RESEARCH ARTICLE Legume Research- An International Journal, Volume 44 Issue 5: 562-567 (May 2021)

Effect of Integrated Nutrient Management on Seed Vigour Potential of Fenugreek (*Trigonella foenum-graecum* L.) during Ambient Storage

Ovais Hamid Peerzada, V.S. Mor, O.S. Dahiya

10.18805/LR-4124

ABSTRACT

The experiment was conducted at Department of Seed Science & Technology CCS, Haryana Agriculture University, Hisar, Haryana from 2013-15 and comprised of seventeen treatment combinations of manures (*viz*., FYM and Vermicompost), bio-fertilizers (*viz*., Rhizobium & PSB) and fertilizers. The freshly harvested fenugreek seeds of all the seventeen treatment plot combinations were stored in plastic containers under ambient conditions up to a period of eighteen months. Seed quality was assessed at a regular interval of six months. A significant decline in seed quality was observed in all the nutrient combinations as the period of ageing increased. It was observed that the treatment combination of Rhizobium and PSB along with 75% Recommended Dose of Nitrogen (RDN) recorded significantly higher germination % (87.33%), seedling length (24.77 cm), dry weight (7.5 mg), vigour index-I (2163) and vigour index-II (657) followed by PSB with 100% RDN and Rhizobium with 100% RDN after eighteen months of ambient storage as compared to control. The electrical conductivity (333 µS $cm^{-1}g^{-1}$) was also recorded minimum in the treatment Rhizobium and PSB along with 75% RDN followed by PSB with 100% RDN and Rhizobium with 100% RDN after the period of ambient storage while the maximum was recorded in control. The study highlighted that the slightly reduced dose of inorganic nitrogen was best when applied in combination with bio-fertilizer (Rhizobium+PSB) for maximizing the storage potential of fenugreek seed as compared to the rest of treatments.

Key words: FYM, PSB, RDN, Rhizobium, Vermicompost.

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) belongs to the family Fabaceae and is an important seed spice crop. In India, it is mainly grown in Rajasthan, Gujarat, Madhya Pradesh, Maharashtra and Haryana. The seeds of fenugreek are used as a condiment and seasoning agent for garnishing and flavouring dishes. Being a leguminous crop, the root nodules enrich the soil with the fixing of atmospheric nitrogen.

India has made a spectacular breakthrough in production and consumption of fertilizers during the last four decades. But use of non-renewable form of energy, *i.e.* chemical fertilizers will be quite a limiting factor of agricultural production in future. Because of escalating energy cost, chemical fertilizers are not available at affordable price to the farmers. Moreover, the imbalance and continuous use of chemical fertilizers has adverse effect on soil physical, chemical and biological properties thereby affecting the sustainability of crop production, besides causing environmental pollution (Virmani, 1994).

Chemical fertilizers, although, are sufficient for nutritional requirement of crop, but their continuous usage leads to nutrient exhaustion which is a matter of concern for sustainability of agriculture and therefore it is essential to reduce dependency on chemical fertilizers and promote the use of organics but organics contain less nutrients and hence does not result in better yields. (Subba Rao and Tilak, 1977). The organic matter being the store–house of nutrients, the combined application of organic and inorganic fertilizer can increase the yield, improve the fertility status of soil, improve the input-use efficiency by the crop and can certainly cut down the expenditure on costly fertilizers (Lakshminarayana and Sharma, 2015).

The seed is an important component of agricultural production and industry in India. The quality seed plays important role in agricultural production as well as in national economy. Therefore, the good quality seed is necessary to enhance production and productivity. Availability of viable and vigorous seed at the planting time is important for achieving targets of agricultural production because good quality seed acts as a catalyst for realizing the full potential of other inputs. Since the total cultivable area is decreasing and population is growing, thus improvement in agricultural

Department of Seed Science and Technology, CCS Haryana Agriculture University, Hisar-125 004, Haryana, India.

Corresponding Author: Ovais Hamid Peerzada, Department of Seed Science and Technology, CCS Haryana Agriculture University, Hisar-125 004, Haryana, India. Email: ovaishamid786@gmail.com

How to cite this article: Peerzada, O.H., Mor, V.S. and Dahiya, O.S. (2021). Effect of Integrated Nutrient Management on Seed Vigour Potential of Fenugreek (*Trigonella foenum-graecum* L.) during Ambient Storage. Legume Research 44(5): 562-567. DOI: 10.18805/LR-4124.

Submitted: 30-01-2019 **Accepted:** 08-11-2019 **Online:** 17-02-2020

productivity is the only option. Use of quality seeds increased productivity of crop by 15-20% (Sidhwani, 1991).

Seed possesses maximum viability and vigour at physiological maturity Meena *et al*. (1994) thereafter, seeds show gradual ageing and decline in viability and vigour. Seed deterioration leads to a reduction in seed quality, performance and stand establishment which is a major problem in agriculture production (Chiristiansen and Rowland, 1981). Temperature and relative humidity are the main factors influencing seed deterioration and viability loss in storage Barton (1964), James (1964) and Roberts (1972). Lower temperature and humidity result in delayed seed deteriorative process and ageing thereby leads to extended viability period. Seed ageing is generally marked by reduction in vigour Trawatha *et al.,* 1995; Saxon *et al.,* 1987), viability, rate and capacity of germination (Arefi and Abedi, 2003), increased solute leakage (Basra *et al.* 2003) and susceptibility to stresses and reduced tolerance for storage under adverse conditions (Duffs and Slaughter, 1980).

Seed ageing causes gradual decline in all vital cellular components which leads to progressive loss of viability. Lipid auto-oxidation, which involve production of free radicals has also been suggested to be one of the causes of seed ageing (Willson and McDonald, 1986).Therefore, effective management of viability and vigour of seed is important to tackle these problems and to avoid any serious threat to agriculture.

MATERIALS AND METHODS

The research experiment was conducted during 2013-15 at the laboratories of Department of Seed Science and Technology CCS Haryana Agriculture University, Hisar, Haryana. The freshly harvested seeds of the fenugreek variety “Hisar Suvarna” were stored in plastic containers under ambient conditions for a period of eighteen months. The seeds of each treatment plot were sampled at an interval of six months and evaluated for seed quality parameters in a completely randomized design (CRD). The biofertilizers Rhizobium and Phosphorous Solubilizing Bacteria (PSB) were used as seed treatment @10 ml/10 kg of seed while Farm Yard Manure (FYM) and vermicompost were used @ 20 t/ha and 5 t/ha respectively. The recommended dose of fertilizers (RDF- 25 kg N + 40 kg P_2O_5 + 0 kg K_2O per ha) was applied to the plots as per the treatment details in the form of urea, diammonium phosphate and muriate of potash. The samples were analyzed for key characters *viz*. germination %, seedling length, dry weight, vigour index-I, vigour index-II and electrical conductivity. The statistical analysis was carried out as per the methods suggested by (Panse and Sukhatme, 1985).

List of treatment combinations:

T_0 : Control
T_1 : Rhizobium + 20 t/ha FYM
T_2 : Rhizobium + 15 t/ha FYM
T_3 : Rhizobium + 5 t/ha Vermicompost
T_4 : Rhizobium + 3.75 t/ha Vermicompost
T_5 : Rhizobium + 100% RDN
T_6 : Rhizobium + 75% RDN
T_7 : PSB + 20 t/ha FYM
T_8 : PSB +15 t/ha FYM
T_9 : PSB + 5 t/ha Vermicompost
T_{10} : PSB + 3.75 t/ha Vermicompost
T_{11} : PSB + 100% RDN
T_{12} : PSB + 75% RDN
T_{13} : Rhizobium + PSB + 15 t/ha FYM
T_{14} : Rhizobium + PSB + 3.75 t/ha Vermicompost
T_{15} : Rhizobium + PSB + 75% RDN
T_{16} : NPK (25:40:0 kg/ha)

The following parameters were tested on the seed obtained from the above treatments after adopting standard seed production and post-production practices.

Germination (%)

One hundred seeds obtained from each treatment plot in three replicates were placed in between sufficient moistened rolled towel papers (BP) and kept at 20°C in seed germinator. The first count was taken on 5th day and final count on 14th day and only normal seedlings and hard seeds were considered for percent germination according to the rules of International Seed Testing Association. ISTA (2011).

Seedling length (cm)

Seedling length was measured on 10 randomly selected normal seedlings taken from three replications of standard germination test and average of 10 seedlings was recorded in centimeter for final calculation.

Dry weight (mg)

Seedling dry weight was assessed after the final count in the standard germination test (14 days). The 10 seedlings of each treatment replicated thrice were taken. Seedlings were dried in a hot air oven for 24 h at 80±1°C. The dried seedlings of each replication were weighed and average seedling dry weight of each treatment was calculated.

Vigour index I and II

Seedling vigour indices were calculated according to the method suggested by (Abdul-Baki and Anderson, 1973).

I. Vigour index-I (on seedling length basis):

Vigour index–I = Standard germination (%) × Average seedling length (cm)

II. Vigour index–II (on seedling dry weight basis):

Vigour index–II = Standard germination (%) × Average seedling dry weight (g)

Electrical conductivity test (μS $cm^{-1}g^{-1}$)

To measure the electrical conductivity, 50 normal and uninjured seeds in three replications were soaked in 75 ml deionized water in 100 ml beakers. Seeds were immersed completely in water and beakers were covered with foil. Thereafter, these samples were kept at 25°C for 24 h. The electrical conductivity of the seed leachates was measured

using a direct reading conductivity meter. The conductivity was expressed in µS/cm/ gram.

RESULTS AND DISCUSSION

Deterioration of seed quality and longevity during storage are well known. However, the extent of losses is governed by a number of internal and external factors. Relative humidity and temperature are the major factors which are known to influence the seed quality during storage. Seed moisture content and temperature also influences storability through its influence on growth, activity and reproduction of storage molds and insects (Delouche, 1968).

The present investigation is an effort made to determine the effect of organic manures, inorganic fertilizers and biofertilizers on seed quality of fenugreek during natural ageing at ambient storage. This effort will provide an understanding of the role of fertilizers applied during crop growth, on seed quality and its storability.

In the present study, standard germination percentage showed a significant decline after six, twelve and eighteen months of ambient storage. The maximum decline was recorded after eighteen months of natural storage in all the treatment combinations. However, the maximum germination percentage (87.33) after eighteen months of ambient storage of fenugreek seed was observed in the treatment combination of (T_{15}) *Rhizobium* + PSB + 75% RDN followed by (T_{11}) PSB + 100% RDN (82.33) while minimum (61.67) was observed in control (T_0) where no nutrients were applied (Table 1). The higher germination percentage in T_{15} during the period of natural storage might be because of the better accumulation of food reserves like protein and carbohydrates due to the inoculation of biofertilizers along with nitrogen at the time of seed development. There was decrease in germination percent in all the nutrient combinations because of natural ageing irrespective of treatment leading to seed deterioration and loss in vigour. These results are in accordance with that of Amjad and Arjun (2002), Deepak and Yadav (2014), Singh *et al.* (2015) and Khan *et al.* (2013).

Seedling length and dry weight of all the treatment combinations also showed a significant decrease with the advancement of ageing period and the highest decline in both the characters was observed after eighteen months of natural storage (Table 2). The highest seedling length (24.77 cm) after eighteen months of ambient storage was recorded with the application of (T_{15}) *Rhizobium* + PSB + 75% RDN followed by the application of (T_{11}) PSB + 100% RDN (23.77 cm) while the shortest was recorded in (T_0) control (13.53cm). The perusal of data from Table 2 showed that the highest dry weight after eighteen months of natural ageing was also observed in the treatment combination of *Rhizobium* + PSB + 75% RDN (7.5) followed by the treatment (T_{11}) PSB + 100% RDN (7.2) and the lowest was observed in (T_0) control (3.7). Among all the treatments T_{15} and T_{11} showed better seedling length and dry weight throughout storage This might be due to the accumulation of higher quantities of seed constituents like carbohydrates in the seed due to the nutrition of fenugreek plants by the co-inoculation of Rhizobium and PSB along with inorganic nitrogen and conversion of macromolecules into micromolecules due to release of certain enzymes (Yadav and Khurana, 2003).

Table 1: Effect of integrated nutrient management on standard germination (%) of fenugreek seed stored at ambient condition.

Treatments	Fresh seed	6 months storage	12 months storage	18 months storage
T_0 Control	76.00	73.33	70.67	61.67
T_1 Rhizobium + 20 t/ha FYM	86.00	83.22	79.67	74.00
T_2 Rhizobium + 15 t/ha FYM	85.33	82.00	77.00	72.67
T_3 Rhizobium + 5 t/ha vermicompost	83.00	81.33	76.33	71.00
T_4 Rhizobium + 3.75 t/ha vermicompost	79.67	77.33	74.67	70.00
T_5 Rhizobium + 100% RDN	91.67	86.66	84.00	80.33
T_6 Rhizobium + 75% RDN	89.00	86.22	83.33	79.33
T_7 PSB + 20 t/ha FYM	87.00	83.67	79.00	73.33
T_8 PSB + 15 t/ha FYM	83.33	79.00	76.67	70.33
T_9 PSB + 5 t/ha vermicompost	82.00	78.00	73.67	68.33
T_{10} PSB + 3.75 t/ha vermicompost	78.33	74.67	71.67	65.67
T_{11} PSB + 100% RDN	91.33	89.22	86.33	82.33
T_{12} PSB + 75% RDN	88.00	85.14	81.33	77.33
T_{13} Rhizobium + PSB + 15 t/ha FYM	87.33	83.96	79.33	74.67
T_{14} Rhizobium + PSB + 3.75 t/ha Vermicompost	84.00	81.44	78.00	73.00
T_{15} Rhizobium + PSB + 75% RDN	94.33	91.44	89.67	87.33
T_{16} N:P:K	87.67	84.33	81.00	75.33
Grand mean	85.53	82.40	78.96	73.77
Range	18.33	18.11	19.00	25.66
SE(m)	0.524	0.473	0.42	0.45
CD($p \leq 0.05$)	1.51	1.36	1.21	1.30

Table 2: Effect of integrated nutrient management on seedling length (cm) and Seedling Dry Weight (mg) of fenugreek seed stored at ambient condition.

Treatments	Seedling length (cm)				Seedling Dry weight (mg)			
	Fresh Seed	6 months storage	12 months storage	18 months storage	Fresh Seed	6 months storage	12 months storage	18 months storage
T_0 Control	17.5	16.00	14.57	13.53	4.5	4.3	4.0	3.7
T_1 Rhizobium + 20 t/ha FYM	22.5	20.73	18.90	17.30	7.5	7.2	6.9	6.5
T_2 Rhizobium + 15 t/ha FYM	21.1	19.80	17.50	15.20	7.5	7.1	6.8	6.4
T_3 Rhizobium + 5 t/ha vermicompost	20.6	18.97	17.40	16.40	6.5	6.3	6.2	6.0
T_4 Rhizobium + 3.75 t/ha vermicompost	19.1	17.90	16.37	14.80	6.3	6.0	5.8	5.5
T_5 Rhizobium + 100% RDN	28.1	27.27	24.53	22.40	8.0	7.6	7.4	7.0
T_6 Rhizobium + 75% RDN	26.8	24.97	22.77	21.37	7.7	7.5	7.1	6.7
T_7 PSB + 20 t/ha FYM	21.8	20.67	18.83	17.00	7.2	7.0	6.7	6.3
T_8 PSB + 15 t/ha FYM	20.3	19.20	17.73	16.30	7.1	6.7	6.5	6.0
T_9 PSB + 5 t/ha vermicompost	19.8	18.63	17.20	15.67	6.2	5.9	5.6	5.3
T_{10} PSB + 3.75 t/ha vermicompost	18.5	17.33	16.77	15.33	6.2	5.8	5.5	5.2
T_{11} PSB + 100% RDN	27.3	26.27	25.63	23.77	7.9	7.8	7.6	7.2
T_{12} PSB + 75% RDN	25.2	23.97	21.93	20.37	7.5	7.4	7.3	7.0
T_{13} Rhizobium + PSB + 15 t/ha FYM	24.2	22.73	20.80	19.57	7.1	6.9	6.6	6.3
T_{14} Rhizobium + PSB + 3.75 t/ha vermicompost	23.2	21.80	19.97	18.33	6.9	6.7	6.5	6.0
T^{15} Rhizobium + PSB + 75% RDN	29.4	28.10	26.87	24.77	8.2	8.0	7.8	7.5
T_{16} N:P:K	24.8	23.00	21.77	20.47	7.5	7.3	7.0	6.5
Grand Mean	22.9	21.61	19.97	18.39	7.0	6.8	6.6	6.2
SE(m)	0.256	0.272	0.221	0.237	0.068	0.024	0.033	0.035
Range	11.9	12.1	12.3	11.2	3.7	3.7	3.8	3.8
CD(p≤0.05)	0.74	0.78	0.64	0.68	0.20	0.07	0.10	0.10

Table 3: Effect of integrated nutrient management on Vigour Index-I and Vigour Index-II of fenugreek seed stored at ambient condition.

Treatments	Vigour Index-I				Vigour Index-II			
	Fresh Seed	6 months storage	12 months storage	18 months storage	Fresh Seed	6 months storage	12 months storage	18 months storage
T_0 Control	1330	1173	1029	861	341	312	302	233
T_1 Rhizobium + 20 t/ha FYM	1935	1725	1505	1280	640	600	584	481
T_2 Rhizobium + 15 t/ha FYM	1800	1623	1347	1104	637	581	558	466.
T_3 Rhizobium + 5 t/ha vermicompost	1712	1542	1328	1164	540	512	471	426
T_4 Rhizobium + 3.75 t/ha vermicompost	1521	1441	1221	1036	499	484	429	385
T_5 Rhizobium + 100% RDN	2572	2363	2060	1799	734	658	621	562
T_6 Rhizobium + 75% RDN	2382	2152	1897	1695	685	648	591	531
T_7 PSB + 20 t/ha FYM	1896	1729	1487	1229	626	583	567	454
T_8 PSB + 15 t/ha FYM	1689	1516	1359	1146	588	530	517	423
T_9 PSB + 5 t/ha vermicompost	1620	1453	1267	1070	510	461	446	360
T_{10} PSB + 3.75 t/ha vermicompost	1446	1294	1201	1006	485	433	417	339
T_{11} PSB + 100% RDN	2493	2343	2212	1956	718	695	656	592
T_{12} PSB + 75% RDN	2220	2040	1784	1575	661	625	593	541
T_{13} Rhizobium + PSB + 15 t/ha FYM	2110	1908	1649	1460	619	580	562	467
T_{14} Rhizobium + PSB + 3.75 t/ha vermicompost	1948	1775	1557	1338	579	547	530	441
T_{15} Rhizobium + PSB + 75% RDN	2770	2569	2409	2163	773	734	719	657
T_{16} N:P:K	2174	1939	1763	1541	654	611	597	492
Grand mean	1977	1799	1593	1378	605	565	546	462
SE(m)	24.56	24.4	17.32	18.79	6.35	4.08	13.91	3.31
Range	1440	1396	1380	1302	432	422	417	424
CD(p≤0.05)	70.87	70.43	49.91	54.23	18.33	11.78	40.13	9.57

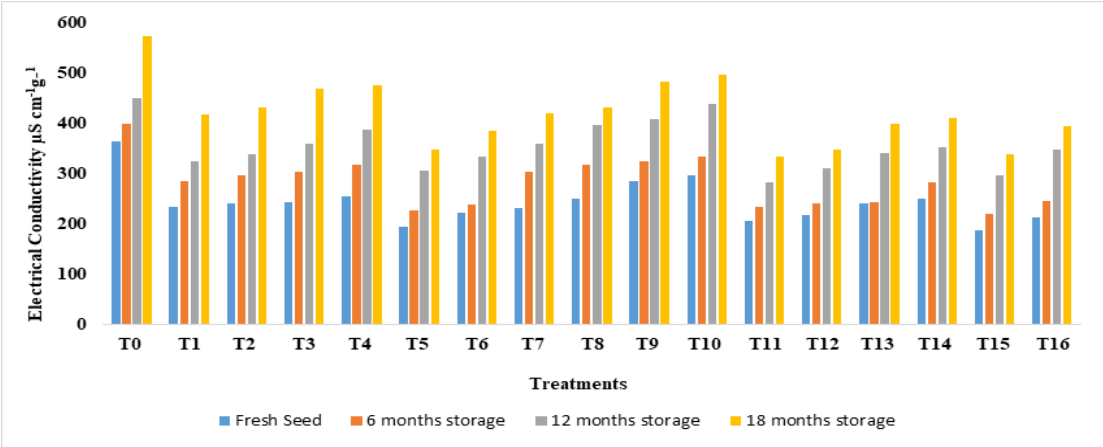

Fig 1: Effect of integrated nutrient management on electrical conductivity (µS $cm^{-1}g^{-1}$) of fenugreek seed stored at ambient condition.

Reduction in seedling length and seedling dry weight during storage may be due to decrease in mobilization of reserve substances during germination of the stored seeds (Dhakal and Pandey, 2001). Ageing led to decrease in seedling length and seedling dry weight which is confirmed with the earlier findings of Kumar and Verma (2008), Verma *et al.* (2003), Singh *et al.* (2003) and Nagarajan *et al*. (2004).

Vigour index -I and Vigour index -II declined significantly with the increase in period of ageing in all the seventeen treatment combinations of fenugreek seed (Table 3). Among treatments, the vigour index-I and II after the eighteen months of natural ageing was maximum (2163, 657) in (T_{15}) *Rhizobium* + PSB + 75% RDN followed by (T_{11}) PSB + 100% RDN (2432, 596) and minimum (861, 233) in (T_0) control respectively. Similar results in fenugreek were reported by Kumar and Verma (2008) and Singh *et al.* (2015).

The change of electrical conductivity during seed soaking is commonly used as an indicator for testing the integrity of plasma membrane (Bewley and Black, 1994). Electrical conductivity (µS/cm/g) of seed leachates increased significantly after ageing in all the treatment combinations of fenugreek (Fig 1). The maximum (572 µS/cm/g) electrical conductivity after eighteen months of ambient storage was recorded in control (T_0) while minimum (333 µS/cm/g) was recorded in the treatment (T_{11}) PSB + 100% RDN followed by T_{15}, *Rhizobium* + PSB + 75% RDN (339). The better performance in T_{11} and T_{15} may be due to the inoculation of biofertilizers along with the inorganic nitrogen which may have increased the cell membrane stability and decreased the leakage of solutes from the seeds because of availability of more nutrients for the growth of plant and seed development which ultimately lead to intact seed coat (Namvar *et al*. 2013). The increase in electrical conductivity during the period of ageing is because of the enhancement of leakage due to alterations in the membranes of aged seeds which led to electrolyte leakage. The loss of membrane integrity due to damage of phospholipids leads to increased membrane permeability and release of electrolytes, aminoacids and enzymes from cells (Zamani *et al.,* 2010). Results were in conformity with the earlier findings of Kumari *et al.* (2014), Kumar and Verma (2008) and Goel *et al.* (2003).

From the above study it was concluded that the treatment combination of Rhizobium and PSB along with 75% Recommended Dose of Nitrogen (RDN) performed best as compared to other treatments in terms of seed quality parameters *viz*., germination%, seedling length, dry weight, vigour index-I and II and electrical conductivity followed by PSB with 100% RDN and rhizobium with 100% RDN after eighteen months of ambient storage. The study highlighted that the slightly reduced dose of inorganic nitrogen was best when applied in combination with bio-fertilizer (Rhizobium + PSB) for maximizing the storage potential of fenugreek seed as compared to the rest of treatments.

REFERENCES

Amjad, M. and Anjum, M.A. (2002). Effect of relative humidity and ageing period on the quality of onion seed. Intern. J. Agric. and Bio. 4: 291-296.

Arefi, H.M. and Abdi, N. (2003). Study of variation and seed deterioration of *Festuca ovina* germplasm in natural resources genebank. Iranian J. Rangelands and Forests Pl. Breeding and Genet. Res. 11: 105-125.

Abdul-Baki, A.A. and Anderson, J.D. (1973). Vigour determination in soybean by multiple criteria. Crop Sci. 10: 31-34.

Barton, L.V. (1964). Seed Preservation and Longevity. Inter-social Publishers, Inc. New York, pp: 138-157.

Basra, S.M.A., Ahmad, N., Khan, M.M., Iqbal, N. and Cheema, M.A. (2003). Assessment of cotton seed deterioration during accelerated ageing. Seed Sci. and Technol. 31: 531-540.

Bewley, J.D. and Black, M. (1994). Seeds, Physiology of Development and Germination, 2nd Edition, New York, Plenum Press, 445.

Chiristiansen, H.R. and Rowland, R. (1981). Cotton Physiology Seed and Germination. In: Proceedings of Beltwide Cotton Production Research Conferences, J.M. (Ed.), 4-8 Jan, New Orleans.

Deepika, V. and Yadav, A. (2014). Effect of seed storage on seed viability, germinability and morphological characteristics of karonda (*Carissa carandas*) seedlings. Asian J. Adv. Basic Sci. 2: 2347-4114.

Delouche, J.C. (1968). Physiology of Seed Storage. American in The Proc. 23rd Corn and Sorghum Res. Conf. Seed Trade Assn. Washington D.C. Pp: 83-90.

Dhakal, M.R. and Pandey, A.K. (2001). Storage potential of niger (*Guizotia abyssinica*) seeds under ambient conditions, Seed Sci. and Technol. 29:205 - 213.

Duffus, C.M. and Slaughter, J.C. (2003). Seed and Their Uses.1980, J. Wiley and Sons. New York.

Goel, A., Goel, A.K. and Sheoran, I.S. (2003). Changes in oxidative stress enzymes during artificial ageing in cotton (*Gossypium hirsutum* L.) seeds. J. Plant Physiol. pp: 1093–1100.

ISTA., International Rules for Seed Testing (2011). Chapter 5: The Germination Test. 2011, International Seed Testing Association, Baserdorf, Switzerland. ISBN 978-3-906549-53-8.

James, E. (1964). Preservation and seed stocks. Adv. Agron. 19: 87-106.

Khan, M.M., Abbas, M., Awan, F.S., Shahid, M., Ali, M. and Ahmad, S. (2013). Physio-biochemical and genetic changes in stored pea (*Pisum sativum*) seeds. Intern. J. of Agric. and Bio. 15: 951-956.

Kumar, S. and Verma, S.S. (2008). Studies on viability and vigour in fenugreek seeds stored under ambient conditions. Haryana J. Horti. Sci. 37: 349-352.

Kumari, S., Amar, K. and Tehlan, S.K. (2014). Study on biochemical changes associated with seed viability and its deterioration under ambient conditions in fenugreek. Annals Agri-Bio Res. 19: 754-756.

Laxminarayana, K. and Patiram. (2006). Effect of integrated use of inorganic, biological and organic manures on rice productivity and soil fertility in Ultisols of Mizoram. J. of the Ind. Soc. of Soil Sci. 54: 213-220.

Meena, R.A., Rathinavel, K. and Singh, P. (1994). Seed development and maturation in cotton. Indian J. Agric. Sci. 64: 111-113.

Nagarajan, S., Sinha, J.P. and Pandita, V.K. (2004). Accelerated ageing behaviour of okra seed lots conditioned to different moisture levels and its relation to seed water characteristics. Seed Res. 32: 113-117.

Namvar, A., Rauf, S. S., Teymur, K. and Majid, J. M. (2013). Seed inoculation inorganic nitrogen fertilization effects on some physiological and agronomical traits of chickpea (*Cicer arietinum* L.) in irrigated conditions. J. Cen Euro Agric. 14: 28-40.

Panse, V.G. and Sukhatme, P.V. (1985). Statistical Methods for Agricultural Workers, 4th Ed., ICAR, New Delhi.

Roberts, E.H. (1972). Storage environment and control of viability, cytological, genetical and metabolic changes associated with loss of viability. Inc: Viability of seeds. [Roberts, E.H., 1972, (ed.)] Chapman and Hall, London.

Saxena, O.P., Singh, G., Pakeeraiah, J., Pandey, N. (1987). Seed deterioration studies in some vegetable seeds. Acta. Hort. 215: 39-44.

Sharma, G. D., Thakur, R., Chouhan, N. and Keram, K. S. (2015). Effect of integrated nutrient management on yield, nutrient uptake, protein content, soil fertility and economic performance of rice (*Oryza sativa* L.) in a Vertisol. J. of the Ind. Soc. of Soil Sci. 63: 320-326.

Sidhawani, S.K. (1991). Use of certified seeds and its contribution towards productivity. In: seminar seed industry in Haryana held on September 12-13, CCS HAU, Hisar.

Singh, B., Bhuker, A., Mor, V.S., Dahiya, O.S. and Punia, R.C. (2015). Effect of natural ageing on seed quality of fenugreek (*Trigonella foenum-graecum* L.). Intern. J. of Sci. Res. in Sci. and Techn. 1: 243-248.

Singh, B., Singh, C.B. and Gupta, P.C. (2003). Influence of seed ageing in Vigna species. Farm Sci. J. 12: 4-7.

Subba Rao, N.S. and Tilak, K.V.B.R. (1977). Rhizobial culture- Their role in pulse production. Souvenir Bulletin. Directorate of Pulse Development, Govt. of India, Lucknow. pp. 31-34.

Trawatha, S.E., Tekrony, D.M. and Hidebrand, D.F. (1995). Relationship of soybean seed quality to fatty acid and C6-Aldehyde levels during storage. Crop Sci. 35: 1415-1422.

Verma, S.S., Verma, U. and Tomer, R.P.S. (2003). Studies on seed quality parameters in deteriorating seeds in brassica (*Brassica campestris*). Seed Sci. and Technol. 31: 389-396.

Virmani, S.M. (1994). The twenty first – Dr. R.V. Tamhane memorial Lecture: UNCEED Agenda 21: The new challenge for soil research. J. Indian Soc. Soil Sci. 42: 516-523.

Willson, D.O. and McDonald, M.B. (1986). The lipid peroxidation model of seed deterioration. Seed Sci. and Technol. 14: 269-300.

Yadav, B.D and Khurana, S.C. (2005). Effect of growth substances and azotobacter on quality of seed produced by different order umbels in transplanted fennel. Indian. J. Hort. 62: 52-55.

Zamani, A., Sadat, N.S.A., Tavakol, A.R., Iran, N.H., Ali, A.G. and Tavakoli A. (2010). Lipid peroxidation and antioxidant enzymes activity under natural and accelerated ageing in safflower (*Carthamus tinctorius* L.) seed. Iranian J. Agric. Sci. 41: 545-554.