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Effect of plant density and INM on vegetative, floral and yield attributes of gladiolus (*Gladiolus grandiflorus* L.)- A review

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ABSTRACT

Gladiolus (*Gladiolus grandiflorus* L.) is one of the important leading cut flowers worldwide. It is popularly known as queen of bulbous flower crop. It is popular for its attractive spike, magnificent florets which vary in size and colour. The flowers are used for making bouquets and flower arrangements. It is considered as a viable diversification option from traditional field crop due to increased per unit return. Farmers profit can be augmented by selling the corms and cormels as well as spikes. Consequently, a comprehensive acquaintance is needed on quality and quantity production of the flowers of gladiolus. Though the quality of flower is primarily a varietal but it is greatly influence by various cultural operations. Optimum plant density is essential for proper growth and development of plant as it allows the plant to acquire the essential growth elements i.e., light, nutrients and CO_2. Besides plant spacing, nutrition play an important role. Excessive and continuous use of inorganic fertilizers has various ill effects on soil health therefore attention shifted towards the holistic approach i.e., integrated nutrient management (INM). This approach has profound effect in improving flower quality and quantity. This paper reviews all the literature on important aspects of cultivation practices of gladiolus *viz*., plant density and INM for better understanding and to develop future strategies for quality and quantity of production of gladiolus spikes and corms.

Key words: Biofertilizers, Chemical Fertilizers, Gladiolus, Integrated Nutrient Management, Manures, Plant spacing.

Gladiolus (*Gladiolus grandiflorus* L.) is one of the most important cut flower for trade in India and abroad. It is cultivated throughout the world for its magnificent spike and good keeping quality. Its popularity among growers makes its Queen of bulbous flowering plant. It belongs to the family Iridaceae and is native to South Africa, Central Europe and Mediterranean region. The word Gladiolus is derived from the Latin word "Gladius", meaning a sword which describes the shape of the leaves. Therefore, it is also known as "Sword lily" and "Corn Flag". It has great economic value for cut flower trade and also much valued by the aesthetic world. Majestic spike contains attractive and elegant florets. Florets open in acropetal sequence over long duration and hence the flower has good keeping quality. The flowers are used for making bouquets, floral arrangements and table decorations when arranged in vases. In landscape gardening, it is used in herbaceous borders, beddings, rockeries and pots. It is also ideal for intercropping with knol khol, radish, coriander and marigold (Nazir, 2018).

Commercial growing of gladiolus is increasingly being considered a high remunerative economic activity by large as well as small farmers across the country (Swaroop *et al.*, 2018). It has become a money spinner crop for farmers. Therefore, improving quality and production of the crop has become a priority. The quality of flower is principally a varietal but it is influenced by various cultural operations. Among the cultural operations plant density plays an important role. It has a pronounced effect on growth and development of plants. The effect of plant density can be verified in terms of exposure to light; with narrower plant spacing there is greater overlap and shading of leaves, reduced penetration of solar radiation to basal leaves and hence higher competition for light, reducing photosynthetic efficiency of the plant (Hachmann *et al.*, 2014). Under higher plant density, plant growth rate is decreased due to reduced light interception per plant (Heuvelink, 1995). The competition for light promotes increased energy expenditure in processes of cell growth (Mueller and Wamser, 2009). Similarly, too wider spacing also results in low flower yield due to insufficient number of plants per unit area.

Gladiolus crop is a highly nutrient responsive crop. It requires higher doses of nutrients *viz.*, nitrogen, phosphorous and potassium. One can get higher yield by use of chemical fertilizers but it has adverse effect on soil structure as well as flora and fauna. Patil and Dhaduk (2010) reported that chemical fertilizer is no longer the conqueror

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for attaining high rate of production and it can be achieved by judicious use of fertilizers along with organic sources with integrated nutrient management (INM) to maintain the sustainability of soil. It appeared to be a feasible option to maintain and sustain a higher level of soil fertility and productivity thus causing less environmental problems (Satapathy *et al.*, 2016). The use of organic manures, composts, crop residues, biofertilizers and their synergistic effect with chemical fertilizers is helpful for increasing balanced nutrients supply (Wani *et al.*, 2016). Organic inputs play an important role in growth, yield and quality attributes of different crops and also economic in nature (Rambuatsaiha and Noyingthung, 2017; Mahto and Datta, 2018).

Hazarika *et al.* (2015) found that organic and microbial sources of nutrients have advantage of consistent and slow release of nutrients, maintaining ideal C:N ratio, improvement of water holding capacity and microbial biomass of soil profile without having any residual effects. Singh *et al*. (2016) reported that optimum chemical fertilizer dose and biofertilizers are essential for improving the crop growth. The use of organic manures in conjugation with fertilizers enhances the efficiency of fertilizers, partly supply nutrients and also improve the soil physical, chemical and biological properties (Airadevi and Mathad, 2012). In general, INM is commercially a viable and sustainable approach for crop production (Verma *et al.*, 2011). Considering the crop as one of the most preferential flower crops for domestic as well as international market therefore, efforts are needed to increase quality and quantity of flower by optimizing cultural practices i.e., plant density and INM. In view of above, the research works conducted worldwide on the influence of plant density and INM on vegetative, floral and yield attributes of gladiolus are being reviewed and discussed in present paper.

Effect of plant density on vegetative and floral attributes of gladiolus: Plant space in gladiolus plays an important role for manipulating growth and development of plants which have direct influence on quality and yield. The closer spacing leads to competition among plants and thus flower yield get impaired. Similarly, wider spacing also results in low flower yield due to insufficient number of plants per unit area. Gowda (1987) reported that gladiolus cv. Snow Princess, corms planted at a spacing of 30 cm x 25 cm recorded minimum days taken to corm sprouting, maximum plant height, number of leaves and flower spikes per plant. Duthie *et al.* (1999) reported that yield per unit area tends to increase with plant density up to certain threshold and then decline due to interplant competition. According to Singh and Bijimol (2000) corms planted at a spacing of 20 cm x 30 cm along with application of 30 g N per m^2 produced significant increasing spike length and maximum number of florets with bigger sized flowers in gladiolus cv. Pink Friendship. The highest number of leaves per plant, earliest spike emergence, opening of first flower, maximum number of flowers per spike and size of spike were recorded with the spacing 25 cm x 30 cm in gladiolus cv. Sylvia (Singh and Singh, 2000). Singh and Bijimol (2002) again conducted a field experiment on gladiolus cv. Pink Friendship with different spacing 10 cm x 30 cm, 15 cm x 30 cm, 20 cm x 30 cm and 25 cm x 30 cm. They observed that the wider spacing of 25 cm x 30 cm produced maximum number of leaves, flower spikes per plant, number of florets per spike and spike size. The wider spacing of 45 cm x 20 cm and 60 cm x 25 cm were found to be superior over the closer spacing of 15 cm x 15 cm in terms of plant growth parameters such as sprouts per corm, plant height, leaf length, number of leaves, shoot emergence, spike emergence, number of florets per spike, spike length, floret size and vase life of spike in gladiolus cv. Sylvia (Misra and Sanyat, 2002). Sanjib and Talukdar (2002) also reported that proper plant spacing helps in providing good open position for sunlight, availability of moisture and nutrients vital for successful crop production and quality. With an increased plant density per unit area, plants compete for essential growth factors such as nutrients, light and water, with direct influence on yield and quality of crop (Resende and Costa, 2003).

The corms planted at a wider spacing i.e. 25 cm x 30 cm produced minimum number of days to spike emergence, maximum length and diameter of spike, number of florets per spike, number of spikes per hectare and vase life (Singh and Bijimol, 2003). Sharma and Gupta (2003) found that maximum plant height, spike length, number of florets per spike, number of spikes per plant and the number of corms per plant were recorded in wider spacing. The highest number of cormels produced per plant was recorded at a spacing of 45 cm x 20 cm (Sharma and Talukdar, 2003). Nair and Singh (2004) conducted experiments to standardize the plant spacing in gladiolus in Port Blair. They found that the maximum plant height, spike length, florets size, number of spikes per meter square and number of corms per plant were recorded with the spacing of 25 cm x 30 cm. The highest vegetative, floral and corm yield were observed from the corms planted at a spacing of 20 cm x 30 cm in gladiolus cv. Debora (Shalini *et al.*, 2004). While Anwar and Maurya (2005) tried 3 different spacing *viz.*, 25 cm x 10 cm, 25 cm x 20 cm and 25 cm x 30 cm for cultivation of gladiolus and also found that wider spacing of 25 cm x 30 cm resulted into maximum number of leaves per plant, spike length, number of florets per spike, diameter of floret, number of corms per plant, diameter of new corm and earliest floret opening. Similar corm spacing found effective in improving various

growth parameters in gladiolus (Shiraz and Maurya, 2005). Optimum plant spacing provided favorable conditions to flourish the crop for higher flower yield (Karuppaiah and Krishna, 2005).

Other spacing also found good in improving various floral traits probably due to climate and other factors. Rana *et al.* (2005) found that minimum days taken to flowering, maximum plant height, number of leaves per plant, spike length, rachis length, flowering duration, number of corms per plant and corm weight were recorded in plants where corms are planted at a spacing of 30 cm x 20 cm as compared to 20 cm x 20 cm and 20 cm x 40 cm. Singh and Singh (2006) stated that the weed density and other measures of weed abundance usually decrease as crop density increases. They also found that narrow row spacing affects the weeds and increases crop yield. Bhat and Khan (2007) found that gladiolus cv. White Prosperity under Kashmir conditions planted at a spacing of 20 cm x 20 cm produced maximum number of leaves per plant, plant height, spike length and floret diameter, number of florets per spike, cormels per plant and size of corm per plant. A similar experiment on gladiolus cv. White Prosperity in Goa also had the significant improvement on vegetative growth parameters (Ramachandrudu and Thangam, 2007). However, maximum corm diameter and weight was recorded at a spacing of 45 cm x 20 cm. Yadav and Tyagi (2007) stated that growth and flowering parameters in gladiolus increased with the corm size and spacing.

Besides improving quality, plant density plays an important role in the competitive balance between crop and weed (Abouziena *et al.*, 2008). Bhat *et al.* (2008) found that in gladiolus cv. White Prosperity, maximum growth, flowering, corm and cormels production were recorded at a spacing 20 cm x 20 cm. Dalvi *et al.* (2008) conducted a field experiment to study the effect of plant spacing in growth and yield attributes of gladiolus. They found that plant height, number of leaves, leaf length, leaf width and number of florets per spike was highest in cv. American Beauty and Condiment Red, when corms were planted at spacing of 30 cm x 20 cm. They found that in both the cultivars flowering characters like spike length, longevity of spike and yield of corms were maximum with spacing of 30 cm x 10 cm. However maximum number of cormels per plant recorded with widest spacing 30 cm x 30 cm. In addition, Ahmed *et al.* (2010) observed that the wider plant spacing allowed the cultivars to gain maximum plant height than narrow spacing in gladiolus cv. Sarhad. Jamil *et al.* (2010) reported that maximum plant height (133.7 cm), corm size (8.0 cm) and cormels size (2.0 cm) has obtained with plant spacing of 30 cm x 30 cm. However, minimum days taken to spike emergence 76.3 and maximum number of florets per spike 18.8 were recorded from the plants planted at a spacing of 15 cm x 30 cm.

Patil and Dhaduk (2010) however found diverse results while conducting experiment on spacing. The gladiolus corms planted at a spacing of 20 cm x 30 cm recorded superior in quality traits *viz.*, number of florets per spike and longevity of spike while corms planted at a spacing of 20 cm x 10 cm had superior quantity traits such as yield of spikes and corms per plant. Rohidas *et al.* (2010) observed that in gladiolus growth parameters i.e. plant height (cm) and number of leaves per plant was found to be maximum in plants planted at a spacing of 30 cm x 30 cm. However, total leaf area (cm) and number of tillers per corm were found maximum in 30 cm x 25 cm. The yield i.e. number of spike/ plant, per plot and per hectare were found to be maximum from the plants planted at a spacing of 30 cm x 15 cm. Ibrahim (2012) reported that plant density per unit area determines the optimal above ground conditions that allow the plant to acquire the essential growth elements i.e., light and CO_2 that influence the productivity of dry matter and hence the final yield. Sudhakar and Kumar (2012) in gladiolus cv. White Friendship reported that maximum vegetative growth of gladiolus under widest spacing 45 cm x 15 cm as compared to closest spacing 30 cm x 20 cm. In gladiolus cv. White Prosperity, maximum number of leaves, leaf length, minimum days to opening of first floret, visibility of first spike, maximum spike length and number of florets per spike were recorded at a spacing of 20 cm x 20 cm (Ram *et al.*, 2012). The maximum plant height (81.72 cm), number of leaves per plant (11.87), leaf area (315.48 cm^2) and specific leaf weight (612.81 mg/dm^2) were recorded in wider spacing 30cm x 40cm in gladiolus cv. Sapna (Verma *et al.*, 2012).

Khalaj *et al.* (2013) found that in gladiolus, plant spacing at 25 cm x 25 cm has significant effect on flower stalk height, stem diameter, spike length and floral diameter. Kumari *et al.* (2013) reported that minimum days taken for spike emergence (52.48 days) and flower bud opening (56 days) were recorded spacing of 30 cm x 20 cm in gladiolus (*Gladiolus hybridus* L.). Other parameters *viz.*, maximum number of florets per spike (9.42), spike length (86.87 cm), number of floret opening at a time (1.21), duration of spikes (8.17 days), number of spikes per plant (1.59), number of corms per plant (1.41) and number of cormels per plant (41.64) were also recorded under the same spacing. Gupta *et al.* (2014) studied the growth and flowering behavior of newly evolved hybrid of gladiolus (*Gladiolus hybridus* L.) under different plant spacing and corm size in mid hill areas of Himachal Pradesh. They found that corms planted at a spacing of 30 cm x 14 cm showed minimum number of days taken for sprouting, maximum plant height, minimum number

of days taken for bud break, number of days taken for first floret opening, spike length, number of corms per plant and number of cormels per plant. Regar *et al.* (2016) found the best quality of gladiolus spike and longer postharvest life of gladiolus from the spikes harvested from plants grown at a spacing of 40 cm x 20 cm. Mamatha Sree (2018) reported that wider spacing in gladiolus var. Arka Amar was found significantly in improving vegetative and floral attributes.

Effect of INM on vegetative and floral attributes of gladiolus: Among the various factors that affect growth and quality of gladiolus florets, nutrition plays an important role. Gladiolus needs heavy nourishment. Use of chemical fertilizers increases the crop yield but also deteriorates the soil fertility status. Therefore, currently INM approach becomes popular among the growers. The application of recommended dose of NPK (100:60:60 kg/ha) and FYM (15 t/ha) resulted earliness in 50% flowering (64.73 days) in gladiolus cv. White Prosperity (Gangadharan and Gopinath, 2000). Dubey and Mishra (2005) observed that the combined inoculation of gladiolus corms with *Azotobacter* + PSB was found best for corm weight, corms per plant, cormel per plant and cormels weight. The gladiolus plants receiving vermicompost 8 t/ha+ *Azotobacter* and PSB (@25 kg/ha each+ 80% RDF) significantly increased growth, yield and quality attributes (Godse *et al*., 2006). Chaitra and Patil (2007) stated that inoculation of *Azospirillum* and PSB, enhanced the cell division and enlargement and also produced growth hormones, which causes increased in plant growth parameters.

Srivastava and Govil (2007) found that corms of gladiolus cv. American Beauty when treated with *Azotobacter* (100 g/L) produced minimum days taken to vegetative bud emergence (7.95 days) and maximum plant height (36.97 cm). They also observed that minimum days taken to spike emergence (80.95 days), opening of lower most floret (9.78 days) and maximum diameter of the lowermost floret (19.17 cm) were found in the treatment containing PSB (100 g/L). Dalvi *et al*., 2009 reported that use of biofertilizers with reduced dose of nitrogen significantly improved flowering and yield parameters of gladiolus. They stated that use of biofertilizers helps in saving 25% of nitrogenous fertilizers. The application of VAM + vermicompost+ vermiwash treatment in gladiolus (*Gladiolus hybrida*) cv. White Prosperity resulted in minimum days taken to spike emergence, maximum spike length, rachis length, number of florets per spike, diameter of first floret and vase life (Pathak and Kumar, 2009). Dubey *et al*., 2010 revealed that the combined inoculation of gladiolus corms with *Azotobacter* + PSB was found best in terms of days to flowering, first floret diameter, florets remaining open and days to last floret opening.

Kumar *et al.*, (2010) found that the treatment combination of vermicompost + AMF recorded longest plant height and highest number of leaf count per plant in gladiolus cv. White Prosperity. An application of treatment containing 75% recommended dose of fertilizer + FYM (20 t/ha) + vermicompost (2 t/ha) recorded significant increase in vegetative and floral parameters of gladiolus (Chaudhary *et al*., 2013). They also found maximum number of leaves from the plants treated with FYM (20 t/ha). Kumari *et al*. (2013) conducted an experiment to study the effect of integrated nutrient management on growth parameters in gladiolus (*Gladiolus hybridus* L) cv. American Beauty during both kharif and rabi seasons. They found that application of 75% recommended dose of fertilizer + vermicompost (3 t/ha) + VAM (10 kg/ha) + *Azospirillum* (10 kg/ha) + *Trichoderma harzianum* (5 kg/ha) resulted in maximum plant height (116.28 and 118.60 cm, respectively), least time for spike emergence (52.31days and 48.49 days, respectively), number of days taken for first flower bud opening (58.74 days and 54.56 days, respectively), maximum number of florets per spike (12.00 and 13.67, respectively), spike length (100.26 cm and 129.79 cm, respectively) and spike girth (1.07 cm and 1.10 cm, respectively). However, maximum number of leaves per plant (9.79 and 10.95), leaf area (519.32 cm^2 and 1296.07 cm^2, respectively) were recorded from plants grown under the plot applied with 75% recommended dose of fertilizer + vermicompost (3 t/ha) + VAM (10 kg/ha) + *Azospirillum* (10 kg/ha) + *Trichoderma harzianum* (5 kg/ha). Singh *et al.*, 2013 observed that application of 75% RDF (NPK 225:150:150 kg/ha) + vermicompost (2 t/ha) + PSB (2.5 kg/ha) + *Azotobacter* (2.5 kg/ha) found to improve the vegetative and floral attributes of gladiolus (*Gladiolus grandiflorus* L.) cv. White Prosperity.

Ahmed *et al*., 2014 found that minimum number of days taken to corm sprouting (17.58 days) were obtained from the corms treated with *Azospirillum (*@5 kg/ha). The application of 75% RDF (135:60:60 Kg/ha) + 25% vermicompost + *Azospirillum* (2 g/plant)+ PSB (2 g/plant) recorded minimum days taken to corm sprouting, maximum plant height, number of leaves per plant and length of the longest leaf per plant in gladiolus cv. Peter Pears (Mukesh, 2014). Pradeep *et al.*, 2014 reported that application of organic and biofertilizers (vermicompost, VAM and humic acid) significantly influenced the different growth parameters in gladiolus *(Gladiolus grandiflorus* L.). Akter (2015) revealed that use of FYM (5 t/ha) + Trichocompost (3 t/ha) + ¼ recommended dose of fertilizer causes early sprouting of corm (8.00 days). According to Anjana and Singh (2015), gladiolus plants received FYM + *Trichoderma* resulted in early spike emergence, opening of first floret and increased diameter of floret. They also found that maximum spike length, number of florets/spike and duration of flowering

recorded with treatment of vermicompost (5 kg/m^2) + *Trichoderma*. Whereas, significantly enhanced vase life of flower was recorded from the flower harvested from the plants grown in plot applied with FYM (2.5 kg/m^2) + vermicompost ((2.5 kg/m^2). Pansuriya and Chauhan (2015) reported that combined application of organic manure and biofertilizers i.e. FYM @ 20 t/ha + *Azotobacter* @ 4 kg/ha + Phosphobacteria @ 4 kg/ha in gladiolus cv. Psittacinus hybrid recorded increase in plant height and earliness in spike emergence. Whereas, quality and quantity traits of flowers were found maximum under the plants grown in plots applied with 75% recommended dose of fertilizer + Neem cake @ 1 t/ha + *Azotobacter* @ 2 kg/ha + Phosphobacteria @ 2 kg/ha.

Gladiolus corms treated with vermicompost (5 t/ ha) + *Trichoderma* (3 t/ha) + 75% N + 200 kg P_2O_5 + 200 kg K_2O recorded in earliest corm sprouting, highest number of sprouts per corm, plant height, number of leaves, earliest spike initiations, highest diameter of floret, length of spike, number of spikes per plant and spike per hectare (Singh *et al.*, 2015). In an experiment Sisodia and Singh (2015) reported application of vermicompost 2.5 kg/m^2 + *Trichoderma* 2.5 kg/m^2 produced early spike emergence, floret colour show, opening of first floret and increased diameter of first, third and fifth floret. They also reported that application of FYM 5 kg/m^2 was found effective in significantly improving the spike length, number of florets/ spike and duration of flowering. However, treatment containing FYM 2.5 kg/m^2 + vermicompost 2.5 kg/m^2 recorded significantly enhanced shelf life of first (5.66 days) and third floret (5.89 days). Application of 100% RDF (200:200:200 NPK kg/ha) + FYM @ 7.5 t/ha + *Azotobacter* + Phosphobacteria + Potassium mobilizing biofertilizers (KMB) + 1% foliar spray of *Nauroji* Novel Organic Liquid Fertilizer produced minimum days taken to spike initiation, maximum diameter of 2nd floret, number of florets per spike, number of spikes per plant, number of spikes per hectare, number of corms per plant, weight of corms per plant, weight of cormels per plant and size of the corm in gladiolus cv. American Beauty (Sathyanarayana *et al*., 2017).

Adhikari *et al.* (2018) studied the effect of INM on vegetative growth, floral attributes, corm yield and economics of gladiolus cv. Arka Amar in Bharsar, Uttarakhand. They found that minimum number of days taken to corm sprouts, maximum number of sprouts per corm and number of leaves were recorded in treatment containing 50% RDF + 50% FYM + *Azotobacter* @ 25 g/ l + *Trichoderma harzianum* @ 20 g/m^2. The results also showed that earliness in spike emergence and first floret opening, maximum days taken to full bloom of spike, spike length, rachis length, spike weight, number of florets per spike, number of spike per plant and per plot and vase life, number of corms per plant and corms per plot were recorded in same treatment. The similar treatment was also found most profitable in terms of economics of cultivation with a cost: benefit ratio of 1:2.12. Chakradhar *et al.* (2018) reported that maximum number of sprouts per corm, plant height, number of leaves per plant, spike length, number of florets per spike, length of floret and vase life in gladiolus cv. Arka Amar were recorded from the corms inoculated with PSB @ 2ml/l + *Azotobacter* @ 25 g/l + VAM @ 20 g/l + RDF. Negi (2018) reported that application of 75 % RDF +25 % FYM + *Trichoderma* @0.005 ml/l along with black polythene mulch was found to be effective in improving qualitative and quantitative traits of gladiolus var. Amsterdam.

CONCLUSION

On the basis of literature cited above it can be concluded that plant spacing and integrated nutrients application through chemical fertilizers, organic manures and biofertilizers is quite effective in improving vegetative, floral as well as yield attributing traits of gladiolus. By planting gladiolus corm at an optimum spacing and applying standardized INM doses in gladiolus crop helps in increasing the per unit area income as well producing good quality of flower spikes and corms in lesser input cost. Besides improving quality and quantity traits in flower, use of INM approach helps restoring the soil fertility. It is an economical, environmentally safe and sustainable approach. Therefore, there is need to emphasized studies on combined effect of plant spacing and INM package of gladiolus.

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