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EFFECT OF PHYSIOLOGICAL MATURITY ON SEED QUALITY OF MAIZE (*ZEA MAYS* L.)

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SUMMARY

Considering the lack of information about the time of physiological maturity of maize seeds and its effect on seed quality, this work was aimed at evaluating physiological maturity effect on seed quality of maize. Seeds of different varieties were harvested at 25, 35, 45 and 55 days after silking (DAS) at four different stages. Subsequently, the quality of seed samples was determined in the laboratory. It was analysed that seed harvested at 45 DAS showed maximum seed quality in terms of enhanced seed weight, seed germination, seedling length, seedling dry weight and seedling vigour index and minimum electrical conductivity of seed leachates was found at 45 DAS. HQPM 1 variety showed maximum seed weight (30.27 g) among 13 varieties. BIO 9681 variety showed maximum seed quality parameters viz., seed germination (96.00%), seedling length (35.51 cm) and seedling vigour index (3760). JH 3459 recorded highest seedling dry weight (1.60 mg) and minimum electrical conductivity was observed in PMH 1 (0.026). Differences in maximum seedling dry weight of maize cultivars were attributed to variation in genetic constitution. It was concluded that in maize cultivars, maximum seed quality could be achieved at physiological maturity which was found at 45 DAS.

Key words : Maize, physiological maturity, germination, seed quality, seed development

Maize (*Zea mays* L.) is one of the most important cereals of the world. It has worldwide significance as human food, animal feed and as a raw material for large number of industrial products. It is a versatile, miracle crop and thus termed as "Queen of Cereals" (Hanegave *et al.,* 2011). It is highly cross pollinated crop. Maize being a C_4 plant has the highest potential of per day carbohydrate productivity. A mature seed is the one that has fully formed and developed, and is capable of sprouting after planting. Immature seeds will not have the capability to produce new plants as they have not fully developed. However, there is a lot of variation in the physiology of seed development among maize genotypes (Ingale *et al.*, 1965). High quality seeds may improve crop yield via high and rapid emergence of seedlings, leading to the production of vigorous plants and optimum stand establishment under a wide range of environmental conditions (Ghassemi-Golezani *et al.,* 2011). Therefore, cultivation of high quality seeds is essential for satisfactory yield production. Several reports have shown poor stand establishment caused by low seed quality and consequently yield loss in corn (Cruz-Garcia *et al.*, 1995). The maximum values of these regressive equations were considered as the end of seed filling phase. Seed development is the period between fertilization and maximum fresh weight accumulation and seed maturation begins at the end of seed development and continues till harvested (Mehta *et al.*, 1993). The seed reaches its maximum dry weight at physiological maturity. Physiological maturity is the stage at which translocation of food materials to the seed stops and represents the highest quality level but moisture is too high (20%) for storage. Harvest maturity occurs 7-10 days following physiological maturity and is an important process where moisture is lost from the plant and is safe for storage (Randall, 2011). Rench and Shaw (1971) described the point of maximum physiological quality of corn seeds with moisture content and dry weight accumulation, and observed that those characteristics vary with genotype and seeding date. The

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seed quality is the important factor effecting corn growth and yield as well. The seeds which are to be used for planting must have the highest seed germination and vigour. Normally all the seed types are of highest seed quality which reaches the physiological maturity stage. It has been studied that the maturity affects the seed quality of the seeds. It has been noted that hybrid corn variety reached the physiological maturity stage at 40-45 DAS (Sriyisoon, 1997). Therefore, investigation was carried out to find out the effect of physiological maturity on seed quality of maize.

MATERIALS AND METHODS

The present study was conducted using completely randomized block design at the Department of Genetics & Plant Breeding, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Deemed to be University, Allahabad (U. P). Experimental materials for the present study were obtained from Directorate of Maize Research (ICAR) Pusa Campus, New Delhi. The experiment consisted of 13 maize varieties HM 9, HM 4, PMH 3, HQPM 1, HQPM 5, HQPM 7, PMH 1, BIO 9637, BIO 9681, JH 3459, Seed Tech 2324, Vivek QPM 4 and Vivek Hybrid 9 (Table 1). The crop was sown on 23 November 2010 during **rabi** season and harvesting was done on different dates. Harvesting was performed in all varieties after 25, 35, 45 and 55 DAS. The observation was recorded on physiological and biochemical parameters in laboratory. After each harvest, seeds were dried under shade. Seeds were air-dried at 18-20°C and 100-seed weight of each sample was determined on electronic balance. Seed samples within separate sealed bags were then placed in a refrigerator at 12-14°C. Three replicates of 100 seeds from each sample were tested for germination in sterilized filter papers. These papers were incubated at 20±1°C for seven days and germinated seeds (protrusion of radicle by 2 mm) were counted at seven days. At the end of each test, numbers of normal and abnormal seedlings were counted (ISTA, 2010) and germination percentage was calculated. Seedling length was calculated on 7th day after germination for measuring seedling length (cm) of the seedling on randomly selected five seedlings/ replications. The mean value was taken as average seedlings length (Khare and Bhale, 2000). The seedling vigour index was calculated by multiplying germination percentage and seedling length in centimetre. Seed lot with high vigour index is considered as vigorous (Abdul-Baki and Anderson, 1973). Seedlings were then dried in an oven at 100°C for 24 h (Khare and Bhale, 2000) and mean seedling dry weight for each treatment at each replicate was determined. Two replicates of 50 seeds from each sample were weighed (SW1 and SW2) and then seeds of each replicate immersed in 250 ml deionized water in a container at 20°C for 24 h. The seed-steep water was then gently decanted and EC was measured, using an EC meter and expressed in deci Siemens per meter per gram. The data collected in respect to various parameters on seed quality attributes were analysed statistically which is described by Panse and Sukhatme (1967). The critical difference values were calculated at 5% (=0.05) probability level where 'F' test was significant.

TABLE 1
Pedigree details of maize varieties/hybrids

S. No.	Variety	Pedigree	Developed at	Year
1.	HM 9	HKI 1105 x HKI 11028	CCSHAU, Karnal	2007
2.	HM 4	HKI 1105 x HKI 1123	CCSHAU, Karnal	2005
3.	PMH 1	LM 13 x LM14	PAU, Ludhiana	2007
4.	PMH 3	LM 17 x LM 14	PAU, Ludhiana	2008
5.	HQPM 1	HKI 193-1 x HKI 163	CCSHAU	2005
6.	HQPM 5	HKI 1344 x HKI 1348-6-2	CCSHAU	2007
7.	HQPM 7	HKI 193-1 x HKI 161	CCSHAU	2008
8.	BIO 9637	Bioseeds	Bioseeds	-
9.	BIO 9681	Bioseeds	Bioseeds	-
10.	JH 3459	CM 143 x CM 144	PAU, Ludhiana	2001
11.	Seed Tech 2324	Seed Tech	Seed Tech	-
12.	Vivek QPM 4	CM 214 x CM 245	VPKAS, Almora	2001
13.	Vivek Hybrid 9	CM 214 x CM 145	VPKAS, Almora	2001

RESULTS AND DISCUSSION

Physiological study on maturation of seed of different maize varieties gave better result in terms of seed weight, seed germination, seedling length, seedling dry weight, seedling vigour index and EC test when these varieties were harvested at 45 DAS.

Seed Weight

Seed weight of all maize cultivars linearly increased with progressing seed development up to 45 DAS. The highest maximum seed weight (mass maturity) was obtained for 'HQPM 1' cultivars (30.27 g) followed by BIO 9637 (29.89 g) (Table 2). These variations in seed weight could be largely attributed to differences in seed filling rate. Therefore, 'HQPM 1' with the highest seed filling rate produced the largest seeds. The mean performance of the varieties indicated that test weight had high positive direct effect on grain and fodder yield. Thus, these characters serve as effective selection parameters in direct breeding programme for yield improvement in maize.

TABLE 2
Mean performance of 13 maize genotypes for seed weight at different days of harvesting

S. No.	Genotypes	Seed weight (mg) at different days of harvesting			
		25 DAS	35 DAS	45 DAS	55 DAS
1.	HM 9	14.25	24.10	25.59	24.59
2.	HM 4	15.25	19.91	20.86	19.15
3.	PH 3	17.81	20.55	23.08	20.63
4.	HQPM 7	18.14	23.01	22.00	18.80
5.	HQPM 5	13.91	19.77	20.80	20.07
6.	PMH 1	14.26	24.67	22.21	20.22
7.	HQPM 1	29.73	29.25	30.27	29.53
8.	BIO 9637	15.04	27.55	28.03	23.62
9.	BIO 9681	16.56	20.78	23.37	22.60
10.	JH 3459	24.39	29.14	29.89	28.03
11.	ST 2324	11.63	15.15	17.28	16.52
12.	VIVEK QPM 4	26.18	19.12	24.91	20.57
13.	VIVEK HYP 9	13.93	17.49	25.68	23.06
	G M	18.91	22.34	23.16	22.13
	Range max.	29.73	29.25	30.27	29.53
	Range min.	10.91	15.15	17.28	16.52
	CV	13.83	6.030	6.820	8.184
	SE	2.0	1.09	1.34	1.48
	C. D. (P=0.05)	4.135	2.275	2.772	3.051

DAS : Days after silking.

Seed Germination

The maximum seed germination per cent was recorded in BIO 9681 (96%) followed by HQPM 1 (95.66%) when seed was harvested at 45 DAS (Table 3). Percentages of seed germination of maize cultivars increased with enhancing seed weight up to 45 days mass maturity. Maximum seed germination of all maize cultivars was attained at mass maturity. Similar results were reported for corn (Ghassemi-Golezani *et al.*, 2011).

TABLE 3
Mean performance of 13 maize genotypes for seed germination at different days of harvesting

S. No.	Genotypes	Seed germination (%) at different days of harvesting			
		25 DAS	35 DAS	45 DAS	55 DAS
1.	HM 9	90.33	90.66	94.00	95.66
2.	HM 4	82.33	89.33	91.66	93.33
3.	PH 3	85.00	90.33	94.00	95.33
4.	HQPM 7	84.00	91.66	93.00	93.66
5.	HQPM 5	90.33	90.00	94.00	94.66
6.	PMH 1	81.66	90.33	94.66	92.33
7.	HQPM 1	81.66	88.00	95.66	91.66
8.	BIO 9637	88.33	89.66	95.00	90.00
9.	BIO 9681	91.00	91.66	96.00	91.00
10.	JH 3459	89.33	91.33	93.00	91.33
11.	ST 2324	90.66	90.66	91.66	91.00
12.	VIVEK QPM 4	90.33	89.66	95.00	92.0
13.	VIVEK HYP 9	92.00	91.33	91.66	95.33
	G M	87.46	90.30	93.79	92.87
	Range max.	92.00	91.66	96.00	95.66
	Range min.	81.66	88.00	91.66	90.00
	CV	3.542	1.114	1.187	1.832
	SE	2.53	0.82	0.90	1.36
	C. D. (P=0.05)	7.072	1.701	1.863	2.878

DAS : Days after silking.

Seedling Length

The maximum seedling length was observed in BIO 9637 (35.51 cm) followed by PH3 (35.41 cm) when seeds were harvested at 45 DAS (Table 4). The seedlings fresh weight, mitochondrial protein and mitochondrial biochemical activity positively correlated with seed weight were reported in barley (McDaniel, 1969). Seedling dry weight of maize cultivars at the early stages of seed development was low, but it was improved with progressing towards physiological maturity.

TABLE 4
Mean performance of 13 maize genotypes for seedling length at different days of harvesting

S. No.	Genotypes	Seedling length (cm) at different days of harvesting			
		25 DAS	35 DAS	45 DAS	55 DAS
1.	HM 9	12.71	24.00	32.42	28.25
2.	HM 4	15.16	23.73	35.30	28.80
3.	PH 3	15.35	28.52	35.41	30.56
4.	HQPM 7	17.51	26.47	32.58	24.90
5.	HQPM 5	16.65	18.59	32.26	20.84
6.	PMH 1	14.73	19.83	25.02	24.39
7.	H QPM 1	18.04	24.29	29.70	24.44
8.	BIO 9637	14.02	26.05	32.68	27.69
9.	BIO 9681	16.99	30.66	35.51	30.71
10.	JH 3459	15.38	26.27	31.98	25.65
11.	ST 2324	14.53	23.76	32.70	23.74
12.	VIVEK QPM 4	13.59	24.70	32.47	25.05
13.	VIVEK HYP 9	14.00	24.86	31.58	27.52
	G M	15.2	24.75	32.29	26.30
	Range max.	18.04	30.66	35.51	30.56
	Range min.	12.71	18.59	25.02	20.84
	CV	10.489	10.677	1.349	8.857
	SE	1.30	2.15	0.35	1.90
	C. D. (P=0.05)	2.705	4.451	.731	3.927

DAS : Days after silking.

Seedling Dry Weight

Maximum seedling dry weight of 'BIO 9681' (1.38 mg) and 'HQPM 1' (1.40 mg) was lower than that of 'JH 3459' (1.60 mg) (Table 5). Differences in maximum seedling dry weight among maize cultivars could be related with variation in genetic constitution, which can strongly influence seed quality and seedling vigour in corn reported by (Ghassemi-Golezani *et al.*, 2011).

Seedling Vigour Index

The maximum seedling vigour index was recorded in BIO 9681 (3760) followed by JS 3459 (3342) when seed was harvested at 45 DAS (Table 6). The higher seedling vigour in this variety may be due to their favourable effects on the metabolism of nucleic acids, vitamins and growth substances. These effects are manifested in metabolities formed in plant tissues and have direct impact through utilization in growth and development process which may be reflected in drastic changes in seed quality as reported by Dharmatti *et al.*, (1990).

TABLE 5
Mean performance of 13 maize genotypes for seedling dry weight at different days of harvesting

S. No.	Genotypes	Seedling dry weight (mg) at different days of harvesting			
		25 DAS	35 DAS	45 DAS	55 DAS
1.	HM 9	0.48	0.89	1.24	0.92
2.	HM 4	0.60	0.85	1.20	0.90
3.	PH 3	0.60	0.67	0.97	0.83
4.	HQPM 7	0.54	0.83	0.98	0.79
5.	HQPM 5	0.46	0.79	1.19	0.92
6.	PMH 1	0.39	0.69	1.04	0.78
7.	H QPM 1	0.94	0.85	1.40	0.81
8.	BIO 9637	0.75	0.97	1.04	0.95
9.	BIO 9681	0.46	0.84	1.38	0.86
10.	JH 3459	0.29	0.82	1.60	0.92
11.	ST 2324	0.50	0.77	1.53	0.92
12.	VIVEK QPM 4	0.77	0.85	1.15	0.95
13.	VIVEK HYP 9	0.92	0.96	1.13	1.06
	G M	0.60	0.82	1.210	0.89
	Range max.	0.94	0.97	1.60	1.06
	Range min.	0.29	0.67	0.97	0.78
	CV	19.551	4.757	1.349	9.449
	SE	0.10	0.057	0.09	0.03
	C. D. (P=0.05)	0.197	0.067	0.731	0.145

DAS : Days after silking.

Electrical Conductivity

Electrical conductivity of seed leachates for all maize cultivars decreased with improving seed development. Minimum electrical conductivity was observed for 'BIO 9681' (0.026) 45 DAS (Table 7). High electrical conductivity values of seed lots at the early harvests were due to immaturity, which had placed them as low quality seed lots was observed by (Vieira *et al.*, 2004; Ghassemi-Golezani and Mazloomi-Oskooyi, 2008).

TABLE 6
Mean performance of 13 maize genotypes for seedling vigour index at different days of harvesting

S. No.	Genotypes	Seedling vigour index at different days of harvesting			
		25 DAS	35 DAS	45 DAS	55 DAS
1.	HM 9	1201	2313	3205	2543
2.	HM 4	1242	2195	3397	2566
3.	PH 3	1253	2849	3471	2922
4.	HQPM 7	1551	2033	3236	2595
5.	HQPM 5	1459	1640	2903	2102
6.	PMH 1	1345	1874	2597	2288
7.	H QPM 1	1551	2349	2797	2339
8.	BIO 9637	1241	2158	3236	2413
9.	BIO 9681	1348	2953	3761	2895
10.	JH 3459	1466	2539	3343	2797
11.	ST 2324	1328	2468	3269	2573
12.	VIVEK QPM 4	1185	2263	3167	2749
13.	VIVEK HYP 9	1275	2346	3160	2810
	G M	1342	2306	2975	2584
	Range max.	1551	2953	3761	2922
	Range min.	1185	1640	2597	2102
	CV	2.661	9.5	7.311	8.241
	SE	29.24	178.91	190.81	174
	C. D. (P=0.05)	60.361	369.271	393.837	359.122

DAS : Days after silking.

TABLE 7
Mean performance of 13 maize genotypes for electrical conductivity at different days of harvesting

S. No.	Genotypes	Electrical conductivity (dS/cm/g) at different days of harvesting			
		25 DAS	35 DAS	45 DAS	55 DAS
1.	HM 9	0.083	0.076	0.069	0.060
2.	HM 4	0.152	0.120	0.063	0.120
3.	PH 3	0.169	0.081	0.070	0.260
4.	HQPM 7	0.120	0.100	0.035	0.075
5.	HQPM 5	0.080	0.056	0.060	0.330
6.	PMH 1	0.100	0.085	0.026	0.050
7.	H QPM 1	0.140	0.084	0.040	0.047
8.	BIO 9637	0.105	0.047	0.035	0.060
9.	BIO 9681	0.080	0.050	0.029	0.059
10.	JH 3459	0.109	0.056	0.036	0.142
11.	ST 2324	0.154	0.077	0.040	0.187
12.	VIVEK QPM 4	0.080	0.130	0.052	0.107
13.	VIVEK HYP 9	0.100	0.050	0.044	0.050
	G M	0.113	0.077	0.046	0.119
	Range max.	0.169	0.130	0.070	0.260
	Range min.	0.080	0.050	0.026	0.047
	CV	19.830	25.863	36.580	35.071
	SE	0.044	0.044	0.04	0.057
	C. D. (P=0.05)	0.035	0.030	0.021	0.069

DAS : Days after silking.

CONCLUSION

It was concluded that in maize cultivars maximum seed quality as measured in terms of seed germination percentage, seedling length, seedling dry weight and seedling vigour index was achieved at mass maturity, which was maximum at 45 DAS and can be termed as physiological maturity. However, when seed quality was evaluated by electrical conductivity test, maximum quality was obtained at 45 DAS and it can be related to before the end of seed filling phase. Thereafter, as above performed study it can be concluded that there are no considerable changes in seed quality thereafter in maize cultivars once the seeds have reached the physiological maturity. Thus, high quality seeds of maize cultivars could be produced if the seeds are harvested at physiological maturity which can be attainable at 45 DAS evaluated from the above study. High quality seeds perform well in the field, ensuring optimum stand establishment and satisfactory yield under a wide range of environmental conditions.

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