Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(3): 2616-2623
Received: 18-03-2018
Accepted: 24-04-2018

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Impact of environmental conditions, seed age and chemical treatments on quality of rice cv. Annada during storage

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Abstract
The study was conducted to elucidate the influence of production environment, seed age and chemical treatments on storability and quality of rice cv. Annada at College of Agriculture, Acharya N. G. Ranga Agricultural University and Indian Institute of Rice Research, Hyderabad (India). In this present investigation, among different environment conditions, the maximum germination (74.12%), dry matter (203.28 mg), seed vigour index I (1897), alpha amylase activity (8.90 mm), dehydrogenase activity (0.213 OD value) and the minimum seed moisture content (11.14%), EC of leachates (1.536dSm^{-1}), seed infection (18.51%) was observed under arid environment (Q_2). With respect to the age of seed, the maximum germination (64.08%), dry matter (170.17mg), seed vigour index I (1526), alpha amylase activity (8.21mm), dehydrogenase activity (0.198 OD value) and minimum seed moisture content (11.64%), EC of leachates (1.738dSm^{-1}), seed infection (18.17%) was recorded from freshly harvested seeds (P_2). Among treatments, the maximum germination (62.20%), dry matter (163.83mg), seed vigour index I (1483), alpha amylase activity (8.72mm), dehydrogenase activity (0.378 OD value) and minimum seed moisture content (11.14%), EC of leachates (1.757dSm^{-1}), seed infection (16.71%) was recorded in seeds with carbendazim treatment @ 2.0g/kg (T_1). Interaction among production environment, seed age and chemical treatments also showed significant difference for quality parameters. This investigation helps in understanding the potential role of production environment, seed age and means to control the seed from deterioration during storage.

Keywords: annada, infection, rice, seed age, seed treatment, storability

Introduction
Unfavourable environmental conditions (high temperature, high moisture, and drought) during seed growth and development in the field and seed storage in storehouse can reduce germination, vigour and processing quality of seeds of field crops (Wang *et al.* 2012) [17]. The loss of viability during storage due to atmospheric factors at the time of maturity is a common phenomenon in all crop seeds (Roberts, 1972) [27]. The two important factors *i.e.*, temperature and relative humidity affect seed longevity during storage were well studied and quantified for rice (Ellis *et al.*1992) [9]. But, there is a lack of information about the preharvest factors *i.e.*, seed production environment and degree of seed maturity which affect the initial quality and subsequent storage longevity of seeds (Rao *et al.* 1996) [14].

Rice (*Oryza sativa* L.) is one of the most important cereal crops and occupies second prominent position in global agriculture. Globally rice is being grown in 117 countries and accounts for more than one-fifth of the calories consumed by ~3billion people as a source of staple food, which may escalate to 4.6 billion by the year 2050 (Economic survey of India, 2011) [7]. India alone produces one fourth (22%) of the world rice and is grown in an area of 43.39 millon ha with the production and productivity levels of 104.32 million tonnes and 2404 kg/ha, respectively during 2015-16 (DAC & FW, 2016; http://eands.dacnet.nic.in). Rice being a major food grain throughout the world requires storage for one or more planting seasons before cultivation. In some countries like India have a preference for stored rice whilst others (e.g. Japan and China) favours fresh rice for consumption (Zhou *et al.* 2002) [31]. During storage, a number of physiochemical and physiological changes occur, this is usually termed ageing. These changes which include pasting properties, color, flavor and composition affect rice quality.

During storage, number of biotic and abiotic factors also influenced the storage potential of seeds and results in gradual seed deterioration and ultimately death of the seeds (Kumar *et al.* 2014) [16]. Among several biotic factors threatening rice production, fungal diseases account for major losses (Grover *et al.* 2003) [10].

In general most of the fungicides act by inhibiting the energy metabolism, blocking biosynthesis or altering cell membranes of fungus. Carbendazim (Benzimazimidazoles) a systemic fungicide with curative and protection action, extensively used in agriculture, inhibit the development of germinal tube, formation of the aspersoria and growth of nucleus of fungus (Paweri *et al.* 2016) [20]. With this context, investigations were undertaken to know the effect of production environment, age of seed and chemical seed treatment on storability and quality of rice Cv. Annada.

Materials and Methods

The storage experiment to understand the influence of production environment in association with seed age and chemical treatments on seed quality of rice Cv. Annada was conducted at ICAR - Indian Institute Rice Research (IIRR) and College of Agriculture, Acharya N. G. Ranga Agricultural University, Hyderabad (India).

The seeds of rice Cv. Annada were procured from two production environment conditions *viz.*,Q_1 – Central Rice Research Institute (CRRI), Cuttack (humid region) and Q_2 – IIRR, Hyderabad (arid region). The weather data during the production period was also collected (Table 1). Seeds of one year old (P_1) and freshly harvested (P_2) crop were used for study. Before all the studies, seeds were treated with carbendazim @2.0 g/kg of seed (T_1), mancozeb@ 2.5 g/kg of seed (T_2) along with control (T_3) and kept storage under ambient conditions (33°C and 57% RH) for 9 months. Seed samples from the respective treatments were drawn at tri-monthly intervals and subjected to test the proposed physiological, biochemical and seed health parameters. The experiment was conducted in Completely Randomized Block Design with Factorial concept (FCRD) and three replications have been taken with 100 seeds in each replication.

The observations for seed quality parameters *viz.*, moisture content of seed was determined as per ISTA rules (ISTA, 1985) [12], Germination test was conducted on pure seed fraction using 100 seeds in three replicates following between paper (BP) method at 25ºC temperature and 93±2% relative humidity as per ISTA, 1985 [12] (Anonymous, 1999) [2]. The numbers of normal seedlings were counted on 5th day (first count) and 14th day (final count) of germination from all the replications. The average of three replications was expressed as germination percentage. Seedling vigour index I (shoot and root length basis) was calculated as per the following formula (Abdul-baki and Anderson, 1973) [1] *i.e.*, SVI I = Seed germination (%) × seedling length (cm); where in seedling length = shoot length (cm) + root length (cm). Ten normal seedlings were taken randomly from each replication at final count of germination test for measuring the shoot length and root length in centimeters.

Electrical conductivity of seed leachates (dSm^{-1})

Electrical conductivity of seed leachate was estimated as described by Presley (1958) [22] as follows. Four replications of 25 seeds from each treatment was drawn and pre-washed thoroughly with distilled water to remove the adhering chemicals and then soaked in 50 ml of distilled water for 16 hours at room temperature. After soaking, the seed steep water was decanted to obtain the seed leachate. The electrical conductivity of seed leachate was measured in a digital conductivity meter with a cell constant of one and expressed as dSm^{-1}.

Alpha amylase activity [EC 3.2.1.1]

The α-amylase activity was analyzed as per the method suggested by Simpson and Naylor (1962) [28]. Two gram of agar shreds and one gram of potato starch was mixed together in water to form paste and the volume was made up to 100 ml with distilled water. The homogenous solution of agar- starch mixture after boiling was poured into sterilized petri-dishes and allowed to settle in the form of gel after cooling. Ten pre-soaked (for 8 hours) and half cut seeds (with their half endosperm and embryo portion intact) were placed in the petri-dishes in such a way that endospermic part remained in contact with agar-starch gel. The petri-dishes were closed and kept in dark at 30ºC. After 24 hours the petri-dishes were uniformly smeared with potassium iodide solution (0.44 g of iodine crystal + 20.008 g potassium iodide in 500 ml distilled water) and excess solution was drained off after few minutes. The diameter of halo (clear) zone formed around the seed was measured in mm and reported as α – amylase activity.

Dehydrogenase activity (OD value)

Dehydrogenase activity was determined as described by Kittock and Law (1968) [15] using 2, 3, 5-triphenyl tetrazolium chloride solution at 0.1 % concentration prepared by using Sorenson's buffer solution as solvent. Five seeds from each treatment were taken randomly and preconditioned by soaking in water for 7 hours. Seeds were steeped in tetrazolium solution and kept in dark for 2hr at 40°C for staining. After staining, the excess solution was drained and the seeds were washed thoroughly with distilled water and transferred to a test tube containing 10 ml of 2-methoxy ethanol (methyl cello solve). The test tube was closed air tight and allowed to remain in the incubator in darkness overnight for extracting the red coloured formazon. The coloured solution was decanted and the colour intensity was measured in an Optima UV-VIS spectrophotometer using blue filter (470 nm) and methyl cello solve as the blank. The dehydrogenase activity was expressed as OD value per 5 seeds per 10 ml.

Seed infection (%)

During storage period of nine months, periodical observations on seed infection were recorded in terms of infected seeds. Observations were recorded at initial and at tri-monthly intervals from the seed of all treatments stored in gunny bags for 9 months under ambient conditions. Fungal infestation in the seed sample was determined by using standard blotter method (ISTA, 1993) [13]. Three discs of blotter paper (9 cm diameter) were dipped in beaker containing sterile distilled water and placed in petri plates on which seeds were placed with the help of forceps. Four hundred seeds of each variety were tested in 16 petriplates having twenty five seeds per plate. After labelling, these petri-plates were incubated at 25±1ºC under alternate cycles of 12 hours light and 12 hours darkness for seven days in BOD incubator. On seventh day, these plates were examined under stereo binocular microscope and the percentage of total number of fungal colonies was calculated and the infected seeds were counted and identified the causal organism under binocular microscope.

Statistical analysis

In each experiment, 100 seeds in each replication for germination test, 25 seeds from each treatment for electrical conductivity test, 10 seeds were used per treatment for α-amylase activity, 5 seeds for dehydrogenase activity and each

experiment was repeated three times. Standard errors (SEs) of the arithmetic means were calculated for each treatment. Three factorial analysis was made by using Indostat software package 8.0 version and Analysis of variance (ANOVA) constructed as per Panse and Sukhatme (1954) [21].

Results and Discussion

The storability and quality of cv. Annada seeds was influenced by production environment, age of seed and chemical seed treatment (Table 2, Table 3 and Table 4).

Among various environment conditions, the maximum germination (74.12%), dry matter accumulation (203.28 mg), seed vigour index I (1897), alpha amylase activity (8.90 mm), dehydrogenase activity (0.213 OD value) and the minimum seed moisture content (11.14%), EC of leachates (1.536dSm^{-1}), seed infection (18.51%) was observed under arid environment (Q_2) (Table 2-4 and Figure 1). With respect to the age of seed, the maximum germination (64.08%), dry matter (170.17 mg), seed vigour index I (1526), alpha amylase activity (8.21 mm), dehydrogenase activity (0.198 OD value) and minimum seed moisture content (11.64%), EC of leachates (1.738dSm^{-1}), seed infection (18.17%) was recorded from freshly harvested seeds (P_2) (Table 2-4 and Figure 2). The maximum germination (62.20%), dry matter (163.83 mg), vigour index I (1483), alpha amylase activity (8.72 mm), dehydrogenase activity (0.378 OD value) and minimum seed moisture content (11.14%), EC of leachates (1.757dSm^{-1}), seed infection (16.71%) was recorded in seeds using carbendazim treatment @ 2.0g/kg (T_1) (Table 2, Table 3 and Table 4 and Figure 3).

Interaction of production environment (Q) and seed age (P) showed significance difference, where the maximum germination (75.19%), dry matter (219.89 mg), vigour index I (2068), alpha amylase activity (9.10 mm), dehydrogenase activity (0.224 OD value) and minimum seed moisture content (11.07%), EC of leachates (1.492dSm^{-1}), seed infection (16.94%) was noticed in freshly harvested seeds under arid environment condition (Q_2P_1) (Table 2, Table 3 and Table 4).

Interaction of production environment (Q) and chemical seed treatment (T) showed significance difference, where the maximum germination (76.49%), dry matter (205.17 mg), vigour index I (2106), alpha amylase activity (9.50 mm), dehydrogenase activity (0.411 OD value) and minimum seed moisture content (10.64%), EC of leachates (1.503dSm^{-1}), seed infection (14.26%) was observed from seeds of arid environment condition with carbendazim treatment @2.0g/kg seeds (Q_2T_1) (Table 2, Table 3 and Table 4).

Interaction of seed age (P) and chemical treatment (T) showed significance difference, where the maximum dry matter (172.50 mg), vigour index I (1743), alpha amylase activity (8.89 mm), dehydrogenase activity (0.395) and minimum seed moisture content (11.05%), EC of leachates (1.724dSm^{-1}) was observed from freshly harvest seeds and carbendazim treatment @2.0g/kg seeds (P_2T_1) (Table 2, Table 3 and Table 4).

Overall, interaction effect of production environment, seed age and chemical treatments (QxPxT) showed significance difference, where the maximum dry matter (221.67 mg), vigour index I (2340), alpha amylase activity (9.70 mm), dehydrogenase activity (0.429 OD value) and minimum seed moisture content (10.60%), EC of leachates (1.478dSm^{-1}), seed infection (10.40 %) was observed from ($Q_2P_2T_1$) arid environment, freshly harvest seeds and carbendazim treatment @2.0g/kg seeds.

The high quality parameters were recorded from seeds of IIRR, Hyderabad may be due to the higher temperature, sunshine, evaporation and lower rainfall and relative humidity as compared to seeds produced at CRRI, Cuttack, humid region for crop cultivation, where prevailing of high humidity in the environment. Maintenance of viability, vigour and storability of seeds is a problem in tropical regions where high temperature and high humidity accelerate the seed deterioration which ultimately result in non- viability (Ellis *et al*. 1993) [9] Similarly, same results were recorded in rice cv. Swarna (Rao *et al.* 1993) [25] and in rice hybrid ADTRH 1 (Ramanadane *et al.* 2005) [24].

Among the age of seeds, better quality was observed from freshly harvested seeds as compared to one year old seeds. During seed ageing, a number of physiochemical and physiological changes occur (Noomhorm *et al*. 1997) [19]. These changes in seed lead to reduce viability, growth efficiency and seedling characteristics after germination and quality. Gao *et al.* (2016) [11] and Bewley *et al*. (2013) [3] reported that rice seeds deteriorate during storage, leading to significant losses due to decreased viability and germination rates. Similar findings were also reported in rice (Zhou *et al.* 2002) [31] and soybean (Wang *et al.* 2012) [17].

The present study revealed that, with the advance in the storage period and seed treatments with chemicals, all the seed quality parameters were gradually decreased. Similar findings were reported in marigold (Kumar *et al*. 2014) [16] and chickpea (Chormule *et al.* 2015) [5]. Among chemicals, carbendazim constituent may inhibit the pathogen activity and favours for germination and quality parameters as compared to mancozeb. The results of this study were confirmed with Prasad *et al*. (2010) [18] in rice. This is in accordance with the findings of Singh *et al.* (1996) [29] in onion who have reported carbendazim as an effective fungicide against *Alternaria alternata*, *Rhizopus* spp, *Fusarium* spp and exhibited higher germination and vigour index in seeds of onion and other crop seeds. Similar results were made by Pameri *et al*. (2016) [20] in rice. Fungicide seed treatments containing fludioxonil and azoxystrobin can improve germination, plant population, growth, and yield in maize (Solorzano *et al*. 2011) [30], and with thiram and delson in eggplant (Reddy and Reddy, 1994) [26] and scented rice Cv. Mugad Sugandha (Raikar *et al*. 2008) [23]. Similarly, Butt *et al.* (2011) [4] investigated the effect of four chemical fungicides namely antracal, topsin, mancozeb and derosal on seed-borne mycoflora of rice.

Conclusion

From the investigation it is concluded that, in the context where rice has to be stored at least for a year or more, before it's planting in the field, so the factors studied helps in understanding and control the seed deterioration and infection during storage. Overall, interaction effect of production environment, seed age and chemical treatments (QxPxT) showed significance difference. The maximum dry matter, vigour index-I, alpha amylase activity, dehydrogenase activity and minimum seed moisture content, EC of leachates, seed infection was observed from ($Q_2P_2T_1$) arid environment, freshly harvest seeds and carbendazim treatment @2.0g/kg seeds. The successful and fruitful crop production depends on the availability of good quality seed and this sort of study would definitely helps in recommending the possible means to improve the storability and quality of rice seed, without which the expensive and well planned crop production approach may fail.

Table 1: Monthly meteorological data recorded at ARI, Rajendranagar and CRRI, Cuttack from April, 2011 to March, 2012.

Month	Temperature (^{0}C)				Mean temp (^{0}C)		Relative humidity (%)				Rainfall (mm)		Sunshine (hrs)		Evaporation	
	Max		Min				I		II							
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Apr-11	36.7	35.6	21.9	24.8	29.3	30.2	74.0	92.0	35.0	52.0	0.0	10.6	8.2	7.2	5.0	4.8
May-11	39.2	36.9	25.4	29.0	32.3	33.0	56.0	90.0	28.0	58.0	1.0	175.6	8.5	8.1	6.4	5.2
Jun-11	35.0	33.2	24.4	28.5	29.7	30.9	74.0	89.0	45.0	63.0	4.0	310.2	6.1	5.3	6.1	5.5
Jul-11	31.2	30.5	22.7	27.2	26.9	28.9	86.0	91.0	62.0	73.0	11.0	315.9	4.8	3.2	4.8	4.0
Aug-11	30.2	30.1	22.7	27.0	26.4	28.6	90.0	93.0	71.0	80.0	9.0	375.6	3.9	2.6	4.4	4.1
Sep-11	30.7	29.5	22.0	26.0	26.3	27.8	88.0	92.0	74.0	76.0	5.0	368.6	5.5	2.9	2.8	4.3
Oct-11	32.1	31.6	20.3	22.8	26.2	27.2	90.0	90.0	69.0	61.0	4.0	30.5	6.6	8.8	2.7	4.0
Nov-11	30.1	30.0	15.4	19.8	22.8	24.9	82.0	92.0	45.0	49.0	1.0	0.0	8.2	9.0	2.4	3.8
Dec-11	29.9	28.7	12.6	15.9	21.3	22.3	83.0	89.0	40.0	42.0	0.0	0.0	8.5	5.8	2.3	3.7
Jan-12	30.1	26.5	14.2	15.0	22.2	20.8	77.0	93.0	37.0	56.0	0.0	100.2	8.5	6.2	2.3	3.9
Feb-12	33.0	31.2	15.4	19.3	24.2	25.3	73.0	91.0	25.0	40.0	0.0	0.0	9.5	8.5	3.2	4.1
Mar-12	36.9	34.8	17.3	24.5	27.1	29.7	62.0	95.0	21.0	43.0	0.0	0.0	8.9	7.3	4.4	4.8

* A – Agricultural Research Institute, Rajendranagar, Hyderabad and B - Central Rice Research Institute, ICAR, Cuttack

Source: ARI, Agro Climatic Research Centre, Rajendranagar, Hyderabad- 500 030 and CRRI, Annual Report 2011-12, Central rice research institute, ICAR, Cuttack, (Odisha), 753006, India.

Table 2: Influence of production environment, seed age and seed treatment on seed moisture content (%) and seed germination (%) in rice Cv. Annada during storage.

	Seed moisture content (%)				Seed germination (%)			
	Months of storage							
Treatments	0	3	6	9	0	3	6	9
Production environment (Q)								
Q_1	10.91^a	11.45^a	11.85^a	12.31^a	59.44 (50.63)^b	56.94(49.15)^b	53.28(46.97)^b	49.83(44.92)^b
Q_2	10.26^b	10.56^b	10.89^b	11.14^b	97.22(80.50)^a	95.61(78.11)^a	93.89(75.84)^a	92.33(74.12)^a
Seed age (P)								
P_1	10.65^a	11.07^a	11.44^a	11.81^a	72.33(61.96)^b	70.11(59.83)^b	66.61 (57.10)^b	63.66(54.95)^b
P_2	10.52^{ab}	10.95^{ab}	11.30^b	11.64^{ab}	84.33(69.17)^a	82.44(67.43)^a	80.56 (65.72)^a	78.50(64.08)^a
Seed treatment (T)								
T_1	10.15^c	10.47^c	10.83^c	11.14^c	79.92(66.79)^a	79.00(65.76)^a	76.25(63.43)^a	74.66(62.20)^a
T_2	10.61^b	11.05^b	11.39^b	11.57^b	77.42(64.80)^{bc}	76.08(63.50)^b	73.58(61.54)^b	70.25(59.05)^b
T_3	10.99^a	11.51^a	11.89^a	12.46^c	77.67(65.11)^b	73.75(61.63)^c	70.92(59.26)^c	68.33(57.30)^c
Q x P Interaction								
Q_1P_1	11.01^a	11.54^a	11.97^a	12.41^a	47.56(43.60)^c	45.00(42.13)^c	40.11(39.29)^d	36.00(36.85)^d
Q_1P_2	10.80^b	11.35^b	11.73^b	12.20^{ab}	71.33(57.68)^b	68.89(56.17)^b	66.44(54.66)^c	63.66(52.98)^c
Q_2P_1	10.29^c	10.60^c	10.92^c	11.22^b	97.11(80.32)^{ab}	95.22(77.54)^{ab}	93.11(74.91)^b	91.33(73.04)^b
Q_2P_2	10.24^{cd}	10.55^{cd}	10.86^{cd}	11.07^{bc}	97.33(80.67)^a	96.00(78.68)^a	94.66(76.78)^a	93.33(75.19)^a
Q x T Interaction								
Q_1T_1	10.33^d	10.85**	11.26^{cd}	11.63^{cd}	62.16(52.32)**	61.50(51.94)**	57.33(49.43)^c	54.83(47.91)^d
Q_1T_2	11.02^b	11.54**	11.95^b	12.28^b	58.00(49.73)**	56.33(48.74)**	52.66(46.58)^d	47.83(43.71)^e
Q_1T_3	11.37^a	11.95**	12.34^a	13.01^a	58.16(49.85)**	53.00(46.76)**	49.83(44.90)^{de}	46.83(43.13)^{ef}
Q_2T_1	9.96^e	10.09**	10.40^e	10.64^{de}	97.66(81.26)**	96.50(79.59)**	95.16(77.42)^a	94.50(76.49)^a
Q_2T_2	10.21^{de}	10.57**	10.82^d	10.87^d	96.82(79.86)**	95.83(78.26)**	94.50(76.49)^{ab}	92.66(74.39)^b
Q_2T_3	10.61^c	11.06**	11.44^c	11.92^c	97.16(80.38)**	94.50(76.49)**	92.00(73.62)^b	89.83(71.48)^c
P x T Interaction								
P_1T_1	10.19**	10.51^d	10.90^d	11.22^{cd}	73.50(62.94)**	72.16(61.55)**	68.50(58.66)^d	66.83(57.45)**
P_1T_2	10.75**	11.18^b	11.51^b	11.70^b	71.83(61.44)**	70.16(59.83)**	66.83(57.33)^{de}	62.50(54.19)**
P_1T_3	11.02**	11.53^a	11.92^a	12.52^a	71.66(61.51)**	68.00(58.12)**	64.50(55.30)^e	61.66(53.21)**
P_2T_1	10.11**	10.43^{de}	10.76^{de}	11.05^d	86.33(70.64)**	85.83(69.98)**	84.00(68.19)^a	82.50(66.96)**
P_2T_2	10.48**	10.93^c	11.27^c	11.45^c	83.00(68.16)**	82.00(67.17)**	80.33(65.74)^b	78.00(63.90)**
P_2T_3	10.97**	11.49^{ab}	11.86^{ab}	12.41^{ab}	83.66(68.72)**	79.50(65.13)**	77.33(63.22)^c	75.00(61.39)**
Q x P x T Interaction								
$Q_1P_1T_1$	10.37**	10.89^c	11.35^{cd}	11.76^c	49.33(44.62)**	48.00(43.85)**	42.33(40.58)**	39.66(39.04)**
$Q_1P_1T_2$	11.24**	11.72^{ab}	12.13^{ab}	12.30^b	47.00(43.28)**	45.00(42.13)**	40.00(39.23)**	33.66(35.46)**
$Q_1P_1T_3$	11.43**	12.00^a	12.42^a	13.16^a	46.33(42.90)**	42.00(40.39)**	38.00(38.05)**	34.66(36.07)**
$Q_1P_2T_1$	10.29**	10.81^{cd}	11.17^{cd}	11.50^{cd}	75.00(60.02)**	75.00(60.03)**	72.33(58.28)**	70.00(56.79)**
$Q_1P_2T_2$	10.79**	11.35^b	11.76^b	12.26^{bc}	69.00(56.19)**	67.67(55.36)**	65.33(53.94)**	72.00(51.95)**
$Q_1P_2T_3$	11.32**	11.90^{ab}	12.26^{ab}	12.85^{ab}	70.00(56.79)**	64.00(53.13)**	61.66(51.75)**	59.00(50.19)**
$Q_2P_1T_1$	10.01**	10.13^e	10.44^e	10.68	97.66(81.26)**	96.33(79.24)**	94.66(76.73)**	94.00(75.85)**
$Q_2P_1T_2$	10.26**	10.63^{cd}	10.88^d	11.09^d	96.66(71.60)**	95.33(77.54)**	93.66(75.43)**	91.33(72.92)**
$Q_2P_1T_3$	10.61**	11.05^{bc}	11.42^c	11.88^{bc}	97.00(80.12)**	94.00(75.85)**	91.00(72.56)**	88.66(70.35)**
$Q_2P_2T_1$	9.92**	10.04^{ef}	10.36^{ef}	10.60^{ef}	97.66(81.26)**	96.67(79.93)**	95.66(78.10)**	95.00(77.12)**
$Q_2P_2T_2$	10.17**	10.52^d	10.77^{de}	10.65^e	97.00(80.12)**	96.33(78.98)**	95.33(77.54)**	94.00(75.85)**
$Q_2P_2T_3$	10.62**	11.07^{bc}	11.46^{bc}	11.96^{bc}	97.33(80.64)**	95.00(77.12)**	93.00(74.68)**	91.00(72.60)**

*Figures within the parentheses indicate arcsine transformed values. ** Non significant, Q_1: Seed produced in humid environment, Q_2: Seed produced in arid environment, P_1: One year old seed after harvest (*Kharif, 2011*), P_2: Freshly harvested seed (*Rabi, 2012*), T_1: Seed treated with carbendazim@ 2.0g/kg, T_2: Seed treated with mancozeb@ 2.5g/kg and T_3: Untreated (control)

Table 3: Influence of production environment, seed age and seed treatment on Dry matter (mg) and Seedling Vigour Index-I in rice Cv. Annada during storage.

	Dry matter (mg)				Seedling vigour index-I			
	Months of storage							
Treatment	**0**	**3**	**6**	**9**	**0**	**3**	**6**	**9**
Production environment (Q)								
Q_1	137.28^{b}	129.06^{b}	122.89^{b}	118.17^{b}	1175^{b}	1030^{b}	883^{b}	738^{b}
Q_2	229.13^{a}	221.85^{a}	212.08^{a}	203.28^{a}	2586^{a}	2328^{a}	2122^{a}	1897^{a}
Seed age (P)								
P_1	178.83^{b}	169.92^{b}	158.81^{b}	151.28^{b}	1661^{b}	1439^{b}	1266^{b}	1109^{b}
P_2	187.58^{a}	180.99^{a}	176.17^{a}	170.17^{a}	2100^{a}	1920^{a}	1739^{a}	1526^{a}
Seed treatment (T)								
T_1	186.53^{a}	181.48^{a}	175.12^{a}	163.83^{a}	2080^{a}	1850^{a}	1689^{a}	1483^{a}
T_2	183.54^{b}	174.42^{b}	165.96^{b}	161.25^{bc}	1849^{b}	1681^{b}	1503^{b}	1313^{b}
T_3	179.55^{c}	170.46^{bc}	161.48^{bc}	157.08^{c}	1713^{c}	1507^{c}	1315^{c}	1157^{c}
Q x P Interaction								
Q_1P_1	134.78^{d}	126.56^{cd}	120.39^{cd}	115.89^{d}	892^{d}	756^{d}	624^{d}	493^{d}
Q_1P_2	139.78^{c}	131.56^{c}	125.39^{c}	120.44^{c}	1458^{c}	1305^{c}	1143^{c}	983^{c}
Q_2P_1	222.89^{b}	213.28^{b}	197.22^{b}	186.67^{b}	2431^{b}	2121^{b}	1909^{b}	1725^{b}
Q_2P_2	235.38^{a}	230.42^{a}	226.94^{a}	219.89^{a}	2741^{a}	2536^{a}	2336^{a}	2068^{a}
Q x T Interaction								
Q_1T_1	139.97^{d}	132.83^{d}	128.87^{d}	122.50^{c}	1342**	1184**	1036^{d}	860^{d}
Q_1T_2	137.33^{de}	128.17^{e}	121.33^{e}	118.50^{d}	1134**	1027**	861^{e}	710^{e}
Q_1T_3	135.53^{e}	126.17^{f}	119.17^{ef}	113.50^{e}	1050**	880**	752^{f}	644^{f}
Q_2T_1	233.88^{a}	230.13^{a}	221.87^{a}	205.17^{a}	2818**	2516**	2342^{a}	2106^{a}
Q_2T_2	229.75^{b}	220.67^{b}	210.58^{b}	204.00^{ab}	2565**	2336**	2146^{b}	1915^{b}
Q_2T_3	223.77^{c}	214.75^{c}	203.80^{c}	200.67^{b}	2375**	2134**	1878^{c}	1669^{c}
P x T Interaction								
P_1T_1	181.50**	176.42^{c}	168.00^{bc}	155.17^{cd}	1824**	1541**	1388^{d}	1223^{d}
P_1T_2	179.08**	168.17^{d}	155.75^{c}	155.50^{c}	1636**	1448**	1267^{e}	1107^{e}
P_1T_3	175.92**	165.17^{e}	152.67^{cd}	147.17^{d}	1524**	1328**	1144^{f}	998^{f}
P_2T_1	191.55**	186.55^{a}	182.03^{a}	172.50^{a}	2336**	2159**	1990^{a}	1743^{a}
P_2T_2	188.00**	180.67^{b}	176.17^{ab}	171.00^{ab}	2062**	1915**	1740^{b}	1519^{b}
P_2T_3	183.18**	175.75^{cd}	170.30^{b}	167.00^{b}	1902**	1686**	1487^{c}	1315^{c}
Q x P x T Interaction								
$Q_1P_1T_1$	136.67**	130.33^{de}	125.67^{de}	121.67^{cd}	1001**	846^{h}	722^{i}	573^{i}
$Q_1P_1T_2$	134.83**	125.67^{e}	118.83^{e}	116.00^{de}	868**	770^{hi}	615^{j}	470^{j}
$Q_1P_1T_3$	132.83**	123.67^{ef}	116.67^{ef}	110.00^{e}	809**	653^{i}	535^{k}	436^{jk}
$Q_1P_2T_1$	141.67**	135.33^{d}	130.67^{d}	123.33^{c}	1683**	1523^{e}	1350^{f}	1147^{f}
$Q_1P_2T_2$	139.83**	130.67^{de}	123.83^{de}	121.00^{cd}	1400**	1284^{f}	1108^{g}	951^{g}
$Q_1P_2T_3$	137.83**	128.67^{de}	121.67^{de}	117.00^{d}	1292**	1107^{g}	970^{h}	853^{h}
$Q_2P_1T_1$	226.33**	222.50^{bc}	210.33^{bc}	188.67^{b}	2648**	2236^{cd}	2054^{c}	1873^{c}
$Q_2P_1T_2$	223.33**	210.67^{c}	192.67^{c}	187.00^{bc}	2405**	2126^{d}	1919^{d}	1743de
$Q_2P_1T_3$	219.00**	206.67^{cd}	188.67^{cd}	184.33^{bc}	2239**	2002de	1752^{e}	1560^{e}
$Q_2P_2T_1$	241.43**	237.77^{a}	233.40^{a}	221.67^{a}	2989**	2796^{a}	2630^{a}	2340^{a}
$Q_2P_2T_2$	236.43**	230.67^{ab}	228.50^{ab}	221.00^{ab}	2724**	2546^{b}	2372^{b}	2087^{b}
$Q_2P_2T_3$	228.53**	222.83^{b}	218.93^{b}	217.00^{ab}	2511**	2265^{c}	2004^{cd}	1777^{d}

*Figures within the parentheses indicate arcsine transformed values. ** Non significant, Q_1: Seed produced in humid environment, Q_2: Seed produced in arid environment, P_1: One year old seed after harvest (*Kharif, 2011*), P_2: Freshly harvested seed (*Rabi, 2012*), T_1: Seed treated with carbendazim@ 2.0g/kg, T_2: Seed treated with mancozeb@ 2.5g/kg and T_3: Untreated (control)

Table 4: Influence of production environment, seed age and seed treatment on EC of seed leachates (dSm^{-1}) and Seed infection (%) in rice Cv. Annada during storage.

	EC of seed leachates (dSm^{-1})				Seed infection (%)			
	Months of storage							
Treatment	**0**	**3**	**6**	**9**	**0**	**3**	**6**	**9**
Production environment (Q)								
Q_1	1.626^{a}	1.704^{a}	1.828^{a}	2.042^{a}	11.62(19.49)^{a}	12.56(20.39)^{a}	13.57(21.28)^{a}	14.55(22.14)^{a}
Q_2	1.244^{b}	1.320^{b}	1.445^{b}	1.536^{b}	7.56(15.26)^{b}	8.50(16.35)^{b}	9.52(17.44)^{b}	10.51(18.51)^{b}
Seed age (P)								
P_1	1.464^{a}	1.570^{a}	1.696^{a}	1.839^{a}	12.00(19.88)^{a}	12.94(20.76)^{a}	13.95(21.63)^{a}	14.94(22.48)^{a}
P_2	1.407^{b}	1.454^{b}	1.577^{b}	1.738^{b}	7.17(14.87)^{b}	8.11(15.98)^{b}	9.12(17.09)^{b}	10.12(18.17)^{b}
Seed treatment (T)								
T_1	1.403^{c}	1.485^{b}	1.610^{c}	1.757^{c}	5.75(13.12)^{c}	6.67(14.32)^{c}	7.69(15.53)^{c}	8.67(16.71)^{c}
T_2	1.439^{b}	1.495^{a}	1.618^{b}	1.789^{b}	9.25(17.55)^{b}	10.25(18.54)^{b}	11.26(19.48)^{b}	12.25(20.38)^{b}
T_3	1.463^{a}	1.457^{c}	1.681^{a}	1.820^{a}	13.76(21.45)^{a}	14.67(22.25)^{a}	15.68(23.08)^{a}	16.68(23.88)^{a}
Q x P Interaction								

Q_1P_1	1.657[a]	1.764[a]	1.887[a]	2.099[a]	15.12(22.55)[a]	16.00(23.30)[a]	17.01(24.10)[a]	18.00(24.88)[a]
Q_1P_2	1.596[b]	1.645[b]	1.769[b]	1.984[b]	8.11(16.43)[bc]	9.11(17.47)[bc]	10.13(18.46)[bc]	11.12(19.40)[bc]
Q_2P_1	1.270[c]	1.377[c]	1.504[c]	1.580[c]	8.89(17.21)[b]	9.89(18.21)[b]	10.90(19.17)[b]	11.88(20.08)[b]
Q_2P_2	1.218[d]	1.264[d]	1.385[d]	1.492[d]	6.22(13.31)[c]	7.12(14.50)[c]	8.12(15.72)[c]	9.12(16.94)[c]
Q x T Interaction								
Q_1T_1	1.593[c]	1.677[bc]	1.802[c]	2.010[c]	7.84(16.18)**	8.85(17.23)[cd]	9.85(18.22)[cd]	10.84(19.17)[cd]
Q_1T_2	1.630[b]	1.686[b]	1.812[b]	2.039[b]	10.67(18.87) **	11.66(19.80)[bc]	12.68(20.70)[bc]	13.66(21.57)[bc]
Q_1T_3	1.656[a]	1.749[a]	1.870[a]	2.075[a]	16.32(23.43) **	17.16(24.13)[a]	18.18(24.92)[a]	19.17(25.68)[a]
Q_2T_1	1.213[f]	1.293[e]	1.418[ef]	1.503[f]	3.67(10.07) **	4.51(11.42)[d]	5.52(12.84)[d]	6.50(14.26)[d]
Q_2T_2	1.248[e]	1.304[d]	1.425[e]	1.539[e]	7.83(16.23) **	8.83(17.27)[c]	9.84(18.26)[c]	10.83(19.20)[c]
Q_2T_3	1.270[d]	1.365[c]	1.492[d]	1.566[d]	11.17(19.47) **	12.15(20.37)[b]	13.18(21.24)[b]	14.17(22.08)[b]
P x T Interaction								
P_1T_1	1.430**	1.533[bc]	1.653[b]	1.790[c]	7.99(16.37)[c]	9.01(17.41)[c]	10.02(18.39)[c]	11.02(19.33) **
P_1T_2	1.465**	1.540[b]	1.664[ab]	1.842[b]	11.01(19.22)[b]	12.02(20.14)[b]	13.03(21.02)[b]	14.01(21.87) **
P_1T_3	1.495**	1.639[a]	1.770[a]	1.886[a]	17.02(24.07)[a]	17.81(24.72)[a]	18.82(25.49)[a]	19.82(26.23)**
P_2T_1	1.376**	1.437[e]	1.567[de]	1.724[f]	3.50(9.87)[d]	4.35(11.24)[d]	5.32(12.67)[d]	6.32(14.09) **
P_2T_2	1.414**	1.450[d]	1.573[d]	1.736[e]	7.49(15.88)[cd]	8.48(16.94)[cd]	9.52(17.94)[cd]	10.50(18.90) **
P_2T_3	1.431**	1.475[c]	1.592[c]	1.755[d]	10.50(18.86)[bc]	11.51(19.78)[bc]	12.48(20.67)[bc]	13.51(21.52) **
Q x P x T Interaction								
$Q_1P_1T_1$	1.624**	1.726[bc]	1.846[bc]	2.051[c]	9.34(17.78)[cd]	10.34(18.75)[cd]	11.36(19.67)[d]	12.34(20.56)[cd]
$Q_1P_1T_2$	1.657**	1.731[b]	1.858[b]	2.098[b]	13.66(21.69)[b]	14.68(22.51)[b]	15.68(23.31)[b]	16.66(24.10)[b]
$Q_1P_1T_3$	1.690**	1.834[a]	1.957[a]	2.147[a]	22.35(28.18)[a]	23.00(28.65)[a]	24.02(29.33)[a]	25.03(29.99)[a]
$Q_1P_2T_1$	1.563**	1.628[de]	1.758[de]	1.969[d]	6.32(14.57)[de]	7.35(15.70)[de]	8.35(16.77)[g]	9.32(17.78)[de]
$Q_1P_2T_2$	1.604**	1.641[d]	1.767[d]	1.681[e]	7.67(16.05)[d]	8.66(17.10)[d]	9.69(18.10)[e]	10.67(19.05)[d]
$Q_1P_2T_3$	1.621**	1.665[c]	1.783[c]	2.003[c]	10.33(18.68)[cd]	11.32(19.61)[cd]	12.34(20.51)[cd]	13.35(21.37)[cd]
$Q_2P_1T_1$	1.237**	1.340[fg]	1.461[fg]	1.528[h]	6.67(14.95)[de]	7.66(16.07)[de]	8.69(17.12)[ef]	9.65(18.11)[de]
$Q_2P_1T_2$	1.273**	1.349[f]	1.470[f]	1.586[g]	8.33(16.75)[cd]	9.34(17.77)[cd]	10.35(18.73)[de]	11.34(19.66)[cd]
$Q_2P_1T_3$	1.300**	1.444[e]	1.583[e]	1.624[f]	11.67(19.91)[bc]	12.66(20.79)[bc]	13.65(21.65)[c]	14.66(22.48)[bc]
$Q_2P_2T_1$	1.190**	1.246[hi]	1.375[hi]	1.478[k]	0.66(5.18)[e]	1.33(6.77)[e]	2.35(8.56)[h]	3.35(10.40)[e]
$Q_2P_2T_2$	1.223**	1.259[h]	1.379[h]	1.492[j]	7.34(15.70)[de]	8.34(16.77)[de]	9.34(17.78)[ef]	10.36(18.75)[de]
$Q_2P_2T_3$	1.240**	1.285[g]	1.401[g]	1.507[i]	10.67(19.03)[c]	11.68(19.95)[c]	12.66(20.83)[cd]	13.67(21.68)[c]

*Figures within the parentheses indicate arcsine transformed values. ** Non significant, Q_1: Seed produced in humid environment, Q_2: Seed produced in arid environment, P_1: One year old seed after harvest (*Kharif, 2011*), P_2: Freshly harvested seed (*Rabi, 2012*), T_1: Seed treated with carbendazim@ 2.0g/kg, T_2: Seed treated with mancozeb@ 2.5g/kg and T_3: Untreated (control)

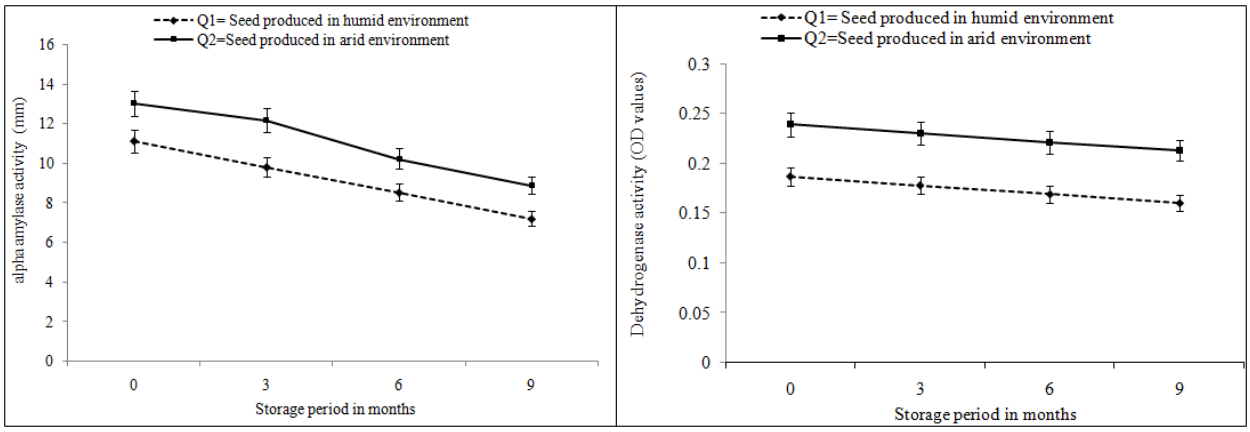

Fig 1: Influence of production environment on alpha amylase activity and dehydrogenase activity (OD values) in rice Cv. Annada during storage

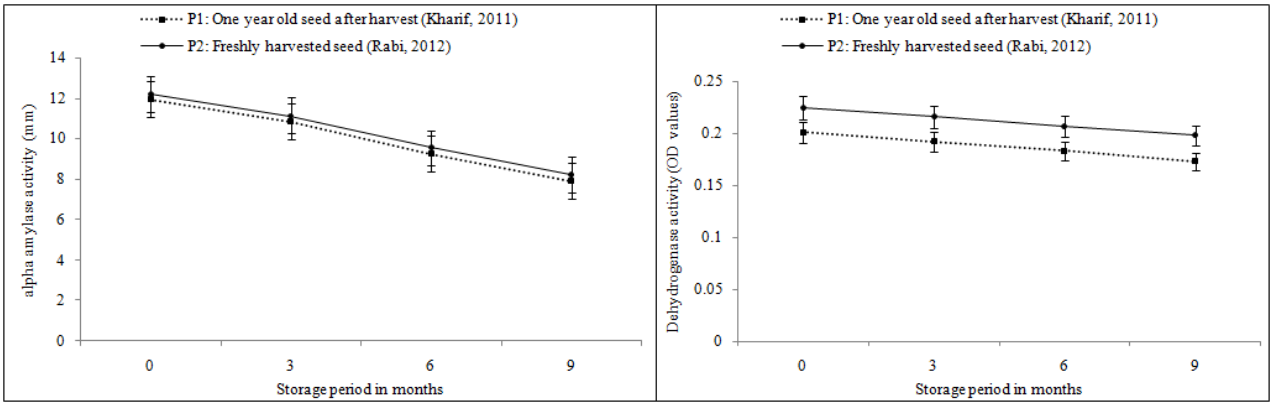

Fig 2: Influence of seed age on alpha amylase activity and dehydrogenase activity (OD values) in rice Cv. Annada during storage

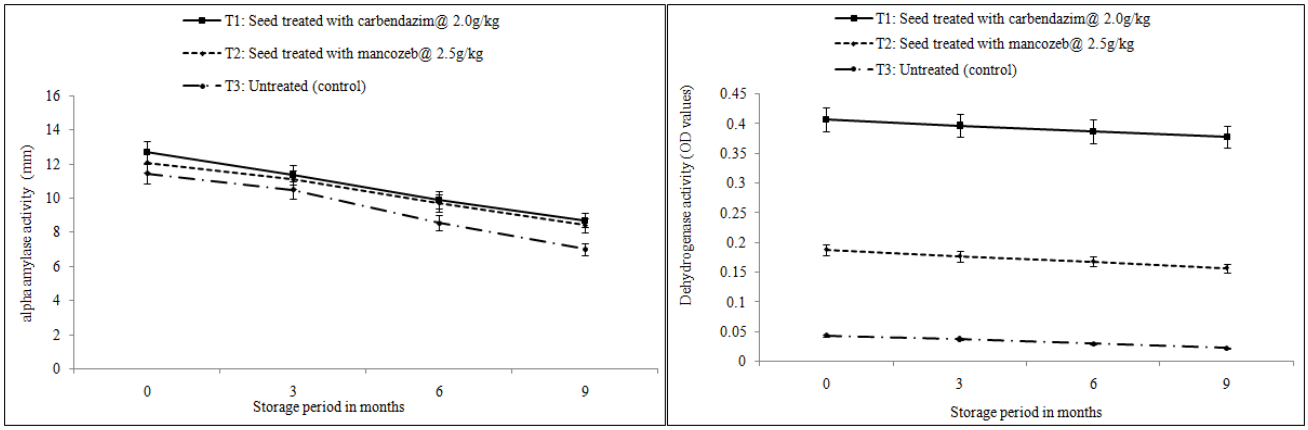

Fig 3: Influence of seed treatment on alpha amylase activity and dehydrogenase activity (OD values) in rice Cv. Annada during storage

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