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Effect of different plant spacing and planting depth on growth and flower yield of Gladiolus (*Gladiolus grandiflorus* L.)

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Abstract
The present experiment was carried out during August, 2017 to December, 2017 in Departmental Research Field of Department of Horticulture, SHUATS, Allahabad. The experiment was conducted in Randomized Block Design (RBD), four spacing i.e. 20x25 cm, 25x25cm, 30x40 cm and 40x40 cm and four planting depth i.e. 4 cm, 6 cm, 8 cm and 10 cm are used for Gladiolus Planting, the total number of treatments were sixteen, each treatment replicated thrice. From the present investigation on different spacing and planting depth of Gladiolus, it is found that the treatment T_7 (Spacing 25x25 cm + Depth 8 cm) was found to be the best in terms of growth and flower yield parameters, followed by treatment T_4 (Spacing 20x25 cm + Depth 10 cm) and the Vase life of flower was recorded maximum in treatment T_3 (Spacing 20x25 cm + Depth 8 cm), and the minimum growth and flower yield was recorded in treatment T_{16} (Spacing 40x40 cm + Depth 10 cm).

Keywords: Gladiolus, plant spacing and planting depth

Introduction
Gladiolus (*Gladiolus grandiflora* L.) is considered as the 'Queen of bulbous flowers' and is one of the most beautiful and popular ornamental cormous plant. The appurtenance, beauty and colour of the bloom are very spectacular and attractive. The name 'gladiolus' was coined by Pliny (AD 23-79) from a Latin word 'gladius' which means sword and hence it is somtimes also called the 'Sword lily'.

The genus Gladiolus belongs to family Iridaceae and occurs in Asia, mediterranean Europe, South Africa. The center of diversity is the cape Floristic Region. It contain about 260 species

The major countries producing gladiolus cut flowers are USA, Holland, Italy, France, Bulgaria, Brazil. In India, it is commercially cultivated on West Bengal, Himachal Pradesh, Sikkim, Karnataka, Uttar Pradesh, Tamil Nadu, Punjab and Delhi. In the eastern states like Tripura, Assam, Manipur, Maghalaya and Nagaland, this flower has established itself as a commercial proposition. There is a sizeable area under gladiolus in Jammu- Kashmir, Andra Pradesh and Gujarat also, Gladiolus is the 5th place in the International flower market and 4th position in bulbous trade.

Gladiolus requires well drained soil for achieving healthy plants. They also need position for getting more sunlight, ample water with heavy soaking weekly. Gladiolus corms are harvested six to eight weeks after flowering. Harvested corms are washed with clean water, dried under shade, treated with fungicide and kept in ventilated area.

The plant density significantly influences the period for emergence of flower buds. Earlier emergence and opening occur in close planting. The length of flower stalk and size of flower also varies with the change in plant density.

Proper plant spacing is an important practice for providing good open position for sunlight, availability of moisture and nutrients are vital for successful crop production and quality. Plant spacing affects yield of quality spikes and corms.

Plants require proper space to grow and to take other available essential like water, air and light. Plants have to get these from the limited space in which they grow. Therefore they are more vulnerable to deprivation of essentials, if they are not providing enough living space (Anonymous. 2011).

Correct planting depth influences the available space for development of plant and therefore bulbs, corms and seeds should be planted according to their requirement.

Additionally the planting depth influences time to emergence and subsequently the flowering time and total crop duration. Hence, planting at a uniform depth is necessary for a uniform crop time (Cameron and padhye, 2007) [2].

Materials and Methods

The Experimental was conducted in Randomized Block Design (RBD) in Departmental Research field of Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad during August, 2017 to December, 2017.with four spacing i.e. 20x25 cm, 25x25cm, 30x40 cm and 40x40 cm and four planting depth i.e. 4 cm, 6 cm, 8 cm and 10 cm are used for Gladiolus Planting, the total number of treatments were sixteen, each treatment replicated thrice. The treatments were *viz.* T_1 (Spacing 20x25 cm + Depth 4 cm), T_2 (Spacing 20x25 cm + Depth 6 cm), T_3 (Spacing 20x25 cm + Depth 8 cm), T_4 (Spacing 20x25 cm + Depth 10 cm), T_5 (Spacing 25x25 cm + Depth 4 cm), T_6 (Spacing 25x25 cm + Depth 6 cm), T_7 (Spacing 25x25 cm + Depth 8 cm), T_8 (Spacing 25x25 cm + Depth 10 cm), T_9 (Spacing 30x40 cm + Depth 4 cm), T_{10} (Spacing 30x40 cm + Depth 6 cm), T_{11} (Spacing 30x40 cm + Depth 8 cm), T_{12} (Spacing 30x40 cm + Depth 10 cm), T_{13} (Spacing 40x40 cm + Depth 4 cm), T_{14} (Spacing 40x40 cm + Depth 6 cm), T_{15} (Spacing 40x40 cm + Depth 8 cm) and T_{16} (Spacing 40x40 cm + Depth 10 cm). Recommended dose of manures and fertilizers were applied in each treatments.

Climatic condition in the experimental site

The area of Allahabad district comes under subtropical belt in the south east of Utter Pradesh, which experience extremely hot summer and fairly cold winter. The maximum temperature of the location reaches up to 46 ºC- 48 ºC and seldom falls as low as 4 ºC- 5 ºC. The relative humidity ranges between 20 to 94 %. The average rainfall in this area is around 1013.4 mm annually. However, occasional precipitation is also not uncommon during winter months.

Results and Discussion

The present investigation entitled "Effect of different plant spacing and planting depth on growth and flower yield of Gladiolus (*Gladiolus grandiflorus* L.)" was carried out during August 2017 to December 2017 in Departmental Research Field of Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad (U.P.) India. The results of the present investigation, regarding the effect of plant spacing and planting depth on growth and flower yield of Gladiolus, have been discussed and interpreted in the light of previous research work done in India and abroad. The experiment was conducted in Randomized block design with 16 treatments, and three replications.

The results of the experiment are summarized below.

Corm Parameter

Days to first sprouting was recorded minimum in treatment T_7 (Spacing 25x25 cm + Depth 8 cm) with (6.957 days to first sprouting) during different spacing and depth of sowing followed by T_{14} (Spacing 40x40 cm + Depth 6 cm) and T_{15} (Spacing 40x40 cm + Depth 8 cm) with (7.33 days) respectively, where as maximum Days to first sprouting (8.153 days) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). The earliness in sprouting maybe due to the effect of spacing and depth as providing proper spacing and depth allows the plants to receive required amount of sunlight and ample space to grow which allows the plant to have more vegetative growth as compared to narrow spaces which leads the plants towards more reproductive growth. Also, deeper planting of corms allows the plants to receive proper moisture and required temperature. This result is confirmed with the findings of Dogra *et al.* (2012) [3].

Days to 50% Sprouting was observed minimum in treatment T_7 (Spacing 25x25 cm + Depth 8 cm) with (15.667 days to 50% sprouting) during different spacing and depth of sowing followed by T_5 (Spacing 25x25 cm + Depth 4 cm) with (16.370 days), where as maximum Days to 50% sprouting (22.707 days) was found with treatment T_{12} (Spacing 30x40 cm + Depth 10 cm). Minimum number of days taken for 50% sprouting of the corms maybe due to the effect of plant spacing and planting depth which promotes or induces sprouting of corms by allowing the corms to receive proper soil temperature, soil moisture and required amount of sunlight to induce vegetative growth. Similar results were observed by Verma *et al.* (2015) [15] in Gladiolus.

Number of sprouts/corm was noticed maximum in treatment T_7 (Spacing 25x25 cm + Depth 8 cm) with (2.297 sprouts/corm) during different spacing and depth of sowing followed by T_{10} (Spacing 30x40 cm + Depth 6 cm) with (15.547 sprouts/corm), where as minimum Number of Sprouts/corm (1.040) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). The combined effect of the spacing and depth may have resulted in producing maximum number of sprouts per corm. Spacing and depth play a vital role in vegetative growth of a plant. Deeper planting and closer spacing allows the plant to receive better soil temperature for growth and soil holding around the bulbs which help in maximum nutrient uptake. The result are similar to the findings of Karavadia and Dhaduk (2002) [5].

Growth Parameter

The plant height (cm) of gladiolus was recorded maximum in treatment T_7 (Spacing 25x25 cm + Depth 8 cm) with (54.677, 90.307 and 114.387 cm) Plant height at 30, 60 and 90 days interval, during different spacing and depth of sowing followed by T_6 (Spacing 25x25 cm + Depth 6 cm) with (53.523, 82.403 and 109.173 cm), where as minimum Plant height (44.650, 69.357 and 85.400 cm) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). The interaction effect between the plant spacing and planting depth of the corms shows that the parameters play an important role in plant height. The probable reason for increased plant height maybe due to availability of proper plant space, air, water, sunlight and nutrition for proper physiological process of the plant. Similar results were observed by Singh *et al.* (2000) [13], Kumar and Yadav (2004-2005) [6], Shiraz *et al.* (2005) [10] and Kumar *et al.* (2007).

Number of leaves was noticed maximum in treatment T_7 (Spacing 25x25 cm + Depth 8 cm) with (5.433, 8.120 and 13.610) Number of leaves, at 30, 60 and 90 days interval, during different spacing and depth of sowing followed by T_1 (Spacing 20x25 cm + Depth 4 cm) with (5.053, 7.730 and 12.447) Number of leaves, where as minimum Number of Leaves (3.547, 6.520 and 9.580) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). The combined effect of spacing and depth might have played role in activation of photosynthetic system for enhanced biological efficiency, enabling synthesis of maximum photosynthesis and their translocation and assimilation resulting in increase of number of leaves. Similar findings were reported by Karavadia and Dhaduk (2002) [5], Shiraz *et al.* (2005) [10], Pandey and Mishra

(2005) [7] and Rohidas *et al.* (2010) [9].

Flower Parameters

In terms of days taken for basal floret to open was recorded minimum in treatment T_7 (Spacing 25x25 cm + Depth 8 cm) with (73.553 days) for days taken for basal floret to open, during different spacing and depth of sowing followed by T_{13} (Spacing 40x40 cm + Depth 4 cm) with (75.880 days) for basal floret to open, where as maximum days for basal floret to open (83.493 days) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). The interaction effect between the plant spacing and planting depth of the corms shows that the parameters play an important role in days taken for basal floret to open. The probable reason for minimum number of days taken for basal floret to open maybe due to availability of proper plant space, air, water, sunlight and nutrition for proper physiological process of the plant. Similar results were observed by Sharma *et al.* (2003) and Singh *et al*. (2012).

The Number of floret/spike was noticed maximum in treatment T_7 (Spacing 25x25 cm + Depth 8 cm) with (14.357) Number of floret/spike, during different spacing and depth of sowing followed by T_3 (Spacing 20x25 cm + Depth 8 cm) with (13.343 floret/spike), where as minimum Number of floret/spike (10.817) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). The combined effect of spacing and depth might have played role in activation of photosynthetic system for enhanced biological efficiency, enabling synthesis of maximum photosynthesis and their translocation and assimilation resulting in increase of number of florets per spike. Similar findings were reported by Kumar and Yadav (2004-2005) [6] and Singh and Bijimol (1999) [12].

From the data regarding the longevity of first floret the treatment T_7 (Spacing 25x25 cm + Depth 8 cm) recorded maximum (13.467 days) Longevity of first floret, during different spacing and depth of sowing followed by T_{11} (Spacing 30x40 cm + Depth 8 cm) with (12.723 days), where as minimum Longevity of first floret (10.153 days) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). Plant spacing and planting depth might have affected the longevity of first floret on spike as ample spacing and depth allows a plant to extract required nutrients from the soil and to receive required amount of sunlight for physiological functions of the plant. This result is similar to the findings of Sharma *et al.* (2003) and Kumar and Yadav (2004-2005) [6].

The Rachis length (cm) was recorded significantly higher in treatment T_7 (Spacing 25x25 cm + Depth 8 cm) with (55.183 cm) Rachis length, during different spacing and depth of sowing followed by T_1 (Spacing 20x25 cm + Depth 4 cm) with (52.700 cm), where as minimum Rachis length (45.687 cm) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). The interaction effect between the plant spacing and planting depth of the corms shows that the parameters play an important role in greater rachis length. The probable reason for longest rachis length maybe due to availability of proper plant space, air, water, sunlight and nutrition for proper physiological process of the plant. Similar results were observed by Thockchom and Singh (2015) [14] and Amjad and Ahmad (2012) [1].

Floret diameter (cm) of Gladiolus was recorded maximum in treatment T_7 (Spacing 25x25 cm + Depth 8 cm) with (11.867 cm) Floret diameter, during different spacing and depth of sowing followed by T_1 (Spacing 20x25 cm + Depth 4 cm) with (11.107 cm), where as minimum Floret diameter (83.690 cm) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). Plant spacing planting depth might have affected the floret diameter. Plant spacing and planting depths greatly affect the nutritional availability and amount of sunlight that the plant receive which directly affect the floral character of the plant. Similar results were observed by Shah *et al.* (2005), Thockchom and Singh (2015) [14] and Piya *et al.* (2008) [8].

Vase life was recorded significantly higher in treatment T_3 (Spacing 20x25 cm + Depth 8 cm) with (12.487 days) Vase life, during storage in room temperature, in a jar containing tap water, followed by T_1 (Spacing 20x25 cm + Depth 4 cm) with (12.403 days), where as minimum Vase life (9.150 days) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). Plant spacing and planting depth provide the required amount of space to grow and required amount of sunlight for photosynthetic processes. Vase-life of the flower might have been affected by the spacing and depth of the planting. Shah *et al.* (2005) reported similar results.

Yield Parameters

The number of spike/plant was recorded significantly higher in treatment T_7 (Spacing 25x25 cm + Depth 8 cm) with (1.747) spike/Plant, during different spacing and depth of sowing followed by T_{11} (Spacing 30x40 cm + Depth 8 cm) with (1.400 spike/plant), where as minimum Number of spike/plant (1.140) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). Plant spacing planting depth might have affected the floret diameter. Plant spacing and planting depths greatly affect the nutritional availability and amount of sunlight that the plant receive which directly affect the floral character of the plant. Similar results were observed by Verma *et al.* (2015) [15].

The Number of spike/plot was recorded maximum in treatment T_7 (Spacing 25x25 cm + Depth 8 cm) recorded maximum (91.950) spike/Plot, during different spacing and depth of sowing followed by T_4 (Spacing 20x25 cm + Depth 10 cm) with (85.017 spike/plot), where as minimum spike/plot (25.453) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). The interaction effect between the plant spacing and planting depth of the corms shows that the spacing and depth play an important role. The probable reason for maximum spike yield per plot maybe due to availability of proper plant space, air, water, sunlight and nutrition for proper physiological process of the plant. Similar results were observed by Singh and Bijimol (2001) and Gaurav *et al.* (2005) [4].

Spike yield/ha was recorded maximum in treatment T_7 (Spacing 25x25 cm + Depth 8 cm) with (183492) spike/ha, during different spacing and depth of sowing followed by T_4 (Spacing 20x25 cm + Depth 10 cm) with (174918 spike/ha), where as minimum spike yield/ha (84717.660) was found with treatment T_{16} (Spacing 40x40 cm + Depth 10 cm). The combined effect between the plant spacing and planting depths shows that the spacing and depth play an important role. The probable reason for maximum spike yield per hectare maybe due to availability of proper plant space, air, water, sunlight and nutrition for proper physiological process of the plant. Similar results were observed by Singh and Bijimol (2001) and Gaurav *et al.* (2005) [4].

Economics

The treatment T_7 (Spacing 25x25 cm + Depth 8 cm) recorded maximum Gross Return Rs. 917460.00, Net Return Rs. 476851.00 and Cost Benefit Ratio 1:2.08, followed by treatment T_{13} (Spacing 40x40 cm + Depth 4 cm) with Gross return Rs. 471413.30, Net Return Rs. 235350.30 and Cost benefit Ratio 1:1.99 and minimum Gross Return, Net Return

and Cost Benefit Ratio (Rs. 646278.50, Rs. 205669.50 and 1:1.47 respectively) was recorded in treatment T_5 (Spacing 25x25 cm + Depth 4 cm).

Table 4.1: Effect of different plant spacing and Planting depth on Days to first and 50% sprouting, Number of sprouts/corm, Plant height (cm) and Number of leaves/plant of Gladiolus

Treatment Symbol	Treatment Combinations	Days to first sprouting	Days to 50% Sprouting	Number of sprouts/corm	Plant height (cm)			Number of Leaves/plant		
					30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T_1	Spacing 20x25 cm + Depth 4 cm	7.590	17.643	1.453	50.327	81.800	104.457	5.053	7.730	12.447
T_2	Spacing 20x25 cm + Depth 6 cm	7.663	19.333	1.270	52.190	87.340	102.450	5.133	7.637	12.373
T_3	Spacing 20x25 cm + Depth 8 cm	7.503	17.330	1.207	51.747	83.457	106.347	4.857	7.647	12.067
T_4	Spacing 20x25 cm + Depth 10 cm	7.520	18.650	1.337	50.057	81.453	107.633	4.737	7.517	11.653
T_5	Spacing 25x25 cm + Depth 4 cm	7.467	16.370	1.517	51.187	81.853	108.423	4.847	7.733	11.677
T_6	Spacing 25x25 cm + Depth 6 cm	7.867	21.003	1.307	53.523	82.403	109.173	4.947	7.650	12.013
T_7	Spacing 25x25 cm + Depth 8 cm	6.957	15.667	2.297	54.677	90.307	114.387	5.433	8.120	13.610
T_8	Spacing 25x25 cm + Depth 10 cm	7.450	20.370	1.463	49.007	79.293	101.363	4.733	7.137	10.793
T_9	Spacing 30x40 cm + Depth 4 cm	7.653	18.647	1.457	49.847	78.967	103.370	4.500	7.727	11.097
T_{10}	Spacing 30x40 cm + Depth 6 cm	7.733	19.023	1.547	50.073	80.633	98.880	4.600	7.553	10.733
T_{11}	Spacing 30x40 cm + Depth 8 cm	7.477	18.213	1.370	50.490	77.683	96.287	4.487	6.393	11.547
T_{12}	Spacing 30x40 cm + Depth 10 cm	7.590	22.707	1.300	48.213	71.820	98.587	3.727	7.127	10.387
T_{13}	Spacing 40x40 cm + Depth 4 cm	7.807	17.380	1.450	49.287	74.917	92.770	4.117	7.403	10.523
T_{14}	Spacing 40x40 cm + Depth 6 cm	7.333	20.037	1.407	48.423	74.033	97.283	4.323	7.257	10.460
T_{15}	Spacing 40x40 cm + Depth 8 cm	7.333	16.623	1.483	48.380	75.253	89.053	4.803	7.453	10.730
T_{16}	Spacing 40x40 cm + Depth 10 cm	8.153	21.517	1.040	44.650	69.357	85.400	3.547	6.520	9.580
F-test		S	S	S	S	S	S	S	S	S
SE(d)		0.062	0.247	0.051	0.441	0.469	0.689	0.042	0.357	0.204
C.V.		1.010	1.614	4.378	1.079	0.723	0.836	1.108	5.890	2.198
C.D. at 5%		0.128	0.508	0.105	0.906	0.962	1.414	0.086	0.732	0.418

Table 2: Effect of different plant spacing and Planting depth on Days taken for basal floret to open, No. of floret/spike, Longevity of first floret, Rachis length (cm), Floret diameter (cm), Vase life (days), Number of Spike/plant, Spike yield/plot, spike yield/ha and cost benefit ratio of gladiolus

Treatment Symbol	Treatment Combinations	Days taken for basal floret to open	No. of floret/spike	Longevity of first floret	Rachis length (cm)	Floret diameter (cm)	Vase life (days)	Number of spike/plant	Spike Yield/plot	Spike Yield/ha.	Cost Benefit Ratio
T_1	Spacing 20x25 cm + Depth 4 cm	75.887	12.733	12.600	52.700	11.107	12.403	1.267	81.723	170,235.700	1:1.74
T_2	Spacing 20x25 cm + Depth 6 cm	76.237	12.623	12.480	51.780	10.870	12.263	1.170	80.607	161,159.300	1:1.65
T_3	Spacing 20x25 cm + Depth 8 cm	76.100	13.343	12.667	52.403	11.163	12.487	1.210	84.390	170,368.000	1:1.74
T_4	Spacing 20x25 cm + Depth 10 cm	78.173	11.647	11.323	52.303	10.387	11.380	1.217	85.017	174,918.000	1:1.78
T_5	Spacing 25x25 cm + Depth 4 cm	76.163	12.797	12.537	51.823	10.830	11.727	1.203	64.930	129,255.700	1:1.47
T_6	Spacing 25x25 cm + Depth 6 cm	77.140	12.877	12.447	51.840	10.877	11.667	1.227	66.447	133,432.000	1:1.51
T_7	Spacing 25x25 cm + Depth 8 cm	73.553	14.357	13.467	55.183	11.867	10.073	1.747	91.950	183,492.000	1:2.08

T_8	Spacing 25x25 cm + Depth 10 cm	77.470	11.777	11.600	51.607	9.700	10.403	1.277	68.447	136,814.700	1:1.55
T_9	Spacing 30x40 cm + Depth 4 cm	77.017	12.597	12.380	48.013	10.547	10.923	1.233	40.900	94,001.340	1:1.59
T_{10}	Spacing 30x40 cm + Depth 6 cm	76.287	12.053	12.423	49.047	10.533	10.623	1.220	39.967	95,085.340	1:1.61
T_{11}	Spacing 30x40 cm + Depth 8 cm	77.387	13.300	12.723	48.417	10.787	11.320	1.400	42.053	95,735.340	1:1.62
T_{12}	Spacing 30x40 cm + Depth 10 cm	81.697	11.170	10.433	48.100	9.690	9.580	1.327	38.853	95,718.000	1:1.62
T_{13}	Spacing 40x40 cm + Depth 4 cm	75.880	12.393	12.710	46.547	10.193	10.413	1.310	28.987	94,282.660	1:1.99
T_{14}	Spacing 40x40 cm + Depth 6 cm	75.967	12.170	12.603	48.023	10.667	9.930	1.230	27.637	92,761.660	1:1.96
T_{15}	Spacing 40x40 cm + Depth 8 cm	76.497	12.267	12.100	47.190	9.650	9.907	1.200	25.917	88,278.340	1:1.87
T_{16}	Spacing 40x40 cm + Depth 10 cm	83.493	10.817	10.153	45.687	8.690	9.150	1.140	25.453	84,717.660	1:1.79
F-test		S	S	S	S	S	S	S	S	S	
SE(d)		0.725	0.250	0.151	0.590	0.148	0.084	0.018	1.203	789.486	
C.V.		1.150	2.461	1.516	1.445	1.733	0.944	1.749	2.638	0.773	
C.D. at 5%		1.487	0.513	0.309	1.211	0.304	0.172	0.037	2.468	1,620.145	

Conclusion

From the present experimental findings it is concluded that the treatment T_7 (Spacing 25x25 cm + Depth 8 cm) was found to be the best in terms of growth and flower yield parameters, followed by treatment T_4 (Spacing 20x25 cm + Depth 10 cm) and the Vase life of flower was recorded maximum in treatment T_3 (Spacing 20x25 cm + Depth 8 cm), and the minimum growth and flower yield was recorded in treatment T_{16} (Spacing 40x40 cm + Depth 10 cm).

Hence from the present investigation it is recommended that the spacing 25x25 (cm) along with the planting depth of 8 (cm) is found suitable for Allahabad agro climatic condition.

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