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Phytotoxic effect of herbicides on gladiolus and their effectiveness against weed flora associated with the crop

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Abstract

The present investigation was conducted during 2018-19 at Centre for Quality Planting Material, RDS Seed Farm CCSHAU, Hisar, Haryana. The experiment comprised of 16 treatments *i.e.* nine herbicidal treatments [*viz.* oxyfluorfen @ 500 g ha⁻¹, pendimethalin @ 1000 g ha⁻¹, butachlor @ 1000 g ha⁻¹, carfentrazone @ 30 g ha⁻¹ and metsulfuron-methyl @ 5 g ha⁻¹ in combinations of pre and pre/post-emergence application at 50 DOP (days of planting) after the HW (hand weeding) or without HW], five mulch treatments [*viz.* mulching of black polyethylene sheet of 100 μ alone, and the paddy straw mulching @ 10 tonnes ha⁻¹ in combinations with HW at 75 DOP or pre-emergence application of pendimethalin @ 1000, 1250 & 1500 g ha⁻¹], and one treatment of hand weeding/hoeing (at 25, 50 & 75 DOP), and weedy check (control), laid out in simple randomized block design with three replications. *Polypogon monspeliensis*, *Phalaris minor*, *Cyperus rotundus* and *Cynodon dactylon* among monocots and *Chenopodium murale*, *Convolvulus arvensis*, *Fumaria parviflora* and *Coronopus didymus* in dicots were found dominant weeds in experimental field. Among the application of herbicides or mulch materials either alone or in combinations, black polyethylene mulch (T₁₃) was found highly effective in controlling weeds followed by pendimethalin 1000 g fb HW + pendimethalin 1000 g (T₁₂), straw mulch fb HW at 75 DOP (T₁₄) and pendimethalin 1500 g/ha + straw mulch (T₆). Amongst the herbicidal treatments, pendimethalin 1000 g fb HW + pendimethalin 1000 g (T₁₂) was found comparatively more efficient in controlling weeds without any phytotoxic effect on crop. Interestingly, the applications of oxyfluorfen as a pre-emergence and metsulfuron-methyl as a post-emergence in different herbicidal combinations caused phytotoxicity in crop plants up to the level of growth check or one leaf burning, and the phytotoxic effect of metsulfuron-methyl was more than the oxyfluorfen. At 30 DOP the maximum level of phytotoxicity (1.70) was recorded with the pre-emergence application of oxyfluorfen 500 g fb HW + oxyfluorfen 500 g (T₃), while at 60 DOP it was observed non-significant with most of the herbicidal applications, whereas at 90 DOP and 120 DOP, it was recorded highest (*i.e.* 2.73 and 2.97, respectively) with the application of oxyfluorfen 500 g fb metsulfuron-methyl 5 g (T₂) and it was followed by post-emergence application of metsulfuron-methyl 5 g in combinations with pre-emergence application of other herbicides (T₈ & T₁₁).

Overall, the application of mulch materials (either alone as a black polyethylene sheet of 100 μ or paddy straw @ 10 tonnes ha⁻¹ in the combination with HW or pendimethalin 1500 g ha⁻¹) was found very effective with the aspect of weed control in gladiolus.

Keywords: Gladiolus, weed management, herbicidal treatment, phytotoxicity, DOP (days of planting), HW (hand weeding), fb (followed by)

Introduction

Gladiolus (*Gladiolus x hybrida*), generally called "Glad" belongs to family Iridaceae and originated from South Africa. It was introduced in France from South Africa and later it spread to England, Holland and North America (Mishra and Singh, 1989) [15]. Being an important bulbous ornamental plant, it occupies a prime position among commercial flower crops which have high demand in both domestic and international markets. In India, popularity of this flower is increasing day by day. The spikes of gladiolus are mainly used for display in gardens, interior decoration and for making bouquets. It produces beautiful spikes from December to March in plains and from June to September in hills. For successful cultivation of this crop, several cultural operations are required and out of which weed management is one of the most important operation. The different environmental conditions determine the specific weed spectrum, composition and population of each region. The late emergence of gladiolus and faster growth of weeds cause severe competition with the crop plant for light, moisture, space and nutrients, resulting in yield losses.

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It has been seen that application of herbicides or mulch materials either alone or in combinations are comparatively economical, convenient and efficient in eradicating weeds, hence it becomes necessary to use herbicides that may provide effective weed control without any phytotoxic effect on gladiolus (Leghari *et al.* 2015) [13]. Further, mulching retards the losses of soil moisture by intercepting the upward movement of capillary water by shading the soil, regulates soil temperature fluctuations, suppresses weed growth and on decaying enhance the soil fertility level.

Experiments conducted by several workers on weed management practices in gladiolus field also revealed the effectiveness of mulch materials or herbicides in controlling weeds as well as enhancement in growth, flowering and the production of corms mainly due to suppression of weeds in this crop (Kumar *et al.*, 2012; Chahal *et al.*, 2013; Rao *et al.*, 2014; Swaroop *et al.*, 2017) [12, 3, 26, 21]. In Haryana and adjoining areas, very less information is available on the effectiveness of mulching and herbicides against the weed flora associated with this crop and the phytotoxic effect of herbicides on gladiolus plants under physicochemical status of the soil of Hisar District in Haryana. Keeping in view the importance of the crop and this particular variety, the present investigation was undertaken to study the phytotoxic effect of herbicides on crop plants and their effectiveness against weed flora associated with this crop.

Materials and Methods

The experiment was conducted at demonstration farm of the Centre for Quality Planting Material, RDS Seed Farm, CCS HAU, Hisar (Haryana) during the cropping season of year 2018-2019. The experimental site has a semi-arid subtropical climate with hot, dry and desiccating winds during summer season and severe cold during winter season. The mean monthly maximum temperature during the cropping season (Nov. 2nd week to May 2nd week) of that year was observed between 17.1 to 40.7 °C, whereas the minimum temperature was observed between 1.9 to 21.7 °C, and the mean weekly maximum temperature (40.7 °C) was recorded in last week of April, while the minimum (1.9 °C) was noticed in last week of December. Relative humidity throughout the cropping season varied between 19.0 to 99.0 per cent. The soil of district Hisar has been derived from Indo-Gangetic alluvial plain, which is sandy loam in texture and has some amount of calcium carbonate in the profile. Physicochemical analysis of the soil of experiment field was done and found that it was sandy loam in texture, alkaline in nature (pH: 8.10 & EC: 0.26 mmhos/cm), low in organic carbon (< 0.40%), low in available nitrogen (<250 kg ha⁻¹), medium in phosphorus (10-20 kg ha⁻¹) and high with respect to available potassium (>250 kg ha⁻¹).

A newly developed and commercialized gladiolus cultivar 'Nova Lux' was selected to conduct this experiment and except weed management practices, other agronomical practices were applied according to the 'Package of practices for horticultural crops' as recommended by CCSHAU, Hisar. According to layout-plan, healthy and uniform sized corms (diameter 4.0-5.0 cm) were planted in 2nd week of November on well prepared flat beds (1.50 x 1.50 m) with row to row distance of 30 cm and plant to plant distance of 20 cm. The experiment comprised of 16 treatments laid out in simple randomized block design with three replications *i.e.* nine herbicidal treatments [*viz.* oxyfluorfen @ 500 g ha⁻¹, pendimethalin @ 1000 g ha⁻¹, butachlor @ 1000 g ha⁻¹,

carfentrazone @ 30 g ha⁻¹ and metsulfuron-methyl @ 5 g ha⁻¹ in combinations of pre and pre/post-emergence application at 50 DOP (days of planting) after the HW (hand weeding) or without HW], five mulch treatments (*viz.* mulching of black polyethylene sheet of 100 µ alone, and the paddy straw mulching @ 10 tonnes ha⁻¹ in combinations with HW at 75 DOP or pre-emergence application of pendimethalin @ 1000, 1250 & 1500 g ha⁻¹), and one treatment of hand weeding/hoeing (at 25, 50 & 75 DOP) and weedy check (no weed was uprooted) as a control.

The experimental field, in which trial was conducted was fallow from last six months and well ploughed and levelled before preparation of experimental plots. A basal dose of well rotten Farm Yard Manure (50 tonnes ha⁻¹) was uniformly mixed in the soil one week before planting of corms. The recommended dose of nitrogen (Urea @ 600 kg ha⁻¹), phosphorus (SSP @ 625 kg ha⁻¹) and potassium (MOP @ 160 kg ha⁻¹) was applied in each plot. Half dose of nitrogen and the full dose of phosphorus and potassium was mixed in soil just before the planting of corms, and the second & third doses of nitrogen (one fourth each) were applied as top dressing at 3-5 leaves stage and at the time of spike emergence, respectively.

The calculated quantity of herbicides, after dissolving in water @ 500 lit. ha⁻¹, was applied with the help of hand operated knapsack compressor sprayer with a flat fan nozzle having rectangular spray pattern. Butachlor, oxyfluorfen and pendimethalin were applied as pre-emergence herbicides, and carfentrazone and metsulfuron-methyl were applied post-emergence of weeds at 50 DOP. Second dose of pre-emergence herbicides was applied at 50 DOP after the hand weeding operation in T₃, T₉ and T₁₂ plots. Mulching treatments with paddy straw (10 tonnes ha⁻¹) in T₄, T₅, T₆ & T₁₄ and black polyethylene sheet of 100 µ in T₁₃ were continued from planting up to the harvesting of corms. In case of hand weeding/ hoeing plots this operation was done at 25, 50 and 75 DOP. In weedy check (control) no weed was uprooted till the harvesting of corms.

Various horticultural operations like- staking and plant protection measures were adopted according to the 'Package of practices for flower crops' as recommended by SAU and nearby ICAR Institutes for this crop. By keeping in view, the climatic conditions of Hisar District, the crop was irrigated at 10 days intervals in summer and 15 days intervals in winter up to 2-3 weeks before the harvesting of corms. The attack of specific diseases such as 'Corm Rot' caused by *Fusarium* sp. was controlled with the drenching of carbendazim (0.1%) plus mancozeb (0.2%).

Survey of experimental area was conducted at weekly intervals after the planting of corms with a view to identify the weed flora associated with gladiolus crop under the agro climatic conditions of the site. The whole crop period was divided into two spans. First span - from planting to 75 days of planting (*i.e.* up to 75 DOP) and second span - from 75 days after planting up to harvesting of corms (*i.e.* 75 DOP and onwards). The total weed flora was divided into two main groups *i.e.* monocot and dicot weeds.

Data regarding weed intensity in different plots was recorded at 30, 60, 90, 120 DOP and at the harvesting stage of corms. For each counting a quadrat (50 x 50 cm) measuring 0.25 m² was randomly placed at two sites in each plot and different weed species growing within this quadrat were counted group-wise (*i.e.* monocots and dicots) collectively and then computed for one square meter.

At the interval of 30 days, the dry weight of weeds uprooted from 0.25 m² area in each plot was taken. For each date of sampling new area was selected in each plot. For dry weight, weed samples were dried in a thermostat oven at 65°C for 48 hours and then weighed. The final data was expressed in grams m⁻². At the interval of 30 days, control of weeds was also observed visually on the basis of 0-100 scale. The observations on monocot and dicot weeds recorded separately. Weed control efficiency (WCE) was worked out on the basis of dry weight of weeds in weedy check (control) plot minus dry weight of weeds in treated plot and divided by dry weight of weeds in weedy check (control) plot by the formula as given by (Sivamurugan *et al.*, 2009) [25]. Phytotoxic effect of herbicides on five healthy competitive crop plants in each plot was recorded at 30, 60, 90, 120 DOP and at harvesting stage. On the basis of injury symptoms on each individual selected plant, a phytotoxicity index (0-10 scale) was prepared for each treatment in each replication.

The recorded data on different parameters were statistically analysed by applying the analysis of variance technique and the treatment differences were tested by 'F' test of significance on the basis of null hypothesis (Cochran and Cox, 1963) [4]. The data on weed count and dry weight of weeds were subjected to transformation as mentioned by Gomez and Gomez (1976) [6]. Statistical analysis was done by using OPSTAT statistical software design developed by CCSHAU, Hisar to find out the significance of variation resulting from the experimental treatments. All tests of significance were made at 5% level of the significance.

Results and Discussion

Survey of weed flora

Survey of the experimental area conducted at weekly intervals to identify the weed flora associated with gladiolus crop, however clearly indicated the presence of monocot as well as dicot weeds in noticeable number after the sprouting of corms up to the completion of flowering stage, whereas before sprouting of corms and near to harvesting of daughter corms, the monocot weeds were found dominant in the experimental field. Further, the predominance of *Polypogon monspeliensis*, *Phalaris minor* and *Cyperus rotundus* in monocots, and *Chenopodium murale* and *Coronopus didymus* in dicots was noticed almost throughout the cropping season. The marked reduction in intensity of total weeds after 120 days of planting (DOP) in this study (table 3) might be due to completion of life cycle in several weeds' species like *Convolvulus arvensis*, *Coronopus didymus*, *Chenopodium album*, *Cyperus rotundus* and *Melilotus indica*. A similar pattern of reduction in weed population has already been observed by Chahal *et al.* (2013) [3] in gladiolus field. Data presented in table 1 & 2 indicates the significant difference in progressive count of monocots, dicots and total weeds due to the application of herbicides as well as mulch materials alone or in combinations and the cultural operations at almost all the stages of observations.

Intensity of monocot weeds (m⁻²)

During the initial stages of crop growth, the intensity of total monocot weeds (table 1) was increasing at tremendous rate and at the later stages of crop (*i.e.* 120 DOP and onwards) it was comparatively higher than earlier stages of crop (*i.e.* up to 90 DOP) under most of the treatments. Further, the intensity of such weeds under most of the treated plots (T₁ to T₁₅) was recorded generally less than the control (T₁₆) at almost all dates of observations. During later stages of crop growth,

such results may be attributed to reduction in effectiveness of herbicidal applications and emergence of new weed flora. Gupta and Lamba (1978) [7] also reported that if an environment around the weed suddenly becomes unfavourable, then there are several other weed species waiting in preparedness to take over from the withering species. Among the application of herbicides or mulch materials either alone or in combinations, the minimum weed intensity was recorded in T₁₃ (black polyethylene mulch) at all dates of observations and it was followed by pre-emergence application of pendimethalin (T₆, T₅, T₄, T₁₁, T₁₀ & T₁₂) at 30 DOP and 60 DOP; T₁₄, T₁₂, T₃ & T₆ at 90 DOP, and T₁₂ & T₁₄ at 120 DOP & the harvesting stage. These results are in confirmative with Chahal *et al.* (1994) [2] who reported that in gladiolus field only mulching (3" local grasses) proved effective against monocot weeds. However, Swaroop *et al.* (2017) [26] recorded the minimum intensity of monocot weeds with pre-emergence application of pendimethalin 1.0 kg ha⁻¹ + dry grass residue 5.0 tonnes ha⁻¹ in the same crop.

The reason for less intensity of monocot weeds during later stages may be either due to the suppression of new emerging weeds in control (T₁₆) plots by the spreading roots and dead shoots of those weed species which had already completed their life cycle, or the encouragement to new weeds by hand hoeing operation in herbicidal plots which restored to enforce the dormant seeds or vegetative parts of grassy weeds. Zimdahl (1980) [28] also suggested that soil temperature modified by shallow tillage can increase the emergence of some grass seedlings. Further, the variation in intensity of monocots (individual and total) observed during this study under different treatments may be attributed to the presence or absence of other competitive weed species in their association. However, in this study, it might be pointed out that all of the mulch treatments either alone or in combination effectively controlled the monocot weeds than the herbicidal treatments.

Intensity of dicot weeds (m⁻²)

All herbicidal as well as mulch treatments reduced the intensity of individual as well as total dicot weeds (table 1) very effectively at earlier stages of crop (*i.e.* up to 90 DOP) than the later stages (*i.e.* 120 DOP and onwards). Further, the intensity of such weeds was recorded less under most of the treated plots (T₁ to T₁₅) as compared to control (T₁₆) at almost all dates of observations. However, the minimum intensity of dicot weeds was recorded in T₁₃ (black polyethylene mulch) except at 60 and 90 DOP, where it was registered minimum under T₁₅ (hand hoeing) and T₁₀ (pendimethalin 1000 g fb carfentrazone 30 g). Interestingly, the density of monocot weeds was found higher than the dicot weeds under most of the mulch treatments and reason might be the competitive nature of different weed species. These results are in conformity with Pramanik *et al.* (2006) [17], who reported the minimum intensity of broad-leaved weeds *viz.* *Amaranthus spinosus*, *Tridax procumbens* and *Eclipta alba* under the blue and black polyethylene mulch.

Among different herbicidal treatments, post-emergence applications of oxyfluorfen, pendimethalin, carfentrazone and metsulfuron-methyl were found superior in controlling dicot weeds (table 1) as compared to mulching either alone or in combinations with other herbicides during the second span (*i.e.* 90 DOP and onwards). Though none of the herbicidal treatments was found to provide near to complete control of *Convolvulus arvensis* and the ultimately control of total dicot

weeds.

Effectiveness of carfentrazone (Punia and Yadav, 2014; Dhakar *et al.* 2016) ^[18, 5], metsulfuron-methyl (Hossain and Mondal, 2014) ^[8], oxyfluorfen (Manuja *et al.*, 2005) ^[14] and pendimethalin (Bhat and Sheikh, 2015; Qadeer *et al.*, 2016) ^[1, 19] in controlling dicot weeds under gladiolus field and other field crops has already been reported.

Intensity of total weeds (m^{-2})

In general, however the intensity of total weeds at earlier stages of crop (*i.e.* up to 90 DOP) was observed in increasing order, whereas at the later stages of crop (*i.e.* 120 DOP and onwards) it was recorded comparatively higher but with slower increasing rate than the earlier stages of crop (*i.e.* up to 90 DOP) under most of the treated plots (table 2). During earlier stages, the increasing trend in intensity of total weeds might be due to the favourable conditions as well as lack of competition among weeds for their germination and growth. During later stages, such higher intensity but at slower increasing rate was might be due to emergence of new flush of weeds in mulch treated plots, whereas in herbicidal treated plots, it may be attributed to the ineffectiveness of herbicides against several monocot weeds as well as lack of competition for the emergence of such new weeds after the successive control of dicot weeds. Among herbicidal treatments, minimum weed intensity at 30 DOP (17.60, 18.60 & 19.25 m^{-2}) and 60 DOP (60.50, 61.33 & 58.50 m^{-2}) was recorded with pre-emergence applications of pendimethalin (T_{11} , T_{12} & T_{10} , respectively), whereas at 90 DOP, 120 DOP and harvesting stage, the minimum weed intensity (15.50, 30.40 & 31.22 m^{-2} , respectively) was observed under T_{12} (pendimethalin 1000 g *fb* HW + pendimethalin 1000 g) which was followed by T_3 , T_{10} and T_{11} . Almost similar influence of herbicidal treatments on total weed intensity was observed by Chahal *et al.* (1994) ^[2] in gladiolus field and reported the lower intensity of total weeds under most of the herbicidal treatments than the weedy check at almost all dates of observations. Further, the pre-emergence herbicidal treatments were observed more effective than the post-emergence herbicidal treatments for controlling weeds in gladiolus field by Qadeer *et al.* (2016) ^[19]. Among the different treatments, minimum intensity of total weeds was recorded in T_{13} (black polyethylene mulch) at all dates of observations and these findings are in agreement with those of Jeevan *et al.* (2016) ^[10], who reported the significantly lowest weed density at different dates of observation with mulching of black polythene sheet followed by hand weeding as compared to other treatments in tuberose field. Khan *et al.* (2015) ^[11] also reported that among the various mulching treatments, plastic mulch was found most effective for inhibiting the weed germination in gladiolus field.

Dry weight of weeds ($g m^{-2}$)

Dry weight of weeds per unit area was reduced effectively in all the treatments throughout the cropping season (table 2). The dry weight of weeds in all the treatments was found at lower increasing rate up to 90 DOP, but at later stages of crop *i.e.* 120 DOP and onwards, dry weight of weeds increased at tremendous rate.

Among the applications of herbicides or mulch materials either alone or in combinations, the minimum dry weight of weeds was recorded with T_{13} (polyethylene mulching) at all dates of observations, except at 90 DOP where the minimum dry weight of weeds was observed under T_{12} (pendimethalin

1000 g *fb* HW + pendimethalin 1000 g). Such findings regarding polyethylene mulching are in conformity with the findings of Jeevan *et al.* (2016) ^[10] who reported the lowest weed density and dry weight of weeds at all the stages of crop growth with the application of black polythene mulch followed by hand weeding in tuberose. Singh *et al.* (2019) ^[24] also observed the minimum intensity and dry weight of total weeds under black polythene mulch (200 μ) followed by hand weeding in rose crop. The effectiveness of pendimethalin applications for weed control in gladiolus field are well supported by the findings of Bhat and Sheikh (2015) ^[1] who reported the lowest dry weight of weeds with the application of pendimethalin @ 0.75 kg ha^{-1} in this crop.

Weed control efficiency (%)

The highest weed control efficiency (WCE) was recorded under T_{13} (black polyethylene mulch) at almost all dates of observations (30, 60, 120 DOP and at harvesting stage) except at 90 DOP (table 3 & figure 1), where the highest WCE (95.15%) was observed under T_{12} (pendimethalin 1000 g *fb* HW + pendimethalin 1000 g). Further T_{13} was followed by pre-emergence applications of pendimethalin (T_6 , T_5 , T_4 , T_{11} & T_{12}) at 30 DOP and 60 DOP; T_{13} , T_{14} , T_3 & T_{10} at 90 DOP, and T_{12} , T_{14} & T_3 at 120 DOP & harvesting stage. Such results are in conformity with Chahal *et al.* (1994) ^[2] who recorded the maximum WCE at almost all dates of observations (90, 135, 180 and 225 DOP) with the application of mulch material (3" layer of local grasses) except at 45 DOP, where maximum WCE was observed with atrazine @ 2.0 kg ha^{-1} *fb* two HW in gladiolus field. Jeevan *et al.* (2016) ^[10] also noticed the highest weed control efficiency with black polythene mulch followed by the pre-emergence application of pendimethalin plus hand weeding in tuberose field.

The higher WCE at 90 DOP with the applications of pendimethalin (twice) might be due to high efficiency of single herbicide or the synergistic effect of herbicidal combination/sequential herbicidal application on controlling the all types of weed flora. Rao *et al.* (2014) ^[21] also noticed the similar effect of pendimethalin in gladiolus field and reported the highest WCE (63.7%) with the application of pendimethalin @ 1.0 kg ha^{-1} and it was followed by the metribuzin application @ 0.5 kg ha^{-1} with WCE (63.2%).

Level of phytotoxicity induced by herbicides in gladiolus crop

Among different herbicidal treatments oxyfluorfen and metsulfuron-methyl induced phytotoxic effect on gladiolus crop. Table 4 clearly indicates that the phytotoxic effect of metsulfuron-methyl was more than the oxyfluorfen. At 30 DOP the maximum phytotoxicity level (1.70) was recorded in T_3 (oxyfluorfen 500 g *fb* HW + oxyfluorfen 500 g), while at 60 DOP, none of the herbicidal applications was observed phytotoxic significantly, whereas at 90 DOP and 120 DOP, the application of oxyfluorfen 500 g *fb* metsulfuron-methyl 5 g (T_2) was observed more phytotoxic (2.73 and 2.97) than the other herbicidal treatments *i.e.* T_8 (2.30 and 2.60) & T_{11} (2.33 and 2.63, respectively), which might be due to cumulative effect of pre and post-emergence applications of these two herbicides.

These results are in consonance with the findings of Richardson and Zandstra (2006) ^[22] who reported that oxyfluorfen caused unacceptable crop injury to gladiolus and the injured plants appear stunted and chlorotic. Phytotoxicity symptoms as appeared in this study may be due to higher dose

of oxyfluorfen. Uygur *et al.* (2010)^[27] and Ramalingam *et al.* (2013)^[20] also reported that oxyfluorfen provided the better control of weeds in onion field but the same time it also caused phytotoxicity to crop plants. In contrary to this, pre and post-emergence application of oxyfluorfen @ 0.25 + 0.25 kg ha⁻¹ caused no phytotoxicity to gladiolus plant as reported by Chahal *et al.* (1994)^[2]. Further, post-emergence application of herbicide (*i.e.* metsulfuron-methyl) was observed more phytotoxic as compared to pre-emergence application of herbicide (*i.e.* oxyfluorfen) and it may be due to direct contact of chemical with crop plants which caused burning. Similar results were also reported by Panwar *et al.*

(2010)^[16] in tuberose crop.

Among post-emergence herbicidal applications, metsulfuron-methyl was found to be phytotoxic to gladiolus plants. These results are in conformity with Jadhav and Panwar (2014)^[9] who reported that post-emergence application of fenoxaprop + metsulfuron-methyl @ 67 + 4 g ha⁻¹ caused 50% injury to turmeric crop and similar results were also observed by Sachdeva *et al.* (2015)^[23] who reported that post-emergence application of fenoxaprop @ 67 g + metsulfuron-methyl @ 4 g ha⁻¹ found phytotoxic to turmeric and resulted in lower plant height, number of leaves per plant, number of shoots per plant and weight of rhizomes per plant.

Table 1: Effect of weed management practices on periodical change in intensity of monocot and dicot weeds

Treatments		Monocot weeds (m ⁻²)					Dicot weeds (m ⁻²)				
		30 DOP*	60 DOP	90 DOP	120 DOP	Harv. stage	30 DOP*	60 DOP	90 DOP	120 DOP	Harv. stage
Oxyfluorfen 500g <i>fb</i> carfentrazone 30g	T1	4.86 (22.66)**	5.62 (30.59)	6.09 (36.11)	6.42 (40.21)	6.80 (45.27)	3.11 (8.67)**	6.09 (36.08)	2.87 (7.22)	4.38 (18.22)	4.01 (15.13)
Oxyfluorfen 500 g <i>fb</i> metsulfuron-methyl 5g	T2	4.91 (23.11)	5.67 (31.22)	6.27 (38.28)	6.59 (42.51)	6.84 (45.80)	3.42 (10.74)	5.78 (32.44)	3.08 (8.5)	4.98 (23.79)	4.77 (21.74)
Oxyfluorfen 500g <i>fb</i> HW+oxyfluorfen 500g	T3	4.68 (20.90)	5.80 (32.65)	4.14 (16.18)	5.34 (27.48)	5.92 (34.11)	3.45 (10.90)	6.24 (38.01)	3.05 (8.32)	4.69 (21.02)	4.14 (16.10)
Pendimethalin 1000g+straw mulch	T4	3.57 (11.75)	4.85 (22.59)	5.41 (28.27)	6.12 (36.56)	6.50 (41.25)	2.60 (5.75)	5.00 (24.01)	5.60 (30.33)	5.53 (29.57)	5.16 (25.62)
Pendimethalin 1250g+straw mulch	T5	3.26 (9.60)	4.49 (19.20)	5.10 (25.02)	5.85 (33.25)	6.33 (39.11)	2.15 (3.60)	4.73 (21.40)	5.29 (27.02)	5.32 (27.25)	4.92 (23.20)
Pendimethalin 1500g+straw mulch	T6	2.81 (6.88)	4.25 (17.10)	4.91 (23.09)	5.66 (31.12)	5.86 (33.33)	1.82 (2.32)	4.53 (19.50)	5.11 (25.11)	5.14 (25.43)	4.93 (23.33)
Butachlor 1000g <i>fb</i> carfentrazone 30g	T7	8.18 (66.08)	8.87 (77.84)	7.34 (52.96)	7.43 (54.13)	7.94 (61.50)	3.91 (14.32)	6.94 (47.16)	3.68 (12.54)	4.41 (18.52)	3.88 (14.09)
Butachlor 1000g <i>fb</i> metsulfuron-methyl 5g	T8	8.05 (63.88)	8.98 (79.62)	7.60 (56.91)	7.68 (57.10)	7.80 (59.97)	3.66 (12.42)	7.17 (50.38)	3.54 (11.53)	4.51 (19.39)	4.55 (19.74)
Butachlor 100g <i>fb</i> HW+butachlor 1000g	T9	8.12 (65.04)	8.74 (75.45)	6.49 (41.26)	6.66 (43.32)	6.80 (45.21)	3.66 (12.36)	7.24 (51.55)	4.60 (20.24)	5.77 (32.33)	5.67 (31.11)
Pendimethalin 1000g <i>fb</i> carfentrazone 30g	T10	3.71 (12.74)	5.29 (26.94)	5.49 (29.19)	5.67 (31.21)	6.05 (35.61)	2.74 (6.51)	5.70 (31.56)	2.51 (5.31)	4.82 (22.23)	4.45 (18.84)
Pendimethalin 1000g <i>fb</i> metsulfuron-methyl 5g	T11	3.63 (12.18)	5.36 (27.74)	5.60 (30.40)	5.94 (34.25)	6.42 (40.25)	2.53 (5.42)	5.81 (32.74)	2.71 (6.32)	5.02 (24.25)	4.55 (19.75)
Pendimethalin 1000g <i>fb</i> HW+ pendimethalin 1000g	T12	3.76 (13.12)	5.37 (27.89)	4.06 (15.50)	4.15 (16.25)	4.43 (18.63)	2.55 (5.48)	5.87 (33.44)	2.65 (6.05)	3.89 (14.15)	3.68 (12.59)
Mulching of black poly-ethylene sheet (100 µ)	T13	2.02 (3.08)	2.19 (3.79)	2.28 (4.21)	3.49 (11.20)	3.81 (13.56)	1.61 (1.58)	3.10 (8.61)	3.49 (11.19)	3.34 (10.20)	2.92 (7.54)
Mulching of straw (10 t) <i>fb</i> HW (75 DOP)	T14	4.09 (15.69)	5.14 (25.42)	3.19 (9.20)	4.92 (23.24)	5.27 (26.75)	3.10 (8.64)	5.57 (30.03)	3.54 (11.53)	4.50 (19.29)	4.21 (16.75)
Hand weeding/hoeing at 25, 50 & 75 DOP	T15	2.51 (5.28)	4.54 (19.61)	4.61 (20.24)	5.30 (27.12)	5.75 (32.12)	2.05 (3.22)	2.83 (6.99)	3.62 (12.16)	5.12 (25.21)	4.55 (19.74)
Weedy check (control)	T16	9.97 (98.57)	10.80 (115.6)	11.27 (126.04)	11.94 (141.72)	12.70 (160.54)	9.15 (82.76)	11.41 (129.34)	11.98 (142.46)	11.60 (133.74)	11.01 (120.16)
CD @ 5%		0.35	0.35	0.40	0.44	0.48	0.15	0.41	0.26	0.30	0.27

* Days of planting, ** Original values are given in parenthesis

Table 2: Effect of weed management practices on periodical change in intensity of total weeds and dry weight of weeds

Treatments		Total weeds (m ⁻²)					Dry weight of weeds (g m ⁻²)				
		30 DOP*	60 DOP	90 DOP	120 DOP	Harv. stage	30 DOP*	60 DOP	90 DOP	120 DOP	Harv. stage
Oxyfluorfen 500g <i>fb</i> carfentrazone 30g	T1	5.68 (31.33)**	8.21 (66.67)	6.65 (43.33)	7.70 (58.43)	7.83 (60.40)	2.10 (3.45) **	6.90 (46.67)	8.90 (77.99)	11.51 (131.47)	12.68 (160.06)
Oxyfluorfen 500 g <i>fb</i> metsulfuron-methyl 5g	T2	5.90 (33.85)	8.02 (63.33)	6.52 (46.60)	8.20 (66.30)	8.28 (67.54)	2.17 (3.72)	6.72 (44.33)	9.21 (83.88)	12.25 (149.18)	13.41 (178.98)
Oxyfluorfen 500g <i>fb</i> HW+oxyfluorfen 500g	T3	5.72 (31.80)	8.46 (70.66)	5.04 (24.50)	7.04 (48.50)	7.16 (50.21)	2.12 (3.50)	7.10 (49.46)	6.80 (45.33)	10.38 (106.70)	11.57 (133.06)
Pendimethalin 1000g+straw mulch	T4	4.29 (17.50)	6.89 (46.60)	7.71 (58.60)	8.19 (66.13)	8.24 (66.87)	1.65 (1.75)	5.79 (32.62)	10.86 (117.20)	12.10 (145.49)	13.35 (177.21)
Pendimethalin 1250g+straw mulch	T5	3.76 (13.20)	6.44 (40.60)	7.30 (52.50)	7.84 (60.50)	7.96 (62.31)	1.52 (1.32)	5.03 (24.36)	10.28 (105.00)	11.57 (133.10)	12.89 (165.12)

Pendimethalin 1500g+straw mulch	T6	3.19 (9.22)	6.12 (36.60)	7.01 (48.20)	7.59 (56.55)	7.59 (56.66)	1.35 (0.83)	4.79 (21.96)	9.86 (96.40)	11.19 (124.41)	12.29 (150.15)
Butachlor 1000g <i>fb</i> carfentrazone 30g	T7	9.02 (80.40)	11.21 (125.00)	8.15 (65.50)	8.59 (72.86)	8.74 (75.33)	3.26 (9.65)	10.04 (100.00)	10.90 (117.90)	12.83 (163.94)	14.15 (199.62)
Butachlor 1000g <i>fb</i> metsulfuron-methyl 5g	T8	8.78 (76.30)	11.44 (130.00)	8.33 (68.44)	8.86 (77.51)	9.04 (80.75)	3.18 (9.16)	10.24 (104.00)	11.14 (123.19)	13.23 (174.40)	14.66 (213.99)
Butachlor 100g <i>fb</i> HW+butachlor 1000g	T9	8.85 (77.40)	11.29 (127.00)	7.90 (61.50)	8.76 (75.65)	8.79 (76.32)	3.20 (9.29)	10.12 (101.60)	10.71 (113.78)	12.93 (166.43)	14.26 (202.25)
Pendimethalin 1000g <i>fb</i> carfentrazone 30g	T10	4.49 (19.25)	7.70 (58.50)	5.93 (34.17)	7.37 (53.44)	7.45 (54.45)	1.71 (1.93)	6.47 (40.95)	7.07 (49)	11.00 (120.24)	12.05 (144.29)
Pendimethalin 1000g <i>fb</i> metsulfuron-methyl 5g	T11	4.30 (17.60)	7.83 (60.50)	6.14 (36.76)	7.71 (58.50)	7.81 (60.00)	1.66 (1.76)	6.58 (42.35)	8.62 (73.52)	11.50 (131.63)	12.65 (159.00)
Pendimethalin 1000g <i>fb</i> HW+ pendimethalin 1000g	T12	4.42 (18.60)	7.89 (61.33)	4.05 (15.50)	5.60 (30.40)	5.67 (31.22)	1.69 (1.86)	6.62 (42.93)	5.44 (28.68)	8.24 (66.88)	9.15 (82.73)
Mulching of black poly-ethylene sheet (100 μ)	T13	2.37 (4.66)	3.65 (12.40)	4.04 (15.40)	4.73 (21.40)	4.70 (21.10)	1.19 (0.42)	2.90 (7.44)	5.50 (29.26)	6.93 (47.08)	7.45 (54.86)
Mulching of straw (10 t) <i>fb</i> HW (75 DOP)	T14	5.02 (24.33)	7.50 (55.45)	4.62 (20.40)	6.60 (42.53)	6.67 (43.50)	1.85 (2.43)	5.85 (33.27)	6.14 (36.72)	9.50 (89.31)	10.78 (115.28)
Hand weeding/hoeing at 25, 50 & 75 DOP	T15	3.08 (8.50)	5.25 (26.60)	5.77 (32.40)	7.30 (52.33)	7.27 (51.86)	1.33 (0.77)	4.11 (15.96)	7.69 (58.32)	10.78 (115.13)	11.76 (137.43)
Weedy check (control)	T16	13.50 (181.33)	15.68 (245.00)	16.41 (268.50)	16.63 (275.46)	16.78 (280.70)	4.95 (23.57)	14.87 (220.50)	24.29 (590.70)	26.25 (688.65)	27.54 (757.89)
CD @ 5%		0.30	0.59	0.59	0.44	0.42	0.14	0.46	0.63	0.88	0.73

* Days of planting, ** Original values are given in parenthesis

Table 3: Effect of weed management practices on weed control efficiency (%)

Treatments		30 DOP	60 DOP	90 DOP	120 DOP	Harvesting stage
Oxyfluorfen 500g <i>fb</i> carfentrazone 30g	T1	85.38	78.83	86.80	80.91	78.88
Oxyfluorfen 500 g <i>fb</i> metsulfuron-methyl 5g	T2	84.20	79.90	85.80	78.34	76.38
Oxyfluorfen 500g <i>fb</i> HW+oxyfluorfen 500g	T3	85.16	77.57	92.33	84.51	82.44
Pendimethalin 1000g+straw mulch	T4	92.58	85.21	80.16	78.87	76.62
Pendimethalin 1250g+straw mulch	T5	94.40	88.95	82.22	80.67	78.21
Pendimethalin 1500g+straw mulch	T6	96.48	90.04	83.68	81.93	80.19
Butachlor 1000g <i>fb</i> carfentrazone 30g	T7	59.07	54.65	80.04	76.19	73.66
Butachlor 1000g <i>fb</i> metsulfuron-methyl 5g	T8	61.16	52.83	79.14	74.68	71.77
Butachlor 100g <i>fb</i> HW+butachlor 1000g	T9	60.60	53.92	80.74	75.83	73.31
Pendimethalin 1000g <i>fb</i> carfentrazone 30g	T10	91.83	81.43	91.70	82.54	80.96
Pendimethalin 1000g <i>fb</i> metsulfuron-methyl 5g	T11	92.53	80.79	87.55	80.89	79.02
Pendimethalin 1000g <i>fb</i> HW+ pendimethalin 1000g	T12	92.11	80.53	95.15	90.29	89.08
Mulching of black poly-ethylene sheet (100 μ)	T13	98.22	96.63	95.05	93.16	92.76
Mulching of straw (10 t) <i>fb</i> HW (75 DOP)	T14	89.68	84.91	93.78	87.03	84.79
Hand weeding/hoeing at 25, 50 & 75 DOP	T15	96.75	92.76	90.13	83.28	81.87
Weedy check (control)	T16	-	-	-	-	-

Fig 1: Weed control efficiency of weed management (T₁ to T₁₅) at different dates of observation

Table 4: Level of phytotoxicity in gladiolus as induced by oxyfluorfen and metsulfuron-methyl applications

Treatments		30 DOP*	60 DOP	90 DOP	120 DOP
Oxyfluorfen 500g <i>fb</i> carfentrazone 30g	T1	1.67	1.17	1.00	1.00
Oxyfluorfen 500g <i>fb</i> metsulfuron-methyl 5g	T2	1.67	1.23	2.73	2.97
Oxyfluorfen 500g <i>fb</i> HW+oxyfluorfen 500g	T3	1.70	1.13	1.00	1.00
Butachlor 1000g <i>fb</i> metsulfuron-methyl 5g	T8	1.00	1.00	2.30	2.60
Pendimethalin 1000g <i>fb</i> metsulfuron-methyl 5g	T11	1.00	1.00	2.33	2.63
CD @ 5%		0.15	NS	0.20	0.10

*Days of planting

Note:

Phytotoxicity index	Injury symptoms	Phytotoxicity index	Injury symptoms
1	Very healthy	6	Four leaves burning
2	Healthy but growth checked	7	Five leaves burning
3	One leaf burning	8	Six leaves burning
4	Two leaves burning	9	Near to complete death
5	Three leaves burning	10	Complete death

Conclusion

It is concluded from the present investigation that *Polypogon monspeliensis*, *Phalaris minor*, *Cyperus rotundus* and *Cynodon dactylon* among the monocots and *Chenopodium murale*, *Convolvulus arvensis*, *Fumaria parviflora* and *Coronopus didymus* in dicots were found dominant weeds in the experimental field. Among the application of herbicides or mulch materials either alone or in combinations, T₁₃ (black polyethylene mulch) was observed very effective in controlling weeds followed by T₁₂ (pendimethalin 1000 g *fb* HW + pendimethalin 1000 g/ha ha⁻¹), T₁₄ (paddy straw mulch @ 10 tonnes ha⁻¹ *fb* HW at 75 DOP) and T₆ (pendimethalin 1500 g + paddy straw mulch). Amongst the herbicidal treatments, T₁₂ (pendimethalin 1000 g *fb* HW + pendimethalin 1000 g ha⁻¹) was observed comparatively more efficient in controlling weeds. Interestingly, the herbicidal applications of oxyfluorfen and metsulfuron-methyl (T₂ & T₈) caused phytotoxicity to the crop plants and the symptoms of phytotoxicity were observed at all the dates of observation. Overall, the application of mulch materials (either alone as a black polyethylene sheet of 100 μ or paddy straw mulch @ 10 tonnes ha⁻¹ in combination with HW or pendimethalin 1500 g ha⁻¹) was found very effective with the aspect of weed control in gladiolus field.

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