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Floret position in the capitulum determines the seed quality in marigold

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Abstract
Marigold is an annual flower crop that is mostly grown and propagated through seeds. Floret's position within a capitulum in marigold leads to varied differences in the seed quality. Hence, the present study was undertaken to reveal the influence of floret position within a capitulum on seed quality in marigold varieties. Seeds of marigold collected from cultivars, Pusa Deep, Dainty Marietta and Pusa Bahar, October-November and February-March flowering period, 2018-19. The experimental results showed that, of the three different whorls, Outer whorls recorded significantly higher mean values for seed quality parameters *viz.*, germination, seedling length, seedling dry weight, 1000-seed weight and Seed vigour indices (SVI-I and SVI-II); seed geometric properties *viz.*, surface area, length, and perimeter also recorded significantly higher mean values for outer whorls. Seed germination had shown a high correlation with 1000 seed weight and seed surface area. The present study suggested that good-quality seeds in marigolds can be obtained from the outer whorls of the capitulum.

Keywords: Marigold, floret, germination, seed vigour, seed quality

1. Introduction
Floriculture with growth potential is one of the important agriculture industries in India. The government of India has accorded it 100% export-oriented status. Among loose flowers, marigold ranks first followed by chrysanthemum, jasmine, tuberose and crossandra. It accounts for more than half of the nation's loose flower production. It has an area of 64.65 thousand hectares with an annual production of 755.10 thousand tons of flowers (NHB, 2021-22) [1]. India exported 23,597.22 MT of floral products worth 103.50 USD million in 2021-22 (APEDA, 2022) [2]. It belongs to the family *Asteraceae* and the genus *Tagetes*. Among *Tagetes*, two main Indian-grown species are *Tagetes erecta* L (African marigold) and *Tagetes patula* L (French marigold), having their origin in Mexico and South Africa, respectively. Other species of marigold include: *Tagetes tenuifolia* (striped marigold); *T. lucida* (sweet-scented marigold); *T. minuta* and *T. lacera*. Marigold flowers have fairly good keeping quality. The marigold flowers are generally large with bright shade, ranging from yellow to orange and suit well for various floral arrangements like garland, loose flower, cut flower, and decoration during pooja and ritual functions, besides it is used in landscape gardening. Despite its ornamental significance, it has other values also. 'Tagetes oil' extracted from marigold is aromatic and can be used in the production of high-grade perfumes. It possesses medicinal, insect-repellent properties, cosmetics and colouring pigment for food and flour industries (Chaudhary, 2001) [3]. Marigold seed exudates affect plant parasitic nematodes (Riga *et al.*, 2005) [4]. Dried flower petals of marigold are used as feed in poultry for improving egg yolk colour as well as broiler skin colour (Lokaewmanee, 2011) [5]. Marigold is easily adapted to various growing conditions compared to other flowering annuals. It is propagated by seeds and comes up well in all types of soil. It is a hardy annual plant and attains more than 150 cm in height in its life span of four to four and half months. Despite the marigold being one of the important commercial flowers in India. Its yields are quite low due to the non-availability of good-quality seeds. Seed is the crucial input in flower production, and its viability and vigour are essential for realizing the yield potential. In marigold, the seed development varies with the position of the floret within a capitulum. Previous studies from the division of Seed Science & Technology, IARI, indicated that the outer and middle whorls have better seed quality compared to the inner whorls (Murali, 2018) [6]. Marigold, being cross-pollinated crop, requires pollen from the other plants for proper seed setting. The poor pollination at the center whorls due to increased compactness may be one of the possible reasons for low seed setting. Empty seeds (achenes), produced from any kind of fertilization failure, do not integrate substantial

amounts of storage compounds or do not contain an embryo. Moreover, at different stages of seed development, the embryo may perhaps be aborted due to genotypic and environmental reasons (Alkio *et al*., 2002) [7]. The literature on seed quality in relation to floret position in marigold species is either fragmented or meagerly available. Improper seed filling is common and may decrease yield. Although marigold is one of the essential commercial flowers of India, their yield is quite low due to the non-availability of good quality seeds. Hence, improving seed quality in relation to floret position has been identified as an essential idea to tackle poor seed quality.

2. Materials and methods

Seeds of marigold cultivars, Pusa Deep, Dainty Marietta and Pusa Bahar were obtained from the Division of floriculture and landscaping (ICAR -IARI), New Delhi. The experiments were conducted in the Division of Seed Science and Technology, Indian Agricultural Research Institute (IARI), New Delhi. The marigold crop of three cultivars was raised during 2018-19 with a spacing of 60 cm (row) x 45 cm using a randomized block design, with standard agronomic practices. From a population of plants, 120 plants in each variety during one flowering season were selected randomly. Of these 40 plants were used in three replicates. From these selected plants, 10 flowers per plant were tagged; seeds collected from these plants were used for the studies.

Whorls in marigold vary from species to species and variety to variety. Whorls in French marigold are: 1-6 in the variety Dainty Marietta and 1-9 in the variety Pusa Deep, whereas in African marigold are 1-10 in the variety, Pusa Bahar. Seeds obtained from marigold capitulum were divided into three categories *i.e.,* from the outermost to innermost whorls *viz* outer, middle and inner. The first one-third of the total whorls were taken as outer, the next one-third as middle and the last one-third, towards the center of a flower, as inner whorls. The details of the number of rows of florets for each whorl are given (Table 1). The effects of floret position on seed quality were studied among varieties and species grown in two seasons *i.e.,* October-November and February-March flowering crops.

Table 1: Number of rows of florets for each whorl

Varieties	Whorls		
	Outer	Middle	Inner
Pusa Deep (V1)	1-3	4-6	7-9
Dainty Marietta (V2)	1-2	3-4	5-6
Pusa Bahar (V3)	1-3	4-6	7-10

2.1. Seed germination (%)

The germination percentage of seeds was tested following ISTA rules (2017)[8] with slight modification using 3 replicates of 100-seeds each. Between paper (BP) method: moistened towel paper as germination substratum was used. Seeds were placed on moistened towel paper and kept under 20^0~30^0C. The final count was recorded on the 14^{th} day from the date of seed planting.

2.2. Seedling length (cm)

On the final count (14th) day, 10 normal seedlings from each replicate were taken randomly to measure seedling length. The seedling length was measured from the tip of the primary shoot to the tip of the primary root (plate). The mean values were calculated and expressed in centimeter's.

2.3. Seedling dry weight (mg)

Seedling dry weight was determined by taking 10 normal seedlings randomly drawn on the final count day. These were dried at $80^0 \pm 2^0$ C for 24 hrs and cooled to laboratory ambient temperature in a closed desiccator containing silica gel and these were weighed to determine biomass. The dried seedlings were weighed and the mean values were expressed in g seedlings^{-10}.

2.4. Seedling vigour indices-I & II

Seedling vigour indices were determined following Abdul-Baki and Anderson (1973) [9], by using the following formula: SVI-I: Germination % x Seed length (cm) and SVI-II: Germination % x Seed dry weight (mg).

2.5. Seed geometric properties

An attempt was made to study the morphology of seeds in different varieties using machine vision technology. Image acquisition by A flat-bed scanner (Canon LiDE 110version 1.200) was used at 600 dpi resolution was used to capture a high-quality image of seeds. Data processing and analysis of seeds were computed using grain analysis software designed and developed by CIAE, Bhopal was used for images. Five parameters measured by the software were: Area, Perimeter, length, Breadth and Length-width ratio. 1000-seed weight was estimated based on 8 replicates of 100 seeds as per ISTA (2017).

Statistical analysis

All data were taken in replications of 3. DSAASTAT was used to perform ANOVA and RStudios was used for correlation analysis.

3. Results and discussion

3.1 Seed quality parameters

Seed collected from the different whorl, within a capitulum across the varieties and seasons were investigated for different seed quality parameters *viz* seed germination, seedling length, seedling dry weight, seed vigour indices (i.e. SVI and SVII) and seed morphological traits. The present study identifies the best whorls based on seed germination and vigour parameter. The seed germination was studied after the seed was collected from different whorls (outer to inner). The top-of-the-paper method was used. The germination percentage of outer whorls was significantly superior to middle and inner whorls with nearly 16% and 50% higher respectively. The germination percentage was higher for the outer whorls (77.2%) compared to the middle (63.7%) and inner whorls (46.5%). Varietal mean indicated that Pusa Bahar recorded the highest germination percentage among the varieties. Similar results of higher germination per cent of outer and middle whorls were observed in several crops by previous workers Murali (2018) [1]. Seedling length measured as a total of shoot and root length showed significant differences among the whorls. Outer whorls were recorded highest Seedling length (11.5 cm) but the varietal mean showed no significant difference. The Seedling dry weight both among varieties and whorls & varieties x whorls interaction effect was observed significant differences. Outer whorls maximum seedling dry weight as compared to middle and inner whorls and Dainty Marietta recorded maximum Seedling dry weight compared to the other two varieties. Seedling vigour was estimated to find

out the field performance potential of the outer and middle whorls seeds showed significant vigour as compared to inner whorls across varieties and seasons. The seed vigour measured as vigour index-I showed a significant difference among the whorls. The maximum mean value for vigour index-I was noticed in outer whorls (882.4) compared to middle and inner whorls (663.3 & 430.7) (Table 3). In the case of varieties, Pusa Bahar recorded maximum vigour as compared to Pusa Deep and Dainty Marietta but it was statistically at par.

Table 2: Effects of floret position within a capitulum on seed germination, seedling length and seedling dry weight of marigold varieties

Varieties	Whorls			
	Outer	Middle	Inner	Mean
Germination				
Pusa Deep	77.2	63.7	46.5	62.5
Dainty Marietta	75.7	65.8	46.7	62.7
Pusa Bahar	77.8	69.9	60.0	69.2
Mean	76.9	66.5	51.1	64.8
Seedling length				
Pusa Deep	12.0	9.3	9.8	10.4
Dainty Marietta	11.0	10.3	8.9	10.1
Pusa Bahar	11.4	10.0	7.6	9.7
Mean	11.5	9.9	8.7	10.0
Seedling dry weight				
Pusa Deep	18.8	16.1	12.2	15.7
Dainty Marietta	20.3	16.5	14.3	17.0
Pusa Bahar	15.9	14.5	10.9	13.8
Mean	18.3	15.7	12.5	15.5
		Germination	**Seedling length**	**Seedling dry weight**
LSD (p<0.05)for variety		NS	0.35	0.33
LSD (p<0.05)for treatment		1.25	0.4	0.38
LSD (p<0.05)for variety X treatment		2.17	NS	0.66
CV%		4.26	6.49	4.88

Note: Data are presented as the average of two seasons

3.2 Seed geometric properties

The three whorls of Marigold varieties have shown distinct differences in their seed physical-morphological characters. Among the three whorls, outer whorls seeds possess bigger seeds encompassing 100% more area than middle and inner whorls. Among the varieties, Pusa Deep has recorded the maximum mean value of the area. The length and perimeter length of the seeds are more in outer whorls seeds in relation to middle and inner whorls and the length and perimeter length of the seeds are more in Dainty Marietta in relation to Pusa Deep and Pusa Bahar varieties. But weed and length-width ratio are statistically at par with each other (Table 3). The test weight is one of the important yield characteristics and influences the number of seeds per unit weight. The test weight of the outer whorls seed is significantly higher than the middle and inner whorls seeds as it contains bigger seeds (with more area size, length and perimeter length). The test weight also implies that 1 kg of outer whorls contain 434783 seeds whereas middle and inner whorls contain 526316 and 588235 respectively.

Table 3: Effects of floret position within a capitulum on seed vigour Indices of marigold varieties

Varieties	Whorls			
	Outer	Middle	Inner	Mean
Vigour Index-I				
Pusa Deep	924.3	607.3	458.8	663.5
Dainty Marietta	834.1	676.0	414.4	641.5
Pusa Bahar	888.8	706.6	418.7	671.4
Mean	882.4	663.3	430.7	658.8
Vigour Index-II				
Pusa Deep	1456.3	1035.6	583.7	1025.2
Dainty Marietta	1533.2	1090.1	663.7	1095.6
Pusa Bahar	1241.0	1022.7	595.2	953.0
Mean	1410.1	1049.5	614.2	1024.6
			Vigour Index-I	**Vigour Index-II**
LSD (p<0.05)for variety			NS	54.04
LSD (p<0.05)for whorl			55.26	54.04
LSD (p<0.05)for variety X whorl			1.87	93.61
CV%			12.47	7.80

Note: Data are presented as the average of two seasons

Quality seed is the most vital requirement for any successful seed programme. Seed developed from different whorls (outer to inner) within a capitulum had shown significant differences among seed quality parameters. Seeds with maximum germination can be obtained from outer whorls, followed by middle whorls, irrespective of the variety; under rainy season

sown crops which flower during October-November, these results were in agreement with earlier work of Murali, 2018 [6], who reported that seeds collected from outer and middle whorls florets had better quality than those to inner whorls in marigold. In the African type, seed quality parameters *viz* seed germination, seedling length, seedling dry weight, seed vigour index-I & seed vigour index II, and 1000-seed weight were higher in seeds obtained from outer and middle whorls of the terminal and lateral-I branches than those to inner whorls as well from the lateral-II branch. A similar trend of seed quality was observed in seeds obtained in the French type. These results were in similar patterns as obtained by Kolodziek (2017) [10] in *Paeucedanum oreoselinum*, who studied the effects of the position of a seed within a plant; and of soil nutrients on seed mass, germination and seedlings growth. Within an individual plant, seed mass diminished with umbel order; and seeds from the central umbellate of the umbel were lighter than those from the outer edge; also suggested that variation in seed mass within an individual plant was due to the position effect. Alike results, where maximum germination and highest vigour in seeds from an outer position of the umbel were reported in celery and anise (Lamichaney *et al*., 2016) [11], in carrot (Muhammad and Anjum, 2001) [12], (Pereira *et al*., 2008) [13], and (Panayotov, 2010) [14]. Variations in seed quality with respect to seed position in marigold were also reported by Pramila (2010) [15], who suggested that maximum germination and high vigour were recorded in seeds from the outer position than those to the inner position of seeds. Variation in seed quality with respect to florets located within a capitulum may be due to competition for the source or limitation of source and sink ratio *i.e.*, lack of photosynthates which moves via a vast network of vascular tissue into seeds in a complex architecture of plant system (Carlson, 1973)[16]. Various seed morphological traits characteristics (*i.e.*, seed geometric properties) had registered varying degrees of differentiation among the varieties as well as floret position within a capitulum. Variation is because of several morphological features possessed by the genotype, which are unique to a particular variety. These seed characteristics were qualitative rather quantitative in nature *i.e.* less influenced by the environment. Seed geometric properties had little but distinct differences among species, varieties, and across seasons. Measured properties were significantly different in outer whorls than those in inner whorls. Our findings were in line with Kurtulmus *et al*. (2016)[17], who reported that seed characteristics like colour, shape and texture can be used to classify the seed varieties; an accuracy of 84.94% was achieved in the case of pepper seed varieties. With the available reports on variation in seed physical characteristics, only *wrt* seed length was reported by Kennedy (1997) [18], Singh & Singh (2005) [19], and Singh *et al.* (2008) [20] in *Tagetes* spp. These reports that the distinction of seed genotypes in *Tagetes* spp was done using seed length alone. Correlation analysis between seed quality parameters and seed geometric properties. Among various seed geometric properties and quality, seed germination had shown a high correlation with 1000- seed weight and seed surface area (Plot 1).

Conclusion

Seeds collected from outer whorls recorded significantly higher seed quality followed by middle and inner whorls. Good quality seeds in marigold can be obtained from outer whorls, irrespective of the variety and seasons. The seeds from middle whorls may be used to blend the seed lots under exigency situations. Outer whorl seeds can also be used for selection and improving seed vigour. Based on seedling length, seedling dry weight, seed vigour index-I and seed vigour index-II one may obtain better quality seed from the outer whorls irrespective of the variety across the seasons. Variety Pusa Deep recorded the maximum mean value for 1000-seed weight, irrespective of the seasons. Seeds collected from outer whorls recorded maximum mean values for the area size, seed length, seed width, perimeter length, and length-to-width ratio among three varieties studied, across the seasons. Among the varieties, Dainty Marietta, irrespective of the seasons, variety recorded maximum mean values for seeds in area size (12.4mm^2), seed length (12.8 mm) and perimeter length (28.1mm^2). Among various seed geometric properties and quality, seed germination had shown a high correlation with 1000- seed weight and seed surface area (Table 5).

Table 4: Effects of floret position within a capitulum on seed geometric properties of marigold varieties

Varieties	Whorls			
	Outer	Middle	Inner	Mean
Swt(g)				
Pusa Deep	2.3	2.2	1.8	2.1
Dainty Marietta	2.4	1.6	1.6	1.9
Pusa Bahar	2.2	1.8	1.6	1.9
Mean	2.3	1.9	1.7	1.9
AS(mm^2)				
Pusa Deep	13.3	10.9	9.9	11.4
Dainty Marietta	14.1	13.2	9.9	12.4
Pusa Bahar	12.4	11.1	9.1	10.9
Mean	13.3	11.7	9.6	11.6
SL(mm)				
Pusa Deep	13.3	10.4	8.9	10.9
Dainty Marietta	14.6	13.0	10.8	12.8
Pusa Bahar	11.8	12.2	11.3	11.8
Mean	13.2	11.9	10.3	11.8
SW(mm)				
Pusa Deep	1.8	1.6	1.6	1.6
Dainty Marietta	2.0	1.8	1.7	1.9
Pusa Bahar	1.9	1.8	2.0	1.9

Mean	1.9	1.7	1.8	1.8
PL(mm)				
Pusa Deep	28.9	23.1	19.7	23.9
Dainty Marietta	31.9	28.6	23.8	28.1
Pusa Bahar	25.7	26.9	21.9	24.8
Mean	28.8	26.2	21.8	25.6
LWR				
Pusa Deep	7.6	6.6	5.4	6.5
Dainty Marietta	7.2	7.3	7.0	7.2
Pusa Bahar	6.4	6.7	5.9	6.3
Mean	7.1	6.9	6.1	6.7

	Swt(g)	AS(mm^2)	SL(mm)	SW(mm)	PL(mm)	LWR
LSD (p<0.05)for variety	0.049	0.47	1.49	NS	2.18	NS
LSD (p<0.05)for whorl	0.49	0.47	1.49	NS	2.18	NS
LSD (p<0.05)for variety X whorl	0.086	0.82	NS	NS	NS	NS
CV%	3.75	6.06	18.73	16.61	12.59	19.53

Note: Swt: 1000-seed weight; AS: area size (mm); SL: Seed length (mm); SW: Seed width (mm); PL: Perimeter length (mm); LWS: Length-to-width ratio; Data are presented as the average of two seasons

Plot 1: Correlation analysis between seed quality parameters and seed geometric properties

	1	2	3	4	5	6	7	8	9	10	11
1	1.000	0.577	0.646	0.905	0.884	0.656	0.747	0.459	0.223	0.595	0.288
2	0.577	1.000	0.589	0.866	0.654	0.511	0.568	0.289	0.090	0.387	0.234
3	0.646	0.589	1.000	0.712	0.920	0.653	0.671	0.375	0.073	0.467	0.327
4	0.905**	0.866**	0.712*	1.000	0.886	0.682	0.741	0.423	0.182	0.547	0.290
5	0.884**	0.654	0.920**	0.886**	1.000	0.742	0.769	0.455	0.152	0.572	0.341
6	0.656*	0.511	0.653	0.682	0.742*	1.000	0.546	0.230	0.101	0.305	0.117
7	0.747*	0.568	0.671	0.741*	0.769*	0.546	1.000	0.586	0.374	0.733	0.290
8	0.459	0.289	0.375	0.423	0.455	0.230	0.586	1.000	0.500	0.873	0.678
9	0.223	0.090	0.073	0.182	0.152	0.101	0.374	0.500	1.000	0.230	-0.284
10	0.595	0.387	0.467	0.547	0.572	0.305	0.733*	0.873*	0.230	1.000	0.740
11	0.288	0.234	0.327	0.290	0.341	0.117	0.290	0.678	-0.284	0.740*	1.000

Note: 1:Seed germination (%); 2:Seedling length(cm); 3:Seedling dry weight(mg); 4:Seed vigour index-I; 5:Seed vigour index-II; 6:1000-seed weight(g); 7:Area mm2; 8:Seed length(mm); 9:Breadth(mm); 10:Perimeter(mm); 11:Length/Breadth Ratio. (**) Significant at 5%; (*) Significant at 1% and ( ) Non-significant

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