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Effect of Phosphorus and Planting Distance on Corm Production of Saffron (*Crocus sativus*)

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ABSTRACT

The influence of phosphorus and planting distance on corm production of *Crocus sativus* was studied at the Ornamental Horticulture Farm of Department of Horticulture, Kabul University during 2019-2020. Four different phosphorus (P) doses i.e. 0, 20, 40 and 60 kg ha^{-1} were applied to five different densities viz. 242, 107, 54, 30 and 20 plants m^{-2}. The experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement. P effect was largely non-significant, whereas planting densities had considerable effects. The increase in corm number m^{-2} with increase in plant density means that more corms were planted per unit area. Hence more production in terms of corm number was obtained from the densely planted areas. However, as we know crocus is a perennial crop and the corms are left in soil to grow for several years. Maximum days to sprouting (29.8), number of cormels m^{-2} (441.7), number of corm m^{-2} (371.1) were produced by 242 plants m^{-2}, while minimum in these were recorded at 20 plants m^{-2} density. Number of cormels (2.5), cormel weight (1.6 g), number of corms (2.0), corm weight (11.1 g), corm volume (10.7 ml) and corm diameter (3.1 cm) were produced by plants at 20 m^{-2} densities, while minimum values for the above parameters were noted in 242 plants m^{-2}. The interaction of phosphorus doses and planting distance was significant for some parameters. A comparison of means values for plant densities revealed that maximum corm volume (10.7 ml) was produced by plants at the lowest density (20 plants m^{-2}), while it was minimum (8.8 ml) at the highest density (242 plants m^{-2}).

Keywords: Ancient corm, Density, Diameter, Spices, Sprouting

INTRODUCTION

Saffron is a triploid mutant, which do not produce viable seeds and because of this it is mainly propagated through corms. In fall, immediately after sprouting, purple colour flowers appear in the centre of leaves having tricarpellary (3 stigmas) ovary. These stigmas are carefully removed from fresh flowers, oven dried and used as Saffron (Hashim et al., 2007; Negbi et al., 1989; Kaffi, 2002; Jitendra, 2004; Sharma, et al., 2004).

The use of saffron is very ancient. Evidence shows that Saffron was in cultivation in Azperano village, at the coast of Farat river (Iraq) in the year 2300 B.C. Saffron (*C. sativus*) is a perennial bulbous plant belonging to family Iridaceae. The word saffron is derived from Arabic word *Zafran*, which means orange yellow colour, because it was exclusively used for colouring as well as flavouring dishes, especially those of rice (Anonymous, 1994). The word Crocus is derived from Greek word KroKus which means something like a string, fibre or hair having horns. In 1754, the well-known Swedish botanist Carolus Linnaeus converted Krokus to its present Latin form *Crocus* (Kaffi, 2002).

Several ancient authors like Vergile, Homer and Pline mentioned about this plant. Egyptions, Greeks, Jews and Romans used this plant for dying, seasoning, as well as making the food sweet scented. They used it for dying their cloths and also burnt it as a sacrifice in front of their gods in religious ceremonies (Winter et al., 2000; Kaffi, 2002; Akhondzadeh et al., 2005). However, the proper dose of these essential elements for *Crocus* production, especially in Peshawar region is not known. Experiments conducted on *Crocus* and some other corm ornamentals in different organic media have shown that media with high P content had a prominent effect on corm production (Folle, et al., 1995, Onayango, 1997, Nknonge, et al., 1998; Behnia et al., 1999; Shah, 2004; Ali, 2005; Wazir, 2005). Apart from that, developing a production technology package for this area is also needed. Optimizing plant spacing is an important component of that package.

Saffron is one of the most expensive spices in the world. In Europe, good quality saffron would fetch €4.00 per gram. According to Peshawar market rate it is Rs. 150.00 per gram (whole sale). Saffron's high price reveals that it is only crop which has the potential to replace opium poppy cultivation in the tribal areas of Pakistan and across the border in Afghanistan. However, farmers in both the areas are not aware of the potential benefits of this lucrative crop. Moreover, they are not familiar with *Crocus* cultivation techniques. They are even unable to produce their own corms and have to rely on expensive imported *Crocus* corms, which also result in extra burden on the country foreign exchequer. Thus, this study focuses on nutrient management to increase Saffron production in Afghanistan. The aims of the study are to observe the effect of phosphorus on corm and cormel production of *C. sativus*, to find out the effect of planting distance on corm and cormel production of *C. sativus*, and to observe the growth, development and production of *C. sativus* under the agro-climatic conditions.

MATERIALS AND METHODS

Study Area and Design

An experimental trial on the effect of phosphorus and plant density on corm production of *Crocus sativus* was conducted at the Ornamental Farm, Dept. of Horticulture, Kabul University during 2019-2020. The experiment was laid out in Randomized Complete Block Design (RCBD) with Split Plot arrangement. Special modifications were made into the design while plotting it into the field. This modification is known as Fan or Wagon Wheel design (Dacaar, 2007) which is specific for plant spacing experiments. In this case the planting distance changes in two directions, i.e. plant to plant and row to row distances change simultaneously. Near the centre the planting distance is kept smaller and it increases towards the periphery. Starting from the centre, the plants were planted at 5, 5, 10, 15, 20, 25, 25 cm distances. Similarly, 7 rows were planted, separated 5 cm near the centre and 25 cm at the periphery, from each other. These provided a guard row on all the four sides and 5 planting densities each having 5 plants were obtained. One wheel represented one replication which was divided into four quarters to accommodate four phosphorus doses. Each quarter (P dose) was further split into different planting densities.

The detail of plant spacing is given in table, which shows the accumulated distances. The different Phosphorus (P) doses were applied to the main plots, planting densities were assigned to sub plots (Table 1). There were twenty treatments, each replicated three times. The field was thoroughly prepared before planting the corms, and the assigned fertilizer dose was applied to each treatment. Nitrogen (N) and potassium (K) were kept constant at 10 and 20 kg ha^{-1} respectively, while four different P doses were applied to the main plots in the following manner.

D1= 0 kg per hectare, D2= 20 kg per hectare, D3= 40 kg per hectare and D4= 60 kg per hectare

N was given in the form of urea and K in the form of potassium sulphate. Single super phosphate (SSP) was used for supplying P in different doses. P and K were incorporated in soil before planting the corms. N was given in two split doses at active growth stage. Healthy corms of average size (2.5-3.0 cm) and weight (10g) were selected, brought from Herat province of Afghanistan. The sheaths (outer dry husk around the corms) of the corms were removed before planting for quick sprouting. Each main plot was split into 5 sub plots and five corms of *C. sativus* were planted at 10 cm depth.

Table 1. Plant spacing in Wagon Wheel/ Fan design. Guard rows are not included.

Densities (Plant m^{-2})	**Distance (cm)**			
	Separated in Fan	Plant to plant	Row to row	Avg. P to P or R to R
242	5	5.5	7.5	6.5
107	10	7.5	12.5	10
54	15	10.5	17.5	14
30	20	15	22.5	18.8
20	25	20	25	22.5

Management Practices

All the crop husbandry management practices were carried out well in time according to need and requirement. Cultural practices like weeding and hoeing were done and irrigation water was applied with the help of a hose pipe according to need.

Soil analysis

Soil samples were taken from all the plots before planting corm. These samples were then analyzed for their physical and chemical characteristics including organic matter composition, pH, EC, nitrogen (N), phosphorus (P) and potassium (K) concentration. The detail is given in Table 2 as bellow.

Table 2. Analysis of soil sample taken randomly from various places of the experimental field before planting.

pH	**EC (dSm^{-1})**	**OM %**	**N (ppm)**	**P (ppm)**	**K (ppm)**
8.07	0.46	2.1	473	54	75

Temperature data

Temperature data were recorded for soil (15 cm deep) and atmosphere (30 cm above ground level) at alternate days during December 2005 with the help of soil and atmosphere thermometer respectively. The morning data were recorded before sunrise and afternoon was collected between 1.00 to 2.00 pm and the averages are presented in table 3 below.

Table 3. Average temperature (^{o}C) of soil and atmosphere during December 2005.

Temperature recording time	Soil Temperature (^{o}c)				Atmosphere Temperature(^{o}c)
	P1	P2	P3	P4	
Morning	4.8	4.5	4.4	5.0	2.4
Afternoon	8.6	8.3	8.7	8.8	16.9

Parameters

Number of corms per plant was calculated. Corm weight was measure with an electronic balance (1022 W Jackson Boulevard, Chicago, IL 60607) and average was recorded. Corm volume was measured using water displacement method calculated. Corm diameter was measured with the help of Vernier-calliper from three different sides and calculated. Cormel weight was measure with the help of electronic balance and average was calculated (1022 W Jackson Boulevard, Chicago, IL 60607). Number of corm was calculated by multiplying the number of daughter corms produced per plant with the number of mother corms accommodated in 1 m^{-2} area. The number of cormels per square meter was calculated by multiplying the number of cormels produced per plant with the number of mother corms accommodate in 1 m^{-2} area.

RESULTS and DISCUSSION

A comparison of means values indicated that maximum number of cormels m^{-2} (441.7) were produced by plants grown at the highest density (242 plants m^{-2}), followed by 213.1 cormels m^{-2}, produced by plants grown at 107 m^{-2} densities. The number of cormels m^{-2} decreased as the density decreased such that 54, 30 and 20 plants m^{-2} densities produced 113.9, 72.8 and 50.3 cormels m^{-2} respectively. The results followed a similar pattern as those of corm number m^{-2}, mentioned above. The reasons are already discussed above.

Cormels per plant

The data regarding cormels per plant are presented in Table 4. The analysis of variance revealed that different plant densities had significant ($P \leq 0.001$) effect on cormels number plant^{-1}, while phosphorus doses had no effect. The interaction between phosphorus doses and plant densities was also non-significant. A comparison of means values for plant densities showed that the lowest density (20 plants m^{-2}) produced maximum cormels (2.5), closely followed by 30 plants m^{-2} density where 2.4 cormels plant^{-1} were produced. Densities of 54, 107 and 242 plants m^{-2} behaved alike, producing 2.1, 2.0 and 1.8 cormels plant^{-1} respectively.

There was a trend that the cormel number plant^{-1} increased as the density decreased. This might be due to sufficient availability of light, water and nutrient for plant. As a result, more cormels were produced by the plants grown at lower densities. Similar results were also obtained by Alvi et al. (1994) Qalawand et al. (1994) and Bullitta et al. (1996).

Table 4. Corm number per plant as affected by different doses of phosphorus and plant densities.

Planting Densities (Plants m^{-2})	Phosphorus Doses kg ha^{-1}				Mean
	0 k	20	40	60	
242	1.53	1.66	1.53	1.40	1.53 C
107	1.83	1.70	1.56	1.63	1.68 BC
54	1.86	1.76	1.60	1.66	1.72 B
30	1.93	1.86	1.73	1.86	1.85 AB
20	1.96	2.00	2.13	1.90	2.00 A
Mean	1.82	1.80	1.71	1.69	

LSD value for plant densities at α 0.001 = 0.1803
Means followed by the same letters are not significantly different at 1% level of significance

Cormel weight

The data pertaining to the single cormel weight are presented in Table 5. The analysis of variance revealed that different plant densities had significant ($P \leq 0.01$) effect on cormel weight while phosphorus doses and the interaction had non-significant effects on cormel weight. A comparison of means values for plant densities revealed that maximum cormel weights of 1.6 and 1.4 g were produced by plants grown at lower densities i.e. 20 and 30 plants m^{-2}. The rest of the plant densities, i.e. 54, 107 and 242 plants m^{-2} were at par with each other producing 1.3, 1.3, 1.2 g cormels. In this case too, the cormel weight increased, as the distance between plants increased. As mentioned earlier, this might be due to the sufficient availability of light.

Table 5. Single corm weight (g) as affected by different doses of phosphorus and plant density.

Planting Densities (Plants m^{-2})	Phosphorus Doses kg ha^{-1}				Mean
	0	20	40	60	
242	1.1	1.3	1.2	1.2	1.2 B
107	1.1	1.3	1.3	1.3	1.3 B
54	1.3	1.3	1.3	1.3	1.3 B
30	1.5	1.4	1.3	1.3	1.4 AB
20	1.8	1.6	1.4	1.4	1.6 A
Mean	1.4	1.4	1.3	1.3	

LSD value for plant densities at α 0.001 = 1.078

Corm volume

The data regarding single corm volume are presented in Table 6. The analysis of variance revealed that different plant densities had significant ($P \leq 0.001$) effect on single corm volume, while phosphorus doses and the interaction had non-significant effect on corm volume.

A comparison of means values for plant densities revealed that maximum corm volume (10.7 ml) was produced by plants at the lowest density (20 plants m^{-2}), while it was minimum (8.8 ml) at the highest density (242 plants m^{-2}). The rest of the densities i.e. 30, 54 and 107 plants m^{-2} behaved alike producing 10.1, 9.9 and 9.5 ml corms respectively.

Table 6. Single corm volume (ml) as affected by different doses of phosphorus and plant densities

Planting Densities (Plants m^{-2})	Phosphorus Doses kg ha^{-1}				Mean
	0	20	40	60	
242	7.8	9.1	9.6	8.6	8.8 C
107	8.4	9.5	10.0	9.8	9.5 BC
54	9.3	9.9	10.3	10.1	9.9 AB
30	9.6	10.1	10.4	10.2	10.1 AB
20	10.7	10.9	10.8	10.3	10.7 A
Mean	9.2	9.9	10.2	9.8	

LSD value for plant densities at α 0.001 = 1.064
Means followed by the same letters are not significantly different at 1% level of significance

Corm diameter

The data on corm diameter are presented in Table 7. The ANOVA revealed that different plant densities had significant ($P \leq 0.01$) effect on corm diameter, while phosphorus doses showed no effect. The interaction between plant densities and P doses was also non-significant. A comparison of means values for plant densities showed that maximum corm diameter (3.1 cm) was gained by plants grown at the lowest density (20 plants m^{-2}), closely followed by 30 and 54 plants m^{-2} densities with corms of 2.9 cm diameter each.

Table 7. Corm diameter (cm) as affected by different doses of phosphorus and plant densities.

Planting Densities (Plants m^{-2})	Phosphorus Doses kg ha^{-1}				Mean
	0	20	40	60	
242	2.27	2.7	2.8	2.5	2.6 C
107	2.43	2.8	2.9	2.8	2.7 BC
54	2.70	2.9	3.0	2.9	2.9 AB
30	2.80	2.9	3.0	2.9	2.9 AB
20	3.13	3.2	3.1	3.0	3.1 A
Mean	2.7	2.1	2.1	2.9	

LSD value for plant densities at α 0.010 = 0.3182
Means followed by the same letters are not significantly different at 1% level of significance

Number of corms per plant

The data regarding the number of corm m^{-2} are presented in Table 8. The ANOVA revealed that different plant densities had significant ($P \leq 0.001$) effect on corm number m^{-2}, while effects of phosphorus doses and the interaction were non-significant. The means values for plant densities indicated that maximum number of corm m^{-2} (371.1) were produced by plants grown at the highest density (242 plants m^{-2}), followed by 180.1 corm m^{-2}, which were produced by plants at 107 m^{-2} densities. The number of corms m^{-2} decreased as the density decreased such that 54, 30 and 20 plants m^{-2} densities produced 93.2, 55.5 and 40.0 corms m^{-2} respectively.

Table 8. Number of corms m^{-2} as affected by different doses of phosphorus and plant densities.

Planting Densities	Phosphorus Doses kg ha^{-1}				Mean
(Plants m^{-2})	0	20	40	60	
242	371.0	403.3	371.0	338.8	371.1 A
107	196.1	181.9	167.6	174.7	180.1 B
54	100.8	95.4	86.4	90.0	93.2 C
30	58.0	56.0	52.0	56.0	55.5 CD
20	58.0	40.0	42.6	38.0	40.0 D
Mean	153.0	155.3	143.9	139.5	

LSD value for plant densities at α 0.001 = 44.41
Means followed by the same letters are not significantly different at 1% level of significance

Cormels in m^{-2}

The data regarding the number of cormels m^{-2} are presented in Table 9. The ANOVA revealed that different plant densities had significant ($P \leq 0.001$) effect on cormel number m^{-2}, while phosphorus doses and the interaction had non-significant effect. Again, there was a trend that the corm weight increased with the decrease in plant density. This might be due to sufficient availability of light, water and nutrient for the plants at lower densities, due to which the plants absorbed more nutrient, gaining more growth and hence more corm weight. Similar results reported by Alvi, *et al.* (1994), Qlawand *et al.* (1994) and Bullitta, *et al.* (1996).

Table 9. Number of cormels m-^{2} as affected by different doses of phosphorus and plant densities.

Planting Densities	Phosphorus Doses kg ha^{-1}				Mean
(Plants m^{-2})	0	20	40	60	
242	419.5	467.9	435.6	443.6	441.7 A
107	203.3	206.8	241.0	228.2	213.1 B
54	108.0	111.6	115.2	120.6	113.9 C
30	67.0	68.0	76.0	80.0	72.8 CD
20	44.0	46.6	57.3	53.3	50.3 D
Mean	168.3	180.2	179.6	185.1	

Means followed by the same letters are not significantly different at 1% level of significance

DISCUSSION

The increase in corm number m^{-2} with increase in plant density means that more corms were planted per unit area. Hence more production in terms of corm number was obtained from the densely planted areas. Similar results were reported by De Mastro et al. (1993). However, as we know crocus is a perennial crop and the corms are left in soil to grow for several years.

Maximum days to sprouting (29.8), number of cormels m^{-2} (441.7), number of corm m^{-2} (371.1) were produced by 242 plants m^{-2}, while minimum in these were recorded at 20 plants m^{-2} density. Number of cormels (2.5), cormel weight (1.6 g), number of corms (2.0), corm weight (11.1 g), corm volume (10.7 ml) and corm diameter (3.1 cm) were produced by plants at 20 m^{-2} density, while minimum values for the above parameters were noted in 242 plants m^{-2}. The interaction between phosphorus doses and planting density was significant for some parameters.

The corms increase in number every year until the soil is saturated. The crop is then removed, extra corms are taken away and suitable corms are replanted at proper distances for further production. So if the corms are planted at higher densities, they will produce more corms for the first year, but the soil will be too congested for the onward years to keep the crop productive for long. The other drawback of growing at higher densities is that more corms will be needed to be grown per unit area. This will increase the initial cost of production, which may be out of the reach of the common farmer. Alvishahri (1994), Azizbekova (1999) and Milyaeva (1999) also had similar views about spacing *Crocus* corms.

CONCLUSION

There was a trend that the cormel number $plant^{-1}$ increased as the density decreased. This might be due to sufficient availability of light, water and nutrient for plant. As a result, more cormels were produced by the plants grown at lower densities. Phosphorus doses showed no effect on corm weight. This is against expectations, because, P is one of the main elements responsible for corm formation. However, the P effect might be overwhelmed by the high pH (8.07) levels of the soil used in the experiment.

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