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Response of Gladiolus (*Gladiolus grandiflora* Linn.) cv. White Prosperity to Varying Fertigation Levels and Planting Geometry

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Abstract

The spike yield and quality can be enhanced in gladiolus by proper application of nutrients in the available form. An experiment was conducted to find out the effect of varied fertigation levels *viz.,* fertigation at 50 per cent RDF, fertigation at 75 per cent RDF, fertigation at 100 per cent RDF and surface application of 100 per cent RDF along with different planting geometry *i.e.,* 30×10 cm, 30×20 cm and 30×30 cm. Application of 100 per cent recommended dose through fertigation resulted in higher plant height, number of leaves, relative chlorophyll content, number of tillers and spikes per plant, while corms per plant was recorded highest with surface application of 100 per cent RDF. Among spacing, 30×20 cm showed greater plant height and number of leaves, meanwhile spacing of 30×10 cm depicted highest spikes per plant, corms per plant and nutrient use efficiency.

Keywords : Fertigation, Gladiolus, Planting geometry, Corm yield, Spike yield, NUE

Gladiolus is valued as one of the major cut flowers among the floriculture industry. Owing to its long vase-life and appealing range of colours, this crop is becoming increasingly popular and a significant cut-flower crop in both the domestic and foreign markets. Due to the long spike, variety of colours and forms, its cut-spikes are in high demand for bouquets and flower arrangements (Ankit *et al*., 2015). The blossoms come in a variety of colours, including crimson, pink, salmon, scarlet, purple, cherry red, apricot, cream, white or a mix of two or more colours. This exquisite cut flower is also suitable for use in the home, public gardens and exhibitions. Besides, it is also grown in the beds for garden display and in pots for its magnificent inflorescence. *Gladiolus* holds the fourth place as a cut flower in the international market after rose, carnation and chrysanthemum (Anonymous, 2015). Plants have a high requirement of nutrients for storage of food materials (corm) as well as for flower production. Hence, the need for large quantities of fertilizers which is costly. However, the amount of application can be reduced by adopting modern agro-techniques *viz.,* fertigation, planting geometry *etc.,*

Drip irrigation allow plants to have a continual supply of nutrients solution at their root surface, assisting them in taking up water and nutrients while also improving their growth by boosting fertiliser and water use efficiency, a new agro-technique provides an ideal opportunity to improve crop yield while minimising environmental pollution. Fertilizer use efficiency with fertigation ranges from 75 to 90 per cent, saving at least 25 per cent of nutrients. To ensure optimal growth and yield, an effective flow of nutrients to the root surface is important. Similarly, for optimum growth and yield, the best planting geometry is essential.

Therefore, it is necessary to standardize the fertigation schedule with optimizing the planting density without affecting the corm and stalk production along with increasing the nutrient use efficiency (NUE). The present study is aimed at finding the optimum level of nue with optimizing the planting geometry to get maximum growth and yield.

Material and Methods

The experiment was laid out with four different fertigation levels and three planting geometry levels (Table 1-3) in a split-plot design with three replications during the *rabi* season of 2018-19 and 2019-20 at Department of Horticulture, University of Agricultural Sciences, Raichur (16.21°N and 77.35°E, 407 meter msl). The soil of the experimental site was red loamy with pH of 7.2, low in organic cabron (0.26%), high available N (296.3 kg/ha), medium P (42.3kg/ha) and low K (46.4kg/ha). Uniform size corm (5.0-8.0 cm diameter, 20-25 g weight per corm) cv white prosperity was planted on 05.08.2018 and 07.08.2019 at specified geometry levels according to the treatments. A dose of 125:150: 140 kg N: P_2O_5: K_2O ha^{-1} (RDF) was applied in 12 splits during the crop growth according to the specified levels of fertigations. Half a dose of nitrogen and the whole amount of phosphorus and potassium were applied as a basal application to the surface application treatment before planting (15 days). The remaining dose of n was top-dressed at 45 days after planting (DAP) to the surface application treatment. The water-soluble fertilizers were mixed in water and fed with 0.75-inch ventury to respective beds. The standard method of 'analysis of variance' was used for analysing the data for split-plot design by Panse and Sukhatme, (1985). Plant height was measured from ground level to the extreme tip of the leaf at different intervals of time in each tagged plant with the help of meter scale. The numbers of leaves present on the tagged plants at a different intervals were counted and the average was calculated.

Similarly leaf area index (LAI) was calculated using the below formula:

$$\text{LAI} = \frac{\text{Total land area (cm}^2\text{)}}{\text{Total leaf area (cm}^2\text{)}}$$

The relative chlorophyll content was measured with the help of spad meter at top, middle and basal part of leaves, averaged and analysed the data.

Meanwhile floral parameters and yield attributes were recorded at proper stages in the laboratory. Further, the total number of spikes produced from each planted corm of the tagged plant was counted and the average was calculated. The number of corms obtained after harvesting was recorded from each plant. Observations for ten plants were recorded and their average was calculated. The total weight of cormels produced from each planted corm in each tagged plant was weighed in grams using a digital balance after digging up of the cormels in the last of the trial period. while nutrient use efficiency was calculated by the yield data and total fertilizers applied. Similar findings were also given by (Nosir, 2011) on gladiolus to study the flowering and characteristics.

Nutrient use efficiency was calculated by the following formula :

$$\text{NUE for spike} = \frac{\text{Toatal number of spikes ha}^{-1}}{\text{Total fertilizers applied ha}^{-1}}$$

$$\text{NUE for corms} = \frac{\text{Total numbe of coms ha}^{-1}}{\text{Total fertilizers applied ha}^{-1}}$$

Results and Discussion

Germination

The data was recorded over two years, averaged and presented (Table 1). No significant effect on days to sprouting and germination of corms was observed for either fertigation levels and or for spacing. It might be due to that the fertigation was initiated after fifteen days of sowing the corms, by the time the corms might have germinated and the spacing also did not make any significance as the corms will have prevailing stored carbohydrates for

TABLE 1

Influence of fertigation and planting geometry on days to sprouting, germination and plant height of gladiolus (*Gladiolus grandiflora* L) cv. White prosperity

	Germination (%)			Number of days to sprout			Plant height (cm)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Main plot: fertigation levels									
F_1 (Fertigation, 50% RDF)	91.39	90.62	91.01	17.58	15.34	16.46	63.40	61.12	67.26
F_2 (Fertigation, 75% RDF)	92.55	87.22	89.89	18.04	17.98	18.01	73.67	68.71	71.19
F_3 (Fertigation, 100% RDF)	89.96	92.94	91.45	16.05	18.41	17.23	71.23	76.21	73.72
F_4 (Surface, 100% RDF)	91.86	94.09	92.98	17.66	18.27	17.97	66.81	59.20	63.01
S.Em±	0.64	0.63	0.63	0.37	0.42	0.39	1.90	1.91	1.90
Cd @ 5%	2.20	2.19	2.19	NS	NS	NS	6.58	6.60	6.59
Sub-plot: spacing levels									
S_1 (30×10 cm)	92.66	85.34	89.00	17.84	18.02	17.93	68.84	62.54	65.69
S_2 (30×20 cm)	93.03	82.89	87.96	17.54	18.65	18.10	66.69	64.41	65.55
S_3 (30×30 cm)	83.13	92.17	87.65	17.37	17.88	17.63	60.56	64.98	62.77
S.Em±	1.43	1.38	1.40	1.28	1.45	1.37	5.29	5.18	5.25
Cd @ 5%	NS	NS	NS	NS	NS	NS	11.16	11.08	11.12
Cv%	5.32	5.16	5.24	5.25	6.09	5.67	12.88	12.98	12.93

their germination, upon which they will not compete for the nutrients in the soil during the initial phase.

And also germination is a natural biological process by which the seeds or buds come out of the latency stage, soil application of fertilizers has resulted in maximum sprouting which might have triggered the sprouting by providing essential nutrients required for initiation of buds present in the corms.

Plant Height

The data of the two-year mean (Table 1) indicated a significant impact among the treatments. Plant height was found significantly superior (71.23, 76.21 and 73.72 cm) in fertigation of 100 per cent rdf which was also on par with fertigation of 75 per cent rdf (73.67, 68.71 and 71.19 cm) as compared to rest of the treatments. Meanwhile, a successive increase in fertigation levels from 50-100 per cent significantly increased the plant height of gladiolus. Similarly, the spacing of 30×20 cm was indicated greater plant height (66.69, 64.41 and 65.55 cm). It might be because fertigation is a very precise way to apply nutrients that results in minimum leaching. Nutrients are applied only to the wetted soil volume where roots are active, which lowers nutrient loss through leaching or soil fixation and improves fertilizer efficiency. This could be explained by the enhanced availability of key nutrients throughout the crop growth period as a result of fertigation's higher split application in a smaller quantity. Similar findings of enhanced crop growth through fertigation of major nutrients were reported by Diane *et al.* (2021) in gladiolus, Prasad *et al.* (2022) in gladiolus and by Babu and Sumangala (2018) in marigold.

Number of Leaves

Similar results of significantly highest number of leaves (5.13, 5.93 and 5.53) was recorded (Table 2) in fertigation of 100 per cent rdf, which was also on par with fertigation of 75 per cent rdf (5.64, 5.05 and 5.34) and among plant geometry 30×20 cm (4.93, 5.94 and 5.43) also at par with 30×30 cm

(5.29, 4.93 and 5.11) during both year and pooled, respectively. Fertigation had a greater impact on the number of leaves and often preferred over soil application because of its high water application efficiency along with enhanced nutrient uptake, which enhances the cell elongation, cell multiplication and ultimately resulting in the production of higher number of leaves. The optimum spacing provided more space and less competition for nutrients which promoted the enhanced growth of the plant by increasing the number of leaves per plant along with high chlorophyll content. Similar results of the increased number of leaves with the optimum nutrient application were reported by Kumar and Sahu, (2013) in cabbage.

Leaf Area Index

Leaf area index (LAI) was significantly influenced with fertigation and planting geometry (Table 2). Fertigation of 100 percent RDF has resulted significantly highest LAI (2.36, 2.21 and 2.62), meanwhile geometry of 30×20 cm depicted (2.13, 2.14 and 2.13) was also on par with 30×30 cm (2.09, 1.92 and 2.01) during both years and pooled, respectively. The lai, which is equal to half of the total green leaf area per unit horizontal ground surface, is a crucial structural feature of vegetation. As, plant survival is influenced by plant population density, where in closely spaced plants will have higher competition for the same resources. So, the weaker plants died before harvest due to a higher plant density, a lower plant density provided better circumstances for optimal growth. Net primary production, water and nutrient usage and carbon balance are all influenced by it. Important activities including evapotranspi ration, canopy interception and gross photosynthesis are directly proportional to LAI since leaf surfaces constitute the primary frontier of energy and mass exchange. A similar finding of increased LAI with fertigation was recorded by Gonsalves and Pavani (2011) in watermelon and Zhou *et al*. (2017) in potato.

TABLE 2

Influence of fertigation and planting geometry on number of leaves, leaf area index (LAI) and relative chlorophyll content of gladiolus (*Gladiolus grandiflora* L) cv. White prosperity

	Number of leaves			Leaf area index			Relative chlorophyll content		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Main plot: fertigation levels									
F_1 (Fertigation, 50% RDF)	4.82	5.16	4.99	1.77	1.53	1.65	33.61	39.20	36.40
F_2 (Fertigation, 75% RDF)	5.64	5.05	5.34	2.18	2.01	2.09	39.72	35.80	37.76
F_3 (Fertigation, 100% RDF)	5.13	5.93	5.53	2.36	2.21	2.28	43.64	46.15	44.89
F_4 (Surface, 100% RDF)	5.01	5.48	5.02	1.62	1.87	1.74	33.98	42.89	38.43
S.Em±	0.15	0.14	0.14	0.03	0.03	0.03	1.47	1.41	1.44
Cd @ 5%	0.50	0.49	0.50	0.06	0.11	0.08	5.09	4.88	4.98
Sub-plot: spacing levels									
S_1 (30×10 cm)	5.15	4.03	4.59	1.78	1.71	1.75	36.94	30.76	33.85
S_2 (30×20 cm)	4.93	5.94	5.43	2.13	2.14	2.13	37.76	40.40	39.08
S_3 (30×30 cm)	5.29	4.93	5.11	2.09	1.92	2.01	46.01	42.88	44.45
S.Em±	0.11	0.12	0.12	0.06	0.07	0.06	1.78	1.75	1.77
Cd @ 5%	0.69	0.72	0.70	0.37	0.40	0.36	5.31	5.24	5.29
Cv%	7.28	7.58	7.43	10.21	11.75	10.98	15.35	14.45	14.90

Relative Chlorophyll Content

The effect of spacing and fertigation was found significantly different with relative to chlorophyll content (Table 2). Highest (43.64, 46.15 and 44.89) was recorded in fertigation of 100 per cent rdf and spacing of 30×30 cm has resulted significantly maximum chlorophyll (46.01, 42.88 and 44.45) during both years and pooled, respectively. Photosynthesis is a crucial physiological mechanism in plants that accounts for 90 per cent of their biomass. It is a primary purpose of leaves. However, the key factors that promote leaf growth and as a result, boost plant growth, yield and quality are fertigation and spacing. Fertigation delivers the optimal level of nutrients in a cell, where nitrogen is a major element of protoplasm and adequate nitrogen is required for growth and development. Phosphorus is a component of chlorophyll and is involved in a variety of physio logical activities, including cell division, meriste matic tissue formation, photosynthesis and glucose, fat and protein metabolism. Similar results were reported by Chopde and Gonge (2014) and (Margenot *et al.*, 2018) in marigold.

Tillers Per Plant

Tillers per plant showed no significant differences (Table 3). While, highest (1.49, 1.35 and 1.42) in fertigation of 100 per cent rdf and among spacing 30×20 cm noted (1.40, 1.47 and 1.44) highest during both years and pooled, respectively.

Number of Corms Per Plant

The data on corms per plant was recorded for two years, averaged and presented in Table 3. Surface application of 100 per cent rdf has resulted significantly greater number of corms (1.28, 1.35 and 1.31). Meanwhile, among planting geometry, 30×10 cm showed higher corm number (1.41, 1.45 and 1.43) which was also on par with 30×20 cm (1.36, 1.40 and 1.28) during both years and pooled, respectively. It was noted from the observations that, the corm development will take place during the vegetative

TABLE 3

Influence of fertigation and planting geometry on number of tillers, corms per plant and spikes per plant of gladiolus (*Gladiolus grandiflora* L) cv. White prosperity

	Number of tillers			Number of corms			Spikes per plant		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Main plot: fertigation levels									
F_1 (Fertigation, 50% RDF)	1.23	1.31	1.27	1.03	1.14	1.09	1.11	1.02	1.07
F_2 (Fertigation, 75% RDF)	1.21	1.51	1.36	1.18	1.21	1.19	1.14	1.10	1.12
F_3 (Fertigation, 100% RDF)	1.49	1.35	1.42	1.03	1.17	1.10	1.25	1.33	1.29
F_4 (Surface, 100% RDF)	1.29	1.38	1.34	1.28	1.35	1.31	1.21	1.19	1.20
S.Em±	0.04	0.04	0.04	0.03	0.03	0.03	0.01	0.02	0.01
Cd @ 5%	NS	NS	NS	0.09	0.09	0.09	0.04	0.06	0.05
Sub-plot: spacing levels									
S_1 (30×10 cm)	1.36	1.42	1.39	1.41	1.45	1.43	1.28	1.22	1.25
S_2 (30×20 cm)	1.34	1.48	1.41	1.36	1.40	1.38	1.17	1.20	1.19
S_3 (30×30 cm)	1.40	1.47	1.44	1.19	1.21	1.20	1.11	1.14	1.13
S.Em±	0.14	0.04	0.09	0.03	0.04	0.03	0.02	0.01	0.02
Cd @ 5%	NS	NS	NS	0.19	0.23	0.21	0.11	0.09	0.11
Cv%	9.93	10.11	10.02	10.14	9.74	9.94	5.31	5.18	5.24

phase where the photosynthates are stored in the corm for reproductive phase. The top dressing of fertilizers as soil application has led to an uptake of bulk amount of nutrients. Also, the smaller spacing has resulted in small corms with larger number while wider spacing produced bigger corms in lesser numbers. These results are also at par with (Aklade *et al.*, 2010) in gladiolus, (Busari *et al.*, 2019) in taro.

Number of Spikes Per Plant

The spike number per plant is an important yield attribute governing the final yield. The effect of fertigation and planting geometry significantly affected the spikes per plant. Fertigation of 100 per cent rdf has given significantly highest (1.25, 1.33 and 1.29) number of spikes per plant over other treatments and the spacing of 30×10 cm (1.28, 1.22 and 1.25) produced greater spike number during both years and pooled, respectively. the fact that nitrogen expedited the developmental phases by enhancing the protein synthesis and so promoted faster floral primordial development, which could explain the positive influence of nutrients supplied through NPK fertilizers on flowering behaviour. Nitrogen is thought to be a crucial nutrient for encouraging rapid development, as it increases net photosynthesis on the one hand and increases photosynthate mobility to the sink on the other, thereby enhancing yield. Phosphorus is a component of many energy-rich molecules in plants and it also promotes root growth and aids in the uptake of other nutrients, resulting in greater output. Potassium enhances the rate of photosynthesis and the mobilisation of sucrose to the shoots, both of which help to initiate flowering. Further, aids in protein synthesis and boosts stress tolerance, which may have resulted in greater plant growth and development and as a result, increased output. The yield was significantly influenced by plant spacing and fertigation. The yield attributes were significantly influenced by plant spacing. Wider spacing resulted in fewer spikes per plant but more florets; closest spacing had vice-versa. Plants with a medium spacing generated a higher number of spikes with a higher marketability.

When plants are spread further apart, there is more surface area for light interception and less competition or interference. Thus, photo assimilate production is higher and plants display the appropriate architecture, which allows them to express their potential by forming more racemes. These results are in conformity with (Sharma, 2022) in marigold and tuberose, (Munikrishnappa *et al.*, 2002) in tuberose, (Anwar and Maurya, 2005), (Kumar *et al.*, 2015) in gladiolus, (Shashidhar *et al.*, 2008) in tuberose.

Corm and Cormel Character

The diameter of gladiolus corm was significantly influenced by fertigation and planting geometry (Fig.1). The weight of corm (67.32, 68.50 and 67.91 g plant^{-1}) and cormel (9.87, 9.98 and 9.93 g plant^{-1}) was found to be significantly greater in soil application during both years and pooled, respectively. Similarly spacing of 30×30 cm has resulted significantly maximum weight of corms (66.66, 65.94 and 66.30 g plant^{-1}), however bigger cormels were recorded in 30×10 cm (10.67, 10.70 and 10.68 g plant^{-1}) during both years and pooled, respectively. The diameter might have also been influenced by the nutrient supply to the gladiolus crop. Wider spacing might have provided more nutrient, sunlight and moisture per plant, which is beneficial in improving the weight of corms. It might be due to the higher availability of fertilizer due to soil applications top dressing during the vegetative phase, which has resulted in better uptake of nutrients by the plant for development of corm.it was noted from the record that, this character had a negative relationship with the number of cormels produced per plant. The fertigation had a significant effect on the weight, as it may be due to the application of nutrients in higher split doses at reproductive phase might have led to better uptake of nutrients. The closure spacing produced well-developed cormels due to less space available for corm development, as the photosynthates have equally distributed to corm and cormels. The increased in corm characters by the application of fertigation and planting geometry was also noticed by Nedunchezhiyan (2017), Venkatesan *et al.* (2015) in elephant foot yam and by Akakpo *et al.* (2021) in African potato.

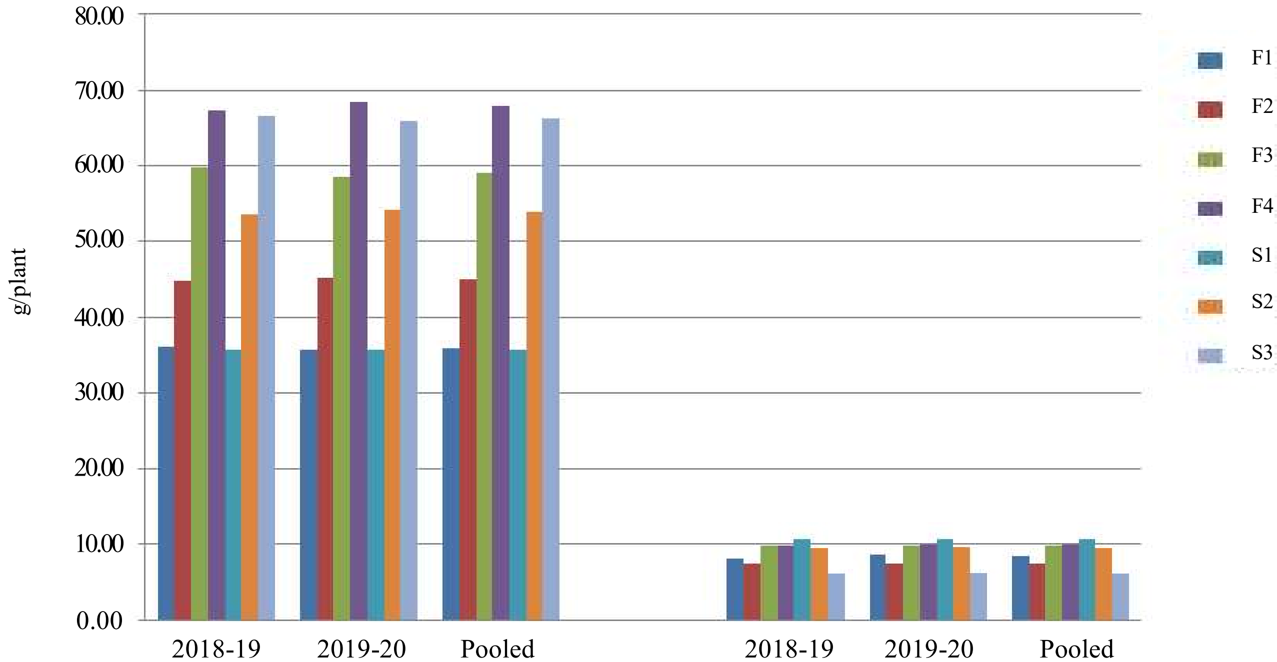

Fig. 1 : Weight of corm and cormel influenced by fertigation and planting in gladiolus (*Gladiolus grandiflora* L) cv. White prosperity

TABLE 4

Influence of fertigation and planting geometry on nutrient use efficiency (NUE) of gladiolus (*Gladiolus grandiflora* L) cv. white prosperity

	Nitrogen use efficiency		Phosphorus use efficiency		Potassium use efficiency	
	Corms ha^{-1} kg of n	Spikes ha^{-1} kg of n	Corms ha^{-1} kg of n	Spikes ha^{-1} kg of n	Corms ha^{-1} kg of n	Spikes ha^{-1} kg of n
Main plot: fertigation levels						
F_1 (Fertigation, 50% RDF)	2523.58	4448.48	2018.864	3558.78	2163.07	3812.98
F_2 (Fertigation, 75% RDF)	2847.15	4381.48	2277.719	3505.19	2440.41	3755.56
F_3 (Fertigation, 100% RDF)	3410.09	5152.78	2728.07	4122.22	2922.93	4416.67
F_4 (Surface, 100% RDF)	3252.75	4835.19	2602.2	3868.15	2788.07	4144.44
S.Em±	36.30	67.41	29.03	53.93	31.11	57.78
Cd @ 5%	125.60	233.27	100.48	186.62	107.66	199.95
Sub-plot: spacing levels						
S_1 (30×10 cm)	3143.71	5006.94	2514.97	4005.56	2694.61	4291.67
S_2 (30×20 cm)	3060.98	4668.29	2448.78	3734.63	2623.70	4001.39
S_3 (30×30 cm)	2820.48	4438.21	2256.39	3550.57	2417.56	3804.18
S.Em±	79.88	70.32	63.90	56.26	68.46	60.28
Cd @ 5%	478.94	421.65	383.15	337.32	410.52	361.41
Cv%	9.20	5.18	9.20	5.18	9.20	5.18

Nutrient Use Efficiency

The influence of fertigation and planting geometry on nutrient use efficiency (nue) of gladiolus was worked out and presented in Table 4. The corm ha^{-1} (3410.09, 2728.07 and 2922.93) and spike ha^{-1} (5152.78, 4122.22 and 44.16.67) was found significantly efficient nitrogen, phosphorous and potassium applied, respectively. It is because fertigation is a very precise way to apply nutrient that results in minimum leaching.

Nutrients are applied to only the wetted soil volume where roots are active, lowers nutrient loss through leaching or soil fixation and improves fertilizer efficiency. This could be due to better availability of key nutrients throughout the crop growth period as a result of higher split application through fertigation in a smaller amount. similar findings of enhanced crop growth through fertigation of major nutrients were reported by Sanjeev and Renu (2015), Jayakumar *et al.* (2017) in coconut and by Ucar *et al.* (2017) in rose.

It can be concluded from the research that the fertigation and planting geometry will not have any influence over corm germination, germination per cent and number of tillers. While other characters and yield was recorded highest in fertigation of 100 per cent rdf and 30×20 cm spacing as compared to other treatments.

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