

# Enhancing Seed Storability in Soybean Cultivars: Comparative Impact of Packaging Materials and Storage Environments

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**ABSTRACT:** Storage of seeds till the next sowing with appropriate packages and suitable locations is an essential segment of the seed industry. Thus, the study was conducted to identify suitable location with appropriate package material for safe seed storage until next planting season using four packaging materials (cloth bag, jute bag, HDPE bag and air tight container with drying beads) at three locations viz., Hyderabad, Nizamabad and Guntur Districts of Telangana and Andhra Pradesh, India for 10 months under ambient conditions. The experiment was initiated with two cultivars with initial germination of 93% and 90% respectively and seed moisture content (SMC) of 9.62% and 9.16% for JS 335 and JS 93-05 respectively. The experimental results revealed significant variation for seed quality parameters studied. An overall perusal of the results at three different locations indicated that air tight container using drying beads (impervious) followed by HDPE bags with SMC around 6-8% could be better packaging material than the pervious material (cloth and jute bags) irrespective of locations to maintain seed quality. Among the cultivars studied, JS 335 had higher seed quality as compared JS 93-05 during storage period. While, the Hyderabad location found better for safe seed storage as compared to other locations. Thus, commercial storage of soybean seed can be done at below 7% SMC with moisture proof packaging material, so as to maintain seed germination above seed certification standards upto 10 months.

**Keywords:** Soybean, seed quality, packaging material, location, safe seed storage

## INTRODUCTION

Soybean [*Glycine max* (L.) Merrill.] is a very important legume oilseed crop at global level and extensively grown in warm and moist climatic conditions. It is now the second largest oilseed crop in India after groundnut and it ranks 5<sup>th</sup> in the world in area and production of soybean. In India, area and production of soybean has been increasing every year in the past one decade. Despite an increase in the area and production of soybean over the years, the yield per unit area is still low. Among the factors responsible for poor productivity of soybean crop, non-availability of good quality seed is the most important one. On the other hand, germination and emergence are important issues in crop production and they have significant effect on the next stages of plant growth in field. Rapid and uniform field emergence with good seedling establishment is essential to achieve high seed yield having good quality in soybean [1]. Though the seed production is being taken up in several soybean growing states, maintenance of seed quality is becoming difficult

and unable to maintain it until next planting season in many states of India.

Soybean seed is known to have poor viability and field emergence due to its inherent seed structure and composition. Soybean genotypes differ in their ability to maintain seed longevity under storage [2]. Seed longevity is greatly influenced by the storage conditions [3]. The variation in speed of seed deterioration and the longevity of soybean seeds in storage is influenced by various factors like genetics and ambient storage environment [4]. Seeds are required to be kept in safe storage for the next planting season and usually used for sowing in the subsequent season often after a time gap of about 9 months or longer. There are numerous factors which affect the seed longevity starting from seed maturation to storage and amongst these most of the factors are difficult to control. At physiological maturity, soybean seed reaches its maximum potential for germination and vigour [5]. This potential is short lived as compared to other grain crops and is often reduced prior to planting time [6]. Loss

of germination potential is more acute in tropical countries [7]. The effective preservation of planting seed can be a major problem in India as it is located in tropical and subtropical regions, where the combination of high temperature and high relative humidity (RH) causes rapid deterioration of seed quality [8]. Between harvest and planting periods, the relative humidity often exceeds 75% and temperatures remain above 30°C. Seeds absorb water from the ambient air when they are stored in humid environments, resulting in high equilibrium seed moisture contents (MC). The soybean seed imbibe high amount of water to create equilibrium inside and outside the seed. The hydrophilic nature of high protein content of soybean helps in more absorption of water and high oil content of seed increases seed deterioration [9, 10] by increased hydrolytic enzyme activity, enhanced respiration and an increase in free fatty acids. High temperature accelerates the rate of these biochemical processes causing more rapid deterioration that might have resulted in rapid losses in seed having high moisture content [11]. The germination percentage was also affected by packaging materials during storage [12]. Thus, the deterioration of stored seed is an inevitable natural phenomenon and the seeds tend to lose viability even under ideal storage conditions and the major factors responsible for seed deterioration are physical, physiological, environmental, mechanical damage, pathogens, storage conditions like package and location of storage besides genotype and its composition. Mitigating seed quality loss during storage under ambient conditions can be made possible by identifying suitable packaging material and locations where the uncontrollable elements like air temperature and moisture content can be controlled to certain extent to reduce the rate of seed deterioration.

The minimum seed certification standard is 70 per cent for germination in India for obtaining optimum productivity for soybean as against higher seed standards set by other countries [13]. However, even maintaining 70% germination of soybean seed is difficult due to combined effect of higher relative humidity and temperatures and infection of seed borne diseases as well. In addition, suitability of packaging material needs to be evaluated at different locations for storing of soybean seeds as it is short lived compared to cereals and other oil seed crops. Therefore, storage of seeds till the next sowing with appropriate packages and suitable locations is an essential segment of the seed industry and is a prerequisite for maintaining high quality seed with higher seed vigour and germination. The present study was thus

carried out to identify suitable location with appropriate package material for safe seed storage.

## MATERIAL AND METHODS

The experiment was conducted at Department of Seed Science and Technology, PJTAU (formerly Acharya N. G. Ranga Agricultural University), Hyderabad, India. Freshly harvested seeds of two popular soybean cultivars JS 335 ( $V_1$ ) and JS 93-05 ( $V_2$ ) with initial seed moisture content (SMC) of 9.620% and 9.160% and germination of 93% and 90% respectively were used for the study. The storage studies under ambient conditions with four packaging material viz., cloth bag ( $P_1$ ), jute bag ( $P_2$ ), High Density Poly Ethylene (HDPE) bag ( $P_3$ ) and air tight container enclosing drying beads (zeolite) ( $P_4$ ) were conducted to identify better packaging material and tested at three (treatment) locations i.e., Department of Seed Science and Technology, Hyderabad ( $L_1$ ), Regional Sugarcane and Rice Research Station (RS & RRS), Rudrur of Nizamabad District ( $L_2$ ) and Agriculture Research Station (ARS), Jangamaheshwarapuram of Guntur District ( $L_3$ ) to evaluate safe seed storage locations. The air tight containers with drying beads ( $T_4$ ) as package material for seed storage was developed by the Department of Seed Science and Technology, PJTAU formerly Acharya N.G. Ranga Agricultural University (ANGRAU), Hyderabad, India in collaboration with the University of California, Davis, USA and Rhino Research, Thailand with financial assistance of USAID (<http://hortcrsp.ucdavis.edu>). Drying beads are modified ceramic materials (aluminum silicates or “zeolites”) that specifically absorb and hold water molecules very tightly in their microscopic pores. With these drying beads, seeds can easily be dried to low MC (as desired or to ultra dry conditions) for extended storage in airtight conditions. When placed in an enclosed, water-impermeable space like a plastic bag or box or a metal container, the beads will remove water from the air, creating and maintaining a very low humid environment. Seeds, when placed into the container with the beads, will lose water due to low air humidity and will continue to do so until they come to equilibrium. Thus, the moisture in the seed simply transfers to the desiccant drying beads through air without the need for heating ([www.dryingbeads.org](http://www.dryingbeads.org)).

## Treatments and Experimental Design

The experiment was carried out with the Factorial Completely Randomized Block Design (FCRBD) with

three replications and consisted of 24 treatment combinations with three factors viz., two varieties (factor 1) in four packaging materials (factor 3) and stored for 10 months at three different locations (factor 2). The quantity of drying beads (Zeolite beads) used in the treatments  $P_4$  is determined based on the moisture absorbing capacity (20 per cent) of drying beads and the initial seed moisture content that is to be reduced to 6 per cent for safe seed storage ([www.dryingbeads.org](http://www.dryingbeads.org)).

### Characters studied

Observation on seed moisture content, germination, seedling length, seedling vigour index, field emergence and electrical conductivity of seed leachates were recorded bimonthly during storage period. Initial observations are recorded before imposing the treatments. The seed moisture content was determined using the low constant temperature oven method [14] in two replicates of five grams seed material. The powdered seed material was placed in a weighed metal cup, and after removing the lid, moisture cups were placed in hot air oven maintained at  $103 \pm 2^\circ\text{C}$  for  $16 \pm 1$  h and the contents were allowed to dry. Moisture content was calculated and expressed as percentage on fresh weight basis while, the per cent of germination was calculated as per ISTA procedures [15]. For measuring seedling length ten normal seedlings were selected randomly from each replication of germination test and the mean value was computed and expressed in centimeters. The seedling vigor index was calculated by multiplying germination (%) with seedling length (cm) as given by Abdul-Baki and Anderson [16] and expressed in whole number. Field emergence was estimated by following the method recommended by ISTA [17]. In this method three replicates of 100 seeds were planted on raised seed beds. The number of emerged seedlings at the first leaf stage is counted regularly until no further seedlings appeared. For electrical conductivity of seed leachates, a sample of 25 seeds was taken randomly from each treatment in four replications. They were washed with acetone followed by distilled water to remove chemical resistance if any. Then they were soaked in 25 ml distilled water for 18 h at constant temperature of  $25 \pm 1^\circ\text{C}$ . After incubation, the solution was decanted into another beaker and the electrical conductivity (EC) of seed leachates was measured with a digital conductivity meter (Model: EUTECH CON 510) and the EC was expressed in  $\mu\text{S cm}^{-1} \text{g}^{-1}$  [14].

### Statistical analysis

The data collected was analysed statistically by using Fisher Analysis of Variance techniques and least significant difference (LSD) at 5% probability level was applied to compare the differences among treatment means [18]. Angular transformation is done, a technique which is used to convert data made up of percentage or frequencies (because percentage data will not follow normal distribution) into a form that can be analyzed by ANOVA according to Panse and Sukhatme [19].

## RESULTS AND DISCUSSION

Maintenance of high-quality seeds in storage is the most important aspect in many crops. In India 80% of seed is kept in storage for at least one planting season and remaining 15-20 per cent has to be carried over for subsequent sowings due to various reasons. Soybean seed is known to have poor viability and field emergence due to its seed composition and structure, position of radical and cracking of test a and therefore, it is vulnerable to injuries during harvest, processing, packing and storage [20]. Seed packaging material and place of seed storage also determine the longevity of seed in the storage [21, 22]. Therefore, the present study was envisaged to gain more information regarding the cultivars, different packaging materials and seed storage location upto 10 months storage. The data for seedling quality characters during storage under ambient conditions are presented in Table 1 and 2 and results are discussed below.

### Variety

The cultivar JS 335 ( $V_1$ ) recorded significantly higher seed germination, seedling length, seedling vigour index and field emergence with lower EC of seed leachate throughout the storage period over the cultivar JS 93-05 (Table 1 and 2). However, SMC did record significant variation upto four months of storage and subsequently did observe on par with each other up to end of the storage period due to cultivars. With the progress of seed storage period, irrespective of cultivar all the seed quality parameters recorded were steadily decreased and seed germination dropped to the below seed standards. The seed germination of cultivars JS 335 and JS 93-05 was initially 93 and 90 respectively, and maintained standard germination up to 8 months in JS 335 (70%) and 6 months in JS 93-05 (71%) and dropped down to below standards thereafter irrespective of location and packaging material.

Similarly, the mean seedling length (18.76 cm), seedling vigour index (1213) and field emergence (55%) recorded higher with lower EC of seed leachates ( $2.061 \mu\text{Scm}^{-1}\text{g}^{-1}$ ) at the end of the 10 months of storage in JS 335 cultivar (Table 1 and 2). Thus, the current results indicated that a gradual decline of above seed quality parameters was observed in both JS 335 and JS 93-05 cultivars throughout the storage period with JS 335 maintaining better seed quality over JS 93-05.

It is quite natural phenomenon that seed loses its seedling quality including seed germination and vigour during storage. The loss of seed viability and vigour due to seed deterioration is inexorable, irreversible and inevitable [23]. However, it is a serious problem in tropical and sub-tropical countries where combined effect of higher temperature and humidity causes rapid seed deterioration in soybean [3]. The present study indicated that the genotypic variability exists in soybean in terms of seed

**Table 1.** Influence of location and packaging material on moisture content (%), germination (%) and seedling length (cm) in soybean during storage

| Treatment                           | Moisture content (%)            |                                 |                                 |                                 | Germination (%)          |                         |                         |                          | Seedling Length (cm)     |                      |                        |                          |
|-------------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|--------------------------|-------------------------|-------------------------|--------------------------|--------------------------|----------------------|------------------------|--------------------------|
|                                     | 2 M<br>February,<br>2013        | 6 M<br>June,<br>2013            | 8 M<br>August,<br>2013          | 10 M<br>October,<br>2013        | 2 M<br>February,<br>2013 | 6 M<br>June,<br>2013    | 8 M<br>August,<br>2013  | 10 M<br>October,<br>2013 | 2 M<br>February,<br>2013 | 6 M<br>June,<br>2013 | 8 M<br>August,<br>2013 | 10 M<br>October,<br>2013 |
| <b>Variety (V)</b>                  |                                 |                                 |                                 |                                 |                          |                         |                         |                          |                          |                      |                        |                          |
| V <sub>1</sub>                      | 8.230<br>(16.354)               | 8.587<br>(16.491)               | 9.022<br>(16.938)               | 9.112 <sup>Ns</sup><br>(16.836) | 84<br>(67)               | 74<br>(59)              | 69<br>(57)              | 64<br>(54)               | 27.90                    | 23.78                | 21.10                  | 18.76                    |
| V <sub>2</sub>                      | 8.054 <sup>*</sup><br>(16.729)  | 8.636<br>(17.464)               | 9.004 <sup>Ns</sup><br>(17.805) | 9.295<br>(18.165)               | 83 <sup>Ns</sup><br>(65) | 71 <sup>*</sup><br>(57) | 66 <sup>*</sup><br>(54) | 63 <sup>*</sup><br>(52)  | 27.11 <sup>*</sup>       | 21.93 <sup>*</sup>   | 19.83 <sup>*</sup>     | 17.87 <sup>*</sup>       |
| S.Em                                | 0.008                           | 0.115                           | 0.006                           | 0.176                           | 0.184                    | 0.194                   | 0.166                   | 0.186                    | 0.144                    | 0.179                | 0.212                  | 0.240                    |
| CD at 5%                            | 0.023                           | 0.328                           | 0.018                           | 0.502                           | 0.523                    | 0.552                   | 0.473                   | 0.529                    | 0.410                    | 0.509                | 0.604                  | 0.684                    |
| <b>Location of seed storage (L)</b> |                                 |                                 |                                 |                                 |                          |                         |                         |                          |                          |                      |                        |                          |
| L <sub>1</sub>                      | 7.857 <sup>*</sup><br>(16.449)  | 7.815 <sup>*</sup><br>(16.851)  | 8.304 <sup>*</sup><br>(17.221)  | 8.453 <sup>*</sup><br>(17.431)  | 85<br>(67)               | 74<br>(59)              | 71<br>(57)              | 66<br>(53)               | 25.62 <sup>*</sup>       | 23.60                | 20.53 <sup>*</sup>     | 17.20 <sup>*</sup>       |
| L <sub>2</sub>                      | 8.137 <sup>*</sup><br>(16.538)  | 8.888 <sup>Ns</sup><br>(16.761) | 9.196 <sup>*</sup><br>(17.244)  | 9.064 <sup>*</sup><br>(17.666)  | 83 <sup>*</sup><br>(65)  | 72 <sup>*</sup><br>(58) | 67 <sup>*</sup><br>(55) | 64 <sup>*</sup><br>(53)  | 26.56 <sup>*</sup>       | 21.47 <sup>*</sup>   | 18.90 <sup>*</sup>     | 18.74 <sup>Ns</sup>      |
| L <sub>3</sub>                      | 8.432<br>(16.637)               | 9.132<br>(17.321)               | 9.540<br>(17.650)               | 10.004<br>(17.405)              | 82 <sup>*</sup><br>(66)  | 70 <sup>*</sup><br>(58) | 65 <sup>*</sup><br>(55) | 62 <sup>*</sup><br>(53)  | 30.33                    | 23.49                | 21.98                  | 18.99                    |
| S.Em                                | 0.010                           | 0.141                           | 0.008                           | 0.216                           | 0.225                    | 0.238                   | 0.204                   | 0.228                    | 0.176                    | 0.219                | 0.260                  | 0.294                    |
| CD at 5%                            | 0.028                           | 0.402                           | 0.022                           | 0.615                           | 0.641                    | 0.677                   | 0.580                   | 0.648                    | 0.502                    | 0.624                | 0.740                  | 0.838                    |
| <b>Packaging material (P)</b>       |                                 |                                 |                                 |                                 |                          |                         |                         |                          |                          |                      |                        |                          |
| P <sub>1</sub>                      | 8.839<br>(17.294)               | 9.540 <sup>Ns</sup><br>(17.972) | 10.182 <sup>*</sup><br>(18.599) | 9.917 <sup>*</sup><br>(18.156)  | 83 <sup>*</sup><br>(65)  | 71 <sup>*</sup><br>(57) | 65 <sup>*</sup><br>(54) | 60 <sup>*</sup><br>(51)  | 26.65 <sup>*</sup>       | 21.94 <sup>*</sup>   | 19.98 <sup>*</sup>     | 18.73 <sup>*</sup>       |
| P <sub>2</sub>                      | 8.785 <sup>Ns</sup><br>(17.238) | 9.980<br>(18.392)               | 10.543<br>(18.938)              | 11.001<br>(19.353)              | 79 <sup>*</sup><br>(62)  | 66 <sup>*</sup><br>(54) | 60 <sup>*</sup><br>(51) | 55 <sup>*</sup><br>(48)  | 28.42                    | 22.53 <sup>*</sup>   | 18.57 <sup>*</sup>     | 15.77 <sup>*</sup>       |
| P <sub>3</sub>                      | 8.613 <sup>*</sup><br>(17.062)  | 8.840 <sup>*</sup><br>(17.263)  | 9.293 <sup>*</sup><br>(17.728)  | 9.874 <sup>*</sup><br>(18.287)  | 84 <sup>*</sup><br>(66)  | 74 <sup>*</sup><br>(59) | 68 <sup>*</sup><br>(56) | 63 <sup>*</sup><br>(53)  | 28.38 <sup>Ns</sup>      | 22.26 <sup>*</sup>   | 20.09 <sup>*</sup>     | 18.79 <sup>*</sup>       |
| P <sub>4</sub>                      | 6.331 <sup>*</sup><br>(14.572)  | 6.086 <sup>*</sup><br>(14.282)  | 6.035 <sup>*</sup><br>(14.221)  | 6.023 <sup>*</sup><br>(14.206)  | 88<br>(70)               | 79<br>(63)              | 77<br>(62)              | 76<br>(61)               | 26.58 <sup>*</sup>       | 24.69                | 23.22                  | 19.96                    |
| S.Em                                | 0.011                           | 0.163                           | 0.0093                          | 0.249                           | 0.260                    | 0.274                   | 0.235                   | 0.263                    | 0.204                    | 0.253                | 0.300                  | 0.340                    |
| CD at 5%                            | 0.033                           | 0.464                           | 0.0264                          | 0.710                           | 0.740                    | 0.781                   | 0.670                   | 0.749                    | 0.580                    | 0.720                | 0.855                  | 0.968                    |
| <b>VxP</b>                          |                                 |                                 |                                 |                                 |                          |                         |                         |                          |                          |                      |                        |                          |
| V <sub>1</sub> P <sub>1</sub>       | 8.847 <sup>Ns</sup><br>(17.068) | 9.667 <sup>Ns</sup><br>(17.432) | 10.360 <sup>*</sup><br>(18.177) | 9.497 <sup>*</sup><br>(17.123)  | 82 <sup>*</sup><br>(65)  | 72 <sup>*</sup><br>(58) | 67 <sup>*</sup><br>(55) | 61 <sup>*</sup><br>(51)  | 25.63 <sup>*</sup>       | 22.76 <sup>*</sup>   | 20.69 <sup>*</sup>     | 19.73 <sup>Ns</sup>      |
| V <sub>1</sub> P <sub>2</sub>       | 8.887<br>(16.973)               | 9.787 <sup>Ns</sup><br>(17.773) | 10.487 <sup>*</sup><br>(18.376) | 11.135<br>(18.648)              | 79 <sup>*</sup><br>(63)  | 67 <sup>*</sup><br>(56) | 62 <sup>*</sup><br>(52) | 57 <sup>*</sup><br>(49)  | 29.923                   | 24.15 <sup>*</sup>   | 18.89 <sup>*</sup>     | 15.60 <sup>*</sup>       |
| V <sub>1</sub> P <sub>3</sub>       | 8.797 <sup>*</sup><br>(16.768)  | 8.827 <sup>*</sup><br>(16.498)  | 9.229 <sup>*</sup><br>(16.994)  | 9.804 <sup>*</sup><br>(17.352)  | 85 <sup>*</sup><br>(68)  | 75 <sup>*</sup><br>(60) | 70 <sup>*</sup><br>(57) | 63 <sup>*</sup><br>(54)  | 28.60 <sup>*</sup>       | 22.94 <sup>*</sup>   | 20.72 <sup>*</sup>     | 19.86 <sup>Ns</sup>      |
| V <sub>1</sub> P <sub>4</sub>       | 6.390 <sup>*</sup><br>(14.606)  | 6.068 <sup>*</sup><br>(14.263)  | 6.012 <sup>*</sup><br>(14.207)  | 6.012 <sup>*</sup><br>(14.223)  | 89<br>(71)               | 81<br>(64)              | 78<br>(63)              | 77<br>(62)               | 27.45 <sup>*</sup>       | 25.27                | 24.12                  | 19.84 <sup>Ns</sup>      |

Contd...

**Table 2.** Influence of location and packaging material on seedling vigour index-I, field emergence (%) and electrical conductivity (mS/cm) in Soybean during storage

| Treatment          | Seedling Vigour Index - I |                      |                        |                          | Field Emergence (%)      |                      |                        |                          | Electrical conductivity ( $\mu\text{Scm}^{-1}\text{g}^{-1}$ ) |                      |                        |                          |
|--------------------|---------------------------|----------------------|------------------------|--------------------------|--------------------------|----------------------|------------------------|--------------------------|---------------------------------------------------------------|----------------------|------------------------|--------------------------|
|                    | 2 M<br>February,<br>2013  | 6 M<br>June,<br>2013 | 8 M<br>August,<br>2013 | 10 M<br>October,<br>2013 | 2 M<br>February,<br>2013 | 6 M<br>June,<br>2013 | 8 M<br>August,<br>2013 | 10 M<br>October,<br>2013 | 2 M<br>February,<br>2013                                      | 6 M<br>June,<br>2013 | 8 M<br>August,<br>2013 | 10 M<br>October,<br>2013 |
| <b>Variety (V)</b> |                           |                      |                        |                          |                          |                      |                        |                          |                                                               |                      |                        |                          |
| V <sub>1</sub>     | 2327                      | 1755                 | 1474                   | 1213                     | 74<br>(60)               | 62<br>(52)           | 59<br>(50)             | 55<br>(49)               | 0.660*                                                        | 1.422<br>*           | 1.751*                 | 2.061*                   |
| V <sub>2</sub>     | 2251*                     | 1561*                | 1320*                  | 1140*                    | 73 <sup>Ns</sup><br>(58) | 60*<br>(51)          | 55*<br>(48)            | 54*<br>(46)              | 0.933                                                         | 1.688                | 1.978                  | 2.281                    |
| S.Em               | 11.783                    | 14.163               | 14.262                 | 14.784                   | 0.309                    | 0.155                | 0.302                  | 0.215                    | 0.003                                                         | 0.002                | 0.003                  | 0.002                    |
| CD at 5%           | 33.507                    | 40.274               | 40.555                 | 42.039                   | 0.879                    | 0.443                | 0.859                  | 0.611                    | 0.009                                                         | 0.006                | 0.010                  | 0.007                    |

| Location of seed storage (L)  |                    |                    |                    |                    |                          |                          |             |                          |        |            |        |        |
|-------------------------------|--------------------|--------------------|--------------------|--------------------|--------------------------|--------------------------|-------------|--------------------------|--------|------------|--------|--------|
| L <sub>1</sub>                | 2179*              | 1760               | 1458               | 1141*              | 75<br>(59)               | 63<br>(52)               | 60<br>(50)  | 56<br>(48)               | 0.544* | 1.050<br>* | 1.288* | 1.447* |
| L <sub>2</sub>                | 2208*              | 1554*              | 1288*              | 1214               | 73*<br>(59)              | 61*<br>(52)              | 57*<br>(49) | 54*<br>(47)              | 1.453  | 2.126      | 2.334  | 2.583  |
| L <sub>3</sub>                | 2480               | 1661*              | 1446 <sup>Ns</sup> | 1174 <sup>Ns</sup> | 72*<br>(59)              | 60*<br>(51)              | 55*<br>(49) | 52*<br>(48)              | 0.392* | 1.490<br>* | 1.973* | 2.482* |
| S.Em                          | 14.432             | 17.347             | 17.468             | 18.107             | 0.378                    | 0.190                    | 0.370       | 0.263                    | 0.003  | 0.002      | 0.004  | 0.003  |
| CD at 5%                      | 41.037             | 49.325             | 49.670             | 51.487             | 1.077                    | 0.542                    | 1.053       | 0.749                    | 0.011  | 0.007      | 0.012  | 0.008  |
| Packaging material (P)        |                    |                    |                    |                    |                          |                          |             |                          |        |            |        |        |
| P <sub>1</sub>                | 2209*              | 1550*              | 1301*              | 1122*              | 72*<br>(58)              | 60*<br>(51)              | 55*<br>(48) | 51*<br>(45)              | 0.779* | 1.541<br>* | 1.913* | 2.323* |
| P <sub>2</sub>                | 2231*              | 1492*              | 1127*              | 871*               | 69*<br>(56)              | 56*<br>(48)              | 50*<br>(45) | 47*<br>(43)              | 0.799* | 1.676      | 1.991  | 2.378  |
| P <sub>3</sub>                | 2376               | 1648*              | 1375*              | 1189*              | 73*<br>(59)              | 63*<br>(53)              | 58*<br>(50) | 55*<br>(48)              | 0.750* | 1.582<br>* | 1.860* | 2.072* |
| P <sub>4</sub>                | 2341 <sup>Ns</sup> | 1942               | 1785               | 1523               | 78<br>(62)               | 66<br>(54)               | 66<br>(55)  | 64<br>(53)               | 0.858  | 1.421<br>* | 1.696* | 1.911* |
| S.Em                          | 16.664             | 20.030             | 20.170             | 20.908             | 0.437                    | 0.220                    | 0.427       | 0.304                    | 0.004  | 0.003      | 0.005  | 0.003  |
| CD at 5%                      | 47.386             | 56.956             | 57.354             | 59.453             | 1.243                    | 0.626                    | 1.215       | 0.865                    | 0.012  | 0.008      | 0.014  | 0.009  |
| VxP                           |                    |                    |                    |                    |                          |                          |             |                          |        |            |        |        |
| V <sub>1</sub> P <sub>1</sub> | 2097*              | 1639*              | 1395*              | 1200*              | 72*<br>(59)              | 62*<br>(52)              | 57*<br>(49) | 52*<br>(46)              | 0.625* | 1.486<br>* | 1.868* | 2.248* |
| V <sub>1</sub> P <sub>2</sub> | 2347*              | 1619*              | 1171*              | 885*               | 69*<br>(57)              | 57*<br>(50)              | 51*<br>(46) | 48*<br>(44)              | 0.682* | 1.502<br>* | 1.809* | 2.248* |
| V <sub>1</sub> P <sub>3</sub> | 2427 <sup>Ns</sup> | 1725*              | 1454*              | 1243*              | 75*<br>(60)              | 64*<br>(53)              | 60*<br>(51) | 56*<br>(49)              | 0.683* | 1.472<br>* | 1.759* | 1.986* |
| V <sub>1</sub> P <sub>4</sub> | 2436               | 2038               | 1876               | 1522 <sup>Ns</sup> | 79<br>(64)               | 66<br>(55)               | 69<br>(57)  | 63*<br>(54)              | 0.652* | 1.229<br>* | 1.570* | 1.761* |
| V <sub>2</sub> P <sub>1</sub> | 2320*              | 1461*              | 1207*              | 1045*              | 73*<br>(58)              | 59*<br>(50)              | 53*<br>(46) | 50*<br>(45)              | 0.933* | 1.597<br>* | 1.958* | 2.398* |
| V <sub>2</sub> P <sub>2</sub> | 2115*              | 1365*              | 1083*              | 857*               | 69*<br>(55)              | 55*<br>(47)              | 49*<br>(44) | 46*<br>(42)              | 0.916* | 1.850      | 2.173* | 2.507  |
| V <sub>2</sub> P <sub>3</sub> | 2324*              | 1571*              | 1296*              | 1135*              | 72*<br>(58)              | 62*<br>(52)              | 56*<br>(48) | 54*<br>(46)              | 0.817* | 1.693<br>* | 1.961  | 2.157* |
| V <sub>2</sub> P <sub>4</sub> | 2246*              | 1846*              | 1695*              | 1524               | 78 <sup>Ns</sup><br>(61) | 66 <sup>Ns</sup><br>(54) | 64*<br>(53) | 65<br>(52)               | 1.065  | 1.614<br>* | 1.821* | 2.061* |
| S.Em                          | 23.567             | 28.327             | 28.525             | 29.569             | 0.618                    | 0.311                    | 0.604       | 0.430                    | 0.006  | 0.004      | 0.007  | 0.004  |
| CD at 5%                      | 67.014             | 80.548             | 81.111             | 84.079             | 1.759                    | 0.886                    | 1.719       | 1.223                    | 0.018  | 0.012      | 0.020  | 0.014  |
| LxP                           |                    |                    |                    |                    |                          |                          |             |                          |        |            |        |        |
| L <sub>1</sub> P <sub>1</sub> | 2173*              | 1691*              | 1372*              | 1030*              | 74*<br>(58)              | 63*<br>(52)              | 57*<br>(48) | 52*<br>(46)              | 0.565* | 1.090*     | 1.430* | 1.520* |
| L <sub>1</sub> P <sub>2</sub> | 2080*              | 1620*              | 1293*              | 892*               | 71*<br>(57)              | 59*<br>(49)              | 52*<br>(45) | 51*<br>(45)              | 0.620* | 1.265*     | 1.515* | 1.875* |
| L <sub>1</sub> P <sub>3</sub> | 2284*              | 1768*              | 1455*              | 1161*              | 74*<br>(60)              | 64*<br>(54)              | 60*<br>(50) | 56*<br>(47)              | 0.470* | 1.030*     | 1.170* | 1.280* |
| L <sub>1</sub> P <sub>4</sub> | 2179*              | 1962 <sup>Ns</sup> | 1713*              | 1481*              | 82<br>(62)               | 66*<br>(54)              | 70<br>(54)  | 66<br>(53)               | 0.520* | 0.815*     | 1.035* | 1.115* |
| L <sub>2</sub> P <sub>1</sub> | 2174*              | 1390*              | 1217*              | 1236*              | 71*<br>(58)              | 59*<br>(51)              | 55*<br>(48) | 52*<br>(45)              | 1.370* | 1.997*     | 2.218* | 2.772  |
| L <sub>2</sub> P <sub>2</sub> | 2234*              | 1405*              | 980*               | 739*               | 69*<br>(55)              | 55*<br>(48)              | 50*<br>(45) | 45*<br>(43)              | 1.360* | 1.973*     | 2.297* | 2.517* |
| L <sub>2</sub> P <sub>3</sub> | 2160*              | 1521*              | 1332*              | 1186*              | 74*<br>(58)              | 64*<br>(52)              | 59*<br>(49) | 56*<br>(47)              | 1.444* | 2.329      | 2.567  | 2.595* |
| L <sub>2</sub> P <sub>4</sub> | 2266*              | 1899 <sup>Ns</sup> | 1621*              | 1694               | 76*<br>(63)              | 68<br>(55)               | 65*<br>(55) | 65 <sup>Ns</sup><br>(53) | 1.638  | 2.206*     | 2.255* | 2.447* |
|                               |                    |                    |                    |                    |                          |                          |             |                          |        |            |        | Contd. |

Contd...

|                               |        |        |        |         |       |       |       |       |        |        |        |        |
|-------------------------------|--------|--------|--------|---------|-------|-------|-------|-------|--------|--------|--------|--------|
| L <sub>3</sub> P <sub>1</sub> | 2279*  | 1570*  | 1314*  | 1102*   | 72*   | 59*   | 53*   | 49*   | 0.402* | 1.538* | 2.091* | 2.677* |
|                               |        |        |        |         | (58)  | (50)  | (47)  | (46)  |        |        |        |        |
| L <sub>3</sub> P <sub>2</sub> | 2380*  | 1452*  | 1108*  | 982*    | 67*   | 53*   | 49*   | 45*   | 0.416* | 1.790* | 2.161* | 2.741* |
|                               |        |        |        |         | (55)  | (47)  | (44)  | (42)  |        |        |        |        |
| L <sub>3</sub> P <sub>3</sub> | 2683   | 1655*  | 1338*  | 1220*   | 72*   | 63*   | 55*   | 53*   | 0.335* | 1.388* | 1.844* | 2.341* |
|                               |        |        |        |         | (59)  | (53)  | (49)  | (49)  |        |        |        |        |
| L <sub>3</sub> P <sub>4</sub> | 2580*  | 1965   | 2022   | 1394*   | 77*   | 65*   | 64*   | 62*   | 0.417* | 1.243* | 1.797* | 2.171* |
|                               |        |        |        |         | (62)  | (55)  | (54)  | (54)  |        |        |        |        |
| S.Em                          | 28.864 | 34.694 | 34.936 | 36.214  | 0.757 | 0.381 | 0.741 | 0.527 | 0.007  | 0.005  | 0.008  | 0.006  |
| CD at 5%                      | 82.075 | 98.651 | 99.341 | 102.975 | 2.154 | 1.085 | 2.106 | 1.498 | 0.022  | 0.015  | 0.025  | 0.017  |

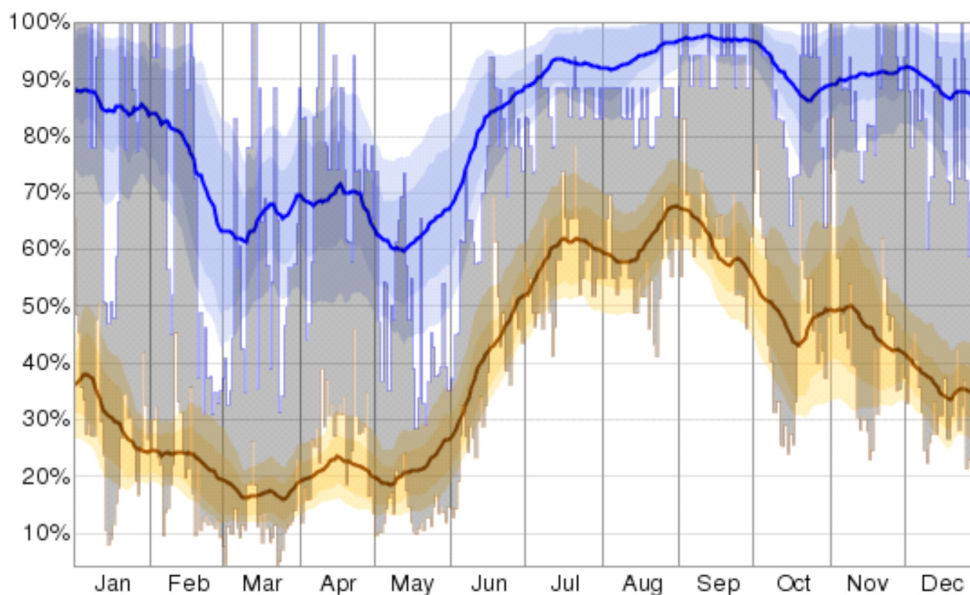
V<sub>1</sub>: JS 335      L<sub>1</sub>: Hyderabad      P<sub>1</sub>: Cloth bag      P<sub>2</sub>: Jute bag  
V<sub>2</sub>: JS 93-05      L<sub>2</sub>: Rudrur, Nizamabad      P<sub>3</sub>: High Density Poly Ethylene bag (HDPE)  
L<sub>3</sub>: Jangamaheswarapuram, Guntur      P<sub>4</sub>: Air tight container with zeolite beads  
(Values in parenthesis are angular transformed values)

quality loss and this is in with the agreement of Vanangamudi [24]. However, the rate of seed deterioration could be slowed down to greater extent through suitable selection of seed packing material and ambient conditions during storage.

### Location

Maintenance of seed quality mainly depends on initial seed quality, SMC, storage temperature, relative humidity, location and length of seed storage [25]. The influence of location of seed storage on seed longevity is due to hygroscopic nature of seeds and ambient conditions. In the present study, the results on among location of seed storage and their interactions with cultivar and packaging material showed significant differences on seed quality

parameters during storage (Table 1 and 2). The study revealed that Hyderabad location (L<sub>1</sub>) had recorded lower SMC and EC of seed leachates, higher seed germination, seedling length, seed vigour index and field emergence than Rudrur of Nizamabad District and Jangamaheswarapuram of Guntur District throughout the storage period and also observed that all the parameters were decreased as the storage period progressed up to 10 months of storage (Figure 1). The SMC recorded was ranged from 7.857% to 8.453% at Hyderabad location during storage. Least SMC (7.815%) was recorded after six months of storage that coincides with lower relative humidity during April– May month due to cool and dry weather while, higher SMC (8.453%) was recorded during monsoon season where combination of higher relative



**Figure 1.** The daily low (brown) and high (blue) relative humidity of Hyderabad location during 2012-13 with the area between them shaded gray and superimposed over the corresponding averages (thick lines), and with percentile bands (inner band from 25% to 75%, outer band from 10% to 90%)

humidity and temperature recorded at Hyderabad. Vanangamudi and Ramaswamy [26] also reported that the prevailing relative humidity and temperature of atmosphere influence greatly the seed quality due to fluctuations of SMC in pervious containers than air tight containers.

Similarly, Hyderabad location of seed storage shows significantly higher influence on germination (71%) and maintained above Indian Minimum Seed Certification standards (IMSCS) as compared to other locations upto 8 months of storage. Similarly, higher seedling vigour index was recorded (1760 and 1458) at 6 and 8 months of storage respectively at Hyderabad location ( $L_1$ ) as compared other locations. The EC of seed leachate was recorded lower at Hyderabad location throughout the storage period and recorded least ( $1.447 \mu\text{Scm}^{-1}\text{g}^{-1}$ ) at end of 10 months of storage (Table 2). Hyderabad location ( $L_1$ ) has also recorded higher field emergence, associated with the result of high seed germination and at the end of 10 months of storage has recorded higher field emergence (59.70%) as compared to Rudrur, Nizamabad and Jangamaheswaram, Guntur. All the quality parameters have recorded a progressive decrease at  $L_2$  and  $L_3$  locations. The results indicate that Hyderabad location is good for seed storage as the e the combinations of relative humidity and temperatures recorded at Hyderabad were relatively low as against Rudrur, Nizamabad and Jangamaheswaram, Guntur locations. Thus, the decline of seed quality with higher SMC is related with storage conditions associated with the relative humidity and temperature [27]. [28, 29] reported that Hyderabad location is bestowed with congenial climatic conditions for seed production and storage as a result of which the farmers in this region have been well acquainted with advanced seed production practices for the past four decades. By looking congenial climatic conditions for seed production and seed storage more than 400 seed companies including MNCs, National Seed Companies (big, medium and small) of our country established their Research and Development and seed can be stored for 9 - 12 months under ambient conditions in and around Hyderabad. Thus, Hyderabad became "SEED HUB" of India due to prevailing dry and cool conditions throughout the year as compared to other locations of the country.

### Packaging material

As stated above by [6, 10, 11 & 12] several factors affect the longevity of seeds during storage including packaging

material. There is a growing awareness of the deleterious consequences resulting from the wide spread use of seed package material because the seed has a hygroscopic nature, its SMC varies based on ambient temperature and relative humidity. In addition, use of inappropriate package material with more than 8% SMC in soybean is causing seed deterioration due to improper seed drying under tropical and sub-tropical conditions. Therefore, suitable package material with desiccants is most important to ensure low SMC and seed quality during storage [30].

In the present study, seed packed in cloth and jute bags recorded high moisture content and the percentage of moisture recorded varied in relation to ambient conditions from December, 2012 to October, 2013 (Table 1). Whereas, the seed packed along with drying bead desiccant enclosed in air tight container ( $P_4$ ) was dropped to 6.33% from 9.39% SMC within the first two months of storage and maintained steadily around 6.023% of SMC at the end of storage period.

The seed packed in air tight container along with drying beads recorded significantly higher germination (76%), seedling length (19.96cm), seedling vigour index (1523) and field emergence (64%) with lower EC of seed leachates ( $1.911 \mu\text{S cm}^{-1}\text{g}^{-1}$ ) as compared to HDPE ( $P_3$ ), jute ( $P_2$ ) and cloth bag ( $P_1$ ) packages after 10 months of storage. Though the HDPE seed package material acts as moisture impervious material and good for seed storage, however in the present study, the seed stored in HDPE at higher moisture content (9.874%) resulted in loss of seed viability faster due to improper seed drying systems and could be able to maintain germination (74%) above seed certification standards only upto six months of storage. Further, it was observed that slower seed deterioration in HDPE seed packaging material as compared to jute and cloth bag containers which means the SMC of HDPE containers remained on par throughout the storage period. During storage aging is a universal physiological phenomenon followed by deterioration resulting in loss up germination and viability. The mechanism of seed deterioration also depends on seed packaging material. In general, it progresses at faster rate under stress and unfavourable conditions. As described above, the prevailing relative humidity and temperature of ambient atmosphere influence greatly the longevity of seeds, since MC of the seed fluctuates more in the moisture pervious container than moisture vapour proof containers [26 & 30].

The interaction effect of V x P has recorded a moisture content that has maintained steadily around 6% of SMC throughout the storage in both the cultivars (6.01% for V<sub>1</sub>P<sub>4</sub> and 6.03% for V<sub>2</sub>P<sub>4</sub>) packed in airtight container with drying beads while, the SMC in cloth and jute packaging material varied, with lowest reading recorded in February and April, 2013 (Table 1). Both the cultivars packed in airtight container along with zeolite (P<sub>4</sub>) recorded higher seed quality parameters of germination (77% and 76%), seedling vigour index (1522 and 1524), field emergence (63% and 65%) with lower EC of seed leachates (1.761  $\mu\text{Scm}^{-1}\text{g}^{-1}$  and 2.061  $\mu\text{Scm}^{-1}\text{g}^{-1}$ ) followed by varieties packed in HDPE bag.

The results of L x P effects also indicated that the SMC was on par irrespective of the location when stored in hermetic container with zeolite beads [5.99% (L<sub>1</sub>P<sub>4</sub>), 6.07% (L<sub>2</sub>P<sub>4</sub>) and 6.00% (L<sub>3</sub>P<sub>4</sub>)] resulted higher seedling quality parameters above IMSCS upto 10 months after storage. However, the germination was recorded above IMSCS only for 6 months in L<sub>3</sub>P<sub>3</sub> (73%) and L<sub>2</sub>P<sub>3</sub> (74%).

In India, the harvested seeds of soybean are required to be stored for at least 9 months before next planting as it grows as wet season crop. During this period, seeds tend to lose their viability due to the effect of biotic and abiotic factors. The deterioration of stored seed becomes quicker if the seeds are not properly dried and the atmosphere is not controlled [31, 32]. Among the factors that determine the longevity of seeds during storage include SMC, temperature, relative humidity, initial viability, stage of maturity at harvest, storage gas and the initial moisture content of seed entering into the storage [33]. This indicates that seed packaging is the deciding factor for retaining seed quality while in the storage. Haque [34] reported the suitability of metal air tight container over gunny bag in maintaining the higher germination of rice seed. Thus, storing of soybean seeds in air tight container with drying beads, maintained seed quality (planting quality) above minimum seed certification standards upto 10 months as compared to storing them in cloth, jute and HDPE bags. The study also indicates that the drying beads absorb excess moisture present in seeds and keeps it tightly in their micropores of their crystalline structure and maintained lower SMC throughout the storage period. Similar results were observed by [35].

## CONCLUSION

The current study demonstrated that soybean seed quality is varied with genotype, storage locations and

seed packaging material during storage. The cultivar JS 335 is observed to maintain better storability, identified Hyderabad location is better for safe seed storage and seed packaging such as air tight container enclosed with drying beads found better for safe seed storage irrespective of cultivar and location of seed storage throughout the storage period.

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