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Studies on seed development, quality and physiological maturity in marigold (*Tagetes* spp.)

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ABSTRACT Marigold (*Tagetes* spp.) is an important commercial ornamental flower crop of India. To investigate the seed development and seed quality as well as physiological maturity, nine genotypes consists of *Tagetes erecta* L. and *Tagetes patula* L. were planted following standard agronomical practices. The flower buds of all nine genotypes were tagged from the initiation of anthesis. The flowers from both species were harvested at the seven different developmental stages *i.e.* 0^{th}, 7^{th}, 14^{th}, 21^{th}, 28^{th}, 35^{th} and 42^{nd} days from anthesis (DFA). The investigations indicated that the attainment of physiological maturity occurred 35^{th} DFA in *T. erecta* and 28^{th} DFA in *T. patula* which was associated with dark black seed colour, withering of petals, yellowing of capitulum and peduncle as morphological indices of seed maturity.

Key words: Seed development, seed quality, physiological maturity, marigold

The quality of seed is characterized by higher levels of viability and vigour. The seed development and maturation are the prime factors that decide the quality of the seed both in the field and in the store. The studies on biology and physiology, such as duration and pattern of seed development and maturation are essential because of inherent variations in each crop. Marigold is one of the commonly cultivated important annual flower used for commercial purpose across the world and has industrial potential owing to its oil and carotenoid pigment. Non-availability of high quality seeds is one of the major constraints for realizing its potential.

The time of harvest is very critical factor as it affects the seed yield and quality. In case the crop is harvested too early, the possibility of a high frequency of immature seeds increases. On the other hand, if harvesting is delayed there is a loss of both the quality and quantity of the seed. The seed of premier quality can be harvested at physiological maturity. The stage of physiological maturity is crop and environment specific. The seed maturation begins at the end of seed development and continues up to harvest [1]. The quality status of seed changes with respect to development process. There is hardly any information available on this aspect in marigold. Thus, establishing the time of physiological and harvestable maturity of a crop is of utmost interest. So, the study was planned and executed to find out the most suitable stage of seed harvesting for maintaing the seed viability and vigour in both the species *i.e Tagetes erecta* L and *Tagetes patula* L.

MATERIALS AND METHODS

Experimental materials

The present investigation was carried on nine elite lines of two species of marigold (*Tagetes erecta* L. and *Tagetes patula* L.). The experimental material was taken from Floriculture Unit of the Department of Horticulture, CCS Haryana Agricultural University, Hisar. The description of the genotypes is given (Table 1).

The crop was planted in Factorial Randomized Block Design (Plot size 2.4 x 5 m^2) with three replications at the Research Farm of the Department of Horticulture, CCS HAU, Hisar. The seed crop was grown in the spring season during

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Table 1. Pedigree and brief characters of marigold (*Tagetes* spp.) genotypes

Geno-type	Common name	Species	Plant height (cm)	Flower colour
MG-1	African orange	*Tagetes erecta* L.	78	Orange
MG-2	African yellow	*Targetes erecta* L.	70	Yellow
MG-3	African lemon	*Tagetes erecta* L.	92	Lemon
MG-4	French orange	*Tagetes patula* L.	40	Orange
MG-5	French yellow	*Tagetes patula* L.	32	Yellow
MG-6	French rusty red	*Tagetes patula* L.	48	Rusty red
MG-7	French orange	*Tagetes patula* L.	65	Orange
MG-8	French yellow	*Tagetes patula* L.	72	Yellow
MG-9	French rusty red	*Tagetes patula* L.	75	Rusty red

both the years. The seeds were collected from the marigold crop during both the years. About 250-300 flowering buds of similar age and stage were tagged on the day of anthesis in each genotype in each replication. Flower heads/capitulum were harvested at different stages at weekly interval which were designated as S_0, S_1, S_2, S_3, S_4, S_5 and S_6 representing 0^{th}, 7^{th}, 14^{th}, 21^{st}, 28^{th}, 35^{th} and 42^{nd} days from anthesis, respectively. The observations from each harvested flower/capitulum were recorded for different parameters as follows.

The developed seed number per flower in ten flowers was counted randomly at different developmental stages in all genotypes among three replications and mean was computed. The number of black seeds per flower was counted at different developmental stages. The seeds extracted from randomly selected flowers at different developmental stages after removing the petals from achenes. The fresh seed weight was calculated by weighing the 1000-seeds. Dry seed weight (g) was measured by weighing 1000-seeds after drying in oven at 80°C for 16 hr. The dried seeds were weighed after cooling in the desiccator for 30 min. The moisture content of the seeds was computed following ISTA rules [2].

The standard germination test was also performed following ISTA rules [2]. The 100-seeds from each genotype per replication were put on top of paper (TP) and kept at 20°C. After 14 days the seedlings was counted and the total number of normal seedlings recorded. At the time of final count, ten normal seedlings, taken at random for measuring seedling length: the root and shoot length. The average value from ten seedlings was recorded (cm). The seed vigour index-I was calculated [1].

The changes in colour of flower parts *i.e.* petals, capitulum, peduncle and seed were recorded at different developmental stages until maturity in all the genotypes.

RESULTS AND DISCUSSION

Analysis of variance for different characters in marigold (Table 2) showed significant differences among developmental stages as well as genotypes and their interactions in respect of all the characters. The total number of seeds/flower increased continuously from the day of anthesis (S_0) and attained the maximum 35 days from anthesis (S_5) in the genotypes of African spp. (Table 3). The trend was similar in the French spp. However, the maximum numbers of seeds/flower were recorded on 28 days from anthesis (S_4) in this spp. It can be explained by the indeterminate growth of capitulum because the seed development of earlier fertilized ovules and fertilization of new ovules takes place simultaneously. The number of seeds/flower decreased after achieving the maximum-viability and vigour in both the species. The decrease may be due to presence of unfertilized ovule or immature seeds which goes into inert matter at maturity.

The mature ovules in the capitulum started

Table 2. Analysis of variance for seed quality parameters of marigold genotypes at different developmental stages

Parameter	1st year				2nd year			
	Genotype (G)	Developmental stage (D)	G x D	Error	Genotype (G)	Developmental stage (D)	G x D	Error
	8	6	48	126	8	6	48	126
No. of seeds/flower	219897.82*	38477.13*	1062.30*	51.46	218534.85*	36573.35*	1134.74*	40.88
Black seeds/flower	73456.81*	133893.34*	3492.46*	28.41	74771.91*	136021.60*	3614.72*	41.68
Fresh seed weight (g)	2.10*	29.39*	0.28*	0.03	1.71*	29.40*	0.25*	0.03
Dry seed weight (g)	0.65*	26.68*	0.08*	0.02	0.60*	26.46*	0.10*	0.01
Fresh seed moisture content (%)	435.94*	20484.59*	37.23*	1.68	379.31*	20254.91*	43.45*	4.05
Standard germination (%)	491.93*	23815.27*	208.40*	3.85	439.30*	24056.47*	199.80*	3.60
Seedling length (cm)	42.98*	848.19*	4.81*	0.17	42.32*	842.51*	4.68*	0.40
Seedling vigour index-I	220189.99*	4525828.18*	60240.32*	837.25	202223.04*	4528911.79*	55374.31*	826.21

*Significant at (P=0.05)

turning black on fertilization. The fertilization started from the outer whorl and proceeded inwards to the centre. The number of black seeds/flower also showed similar increasing trend with maturity, as of total seeds/flower. The highest on number of black seeds/flower was recorded on 35 days from anthesis (S_5) in African spp., whereas in French spp., it was 28 days from anthesis (S_4). Thereafter the number of black seeds/flower did not increase. The under developed and late fertilized ovules in the inner whorl got eliminated as inert matter.

In French marigold, the fresh weight of the seeds was highest at S_3 stage (21 days from anthesis). Whereas in African spp., it was at S_4 stage (28 days from anthesis). The fresh weight of the seed is an important factor that determines the quality of seed [3], and useful for differentiating seed development and maturation [1]. After these stages in both species the fresh weight started decreasing. This could be attributed to the steady accumulation of dry matter during seed maturation phase. This observation confirms that the loss of water with the accumulation of dry matter is a characteristic feature of seed development [4].

The physiological maturity of a developing seed is normally depicted as the stage at which the seeds attain maximum dry weight [5]. In marigold, it was observed that the dry weight of the seeds increased with the maturity and reached the maximum on 35 days from anthesis (S_5) in African spp. and 28 days from anthesis (S_4) in French spp. The decrease in seed dry weight after attaining maximum weight could be due to oxidation and volatilization of the fluid and gaseous form of nutrients and volatile substances present in the seed which escape from the seed during maturation [3].

The maximum moisture content percentage was observed at S_0 (day of anthesis) which decreased with maturity and reached minimum on 42 days from anthesis. It was 25 per cent at S_4 and S_5 stages in African and French species, respectively.

The reduction in moisture content at the advancing stages of maturity might be due to the desiccation and dehydration [6].

The germination capacity is the prime indicator of seed quality [7] due to its capacity for regeneration. In marigold, it was observed that the seeds of the genotypes of French spp. started to germinate at S_1 stage (On 7 days from anthesis), whereas in African spp. it was on 14 days from anthesis (S_2). The maximum per cent germination registered on 35 days from anthesis (S_5) in African genotypes and on 28 days from anthesis (S_4) in French genotypes. The per cent germination coincides with the accumulation of dry matter at a given stage. The declining trend of seed germination after attaining maximum values in both the species may be due to the development of an inhibitor probably ABA following dehydration of seeds during that period [8].

The seedling length as a measure of seedling vigour aids in the performance of the seed under given environmental conditions [9]. The seedling length was maximum on 35 days from anthesis (S_5) in African genotypes, whereas it was maximum on 28 days from anthesis (S_4) in French genotypes, which was in coincidence with dry weight of seed at different stages. So higher is the dry weight of the seed, higher is the seedling length.

The seed vigour index-I is a function of standard germination (%) and seedling length (cm). The vigour is the inherent ability of the seed to survive, germinate and produce a seedling capable of better performance under wide range of conditions [10]. In marigold, vigour at different developmental stages also coincided with the germination and seedling length. The maximum seedling vigour recorded on 35 days from anthesis (S_5) in African genotypes, whereas it was on 28 days from anthesis in French spp. The highest value was observed to be the indices of seed maturation *i.e.* physiological maturity in both the species.

The above parameters showed that the physiological maturity of marigold seeds was attained on 35 days from anthesis in African spp. and 28 days from anthesis in French spp. because at these stages both species have highest seeds/flower, black seeds/flower, fresh and dry weight, germination, seedling length and seed vigour. These results were in agreement with earlier work in soybean, crossandra and pigeonpea [6, 11, 12].

The morphological traits (Colour change in different plant organs, formation of black abscission layer in basal region of kernel and leaf senescence) were the reliable indices of physiological maturity in many crops [13]. The seed colour changed with seed development in marigold. The dark black colour of seeds was a good indicator of physiological maturity in both the species. The seed became dark black on seven days before physiological maturity and remained dark black up to maturity.

The petal colour in the flowers also changed with the maturity. The flower maintained the original colour up to 21 days from anthesis (S_3) in African genotypes, and 14 days from anthesis (S_2) in French spp., which is an index of the pluking/ornamental value of flowers. The loss of luster of petal colour started on S_4 stage (28 days from anthesis) in African spp. and S_3 (21 days from anthesis) in French spp. At physiological maturity of seed/achene, the petals showed faded colour with withering among all flower colours in both the species, whereas the dried petals with dull colour was the indicator of harvestable maturity among all the genotypes. At physiological maturity, the petals were easily separated from the achene/seed.

The colour of the capitulum and the peduncle also changed with seed or flower maturity. The yellowing followed by browning started near physiological maturity which indicated the harvestable stage of the capitulum to get maximum potential of developed seed among all the genotypes, where dark brown capitulum and peduncle developed at harvestable maturity in both the species of marigold. All these visible changes may be due to degeneration of the vascular system at seed maturity which inhibits the transport of photosynthates in the developing ovule [14] which further coincided with the change of seed coat, petal, peduncle, capitulum, and flower colour.

The inferences drawn from the results indicated that the seed quality differs significantly

Table 3. Mean value of seed quality parameters in African and French marigold genotypes at different developmental stages

Parameter	Developmental stage													
	S_0		S_1		S_2		S_3		S_4		S_5		S_6	
	A	F	A	F	A	F	A	F	A	F	A	F	A	F
Number of seeds/flower	195.84	71.12	281.56	87.42	332.22	120.61	347.89	127.28	350.83	140.09	358.01	138.00	348.22	133.73
Black seeds/flower	0.00	0.00	111.72	52.34	198.78	106.11	245.11	107.70	280.67	132.50	303.06	130.20	299.78	125.98
Fresh 1000-seed weight (g)	1.50	1.14	2.37	1.74	2.96	3.33	3.59	4.12	4.02	3.81	3.90	3.67	3.58	3.28
Dry 1000-seed weight (g)	0.47	0.41	0.69	0.85	1.36	1.65	1.91	2.34	2.40	2.95	2.91	2.85	2.66	2.73
Moisture content (%)	87.15	84.47	81.08	76.86	70.46	66.32	59.51	42.26	45.09	26.50	26.20	19.08	20.66	16.17
Standard germination (%)	0.00	0.00	0.00	1.09	2.39	7.36	21.33	30.36	52.55	64.00	78.44	58.50	69.45	53.45
Seedling length (cm)	0.00	0.00	0.00	2.54	5.15	6.28	8.37	8.76	11.11	14.19	12.51	13.61	10.92	13.33
Seed vigour index-I	0.00	0.00	0.00	2.77	13.27	46.13	181.17	267.73	628.18	918.88	1091.31	807.79	805.39	726.84

A-African marigold; F-French marigold

across the developmental stages. The attainment of physiological maturity occurred on 35 DFA in the seed of *T. erecta* (African marigold) with higher germination percentage and vigour with lower moisture content, whereas in case of *T. patula* (French marigold) the highest germination and vigour with lower moisture content was observed, as physiological maturity, on 28 DFA .

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