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Effect of Relative Humidity and Temperature on Shelf Life of Sorghum, Lentil and Niger Seeds

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Abstract: Seeds of three crops viz. lentil, sorghum and niger were compared for their storability at different relative humidities (RH) and temperatures. Two varieties per crop were selected i.e. lentil (L-4076 and L-4578), sorghum (CSV-15 and CSV-216R.) and niger (GA-10 and JNC-6) for this study. The humidity levels selected were 95, 75, 50, 33 and 5.5% which were maintained using saturated salt solutions of KNO_3, NaCl, $Ca(NO_3)_2$, $MgCl_2$ and $ZnCl_2$ respectively at ambient, 10 and35°C temperatures. Total duration of the experiment was 90 days for storage at all RH except the highest (95%) in which the duration was reduced to 20 days. Monitoring for seed germination, vigour and electrical conductivity was carried out at one-month interval in all the seed lots except those stored at highest RH at three different temperatures. In the later, the seeds were monitored at 10 days interval for the above-mentioned parameters. Results revealed that increased rate of deterioration occurred irrespective of type of seeds or cultivars at high RH and temperature. Germination and vigour index declined significantly when seeds were stored at very high (95%) to high (75%) RH and 35°C temperature while the electrical conductivity recorded a steep increase at these conditions implying their usefulness as indices for seed quality loss.

Keywords: Lentil, Sorghum, Niger, Relative Humidity, Temperature, Electrical Conductivity, Vigor Index

1. Introduction

Maintaining the seed quality during the storage period is a factor that must be considered in the production process of any crop, for the farming success depends, mainly, on the use of high quality seeds (Freitas*et al*., 2004). The temperature and RH conditions fluctuate very significantly between different seasons in tropical climate, like that of India and Ethiopia and therefore, seed storage problems for conservation of plant genetic resources are very common in these countries. This necessitates an improved understanding of the factors affecting the seed moisture contents during processing and storage, particularly for adjusting the water content of the seeds, which is an important factor in maintaining seed-viability during processing and long-term storage (FAO/IPGRI, 1994). The present study was a step in this direction with diverse crop species that would account for the representative genetic variability interacting with factors controlling seed moisture contents.

Seeds of most plant species can be stored for short period without change in their viability. However, they gradually lose viability during storage. Ageing which occurs over time during storageis called natural ageing (Bewley and Black, 1994). However, as storage temperatures and RH affect the seed viability, it can be accelerated by ageing the seed artificially by subjecting them to elevated temperature and high RH (Copeland and McDonald, 1995). Accelerated ageing by manipulation of temperature and moisture levels is therefore a useful procedure for studying the storage potential and ageing process under laboratory conditions.

The rates of aging and potential life spans of seeds vary among species (Hendry *et al*., 1994). Even within species, various accessions often exhibit differences in their storage properties (Nagel and Borner, 2010). Understanding differences in seed longevity among species and their accessions is crucial to the effective management of seed conservation and collection programmes since it influences

the selection of viability retest intervals and hence regeneration or re-collection strategies (Probert *et al.*, 2009).Therefore the objective of the present work was to identify the optimum moisture content required for maintaining maximum seed-viability in three vastly differing crops such as Sorghum (cereal), Lentil (grain legume) and Niger(oil seed) with drastic differences in seed proximate composition and to identify the most suitable temperature and RH regimes for maintenance of viability for relatively longer durations. The electrical conductivity test has been used to evaluate the seeds' vigor in several species for being simple to execute, of low cost, fast, replicable and with easy interpreting results (Vieira and Krzyzanowski, 1999). Therefore, in addition to assessing the germination potential and vigour index of stored seeds, the EC was also determined at regular intervals to see the feasibility using this parameter as an indicator of seed quality.

2. Material and Methods

Seeds: The Freshly harvested seeds of three crops: *Sorghum bicolor*, Variety CSV-15 & CSV-216, *Lens culinaris,* Variety L-4076 & L-4578 and *Guizotia abyssinica,* Variety GA-10 and JNC-6 were procured from the respective National Active Germplasm Sites (NAGS) situated at various ecological zones of the Indian sub-continent.

The RH level selected for the present study were 95% (KNO_3), 75% (NaCl), 50%Ca $(NO_3)_2$, 33% ($MgCl_2$) and 5% ($ZnCl_2$) and were established based on the method of Winston and Bates (1960) using specific standard salt solutions. The saturated salt solutions of the above-mentioned salts prepared in glass petriplates were covered with perforated plates over which the seed samples of the selected cultivars of the three crops were kept in plastic petriplates in a single layer to facilitate uniform absorption/desorption of moisture at any given RH. The whole set up was transferred to incubators maintaining temperatures of 10°C, 35°C and one set was maintained at room temperature. Duration of study was only 20 days in the case of high RH since seeds are expected to age fast, while for others it was three months.

Moisture Content: For determination of moisture content a minimum of 0.5g seed sample (weighed up to four decimal place) was drawn in three replications for each accession of all three-crop seeds. The moisture content was calculated using the formula:

$$\frac{M_2 - M_1}{M_2 - M_3} \times 100$$

M= Moisture contentM_2-M_3

M_1= Weight of empty bottle with its lid

M_2= Weight of bottle with lid and sample before drying

M_3 =Weight of bottle with lid and sample after drying.

Germination percent: Germination tests were conducted using 50 seeds in three replication (ISTA, 1985). For sorghum and lentil seeds between papers, method were used while for Niger seeds top of paper method was used. After planting, the rolled towel or Petri plates were incubated in germinator maintaining adequate humidity (over 90%) and temperature of 25°C. Germination percentage was recorded based on normal seedlings and readings were taken on the 7th day (ISTA, 1985).

Seedling vigour index: This was calculated as the product of germination percentage and seedling length (Abdul-Baki and Anderson, 1973). The formula used for calculations is Vigour index = Root length + Shoot length (in cm) X Germination (percentage)

Electrical conductivity of leachates: The amount of electrolyte leakage can be assessed by measuring the electrical conductivity of the seed soaked water, with a conductivity meter. Twenty-five undamaged seeds in three replications from each accession were weighed. The seeds were soaked overnight in 25ml of distilled water at 20 ± 2°C and electrical conductivity was measured using a digital conductivity meter calibrated with 0.01M KCl to a reading of 1.413µs/cm.

Statistical analysis: The data from the laboratory experiments were analyzed statistically by adopting factorial CRD technique (Panse and Sukatme1985). The data recorded as percentage were transformed to respective angular (arc sin) value before subjecting them to statistical scrutiny. Difference among means were tested for significance using least difference tests (LSD)

3. Result and Discussion

Several authors have demonstrated that safe storage condition for a short period *i. e*. from harvest to the next planting season (1-9 months) are those in which the seed equilibrium moisture is lower than 14% for cereal and millets, 11% for oil seeds (Harrington, 1972) and 7 to 8% for most of the vegetable seeds. In the present study, seeds of two varieties each of sorghum lentil and niger were exposed to three different storage temperatures (10°C, ambient and 35°C) and five different RH conditions (95,75,50,33 and 5.5%) and the pattern of deterioration was examined by determining the germination potential as well as the seedling vigour index and electrical conductivity of seed leachates often considered as good indices for seed quality.

During the present study, Delhi's ambient temperature varied from a minimum 5-14°C to maximum 22-27°C. Seeds equiliberated over higher relative humidities of 75 and 95% had higher moisture content, which increased with decrease in the temperature in all the three crops (Table 1).

Moisture Content:

In general, the Equilibrium Moisture Content (EMC) was the highest for the seeds stored at maximum humidity of 95% and lowest at minimum humidity of 5.5%. While comparing the moisture content at a particular humidity, at different temperatures the general trend was decrease in moisture content with increase in temperature and within a variety, the moisture content decreased with decrease in RH, the highest being maintained at 95% RH. At35°C, EMC was found to be highest at 95% RH in all the crops and was

found maximum in sorghum cv. CSV-15 (15.72), while it was the lowest at 5.5% RH for niger cv.JNC-6 (2.18). The moisture contents maintained by the three types of seeds at different temperatures and RH are given in table 1.

Among the three kind of seeds, both varieties of niger maintained lower levels of moisture content at any given humidity. Properly dried orthodox seeds have all physiological activities proceeding at extremely slow rates, thus limiting extensive deterioration. Low moisture content is beneficial for the storage of the seeds of most agricultural crops. Generally, the rate of deterioration will be slow if the seeds are stored at lower RH and temperature, but even so, it is almost impossible to predict with any accuracy the probable longevity of any particular batch of seeds when placed in storage (Amjad and Anjum, 2002). Seeds equilibrated at higher RH attain higher moisture content which triggers the metabolic activities particularly respiration leading to fungal invasion and spoilage. In the present study as the RH of storage atmosphere increased, the moisture content of the seeds also increased to various extents in different seed lots, which is largely a function of the proximate composition of the seed.

Germination percent:

The effect of storage of the three kinds of the seeds at different humidity levels and three different temperatures is shown in table 2a and 2b.Among the two niger varieties JNC-6, showed significant reduction in germination when stored for 90 days at 75% RH at all 3 temperatures. Maximum reduction was at 35°C (68.67). At 95% RH on the other hand, considerable deterioration occurred in both the varieties even when stored for 20 days at 35°C (78 and 76% respectively in GA-10 and JNC-6).

Among the two sorghum varieties significant reduction in germination was observed in cultivarCSV-15at 75% RH and 35°Ctemperature after 30, 60 and 90 days of storage. In lentil also both the varieties registered significant decrease in germination, when stored at these conditions. Storage at 95% RH and 35°Cfor 20 days resulted in drastic fall in the germinability of both the varieties of sorghum as well as lentil. In sorghum, CSV-15 performed better maintaining 82% germination after 20 days of storage while CSV-216R was poorer with viability dropping to 50%. In lentil variety L-4578 was a better storer with final germination at 66% than L-4076 where the germination declined to 50% after 20 days of storage. In general, higher viability was maintained in both the cultivars of all three-crop seeds when stored at other humilities and temperatures.

Seed viability and vigour are related to the genetic constitution and the capacity of the cultivar to withstand ageing conditions (Anderson and Gupta, 1986). In the present study result of storage over high RH (95 and 75%) and high temperature 35°C only resulted in significant decline in germination per cent. Out of the three crops, however niger proved to be more resistant to adverse environmental condition than sorghum and lentil. This could be due to lower EMC of niger seeds stored for a period of 20 days even at very high RH of 95% (9.8-10.57%), but when stored over 75% RH, JNC-6 recorded maximum decline in viability after 90 days storage (68.67%). In sorghum and lentil, the EMC was in the range of 14.4-15.7 and 13.4-15.1 respectively due to which the degree of deterioration was very high when stored at 35°C. Reduced viability due to storage at unfavorable environments has been reported by other workers also (Byrd and Delouche 1991, Priestly and Leopold 1979, Pukacka and Kuiper 1988, Lin and Pearce 1990).

Vigour Index:

The initial vigour index was maximum in the untreated seeds for all the crops and cultivars. The effect of high RH was very drastic on all the crops, while at low and very low RH, the decrease in vigour index was at par with control. After 90 days of storage all the varieties recorded a significant decrease in vigour index, at all RH. Maximum decline was recorded in sorghum (CSV-216R) at 75% RH, when compared to control (Table 3a and 3b). Irrespective of the proximate composition of the seed, storage at higher RH (50%, 75% and 95%) and higher temperature (35°C) resulted in faster rate of vigour loss (Table 3a and 3b). Similar observations have been reported by Abba and Lovato (1999) for maize, Suma *et al.* (2013) in different species of Brassica and Srinivasan*et al.* (1999) in mustard seeds. Seeds stored at high moisture content manifested increased respiration, heating, and fungal invasion resulting in reduced seed vigour and viability (Jyoti and Malik, 2013). Differences in the initial vigour between cultivars and crops could have been responsible for differential loss of vigour and viability.

Electrical Conductivity:

The electrical conductivity testis a sensitive test which can be relied upon as a useful indicator of seed viability and vigour loss. In all the crops and cultivars, used in the present study, increase in the EC value was recorded with decrease in the seed quality expressed in terms of germination and vigour index. However, the highest EC value (665.43) was recorded for niger variety GA-10 stored at 35°C and 95%RH for 20 days while minimum EC value was recorded for sorghum variety CSV-216R stored for a similar period at similar conditions. The changes in the EC values due to storage at various combinations of temperature and RH is depicted in the Tables 4a and 4b. Such extreme differences could have been due to the differences in the major storage components of the two kinds of seeds as well as the genotypic effect. A chain of physiological events occurs during seed aging long before the viability is lost. It starts with the degradation of membranes leading to an increase in the amount of cell leachates (Khan *et al.*, 2003). Similar increases in electrical conductivity of seed steep water has been reported by Hampton and Tekrony (1995) in onion and Lee *et al.* (1995) in various vegetable seeds. Faster decline in seed germination and seedling vigour was found to be associated with grater electrolyte leakage and production of volatile aldehydes during deterioration in storage (Shanmughavel *et al.,* 1995). Loss of viability in pigeonpea cultivars was accompanied by increased leaching of solutes (Kalpana and Rao, 1996).

4. Conclusions

The study established the fact that at any given RH and temperature seeds rich in oil content will maintain lower seed moisture content than those which are rich in other storage components viz carbohydrates in sorghum and proteins in lentil. Be it any kind of seed, high RH(95%) and high temperature (35°C) are detrimental for seed storage which has been convincingly proved by the present study although differences between crops and cultivars was evident.

Table 1. *Equilibration moisture content at various levels of humidities and different temperature on wet. Weight basis in Niger, Sorghum and Lentil.*

RH	Moisture content (%)		
	10°C	Ambient	35°C
GA-10			
Control	4.15	4.15	4.15
75% (NaCl)	9.22	8.05	6.67
50%$Ca(NO_3)_2$	7.40	6.83	5.46
33% ($MgCl_2$)	5.06	4.57	4.05
5.5% ($ZnCl_2$)	3.57	2.62	2.29
95% (KNO_3)	12.66	10.91	10.57
JNC-6			
Control	4.36	4.36	4.36
75% (NaCl)	8.11	7.96	7.28
50%$Ca(NO_3)_2$	6.33	5.57	5.45
33% ($MgCl_2$)	5.06	4.31	4.18
5.5% ($ZnCl_2$)	3.48	2.48	2.18
95% $(KNO)_3$	12.22	10.17	9.80
CSV-15			
Control	9.97	9.46	9.46
75% (NaCl)	12.77	10.30	8.80
50%$Ca(NO_3)_2$	10.72	8.38	7.59
33% ($MgCl_2$)	7.55	6.31	5.13
5.5% ($ZnCl_2$)	6.41	4.27	3.97
95% (KNO_3)	16.56	16.06	15.72
CSV-216R			
Control	9.36	9.36	9.36
75% (NaCl)	11.83	9.50	8.60
50%$Ca(NO_3)_2$	10.90	7.41	7.19
33% ($MgCl_2$)	7.84	6.37	5.20
5.5% ($ZnCl_2$)	6.50	4.51	3.88
95% $(KNO)_3$	17.66	16.43	14.43
L-4076			
Control	9.52	9.50	9.52
75% (NaCl)	15.30	14.53	13.99
50%$Ca(NO_3)_2$	11.52	9.60	8.15
33% ($MgCl_2$)	9.65	8.52	7.77
5.5% ($ZnCl_2$)	6.53	4.60	4.32
95% (KNO_3)	18.31	17.02	15.11
L-4578			
Control	8.33	8.33	8.33
75% (NaCl)	14.54	13.44	13.15
50%$Ca(NO_3)_2$	10.77	8.78	6.36
33% ($MgCl_2$)	8.33	8.57	7.34
5.5% ($ZnCl_2$)	6.53	4.57	4.43
95% (KNO_3)	17.67	16.54	13.47
Source		CD at 5%	
RH		0.20	
Variety (V)		0.20	
RH x V		0.50	
Temp.		0.14	
Temp. x RH		0.35	
Temp. x V		0.35	
RH x V x Temp.		0.86	

Table 2a. *Effect of storage condition on germination (%) in Niger, Sorghum and Lentil.*

RH	Storage period (days)								
	30 Days			60 Days			90 Days		
	10°C	Ambient	35°C	10°C	Ambient	35°C	10°C	Ambient	35°C
GA-10									
Control	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 90.05)
75% (NaCl)	100.00 (90.05)	93.33 (75.07)	92.00 (73.61)	96.00 (78.50)	93.00 (74.70)	90.00 (71.60)	93.33 (75.07)	92.00 (73.61)	86.00 (68.06)
50%$Ca(NO_3)_2$	98.00 (81.91)	98.00 (81.91)	94.67 (76.69)	96.00 (78.50)	95.33 (77.56)	92.00 (73.61)	92.67 (74.33)	88.67 (70.37)	88.33 (70.060
33% ($MgCl_2$)	98.67 (83.42)	98.00 (81.91)	98.67 (83.42)	98.00 (81.91)	98.00 (81.91)	96.67 (79.53)	96.00 (78.50)	97.33 (80.64)	93.33 (75.070
5.5% ($Zncl_2$)	100.00 (90.05)	100.00 (90.05)	94.00 (75.86)	98.67 (83.42)	97.00 (80.07)	97.00 (80.07)	96.00 (78.50)	96.00 (78.50)	93.00 (74.70)
JNC-6									
Control	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)
75% (NaCl)	92.00 (73.61)	91.33 (72.91)	86.00 (68.06)	91.33 (72.91)	92.00 (73.61)	84.00 (72.25)	90.67 (72.25)	85.33 (67.51)	68.67 (55.99)
50%$Ca(NO_3)_2$	94.00 (75.86)	95.33 (77.56)	92.00 (73.61)	92.00 (73.61)	94.00 (75.86)	92.67 (73.61)	92.00 (73.61)	91.33 (72.91)	92.67 (74.33)
33% ($MgCl_2$)	98.00 (81.91)	94.00 (75.86)	98.00 (81.91)	96.00 (78.50)	92.00 (73.61)	90.00 (73.61)	92.00 (73.61)	95.00 (77.12)	92.00 (73.61)
5.5% ($Zncl_2$)	98.00 (81.91)	94.00 (75.86)	98.00 (81.91)	96.00 (78.50)	92.33 (73.96)	92.67 (74.33)	92.67 (74.33)	92.00 (73.61)	92.00 (73.61)
CSV-15									
Control	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.08)	100.00 90.05)
75% (NaCl)	96.67(79.53)	96.00 (78.50)	90.33 (71.92)	96.67 (79.53)	96.00 (78.50)	90.00 (71.60)	90.33 (71.92)	90.00 (71.60)	88.00 (69.77)
50%$Ca(NO_3)_2$	96.67 (79.53)	96.67 (79.53)	91.33 (72.91)	97.33 (80.64)	95.33 (77.56)	92.00 (73.61)	92.67 (74.33)	92.67 (74.33)	88.33(70.060)
33% ($MgCl_2$)	98.00 (81.91)	96.00 (78.50)	92.00 (73.61)	96.67 (79.53)	94.00 (75.86)	94.67 (76.69)	94.00 (75.86)	94.00 (75.86)	90.67 (72.25)
5.5% ($Zncl_2$)	97.33 (80.64)	98.00 (91.81)	94.00 (75.86	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	94.00 (75.86)	92.00 (73.61)	92.00 (73.61)
CSV-216R									
Control	99.33 (85.35)	99.33 (85.35)	99.33 (85.35)	99.33 (85.35)	99.33 (85.35)	99.33 (85.35)	99.33 (85.35)	99.33 (85.35)	99.33 (85.35)
75% (NaCl)	94.33 (76.26)	92.67 (74.33)	90.67 (72.25)	90.67 (72.25)	90.67 (72.25)	90.00 (71.60)	90.67 (72.25)	92.67 (74.33)	90.67 (72.25)
50%$Ca(NO_3)_2$	94.33 (76.26)	94.00 (75.86	94.00 (75.86)	97.33 (80.64)	90.67 (72.25)	90.00 (71.60)	93.33 (75.07)	92.00 (73.61)	92.00 73.361)
33% ($MgCl_2$)	95.33 (77.56)	96.00 (78.50	91.33 (72.91)	94.67 (76.69)	92.00 (73.61)	92.00 (73.61)	96.67 (79.53)	97.33 (80.64)	93.33 (75.07)
5.5% ($Zncl_2$)	96.00 (78.50)	98.00 (81.91	92.00 (73.61)	97.33 (80.64)	94.00 (75.86)	94.00 (75.86)	94.00 (75.86)	97.00 (80.07)	94.00 (75.86)
L-4076									
Control	97.33 (80.64)	97.33 (80.64)	97.33 (80.64)	97.33 (80.64)	97.33 (80.64)	97.33 (80.64)	97.33 (80.64)	97.33 (80.64)	97.33 (80.64)
75% (NaCl)	92.67 (74.33)	91.33 (72.91)	89.33 (79.97)	90.00 (71.60)	89.33 (70.97)	88.00 (69.77)	88.67 (70.37)	89.33 (70.97)	76.00 (60.70)
50%$Ca(NO_3)_2$	93.33 (75.07)	94.67 (76369)	91.33 (72.91)	90.67 (72.25)	92.00 (73361)	90.00 (71.60)	89.67 (71.29)	89.33 (70.97)	89.33 (70.97)
33% ($MgCl_2$)	92.00 (73.61)	96.00 (78.50)	94.00 (75.86)	90.33 (71.92)	91.00 (72.58)	93.33 (75.07)	94.33 (76.28)	91.00 (72.58)	90.00 (71.60)
5.5% ($Zncl_2$)	96.00 (78.50)	96.00 (78.50)	91.33 (72.91)	94.00 (75.86)	92.00 (73.61)	88.00 (69.77)	90.67 (72.25)	92.00 (73.61)	90.67 (72.25)
L-4578									
Control	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)
75% (NaCl)	94.00 (75.86)	92.00 (73.61)	90.00 (71.60)	89.33 (70.97)	87.00 (68.90)	87.00 (68.90)	87.33 (69.18)	88.67 (70.37)	80.33 (63.70)
50%$Ca(NO_3)_2$	94.00 (75.86)	94.00 (75.83)	93.33 (75.07)	92.67 (74.33)	88.00 (69.77)	88.00 (69.77)	89.67 (71.29)	89.33 (70.97)	89.33 (70.97)
33% ($MgCl_2$)	96.00 (78.50)	96.00 (78.50)	94.00 (75.86)	94.00 (75.86)	92.00 (73.61)	90.00 (71.60)	92.67 (74.33)	90.00 (71.60)	90.00 (71.60)
5.5% ($Zncl_2$)	96.00 (78.50)	96.00 (78.50)	94.67 (76.69)	90.00 (71.60)	90.00 (71.60)	90.00 (71.60)	92.67(74.33)	90.00 (71.60)	90.00 (71.60)
Source		CD at 5%			CD at 5%			CD at 5%	
RH		1.098			1.463			3.218	
Variety (V)		1.098			1.463			3.526	
RH x V		2.689			3.583			7.884	
Temp.		0.776			1.034			2.493	
Temp. x RH		1.901			2.533			5.575	
Temp. x V		1.901			2.254			6.107	
RH x V x Temp.		4.658			6.207			13.656	

Table 2b. *Effect of storage condition on germination (%) in Niger, Sorghum and Lentil.*

RH	Storage period (days)					
	10 Days			20 Days		
	10°C	Ambient	35°C	10°C	Ambient	35°C
GA-10						
Control	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)
95% $(KNO)_3$	94.00(75.86)	94.00 (75.86)	90.00 (71.60)	90.00 (71.60)	88.00 (69.77)	78.00 (62.06)
JNC-6						
Control	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)	98.00 (81.91)
95% (KNO_3)	94.00 (75.86)	94.00 (75.86)	90.00 (71.60)	88.00 (69.77)	86.00 (68.06)	76.00 (60.70)
CSV-15						
Control	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)
95% $(KNO)_3$	98.00 (81.91)	90.00 (71.60)	88.00 (69.77)	86.00 (68.06)	90.00 (71.60)	82.00 (64.93)
CSV-216R						
Control	99.33 (85.35)	99.33 (85.35)	99.33 (85.35)	99.33 (85.35)	99.33 (85.35)	99.33 (85.35)
95% (KNO_3)	94.00 (75.86)	92.00 (73.61)	90.00 (71.35)	92.00 (73.61)	88.00 (69.74)	50.00 (45.35)
L-4076						
Control	93.33 (75.07)	93.33 (75.07)	93.33 (75.07)	93.33 (75.07)	93.33 (75.07)	93.33 (75.07)

RH	Storage period (days)					
	10 Days			20 Days		
	10°C	Ambient	35°C	10°C	Ambient	35°C
95% (KNO_3)	92.00 (73.61)	90.00 (71.60)	88.00 (69.77)	90.00 (71.60)	84.00 (66.46)	50.00 (45.02)
L-4578						
Control	96.00 (78.50)	96.00 (78.50)	96.00 (78.50)	96.00 (78.50)	96.00 (78.50)	96.00 (78.50)
95% (KNO_3)	94.00 (75.86)	90.00 (71.60)	89.00 (70.67)	92.00 (73.61)	80.00 (63.47)	66.00 (54.36)
Source		CD at 5%			CD at 5%	
RH		1.37			1.07	
Variety (V)		1.94			1.51	
RH x V		3.37			2.62	
Temp.		1.12			0.87	
Temp. x RH		1.94			1.51	
Temp. x V		2.75			2.14	
RH x V x Temp.		4.77			3.71	

Table 3a. *Effect of storage condition on the vigour index in Niger, Sorghum and Lentil.*

RH	Storage period (days)								
	30 Days			60 Days			90 Days		
	10°C	Ambient	35°C	10°C	Ambient	35°C	10°C	Ambient	35°C
GA-10									
Control	2,136	2136	2136	2136	2136	2,136	2,136	2,136	2,136
75% (NaCl)	1,885	1801.26	1817	1972	1,6461	1,417.5	1,866.6	1,495.92	1,012.22
50%$Ca(NO_3)_2$	1849	1860.04	1841.33	1933.32	1758.8	1,771.92	1902.51	1,772.51	1,537.82
33% ($MgCl_2$)	1990.17	1957.06	1905.31	1964.51	1,814.96	1,920	2,002.56	1,814.23	1,742.47
5.5% ($ZnCl_2$)	2,011	2040	1796.34	1968	1909.33	1,921.57	1,798	1,738.56	1,700.97
JNC-6									
Control	1,968.82	1968.82	1968.82	1,968.82	1,968.82	1968.82	1968.82	1968.82	1968.82
75% (NaCl)	1,804.12	1790.98	1389.76	1738	1,732.36	1,076.04	1,716.38	1,320.36	622.15
50%$Ca(NO_3)_2$	1,802.92	1813.17	1713.04	1848.96	1,817.96	1,730.143	1,882.32	1,537.99	1,601.33
33% ($MgCl_2$)	1,996.26	1895.00	1925.7	1960.32	1,771	1,672.2	1,788.48	1,819.25	1,726.84
5.5% ($ZnCl_2$)	1,936.48	1854.62	1932.56	2237	1883.532	1,840.42	1,856.18	1,576.88	1,746.16
CSV-15									
Control	2,405	2,405	2,405	2,405	2,405	2,405	2,405	2,405	2,405
75% (NaCl)	2,244.67	1892.16	1271.84	1970	1,5024	1,2402	1,737.04	1,301.4	1,107.92
50%$Ca(NO_3)_2$	2,243.7	2268.84	1878.95	2006	1943.77	1,737.88	1,883.98	1,733.8	1,533.40
33% ($MgCl_2$)	2,326.52	2151.36	1913.6	1960.46	1967.42	1,869.66	2,020.06	1,816.08	1,745.39
5.5% ($ZnCl_2$)	2,162.67	2267.72	2047.32	2318	2,241.26	2,151.1	1,951.44	1,880.48	1,764.56
CSV-216R									
Control	2,328.29	2328.29	2328.29	2,328.29	2,328.29	2,328.29	2328.29	2328.29	2328.29
75% (NaCl)	2,192.22	1784.82	1033.63	2,079.96	1,578.69	856.8	1,945.77	1,368.96	818.75
50%$Ca(NO_3)_2$	2,177.13	2050.14	2122.52	2144.17	1,632.96	1,828.8	1,981.39	1,786.64	1,6284
33% ($MgCl_2$)	1,973.33	2003.52	1918.84	2,095.04	1,890.6	1,794	2,057.13	1,859.97	1,695.8
5.5% ($ZnCl_2$)	2,201.28	2192.26	2140	2260.00	2,094.44	2,136.62	2,236.26	2,1243	2,074.58
Control	2050.74	2050.74	2050.74	2,050.74	2,050.74	2,050.74	2050.74	2050.74	2050.74
75% (NaCl)	1658.79	1697.82	1433.74	1,622.7	1,439.99	1,334.96	1,493.20	1,290.81	919.6
50%$Ca(NO_3)_2$	1765.80	1829.02	1705.13	1,747.21	1,68.36	1,620.9	1,588.05	1,472.15	1,4248
33% ($MgCl_2$)	188.76	1907.52	1852.74	1,622.7	1629.81	1,875.93	1,871.50	1,610.7	1,644.3
5.5% ($ZnCl_2$)	1899.84	1970.88	1847.60	1,980.99	1,826.2	1,838.57	1,861.45	1,748	1,654.7
L-4578									
Control	2042.32	2042.32	2042.32	2043.32	2043.32	2043.32	2043.32	2043.32	2043.32
75% (NaCl)	1727.72	1633.92	1332	1,755.16	1,552.08	1,252.8	1,539.62	1,375.27	992.07
50%$Ca(NO_3)_2$	1774.72	1802.92	1708.87	1739	1,690.48	1,680.8	1,667.86	1,699.2	1,407.84
33% ($MgCl_2$)	1886.4	1864.08	1708.92	1789.76	1,732.36	1.720.8	1,782.04	1,699.2	1,679.4
5.5% ($ZnCl_2$)	1927.68	1890.24	1762.75	1818	1,724.44	1,665	1,845.98	1,7271	1,437.3
Source		CD at 5%			CD at 5%			CD at 5%	
RH		43.4			36.95			42.75	
Variety (V)		43.4			36.99			46.50	
RH x V		106.31			90.60			103.99	
Temp.		30.69			26.15			32.88	
Temp. x RH		75.17			64.06			73.53	
Temp. x V		75.17			64.06			80.85	
RH x V x Temp.		184.14			156.94			180.13	

Table 3b. *Effect of storage condition on the vigour index in Niger, Sorghum and Lentil.*

RH	Storage period (days)					
	10 Days			20 Days		
	10°C	Ambient	35°C	10°C	Ambient	35°C
GA-10						
Control	2136	2136	2136	2136	2136	2136
95% (KNO_3)	1881.88	1697.64	1690	1632.6	1738.8	1503.04
JNC-6						
Control	1968.82	1968.82	1968.82	1968.82	1968.82	1968.82
95% (KNO_3)	1660.04	1617.74	1382.4	1434.4	1382.02	1038.92
CSV-15						
Control	2405	2405	2405	2045	2045	2045
95% (KNO_3)	2198.14	1670	1,189.76	1438	1483	1029
CSV-216R						
Control	2328.29	2328.29	2328.29	2328.29	2328.29	2328.29
95% (KNO_3)	2015.36	1351.48	877.5	1342	1350	354
L-4076						
Control	1966.46	1966.46	1966.46	1966.46	1966.46	1966.46
95% (KNO_3)	1771.92	1858	1538.24	1687.5	1484.28	505
L-4578						
Control	2000.64	2000.64	2000.64	2000.64	2000.64	2000.64
95% (KNO_3)	1779.42	1702.8	1659.85	1681.76	1568.8	732.6
Source		CD at 5%			CD at 5%	
RH		43.4			36.95	
Variety (V)		43.4			36.99	
RH x V		106.31			90.60	
Temp.		30.69			26.15	
Temp. x RH		75.17			64.06	
Temp. x V		75.17			64.06	
RH x V x Temp.		184.14			156.94	

Table 4a. *Effect of storage condition on the electrical conductivity in Niger, Sorghum and Lentil.*

RH	Storage period (days)								
	30 Days			60 Days			90 Days		
	10°C	Ambient	35°C	10°C	Ambient	35°C	10°C	Ambient	35°C
GA-10									
Control	363.07	363.07	363.07	363.07	363.07	363.07	363.07	363.07	363.07
75% (NaCl)	421.35	497.62	507.58	459.92	552.25	594.13	481.18	548.09	608.27
50% $Ca(NO_3)_2$	399.60	433.63	488.86	407.63	471.61	475.83	464.18	499.15	488.79
33% ($MgCl_2$)	370.62	382.32	417.47	379.53	421.57	438.80	409.76	426.85	462.79
5.5% ($ZnCl_2$)	369.70	375.54	359.73	377.79	357.11	387.05	388.73	384.45	424.67
JNC-6									
Control	283.85	283.85	283.85	283.85	283.85	283.85	283.85	283.85	283.85
75% (NaCl)	314.71	326.29	353.57	372.66	412.49	462.12	392.00	463.32	584.80
50% $Ca(NO_3)_2$	297.84	306.48	341.37	261.27	404.26	424.38	405.51	415.80	491.30
33% ($MgCl_2$)	290.12	293.37	320.09	244.84	351.17	384.80	337.70	390.84	419.41
5.5% ($ZnCl_2$)	285.23	287.91	315.85	296.97	320.25	340.13	316.40	359.73	361.70
CSV-15									
Control	99.24	99.24	99.24	99.24	99.24	99.24	99.24	99.24	99.24
75% (NaCl)	126.61	139.12	217.19	144.09	149.07	230.74	156.13	193.46	246.83
50% $Ca(NO_3)_2$	119.12	124.79	134.94	118.70	129.10	138.41	143.37	146.48	149.48
33% ($MgCl_2$)	102.09	120.30	124.59	102.00	121.34	155.61	138.67	140.33	150.67
5.5% ($ZnCl_2$)	100.13	105.57	121.94	100.31	120.05	150.62	135.67	137.97	148.81
CSV-216R									
Control	50.36	50.36	50.36	50.36	50.56	50.36	50.36	50.36	50.36
75% (NaCl)	67.39	74.97	83.43	72.29	86.14	99.54	85.80	100.59	136.80
50% $Ca(NO_3)_2$	64.87	69.30	71.16	69.86	75.47	84.73	94.78	99.82	100.79
33% ($MgCl_2$)	64.34	58.23	57.03	61.48	72.59	83.38	90.00	93.45	98.78
5.5% ($ZnCl_2$)	50.69	56.94	55.38	60.76	60.94	72.11	80.56	81.73	82.09
L-4076									
Control	265.02	265.02	265.02	265.02	265.02	265.02	265.02	265.02	265.02
75% (NaCl)	393.47	426.05	492.24	434.13	446.65	517.98	512.19	581.57	610.79
50% $Ca(NO_3)_2$	386.80	393.01	394.69	393.49	427.64	434.41	402.60	433.94	520.23
33% ($MgCl_2$)	349.26	356.52	367.27	384.81	396.09	411.36	392.19	420.94	496.33
5.5% ($ZnCl_2$)	269.26	269.80	320.17	366.31	395.16	400.31	387.73	402.11	451.50
L-4578									
Control	207.69	207.69	207.69	207.69	207.69	207.69	207.69	207.69	207.69

RH	Storage period (days)								
	30 Days			60 Days			90 Days		
	10°C	Ambient	35°C	10°C	Ambient	35°C	10°C	Ambient	35°C
75% (NaCl)	251.17	350.44	283.66	350.70	358.72	429.73	451.53	483.00	529.37
50% $Ca(NO_3)_2$	236.16	250.34	342.93	263.24	279.40	360.26	368.41	378.57	386.68
33% ($MgCl_2$)	220.00	249.73	262.77	258.35	262.11	273.92	259.30	277.57	291.11
5.5% ($ZnCl_2$)	212.03	238.78	256.25	226.72	239.46	269.11	244.31	275.57	301.68
Source		CD at 5%			CD at 5%			CD at 5%	
RH		8.484			7.995			7.926	
Variety (V)		9.294			8.758			8.682	
RH x V		20.782			19.583			19.414	
Temp.		6.572			6.193			6.319	
Temp. x RH		14.695			13.847			13.727	
Temp. x V		16.097			15.169			15.038	
RH x V x Temp.		35.995			33.919			33.625	

Table 4b. *Effect of storage condition on the electrical conductivity in Niger, Sorghum and Lentil.*

RH	Storage period (days)					
	10 Days			20 Days		
	10°C	Ambient	35°C	10°C	Ambient	35°C
GA-10						
Control	363.07	363.07	363.07	363.07	363.07	363.07
95% (KNO_3)	376.12	401.00	560.44	471.74	479.09	665.43
JNC-6						
Control	283.85	283.85	283.85	283.85	283.85	283.85
95% (KNO_3)	303.76	320.00	376.12	324.85	382.23	394.89
CSV-15						
Control	99.24	99.24	99.24	99.24	99.24	99.24
95% (KNO_3)	120.00	143.84	139.02	149.68	158.67	202.58
CSV-216R						
Control	50.36	50.36	50.36	50.36	50.36	50.36
95% (KNO_3)	66.70	98.67	151.78	86.61	126.83	172.47
L-4076						
Control	265.02	265.04	265.04	265.02	265.04	265.04
95% (KNO_3)	280..57	288.03	398.76	324.70	344.80	568.57
L-4578						
Control	207.69	207.69	207.69	207.69	207.69	207.69
95% (KNO_3)	220.90	248.39	389.14	257.67	279.17	500.89
Source		CD at 5%			CD at 5%	
RH		6.028			7.314	
Variety (V)		10.440			12.667	
RH x V		14.765			17.915	
Temp.		7.382			8.957	
Temp. x RH		10.440			12.667	
Temp. x V		18.083			21.941	
RH x V x Temp.		25.573			31.029	

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