International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(4): 1135-1138

Received: 23-05-2019
Accepted: 27-06-2019

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Studies on seed development and harvesting stages and their impact for the maintenance of seed vigour in rice (*Oryza sativa* L.)

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Abstract
Studies were concerted on four promising varieties of rice in order to standardize their perfect stage of harvest and ideal harvesting tools/machine to be used for maintaining seed vigour based on their seed development and maturation under kharif/wet season. Findings advocated that the highest quality seed parameters *viz*., seed weight, germination and vigour were differed significantly with respect to maturity/harvest stages as well harvesting tools. Seed crop of rice harvested just after physiological maturity and or prior to field maturity followed by proper drying and threshing/winnowing minimized physical loss and maintained higher germination and vigour by the proceeding crop season. Impact of combine harvest on seed quality was drastically visualised. So if possible seed production crops/ plots should be avoided for combine harvest. If essentially required under some unavoidable circumstances, harvesting must be done at perfect harvest stage i.e. field maturity (around one week after physiological maturity) of crop following precise calibrations by its well expertized operator. If crop is harvested prior and after to respective maturation, poor seed quality i.e. below prescribed Indian Minimum Seed Certification Standard were appeared.

Keywords: Harvest stage/seed moisture content/germination/field emergence/rice

Introduction
Rice is the most important and widely grown food crop in the world. It is the staple food of more than 60 per cent of the world population. Rice is mainly produced and consumed in the Asia. India has the largest area under rice in the world and ranks second in the production only after China. The growing population of India along with its food habit needs around 130 million tonnes of rice by 2025. Seed is the basic and critical input in crop production. The yield could be increased around 20 per cent only by inclusion of quality seed in its cultivation. However, quality seed is being influenced by a number of factors. Among them, the harvesting of seed crop at proper stage is key prime. It could only be ascertained if knowledge about seed development and maturation of concerned crop/ variety is thoroughly studied. Such study is now becoming rather worth prime because there are a number of evidences that seed quality attained maximum values at even some duration after physiological maturity [1] in contradiction to long time accepted general hypothesis of Harrington [2] that the maximum seed quality is attained at physiological maturity and thereafter the viability and vigour decline. Keeping these in view, the present investigation was undertaken in order to study the seed development and maturation of most popular rice varietiesunder different maturity groups *viz*., early (NDR 97), medium (NDR 359), medium late (BPT 5204) and late (Swarna Sub 1) leading to standardize their perfect harvest stage at which highest quality seed of respective is obtained.

Materials and Methods
The present study was under taken during the Foundation seed production programmes of four promising varieties *viz*., NDR 97 (85-90 days), NDR 359 (125-130 days), BPT 5204 (140-145 days) and Swarna Sub 1 (155-160 days) at Crop Research Station, Masodha of the University, Faizabad, Uttar Pradesh ($26^0$43`N, $82^0$ 80` E and 113 m above mean sea level) during *Kharif* (wet season) 2014. The soil of production plots was alluvial in nature and neutral in reaction (pH 7.6), medium in organic carbon (0.42%), available nitrogen (133 kg ha^{-1}), Phosphorus (Olsen, P, 12 kg ha^{-1}) and high in potassium (119 kg ha^{-1}).

Recommended package of practices were followed time to time in order to raise an ideal crop.

Monitoring was regularly done in order to visualize the progress of flowering and the date of 50 per cent anthesis. Plants possessed 50 per cent anthesis were randomly tagged and serial harvest of panicles were done at the interval of the then seven days till the seed crop attai harvested of tenly. Panicles of each harvest variety wise were threshed gently by hand. 200/400 seeds were withdrawn from each primary seed lot for initial determination of moisture content and the remaining seed were dried to 10-14 percent (wet basis).Out of which, 1000 seed were weighed and quoted as seed dry weight. Based on these two indices *viz*., seed moisture content and seed dry weight along with morphological appearance of particularly seed colour, the physiological maturity stage of each variety was identified. Manual (MH) and combine harvesting (CH) of each variety was followed at physiological maturity stage and thereafter at three days interval in order to establish precision harvest stage with respect to harvesting tools/ machineries. Physical loss in the terms of immature seed (green, milky, dough, etc.) and damaged (broken, hulled rice, etc.) was determined on percent basis of combine harvest as such loss was negligible in manual harvesting. Random seed samples of each from each harvest cultivar-wise were stored separately in gunny seed bags, which is being used commonly for seed packaging and stored under ambient condition for the duration of 6 months. Two hundred seeds from each sample were withdrawn periodically at the interval of one month for the determination of germination and field emergence as per ISTA rules [3].

Results and Discussion

Seed development and maturation in the terms of seed moisture content and subsequent seed dry weight at weekly interval after 50 per cent anthesis of all four varieties are given in table 1. It was observed that seed moisture content decreased rapidly with time of harvest from earlier stages of seed development to attainment of maturity. The dry weight of seed increased gradually with the advent of maturation and or delay in time of harvest. These both indices *viz*., seed moisture content and seed dry weight of seed development and maturation were varied irrespective of genetic nature of variety. These findings are in confirmations to the earlier report of other groups of rice [4]. Thus while optimizing the stage of harvest, knowledge on seed development and maturation of each cultivar/ variety is essentially required.

Time and stage of harvest of crop is one of the most important strategy influences its yield, quality and storage. Premature or delayed harvest both affect quality and quantity of produce. If the crops left in the field for too long after maturity, the crop will be predisposed to pests and germination is inevitable due to the vagaries of weather. Therefore different stages for various crops, which demarked as maturity stages, harvesting in those stages gives high income and good quality produce. Farmers following traditional technique for harvesting the crops produce, but advancement of science and technology gave way for new innovation and equipment and machineries for harvesting the crops. Ideal time to harvest depends on a number of factors, including the economic part, utilization of the product and post-harvest storage. Crops are to be harvested when the desired product is at its maximum quality and quantity. Crops can be harvested at physiological maturity or at harvest maturity or storage depends on the situation or need of the produce. All the crops are having certain criteria (physiological maturity and harvest maturity symptoms) for harvesting the produce. Physiological maturity is a developmental stage after which translocation of photosynthesis is stopped to economic part and no further increase in dry matter. Translocation of carbohydrates is stopped due to the formation of abscission layer between rachis and grain at this stage. Plants reaches maximum dry weight, increasing production inputs does not produce any gains in yield. The grains at this stage are of hard dough consistency. If crops is harvested prior to its physiological maturity, it would have low dry matter, poor quality and will shrivel upon drying. Harvest maturity is when the product of interest is at best quality and maximum yield. It is generally occurred 7-10 days after physiological maturity. The important process during this stage is loss of moisture from plants and grains and symptomized by yellowing of leaves, drying of grains or pods. Crops is harvested at physiological maturity when there is need to vacate the field for sowing another crop. Under all other situation, it is advisable to follow harvest maturity. Storage maturity when there is no scope or chance for post-harvest drying, the crop is to be harvested at a stage when it can be directly stored. For grains, less than 14 percent moisture content is advocated.

Despite seed quality confirming minimum seed certification standard for genetic purity, physical purity, moisture content, germination, insect-pests and seed borne diseases, etc. finally their healthy emergence in fields are rather important. It is clearly visualised that there is clear cut impact of combine harvest on seed quality on all four varieties (Tables 2 to 5). The germination was standard even around twelve days harvesting by manual harvest but it was normal around one week after combine harvest after physiological maturity in cv. NDR 97. Field emergence was highly effected by both tools of harvesting but drastically by combine harvest over storage. Seed exposed to combine harvest might cause serious degenerative changes in metabolic activities. Field emergence was comparatively higher when crop was harvested three days later than physiological maturity in cv. NDR 97 (Table 2). Almost a similar trend on germination and field emergence was observed in other three varieties *viz*., NDR 359, BPT 5204 and Swarna Sub 1 under studied, but there was a difference in case of combine harvesting where field emergence was comparatively higher when harvesting was done around six days after their physiological maturity. It might be due to the requirement of a condition of good health and natural robustness associated with rapid and complete germination under a wide range of conditions for sufficient toughened to overcome harvesting pressure by combine harvest.

Seed developed under favourable conditions and managed properly from physiological maturity to commercialization played a basic role for improved establishment in the field and subsequently high yield potentiality. Seed physiological potential include germination and vigour which govern the critical capacity of seed to express their vital functions under both favourable and unfavourable conditions varies according to crops/species/varieties. Maximum physiological potential in the terms of germination and field emergence was achieved close to seed maturity and just after this stage seed become prone to deterioration depending on harvesting time and methods, etc. Keeping above and physical loss (Table 6) in view, it could be advised that if possible seed production crops/ plots should be avoided for combine harvest. If essentially required under some unavoidable circumstances, harvesting must be done at perfect harvest stage of crop following precise calibrations by well expertized operator.

Regarding normal harvesting, seed crop of rice could be harvested just after physiological maturity and or prior to field maturity/close to seed maturity in order to maintain higher germination and vigour by the proceeding crop season and finally high crop production.

Table 1: Seed moisture content (%) and 1000 seed weight (g) in four varieties of rice during their seed development and maturation.

Days after 50% anthesis	NDR 97		NDR 359		BPT 5204		Swarna Sub 1	
	Moisture content (%)	1000 seed weight (g)	Moisture content (%)	1000 seed weight (g)	Moisture content (%)	1000 seed weight (g)	Moisture content (%)	1000 seed weight (g)
7	68.23	10.02	75.20	9.34	78.02	7.09	79.13	5.76
14	47.05	15.10	55.53	14.25	60.26	12.12	61.65	10.10
21	21.12	20.43	36.30	20.23	45.31	15.23	48.50	14.10
28	18.21	20.32	22.52	24.11	31.20	17.16	35.18	17.15
35	17.32	20.11	18.72	24.21	20.12	18.73	25.65	18.54
42	16.04	20.09	17.21	24.18	18.27	18.69	19.48	19.20
49	15.10	19.90	16.23	24.13	17.20	18.67	18.43	19.19
56	15.08	19.89	15.50	23.90	16.04	18.51	17.06	18.89
CD (5%)	7.48	2.17	6.29	2.04	5.62	1.62	4.33	1.24

Table 2: Seed germination and field emergence over six month of storage under ambient condition after harvesting at physiological maturity and thereafter three days interval in rice cv. NDR 97.

Storage (Month)	Days after 50% anthesis									
	21		24		27		30		33	
	MH	CH	MH	CH	MH	CH	MH	CH	MH	CH
Germination (%)										
1	96	85	95	88	90	86	88	85	85	81
2	95	84	94	86	89	85	86	84	85	79
3	95	84	93	85	88	83	85	83	84	78
4	94	84	92	84	87	83	84	82	82	77
5	93	83	92	83	87	82	82	81	81	76
6	93	83	91	82	86	82	80	80	80	76
C.D. (5%)	0.72	0.76	1.05	1.23	1.12	1.19	1.18	1.22	1.24	1.32
Field emergence (%)										
1	92	79	93	81	89	79	83	77	80	75
2	90	78	92	80	87	77	81	76	78	73
3	90	78	91	79	86	76	79	75	77	72
4	89	77	91	78	85	76	79	75	77	71
5	89	76	90	78	85	75	78	74	76	71
6	88	75	88	77	84	75	77	72	75	70
C.D. (5%)	1.23	1.31	1.25	1.29	1.25	1.34	1.32	1.38	1.36	1.42

Table 3: Seed germination and field emergence over six month of storage under ambient condition after harvesting at physiological maturity and thereafter three days interval in rice cv. NDR 359.

Storage (Month)	Days after 50% anthesis									
	28		31		34		37		40	
	MH	CH	MH	CH	MH	CH	MH	CH	MH	CH
Germination (%)										
1	84	78	87	79	85	85	82	82	82	80
2	90	78	95	80	94	90	91	85	90	84
3	89	77	93	80	90	89	88	85	88	83
4	88	77	91	79	85	88	84	84	84	80
5	85	76	89	79	85	87	82	84	80	78
6	84	76	87	78	85	87	82	82	82	77
C.D. (5%)	1.32	0.63	1.46	0.57	2.53	1.73	2.64	1.09	2.72	2.16
Field emergence (%)										
1	80	70	85	72	81	75	79	73	73	71
2	87	70	90	75	88	77	84	76	78	74
3	86	69	89	75	85	77	83	76	78	72
4	85	69	88	72	84	76	83	75	76	72
5	84	68	86	72	84	76	82	75	75	71
6	83	68	85	71	82	74	80	73	75	70
C.D. (5%)	1.53	0.76	1.61	1.72	2.66	1.82	1.87	1.17	1.94	1.23

Table 4: Seed germination and field emergence over six month of storage under ambient condition after harvesting at physiological maturity and thereafter three days interval in rice cv. BPT 5204.

Storage (Month)	Days after 50% anthesis									
	35		38		41		44		47	
	MH	CH	MH	CH	MH	CH	MH	CH	MH	CH
Germination (%)										
1	86	80	89	83	87	84	83	81	82	80
2	92	82	93	86	90	86	88	82	87	85
3	92	82	92	85	89	85	86	82	85	83
4	88	81	89	84	88	85	83	81	80	79
5	86	81	89	83	87	83	83	81	82	78
6	84	79	86	82	86	83	82	80	79	75
C.D. (5%)	2.45	1.05	1.96	1.21	1.32	1.14	2.12	0.63	2.23	2.52
Field emergence (%)										
1	81	72	84	75	82	76	77	75	74	71
2	89	75	90	79	86	78	80	74	78	72
3	88	75	90	79	85	77	80	74	77	72
4	83	74	88	78	85	77	79	73	77	70
5	82	74	85	78	84	76	79	73	76	70
6	82	72	84	77	81	76	78	73	76	69
C.D. (5%)	2.61	1.24	2.05	0.74	1.17	0.78	0.74	0.76	0.43	0.51

Table 5: Seed germination and field emergence over six month of storage under ambient condition after harvesting at physiological maturity and thereafter three days interval in rice cv.Swarna Sub 1.

Storage (Month)	Days after 50% anthesis									
	38		41		44		47		50	
	MH	CH	MH	CH	MH	CH	MH	CH	MH	CH
Germination (%)										
1	85	80	89	82	86	82	85	80	81	80
2	87	82	95	85	88	86	87	82	85	82
3	86	82	94	84	86	86	84	82	82	80
4	85	81	91	83	86	84	82	81	80	78
5	85	80	88	82	85	85	85	81	81	76
6	82	79	88	81	84	82	82	80	78	75
C.D. (5%)	1.52	0.67	1.71	0.94	0.87	0.73	0.84	0.42	2.05	2.36
Field emergence (%)										
1	83	72	86	75	84	76	77	73	73	71
2	85	75	92	79	86	80	80	78	77	74
3	84	75	91	78	85	80	80	78	77	73
4	83	74	89	77	83	79	79	76	76	72
5	82	74	86	77	82	78	79	75	76	71
6	81	72	85	76	80	77	78	74	75	70
C.D. (5%)	0.85	0.87	1.56	0.61	1.35	0.75	0.42	0.86	0.48	0.73

Note: MH= Manual Harvest, CH= Combine Harvest

Table 6: Effect of combine harvest on physical loss at physiological maturity and thereafter three days interval in four different maturity groups of rice varieties.

Harvest stage	NDR 97		NDR 359		BPT 5204		Swarna Sub 1	
	Green, Milky/ Dough, etc. (%)	Crake Hulled, Broken etc. (%)	Green, Milky/ Dough, etc. (%)	Crake, Hulled, Broken etc. (%)	Green, Milky/ Dough, etc. (%)	Crake, Hulled, Broken etc. (%)	Green, Milky/ Dough, etc. (%)	Crake, Hulled, Broken etc. (%)
Physiological maturity (PM)	2.74	0.00	3.02	0.00	2.82	0.00	1.79	0.00
3 days after PM	0.68	0.00	1.72	0.00	0.97	0.00	0.17	0.00
6 days after PM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9 days after PM	0.00	0.08	0.00	0.12	0.00	0.36	0.00	0.28
12 days after PM	0.00	1.21	0.00	1.03	0.00	2.51	0.00	1.26

Acknowledgements

The financial assistance of Indian Council of Agricultural Research, New Delhi during the course of study is duly acknowledged.

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