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Influence of Packaging Materials and Seed Treatments on Physiological Attributes during Storage of Rice (*Oryza sativa* L.)

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ABSTRACT

The effect of packaging materials and seed treatments on seed viability during storage was studied during August 2009 to July 2010. Freshly harvested seeds of rice cv. 'MAS 946-1' produced under two systems of cultivation were dried to a safe level of moisture (< 13%), graded to uniform size and treated with Thiram + Bavistin, Malathion (10% dust) and bioneem at recommended dosages and packed in either a cloth bag, polylined cloth bag or polythene bag (700 gauge) and maintained for 10 months under ambient conditions. The results clearly revealed that seeds stored in polythene bags and treated with Thiram + Bavitin (1 g/kg seed) had higher seed quality parameters namely germination (81.50%), mean seedling length (20.92 and 19.62 cm), seedling vigour (1609 and 1704), lower infection (10.27 and 9.44%) and lower electrical conductivity (58.15 and 62.02 µS/ppm), respectively.

Keywords: aerobic rice, packaging materials, seed storage, seed treatments
Abbreviations: ISTA, International Seed testing Association; **MAS**, marker-assisted selection; **ZARS**, Zonal Agricultural Research Station

INTRODUCTION

Food security is the condition of providing enough food with adequate nutrition for a healthy life. It is a critical issue in the developing world. About three billion people, nearly half the world's population depends on rice for survival. In Asia as a whole, much of the population consumes rice in every meal. In many countries, rice accounts for more than 70% of human caloric intake (WHO 2010). Hence, the slogan "Rice is life" is understandable and appropriate. The area covered by rice in India is 44.62 million ha, with a production of 99.15 million tones and productivity of 2,225 kg/ha (Anon. 2009).

Rice (*Oryza sativa* L.), which belongs to the genus *Oryza*, tribe Oryzeae and family *Poaceae*, is one of the main staple food crops in India. It is the third largest principal food crop in the world after wheat and maize. There are 18 valid wild species distributed mainly in Asia, Africa and America. Among the two cultivated species, *Oryza sativa* and *Oryza glaberrima*, the former is cosmopolitan and the latter is confined to Africa. Rice is distributed over a wider range of latitude from 500 N to 400 S and is being grown up to an altitude of 2500 m (IRRI 2002). It evolved in the humid tropics as a semi-aquatic plant and it has adapted uniquely to hot humid environments, which has not been observed in any other major cereal crop. In India, on average, rice accounts for 27% of cereal grain production in the world and is being cultivated over an area of 59.6 million ha and with a production of 81.5 million tones (DRR India 2010). Nearly 90% of the rice-growing area is on the Asian continent and India accounts for 46% (DRR India 2010). The important rice-growing states in India are Andhra Pradesh, Bihar, West Bengal, Tamil Nadu, Punjab and Uttar Pradesh. In Karnataka, rice is grown in an area of 1.39 million ha with a production of 3.4 tones and productivity of 2.6 kg/ha (Anon. 2006-07). Irrigated lowland rice is consequently the most important agricultural ecosystem in Asia and the present and future food security of most of its population depends on it. Traditional lowland rice with continuous flooding in Asia has relatively high water input. It is estimated that around 50% of total irrigation water available is used for rice cultivation. However, poor water quality and availability threatens the sustainability of irrigated rice ecosystems. Water shortage in many rice-growing areas is prompting a search for alternative production systems that use less water to produce rice (IARI 2010). Saving irrigation water and increasing water productivity might be possible if rice could be grown under aerobic soil conditions such as wheat and maize. Aerobic rice systems, wherein the crop establish by direct seeding in unpuddled fields and managed intensively as an upland crop, are among the most promising approaches of water saving (Nagaraj 2004). Aerobic rice is a new concept which reduces water requirements in rice production. Upland crops are grown in non-puddled aerobic soil without standing water. In recent years, with the introduction of new aerobic rice technology in rice cultivation, it has become possible to get reasonably good yields with two to three irrigations, thus resulted in saving 30-40% water.

Rice production systems are undergoing changes due to progressive advancement in technologies and changes in socioeconomic conditions throughout rice-growing countries. Since nowadays farmers are moving towards advanced technologies of rice cultivation that save water, there is a need to evaluate the performance of seed produced under the different systems of cultivation. Seed quality is a multiple concept comprising various physical, chemical and biological components. Seed is a living entity, thus deterioration in its quality is inevitable and occurs as ageing advances. Physiological deterioration of seeds during storage is considered to be one of the main factors preventing seeds from normal germination and vigorous growth. Simple hydration, with or without chemicals, midway during storage followed by immediate drying back, would considerably extend seed viability (Pramila 2008). Keeping these aspects in mind, an investigation was carried out to study the effect

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of packaging materials and seed treatments on the storability of rice seeds produced under both aerobic and transplanted conditions.

MATERIALS AND METHODS

Freshly harvested seeds of rice cv. 'MAS 946-1', a new mid-early, medium-fine grain, high-yielding variety, was released by the University of Agricultural Sciences, Bangalore, Aerobic Cultivation in zone 5 of Karnataka. Seeds were procured from the Zonal Agriculture Research Station, V. C. Farm, Mandya, Karnataka. They were dried to < 13% relative moisture and graded to uniform size (3 mm^3). The seeds were then treated with Thiram + Bavistin at a rate of 1 g/kg seed each, Malathion (10% dust) at a rate of 2.5 g/kg seed and Bioneem (Bayer Crop Science) at a rate of 2.5 ml/kg seed. The treated seeds were packed in a cloth bag, a polylined cloth bag or in a polythene bag (700 gauge) and stored under ambient condition at the Department of Seed Science and Technology, UAS, Bangalore for a period of 10 months from August 2009 until July 2010.

The treated seeds were dried to a safe level of moisture content, i.e., < 13% by oven drying (35°C, 2-3 h) and were packed accordingly and stored under ambient conditions at the Seed Technology Research Unit, University of Agricultural Sciences, GKVK, Bangalore. Several observations were recorded bimonthly during storage in order to determine the suitable packaging material and seed treatment for better storage of rice, as explained next.

Seed moisture content

Seed moisture content was determined by a low constant oven temperature method (ISTA 1996). About 5 g of seed sample was taken at random from each treatment in two replicates, ground and dried in oven at 103 ± 1°C for 17 h. The seed moisture content (%) was determined by using the following formula and was expressed on a wet weight basis.

Moisture content (%) = (M2-M3)/(M2-M1) × 100

where M1 = weight of the container without seed (g), M2 = weight of the container + seed before drying (g), M3 = weight of the container + seed after drying (g).

Standard germination

The germination test was conducted in laboratory using the between paper method (ISTA 1996). 100 seeds/treatment in four replicates were placed on wet germination paper; the rolled towels were incubated in a germination chamber maintained at 25 ± 1°C with 90% relative humidity (RH). The germinated seedlings were evaluated on the 5^{th} and 8^{th} day and percentage germination was expressed based on normal seedlings.

Seedling vigour index

From the seeds kept for the laboratory germination test, 10 normal seedlings from each replication were selected at random on the 8^{th} day and seedling length was measured from the tip of primary leaves to the root tip and the mean seedling length was expressed in cm. The same seedlings were dried at 80 ± 1°C for 24 h and mean seedling dry weight was recorded and expressed in mg. Vigour index was calculated on the basis of mean seedling length and mean seedling dry weight by adopting the formulae suggested by Abdual-Baki and Anderson (1973):

SVI = mean seedling length (cm) × germination (%).

SVII = mean seedling dry weight (mg) × germination (%).

Field emergence

100 seeds were sown in four replicates on a well-prepared seedbed in a polyhouse and adequate soil moisture was maintained by regular (once every 2 days) watering. Field emergence was determined on the 16^{th} day of sowing and the percentage was calculated taking into account the emergence of cotyledons or first true leaves from seedlings in relation to the total number of seeds sown.

Seed health

Detection and identification of seed mycoflora was done by the blotter paper method (top paper) as per ISTA (1996). 25 seeds in two replications were placed at an equidistance in sterile glass Petri dishes of 9 cm diameter containing two moist sheets of blotting paper (Whatman No. 1). The Petri dishes were incubated at 20°C for 5 days in a 12-h photoperiod (700 lux). After incubation, seeds were examined under a stereo binocular micros-cope for the presence of seed infection. Individual species of fungi viz., *Aspergillus*, *Rhizopus* and *Mucor* were identified and expressed as the percentage of total infection.

1000-seed weight (g)

1000 seeds were counted randomly and weighed up to two decimal places. The mean weight of four replications was calculated and expressed in g.

Electrical conductivity of seed leachate

25 seeds were taken randomly from each treatment in four replicates. They were washed with acetone to remove chemical residues, if any. Then they were soaked in 25 ml distilled water for 18 h at a constant temperature of 25 ± 1°C. After incubation the electrical conductivity (EC) of seed leachate was measured in a digital conductivity meter (model-DI 9009) and the EC was expressed in dSm^{-1} (ISTA 1995).

Total dehydrogenase activity

The total dehydrogenase activity was determined by the method described by Perl *et al.* (1978) with slight modifications. 10 seeds were selected randomly and pre-conditioned by imbibing them for 24 h. After removing the seed coat, the cotyledons, and the embryonic axis were soaked in 0.5% tetrazolium solution at 30 ± 1°C for 24 h. Then they were washed twice for a few minutes thoroughly with sterile distilled water. The red colour (formazan) was eluted from the stained embryos by soaking in 5 ml of 2-methoxy ethanol for 6-8 h in airtight vials. The extract was decanted and the colour intensity was measured at 480 nm using a spectro UV-VIS Double Beam PC Scanning Spectrophotometer (UVD-2950). Total dehydrogenase activity was expressed in terms of $OD_{480\ nm}$ values.

Statistical analysis

The data obtained from the experiments were statistically analysed by ANOVA and critical differences between treatment means were calculated at $P = 0.05$ (Snedecor and Cochran 1967).

RESULTS AND DISCUSSION

Worldwide, about 79 million ha of irrigated lowlands provide 75% of the total rice production (IRRI 2009). Lowland rice is traditionally grown in fields that are continuously flooded from crop establishment to close to harvest. It is estimated that irrigated lowland rice receives some 34-43% of the total world's irrigation water or 24-30% of the total world's freshwater withdrawals (IRRI 2009). With increasing water scarcity, the sustainability, food production, and ecosystem services of rice fields are being threatened. Therefore, there is a need to develop and disseminate water management practices that can help farmers to cope with water scarcity. Scientists are now taking on the challenging task of developing rice production systems that can cope with water scarcity. One technology that enables rice to be grown in dry land without flooding, and help farmers cope with water scarcity is the aerobic rice system. To make aerobic rice successful, new varieties and management practices must be developed. Therefore, the crop must be more vigorous and establish itself in the field successfully. Vigour rate that decides the speed of emergence depends on

Table 1 Seed germination (%) as influenced by methods of production, packaging materials and seed treatments during storage in rice cv. MAS 946-1.

Storage periods (months)	2 (October)	4 (December)	6 (February)	8 (April)	10 (June)
Method of production (P)					
P_1	84.88 (67.53)	83.77 (66.40)	80.25 (64.04)	78.55 (62.77)	68.77 (56.40)
P_2	85.16 (67.85)	85.27 (67.75)	82.88 (66.15)	79.05 (63.56)	69.25 (57.07)
SEm ± CD at 5 % level	0.71	0.58	0.95	0.94	1.02
	2.04	1.67	2.70	2.69	2.92
Packaging Materials (C)					
C_1	83.95 (66.87)	83.04 (65.96)	79.50 (63.62)	75.37 (60.72)	62.45 (52.42)
C_2	85.87 (68.23)	84.29 (66.78)	81.83 (65.32)	79.16 (63.46)	68.25 (56.29)
C_3	85.25 (67.98)	86.20 (68.49)	83.37 (66.46)	81.87 (65.32)	76.33 (61.50)
SEm ± CD at 5 % level	0.88	0.72	1.16	1.16	1.25
	2.50	2.04	3.31	3.30	3.57
Treatments (T)					
T_1	87.44 (69.47)	85.22 (67.59)	80.66 (64.49)	79.94 (63.78)	71.00 (57.55)
T_2	89.83 (71.56)	87.27 (69.18)	86.77 (69.21)	86.16 (68.71)	81.50 (65.25)
T_3	85.33 (67.69)	82.77 (65.69)	83.88 (66.53)	79.55 (63.33)	69.50 (56.66)
T_4	77.50 (62.04)	82.77 (65.85)	74.94 (60.19)	69.55 (56.85)	54.05 (47.47)
SEm ± CD at 5 % level	1.01	0.83	1.34	1.34	1.45
	2.89	2.36	3.82	3.81	4.13

Figures in the parentheses are *arcsin* transformed values

Table 2 Mean seedling length (cm) as influenced by methods of production, packaging materials and seed treatments during storage in rice cv. MAS 946-1.

Storage periods (months)	2 (October)	4 (December)	6 (February)	8 (April)	10 (June)
Method of production (P)					
P_1	22.38	22.02	18.90	18.89	19.67
P_2	22.73	21.85	18.97	18.40	19.12
SEm ± CD at 5 % level	0.343	0.296	0.327	0.303	0.313
	0.976	0.843	0.929	0.860	0.890
Packaging materials (C)					
C_1	23.05	21.23	18.05	17.74	17.78
C_2	23.51	22.18	19.20	18.95	19.49
C_3	21.10	22.04	19.56	19.24	20.92
SEm ± CD at 5 % level	0.420	0.3636	0.400	0.371	0.383
	1.195	1.032	1.038	1.054	1.090
Treatments (T)					
T_1	22.56	21.27	18.79	17.88	18.99
T_2	22.78	22.50	20.93	20.47	19.62
T_3	22.80	21.97	18.43	18.17	17.28
T_4	22.07	22.01	17.92	18.06	18.40
SEm ± CD at 5 % level	0.485	0.419	0.462	0.428	0.443
	1.380	1.192	1.314	1.217	1.258

Methods of production	Packaging materials	Seed treatments
P_1- Aerobic condition	C_1- Cloth bag	T_1- Control
P_2- Transplanted condition	C_2 - Polylined cloth bag	T_2- Thiram+Bavistin at 1 g/kg seed
	C_3 - polythene bag (700 gauge)	T_3- Malathion at 2.5 g/kg
		T_4- Bioneem at 2.5 ml/kg seed

the quality of the seeds, which is at its highest when it completes structural and functional development on the plant itself; thereafter, it deteriorates irreparably at varying rates (Pavithravani *et al*. 2008; Lakshmi *et al.* 2009). It is quite natural phenomenon that the seed looses its viability and vigour during storage like any other biological material. The loss of seed viability due to seed deterioration is inexorable, irreversible and inevitable, but the rate of deterioration could be slowed down to a greater extent during storage by manipulating storage conditions or by imposing certain seed treatments before or during mid storage (Mandal and Basu 1983; Basu 1994). Therefore, the present study was envisaged to gain more information regarding the storability in three different packaging materials and three types of seed protectants (for 10 months) and also to know the effect of pre-sowing seed treatment on the seed quality of 6-months-old seeds. The results are discussed next.

The germination percentage and mean seedling length (cm) of rice seeds at bimonthly intervals are presented in **Tables 1** and **2**, respectively. At the end of the 10-month storage period, the seeds stored in a polythene bag (700 gauge) recorded high germination (76.33%) followed by the polylined cloth bag (68.25%) while the cloth bag recorded the lowest germination (62.45%). Among the seed treatments, seeds treated with Thiram + Bavistin at a rate of 1 g/kg each recorded higher germination (81.50%) at the end of the storage period compared to the control (71.00%). The mean seedling length also showed a similar trend. Seeds stored in the polythene bag (700 gauge) and treated with Thiram + Bavistin at a rate of 1 g/kg each recorded a higher mean seedling length (20.92 and 19.62 cm, respectively).

The mean seedling dry weight was also higher in seeds stored in the polythene bag (6.93 mg) and seeds treated with Thiram + Bavistin at a rate of 1 g/kg seed (7.08 mg) at the end of 10 months of storage (**Table 3**).

A gradual decline in seedling vigour was observed throughout the storage period. Seeds stored in the polythene bag and those treated with Thiram + Bavistin at a rate of 1 g/kg seed maintained high vigour (1609 and 1704) during the storage period (**Table 4**). The increase in germination and vigour of seedlings under certain fungicidal treatments might be due to an increase in the production of phenol-reducing sugars and total sugars (Sindhan *et al*. 1996).

Similarly, the shoot: root ratio also showed a similar response during the storage period (**Table 5**). The ratio was higher in seeds stored in the polythene bag (0.62) an in seeds treated with Thiram + Bavistin at a rate of 1 g/kg seed each (0.65).

The EC of seed leachate gradually increased with storage time (**Table 6**); however, a lower EC was recorded in seeds stored in a polythene bag (58.15 µS/ppm) compared to seeds stored in the cloth bag (65.72 µS/ppm). The superi-

Table 3 Mean seedling dry weight (mg) as influenced by methods of production, packaging materials and seed treatments during storage in rice cv. MAS 946-1.

Storage periods (months)	2 (October)	4 (December)	6 (February)	8 (April)	10 (June)
Method of production (P)					
P_1	8.22	7.45	7.55	7.43	6.45
P_2	8.43	7.79	7.76	7.13	6.48
SEm ± CD at 5% level	0.14	0.11	0.12	0.12	0.11
	0.40	0.32	0.34	0.36	0.32
Packaging materials (C)					
C_1	7.92	7.62	7.41	7.16	6.22
C_2	8.85	7.68	7.75	7.37	6.25
C_3	8.31	7.56	7.81	7.31	6.93
SEm ± CD at 5% level	0.17	0.14	0.14	0.15	0.14
	0.49	0.39	0.42	0.45	0.40
Treatments (T)					
T_1	8.66	7.75	7.55	7.05	5.97
T_2	8.25	7.75	8.16	7.66	7.08
T_3	8.31	7.50	7.33	7.75	7.08
T_4	8.08	7.50	7.58	6.66	5.75
SEm ± CD at 5% level	0.20	0.16	0.17	0.18	0.16
	0.56	0.46	0.48	0.51	0.46

Table 4 Seedling vigour index as influenced by methods of production, packaging materials and seed treatments during storage in rice cv. MAS 946-1.

Storage periods (months)	2 (October)	4 (December)	6 (February)	8 (April)	10 (June)
Method of production (P)					
P_1	1903	1858	1521	1482	1362
P_2	1933	1864	1550	1441	1347
SEm ± CD at 5% level	36.76	34.70	39.34	32.52	39.07
	104.54	98.67	111.87	92.48	111.11
Packaging materials (C)					
C_1	1929	1768	1424	1346	1114
C_2	2021	1883	1537	1460	1340
C_3	1804	1933	1646	1578	1609
SEm ± CD at 5% level	45.03	42.49	48.18	39.83	47.85
	128.04	120.84	137.01	113.27	136.08
Treatments (T)					
T_1	1969	1813	1513	1399	1346
T_2	2046	1963	1644	1732	1704
T_3	1945	1822	1616	1442	1350
T_4	1713	1848	1369	1272	1018
SEm ± CD at 5% level	51.99	49.07	55.64	45.99	55.26
	147.85	139.54	158.21	130.79	157.13

Table 5 Shoot to root ratio as influenced by methods of production, packaging materials and seed treatments during storage in rice cv. MAS 946-1.

Storage periods (months)	2 (October)	4 (December)	6 (February)	8 (April)	10 (June)
Method of production (P)					
P_1	0.68	0.67	0.65	0.64	0.62
P_2	0.65	0.63	0.61	0.59	0.57
SEm ± CD at 5% level	0.01	0.01	0.01	0.01	0.01
	0.03	0.03	0.03	0.03	0.05
Packaging materials (C)					
C_1	0.63	0.62	0.61	0.60	0.56
C_2	0.68	0.66	0.64	0.63	0.60
C_3	0.68	0.66	0.65	0.63	0.62
SEm ± CD at 5% level	0.01	0.01	0.01	0.01	0.02
	0.03	0.04	0.04	0.04	0.06
Treatments (T)					
T_1	0.66	0.64	0.63	0.62	0.60
T_2	0.71	0.69	0.67	0.67	0.65
T_3	0.67	0.65	0.65	0.63	0.59
T_4	0.62	0.61	0.57	0.56	0.54
SEm ± CD at 5% level	0.01	0.01	0.01	0.02	0.02
	0.03	0.04	0.04	0.05	0.07

Methods of production	Packaging materials	Seed treatments
P_1- Aerobic condition	C_1- Cloth bag	T_1- Control
P_2- Transplanted condition	C_2 - Polylined cloth bag	T_2- Thiram+Bavistin at 1 g/kg seed
	C_3 – polythene bag (700 gauge)	T_3- Malathion at 2.5 g/kg
		T_4- Bioneem at 2.5 ml/kg seed

ority of the seeds stored in the polythene bag throughout the storage period was due to the slow rate of deterioration as this bag is impervious to moisture, and thus might not have allowed the movement of moisture from the environment, hence, preventing faster seed deterioration (Patil and Shekaragouda 2007). Among the seed treatments, a slightly lower EC was recorded in the Thiram + Bavistin treatment at a rate of 1 g/kg seed each (62.02 µS/ppm) compared to the

Table 6 Electrical conductivity (µS/ppm) as influenced by methods of production, packaging materials and seed treatments during storage in rice cv. MAS 946-1.

Storage periods (months)	2 (October)	4 (December)	6 (February)	8 (April)	10 (June)
Method of production (P)					
P_1	13.44	14.12	40.55	55.11	66.17
P_2	12.18	12.98	42.01	52.95	61.63
SEm ± CD at 5% level	0.35	0.30	0.79	0.78	2.17
	0.99	0.85	2.25	2.22	6.17
Packaging materials (C)					
C_1	13.95	14.22	42.34	57.64	65.72
C_2	12.96	13.72	43.90	53.44	63.82
C_3	13.52	13.71	37.61	51.00	58.15
SEm ± CD at 5% level	0.42	0.36	0.97	0.95	2.66
	1.22	1.04	2.76	2.72	7.56
Treatments (T)					
T_1	13.00	14.02	44.36	57.47	62.57
T_2	12.83	13.00	43.40	52.92	62.02
T_3	12.89	13.57	39.20	54.29	63.64
T_4	12.53	13.61	41.20	54.42	67.37
SEm ± CD at 5% level	0.49	0.42	1.12	1.10	3.07
	1.40	1.20	3.18	3.14	8.73

Table 7 Seed infection (%) as influenced by methods of production, packaging materials.

Storage periods (months)	2 (October)	4 (December)	6 (February)	8 (April)	10 (June)
Method of production (P)					
P_1	4.66 (1.90)	6.33 (2.20)	9.36 (2.86)	13.19 (3.35)	15.88 (3.63)
P_2	2.88 (1.49)	5.22 (2.05)	8.88 (2.84)	10.27 (2.84)	9.27 (2.66)
SEm±	0.17	0.20	0.17	0.26	0.31
CD at 5% level	0.50	0.58	0.50	0.76	0.90
Packaging materials (C)					
C_1	6.33 (2.32)	8.50 (2.69)	11.50 (3.20)	12.83 (3.36)	16.87 (4.03)
C_2	3.16 (1.46)	5.50 (2.16)	8.87 (2.89)	10.00 (2.79)	11.38 (3.10)
C_3	1.83 (1.30)	3.33 (1.52)	7.00 (2.46)	8.33 (2.47)	10.27 (2.84)
SEm±	0.21	0.25	0.21	0.32	0.38
CD at 5% level	0.61	0.71	0.61	0.93	1.10
Treatments (T)					
T_1	6.00 (2.27)	8.00 (2.58)	12.66 (3.51)	15.55 (3.77)	14.44 (3.45)
T_2	1.55 (1.14)	2.00 (1.31)	5.11 (2.00)	8.88 (2.57)	9.44 (2.84)
T_3	4.22 (1.76)	7.55 (2.55)	9.83 (3.10)	11.38 (3.10)	13.11 (3.20)
T_4	3.33 (1.61)	5.55 (2.05)	8.88 (2.78)	11.11 (2.94)	13.33 (3.09)
SEm±	0.25	0.29	0.24	0.37	0.44
CD at 5% level	0.71	0.83	0.7	1.07	1.27

Figures in parentheses are *square root* transformed values

Methods of production	Packaging materials	Seed treatments
P_1- Aerobic condition	C_1- Cloth bag	T_1- Control
P_2- Transplanted condition	C_2 - Polylined cloth bag	T_2- Thiram+Bavistin at 1 g/kg seed
	C_3 – polythene bag (700 gauge)	T_3- Malathion at 2.5 g/kg
		T_4- Bioneem at 2.5 ml/kg seed

control (62.57 µS/ppm).

The results of the seed health test indicated a gradual increase in seed infection during the storage period (**Table 7**). However, reduced infection was noticed in the seeds stored in the polythene bag (10.27%) compared to the cloth bag (16.87%). This may be due to an increase in the moisture content of seeds stored in cloth bags. Malaker *et al*. (2008) found that seed of widely cultivated wheat variety Kanchan when stored in refrigerator (10°C) for six months resulted in higher germination percentage followed by polyethylene bag, tin container and earthen pitcher. Alam *et al*. (2009) concluded that USA organic cocoon (Germax) and an IRRI-made bag maintained an excellent germination rate (>90%) when Aman rice (*O. sativa* L.) seeds were stored in these devices and also maintained moisture content below critical level (14%) and further added that the germination percentage of boro rice stored in organic cocoon was significantly higher as compared to that of rexin cocoon, polythene bag, polythene in gunny bag when the seeds were stored from July to December. Lower seed infection (9.44%) was also recorded from the seeds treated with Thiram + Bavistin at a rate of 1 g/kg compared to the control in which higher infection (14.44%) was noticed. This might be due to a fungicidal effect on the production of pectolytic and cellulolytic enzymes by the fungi and thereby reducing the incidence of fungal pathogens (Mehta *et al*. 1990). Ghelani *et al*. (2009) also showed that seed treatment of pearl millet (*Pennisetum glaucum*) with Thiamethoxam, Methyl pirimiphos, Emamectin benzoate, Spinosad, Lufenuron and Deltamethrin were found effective in protecting the seed from insect damage up to 9 months without any adverse effect on moisture content and germination.

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