



Research Article

SEED DEVELOPMENT AND MATURATION IN FRENCH MARIGOLD (*TAGETES PATULA* L.)

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Abstract: Marigold (*Tagetes* spp) is an annual flower crop, mainly cultivated and propagated through seeds. It is essential to maintain the optimum seed quality to meet the desired standards in emerging seed industry at domestic and global seed trade. Indeterminate flowering in marigold leads to differential maturity of seeds resulting in wide differences in seed quality, major constraints in marigold seed production are optimum stage of physiological maturity and stage of seed harvest. Accordingly, a study was undertaken to identify the optimum stages of seed maturity in French types. The experimental results showed that, on-set of germination starts after 4-6 DFA in French types; and the quality seeds in French marigold can be obtained (harvested) between, and 38-40 DFA. Besides, total oil content in seeds estimated of about 35 % during physiological maturity and it was about 33% at harvest maturity; its content also varied with genotype as well as stage of seed maturity.

Keywords: Seed development, *Tagetes* seeds, On-set of germination, Physiological maturity, Harvest maturity, Total oil in seeds

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Introduction

Marigold (*Tagetes* spp L.), a member of family Asteraceae, is an important annual flower crop native to Central America [12]. African marigold (*Tagetes erecta*) and French marigold (*Tagetes patula*), the two commonly found species in marigold and are mainly cultivated and propagated through seeds. African types are noted for their large flower heads, whereas French types are relatively small and attractive. It becomes imperative to evolve a strategy to produce quality seeds and make them available in time at a reasonable price to the farming community. The improvement of flower seed industries in developed countries like India requires high quality seeds and the mass production of the flowers is limited due to poor seed quality, which is majorly due to improper seed development and maturation under unfavourable weather conditions, as well as by short period of day light [8]. Indeterminate flowering in marigold leads to differential maturity of seeds resulting in wide difference in seed quality. Major constraints in marigold quality seed production are optimum stage of physiological maturity and stage of harvest. Physiological maturity is the stage at which the quality of the seed is at its maximum; early harvested seeds results in immature seeds with low vigour, whereas late harvested risks seed deterioration and seed loss. It is needless to emphasize that good quality seed is a pre-requisite for optimum returns from the seed crop. Hence, it is pre-requisite to determine the optimum stage of physiological maturity and stage of harvesting so as to obtain the quality seeds with maximum germination and vigour. Hence, the present study was undertaken with an objective to study the pattern of seed development and maturation in selected French marigold varieties.

Materials and methods

To study the seed development and maturation, the marigold crop of two cultivars each from African and French types were raised during *rabi* 2015-16 and 2016-17 in 60 cm (row) x 45 cm (plant) spacing following RBD, with standard agronomic practices. The flower buds were tagged in each genotype everyday throughout the flowering period.

The developing seeds were harvested at seven days interval *i.e.* 0 to 49 days from anthesis (DFA) and tested for seed quality parameters like, fresh weight, dry weight, seed moisture content and seed germination in the first year of crop growth. Subsequently, during second year of crop growth, the flower buds were harvested at periodic intervals of one day to confirm the on-set of germination (0-14 days); physiological and harvest maturity (35-49 days). For determining seed moisture content, the fresh and dry weight of flower buds were estimated following ISTA rules [7], in each genotype using three replicates, ten flower buds in each replicate were weighed a fresh and dried at 80 °C for 24 hrs in an electric hot air oven.

a. Seed germination (%): The seed germination was tested using four replicates of 50 seeds each, which were placed on pre-soaked filter paper in a Petri-plates and were kept at 200~30 0C. The final count was taken on 14 day from seed incubation [7].

b. Seedling growth (cm): To determine the seedling growth, ten normal seedlings on 14th day.

c. Seedling dry weight (mg): Estimation of seedling dry weight was done using ten normal seedlings, randomly drawn from standard germination test, on 14 day in each replicate, which were dried using hot air oven at 80o ± 2 °C for 24 hrs, cooled over silica gel and weighed to assess the biomass.

d. Seedling vigour index: Seedling vigour indices (SVI-I and SVI-II) were calculated as per [1].

e. Estimation of total seed oil (%): The total oil in seeds was estimated during seed maturity (physiological and harvest) using Soxhelt method as described by AOAC [2]. A known quantity (5g) of seed sample was grinded into fine powder using sodium sulphate (Na₂SO₄) and subjected it into the Soxhelt apparatus; in which sample was boiled with a petroleum ether (60 to 80 0C) up to 14 hrs. At the end, distilled the solvent completely and repeatedly heated the sample until constant weight was recorded. The obtained oil content (g/g) was expressed in percentage.

Seed Development and Maturation in French Marigold (*Tagetes patula* L.)

Table-1 Fresh weight (g), dry weight (g) and moisture content (%) of flower bud during seed development (2015-16)

Parameter*	Genotype	Days from anthesis								SE(m) ±	CD @ 0.05
		0	7	14	21	28	35	42	49		
Fresh weight* (g)	PA	0.88	2.14	2.46	3.34	3.53	3.62	3.28	2.52	0.020	0.059
	GO	0.73	1.49	2.07	2.45	2.86	3.12	2.68	2.14	0.028	0.085
Dry weight* (g)	PA	0.14	0.38	0.62	1.06	1.43	1.98	2.12	2.12	0.020	0.061
	GO	0.12	0.28	0.58	0.97	1.39	1.68	1.86	1.86	0.018	0.056
Moisture content (%)	PA	84.08	82.05	74.79	68.34	59.36	45.40	35.26	15.85	1.162	3.512
	GO	83.07	81.46	71.97	60.33	51.42	46.16	30.55	13.08	1.072	3.243
Seed germination ¹ (%)	PA	0.00	8.00	22.00	37.00	77.00	86.00	82.00	76.00	1.443	4.238
	GO	0.00	9.00	24.00	41.00	70.00	82.00	78.00	74.00	1.384	4.065
Seedling growth ² (cm)	PA	0.00	2.13	4.54	7.08	10.77	12.43	11.04	10.85	0.177	0.536
	GO	0.00	2.68	4.88	7.43	10.34	11.38	10.65	10.24	0.165	0.499
Seedling dry weight ² (mg)	PA	0.00	4.63	12.69	18.27	20.57	22.18	21.05	20.68	0.229	0.692
	GO	0.00	4.77	11.63	17.59	20.02	21.05	20.09	19.74	0.152	0.460
SVI-I	PA	0.00	17.04	97.31	254.29	818.41	1076.91	897.96	825.88	22.387	67.694
	GO	0.00	25.32	117.63	297.99	730.44	926.64	838.32	764.41	22.624	68.412
SVI-II	PA	0.00	37.04	270.57	657.89	1563.03	1921.97	1711.87	1573.48	42.023	127.069
	GO	0.00	44.43	278.96	703.75	1415.01	1713.15	1580.23	1474.44	37.001	111.884

Where, PA: Pusa Arpita; GO: Guljafri Orange; *Average of three replicate of 10 flower buds in each replicate; 1Average of four replicates from 50 seeds in each replicate; 2Average of four replicates from 10 seedlings in each replicate.

Table-2 Fresh weight (g), dry weight (g), moisture content (%) and seed germination during seed development (2016-17)

Parameter	Genotype	Days from anthesis (DFA)														SE(m) ±	CD@ 0.05	
		0	1	2	3	4	5	6	7	8	9	10	11	12	13			14
Moisture content ¹ (%)	PA	84.16	85.87	85.53	85.02	84.26	83.77	83.63	81.92	80.94	79.90	78.61	77.29	77.33	76.68	74.79	0.830	2.409
	GO	83.63	86.11	86.33	86.48	85.50	84.04	82.87	81.17	79.62	77.51	75.57	73.66	72.79	71.97	71.95	1.059	3.073
Seed germination ¹ %	PA	0.00	0.00	0.00	0.00	0.00	2.00	5.00	8.00	10.0	12.0	14.0	17.0	18.0	21.0	22.0	0.803	2.294
	GO	0.00	0.00	0.00	0.00	1.00	3.00	5.00	9.00	12.0	14.0	16.0	17.0	20.0	22.0	24.0	1.183	3.381

Where, PA: Pusa Arpita; GO: Guljafri Orange; 1Average of three replicates from 10 flower buds in each replicate; 2Average of four replicates from 50 seeds in each replicate

Table-3 Fresh weight (g), dry weight (g), moisture content (%) and seed germination during seed development (2016-17)

Parameter	Genotype	Days from anthesis																SE(m) ±	CD@ 0.05
		35	36	37	38	39	40	41	42	43	44	45	46	47	48	49			
Fresh weight ¹ (g)	PA	3.62	3.62	3.64	3.55	3.44	3.31	3.28	3.28	3.26	3.17	3.11	2.96	2.83	2.64	2.52	0.014	0.042	
	GO	3.12	3.14	3.16	3.18	2.97	2.81	2.73	2.68	2.59	2.41	2.34	2.29	2.18	2.16	2.14	0.014	0.042	
Dry weight ¹ (g)	PA	1.98	2.13	2.14	2.14	2.13	2.13	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	0.012	0.035	
	GO	1.68	1.78	1.84	1.88	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.82	1.86	1.86	0.013	0.039	
Moisture content (%)	PA	45.30	41.12	41.06	39.66	38.08	35.71	35.36	35.36	34.97	33.19	31.91	28.38	25.18	19.69	15.74	0.479	1.391	
	GO	46.15	43.31	41.77	40.88	37.37	33.89	31.86	30.57	28.18	22.82	20.39	18.78	16.64	14.02	13.08	0.611	1.773	
Seed germination ² %	PA	86.00	88.00	88.00	88.00	88.00	86.00	84.00	82.00	80.00	79.00	79.00	78.00	76.00	76.00	76.00	1.506	4.302	
	GO	82.00	82.00	86.00	86.00	86.00	82.00	81.00	78.00	78.00	76.00	76.00	74.00	74.00	74.00	74.00	1.291	3.689	

Where, PA: Pusa Arpita; GO: Guljafri Orange; 1Average of three replicates from 10 flower buds in each replicate; 2Average of four replicates from 50 seeds in each replicate

Table-4 Total oil content (%) in seeds during maturation

Genotype	Physiological maturity	Harvest maturity	Mean
PA	34.50	27.90	31.20
GO	14.80	10.66	12.73
Mean	30.40	25.73	
Factors	SE(m) ±	CD @ 0.05	
Genotype	0.407	1.231	
Stage	0.288	0.870	
Genotype x Stage	0.576	NS	

Where, PA: Pusa Arpita; GO: Guljafri Orange

Results and discussion

The results on fresh weight, dry weight, seed moisture content, and seed quality parameters during 2015-16 is presented in [Table-1]. The flower buds harvested at periodic intervals of seven days and tested for fresh weight, dry weight and seed quality. Among all the genotypes fresh weight increased from 0.73 (GO) g to a maximum of 3.62 (PA) g during 35 DFA; followed by a decrease in it to 2.14 g at 46 DFA, and dry weight increased from 0.12 g and reached up to 2.14 g followed a decrease and reaches its minimum constant on harvest maturity. At the initial stage of seed development, seed moisture content among the genotypes was very high (84 %) to a low (13 %) during the phase of seed maturation. At first year seed crop growth, the seed germination started at 7 DFP and the seed quality attains its maximum when a seed accumulated with all the reserves required for its germination and it was achieved during 42 DFA up to 86 % in French types during

35 DFA in the first year of seed development. During the subsequent year of seed crop growth (2016-17), developing seeds were harvested at a periodic interval of one day (0-14 & 35-49 days, respectively) and similar observations were made [Table-2 and -3] to confirm on-set of germination, and physiological and harvest maturity, respectively. On-set of germination was observed during 4-5 DFA, seed moisture content at this stage was very high of about 84 %. Physiological maturity noticed with higher seed germination 86 to 88 % in during 36-39 DFA and it was associated with higher fresh weight of 3.18 to 3.62 in and dry weights of 1.88 to 2.14 g. Harvest maturity started noticing after 42 DFA and it was confirmed with slow declining/(negligible declining) in dry weight; and when it reaches no difference between fresh weight and dry weight in a few days. Physiological maturity in seeds is to recapture a high reproducing capacity and it usually coincides with attainment of maximum dry weight [12], during which the flow of nutrients from mother plant to the seed freezes. Seed maturation is a period from fertilization to harvest during which the seed crop undergoes a physiological, biochemical and morphological changes in seeds [5]. To reap the maximum quality in seeds, understanding the optimum stage of seed harvest is crucial. In our results, maximum germination was achieved during 42-44 DFA and 36-39 DFA in African and French marigold, respectively; but at this stage, seeds possess a higher moisture content, which it is not advisable to safe harvest. As the seed maturity advances, moisture content in seeds decreases significantly in marigold [14]. Hence, matured seeds of marigold can be safely harvested on/after 42 DFA in French types.

Thus, our results are in conformity with [13], who reported that French marigold seeds harvested between 120-125 days after transplanting showed higher seed quality parameters. Similar such results were reported by [6] in Gaillardia; [12] in petunia. The present results wrt harvest maturity are in similar line with the results obtained by [14] in marigold, and [3] in sunflower; [11] in china aster. The total oil content varied significantly between species and among genotypes as well with different stages of seed maturity. Seed oil content in PA recorded about 34 % and 28 % and in GO it was about 14 % and about 11% at physiological and harvest maturity, respectively. Among the genotypes, highest seed oil was recorded in PA followed by GO. As the seed heads matures, the oil content and its composition increase and it starts decreasing as it proceeds to the harvest maturity [4]. Thus, our results in total oil is in conformity with [9] who reported that oil content increased significantly and reached its maximum (about 45 %) during 45 DFA and after which it gradually decreased significantly in sunflower seeds. In our study, oil content significantly differed among the genotypes during different stages of seed maturity, and showed a biochemical basis for seed maturation in marigold. From the present results (over two years), it can be concluded that on-set of germination in French marigold starts between 4-6 DFA and matured marigold seeds can be safely harvested between 38-40 DFA in French types. Thus, estimation of oil during seed development gives biochemical basis for the seed maturation in marigold.

Application of research: it will help us in identifying physiological maturity and stage of seed harvest

Research Category: Seed science, Seed development, Seed maturity

Abbreviations: AOAC: Association of Official Agricultural Chemists; ISTA: International Seed Testing Association; PA: Pusa Arpita; GO: Guljafri Orange

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Institute: ICAR-Indian Agricultural Research Institute, New Delhi, 110012
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Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: ICAR-IARI, Pusa Campus (28°40'N and longitude 77°13' E)

Cultivar / Variety name: Pusa Arpita (PA) and Guljafri Orange (GO)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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