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RESEARCH PAPER

Improved packaging materials for soybean seed storage under ambient conditions at Raichur

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Abstract: A laboratory experiment was conducted to know the effect of improved packaging materials on soybean seed quality during storage under ambient conditions at Seed Research and Quality Assurance Laboratory of Seed Unit, University of Agricultural Sciences, Raichur, during 2018-19. The soybean seeds were treated with sprint fungicide @ 3g/kg to control seed deterioration and packed in different packaging materials (gunny bag, polylined gunny bag of 700 gauge, grain pro bag, High-density polyethylene bag, Purdue Improved Crop Storage bag, Zero fly bag and Trial bag and stored under ambient conditions. The results revealed that PICS bag, Grain pro bag, Zero fly bag and Trial bag recorded higher seed quality parameters like seed germination, seedling length, seedling dry weight, seedling vigour index and the lowest seed moisture content, seed infection percentage and electrical conductivity after nine months of storage.

Key words: Packaging materials, Seed quality, Soybean, Storage

Introduction

Soybean (*Glycine max* L.) is also known as boneless or vegetable meat due to its high nutritious cotyledons acting as important component in balanced diet. Soybean account for about 56 per cent of global oilseed production and highly quoted on the world market (Wilson, 2008). The crop is generally designated as golden or miracle crop due to high nutritive value and exploited for vegetable oil extraction for human consumption (Hymowitz and Newell, 1981). It has been considered as a single large source for vegetable oil extraction economically feasible in India. It is regarded as legume cum oilseed crop due to 40-42 per cent protein and 20-22 per cent oil content making it as viable option for oil extraction.

Soybean being an oilseed crop has thin seed coat and prone to mechanical damage and deteriorate faster than other crops (Priestley *et al*., 1985). Loss of seed viability and vigour in any crop is a natural phenomenon which is inexorable, irreversible and inevitable associated with genetic, physical, physiological and biochemical factors besides storage environment such as prevailing relative humidity, temperature, pest and diseases *etc* which are known to cause both qualitative and quantitative loss. Seed borne infection or infected seed is very important discouraging factor, which possess a serious problem in seed certification. Although infected seeds which may otherwise be viable with prescribed germinability as per certification standards, many times it may not be acceptable as seed because of poor physical appearance, high incidence of seed borne fungi and mycotoxin such as aflatoxin.

Material and methods

The present investigation was conducted to evaluate and identify the suitable packaging materials for storage of soybean seeds under ambient condition of raichur. The certified soybean seeds of DSb-21 treated with sprint fungicide @ 3g/kg to control the effects of biotic and abiotic factors on seed and then packed in different packaging materials *viz.;* gunny bag, polylined gunny bag (700 gauge), grain Pro bag, HDPE (High-density polyethylene) bag, PICS (Perdue Improved Crop Storage) bag, Zero fly bag (with inner double layer polythene sheets) and Trial bag. They were stored under ambient conditions.

Germination test was conducted using 400 seeds (100 X 4 replicates) in between paper method and incubated in the walk-in seed germination room. Germination percentage, shoot length and root length was calculated on 8th day (ISTA, 2014). The seedling vigour index-I was worked out by multiplying the per cent germination and root and shoot length (Abdul-Baki and Anderson, 1973).

Ten soybean seeds on pre sterilised petri plates were placed at equal distance on the moist blotters. The plates were incubated at 25 ± 2^{0}C under diurnal conditions (Anon., 2014). On 8th day of incubation the seeds were observed under stereo-binocular microscope for prevalence of fungal growth *viz.*, *Aspergillus flavus, A. niger* and *Alternaria* spp., on seed surface.

Electrical conductivity of the seed leachate was measured in the digital conductivity bridge (WENSAR) with a cell constant 1.0 and the mean values were expressed in deci siemens per meter (dSm^{-1}) (Milosevic *et al*. 2010). The OD value of dehydrogenase enzyme activity was obtained as reported by Kittock and Law (1968).

The data obtained from the experiment was subjected to statistical analysis. The analysis of variance and interpretation of data was done. The level of significance used in 'F' and students 'T' tests was P=0.05. Critical difference values were

calculated whenever 'F' test was significant. The laboratory data was analysed by using simple FCRD (Factorial Completely Randomized Design) with four replications.

Result and discussion

The seed moisture content differed non significantly in initial months of storage, but differed significantly in subsequent months of storage. Among the different packaging materials seeds packed in PICS bag (P_5) was recorded the minimum seed moisture content (7.87 %) which was on par with grain pro bag (P_3), Zero fly bag (P_6) and Trial bag (P_7) (7.90, 7.95, and 8.00 %, respectively) followed by polylined (700 gauge) gunny bag (P_2) and HDPE bag (P_4) (8.10, and 9.28 %, respectively) whereas, the maximum moisture content (10.17 %) was recorded in gunny bag (P_1) at the end of storage period. (Table 1)

The seeds packed in PICS bag recorded significantly lower moisture content (7.87 %) which was on par with grain pro bag, Zero fly bag, and Trial bag compared to the seeds were packed in gunny bag (10.17 %). This might be due to hermetic seal of PICS bags shielded the seeds from changes in relative humidity, resulting in little impact of RH within seed mass or in seed moisture content (Brett lane and Charles, 2017). The results are in consistent with the Martin *et al.* (2015) and Vales *et al.* (2014). Grain pro bag might be attributed to the impervious nature to moisture vapour and thus it caused less fluctuation in seed moisture content and it eliminated the deterioration and enhanced the seed longevity. These findings are in conformity with Shantappa and Ramaiah, (2006) in Pigeon pea and Basavegowda *et al*. (2013) in Chickpea and Basave gowda *et. al.* (2016) in Pigeon Pea who reported less fluctuation in seed moisture in impervious packaging materials as compared to cloth bag. Although the impervious containers prevented the influx of moisture into the seed from outside environment, the increase in seed moisture content with advancement of storage period might be attributed to greater accumulation of metabolic water. Whereas, the poor performance of seeds stored in gunny bag might be due to the absorption of external moisture, facilitated by its porous nature (Umesha *et al.,* 2017) (Table 1).

The data on seed germination differed significantly due to the influence of packaging materials except for initial month. The higher seed germination (81.17 %) was recorded with the seeds packed in PICS bag (P_5) which was on par with grain pro bag (P_3), Zero fly bag (P_6) and Trial bag (P_7) (80.83 %, 80.50 %, and 80.17 %, respectively) followed by seeds packed in polylined (700 gauge) gunny bag (P_2) and HDPE bag (P_4) (77.33 and 75.83 %, respectively). While, the lower seed germination (74.67 %) was recorded with seeds packed in gunny bag (P_1) at the end of storage period (Table 2).

The moisture impervious containers like PICS bag, grain pro bag, Zero fly bag and Trial bag were found superior in maintaining seed germination for longer period than the pervious bags. The prolonged quality of seeds depends on thickness and impervious nature of these packaging materials. The superiority of these packaging materials in maintaining seed germinability for longer period might be due to inverse relationship between seed moisture content and germination percentage. (Table 2).

The data on seedling vigour index-I differed significantly due to the influence of packaging materials except for initial two months. The highest seedling vigour index-I (2391) was recorded with seeds packed in PICS bag (P_5) which was on par with grain pro bag (P_3), Zero fly bag (P_6) and Trial bag (P_7)

Table 1. Effect of packaging materials on soybean seed moisture content (per cent) during storage

Treatment	Months after storage								
	1	2	3	4	5	6	7	8	9
P_1	7.82	8.02	8.40	8.70	9.02	9.30	9.62	9.93	10.17
	(16.24)	(16.45)	(16.85)	(17.15)	(17.47)	(17.76)	(18.07)	(18.37)	(18.59)
P_2	7.67	7.70	7.73	7.83	7.87	7.90	7.93	7.97	8.10
	(16.07)	(16.11)	(16.15)	(16.25)	(16.29)	(16.32)	(16.36)	(16.39)	(16.54)
P_3	7.60	7.63	7.67	7.73	7.77	7.80	7.83	7.87	7.90
	(16.00)	(16.04)	(16.07)	(16.15)	(16.18)	(16.22)	(16.25)	(16.29)	(16.32)
P_4	7.70	7.78	7.95	8.12	8.23	8.42	8.72	8.90	9.28
	(16.11)	(16.20)	(16.38)	(16.55)	(16.67)	(16.86)	(17.17)	(17.36)	(17.74)
P_5	7.60	7.63	7.67	7.70	7.73	7.77	7.80	7.83	7.87
	(16.00)	(16.04)	(16.07)	(16.11)	(16.15)	(16.18)	(16.22)	(16.25)	(16.29)
P_6	7.63	7.67	7.70	7.77	7.80	7.83	7.87	7.90	7.95
	(16.04)	(16.07)	(16.11)	(16.18)	(16.22)	(16.25)	(16.29)	(16.32)	(16.38)
P_7	7.63	7.67	7.72	7.80	7.83	7.87	7.90	7.93	8.00
	(16.04)	(16.07)	(16.13)	(16.22)	(16.25)	(16.29)	(16.32)	(16.36)	(16.43)
Mean	7.66	7.73	7.83	7.95	8.04	8.13	8.24	8.33	8.47
	(16.07)	(16.14)	(16.25)	(16.37)	(16.46)	(16.55)	(16.67)	(16.76)	(16.90)
S. Em. ±	0.03	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04
C.D.@1%	0.13	0.18	0.18	0.17	0.17	0.14	0.15	0.16	0.15

Figures in parentheses are arc transformed values P_1: Gunny bag P_2: Polylined gunny bag (700 gauge) P_3: Grain Pro bag
P_4: HDPE bag P_5: PICS bag P_6: Zero fly bag P_7: Trial bag
Seed treatment with sprint @ 3 g/kg *NS: Non Significant

Table 2. Effect of packaging materials on soybean seed germination (per cent) during storage

Treatment	Months after storage								
	1	2	3	4	5	6	7	8	9
P_1	95.00	93.67	90.33	87.67	83.50	82.00	78.83	76.50	74.67
	(77.28)	(75.68)	(72.22)	(69.74)	(66.26)	(65.09)	(62.69)	(61.07)	(59.84)
P_2	95.50	94.33	92.17	90.67	87.67	86.00	82.00	78.50	77.33
	(77.97)	(76.46)	(74.09)	(72.45)	(69.59)	(68.25)	(64.97)	(62.43)	(61.63)
P_3	96.00	95.33	94.00	92.33	90.67	89.00	86.50	83.00	80.83
	(78.65)	(77.78)	(76.11)	(74.17)	(72.44)	(70.83)	(68.56)	(65.80)	(64.12)
P_4	95.17	94.17	91.50	90.00	86.17	85.17	81.00	77.17	75.83
	(77.47)	(76.28)	(73.35)	(71.78)	(68.27)	(67.56)	(64.23)	(61.52)	(60.61)
P_5	96.17	95.50	94.17	92.67	91.00	89.33	86.83	84.33	81.17
	(78.86)	(77.92)	(76.32)	(74.55)	(72.80)	(71.12)	(68.85)	(66.80)	(64.36)
P_6	95.67	94.83	93.67	92.00	90.17	88.67	86.17	82.17	80.50
	(78.13)	(77.08)	(75.69)	(73.81)	(71.92)	(70.52)	(68.28)	(65.20)	(63.87)
P_7	95.67	94.67	93.33	91.67	89.67	88.33	85.83	81.33	80.17
	(78.13)	(76.82)	(75.30)	(73.48)	(71.40)	(70.20)	(68.00)	(64.60)	(63.62)
Mean	95.60	94.64	92.74	91.00	88.40	86.93	83.88	80.43	78.64
	(78.07)	(76.86)	(74.72)	(72.85)	(70.38)	(69.08)	(66.51)	(63.92)	(62.58)
S.Em. ±	0.33	0.32	0.45	0.40	0.41	0.47	0.35	1.05	0.28
C.D.@ 1%	NS	1.23	1.75	1.55	1.61	1.86	1.35	3.1	1.11

Figures in parentheses are arc transformed values P_1: Gunny bag P_2: Polylined gunny bag (700 gauge) P_3: Grain Pro bag
P_4: HDPE bag P_5: PICS bag P_6: Zero fly bag P_7: Trial bag
Seed treatment with sprint @ 3 g/kg *NS: Non Significant

(2376, 2359, and 2343, respectively) followed by seeds packed in polylined (700 gauge) gunny bag (P_2), and HDPE bag (P_4) (2201, and 2131, respectively). While, the minimum seedling vigour index-I (2065) was recorded with seeds packed in gunny bag (P_1) at the end of storage period.

The highest seedling vigour index-I was recorded in seeds packed in PICS bags which were on par with seeds packed in grain pro bag, Zero fly bag and Trial bag followed by polylined (700 gauge) gunny bag, and HDPE bag compared to gunny bag. The highest seedling vigour index might be due to greater mobilization of food reserve to the growing parts during seed germination indicating greater seed vigour in moisture impervious containers. The present findings confirmed the reports of previous worker (Rashmi Reddy, 2003).The decrease in the seed vigour index may be due to age induced decline in germination, decrease in root and shoot length and seedling dry weight and higher electrical conductivity.

The data on seedling dry weight (mg) differed significantly due to the influence of packaging materials except for initial months. The highest seedling dry weight (mg) (565.34) was recorded with seeds packed in PICS bag (P_5) which was on par with grain pro bag (P_3), Zero fly bag (P_6), and Trial bag (P_7), (564.57, 563.78, and 563.74 mg, respectively) followed by seeds packed in polylined (700 gauge) gunny bag (P_2), and HDPE bag

Table 3. Effect of packaging materials on soybean seedling vigour index-I during storage

Treatment	Months after storage								
	1	2	3	4	5	6	7	8	9
P_1	3325	3275	2998	2881	2717	2622	2407	2230	2065
P_2	3354	3305	3133	3051	2921	2818	2569	2351	2201
P_3	3391	3359	3282	3193	3106	2998	2790	2564	2376
P_4	3336	3296	3078	2996	2840	2760	2508	2284	2131
P_5	3422	3371	3294	3211	3124	3015	2807	2610	2391
P_6	3367	3328	3263	3174	3081	2979	2772	2532	2359
P_7	3362	3318	3243	3155	3056	2961	2754	2500	2343
Mean	3365	3322	3184	3094	2978	2879	2658	2438	2267
S.Em.±	31	28	18	17	21	24	18	18	14
C.D.@1%	NS	NS	68	65	78	92	70	69	54

P_1: Gunny bag P_2: Polylined gunny bag (700 gauge) P_3: Grain Pro bag P_4: HDPE bag P_5: PICS bag
P_6: Zero fly bag P_7: Trial bag
Seed treatment with sprint @ 3 g/kg *NS: Non Significant

(P_4) (561.84, and 559.68 mg, respectively). While, the minimum seedling dry weight (mg) (558.17) was recorded with seeds packed in gunny bag (P_1) at the end of storage period. (Table 4).

The highest seedling dry weight was recorded in seeds packed in PICS bags which were on par with seeds packed in grain pro bag, Zero fly bag and Trial bag followed by polylined (700 gauge) gunny bag, and HDPE bag compared to gunny bag. The highest seedling dry weight might be due to greater mobilization of food reserve to the growing parts during seed germination indicating greater seed vigour in moisture impervious containers. The present findings confirmed the reports of previous worker (Rashmi Reddy, 2003). The reduction of seedling dry weight was always greater when seeds were stored in cloth bag, which is mainly due to increased seed deterioration caused by free exchange of moisture between seed and environment resulted into high moisture of the seeds at higher RH. Likewise, seed moisture contents were also higher when seeds were packed in jute and cloth bags. Large pore size of the jute, cloth and polypropylene bags provided free access to the water vapors which were readily absorbed by the seeds and ultimately elevated seed moisture contents which caused poor germination and seedling growth which lead to decrease in seedling dry weight (Abdul Baki and Anderson, 1973) (Table 4).

The data on seed infection (%) differed significantly due to the influence of packaging materials except for initial four months. The lowest seed infection (%) (2.33) was recorded with seeds packed in PICS bag (P_5) which was on par with grain pro bag (P_3), Zero fly bag (P_6) and Trial bag (P_7), (2.50, 2.83, and

Table 4. Effect of packaging materials on seedling dry weight (mg) during storage of soybean seeds

Treatment	Months after storage								
	1	2	3	4	5	6	7	8	9
P_1	611.67	609.17	604.33	599.82	594.81	589.53	581.43	570.35	558.17
P_2	613.00	610.50	608.00	603.49	598.48	593.20	585.10	574.02	561.84
P_3	614.67	613.17	611.33	606.82	601.81	595.93	587.83	576.75	564.57
P_4	612.33	609.83	606.00	601.49	596.32	591.04	582.94	571.86	559.68
P_5	616.00	613.50	611.67	606.99	601.98	596.70	588.60	577.52	565.34
P_6	613.67	612.83	611.00	606.33	601.32	595.14	587.04	575.96	563.78
P_7	613.33	612.50	610.67	606.16	601.15	595.10	587.00	575.92	563.74
Mean	613.52	611.64	609.00	604.44	599.41	593.81	585.71	574.63	562.45
S.Em. ±	0.83	0.49	0.61	0.75	0.67	0.65	0.61	0.60	0.64
C.D.@1%	NS	1.91	2.18	2.80	2.61	2.43	2.37	2.35	2.40

P_1: Gunny bag P_2: Polylined gunny bag (700 gauge) P_3: Grain Pro bag P_4: HDPE bag P_5: PICS bag
P_6: Zero fly bag P_7: Trial bag
Seed treatment with sprint @ 3 g/kg *NS: Non Significant

Table 5. Effect of packaging materials on seed infection (%) during storage of soybean seeds

Treatment	Months after storage								
	1	2	3	4	5	6	7	8	9
P_1	0.00	0.17	0.50	0.83	1.67	2.00	2.50	3.00	3.67
	(0.00)	(0.96)	(2.87)	(3.67)	(7.24)	(7.95)	(8.91)	(9.88)	(10.99)
P_2	0.00	0.17	0.33	0.83	1.17	1.67	2.00	2.50	3.33
	(0.00)	(0.96)	(1.91)	(3.67)	(5.58)	(7.24)	(7.95)	(9.05)	(10.45)
P_3	0.00	0.00	0.17	0.50	0.50	0.67	1.33	1.83	2.50
	(0.00)	(0.00)	(0.96)	(2.31)	(2.87)	(3.83)	(5.98)	(7.64)	(8.91)
P_4	0.00	0.17	0.33	0.83	1.17	1.67	2.17	2.67	3.33
	(0.00)	(0.96)	(1.91)	(3.67)	(5.58)	(7.15)	(8.21)	(9.31)	(10.45)
P_5	0.00	0.00	0.17	0.50	0.50	0.67	1.17	1.50	2.33
	(0.00)	(0.00)	(0.96)	(2.87)	(2.87)	(3.83)	(5.58)	(6.84)	(8.52)
P_6	0.00	0.00	0.33	0.67	0.83	1.33	1.67	2.17	2.83
	(0.00)	(0.00)	(1.91)	(3.27)	(4.22)	(5.98)	(7.24)	(8.35)	(9.48)
P_7	0.00	0.00	0.33	0.67	0.83	1.33	1.67	2.17	3.00
	(0.00)	(0.00)	(1.91)	(3.27)	(4.22)	(5.98)	(7.24)	(8.35)	(9.88)
Mean	0.00	0.071	0.31	0.69	0.95	1.33	1.79	2.26	3.00
	(0.00)	(0.41)	(1.78)	(3.25)	(4.66)	(5.99)	(7.30)	(8.49)	(9.81)
S.Em. ±	(0.00)	(0.11)	(0.15)	(0.18)	(0.19)	(0.21)	(0.23)	(0.22)	(0.23)
C.D.@1%	NS	NS	NS	NS	(0.74)	(0.82)	(0.89)	(0.85)	(0.89)

Figures in parentheses are arc transformed values P_1: Gunny bag P_2: Polylined gunny bag (700 gauge)
P_3: Grain Pro bag P_4: HDPE bag P_5: PICS bag P_6: Zero fly bag P_7: Trial bag
Seed treatment with sprint @ 3 g/kg *NS: Non Significant

3.00 %, respectively) followed by seeds packed in polylined (700 gauge) gunny bag (P_2), and HDPE bag (P_4) (3.33, and 3.33 %, respectively). While, the maximum seed infection (3.67 %) was recorded with seeds packed in gunny bag (P_1) at the end of storage period.

Hermatic shielding and impervious nature of PICS bag, grain pro bag, Zero fly bag and Trial bag followed by polylined (700 gauge) gunny bag and HDPE bag compared to gunny bag helps to prevent the significant increase in seed moisture at higher RH that will ultimately maintain high seed quality by implementing the dry chain and prevention of growth of fungi due to the fungicidal effect on production of pectolytic and cellulolytic enzymes by the fungi and thereby reducing the incidence of fungal pathogen (Kathiravan *et al.* (2008) (Table 5). Seed storage in Super Bag at 8% seed moisture content can help to prevent the significant increase in seed moisture at higher RH that will ultimately maintain high seed quality by implementing The Dry Chain. Seed storage in Super Bag at 14% seed moisture content is not recommended as it resulted in significant germination losses due to rise in seed metabolic activities. Thus, it is highly recommended that seed must be dried to safe moisture limits before storage and should be maintained this dryness throughout supply chain.

The data on electrical conductivity (dSm^{-1}) differed significantly due to the influence of packaging materials except for initial month. The lowest electrical conductivity (dSm^{-1}) (4.51) was recorded with seeds packed in PICS bag (P_5) which was on par with grain pro bag (P_3), Zero fly bag (P_6), and Trial bag (P_7), (0.457, 0.460, and 0.464 dSm^{-1}, respectively) followed by seeds packed in polylined (700 gauge) gunny bag (P_2), and HDPE bag (P_4) (0.468, and 0.472 dSm^{-1}, respectively). While, the maximum electrical conductivity (dSm^{-1}) (0.481) was recorded with seeds packed in gunny bag (P_1) at the end of storage period.

The lower electrical conductivity was recorded in the seeds packed in PICS bag which was on par with the grain pro bag, Zero fly bag and Trial bag, followed by polylined (700 gauge) gunny bag and HDPE bag and higher electrical conductivity was recorded in gunny bag. This may be due to damage of protoplasmic membrane due to seed ageing might be reason for increase in conductivity values of seed leachate with the advancement of storage period. This damage was caused by the fungal infection and fungal infection is more in gunny bag (Table 6).

Table 6. Effect of packaging materials on electrical conductivity (dSm^{-1}) during storage of soybean seeds

Treatment	Months after storage				
	2	4	6	8	9
P_1	0.326	0.355	0.415	0.459	0.481
P_2	0.321	0.350	0.411	0.452	0.468
P_3	0.317	0.343	0.405	0.440	0.457
P_4	0.324	0.352	0.413	0.456	0.472
P_5	0.315	0.341	0.403	0.433	0.451
P_6	0.318	0.345	0.407	0.445	0.460
P_7	0.320	0.348	0.410	0.449	0.464
Mean	0.320	0.348	0.409	0.448	0.465
S.Em. ±	0.002	0.002	0.002	0.005	0.004
C.D.@1%	0.006	0.007	0.007	0.017	0.014

Figures in parentheses are arc transformed values P_1: Gunny bag P_2: Polylined gunny bag (700 gauge) P_3: Grain Pro bag P_4: HDPE bag P_5: PICS bag P_6: Zero fly bag P_7: Trial bag Seed treatment with sprint @ 3 g/kg *NS: Non Significant

Conclusion

The results revealed that soybean seeds treated with sprint @ 3g/kg and stored in PICS bag (Perdue Improved Crop Storage bag), grain Pro bag, Zero fly bag (with inner double layer polythene sheets) and Trial bag maintained minimum seed certification standards even after nine months of storage and they found economically. The special nature of the bag like having three layers - two liners fitted inside a woven sack and low permeability to air and moisture enables to store seeds for more than one year after harvest with minimal seed deterioration.

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