38.1 | 39.7 | 20.7 | 114.2 | 2.7 | 1.3 | 2.3 |
| Weedy check | 30.9 | 10.9 | 10.1 | 16.6 | 9.8 | 73.4 | 31.2 | 12.2 | 27.7 |
| LSD (p=0.05) | 6.2 | 2.4 | 3.9 | 7.2 | 4.6 | 17.8 | 2.3 | 1.2 | 3.0 |

while it was minimum with pre-emergence application of pendimethalin 0.75 kg/ha *fb* PoE application of metsulfuron-methyl + chlorimuron-ethyl 4 g/ha, PE application of pendimethalin 0.75 kg/ha *fb* PoE application of ethoxysulfuron 20 g/ha, PE application of pendimethalin 0.75 kg/ha *fb* PoE application of orthosulfamuron 100 g/ha and PE application of orthosulfamuron 100 g/ha, all being on par with each other and also comparable with weed free check. Similar trend was observed for the uptake of phosphorus and potassium by weeds.

N, P and K uptake by weeds in hand weeding twice was comparable with that recorded in PE application of pendimethalin 0.75 kg/ha at 3-5 DAS *fb* PoE application of metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 20-25 DAS, PE application of pendimethalin 0.75 kg/ha at 3-5 DAS *fb* PoE application of ethoxysulfuron 20 g/ha at 20-25 DAS, pre-emergence application of pendimethalin 0.75 kg/ha at 3-5 DAS *fb* PoE application of orthosulfamuron 100 g/ha at 20-25 DAS and pre-emergence application of orthosulfamuron 100 g/ha at 3-5 DAS weeds biomass recorded in these treatments was significantly lower compared to rest of the weed control treatments as well as weedy check. Reduced uptake of nutrients (N, P and K) by weeds due to increased weed control efficiency of herbicides was documented earlier (Narolia *et al.* 2014)

## SUMMARY

Among the herbicides, application of orthosulfamuron 100 g/ha was effective in suppressing sedges and broad-leaved weeds, metsulfuron-methyl + chlorimuron-ethyl 4 g/ha was effective in suppressing broad-leaved weeds and sequential application of pendimethalin 0.75 kg/ha at 3-5 DAS *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 20-25 DAS performed better in controlling weeds resulting in higher weed control efficiency and lower weed index when compared to alone application of herbicides either as pre-emergence and post-emergence. Pre-emergence application of pendimethalin 0.75 kg/ha at 3-5 DAS *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha as post-emergence at 20-25 DAS, was evidenced higher grain yield and higher uptake of nutrients in crops and lower uptake of nutrients *i.e.*, N, P and K in weeds.

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**Short communication**

# Degradation dynamics of alachlor in maize ecosystem

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**Key words:** Alachlor, Degradation, Herbicide, Persistence, Residues

Alachlor (CAS No. 15972-60-8) was developed by Monsanto Company (USA) and introduced in 1967 for pre-emergence or pre-plant control of broad spectrum of grass, sedge and broad-leaf weeds in corn, soybeans, dry beans, cotton, grain sorghum, sunflowers, peanuts and other crops. Ramesh *et al.* (2002) investigated the dissipation of alachlor in soil and plant in field condition (cotton cropping system), and in soil, water and fish in simulated model ecosystem. At harvest, cotton lint and seed samples were found to contain alachlor well below the detectable level. However, trace amounts of residues were found in cotton oil. The green leafy vegetable samples did not show any toxic symptoms of alachlor residues. The objectives of this research are the concise enumeration of the gas-liquid chromatographic (GC-ECD) separation methods used for the determination of residual fate, dissipation pattern and degradation behaviour of alachlor in maize crop and in its soil substrates.

The field experiment was conducted at Bidhan Chandra KrishiViswavidyalaya, Mohanpur, Nadia, West Bengal during 2011-12. As alachlor 50% EC is a viscous liquid formulation, the mode of application is spraying in soil at 2500 and 5000 g/ha. Only one spraying was done on 38 days after sowing by knapsack sprayer. Samples of maize leaf and soil were collected from 8-10 places of each replicated plots in each sampling dates. Samples from each untreated control plots were also collected in the similar way. Samples were collected following standard sampling procedure. No trimming/washing was done. After following quartering method, 100 gm of valid representative maize leaf, maize grain and soil samples were collected. Maize leaf and soil samples were collected at 0 (2 hr), 1, 3, 5, 7, 10, and 15 day after the application of the herbicide from each treatment and control plots. Soil samples were also collected at harvest. Maize grain samples were collected only at harvest. Extracts were cleaned up immediately after extraction as far as possible but in some cases the extracts were also stored in the cold chamber (-20$^0$C) for a minimum period of time. Technical grade alachlor of 98% purity was obtained from Sinochem India Company Pvt. Ltd., India. All the reagents used were of analytical reagent (AR) and the solvent used was J T Baker grade. Working solution was prepared in ethyl acetate. GC model Chemito GC 1000 equipped with an Electron Capture Detector coupled with C-2000, 1.7 software was used for quantification of alachlor in different substrate.

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The recoveries of alachlor from maize and soil samples were fortified at 0.01–0.10 µg/g levels using the present method of extraction and cleanup (**Table 1**). The limit of detection (LOD) and limit of quantification (LOQ) were 0.003 µg/g and 0.01 µg/g, respectively. For residue analysis, the samples of maize leaf (0.50 kg) and soil (1 kg) were drawn on 0 (2 h), 1, 3, 5, 7, 10, 15 days after spraying.

The extraction and cleanup of the samples were done according to the QuEChERS method. A representative sub- sample of 100 g was cut into small pieces and macerated at high speed blender for 2 min. 10g (5g for leaf sample) representative sample each of soil/Leaf/grain was taken in a 50 ml polypropylene centrifuge tube with a teflon lined cap and then 10 ml of J T Baker grade ethyl acetate was

**Table 1. Recoveries of alachlor from maize field soil, maize leaf and maize grain**

| Substrate | Amount fortified (µg/g) | Amount recovered* (µg/g) | Recovery (%) | Average recovery (%) |
|---|---|---|---|---|
| Maize Soil | 0.01 | 0.0094 | 94 | |
| | 0.05 | 0.05 | 100 | 94.67 |
| | 0.10 | 0.09 | 90 | |
| Maize Leaf | 0.01 | 0.0093 | 93 | |
| | 0.05 | 0.043 | 86 | 96.33 |
| | 0.10 | 0.11 | 110 | |
| Maize Grain | 0.01 | 0.0091 | 91 | 91 |
| | 0.05 | 0.044 | 88 | |
| | 0.10 | 0.094 | 94 | |

*Average of three replicates

added to it, vortexes for 1 minute. After that 4 g of activated $MgSO_4$ and 1 g of NaCl was added, the sample was again vortexes for 1 min and then centrifuged for 10 minutes at 10000 rpm at 25 $_0$C. After centrifugation, 4 ml supernatant ethyl acetate phase was collected with the help of micropipette in a 15 ml polypropylene centrifuge tube containing 50 mg of PSA and 150 mg of anhydrous $MgSO_4$. The tube was tightly sealed and vortexes for 1 min. and then centrifuged again for 10 min at 10000 rpm. 2 ml clean supernatant was transferred to an appropriate vial, then filtered through 0.2µ membrane filter and was ready for the final analysis in GC-ECD. A stock solution of 1 µg/g analytical grade alachlor (purity 98.1%) was used as an external standard. 1 µl of each cleaned up sample extracts obtained from different substrates were injected into GC-ECD under the operation parameters listed above. The alachlor residues were identified by comparing the retention time of sample peak with that of analytical standard.

**Persistence of alachlor in Soil**

The initial deposit of alachlor in maize field soil was found in the range of 1.15 to 2.50 µg/g for single (2500 g/ha) and the double (5000 g/ha) doses, respectively (**Table 2**). Around 90% of the initial residue was dissipated by 10$^{th}$ day, irrespective of dose. On and from 15$^{th}$ day onwards, no residue was detected in recommended dose, while 95.92% of the initial deposit got dissipated at 15$^{th}$ day at double the recommended dose. The residues of alachlor were below the quantification level of 0.01 µg/gat harvest at both the doses. The dissipation pattern of alachlor in soil followed first order kinetics for both single and double doses (**Figure 1a**). The residual half- life was found to be 3.24 days for single dose and 3.17 days for double dose. A half-life value of 3 days for alachlor in mix load site soil was reported (Anastasia E.M. Chirnside *et al.*2011*)*.The persistence of acetanilide herbicides in soil is dependent on many factors such as temperature, soil moisture, pH and nutrient level (Beetsman and Deming 1974 and Taiwo and Oso 1997). Herbicide dissipation in cover crop residues was often more rapid than in soil with half-lives from 3 to 11 days (Locke *et al.* 2005).

**Persistence of alachlor in maize leaf**

The initial deposit of alachlor in maize leaf was detected to be 0.35 µg/g in case of recommended dose and for double dose the corresponding value was 0.66 µg/g (**Table 2**). Around 80 % of the initial residue was dissipated by 7$^{th}$ day at the recommended dose, while the value was 71% for the double dose. On and from 10$^{th}$ day onwards, no residue was detected at the recommended dose, while for the double dose, around 86.36% of the initial deposit got dissipated at 10$^{th}$ day, and the compound was below quantification limit of 0.01 µg/g on 15$^{th}$ day. No residues of alachlor were detected at harvest. The dissipation behavior of alachlor in maize leaf followed first order kinetics for both single and double doses (**Figure 1b**).The residual half- life was found to be 3.20 days for single dose and 3.62 days for double dose.

**Persistence in maize grain and soil at harvest**

No residue of alachlor was detected in maize grain and cropped soil at harvest. The residues were below the LOQ (0.01 µg/g) in both the treatments and the commodities. Similar observation in cotton lint and seed sample was reported (Ramesh and Maheshwari 2002).

The initial deposits (2 h after spraying) of alachlor in maize leaf ranged from 0.30 - 0.39 µg/g at recommended dose and 0.61 - 0.65 µg/g at double dose but in maize field soil, the corresponding values

**Table 2. Alachlor residue in maize leaf and soil under maize crop**

| Days (Sampling) | Residues in maize soil (µg/g) | | Residues in maize leaf (µg/g) | |
|---|---|---|---|---|
| | $T_1$ = 2500 g/ha Mean ± S.D. (% Dissipation) | $T_2$= 5000 g/ha Mean ± S.D. (% Dissipation) | $T_1$ = 2500 g/ha Mean ± S.D. (% Dissipation) | $T_2$= 5000 g/ha Mean ± S.D. (% Dissipation) |
| 0 | 1.30±0.07 | 2.45±0.08 | 0.35±0.05 | 0.66±0.06 |
| 1 | 1.04±0.05(20) | 1.96±0.06(20) | 0.28±0.03(20) | 0.52±0.05(21.21) |
| 3 | 0.78±0.05(40) | 1.47±0.05(40) | 0.21±0.03(40) | 0.39±0.04(40.91) |
| 5 | 0.58±0.04(55.38) | 1.10±0.06(55.10) | 0.14±0.03(60) | 0.28±0.04(57.58) |
| 7 | 0.39±0.04(70) | 0.72±0.04(70.61) | 0.07±0.02(80) | 0.19±0.03(71.21) |
| 10 | 0.13±0.03(90) | 0.24±0.05(90.20) | 0 | 0.09±0.02(86.36) |
| 15 | 0 | 0.10±0.03(95.92) | - | 0 |
| Regression equation | y = -0.093x + 3.153 | y = -0.095x + 3.433 | y = -0.094x + 2.562 | y = -0.083x + 2.831 |
| Half-life ($T_{1/2}$) in days | 3.24 | 3.17 | 3.20 | 3.62 |

LOQ= Limit of quantification (0.01 µg/g); LOD= Limit of detection (0.003 µg/g)

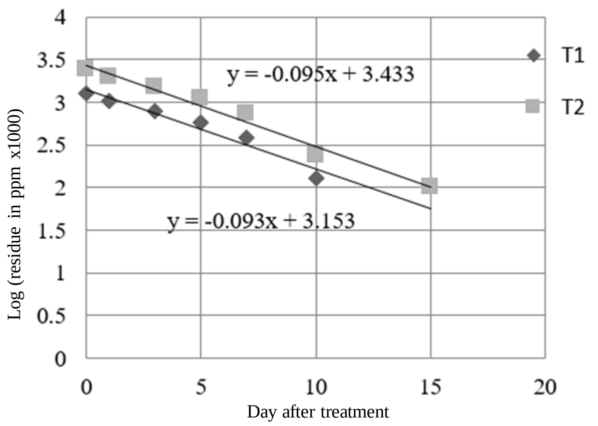


**Figure 1a. Linear plot of dissipation of alachlor in soil under crop**

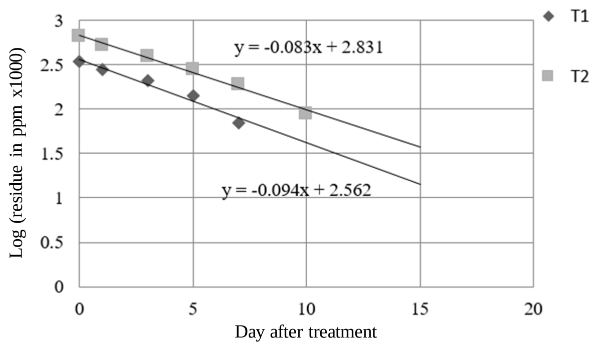


**Figure 1b. Linear plot of dissipation of alachlor in maize leaf**

were 1.23 - 1.31 µg/g and 2.46 to 2.52 µg/g for recommended and double dose respectively. The alachlor residues in maize leaf were below the quantification level of 0.01 µg/g at 15$^{th}$ day after the application whereas, it still persisted up to 15$^{th}$ day in soil samples irrespective of doses. No residue of alachlor was observed at harvest in mature maize grain and soil. The half-life values were in the range 3.17–3.62 days irrespective of dose and substrate. As the alachlor residues were found below the quantification level in all the harvested maize substrates, it may be concluded that the herbicide will not pose any residual problem and may be safely recommended for use in maize ecosystem.

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## SUMMARY

A field experiment was conducted at Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal during 2011-12 to study the degradation dynamics of an acetanilide herbicide alachlor in maize ecosystem. Alachlor (50% EC) was applied to the cropped soil at 2500 and 5000 g/ha at 38 days after the sowing of seed. The initial deposits of alachlor in maize leaf ranged from 0.30 - 0.39 µg/g at recommended dose and 0.61-0.65 µg/g at double dose but in maize field soil, the corresponding values were 1.23-1.31 µg/g and 2.46 to 2.52 µg/g for recommended and double dose, respectively. The alachlor residues in maize leaf were below the limit of quantification LOQ of 0.01 µg/g on 15$^{th}$ day after application whereas, it still persisted up to 15$^{th}$ day in soil samples irrespective of dose. At harvest, residues of alachlor were not observed in maize grains and soil samples. The half-life values of alachlor in maize ranged from 3.17-3.62 days irrespective of dose and substrate.

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Short communication

# Sequential application of pre-and post-emergence herbicides to control mixed weed flora in maize

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**Key words:** Halosulfuron-methyl, Maize, Tembotrione, Sequential application, Weed growth

Maize (*Zea mays* L.) is the most versatile food crop of global importance. In India, maize is cultivated in an area of 9.18 million hectares with a production of 24.17 million tonnes and average productivity of 2.63 t/ha. The low yield of maize under Indian conditions is attributed due to a number of factors, among which weeds rank as prime one. Weed infestation in maize was reported to reduce the yield to the extent of 70.27 per cent (Malaviya and Singh 2007). Among the weeds associated with maize, *Cyperus rotundus* is the dominant weed in Southern Agro-climatic Zone of Andhra Pradesh, India. The recommended pre-emergence herbicides *i.e.* atrazine is less effective against certain weeds associated with maize especially, *Cyperus rotundus*. Hence, the present investigation was undertaken to determine the bioefficacy of sequential application of herbicides either alone or in combination to suppress the weed growth in rainy season maize.

A field experiment was conducted during rainy season, 2016 at S.V. Agricultural College Farm Tirupati, Andhra Pradesh, India. The soil of the experimental field was sandy loam in texture and neutral in reaction. The experiment was laid out in a randomized block design with ten treatments and replicated thrice (**Table 1**). Maize *'DHM-117'* was sown with a spacing of 60 x 20 cm. Recommended dose of fertilizer 200 kg N, 60 kg $P_2O_5$ and 50 kg $K_2O$/ha was applied. Entire dose of phosphorous and potassium and 1/4$^{th}$ dose of nitrogen were applied as basal. Remaining nitrogen was applied at knee height, tasselling and silking stages. Category wise weed density and dry weight was recorded at 60 DAS by adopting standard procedures. The weed data was subjected to square root transformation ($\sqrt{X+0.5}$) before statistical analysis. The number of seeds/cob, test weight and seed yield of maize were recorded at harvest.

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## Weed flora, density and biomass

The predominant weeds associated with crop were *Cyperus rotundus* (55%), *Digitaria sanguinalis* (12%), *Boerhavia erecta* (8%), *Borreria hispida* (6%), *Trichodesma indicum* (5%), *Phyllanthus niruri* (4%) and *Digera arvensis* (3%).

The lowest density and biomass of grasses and broad-leaved weeds were registered with PE application of alachlor 1000 g/ha *fb* PoE application of halosulfuron-methyl 67.5 g/ha + tembotrione 100 g/ha, which is the next best to hand weeding twice. Among the sequential application of herbicides, PE application of alachlor 1000 g/ha *fb* tembotrione 100 g/ha was found effective in suppressing the density and biomass of grasses and broad-leaved weeds most effectively than alachlor 1000 g/ha *fb* halosulfuron-methyl 67.5 g/ha. Tembotrione inhibits 4-hydroxyphenyl pyruvate dioxygenase, a key enzyme responsible for the biosynthesis of plastoquinone leads to bleaching of foliage (Pallet *et al.*1997). Among the herbicidal treatments, the lowest density and biomass of sedges was associated with PE application of alachlor 1000 g/ha *fb* PoE application of halosulfuron-methyl 67.5 g/ha. Pre-emergence application of alachlor 1000 g/ha might have suppressed the sprouting of *Cyperus rotundus* at early stage of the crop growth and post-emergence application of halosulfuron-methyl 67.5 g/ha significantly reduced density and biomass of sedges more effectively compared to rest of the PoE herbicides tested. Halosulfuron-methyl 67.5 g/ha is very effective in suppressing the growth and development treatments of *Cyperus rotundus* (Chand *et al.* 2014). The lowest density and dry weight of all the categories of weeds were recorded with PE application of alachlor 1000 g/ha *fb* PoE application of halosulfuron-methyl 67.5 g/ha + tembotrione 100 g/ha as tank mix application. Among the herbicides

**Table 1. Effect of sequential application of pre-and post-emergence herbicides on weed density, biomass and yield of maize**

| Treatment | Weed density (no/m$^2$) | | | | Weed biomass (g/m$^2$) | | | | No. of seeds/ cob | Test weight (g) | Seed yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grasses | Sedges | BLW's | Total | Grasses | Sedges | BLWs | Total | | | |
| Alachlor (1000 g/ha) 1 DAS | 5.08 (25.33) | 6.77 (45.33) | 6.60 (43.00) | 10.68 (113.66) | 5.14 (25.87) | 8.43 (70.52) | 4.52 (19.94) | 10.81 (116.33) | 301.7 | 25.24 | 3.49 |
| Halosulfuron-methyl (67.5 g/ha) 20 DAS | 34.33 (5.90) | 27.33 (5.28) | 46.66 (6.87) | 108.32 (10.43) | 65.65 (8.13) | 10.94 (3.38) | 27.60 (5.30) | 10.23 (104.19) | 241.8 | 24.01 | 2.95 |
| Tembotrione (100 g/ha) 20 DAS | 5.24 (27.00) | 7.60 (57.33) | 5.46 (29.33) | 10.68 (113.66) | 7.45 (55.00) | 8.11 (65.28) | 3.56 (12.16) | 11.53 (132.44) | 248.2 | 24.78 | 3.33 |
| Halosulfuron-methyl *fb* tembotrione (67.5 + 100 g/ha) 20 DAS | 4.98 (24.33) | 4.71 (21.66) | 5.02 (24.66) | 8.43 (70.65) | 4.95 (24.01) | 2.15 (4.12) | 3.39 (11.02) | 6.30 (39.15) | 325.5 | 26.56 | 3.84 |
| Alachlor *fb* halosulfuron-methyl (1000 + 67.5 g/ha) 1 + 20 DAS | 4.26 (17.66) | 4.34 (18.33) | 4.53 (20.00) | 7.52 (55.99) | 4.02 (15.64) | 2.21 (4.39) | 3.28 (10.26) | 5.55 (30.29) | 364.4 | 27.33 | 4.19 |
| Alachlor *fb* tembotrione (1000 + 100 g/ha)1 + 20 DAS | 3.39 (11.00) | 5.76 (32.66) | 3.49 (11.66) | 7.47 (55.32) | 3.42 (11.17) | 7.48 (55.45) | 2.34 (4.98) | 8.49 (71.60) | 390.0 | 28.35 | 4.31 |
| Alachlor *fb* halosulfuron-methyl+ tembotrione (tank mix) (1000 + 67.5 + 100 g/ha) 1 + 20 DAS | 2.35 (5.00) | 4.18 (17.00) | 2.35 (5.00) | 5.24 (27.00) | 3.33 (10.62) | 1.68 (2.32) | 2.27 (4.65) | 4.25 (17.59) | 447.8 | 29.04 | 4.86 |
| Atrazine *fb* 2,4-D sodium salt (1000 + 800 g/ha) 1 + 20 DAS | 4.45 (19.33) | 5.58 (30.66) | 4.14 (16.66) | 8.19 (66.65) | 4.39 (18.80) | 4.63 (20.91) | 2.34 (4.97) | 6.72 (44.68) | 340.5 | 26.67 | 4.05 |
| Two hand weedings (g/ha)20 and 40 DAS | 1.78 (2.66) | 5.08 (25.33) | 1.68 (2.33) | 5.55 (30.32) | 1.40 (1.46) | 2.72 (6.89) | 1.58 (2.00) | 3.29 (10.35) | 443.3 | 28.33 | 4.55 |
| Unweeded check | 6.62 (43.33) | 10.09 (101.33) | 8.18 (66.33) | 14.54 (210.99) | 9.75 (94.57) | 8.88 (78.42) | 7.49 (55.62) | 15.14 (228.61) | 206.4 | 23.58 | 2.25 |
| LSD (p=0.05) | 0.18 | 0.15 | 0.22 | 0.24 | 0.22 | 0.26 | 0.16 | 0.32 | 14.37 | 0.33 | 0.21 |

Original values are given in parentheses, which were transformed to $\sqrt{x+0.5}$

alone, PoE application of tembotrione 100 g/ha was very effective in suppressing grasses and broad-leaved weeds, where as halosulfuron-methyl 67.5 g/ha was very effective in controlling sedges.

Significantly higher number of seeds/cob and test weight was recorded with sequential application of alachlor 1000 g/ha as PE *fb* PoE application of halosulfuron-methyl 67.5 g/ha + tembotrione 1000 g/ha and it was statistically comparable with two hand weedings at 20 and 40 DAS. Kumar *et al.* (2013) also reported that post-emergence application of atrazine 1000 g/ha + halosulfuron-methyl 90 g/ha recorded significantly higher stature or growth and yield components. The increase in number of seeds/cob in the former weed management practice was 53% compared to unweeded check. Pre-emergence application of alachlor 1000 g/ha *fb* PoE application of halosulfuron-methyl 67.5 g/ha + tembotrione 100 g/ha recorded significantly higher grain yield due to maintenance of weed free environment during critical period of crop weed competition as a result of effective control of all the categories of weeds. Hand weeding twice at 20 and 40 DAS was the next best weed management practice in recording higher number of seeds/cob and grain yield of maize. Among the PoE application of herbicides, tank mix application of halosulfuron-methyl 67.5 g/ha+ tembotrione 100 g/ha recorded significantly higher grain yield followed by tembotrione 100 g/ha and halosulfuron-methyl 67.5 g/ha alone.

## SUMMARY

A field experiment was laid out in randomized block design with ten weed management practices to determine the bioefficacy of PoE herbicides, halosulfuron-methyl 67.5 g/ha and tembotrione 100 g/ha alone or tank mix and sequential application after PE application of alachlor 1000 g/ha, besides two hand weedings and unweeded control. The broad-spectrum weed control and the highest grain yield of rainy season maize was obtained with sequntial application of alachlor 1000 g/ha as PE *fb* PoE application of halosulfuron-methyl 67.5 g/ha + tembotrione 100 g/ha (tank mix). Post-emergence application of halosulfuron-methyl 67.5 g/ha effectively controlled purple nutsedge.

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**Short communication**

# Bio-efficacy of flumioxazine for weed management in soybean and its residual effect on succeeding crops

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**Key words:** Flumioxazine, Residual effect, Soybean, Succeeding crops, Weed management

Soybean [*Glycine max* (L.) Merrill] is the third largest oilseed crop of India after rapeseed and mustard. It has been observed that soybean yields can be reduced if weeds are not controlled (Vollmann *et al*. 2011 and Mohammadi and Amiri 2011). The reduction in soybean yield due to weed infestation varied from 20-77% depending on the type of soil, season and intensity of weed infestation (Kuruchania *et al*. 2000). Thus, efficient weed management is an essential pre-requisite for increasing the crop productivity. Several new herbicides have been evaluated for their weed control efficacy in soybean. Although, the research has provided a few options involving pre-plant incorporation (trifluralin and fluchloralin), pre-emergence (alachlor, pendimethalin, metolachlor and clomazone) and post-emergence (imazethapyr, quizalofop-ethyl and chlorimuron-ethyl), there is a need to identify newer herbicides for selective management of weeds and to overcome the problem of acquiring resistance by certain weeds against recommended herbicides. Flumioxazine (N-phenylphthalimide) is a new contact herbicide which acts on weeds by inhibiting protoporphyrinogen oxidase, an enzyme important in the synthesis of chlorophyll. In this study, an attempt was made to find the effectiveness of flumioxazine to control broad-leaved weeds and some grassy weeds in soybean and its residual effect on succeeding crops.

The experiment was conducted at Agricultural Research Station, Bhavanisagar, in the Western zone of Tamil Nadu during *Rabi* 2013-14. The experiment was laid out in a randomized block design replicated thrice with eight treatments. The experimental field is located at $11^0$ 29'N latitude and $77^0$ 08'E longitude with an altitude of 256 m above MSL. The soil of the experimental field was red sandy clay loam in texture belonging to Typic Paleustalfs, pH 7.4, EC 0.14 dS/m and organic carbon 0.55%. Soil was low in available nitrogen (215 kg/ha), medium in available phosphorus (17.5 kg/ha) and high in available potassium (260 kg/ha). Soybean variety '*CO Soy 3*' with duration of 85-90 days released by TNAU during 2005 was selected for this study. The recommended package and practices was followed as per the; TNAU Crop production guide 2012.

After the harvest of soybean in the monsoon season, two test crops, *viz*. sunflower and pearl millet were raised. The observations such as germination percentage at 10 DAS, plant height and dry matter production at 30 DAS were taken for these test crops. Statistical analysis for all the data pertaining to crop and weeds were carried out using the method suggested by Gomez and Gomez (1984). The original values of weed density were transformed using square root transformation and analyzed statistically. The least significant difference (LSD) at 5% level of probability was worked out for comparison.

## Weed flora and density

The major proportion of the weed flora comprised of grasses at all the stages of growth. At later stages of crop growth, the weed density was higher when compared with early stages. Obviously unweeded control resulted in higher grasses, sedge and broad leaved weed densities. Weed density increased significantly from 25 DAS onwards. Higher density of weeds was observed upto 60 DAS. Results are in corroboration with the finding of Nagaraju and Mohankumar (2009) who have recorded maximum density of weeds upto 60 DAS compared to other stages of the soybean crop covering greater portion of the soil at this stage. Halford *et al.* (2001) reported that critical period of weed control in soybean was reported to begin at the first or second node development stage, whereas the end was at the early flowering.

Chemical weed control methods significantly reduced the weed density over unweeded control. Pre emergence (PE) application of flumioxazine at 250,

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150, 125 g/ha and PE application of pendimethalin 1.0 kg/ha recorded lower weed density at all stages of crop growth. It was followed by PE application of flumioxazine at 112.5 g/ha (**Table 1**). The reason might be the PE control of broad spectrum weed control at all stages. It is in conformity with the results of Sangeetha *et al.* (2011). Weed control efficiency indicated the extent of effectiveness of weed biomass reduction by weed control treatments over unweeded control. Different weed control treatments significantly influenced the weed control efficiency. Weed control treatments *viz.*, PE application of flumioxazine at 250, 150, 125, 112.5 and 100 g/ha and PE application of pendimethalin at 1.0 kg/ha recorded more than 70 per cent WCE. During the cropping period higher weed control efficiency was obtained with PE application of flumioxazine at 250 g/ha, followed by PE application of flumioxazine at 150 g/ha. More reduction of weed dry weight by reducing the weed density in these treatments might have resulted in higher WCE (**Table 1**). These finding were in accordance with the results of PE application of flumioxazin in soybean by Billore *et al.* (2007).

## Yield attributes and yield

The main yield contributing factors, *viz.* number of pods per plant, number seeds per pod and hundred grain weight were significantly influenced by different weed control treatments. Among the treatments, unweeded check recorded significantly lower number of pods and seeds per pod due to weed competition. Durigan *et al.* (1983) reported that number of pods per plant was the most affected character among yield parameters due to heavy infestation of weeds. Pre-emergence application of flumioxazine at 112.5 g/ha recorded higher value for yield attributes (**Table 2**). This enhanced yield attributes could be due to reduced weed-crop and interplant competition, which resulted in higher availability of moisture and nutrients to the crop and increased light interception. These results were in line with earlier finding of Billore *et al.* (2007) in soybean.

Among the weed control treatment, pre-emergence application of flumioxazine 112.5 g/ha has recorded higher grain and haulm yields. Pre-emergence application of pendimethalin at 1.0 kg/ha, PE flumioxazine at 100 g/ha and hand weeding twice also recorded higher yield (**Table 2**). The increased yield may be due to lesser competition and no phytotoxity resulted in better vegetative growth and favorable yield attributes. Similar results were reported by Sunil Kumar *et al.* (1996) who obtained maximum seed yield of soybean crop from weed free environment by different weed control treatments.

The cost of cultivation was least in unweeded check due to less maintenance. But it was higher in hand weeding twice, because of higher labour input. Gross return, net return and B:C ratio were higher in pre emergence application of flumioxazine at 112.5 g/ ha (**Table 2**). This could be due to higher growth parameters and yield attributes as a result of reduced competition between weeds and crop for water and nutrients. Similar findings were reported by Kushwah and Kushwaha (2001) who reported that highest B:C ratio and monetary returns per rupee invested was obtained by the use of herbicides.

## Residual effect of herbicides on succeeding crop

Residual effect of herbicide is one of the important factors for recommending herbicide to the farmers in order to avoid the residual phytotoxity in the succeeding crops. Results indicated that there was no significant difference among the treatments in germination (%), Plant height (cm) and dry matter

**Table 1. Effect of treatments on total weed density and weed control efficiency in soybean**

| Treatment | Total weed density (no./m$^2$) | | | Weed control Efficiency (%) at 60 DAS |
|---|---|---|---|---|
| | 25 DAS | 45 DAS | 60 DAS | |
| Flumioxazine PE 112.5 g/ha 3 DAS | 5.84(32.3) | 7.31(51.7) | 8.30(67.0) | 78 |
| Flumioxazine PE 125 g/ha 3 DAS | 5.29(26.0) | 6.43(39.3) | 7.28(51.1) | 82 |
| Flumioxazine PE 150 g/ha 3 DAS | 4.51(18.3) | 5.80(31.7) | 6.56(41.3) | 84 |
| Flumioxazine PE 250 g/ha 3 DAS | 3.83(12.7) | 5.03(23.3) | 5.50(28.3) | 88 |
| Pendimethalin PE 1000 g/ha 3 DAS | 5.94(33.3) | 7.01(47.3) | 8.25(66.7) | 74 |
| Oxyflourfen PE 125 g/ha 3 DAS | 7.94(61.3) | 9.04(80.0) | 10.5(109) | 66 |
| Chlorimuron-ethyl 9 g/ha 10 DAS | 10.2(103) | 11.1(122) | 11.7(136) | 60 |
| Hand weeding twice at 25 and 45 DAS | 16.3(265) | 8.48(70.0) | 7.95(61.3) | 76 |
| LSD (p=0.05) | 0.93 | 1.05 | 1.25 | - |

DAS = Days after seeding; PE = Pre-emergence; Figures in parentheses are mean of original values; Data were subjected to square root transformation

**Table 2. Effect of treatments on soybean yield attributes, yield and economics**

| Treatment | No. of pods/ plant | No. of seeds/ pod | 100 seed weight (g) | Grain yield (t/ha) | Haulm yield (t/ha) | Harvest index (%) | Net returns (x10$^3$ `/ha) | B:C ratio |
|---|---|---|---|---|---|---|---|---|
| Flumioxazine PE112.5 g/ha 3 DAS | 85.9 | 3.7 | 12.1 | 1.90 | 2.44 | 43.77 | 30.95 | 2.19 |
| Flumioxazine PE 125 g/ha 3 DAS | 79.3 | 3.3 | 10.3 | 1.43 | 2.41 | 37.24 | 19.38 | 1.75 |
| Flumioxazine PE 150 g/ha 3 DAS | 76.3 | 3.0 | 10.5 | 1.40 | 2.33 | 37.48 | 15.98 | 1.61 |
| Flumioxazine PE 250 g/ha 3 DAS | 63.9 | 2.9 | 10.3 | 1.32 | 2.07 | 38.96 | 13.46 | 1.51 |
| Pendimethalin PE1000 g/ha 3 DAS | 84.3 | 3.6 | 11.6 | 1.88 | 2.43 | 43.61 | 29.14 | 2.07 |
| Oxyflourfen PE 125 g/ha 3 DAS | 77.2 | 3.5 | 11.0 | 1.60 | 2.23 | 41.82 | 21.33 | 1.80 |
| Chlorimuron-ethyl 9 g/ha 10 DAS | 76.3 | 3.3 | 10.9 | 1.45 | 2.11 | 40.71 | 17.31 | 1.66 |
| Hand weeding twice 25 and 45 DAS | 81.3 | 3.5 | 11.1 | 1.81 | 2.30 | 44.06 | 17.41 | 1.47 |
| LSD (p=0.05) | 5.75 | NS | 0.85 | 0.26 | 0.29 | - | - | - |

DAS = Days after seeding; PE = Pre-emergence

production (kg/ha) at 30 DAS and it was evident that there was no residual toxicity due to the application of flumioxazine at all doses in the succeeding crops. It is in conformity with the results by Raskar and Bhoi (2002) who reported no carry over effect of PE application of various herbicides on succeeding crop of potato.

It was concluded that the application of flumioxazine at 112.5 g/ha as pre-emergence provides an option to farmers to manage weeds effectively without any phytotoxic effect on succeeding sunflower and pearl millet crops.

## SUMMARY

A Field experiment was conducted at Agricultural Research Station, Bhavanisagar of Tamil Nadu Agricultural University during *Rabi* 2013-14 to study the bio-efficacy evaluation of flumioxazine for weed control in soybean. Higher weed control efficiency was obtained with pre-emergence application of flumioxazine at 250 g/ha followed by its lower dose of 150 g/ha. Among the treatments, pre-emergence application of flumioxazine at 112.5 g/ha recorded increased yield and economic returns in soybean. Hence, the pre-emergence application of flumioxazine at 112.5 g/ha was found to reduce the weed density below the economic threshold level and increased the yield and net return in soybean without any phytotoxic effect on the crop and residual effect on the succeeding crop.

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**Short communication**

# Bioefficacy of different herbicides in fenugreek

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**Key words:** Blackgram, Fenugreek, Herbicides, Weed control, Yield

Fenugreek (*Trigonella foenum-graecum* L.) locally known as '*Methi*' in Hindi, is an important multi use leguminous spice crop of arid and semi-arid regions of India. India is the largest producer of fenugreek in the world where Rajasthan, Gujarat, Uttarakhand, Uttar Pradesh, Madhya Pradesh, Haryana and Punjab are the major fenugreek producing states. Rajasthan produces the lion's share of India's production, accounting for over 80% of the total fenugreek output (Anonymous 2012). In Haryana, the crop is sown in an area of 4978 ha with seed production of 13,973 tonnes (Anonymous 2009). Growth of fenugreek is very slow in the initial stage and it does not form a canopy that can suppress weed growth upto several weeks after sowing. Pendimethalin has been recommended to control weeds but it efficacy is for short period and is inconsistent. Weeds which come up after first irrigation also cause huge losses. Keeping it in view, present experiment was planned to study effectiveness of imazethapyr and its ready mix combination as pre-plant incorporation (PPI), pre-emergence (PE) or post-emergence applications (PoE).

Present study was conducted at vegetable research area of CCS, HAU, Hisar during *Rabi*, 2012-13. Experiment consisted of 10 herbicide treatments replicated thrice in a plot size of 7 x 3.6 $m^2$. Variety '*HM 58*' was planted on 15th November, 2012 with a seed rate of 20 kg/ha. Herbicide pendimethalin at 1000 g/ha as PE, imazethapyr was used as PPI, PE at 80 g/ha and PoE at 2-4 leaf stage at 70 g/ha. Ready-mix combination of imazethapyr and imazamox was also applied as PoE at 2-4 leaf stage at 60 g/ha by using 750 litres of water/ha. Phytotoxic effect on crop was recorded at 60 DAS by using 0-100 scale. Visual weed control was also assessed at harvest on 0-100 scale. Data on weed dry weight was recorded at 60 DAS which was subjected to ANOVA for analysis.

To study residual effect of these herbicides on succeeding crops, after harvest of fenugreek, 2 lines each of cotton, bitter guard, okra and bottle gourd were planted on the same layout with slight disking of soil plots in May, 2017. Observations on plant height, number of leaves/plant and fresh biomass of succeeding crops was recorded at 30 DAS.

**Table 1. Effect of different herbicide treatments on weed control and seed yield of fenugreek**

| Treatment | Dose (g/ha) | Time of application | Weed control (%) at harvest * | Weed dry weight(g/$m^2$) at 60 DAS** | Crop phytotoxicity (%) at 60 DAS | Seed yield (kg/ha) |
|---|---|---|---|---|---|---|
| Imazethapyr | 80 | PE | 63.5(80) | 2.9(7.7) | 0(0) | 1024 |
| Imazethapyr + hoeing | 80 | PE | 73.3(92) | 1(0) | 0(0) | 1182 |
| Imazethapyr | 80 | PPI | 68.8(87) | 3.2(9.6) | 0(0) | 1177 |
| Imazethapyr + hoeing | 80 | PPI | 79.5(95) | 1(0) | 0(0) | 1237 |
| Imazethapyr | 70 | PoE (2-4 LS) | 49.7(58) | 4.7(1.7) | 24(16.7) | 891 |
| Imazethapyr + hoeing | 70 | PoE (2-4 LS) | 60.5(75) | 1(0) | 22.6(15) | 939 |
| Imazethapyr + imazamox(RM) | 60 | PoE (2-4 LS) | 55.7(68) | 4.9(23.1) | 28.6(23.3) | 928 |
| Imazethapyr + imazamox(RM)+hoeing | 60 | PoE (2-4 LS) | 62.2(78) | 1(0) | 29.8(25.0) | 961 |
| Pendimethalin+ one hoeing | 1000 | PRE | 76.2(92) | 1.4(1.2) | 46.9(53.3) | 780 |
| Two hoeings | | 30 and 60 DAS | 75.2(93) | 1(0) | 0(0) | 1318 |
| Weed free | | | 90(100) | 1(0) | 0(0) | 1328 |
| Weedy check | | | 0(0) | (51.2) | 0(0) | 785 |
| LSD (p=0.05) | | | 8.3 | 0.72 | 4.82 | 189 |

PE = Pre-emergence; PPI = Pre-plant incorporation; PoE = Post-emergence application; LS = Leaf stage; DAS = Days after seeding; *Arc sin transformed values. Actual values are in parenthesis, **($\sqrt{x+1}$) transformed values after analysis

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**Table 2. Residual effect of different herbicides applied in fenugreek on succeeding crops**

| Treatment | No of leaves/plant | | | | | Fresh biomass (g/plant) | | | | | Plant height(cms) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cotton | Okra | Black-gram | Bitter guard | Bottle gourd | Cotton | Okra | Black-gram | Bitter guard | Bottle gourd | Cotton | Okra | Black-gram | Bitter guard | Bottle gourd |
| Imazethapyr (80 g/ha) PE | 3 | 5 | 7 | 3 | 6 | 8.5 | 12.4 | 7.6 | 7.3 | 16.3 | 10.4 | 12.4 | 10.4 | 9.3 | 22.9 |
| Imazethapyr + hoeing (80 g/ha) PE | 3 | 4 | 6 | 4 | 5 | 8.7 | 11.7 | 7.7 | 7.0 | 16.0 | 8.7 | 11.7 | 10.7 | 8.7 | 23.0 |
| Imazethapyr (80 g/ha) PPI | 4 | 4 | 8 | 3 | 5 | 9.6 | 10.9 | 9.3 | 6.9 | 15.9 | 9.3 | 12.0 | 11.3 | 9.0 | 23.5 |
| Imazethapyr + hoeing (80 g/ha) PPI | 3 | 3 | 9 | 3 | 6 | 8.9 | 10.3 | 8.9 | 7.4 | 15.7 | 8.4 | 11.4 | 10.9 | 8.8 | 23.0 |
| Imazethapyr (70 g/ha) 2-4 LS | 4 | 3 | 6 | 4 | 7 | 10.1 | 8.4 | 7.8 | 6.8 | 16.5 | 8.5 | 12.6 | 12.0 | 7.6 | 22.3 |
| Imazethapyr + hoeing (70 g/ha) 2-4 LS | 4 | 3 | 8 | 4 | 6 | 12.2 | 8.0 | 8.0 | 7.0 | 17.2 | 7.6 | 12.5 | 11.7 | 8.3 | 21.0 |
| Imazethapyr + imazamox (RM) (60 g/ha) 2-4 LS | 4 | 7 | 6 | 3 | 6 | 8.9 | 28.9 | 8.4 | 7.2 | 15.6 | 7.9 | 19.3 | 11.0 | 10.1 | 21.6 |
| Imazethapyr + imazamox (RM) + hoeing (60 g/ha) 2-4 LS | 3 | 6 | 9 | 4 | 7 | 9.2 | 32.3 | 8.2 | 7.6 | 17.0 | 8.3 | 20.5 | 11.5 | 8.7 | 21.7 |
| Pendimethalin+ one hoeing (1000 g/ha) PE | 7 | 8 | 8 | 4 | 6 | 30.0 | 32.4 | 7.6 | 8.2 | 17.6 | 16.7 | 21.0 | 10.5 | 7.6 | 22.0 |
| Two hoeings 30 and 60 DAS | 8 | 7 | 8 | 3 | 5 | 30.3 | 38.6 | 8.5 | 6.9 | 18.8 | 15.9 | 20.7 | 9.9 | 8.5 | 22.6 |
| Weed free | 7 | 8 | 9 | 3 | 6 | 28.4 | 37.1 | 9.4 | 7.4 | 21.7 | 17.0 | 22.0 | 10.9 | 8.9 | 24.3 |
| Weedy check | 7 | 7 | 7 | 4 | 5 | 29.2 | 35.3 | 9.0 | 7.8 | 22.4 | 17.6 | 22.4 | 12..0 | 8.4 | 33.8 |
| LSD (p=0.05) | 1.8 | 2.3 | NS | NS | NS | 3.1 | 5.4 | NS | NS | NS | 2.5 | NS | NS | NS | NS |

Experimental field was infested with broad-leaf weeds: *Chenopodium album, Chenopodium murale, Coronopus didymus, Melilotus indica* and *Rumex dentatus*. PE or PPI of imazethapyr at 80 g/ha either alone or in combination with one hoeing at 45 DAS provided 80-95% control of *C. album, C. murale, C. didymus* and *R. dentatus* without any adverse effect on fenugreek. PoE of imazethapyr at 70 g/ha or its ready mixture with imazamox (Odessey) although provided 58-78% control of weeds but caused suppression in crop growth with yield penalty of 28-33% as compared to weed free check. Kumar *et al.* (2016) also reported 58% control of weeds in fenugreek with PPI application of imazethapyr 55 g/ha. Excellent efficacy of this herbicide against broad-leaf weeds was also reported by Sikkema *et al.* (2005). PE of pendimethalin (standard check) at 1000 g/ha along with hoeing although gave 92% control of weeds but crop remained stunted even up to 80 DAS with seed yield of 780 kg/ha which was minimum among herbicide treatments which was 36.9% less than imazethapyr applied at 80 g/ha as PPI.

Residual effect of these herbicides applied in fenugreek was studied on succeeding bitter guard, blackgram, okra, cotton and bottle gourd. Post-emergence application treatments of imazethapyr + imazamox (RM) caused suppression in cotton and okra crops as evident from lesser plant height, number of leaves and fresh biomass of cotton in imazethapyr and imazethapyr + imazamox treated plots was significantly than pendimethalin, untreated and weed free check (**Table 2**). Ready-mix combination of imazethapyr + imazamox applied at 60 g/ha at 2-4 leaf stage did not cause any toxicity to okra but to cotton. In urd bean, bitter guard and bottle gourd, no residual toxicity of any herbicide was observed.

## SUMMARY

Pre-emergence or pre-plant incorporation of imazethapyr at 80 g/ha either alone or in combination with one hoeing at 45 DAS provided 80-95% control of *C. album, C. murale, C. didymus* and *R. dentatus* without any adverse effect on fenugreek. Post emergence application of this herbicide at 70 g/ha or its ready mixture with imazamox (Odessey) although provided 58-78% control of weeds but caused suppression in crop growth with yield penalty of 28-33% as compared to weed free check. Pre, PPI and post-emergence application treatments of imazethapyr and imazethapyr + imazamox (RM) caused suppression in cotton and okra crops. Crops blackgram, bottle gourd and bottle gourd were safe to grow after use of imazethapyr and its ready mix combination in fenugreek.

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**Short communication**

# Effect of IWM on weed dynamics, dry matter accumulation, yield and economics of turmeric

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**Key words:** Plant dry matter accumulation, Productivity, Profitability

Turmeric (*Curcuma longa* L.) is one of the important spice crops grown in India in an area of 1.94 Mha with an average production of 9.71 ton and productivity 5 ton/ha (Anonymous 2013). Weed competition is one of the limiting factors for low yield of turmeric. Due to improper weed management, 30-70% yield losses have been reported in the crop (Krishnamurty and Ayyaswamy 2000). Turmeric is a long durational crop takes 8-9 months, therefore, pre-emergence application of herbicides alone can not control weeds throughout critical crop-weed competition period of the crop and needs an integration of pre- and post-emergence application of herbicide or inter-culture operation in combination with pre-emergence herbicide application. Hence, a field experiment was carried out to suggest a suitable integrated weed management for better production of turmeric.

The experiment was carried out during rainy season, 2014 at Birsa Agricultural University, Ranchi, Jharkhand in randomized block design with three replications. The soil of experimental field was sandy loam slightly acidic in reaction (pH 5.9), low in organic carbon (4.2 g/kg) and N (243 kg/ha) while medium in P 19.15 kg/ha and K (188 kg/ha). The turmeric variety '*Rajendra sonia*' was planted at 40 x 25 cm spacing on 3rd July 2014. The recommended dose of FYM at 10 t/ha and 120:60:100 kg/ha NPK was applied. The experiment comprised of 15 treatments (**Table 1**). Un-weeded check as hand weeding at 25, 45 and 75 DAP and un-weeded check respectively. All the herbicides alone or in mixture were applied with knapsack sprayer fitted with flat-fan nozzle using 600 litres water/ha. Crop growth rate ($g/m^2/day$) was calculated by using the following standard formulae suggested by Leopold and Kridemann (1975) between 30-90 and 90-150 DAP –

$$\text{Crop growth rate } (g/m^2/day) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, $W_2$ and $W_1$ are plant dry weight at time $t_2$ and $t_1$.

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## Weed flora

The major weeds found in experimental plot, *viz. Ageratum conyzoides* (L.), *Celosia argentea* (L.), *Acalypha indica* (L.) among broad-leaved weeds; *Digitaria sanguinalis* (L.), *Panicum dichotomiflorum* among grassy and *Cyperus rotundus* (L.) among sedges were predominant. Among all the categories broad-leaved dominated (60.4%) followed by grassy (28%) and sedges (11.6%).

## Effect of weed density and dry matter

Among chemical weed control methods application of metribuzin 0.7 kg/ha PE *fb* fenoxaprop-p-ethyl 67 g/ha + metsulfuron 4 g/ha at 45 DAP recorded reduced total weed density at 90 and 150 DAP to the tune of 66.96 and 54.67% compared to hand weeding at 25, 45 and 75 DAP respectively. Similarly, total weed dry matter accumulation was reduced in metribuzin 0.7 kg/ha PE *fb* fenoxaprop-p-ethyl 67 g/ha + metsulfuron 4 g/ha at 45 DAP at 90 and 150 DAP to the tune of 44.24 and 52.27% respectively compared to hand weeding at 25, 45 and 75 DAP.

The mean dry matter accumulation ($g/m^2$) by total plant parts increased gradually from 30 DAP to 150 DAP and then slightly decreased at 210 DAP. The mean dry matter accumulation at 30, 90, 150 and 210 DAP were 42.8, 345, 570 and 554 $g/m^2$. The respective increase over preceding values were to the tune of 705.2 percent up to 90 DAP and 65.3% up to 150 DAP while at 210 DAP it was decreased to the extent of 2.8%. Maximum mean dry matter accumulation by stem was (41.6 $g/m^2$) at 90 DAP which was 92.5% higher than at 30 DAP and further it reduced marginally by 5.17% (39.4 $g/m^2$) at 150 DAP. The mean dry matter accumulation by rhizomes of turmeric at 90, 150 and 210 DAP was 238, 483 and 386 $g/m^2$ respectively. The dry matter accumulation by rhizomes started decreasing after 150 DAP as majority of leaves dried and stopped photosynthesis. Moreover, dehaulming performed at 167 DAP as a normal practice in order to harden the underground rhizome. This reduced dry matter accumulation by rhizome compared to 150 DAP was marginal (**Table 1**).

Among weed control methods, application of atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP recorded maximum dry matter accumulation to the extent of 7.27, 42.2 and 80.5% higher at 30, 90 and 150 DAP respectively compared to hand weeding at 25, 45 and 75 DAP by turmeric leaves. Similarly, application of atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP also recorded significantly higher stem dry matter accumulation which were 63.5 and 70.6 % higher compared to hand weeding at 25, 45 and 75 DAP, at 90 and 150 DAP respectively (**Table 1**). Moreover, similar result was also observed in case of dry matter accumulation by rhizomes as atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP recorded significantly higher dry matter accumulation by rhizomes to the tune of 180, 152 and 154% compared to hand weeding at 25, 45 and 75 DAP, at 90, 150 and 210 DAP respectively. Application of atrazine 0.75 kg/ha pre-emergence *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP also recorded maximum total dry matter accumulation by plants which were 8.95, 136, 140 and 154% higher than hand weeding at 25, 45 and 75 DAP, at 30, 90, 150 and 210 DAP respectively. Sathiyavani and Prabhakaran (2015) have also reported that either use of mulch or its integration with herbicides and hand weeding has resulted in better dry matter accumulation by plants.

Plant injury of turmeric as a result of phyto-toxicity recorded at 60 DAP was maximum under treatments of integration of chemicals like metribuzin 0.7 kg/ha *fb* fenoxaprop-p-ethyl 67 g/ha + metsulfuron 4 g/ha at 45 DAP *i.e.,* 7.67, at a scale of 0-10. Among all the treatments, integration of chemical along with straw mulch and hand weeding recorded reduced phyto-toxicity on turmeric plant *i.e.* atrazine 0.75 kg/ha pre-emergence each *fb* straw mulch at 10 DAP followed by hand weeding at 75 DAP. The phyto-toxic effect of herbicide on turmeric plants have also been observed by Bharty *et al*. (2016a), Barla *et al.* (2015) and Jadhav and Pawar (2014).

**Yield and net returns**

Application of atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP recorded 50.5% higher fresh yield than hand weeding (**Table 1**). The higher yield owing to treatments integrated with metribuzin 0.7 kg/ha or pendimethalin 1.0 kg/ha or atrazine 0.75 kg/ha PE each *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP can be justified as combined effect of better weed control and reduced phyto-toxicity. Bharty *et al.* (2016a, b), Barla *et al*. (2015), Manhas *et al.* (2011) and Kaur *et al.* (2008) have also observed higher yield of turmeric under the treatments having straw mulch along with heribicides each *fb* hand weeding at 75 DAP. Similarly, maximum net return (` 621216/ha) and B:C ratio (4.45) was under atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP.

**Table 1. Effect of weed control methods on total weed density, total dry matter accumulation by weeds, yield, net return and B:C ratio of turmeric**

| Treatment | Total weed density (no./m$^2$) | | | Total dry matter accumulation by weeds (g/m$^2$) | | | Phyto-toxicity (0-10 scale) | Yield (t/ha) | Net return (x10$^3$ `/ha) | B:C ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAP | 90 DAP | 60 DAP | 30 DAP | 90 DAP | 150 DAP | 60 DAP | | | |
| Metribuzin *fb* 2 HW | 24.6(609) | 32.7(1072) | 25.8(667) | 8.7(76) | 22.6(513) | 20.9(435) | 3.33 | 20.95 | 415.93 | 3.86 |
| Pendimethalin *fb* 2 HW | 31.3(983) | 36.2(1312) | 32.7(1075) | 11.7(138) | 29.8(888) | 22.2(493) | 3.00 | 18.90 | 364.98 | 3.39 |
| Atrazine *fb* 2 HW | 21.2(451) | 32.2(1040) | 22.9(534) | 7.9(61) | 21.3(453) | 19.6(386) | 2.33 | 20.58 | 408.16 | 3.84 |
| Oxyfluorfen *fb* 2 HW | 18.3(340) | 27.8(779) | 20.5(422) | 6.9(47) | 18.6(344) | 19.3(371) | 3.33 | 16.07 | 293.11 | 2.70 |
| Oxadiargyl *fb* 2 HW | 17.7(319) | 26.9(725) | 21.3(454) | 6.7(44) | 18.2(330) | 18.3(336) | 3.67 | 15.26 | 273.74 | 2.54 |
| Glyphosate 1.25 l/ha *fb* 2 HW | 14.7(223) | 24.2(591) | 18.7(350) | 6.8(46) | 17.3(300) | 17.8(316) | 5.00 | 18.51 | 355.96 | 3.33 |
| Glyphosate1.85 l/ha *fb* 2 HW | 14.6(217) | 22.3(496) | 18.6(348) | 6.5(42) | 17.0(289) | 17.6(309) | 5.00 | 18.16 | 346.68 | 3.23 |
| Metribuzin *fb* fenoxaprop-p-ethyl + metsulfuron | 21.9(484) | 15.0(224) | 12.7(160) | 8.0(63) | 13.5(181) | 12.2(148) | 7.67 | 7.44 | 86.16 | 0.86 |
| Pendimethalin *fb* fenoxaprop-p-ethyl + metsulfuron | 26.3(692) | 17.1(292) | 15.7(248) | 10.8(115) | 15.9(254) | 15.0(226) | 8.00 | 5.55 | 39.15 | 0.39 |
| Atrazine *fb* fenoxaprop-p-ethyl + metsulfuron | 18.7(357) | 21.0(443) | 17.6(311) | 7.4(53) | 16.6(275) | 17.1(292) | 8.33 | 3.25 | -17.26 | -0.18 |
| Metribuzin *fb* straw mulch *fb* HW | 23.2(540) | 32.3(1056) | 25.2(640) | 8.2(68) | 21.5(464) | 19.3(371) | 1.33 | 28.06 | 595.38 | 5.61 |
| Pendimethalin *fb* straw mulch *fb* HW | 30.2(917) | 34.3(1179) | 29.3(862) | 11.2(125) | 26.8(721) | 21.0(441) | 1.67 | 26.05 | 545.40 | 5.18 |
| Atrazine *fb* straw mulch *fb* HW | 19.5(384) | 31.2(976) | 21.2(448) | 7.6(58) | 20.6(422) | 18.4(339) | 0.67 | 29.04 | 621.22 | 5.93 |
| Three hand weeding | 15.9(253) | 26.0(678) | 18.8(353) | 6.6(43) | 18.0(325) | 17.7(312) | 0.00 | 19.29 | 371.75 | 3.36 |
| Un-weeded check | 32.9(1086) | 45.8(2096) | 34.4(1182) | 12.1(146) | 33.0(1089) | 25.1(630) | 0.00 | 2.81 | -24.23 | -0.26 |
| LSD (p=0.05) | 3.92 | 3.16 | 2.60 | 0.82 | 1.12 | 0.81 | 1.48 | 3.19 | 798.8 | 0.75 |

Data in parentheses are original values.

**Table 2. Effect of weed control methods on dry matter accumulation and crop growth rate of turmeric plants**

| Treatment | Leaves (g/m$^2$) | | | Stems (g/m$^2$) | | | Rhizomes (g/m$^2$) | | | Total dry matter accumulation (g/m$^2$) | | | | Crop growth rate (g/m$^2$/day) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAP | 90 DAP | 150 DAP | 30 DAP | 90 DAP | 150 DAP | 90 DAP | 150 DAP | 210 DAP | 30 DAP (L+S) | 90 DAP (L+S+R) | 150 DAP (L+S+R) | 210 DAP (R) | 30-90 DAP | 90-150 DAP |
| Metribuzin *fb* 2 HW | 22.3 | 81.4 | 58.7 | 22.5 | 49.2 | 49.5 | 285 | 580 | 462 | 44.8 | 416 | 688 | 462 | 6.19 | 4.53 |
| Pendimethalin *fb* 2 HW | 21.8 | 75.3 | 49.1 | 21.4 | 42.9 | 41.5 | 221 | 480 | 389 | 43.3 | 339 | 570 | 389 | 4.93 | 3.85 |
| Atrazine *fb* 2 HW | 22.2 | 79.0 | 53.1 | 22.2 | 47.2 | 46.4 | 247 | 523 | 419 | 44.4 | 373 | 622 | 419 | 5.48 | 4.16 |
| Oxyfluorfen *fb* 2 HW | 21.1 | 52.7 | 45.0 | 21.1 | 33.5 | 33.4 | 129 | 327 | 262 | 42.1 | 215 | 405 | 262 | 2.89 | 3.16 |
| Oxadiargyl *fb* 2 HW | 20.9 | 52.1 | 37.4 | 20.8 | 29.5 | 32.1 | 144 | 317 | 253 | 41.7 | 226 | 386 | 253 | 3.07 | 2.67 |
| Glyphosate 1.25 l/ha *fb* 2 HW | 21.9 | 71.1 | 48.0 | 21.3 | 37.6 | 40.7 | 204 | 447 | 353 | 43.3 | 313 | 535 | 353 | 4.50 | 3.70 |
| Glyphosate1.85 l/ha *fb* 2 HW | 21.3 | 64.6 | 46.8 | 21.3 | 37.3 | 37.3 | 200 | 400 | 319 | 42.6 | 302 | 484 | 319 | 4.33 | 3.03 |
| Metribuzin *fb* fenoxaprop-p-ethyl + metsulfuron | 20.8 | 38.9 | 27.2 | 20.6 | 25.8 | 27.8 | 110 | 303 | 246 | 41.4 | 175 | 358 | 246 | 2.23 | 3.05 |
| Pendimethalin *fb* fenoxaprop-p-ethyl + metsulfuron | 20.5 | 37.1 | 23.2 | 20.5 | 27.9 | 26.1 | 136 | 270 | 217 | 41.0 | 201 | 319 | 217 | 2.68 | 1.96 |
| Atrazine *fb* fenoxaprop-p-ethyl + metsulfuron | 20.2 | 32.6 | 22.8 | 20.1 | 46.4 | 22.8 | 122 | 233 | 187 | 40.3 | 202 | 279 | 188 | 2.69 | 1.29 |
| Metribuzin *fb* straw mulch *fb* HW | 23.2 | 87.6 | 75.4 | 23.4 | 53.6 | 51.9 | 386 | 787 | 623 | 46.6 | 528 | 914 | 624 | 8.03 | 6.43 |
| Pendimethalin *fb* straw mulch *fb* HW | 22.4 | 85.9 | 70.3 | 23.3 | 53.0 | 50.5 | 354 | 650 | 518 | 45.7 | 494 | 770 | 518 | 7.47 | 4.62 |
| Atrazine *fb* straw mulch *fb* HW | 23.7 | 112.0 | 92.2 | 23.8 | 75.9 | 70.9 | 689 | 1246 | 1003 | 47.6 | 877 | 1409 | 1003 | 13.8 | 8.88 |
| Three hand weeding | 22.1 | 78.7 | 51.1 | 21.5 | 46.4 | 41.5 | 245 | 493 | 393 | 43.7 | 371 | 585 | 393 | 5.46 | 3.58 |
| Un-weeded check | 14.1 | 27.6 | 20.2 | 20.1 | 17.8 | 19.3 | 95.5 | 190 | 152 | 34.2 | 141 | 230 | 152 | 1.78 | 1.49 |
| LSD (p=0.05) | 3.94 | 38.8 | 21.3 | NS | 20.2 | 17.0 | 95.1 | 172 | 140 | 5.2 | 117 | 162 | 140 | 1.94 | 3.03 |

The higher net return was a result of 41.4 % higher yield and 28.8% reduced cost of cultivation compared to mean yield and cost of cultivation recorded by rest of the chemical methods of weed control. Similar trend of yield, net return and B:C ratio also found by Barla *et al.* (2015), Manhas *et al.* (2011) and Kaur *et al.* (2008).

### Crop growth rate

Crop growth rate was also higher under atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP at 30-90 and 90-150 DAP to the tune of 153.3 and 148.0% compared to hand weeding at 25, 45 and 75 DAP, respectively (**Table 2**).

Thus, it was concluded that application of atrazine 0.75 kg/ha pre-emergence *fb* straw mulch and hand weeding at 75 DAP may be practiced for better crop growth, higher productivity and profitability of turmeric owing to better weed control.

### SUMMARY

A field experiment was conducted at Birsa Agricultural University, Ranchi during rainy season of 2014 to study the efficacy of weed control methods as a suitable integrated weed management for better production of turmeric. Dry matter accumulation by total plant parts was maximum under atrazine 0.75 kg/ha pre-emergence (PE) followed by (*fb*) straw mulch at 10 DAP *fb* hand weeding at 75 DAP at all the stages. Application of atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP recorded higher rhizome yield consequently higher gross return (` 725917/ha). However, maximum net return (` 621216/ha) and B:C ratio (5.93) was recorded with application of atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP.

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**Short communication**

# Weed management effect on vegetative growth and flowering parameters of chrysanthemum

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Chrysanthemum *(Chrysanthemum morifolium* Ramat.) is one of the most widely cultivated herbaceous perennial plants belonging to family Asteraceae and commonly known as 'Autumn Queen' or 'Queen of East'. Chrysanthemum produces showy flowers with different flower colour, shape and plant height, that can be used as pot plants for beautifying indoors and outdoors, as cut flowers for making bouquets and base decoration, as loose flower for making garlands, worshipping purpose and for garden decoration (Arora 2013). It contributes largely to the floriculture industry by virtue of its yield potential, colour variation and long life. In the North-Indian plains, the commercial growers propagate chrysanthemum plants through terminal stem cuttings at the end of June that can be extended up to the end of July, *i.e. Kharif* season. After transplanting in July and August, the terminal rooted cuttings have a very slow growth rate initially as they take long time to get established in the field (Singh 2006). The early emergence and faster growth of weeds causes severe competition with crops for light, moisture, space and nutrients, resulting in yield losses up to 50-100% (Rao *et al.* 2007, Mehta *et al.* 2010, Meena *et al.* 2013). Use of pre-emergence herbicide can be a viable option for controlling weeds right from the emergence of crop (Shivasankar and Subramaniam 2011). Chrysanthemum is the most appropriate crop to concentrate on the development of successful weed control strategy to encourage crop growth and flowering that would be greatest benefit to the flower industry as a whole. Chemical weed control is an effective method and an alternative to old practices of manual weeding as manual weeding is costlier and has become impracticable due to non-availability of labourers during the critical period of weed competition. Though use of pre-emergence herbicide, immediately after transplanting of very tender rooted cuttings, can give good control of weeds, but may retard growth and development of the delicate seedlings. Keeping all these in view, the present experiment was conducted to enhance the vegetative growth and flower yield with better weed control, using different combinations of herbicides.

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Field experiment was carried out during the winter season of 2014-15 at the research farm of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana. Soil of the experimental site was sandy loam in texture with a pH of 8.3. Experiment comprises of seven treatments (**Table 1**) was laid out in a randomized block design with three replications. The healthy terminal rooted cuttings (5-7 cm) of chrysanthemum cv. "*Ratlam Selection*", free from symptoms of any disease or insect pest were prepared during mid of June and then planted in propagating plug trays having burnt rice husk as rooting media. Plug trays were kept moist by sprinkling water to ensure satisfactory rooting of cuttings. New roots developed after 15-20 days. After the application of herbicides, the plots were kept undisturbed till transplanting of rooted cuttings. Terminal rooted cuttings were transplanted in field in the first week of August for further evaluation. Planting of terminal rooted cuttings was done at a spacing of 30 x 30 cm having plot size of 1.5 x 1.5 m. All the package of practices recommended by PAU, Ludhiana were followed to get good plant growth and quality flower production. Pinching operation was practiced at two stages *i.e.* first at four weeks after transplanting and second at seven weeks after transplanting to encourage the emergence of lateral shoots. Observations on weed count and weed fresh as well as dry weight (g), at 25 and 50 days after application of herbicides were recorded. Observations on vegetative and flowering parameters like plant height (cm), plant spread (cm), days to colour break stage, days to full bloom stage, number of flowers per plant, flower diameter (cm) and flowering duration (days) were recorded and statistically analysed. Species wise weed count was recorded.

## Effect on weed growth

The major weed flora of the experimental field were *Cyperus rotundus* (Motha), *Dactyloctenium aegyptium* (Makra), *Eleusine indica* (Madana), *Paspalum distichum* (Nadi Ghas) and *Phyllanthus niruri* (Hazardani) (**Table 1**).

Pre-planting application of pendimethalin 1.0 kg/ha *fb* hand weeding 30 and 60 DAP controlled the maximum weed population effectively and recorded the lowest population of *C. rotundus* (8.8), *D. aegyptium* (4.1), *E. indica* (3.6), *P. distichum* (3.0) and *P. niruri* (3.5) per unit area at 50 days after transplanting as compared with weedy check. The pre- planting application of pendimethalin 1.0 kg/ha followed by (*fb)* hand weeding 30 and 60 DAP and post-emergence application of isoproturon 0.75 kg/ha 20 DAP *fb* hand-weeding 60 DAP, however, were statistically at par regarding the reduction in total weed count, weed fresh weight (g) and weed dry weight (g) per unit area 50 days after transplanting (**Table 2**). Reduction in weed population in these treatments can be attributed to relatively better management practices which shifted the competition in favour of chrysanthemum. Similar results were also reported by Kaur *et al.* (2014).

## Effect on vegetative growth and flowering parameters

All the weed management treatments significantly influenced vegetative and flowering parameters like flowers/plant, diameter, flowering duration in chrysanthemum (**Table 3**). Weed free treatment exhibited maximum plant spread, number of branches, followed by pre-planting application of pendimethalin 1.0 kg/ha *fb* hand weeding 30 and 60 DAP which may be due to better availability of nutrients, moisture, sunlight and space for crop growth in weed free treatment. This is in conformity with the findings of Kaur and Bala (2016). The lowest plant height was recorded in weedy check which may be due to more weed pressure, resulting in severe competition with the crop for resources. All the treatments didn't show any significant results with regard to days to bud appearance, days to colour shown and number of days to flowering. Similar results were reported in gladiolus (Kumar 2001), with respect to number of flowers, flower diameter and flowering duration, treatment comprising pre-planting application of pendimethalin 1.0 kg/ha *fb* hand weeding 30 and 60 DAP and weed-free check were comparable with each other that resulted in greater values of floral traits than other treatments. The highest number of flowers per plant (71.9), maximum flower diameter (9.5 cm) and flowering duration (24.8 days) was observed with weed free check, followed by with pendimethalin 1.0 kg/ha *fb* hand weeding 30 and 60 DAP with flowers per plant (65.4), flower diameter (8.3 cm) and flowering duration (20.9 days). This was due to the fact that the crop plants in these treatments experienced good vegetative growth right from the early stages of growth period to the end of cropping period because of less competition of weeds for nutrients, water, space, sunlight and nutrients which might have resulted in higher photosynthetic activity and higher number of flowers per plant. Similar results were also reported in chrysanthemum by Kaur *et al.* (2014).

**Table 1. Effect of herbicides on population of different weed species in chrysanthemum**

| Treatment | Weed density (no./$m^2$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *C. rotundus* | | *D. aegyptium* | | *E.indica* | | *P.distichum* | | *P.niruri* | |
| | 25 DAT | 50 DAT | 25 DAT | 50 DAT | 25 DAT | 50 DAT | 25 DAT | 50 DAT | 25 DAT | 50 DAT |
| Atrazine 0.75 kg/ha (PPA) *fb* hand weeding 30 and 60 DAP | 87.3 (9.3) | 108.7 (10.4) | 8.0 (2.3) | 20.0 (4.6) | 8.3 (3.0) | 16.0 (4.1) | 4.7 (2.3) | 13.3 (3.8) | 5.3 (2.5) | 16.0 (4.1) |
| Pendimethalin 1.0 kg/ha (PPA) *fb* hand weeding 30 and 60 DAP | 68.7 (8.31) | 76.7 (8.8) | 6.0 (2.6) | 16.0 (4.1) | 7.0 (2.8) | 12.0 (3.6) | 2.7 (1.8) | 8.0 (3.0) | 4.0 (2.1) | 11.7 (3.5) |
| Isoproturon 0.75 kg/ha 20 DAP (PoE) *fb* hand weeding 60 DAP | 97.3 (9.9) | 106.7 (10.3) | 11.0 (3.5) | 25.3 (5.1) | 12.0 (3.6) | 20.0 (4.6) | 8.7 (3.0) | 19.3 (4.5) | 10.7 (3.4) | 20.0 (4.5) |
| Three hand weedings at 30, 60 and 90 DAP | 101.3 (10.1) | 110.7 (10.5) | 12.0 (3.6) | 22.0 (4.8) | 13.0 (3.7) | 18.0 (4.3) | 10.7 (3.4) | 26.7 (5.2) | 9.3 (3.1) | 22.0 (4.8) |
| Oxyflurofen 0.2 kg/ha (PPA) *fb* hand weeding 30 and 60 DAP | 80.0 (9.0) | 100.0 (10.0) | 7.0 (2.8) | 17.3 (4.2) | 8.0 (3.0) | 12.0 (3.6) | 6.0 (2.6) | 10.7 (3.4) | 6.7 (2.7) | 12.7 (3.7) |
| Weedy check | 132.7 (11.5) | 166.0 (12.9) | 15.0 (4.0) | 28.0 (5.4) | 16.0 (4.1) | 24.0 (5.0) | 12.7 (3.7) | 40.7 (6.4) | 13.3 (3.7) | 39.3 (6.3) |
| Weed free check | 0 (1.0) | 0 (1.0) | 0 (1.0) | 0 (1.0) | 0 (1.0) | 0 (1.0) | 0 (1. 0) | 0 (1.0) | 0 (1.0) | 0 (1.0) |
| LSD (p=0.05) | 1.93 | 1.98 | 0.11 | 0.41 | 0.33 | 0.43 | 0.99 | 1.02 | 0.99 | 0.94 |

Figures in parentheses are the means of square root transformation; PPA - Pre-planting application, PoE - Post-emergence

**Table 2. Effect of different herbicides on total weed density and dry weight in chrysanthemum**

| Treatment | Weed count/m$^2$ | | Fresh weight (g/m$^2$) | | Dry weight (g/m$^2$) | |
|---|---|---|---|---|---|---|
| | 25 DAT | 50 DAT | 25 DAT | 50 DAT | 25 DAT | 50 DAT |
| Atrazine 0.75 kg/ha (PPA) *fb* hand weeding 30 and 60 DAP | 109.3(10) | 126.3(11.2) | 50.4(7.2) | 62.5(80) | 38.5(6.3) | 49.1(7.1) |
| Pendimethalin 1.0 kg/ha (PPA) *fb* hand weeding 30 and 60 DAP | 70.7(8.4) | 87.8(9.4) | 44.7(6.7) | 55.2(7.5) | 33.5(5.8) | 44.3(6.7) |
| Isoproturon 0.75 kg/ha 20 DAP (PoE) *fb* hand weeding 60 DAP | 79.3(8.9) | 102.0(10.1) | 54.8(7.5) | 65.6(8.2) | 43.1(6.6) | 53.4(7.4) |
| Three hand weedings at 30, 60 and 90 DAP | 81.3(9.0) | 100.0(10.0) | 53.2(7.3) | 63.4(8.0) | 46.8(6.9) | 57.1(7.6) |
| Oxyflurofen 0.2 kg/ha (PPA) *fb* hand weeding 30 and 60 DAP | 102.0(10.1) | 124.7(11.2) | 30.7(4.9) | 53.3(7.4) | 37.7(6.2) | 47.5(7.0) |
| Weedy check | 184.7(13.6) | 236.0(15.4) | 60.3(7.8) | 79.7(9.0) | 51.1(7.2) | 71.5(8.5) |
| Weed free check | 0.0(1.0) | 0.0(1.0) | 0.0(1.0) | 0.0(1.0) | 0.0(1.0) | 0.0(1.0) |
| LSD (p=0.05) | 1.89 | 6.78 | 2.51 | 0.56 | 0.64 | 0.46 |

Figures in parentheses are the means of square root transformation; PPA - Pre-planting application, PoE - Post-emergence

**Table 3. Effect of pre and post-emergence herbicide on growth parameters in chrysanthemum**

| Treatment | Plant height (cm) | No. of branches/ plant | Plant spread (cm) | Days to first bud appearance | Days to colour break | Days to full bloom | No. of flowers/ plant | Flower diameter (cm) | Flowering duration (days) |
|---|---|---|---|---|---|---|---|---|---|
| Atrazine 0.75 kg/ha (PPA) *fb* hand weeding 30 and 60 DAP | 43.40 | 4.27 | 28.34 | 85.92 | 98.67 | 116.87 | 63.20 | 7.95 | 20.61 |
| Pendimethalin 1.0 kg/ha (PPA) *fb* hand weeding 30 and 60 DAP | 45.50 | 5.15 | 30.95 | 83.06 | 98.60 | 115.80 | 67.32 | 8.51 | 21.78 |
| Isoproturon 0.75 kg/ha 20 DAP (PoE) *fb* hand weeding 60 DAP | 42.48 | 4.23 | 30.06 | 86.15 | 99.60 | 117.09 | 58.77 | 6.85 | 19.89 |
| Three hand weedings at 30, 60 and 90 DAP | 40.67 | 4.03 | 28.85 | 83.77 | 101.49 | 117.54 | 60.02 | 6.57 | 19.87 |
| Oxyflurofen 0.2 kg/ha (PPA) *fb* hand weeding 30 and 60 DAP | 44.41 | 4.58 | 30.30 | 84.52 | 99.99 | 116.20 | 65.97 | 8.43 | 20.97 |
| Weedy check | 38.96 | 3.82 | 26.96 | 86.78 | 103.37 | 117.06 | 45.02 | 5.68 | 16.25 |
| Weed free check | 47.26 | 6.37 | 33.67 | 82.43 | 95.89 | 113.52 | 73.80 | 10.57 | 25.60 |
| LSD (p=0.05) | 4.26 | 0.64 | 2.16 | NS | NS | NS | 7.44 | 0.51 | 3.96 |

Weedy check resulted in the lowest number of flowers per plant (43.1), flower diameter (5.5 cm) and flowering duration (14.2 day).

It was concluded that pre-plant application of pendimethalin 1.0 kg/ha *fb* hand weeding at 30 and 60 DAP was effective in controlling weeds and improving growth and flower productivity of chrysanthemum.

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**Short communication**

# Isolation, host specificity and biocontrol potential of *Gibbago trianthemae* against horse purslane weed

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**Key words:** Biocontrol, *Gibbago trianthemae,* Mycoherbicide, *Trianthema portulacastrum*

*Trianthema portulacastrum* L. (Aizoaceae) has been considered as one of the invasive weeds in Visakhapatnam District and has become an important weed due to its significant interference with many agricultural crops like brinjal, okra and other vegetable crops. The weed is currently controlled by mechanical methods and also the application of pre- and post-emergence herbicides. But in view of pesticide residues and environmental pollution, the exploitation of microorganisms especially plant pathogenic fungi is now emerging as an effective and eco-friendly alternative to conventional methods of weed control (Charudattan 1991). Mycoherbicides are attractive agents in weed management because of their specificity, low environmental impact and cost effectiveness (Bohra *et al.* 2005, Boyette *et al.* 2007). The fungal species *G. trianthema*e on *Trianthema* weed was first recorded from India by Aneja and Kaushal (1998). Earlier it was described from the USA, Cuba and Venezuela as a new phaeodictyoconidial genus (Simmons 1986). Several workers reported that *G. trianthemae* is pathogenic to *T. portulacastrum* (horse purslane) and it may be a possible candidate for inundative mycoherbicide to control horse purslane. (Aneja *et al.* 2000, Akhtar *et al.* 2013).

Weed infestation was studied using a random sampling method from different agricultural fields at Vishakhapatnam District. The diseased plants and propagules were collected randomly into sterilized polythene bags and brought to the laboratory for further study. The diseased leaves were washed thoroughly in running tap water to remove soil particles and the infected portions of the leaves were cut into 1.0 - 1.5 cm fragments. The pieces were surface sterilised by 70% ethyl alcohol for 1-2 minutes and then rinsed in sterile distilled water for three to four times. Finally the leaf bits were rinsed in 0.01% mercuric chloride for 1 or 2 minutes followed by washing with sterile autoclaved double distilled water for 2 or 3 times. After surface sterilization, the leaf bites were transferred on to Czapek's Dox Agar (CZA) and potato dextrose agar (PDA) plates supplemented with 1% streptomycin sulphate (antibiotic) under sterile conditions in an inoculation chamber. After inoculation, plates were incubated at 26 ±2°C for 21 days under a 12 h light/dark photoperiod in an incubation chamber. The isolates were purified from the fungal colonies sprouting on inoculated leaf lesions. The stock cultures of the isolates were prepared by monoculture (single conidial culture) and stored at room temperature as slant cultures on PDA media. The isolates were examined by the staining techniques and diagnostic characteristics of the isolates were examined under light microscope.

Seeds of *T. portulacastrum* were collected from the plants. The collected seeds were dried and maintained in healthy conditions. The plants for further studies were grown by sowing the seeds of horse purslande in 25 x 15 cm diameter plastic pots containing sterilized black soil. The pots containing seedlings of weed plants were maintained at 25-30$^0$C on wood stand in a green house with a 12 h light/dark photoperiod. For host range studies, test plants were maintained in replicates along with control plants. The test plants with healthy, young and greenish leaves were used for the spore inoculation of the fungal isolates. Spore inocula harvested from young colonies of the isolates was adjusted as précised concentrations ($5x10^4$ spores/ml) using improved Neubauer haemocytometer (Depth = 0.1 mm) for the spore treatment of test plants and other plants for host range (**Table 1**). The spore application on greenhouse test plants was carried out by using hand spryer and 0.02% of Tween-20 was added to spore suspension as an adjuvant. Spore inoculum was applied onto the test plants of *T. portulacastrum* and host range plants within 2 hours of sunset to avoid drying and to allow for a natural dew period shortly afterwards. Plants were observed three days after treatment (DAT) for disease symptoms.

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The disease intensity of pathogens on test plants was determined using a score chart (-, no symptoms, a healthy plant; +, mild symptoms, a plant showing slight symptoms on 15% of the leaf area; ++, moderate symptoms, a plant showing definitely bigger patches of diseased areas on 16 to 59% of the leaf area; and +++, severe symptoms, enlarged lesions covering 60 to 80% of the leaf area) following methods of Ray and Hill (2012).

**Field observations**

Horse purslane was found severely competing with agricultural crops such as paddy, sorghum, maize, sugarcane, groundnut, brinjal, tomato, ladies' fingers *etc*. The maximum weed infestation was found in the vegetable crops such as ladies' fingers, tomato, capsicum and ridge gourd. The typical fungal symptoms on parasitized parts of the horse purslane were noticed. Disease symptoms on leaves were found as pinpoint round to oval maroon spots in early stages of infection. The disease symptoms were observed on both adaxial and abaxial leaf surfaces. The diseased spots expanded with the passage of time and became sunken and straw coloured with maroon borders. Later, few spots coalesced and the whole leaves became chlorotic and dried up causing severe defoliation. Under severe attack quite similar lesions were also observed around the stems causing withering. Although all the stages of leaves showed infection, the mature leaves were more heavily affected.

**Pathogenicity and host range**

A total of five isolates namely *Alternaria alternata* (Fr.) Keissler., *Bipolaris maydis* (Y.Nisik. and C. Miyake) Shoemaker., *Curvularia lunata* (Wakker) Boedijin., *Curvularia tuberculata* Sivan. and *Gibbago trianthemae* Simmons were identified in cultures of horse purslane infected leaf bits but only the isolate *G. trianthemae* was confirmed by pathogenicity tests as the causal agent of leaf spot on host weed.

A total of 50% test plants of horse purslane were infected within 20 days of spore treatment. *G. trianthemae* caused severe wilting and chlorosis of test plants of horse purslane within 30 days of inoculation. Defoliation followed by mortality of horse purslane was observed between 35 to 40 days of post inoculation (**Table 2**). No pathogenic symptoms were visible on crop plants included *Zea mays* L., *Eleusina coracana* Gaertner, *Cajanus cajan* (L.) Millsp., *Vigna mungo* (L.) Hepper, *Solanum melongena* L., *Abelmoschus esculentus* (L.) Moench, *Lycopersicon esculentum* Miller., *Capsicum annuum* L., *Arachis hypogaea* L., *Sesamum indicum* L., *Amaranthus viridis* L., *Brassica oleraceae* L. and *Spinacia oleraceae* L. Test revealed that isolate of *G. trianthemae* caused extensive damage to host plant (horse purslane) only and was not harmful to crop plants (**Table 1 and 2**).

However, some studies have indicated that host-specific biocontrol agents can also exhibit significant damage to non-target effects (Pearson and Callaway 2003). Our study findings suggested rhat pathogen has virulence against its host plant (horse purslane) only and not harmful to other economically important crop plants tested *in vitro*. To date, the pathogen has not been found to cause disease on any other plant species. This paper has reported only primary information on pathogenicity of *G. trianthemae* against *T. portulacastrum* but extensive studies on host-pathogen interaction, infection process, growth and sporulation, mass culture and compatibility with various pesticides are needed for the development of effective mycoherbicide.

**Table 1. Host specificity of *G. trianthemae* after spore treatment on test plants**

| Plants used for spore treatment | Family | DI | Disease reaction |
|---|---|---|---|
| Control plant | | | |
| *Trianthema portulacastrum* L. | Aizoaceae | +++ | S |
| Test plants | | | |
| *Zea mays* L. | Poaceae | - | R |
| *Eleusina coracana* Gaertner | Poaceae | - | R |
| *Cajanus cajan* (L.) Millsp. | Fabaceae | - | R |
| *Vigna mungo* (L.) Hepper | Fabaceae | - | R |
| *Solanum melongena* L. | Solanaceae | - | R |
| *Abelmoschus esculentus* (L.) Moench | Malvaceae | - | R |
| *Lycopersicon esculentum* Miller. | Solanaceae | - | R |
| *Capsicum annuum* L. | Solanaceae | - | R |
| *Arachis hypogaea* L. | Fabaceae | - | R |
| *Sesamum indicum* L. | Pedaliaceae | - | R |
| *Amaranthus viridis L.* | Amaranthaceae | - | R |
| *Brassica oleraceae L.* | Brassicaceae | - | R |
| *Spinacia oleraceae L.* | Chenopodiaceae | - | R |

DI= Disease intensity; +++ = Severe infection; - =No infection; S= Susceptible; R=Resistant

**Table 2. Disease intensity of *Gibbago trianthemae* at different growth stages of horse purslane weed**

| Concentration of inoculum | Growth stage | PDI |
|---|---|---|
| 5 x $10^4$/ml + 0.02 (Tween-20) | Stage -1 (3-5 foliage) | 95.5 ±1.1 |
| | Stage -2 (6-10 foliage) | 87.04± 2.0 |
| | Stage -3 (11-14 foliage) | 78.9±3.2 |
| | Stage -4 (15-20 foliage) | 77.08±2.4 |

PDI= Percent Disease Index (Mean ± Standard Error)

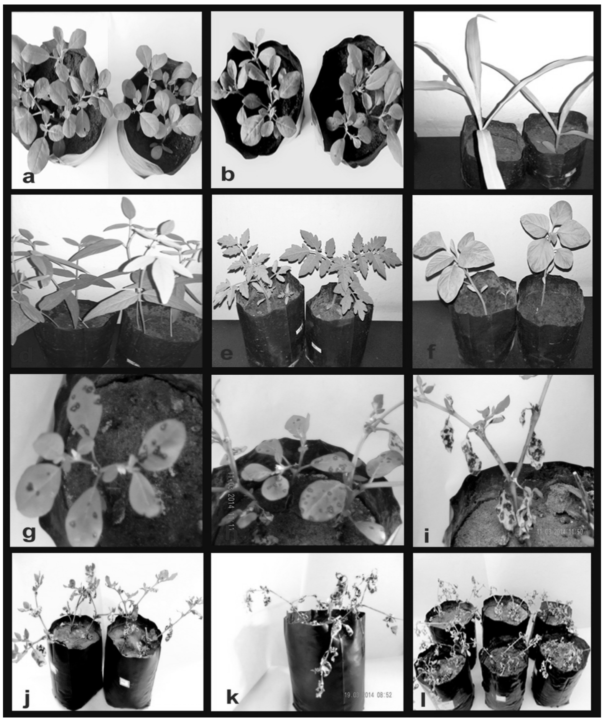


**Figure 1. *In vitro* test on host specificity of *G. trianthemae***

A&B-Control plants of horse purslane;C, D, E & F - test plants *Zea mays*, *Cajanus cajan*,*Lycopersicon esculentum* and *Amaranthus viridis* respectively;G, H & I - Development of leaf spot on host weed; J & K- Defoliation of host weed;I - Eradication of horse purslane weed

## SUMMARY

*In vitro* study, pathogenicity test of the isolate, *Gibbago trianthemae* which causes leaf spot and blight disease on horse purslane was confirmed. Study revealed that *G. trianthemae* is highly pathogenic to horse purslane as evidenced by the rapid rate of infection and colonization of the host. The test plants inoculated with 5x$10^4$ spores/ml concentration showed high susceptibility to *G. trianthemae* incheding of crops only. Foliar pathogen *G. trianthemae* might be useful as a mycoherbicide to control its host weed.

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**Short communication**

# Biopesticidal properties and composting efficiency of *Parthenium*

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**Key words:** *Parthenium* compost, *Spodoptera litura, Pieris brassicae, Parthenium hysterophorous*

*Parthenium hysterophorous* L. of family Astreraceae is an exotic species commonly known as "Congress Grass" which has invaded about 35 billion hectares of land in India (Sushilkumar and Varshney 2010) and is responsible for loss in cop productivity and biodiversity besides causing health problems in man and animals. It has allelopathic effect and inhibits the germination and growth of neighbouring plants by releasing various allelochemicals such as water soluble phenolics and sesquiterpene lactones including parthenin and coronopilin. *Parthenium* extract has been reported to cause insect mortality, antifeedant activity (Sushilkumar and Singh 2004) and inhibit pathogens.

Composting of organic waste is gaining interest as a suitable option for manures with economic and environment profit. Since the economic use of *Parthenium* is impaired by its toxic property, therefore, its compositing can be a useful alternative and it can be used as a soil conditioner. The compost prepared from *Parthenium* has high level of macro and micronutrient. The present investigation was carried out to study the biopesticidal properties and composting efficiency of this weed.

### Biopesticidal studies

Leaves of *Parthenium* were collected during the months of March-April 2014, shade dried under laboratory conditions, grinded and powdered. The plant material was extracted in solvents according to the method used by Singh (1996) and working concentrations prepared. The extracts were tested for ovicidal and larvicidal properties against two phytophagous insects, *viz*. cabbage butterfly (*Pieris brassicae*) and tobacco caterpillar (*Spodoptera litura)* common on vegetable crops and against phytopathogens (*Alternaria alternate, Sclerotium rolfsii, Fusarium oxysporum,Penicillium expansum, Rhizopus stolonifer, Aspergillus niger*).

For phytopathogens, effect on colony diameter in each treatment was measured on the fifth day after inoculation and the per cent inhibition of each phytopathogen was calculated (Vincent 1947).

$$\text{Growth inhibition (\%)} = \frac{\text{Colony diameter in control - colony diameter in treatment (mm)}}{\text{Colony diameter in control (mm)}} \times 100$$

The data was recorded in triplicates and subjected to statistical analysis.

### Compositing studies

*P. hysterophorous* before flowering was collected during April 2014. The collected plants were chopped into small pieces for composting. The experiment was done in cardboard boxes of 50 x 35 x 30 cm (length x breadth x height) in completely randomized design in four replications with five treatments. The boxes were placed in a shed and moisture content was maintained to about 60% by sprinkling water at alternate days. Turning of the compost was made after 15 days to improve aeration. The composting period was recorded. Samples from each treatment were collected from the centre of each compost box for physico-chemical analysis using standard methods. Total number of earthworm from the treatment *Parthenium* + cow dung (3:1) + earthworms 200 g per replication and *Parthenium*+ cow dung + agriculture waste + earthworm [3(1.5+1.5):1+200 g earthworm] were counted and weighed. Recovery percentage (compost prepared in each treatment was weighed at the end of the experiment and total composting period noted) was also calculated.

### Effect on insect

At concentration of 5.0% of petroleum ether and aqueous extracts, egg hatching was not observed in *P. brassicae* after 48 hrs (**Table 1**). Maximum per cent egg hatching 83.1% and 84.8% was recorded in control. At 2.5% concentration of petroleum ether extract, 4.2% egg hatching for *P. brassicae* was recorded. The egg hatching in petroleum ether and aqueous extract for *S. litura* ranged from 21.4-92.1%

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**Table 1. Ovicidal effect of *Parthenium* extract on *Pieris brassicae* and *Spodoptera litura***

| Concentrations | Percent egg hatching after 48 hrs | | | |
|---|---|---|---|---|
| | Petroleum ether extract | | Aqueous extract | |
| | *P. brassicae* | *S. litura* | *P. brassicae* | *S. litura* |
| 5.0% | 0.0 (0.00) | 21.4 (27.09) | 0.0 (0.00) | 22.3 (28.09) |
| 2.5% | 4.2 (6.90) | 18.2 (24.55) | 10.3 (15.43) | 27.4 (31.52) |
| 1.0% | 19.0 (25.32) | 41.9 (40.04) | 18.1 (25.18) | 43.3 (41.14) |
| 0.5% | 15.6 (19.16) | 75.1 (60.28) | 46. (42.31) | 57.3 (45.34) |
| Control | 83.1 (65.76) | 92.1 (76.55) | 84.8 (55.75) | 83.6 (66.42) |
| LSD (p=0.05) | 18.33 | 16.90 | 28.91 | N/S |

Values in parentheses are arc sine transformation

and 22.3 - 83.6%, respectively (**Table 1**). At 0.5% concentration egg hatching for *S. litura* after 48 hrs in petroleum ether and aqueous extracts was 75.1 and 57.3%, respectively. The toxic and ovicidal effect of petroleum ether extract is reported for *Aedes aegypti* (Kumar *et al*. 2011).

The highest mortality of second instar larvae of *P. brassicae* on exposure to petroleum ether extract was 73.3% after 48 hrs at 2.5% concentration which was at par with 5.0% (**Table 2**). The superiority of *Parthenium* for larvicidal effect has been reported by Khan *et al.* (2014).

The highest mortality of 50.0% after 48 hrs of exposure of first instar larvae of *S. litura* was recorded in petroleum ether extract of *Parthenium*. Singh *et al*. (1996) reported 73.23 per cent larval mortality of *S. litura* after 72 hours with ethyl acetate.

## Effect of pathogens

Maximum per cent growth inhibition was observed in *Sclerotium rolfsii* (59.5%) followed by *Fusarium oxysporum* (58.6%), *Penicillium expansum* (53.1%) and *Alternaria alternata* (35.6%), while the least per cent growth inhibition was recorded in *Rhizopus stolonifer* (26.7%) and *Aspergillus niger* (29.3%) (**Table 3**).

## Physicochemical characteristics of compost

The percentage recovery of the compost ranged from 42.2-62.8%. It was highest (62.8%) in treatment *Parthenium* + cow dung + earthworms. The whole process of composting took approximately 18 months for completion which confirmed the study of Yadav and Garg (2011).

In the present study, N and P content was high in the treatments where *E. fetida* was added for composting, similarly K content was also statistically highest in *Parthenium* + cow dung + agriculture waste + earthworms and *Parthenium* + cow dung + earthworms though at par with each other as compared to compost of *Parthenium* alone and other treatments. Bhoyar (2013) also reported high compositing value of *Parthenium* (1.05, 0.84, 1.11 per cent N,P,K content), as compared to FYM alone (0.5, 0.2, 0.5 per cent N,P,K content). The treatments did not differ statistically from each other with respect to C/N ratio and organic carbon. Though the parameters had high value for *Parthenium* + cow dung (3:1) followed by *Parthenium* alone. Compost mixtures *Parthenium* + cow dung + earthworms and *Parthenium* + cow dung + agriculture waste + earthworms recorded low values for organic carbon and C/N ratio.

**Table 3. Growth inhibition of phytopathogens by aqueous extract of *Parthenium* at 10%**

| Phytopathogens | Per cent growth inhibition |
|---|---|
| *Alternaria alternata* | 35.6 (6.05) |
| *Sclerotium rolfsii* | 59.5 (7.77) |
| *Fusarium oxysporum* | 58.6 (7.72) |
| *Aspergillus niger* | 29.3 (5.50) |
| *Penicillium expansum* | 53.1 (7.35) |
| *Rhizopus stolonifer* | 26.7 (5.36) |
| LSD (p=0.05) | 1.39 |

Values in parentheses are arc sine transformation

**Table 2. Toxic effect of *Parthenium* extracts on *Pieris brassicae* and *Spodoptera litura***

| Concentrations | % mortality after 48 hours | | | | | |
|---|---|---|---|---|---|---|
| | Petroleum ether extract | | | Aqueous extract | | |
| | *P. brassicae* | | *S. litura* | *P. brassicae* | | *S. litura* |
| | 1st Instar | 2nd Instar | 1st Instar | 1st Instar | 2nd Instar | 1st Instar |
| 5.0% | 100.0 (90.00) | 50.0 (43.98) | 50.0 (49.21) | 73.3 (63.83) | 70.0 (56.76) | 60.0 (51.12) |
| 2.5% | 100.0 (90.00) | 73.3 (58.98) | 26.7 (30.28) | 60.0 (50.91) | 70.0 (57.26) | 53.3 (46.90) |
| 1.0% | 76.7 (66.13) | 23.3 (28.76) | 23.3 (28.06) | 53.3 (47.28) | 40.0 (39.04) | 26.0 (17.06 |
| 0.5% | 63.3 (52.83) | 16.7 (19.91) | 26.7 (30.28) | 0.0(0.00) | 13.3 (21.13) | 26.7 (30.77) |
| Control | 0.0(0.00) | 0.0(0.00) | 0.0(0.00) | 0.0(0.00) | 0.0(0.00) | 0.0(0.00) |
| LSD (p=0.05) | 19.47 | 23.71 | N/S | 23.47 | 19.90 | 13.04 |

Values in parentheses are arc sine transformation

**Table 4. Physico-chemical characteristics of *Parthenium* compost**

| Treatment | N (%) | P (%) | K (%) | Organic carbon (%) | pH | EC (dS/m) | C/N ratio | Recovery (%) |
|---|---|---|---|---|---|---|---|---|
| *Parthenium* alone | 1.6 (1.60) | 0.4 (1.16) | 1.2 (1.48) | 49.5 (44.6) | 7.9 | 2.7 | 33.7 | 47.5 |
| *Parthenium* + cow dung 3:1 | 1.5 (1.54) | 0.4 (1.18) | 2.0 (1.72) | 54.9 (47.8) | 7.6 | 2.7 | 36.5 | 52.2 |
| *Parthenium* + cow dung + earthworms | 1.8 (1.67) | 1.3 (0.72) | 3.0 (2.00) | 26.0 (30.3) | 8.1 | 2.9 | 16.7 | 62.8 |
| *Parthenium* + cow dung + agriculture waste | 1.6 (1.62) | 0.4 (1.18) | 2.4 (1.83) | 29.8 (31.7) | 7.0 | 1.8 | 16.9 | 42.2 |
| *Parthenium* + cow dung + agriculture waste + earthworms | 1.9 (1.71) | 0.80 (1.34) | 3.1 (2.01) | 21.3 (26.8) | 7.5 | 2.0 | 11.0 | 51.4 |
| LSD (p=0.05) | N/S | N/S | 0.29 | N/S | N/S | N/S | N/S | N/S |

Values in parentheses are square root and are arcsine transformation

The pH and EC of the compost prepared at all the treatments ranged from 7.04-8.11 and 1.82-2.94, dS/m, respectively. Sangwan *et al*. (2011) reported decrease in pH of *Parthenium* compost prepared along with sugar mill sludge and biogas plant slurry by employing *E. fetida* as compared to compost prepared from *Parthenium* alone. In the present study pH values were more *i.e*. 8.11 when *Parthenium* and cow dung was composted with earthworm, but did not differ statistically from other treatments. Yadav and Garg (2011) also reported decrease in pH for compost of *Parthenium* mixed with cow dung using *E. fetida*. In the present investigation, though there was no significant difference in EC value of different compost but highest value of 2.94 dS/m was recorded for compost prepared from *Parthenium* and cow dung by earthworms. The results find support from the findings of Yadav and Garg (2011) who also reported increase in EC value in the compost prepared from *Parthenium* using *E. fetida*.

## SUMMARY

No egg hatching of *P. brassicae* was recorded at the highest concentration (5.0%) of petroleum ether and aqueous extracts of *Parthenium*. After 48 hrs of exposure of first instar of *P. brassicae*, 100% mortality was recorded at 2.5% and 5.0 concentration. Aqueous extract of *Parthenium* provided good control with 70.0% mortality of second instar of *P. brassicae* after 48 hrs of exposure. The petroleum ether extract and aqueous extract of *Parthenium* provided 50% and 60% mortality of first instar of *S. litura*, whereas 10% aqueous extract of *P. hysterophorous* recorded maximum % growth inhibition of *Sclerotium rolfsii* (59.5%). The compost prepared with *E. fetida* inoculum had high N, P, K content and low organic carbon and C/N ratio. Maximum (62.8%) recovery was recorded in *Parthenium* + cow dung + earthworm treatment.

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