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Study of physiological maturity in Indian scented rice cultivars (*Oryza sativa* L.)

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Abstract
The main aim of the present study was to determine the seed development and maturation pattern to fix optimum stage for harvesting of scented rice. Fixation of optimum stage of physiological maturity as well as harvest maturity will ensure better quality seeds and high yield. Reliable information on optimum stage of harvest will enable the seed producer to harvest the seed crop in time. Hence, knowledge on the development of seed from day to anthesis will be highly valuable and useful. To study the physiological maturity of scented rice seeds, five genotypes include Improved Pusa basmati-1, Pusa basmati-1, Type-3, Pusa sugandha-5 and Narendra lalmati were collected at four harvesting stages viz, 15, 25, 35 and 45 days after anthesis (DAA) in three replications to optimum stage for harvest. The dry weight of seed gradually increased with the stages of maturation and reached maximum of 24.7gm on 35 DAA in Pusa basmati-1, followed by 23.4 gm at 45 DAA in Pusa sugandha-5, both the Type-3 and Improved pusa basmati-1 were showed seed dry weight 23.3g on 35 DAA, and minimum 16.1gm at 45 DAA in Narendra lalmati after physiological maturity. Maximum moisture content of 83.8 % at 5 DAA gradually decreased to 13.2 percent at 45 days after anthesis in seeds of the every variety under study. The developing seeds started to germinate at maximum (87.83%) germination on 45 days after anthesis in Improved pusa basmati-1 and minimum (32.0%) germination count was recorded at 15 days after anthesis in Narendra lalmati, which indicates physiological maturity of their seeds.

Keywords: Physiological maturity, moisture, harvesting period, germination %, seed yield

Introduction
Rice (*Oryza sativa* L.) is the world's most important staple food crop, which not only provide food but also influenced traditions, religions, culture and life style since Vedic era. 'Rice is life' for human beings especially in Asian sub-continent, where 90% of world's rice is grown and consumed with 60% of population and where, about two-thirds of world's poor live (Khush and Virk 2000) [14]. Globally, rice is cultivated in 163 million hectares with annual production of around 729 million tones. Scented rice production is limited to the northern states of Indian (Punjab, Haryana, Parts of Western Uttar Pradesh and limited area in Himachal Pradesh and Delhi). In India, scented rice area is 1.9 m/h and production of 4.5 mt and in Uttar Pradesh its area is 5.5 lakh ha. The highest production of scented rice has witnessed in Haryana which accounts 60 % of total production in India **(**FAO, 2017). Aroma is due to certain chemicals present in the endosperm of rice. Although many other compounds are also found in the headspace of fragrant rice varieties due to secondary effects related to the genetic background of the rice variety, 2-acetyl-1-pyrroline is widely known to be the major component of the distinctive basmati and jasmine fragrance. The desirability of fragrance has resulted in strong human preference and selection for this trait (Widjaja *et al*., 1996) [24].
The reported highest prediction accuracy using a vigour index that included standard germination test *i.e*., 7thday germination and accelerated-ageing germination in the case of rice. In rice, seedling vigour has been associated with seed size and density as well as other parameters of the germination seed (Teckrony and Egil, 1977) [20]. Studies on seed development and physiological maturity become important because seeds should be harvested at proper time to ensure their quality in terms of viability and vigor. Seed quality can be limited by environmental conditions both before and after physiological maturity, the stage of development at which the seed possesses its maximum dry mass (Indira and Dharmalingam, 1996) [12]. Viability, the least discriminating measure of seed quality, is quickly gained during seed development and strongly maintained after maturity relative to germination ability. Stage of maturity at harvest is one of the most important factors that can influence the quality of seeds (Demir *et al*., 2008) [7]. Maximum seed quality as measured by seed viability, moisture content, seed mass and germination percentage has obtained at the point of mass maturity.
The determination of physiological maturity apparently has done on the basis of measuring maximum seed dry weight accumulation and found to be tedious, time consuming and

unsatisfactory for routine use (Lee *et al*., 1982; Eastin *et al*., 1973) [16,8]. Maturity is the critical and the most important factor that determines size and quality of seeds (Malarkodi and Srimathi, 2007) [17]. crop in time when the seed quality attributes are at maximum (Egli, 1998) [9]. Seed maturation refers to the physiological and functional changes that occur from time of anthesis until the seeds are ready for harvest. Loss of seed moisture during ripening and maturation of a seed is a common phenomenon and has been observed in many crops (Karivaratharaju, 1974) [13]. Maturity is the critical and the most important factor that determines the size and the quality of seed (Malarkodi and Srimathi, 2007) [17]. Harrington (1972) [10] defined physiological maturity as the stage when the seed attained its maximum dry weight. In the present investigation, dry weight of the seed was maximum at physiological maturity (i.e.) at 45 days after anthesis (0.562 g), which was 93 per cent higher over dry weight at 5 days after anthesis. Aldrich (1943) [1] reported that seed mature when maximum dry weight was achieved. Hard seed percentage was also found to be significant in treatment combination of variety and harvest date. Manohar (1970) [18] and Bhupathi (1978) [3] reported that lowest germination show at early stage might be due to imperfect development of the seeds. Kintile and Burries (1972) [15] suggested that producing of high quality seeds could be facilitated by the harvesting of a seed with maximum vigour at seed maturity. Correlations were worked out among seed maturity indices and seedling vigour parameters including percent germination. Although the germination was high over all the harvest dates, both root and shoot dry weight was maximum only at maturity stage. In the present investigation, exact stage of the seed maturity was determined using five scented rice varieties with variable agro-morphological traits.

Material and Method

Plant materials

The experimental material consisted of five genotypes of scented rice viz., Type-3, Pusa basmati-1, Improved Pusa basmati-1, Narendra lalmati and Pusa sugandha-5. These genotypes exhibited wide spectrum of variation for various agronomic and morphological characters which were obtained from Crop Research Station, Masodha and Seed Testing Laboratory of the Department of Genetics and Plant Breeding, NDUA&T, Kumarganj, Faizabad (UP), India. The experiment was laid in split plot design with main plot (genotype) and sub-plot (harvesting stage) in 3 replications during kharif season of 2011-2012. The experiment was conducted in split plot design following varieties/genotype in main plot and harvesting stage after days to anthesis in sub-plot in three replications. Each plot size was divided in 25 main plot and 125 sub-plot with three replication accompanied by 375 ultimate plots. Uniform panicles were randomly harvesting as per treatments *viz*. 15th, 25th, 35th and 45th days after anthesis (DAA) and thereafter the seeds were separated. Moisture content (%) of the freshly harvested seed were measured by automatic moisture meter and there after seeds were dried under shade on to the level of 12-13 percent moisture from there seed lots, 1000 random seed were counted and weighed. Uniform seed from each treatment were packed in gunny bags and storage under ambient condition for sampling for further lab studies which are elaborated on below. The data were recorded for distinct morphological characters for moisture content (%), seed weight (g), standard germination (%), germination rate (%), and seedling dry weight (g). The seed development and maturation analysis was performed in different stages (Berchie, *et al*., 2004) [3].

Moisture content

Seed moisture contents were analyzed with three replicates of seeds per treatment at 105 ± 3 °C using electric oven method for 24 hrs, following to the defined protocols for seed analysis and the results expressed in percentage (Brasil, 2009) [5].

Dry weight of seeds

Seed dry weight was determined in two subsamples of 100 seeds based on the final outcome of the seeds after drying at 105±3 °C for 24 hrs and results were expressed in gm (Brasil, 2009) [5].

Germination count (%)

Seed germination test was performed with hundred seeds of each accession in three replicates by uniformly spreading over germination test paper (between papers). Seeds were packed in transparent plastic bags and keep in germination chamber at a temperature 22±2 °C. The seedlings were evaluated into a range such as normal seedling; abnormal seedling, dead seed and fresh ungerminated seeds. Evaluations were carried out on daily basis until the seven day after sowing and germination was expressed on the basis of number of normal seedling over total number of seeds placed x 100 (Brasil, 2009) [5]. The germination for the seed of all the treatment combinations was conducted in laboratory using between paper methods as per the ISTA (Anon., 1985) [2].

Result and Discussion

In the present investigation, Pusa basmati-1 seed dry weight was found to be maximum (24.7 g) at physiological maturity on 35 days after anthesis (DAA), followed by Pusa sugandha-5 measured 23.4 g on 45 DAA, both the Type-3 and Improved pusa basmati-1 were showed 23.3g on 35 DAA, and Narendra lalmati maximum (16.1 g) seed weight was at physiological maturity on 45 DAA (Table1).

Table 1: Effect of different harvesting stages (DAA) on seed weight in promising varieties of scented rice

Genotype	Days after anthesis (DAA)	Seed weight (g)	C.V.	C.D.5%
Type- 3	5 DAA	9.00	8.20	3.32
	15DAA	14.70	13.28	4.85
	25DAA	18.90	18.92	2.79
	35DAA	23.30	21.90	2.91
	45DAA	23.00	21.90	2.83
General mean		17.78		
Improved pusa basmati-1	5 DAA	8.60	8.20	3.32
	15DAA	13.90	13.28	4.85
	25DAA	19.20	18.92	2.79
	35DAA	23.00	21.90	2.91
	45DAA	22.70	21.90	2.83
General mean		17.48		
Pusa basmati- 1	5 DAA	8.10	8.20	3.32

	15DAA	14.00	13.28	4.85
	25DAA	19.90	18.92	2.79
	35DAA	24.70	21.90	2.91
	45 DAA	24.30	21.90	2.83
General mean		18.20		
Narendra lalmati	5DAA	6.30	8.20	3.32
	15 DAA	9.70	13.28	4.85
	25DAA	15.60	18.92	2.79
	35DAA	16.00	21.90	2.91
	45 DAA	16.10	21.90	2.83
General Mean		12.74		
Pusa sugandha- 5	5DAA	9.00	8.20	3.32
	15DAA	14.10	13.28	4.85
	25DAA	21.00	18.92	2.79
	35DAA	22.50	21.90	2.91
	45DAA	23.40	21.90	2.83
General Mean	18.00			
Overall Mean	16.84			
Genotypes	C.V		S.E.M.	C.D.1%
Type-3	9.91		1.02	4.83
Imp. Pusa Basmati-1	14.73		1.49	7.05
Pusa Basmati-1	8.13		0.85	4.05
Narendra Lalmati	12.11		0.89	4.23
Pusa Sugandha- 5	8.34		0.87	4.11

Harrington (1972) defined physiological maturity as the stage when the seed attained its maximum dry weight. Mehta *et al*., (1993) reported that seeds harvested at 45 days after anthesis recorded higher germination percentage 87.83, 86.89, 86.83 and 86.17 in Improved pusa basmati-1, Pusa basmati-1, Type-3, Narendra lalmati and Pusa sugandha-5 respectively. At standard harvesting stage on 35 DAA has recorded higher (85.5) germination percent. While promising five genotypes showed the lowest germination count at 15 DAA. The results agreed with the suggestions that seed quality is maximum at the end of seed filling phase (Harington, 1972; Browne, 1978; Tekrony and Hunter, 1995; Tekrony and Egli, 1997) [10, 6, 21, 22]. In the present study, there was a significant variation in moisture content at different stages of seed development and maturation.

The highest moisture contents *viz*, 83.8%, 83.2%, 82%, 81.5% and 79.1% were recorded at 5 DAA in Pusa sugandha-5, Type-3, Pusa basmati-1, Improved pusa basmati-1 and Narendra lalmati respectively. It was decreased to minimum moisture content such as 13.2%, 13.4%, 13.8%, 14.0% and 14.4% within Type-3, Pusa basmati-1, Improved pusa basmati-1, Pusa sugandha-5 and Narendra lalmati respectively at 45 DAA stage. The seed development and maturation were compared with moisture content at different harvesting stages of rice. The results of the study are illustrated in figure 1 and Table 2.

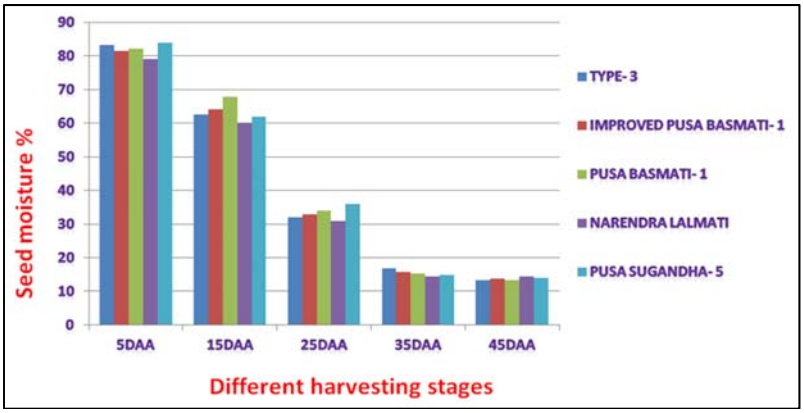

Fig. 1 Seed moisture content (%) in promising varieties of scented rice over different harvesting stages

The seed moisture content was quite high at early stages which reduced considerably at later stages of development and maturation. The decrease in moisture content with advancement of maturity stage might be due to desiccation and dehydration similar reduction in moisture content during maturation was reported by Varshney *et al*., (2001) [23].

Table 2: Comparison of seed moisture content (%) in five popular varieties of Indian scented rice during their seed development and maturation stages

Genotype	5 DAA	15 DAA	25 DAA	35 DAA	45 DAA
Type-3	83.2	62.5	32.0	16.8	13.2
Improved pusa basmati-1	81.5	64.1	32.9	15.7	13.8
Pusa basmati-1	82.0	67.9	34.0	15.2	13.4
Narendra lalmati	79.1	60.0	30.9	14.5	14.4
Pusa sugandha-5	83.8	61.9	36.0	14.9	14.0

Analysis of variance for seed moisture content at different seed development and maturation stages was carried out in Indian scented rice varieties and its results are described in table 3. Significant results were obtained for all the parameters studied.

Table 3: Analysis of variance for seed moisture content during seed development and maturation in Indian scented rice

S. No.	Source of variation	DF	Mean squares
1.	Replication	2	5.84
2.	Genotype (G)	4	16.33
.3.	Error A	8	10.38
4.	Harvesting stage (DAA)	4	13602.65**
5.	G×H	16	8.66
6.	Error B	40	7.56
7.	Total	74	743.40
8.	General mean	1.00	41.51**
10.	C.V. %	1.00	6.63**
11.	C.D. 5%	1.00	
12	Ai - Aj Genotype	1.00	2.71**
13.	Bi - Bj DA Anthesis	1.00	2.03**
14.	AiBi – AiBj	1.00	4.54**
15.	AiBi – AjBi	1.00	4.87**

Note; ** Significant observations

Conclusion

The present study on tracing physiological maturity of seeds revealed that the quality parameters like seed germination and yield were found to be maximum at 45 days after anthesis (DAA) indicating the physiological maturity on rice crop. Hence, for obtaining better seed quality; the rice crop may be harvested at 45 DAA. Considering dry matter content, germination, and vigour reached physiological maturity on 35 DAA. All the parameters studied for physiological maturity at 25 and 45 DAA found high quality seeds but scented rice is better harvested time at 35 DAA which could be regarded as the point of physiological maturity. Mehta *et al*. (1993) [19] reported that seeds harvested at 35 DAA recorded higher germination percentage while seeds harvested at 25 DAA showed the lowest germination ability. The seed dry weight increase to its maximum at 35 days after flowering and 45 DAA when moisture content of the seed decline about 14.5-16.8% and 13.2-14.4 respectively.

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