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# Chemical weed management effects on productivity and profitability of gladiolus (*Gladiolus hybridus*) in north-western Indo-Gangetic Plains

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ABSTRACT

A field experiment, involving ten weed control treatments laid out in a randomized complete block design with three replications, was undertaken at the Indian Agricultural Research Institute, New Delhi during the winter seasons, 2011-12 and 2012-13. The objective was to evaluate the effects of different combinations of herbicides, particularly pre-emergence tank-mix herbicides applications on weeds, and flowering, corm yield and benefit-cost economics of gladiolus (*Gladiolus hybridus* Hort.). It was observed that all herbicidal treatments resulted in significantly lower density of monocot and dicot weeds, and total weed dry weight compared to weedy check, which had the highest two-year mean density of monocot (165/$m^2$) and dicot (364/$m^2$) weeds and total weed dry weight (171 g/$m^2$). Among herbicide treatments, atrazine 1.0 kg/ha pre-emergence followed by rice residue @ 5 tonnes/ha at 2 days after atrazine application caused the greatest reduction in density and dry weight of weeds. All herbicidal treatments, except butachlor 1.0 kg/ha pre-emergence, were equally effective as this treatment against weeds. The herbicides and their doses adopted in this study did not pose any phytotoxicity to gladiolus plants. The tank-mix pre-emergence applications were usually more effective than the single herbicide application. The tank-mix pre-emergence application of pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha resulted in significantly greater two-year mean gladiolus plant height (116 cm), cut-flower yield (172 500 spikes/ha), corm yield (3.82 tonnes/ha) and net returns (₹ 243 100/ha) compared to weedy check and most other treatments, and was most remunerative.

**Key words:** Corm yield, Cut-flower, Gladiolus, Tank-mix herbicide, Weed

Gladiolus (*Gladiolus hybridus* Hort.) is one of the most important ornamentals for cut-flower trade in India and abroad. It is also ideal for garden display, floral arrangements for table and interior decoration as well as making high quality bouquet (Lepcha *et al*. 2007). It is popular for its attractive spikes having florets of different forms and sizes, dazzling colours, and long keeping quality. Gladiolus trade as cut flower is increasing day by day in domestic as well as international markets. In recent years, several new cultivars of gladiolus with wide range of colours have been developed for marketing.

Weed is the most important biotic constraint for realizing higher productivity of gladiolus. Sixty weed species belonging to 24 angiosperm families have been found growing in the fields of gladiolus (Riaz *et al*. 2009). Weed control is important to reduce weed competition and maximize productivity of gladiolus through efficient utilization of resources. 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). Pre-emergence herbicide can be a viable option for controlling weeds right from the emergence of crop (Shivasankar and Subramaniam 2011). Herbicide is a cost-effective alternative to age-old practice of manual weeding. Manual weeding is costlier and has become impracticable due to non-availability of labourers during the critical period of weed competition, making gladiolus cultivation less remunerative. A precise weed management promoting early vigour and greater growth of gladiolus plants, therefore, is highly essential. Knowing selectivity of a herbicide is a pre-requisite for its use in crops. Otherwise, crop injury is imminent (Wallace and Hodges 2005, Richardson and Zandstra 2006). A herbicide, even a broad-spectrum one, falls short in controlling huge weed diversity, comprising of grassy, broad-leaved and sedge weeds in the fields. The spectrum of killing weeds of most selective herbicides is narrow, which necessitates application of more than one herbicide, which can be accomplished through tank-mix or sequential application of herbicides for efficient weed control (Richardson and Zandstra 2006). The tank-mix combination of compatible herbicides usually produces synergistic action due to which the doses of the mixing partner herbicides can be reduced by 25-50% (Authors' observations) than what

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used under single herbicide application. Studies on weed control using tank-mix herbicides have not been undertaken in India or elsewhere in gladiolus, a flower crop with enormous trade potential. Therefore, the present experiment was designed to achieve higher growth, flowering and corm yield of gladiolus through better weed control, using tank-mix combinations of herbicides.

## MATERIALS AND METHODS

A field experiment with ten weed control treatments (Tables 1-5) laid out in a randomized complete block design with three replications was undertaken during the winter seasons of 2011-12 and 2012-13 at the Indian Agricultural Research Institute, New Delhi. Soil was sandy clay loam with pH 7.0-7.5. It was moderately fertile, low in available organic carbon (0.48%), available N (138.0 kg/ha), but medium in P (30.5 kg $P_2O_5$/ha) and K (187.9 kg $K_2O$/ha). Uniform size gladiolus corms (4.0-5.0 cm diameter; 25-30 g weight per corm; 30-40 corm piece/kg) cv Jyotsna were planted on 15.11.2011 and 17.11.2012 at 50 cm (row-to-row) × 20 cm (plant to plant) spacing, which resulted in 100 000 plants/ha. A weed-free check and a weedy check treatment were adopted for comparison with herbicidal treatments. A uniform dose of 120 kg N, 80 kg $P_2O_5$, and 80 kg $K_2O$ per ha was applied in the form of urea, single superphosphate and muriate of potash, respectively. Half dose of N and whole amount of P and K were applied as basal before planting. Remaining dose of N was top-dressed at 45 days after planting (DAP). All pre-emergence herbicides were applied at 2 DAP with 400 litres of water per ha, using a knapsack sprayer fitted with flat fan nozzle. Data on weed density, fresh and dry weight were collected at 30 and 60 DAP from one place in each plot using a 50 cm × 50 cm quadrat. Similarly, gladiolus growth, flower parameters and corm yield were recorded.

Economic analysis was done based on the current cost of inputs/herbicides/operations, and the price of gladiolus cut-flower (₹ 1.25 per spike) and corm (₹ 2.00 per corm). Treatment cost included the cost of herbicide *plus* application cost, and hand weeding as applicable across the treatments (e.g. $T_7$ and $T_9$). Rice residue is readily available in this part of the country when gladiolus is planted. It is mostly burnt in the fields. Therefore, rice residue was included as a mulch after pre-emergence atrazine application and no cost was incurred for it. The net benefit-cost ratio (net B:C) was worked out from the net returns, divided by the cost of cultivation.

## RESULTS AND DISCUSSION

### *Effect on weed growth*

Gladiolus was infested with dicot (*Convolvulus arvensis* L., *Coronopus didymus* (L.) Smith, *Parthenium hysterophorus* L., *Chenopodium murale* L., *Trianthema portulacastrum* L.) and monocot [*Cyperus rotundus* L., *Poa annua* L., *Polypogon monspeliensis* (L.) Desf., *Cynodon dactylon* (L.) Pers.] weeds. All herbicide treatments ($T_1$-$T_8$) caused a significant reduction in the density of monocot and dicot weeds, and total weed dry weight (Table 1) compared to weedy check ($T_{10}$), which had the highest two-year mean density of monocot (165/m$^2$) and dicot (364/m$^2$) weeds and total weed dry weight (171 g/m$^2$). Singh and Singh (2010) observed similar reduction in weed growth due to herbicides in direct-seeded rice. Among herbicide treatments, the application of atrazine 1.0 kg/ha pre-emergence followed by rice residue @ 5 tonnes/ha at 2 days after atrazine application ($T_6$) caused the greatest reduction in density and dry weight of weeds. The pre-emergence tank-mix applications of atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha ($T_4$), and pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha ($T_5$), and other herbicide treatments, however, were statistically similar with this treatment on the reduction of weed density and dry weight (Table 1). The combination treatments, $T_6$, $T_4$ and $T_5$ effectively controlled monocot and dicot weeds for a longer period. Among single herbicide treatments, atrazine 1.0 kg/ha pre-emergence ($T_1$), and metribuzin 0.5 kg/ha pre-emergence ($T_3$) resulted in comparable weed control with these treatments. Butachlor 1.0 kg/ha pre-emergence ($T_8$) among herbicide treatments ($T_1$-$T_8$) was most inferior in controlling weeds in gladiolus.

### *Effect on sprouting, growth and flowering of gladiolus*

Two-year mean data (Table 2) showed that the sprouting of gladiolus corm was delayed by 1-2 days in weedy check ($T_{10}$) compared to all other treatments, including weed-free check ($T_9$). Probable reason could be greater weed interference in weedy check. The sprouting was earliest (12.1 days) in pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha (tank-mix) pre-emergence ($T_5$) among the herbicide treatments ($T_1$-$T_8$). Sprouting(%) of gladiolus was significantly lower in pendimethalin 1.0 kg/ha pre-emergence ($T_2$) compared to other treatments in first year (2011-12). It was as usual in second year (2012-13) in this treatment. This ruled out any negative effect of pendimethalin on sprouting, rather corm character and growing conditions/environment might have played a role. Similar happened true in weed-free check ($T_9$) in which sprouting was relatively less in second year compared to first year. Based on two-year mean values (Table 2), the opening of first floret of gladiolus flower was hastened in weed-free check ($T_9$), pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha (tank-mix) pre-emergence ($T_5$), and weedy check ($T_{10}$) by 2-3 days compared to most other treatments. Probable reasons for early opening of florets might be better/balanced crop growth due to better weed control in $T_9$ and $T_5$, but higher weed pressure, leading to enforced flowering in weedy check ($T_{10}$).

It was observed that gladiolus plant height, spike and rachis length (Table 3), florets per spike and corms per plant (Table 4) were significantly influenced due to different weed control treatments. In weedy check, higher weed growth (population, dry weight), causing stunted growth of crop reduced gladiolus plant height, spike and rachis length, number of florets per spike and number of corms per plant

Table 1 Effect of herbicides on density of monocot and dicot weed and total weed dry weight in gladiolus

| Treatment | Monocot weed density (No./m²) | | | Dicot weed density (No./m²) | | | Total weed dry weight (g/m²) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011-12 | 2012-13 | Mean | 2011-12 | 2012-13 | Mean | 2011-12 | 2012-13 | Mean |
| Atrazine 1.0 kg/ha pre-emergence ($T_1$) | 5.0 | 4.0 | 4.5 | 2.4 | 1.0 | 1.7 | 3.5 | 2.5 | 3.0 |
| Pendimethalin @1.0 kg/ha pre-emergence ($T_2$) | 18.4 | 17.0 | 17.7 | 34.7 | 39.9 | 37.3 | 75.2 | 73.4 | 74.3 |
| Metribuzin 0.5 kg/ha pre-emergence ($T_3$) | 8.7 | 9.3 | 9.0 | 1.0 | 2.3 | 1.7 | 4.2 | 3.10 | 3.6 |
| Atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (tank-mix) pre-emergence ($T_4$) | 5.7 | 3.0 | 4.3 | 1.7 | 0.0 | 0.8 | 5.9 | 3.0 | 4.4 |
| Pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha (tank-mix) pre-emergence ($T_5$) | 10.4 | 13.0 | 11.7 | 7.0 | 5.0 | 6.0 | 6.9 | 6.0 | 6.4 |
| Atrazine @1.0 kg/ha pre-emergence + rice residue @ 5.0 tonnes/ha ($T_6$) | 4.7 | 3.3 | 4.0 | 3.0 | 1.3 | 2.2 | 2.3 | 2.7 | 2.5 |
| Atrazine @1.0 kg/ha pre-emergence + one hand weeding at 30 DAP ($T_7$) | 11.3 | 14.3 | 12.8 | 107.7 | 102.0 | 104.8 | 16.9 | 14.9 | 15.9 |
| Butachlor 1.0 kg/ha pre-emergence ($T_8$) | 52.7 | 49.7 | 51.2 | 190.4 | 214.0 | 202.2 | 94.9 | 102.3 | 98.6 |
| Weed-free check ($T_9$) | 22.0 | 21.0 | 21.5 | 12.0 | 18.0 | 15.0 | 8.3 | 9.6 | 8.9 |
| Weedy check ($T_{10}$) | 164.0 | 166.0 | 165.0 | 374.3 | 354.3 | 364.3 | 173.4 | 168.4 | 170.9 |
| SEm± | 5.07 | 7.13 | | 5.94 | 6.38 | | 4.91 | 5.94 | |
| LSD (P=0.05) | 15.05 | 21.18 | | 17.65 | 18.94 | | 14.58 | 17.64 | |

Table 2 Effect of herbicides on days required for sprouting, sprouting percentage and days to first floret opening in gladiolus

| Treatment | Days to sprout (days) | | | Sprouting (%) | | | Days to first floret opening (days) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011-12 | 2012-13 | Mean | 2011-12 | 2012-13 | Mean | 2011-12 | 2012-13 | Mean |
| Atrazine 1.0 kg/ha pre-emergence ($T_1$) | 12.7 | 12.3 | 12.5 | 95.0 | 97.3 | 96.2 | 100.0 | 102.7 | 101.3 |
| Pendimethalin @1.0 kg/ha pre-emergence ($T_2$) | 13.3 | 13.0 | 13.1 | 90.9 | 96.0 | 93.4 | 101.0 | 102.3 | 101.7 |
| Metribuzin 0.5 kg/ha pre-emergence ($T_3$) | 13.0 | 13.1 | 13.0 | 94.2 | 95.3 | 94.7 | 101.0 | 100.3 | 100.7 |
| Atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (tank-mix) pre-emergence ($T_4$) | 13.3 | 13.6 | 13.4 | 97.5 | 96.0 | 96.7 | 100.0 | 102.0 | 101.0 |
| Pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha (tank-mix) pre-emergence ($T_5$) | 12.0 | 12.3 | 12.1 | 95.8 | 95.3 | 95.6 | 99.0 | 97.3 | 98.2 |
| Atrazine @1.0 kg/ha pre-emergence + rice residue @ 5.0 tonnes/ha ($T_6$) | 13.7 | 13.8 | 13.7 | 96.7 | 93.3 | 95.0 | 100.5 | 101.3 | 100.9 |
| Atrazine @1.0 kg/ha pre-emergence + one hand weeding at 30 DAP ($T_7$) | 13.3 | 13.0 | 13.1 | 95.8 | 95.3 | 95.6 | 101.0 | 101.0 | 101.0 |
| Butachlor 1.0 kg/ha pre-emergence ($T_8$) | 13.0 | 13.3 | 13.1 | 97.5 | 94.7 | 96.1 | 100.0 | 100.3 | 100.2 |
| Weed-free check ($T_9$) | 12.7 | 12.6 | 12.6 | 97.5 | 92.0 | 94.8 | 98.0 | 98.0 | 98.0 |
| Weedy check ($T_{10}$) | 14.3 | 14.0 | 14.1 | 98.3 | 94.0 | 96.2 | 100.0 | 97.7 | 98.8 |
| SEm± | 0.56 | 0.35 | | 0.33 | 0.35 | | 0.78 | 0.91 | |
| LSD (P=0.05) | 1.68 | 1.03 | | 0.99 | 1.03 | | 2.33 | 2.69 | |

significantly in both years (Table 3). Contrarily, all herbicide treatments ($T_1$-$T_8$) and weed-free check ($T_9$) resulted in significantly greater gladiolus plant height than that in weedy check due to better control of weeds. However, pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha ($T_5$) resulted in significantly greater yearly as well as two-year mean plant height of gladiolus (Table 3).

With respect to spike and rachis length (Table 3), and number of florets per spike (Table 4), this treatment and weed-free check were fairly comparable with each other, and resulted in greater values of these floral attributes than those in most other treatments. Metribuzin 0.5 kg/ha pre-emergence ($T_3$) resulted in similar number of florets per spike with these treatments. With respect to two-year mean number of florets opening at a time, atrazine 1.0 kg/ha + rice residue @ 5.0 tonnes/ha ($T_6$), pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha ($T_5$), and metribuzin 0.5 kg/ha ($T_3$) resulted in higher values. In this regard, $T_3$, $T_5$, and $T_7$ were superior to even weed-free check ($T_9$) in first year.

Gladiolus corms per plant differed significantly across the treatments only in first year (Table 4), and pendimethalin 1.0 kg/ha pre-emergence ($T_2$) resulted in significantly greater number of corms per plant than those in all other treatments. Atrazine 1.0 kg/ha pre-emergence ($T_1$), atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha ($T_4$), atrazine 1.0 kg/ha + rice residue @ 5.0 tonnes/ha ($T_6$), and atrazine 1.0 kg/ha + one hand weeding at 30 DAP ($T_7$) were intermediary on their effects on corms per plant. Probable reasons could be differential effects of the treatments on weed growth, resulting in variable crop growth and vigour. Corms per plant and corm weight were inversely related, which caused a reduction in corm number per plant in the pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha ($T_5$). Otherwise, this treatment was superior to most other treatments with respect to most characters of gladiolus studied.

*Gladiolus cut-flower yield, corm yield and economics*

All the herbicides adopted in this study were selective to few field crops. Their selectivity and weed control efficacy have rarely been studied in gladiolus and other flower crops. It was observed that all these herbicides did not pose any harmful effect on the growth, flowering, and corm production of gladiolus at the doses tested. But, they caused varying degrees of weed control. This led to significant variation in cut-flower and corm yield of gladiolus across the treatments (Table 5). All herbicide treatments ($T_1$-$T_8$) resulted in significantly higher cut-flower yield and corm yield than those in weedy check ($T_{10}$), which had the lowest cut-flower yield (27 500 spikes/ha). Pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha (tank-mix) pre-emergence ($T_5$) resulted in highest cut-flower yield (172 500 spikes/ha), which was significantly higher than those in all other treatments, except weed-free check, and metribuzin 0.5 kg/ha pre-emergence ($T_3$). Similarly, the yearly as well as two-year mean corm yield was significantly higher in this treatment compared to other treatments.

Table 3 Effect of herbicides on plant height, spike and rachis length of gladiolus

| Treatment | Plant height (cm) | | | Spike length (cm) | | | Rachis length (cm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011-12 | 2012-13 | Mean | 2011-12 | 2012-13 | Mean | 2011-12 | 2012-13 | Mean |
| Atrazine 1.0 kg/ha pre-emergence ($T_1$) | 105.0 | 97.7 | 101.3 | 85.3 | 79.3 | 82.3 | 57.3 | 48.7 | 52.9 |
| Pendimethalin @1.0 kg/ha pre-emergence ($T_2$) | 118.7 | 104.0 | 111.0 | 89.3 | 88.3 | 88.8 | 61.0 | 65.3 | 63.2 |
| Metribuzin 0.5 kg/ha pre-emergence ($T_3$) | 111.3 | 99.0 | 105.2 | 88.3 | 87.0 | 88.2 | 58.3 | 48.0 | 53.2 |
| Atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (tank-mix) pre-emergence ($T_4$) | 101.7 | 103.3 | 102.5 | 87.7 | 86.3 | 86.9 | 64.0 | 54.3 | 59.2 |
| Pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha (tank-mix) pre-emergence ($T_5$) | 123.0 | 109.7 | 116.3 | 91.7 | 90.0 | 90.8 | 70.0 | 54.7 | 62.3 |
| Atrazine @1.0 kg/ha pre-emergence + rice residue @ 5.0 tonnes/ha ($T_6$) | 119.0 | 93.0 | 106.0 | 91.0 | 86.0 | 88.5 | 63.7 | 54.7 | 59.2 |
| Atrazine @1.0 kg/ha pre-emergence + one hand weeding at 30 DAP ($T_7$) | 108.3 | 87.7 | 97.9 | 76.3 | 77.3 | 76.8 | 50.3 | 50.7 | 50.5 |
| Butachlor 1.0 kg/ha pre-emergence ($T_8$) | 107.7 | 100.0 | 103.9 | 84.0 | 77.0 | 80.5 | 54.7 | 48.3 | 51.5 |
| Weed-free check ($T_9$) | 116.3 | 106.7 | 111.5 | 94.0 | 89.7 | 91.8 | 66.0 | 64.7 | 65.3 |
| Weedy check ($T_{10}$) | 97.0 | 85.0 | 91.0 | 75.0 | 65.7 | 70.3 | 43.0 | 40.4 | 41.7 |
| SEm± | 0.95 | 1.11 | | 0.57 | 0.84 | | 0.08 | 0.65 | |
| LSD (P=0.05) | 2.82 | 3.29 | | 1.71 | 2.51 | | 0.24 | 1.92 | |

Table 4 Effect of herbicides on quantitative characters of gladiolus

| Treatment | Florets per spike (No./spike) | | | Florets opened at a time (No.) | | | Corms per plant (No./plant) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011-12 | 2012-13 | Mean | 2011-12 | 2012-13 | Mean | 2011-12 | 2012-13 | Mean |
| Atrazine 1.0 kg/ha pre-emergence ($T_1$) | 16.7 | 15.7 | 16.2 | 4.7 | 6.0 | 5.3 | 3.0 | 3.0 | 3.0 |
| Pendimethalin @1.0 kg/ha pre-emergence ($T_2$) | 17.7 | 16.0 | 16.8 | 6.0 | 6.7 | 6.3 | 4.0 | 3.3 | 3.7 |
| Metribuzin 0.5 kg/ha pre-emergence ($T_3$) | 17.3 | 17.3 | 17.3 | 7.3 | 6.3 | 6.8 | 2.0 | 3.0 | 2.5 |
| Atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (tank-mix) pre-emergence ($T_4$) | 16.7 | 14.7 | 15.7 | 6.7 | 5.7 | 6.2 | 3.0 | 3.3 | 3.2 |
| Pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha (tank-mix) pre-emergence ($T_5$) | 17.7 | 16.3 | 17.0 | 7.3 | 6.3 | 6.8 | 2.0 | 3.7 | 2.8 |
| Atrazine @1.0 kg/ha pre-emergence + rice residue @ 5.0 tonnes/ha ($T_6$) | 17.3 | 16.3 | 16.8 | 7.0 | 7.0 | 7.0 | 3.0 | 2.7 | 2.8 |
| Atrazine @1.0 kg/ha pre-emergence + one hand weeding at 30 DAP ($T_7$) | 15.0 | 14.7 | 14.8 | 7.3 | 5.3 | 5.8 | 3.0 | 2.3 | 2.7 |
| Butachlor 1.0 kg/ha pre-emergence ($T_8$) | 15.0 | 13.0 | 14.0 | 6.0 | 6.0 | 6.0 | 2.3 | 2.3 | 2.3 |
| Weed-free check ($T_9$) | 18.3 | 17.7 | 18.0 | 6.3 | 6.3 | 6.3 | 2.3 | 3.0 | 2.7 |
| Weedy check ($T_{10}$) | 14.7 | 13.0 | 13.8 | 6.3 | 4.3 | 5.3 | 2.3 | 2.0 | 2.2 |
| SEm± | 0.59 | 0.56 | | 0.26 | 0.21 | | 0.18 | 0.42 | |
| LSD (P=0.05) | 1.75 | 1.66 | | 0.79 | 0.62 | | 0.54 | NS | |

Table 5 Effect of herbicides on corm yield, net returns and net B:C of gladiolus (mean of two years)

| Treatment | Marketable cut-flower yield (× 1000 spikes/ha) | Corm yield (tonnes/ha) | | | Gross returns (×1000 ₹/ha) | Cost of cultivation (×1000 ₹/ha) | Net returns (×1000 ₹/ha) | Net B:C |
|---|---|---|---|---|---|---|---|---|
| | | 2011-12 | 2012-13 | Mean | | | | |
| Atrazine 1.0 kg/ha pre-emergence (T1) | 95.0 | 2.21 | 2.09 | 2.15 | 262.1 | 226.9 | 35.2 | 0.16 |
| Pendimethalin @1.0 kg/ha pre-emergence (T2) | 95.0 | 3.21 | 3.59 | 3.40 | 345.4 | 227.0 | 118.4 | 0.52 |
| Metribuzin 0.5 kg/ha pre-emergence (T3) | 152.5 | 2.95 | 3.25 | 3.10 | 397.3 | 227.6 | 169.7 | 0.75 |
| Atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (tank-mix) pre-emergence (T4) | 100.0 | 2.99 | 3.07 | 3.03 | 327.0 | 227.6 | 99.4 | 0.44 |
| Pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha (tank-mix) pre-emergence (T5) | 172.5 | 3.76 | 3.89 | 3.82 | 470.3 | 227.2 | 243.1 | 1.07 |
| Atrazine @1.0 kg/ha pre-emergence + rice residue @ 5.0 tonnes/ha (T6) | 107.5 | 2.81 | 2.96 | 2.89 | 327.0 | 227.1 | 99.9 | 0.44 |
| Atrazine @1.0 kg/ha pre-emergence + one hand weeding at 30 DAP (T7) | 100.5 | 2.35 | 2.46 | 2.41 | 286.3 | 229.3 | 57.0 | 0.25 |
| Butachlor 1.0 kg/ha pre-emergence (T8) | 60.0 | 2.27 | 2.18 | 2.23 | 223.7 | 226.8 | –3.1 | –0.01 |
| Weed-free check (T9) | 165.0 | 3.53 | 3.69 | 3.61 | 447.0 | 233.8 | 213.1 | 0.91 |
| Weedy check (T10) | 27.5 | 1.59 | 1.37 | 1.49 | 133.7 | 226.6 | –92.9 | –0.41 |
| SEm± | 7.24 | 0.06 | 0.15 | | | | | |
| LSD (P=0.05) | 21.49 | 0.17 | 0.45 | | | | | |

Cut-flower yield in weed-free check ($T_9$) and metribuzin 0.5 kg/ha pre-emergence ($T_3$), and corm yield in pendimethalin 1.0 kg/ha ($T_2$), and metribuzin 0.5 kg/ha ($T_3$) were intermediate but significantly higher than those in other treatments (Table 5). Mixture compatibility between pendimethalin and metribuzin might have greatly influenced corm growth and yield. Pendimethalin is believed to have some plant growth regulator action (yet to be authenticated), which might have been beneficial towards greater number (Table 4), and, in turn, higher yield (Table 5) of corm. Similar effect of herbicides has been reported in rice (Vaishya and Tomar 2000) and potato (Wilson *et al*. 2002).

The economic analysis revealed that pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha ($T_5$) gave the highest monetary advantage in terms of gross and net returns and net B:C (Table 5). The next best treatments, in terms of net returns was pendimethalin 1.0 kg/ha ($T_2$), and atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha ($T_4$). Weed-free check ($T_9$) was less profitable than these treatments. It was more expensive than herbicide treatments due to more labourers involved for weeding the plots frequently.

It may be concluded that the pre-emergence tank-mix application of pendimethalin 0.75 kg/ha + metribuzin 0.3 kg/ha is superior to single application of these herbicides. This combination is more effective than other herbicides for controlling weeds in gladiolus. It gave highest cut-flower and corm yield of gladiolus and net returns than all other treatments, including weed-free check. Therefore, this may be recommended for better weed control and higher productivity and profitability of gladiolus.

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