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INFLUENCE OF PRE-SOWING SEED PRIMING AND PACKAGING MATERIALS ON THE QUALITY OF SESAME (*Sesamum indicum* L.) SEEDS

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ABSTRACT

The aim of this study was to assess the effect of seed priming on seed quality of freshly harvested sesame seeds stored in different packaging materials. During 2017-2018 and 2018-2019 different pre-sowing seed priming treatments were adopted for seed production. Freshly harvested seeds were packed in aluminum foils, plastic packets, brown paper packets and cloth bags; and stored under ambient condition to monitor the deterioration pattern of seed quality during 2018-19 and 2019-2020. Germination (%), vigour index, electrical conductivity and α-amylase activity were evaluated at 2 months interval up to 8 months of storage. The results showed that among the packaging materials evaluated aluminum foil can be used for longer period with least deterioration. Among the treatments, polyethylene glycol (PEG) 6000 @ -0.2 MPa, followed by KNO_3 @ 50 mM and KH_2PO_4 @ 200 mM treatments gave high quality seeds in terms of germination, vigour index and electrical conductivity. Therefore, seed priming of sesame seeds with polyethylene glycol (PEG) 6000 @ -0.2 MPa may be done to produce high quality seeds which can be safely stored in aluminum foil.

Keywords: Packaging material, priming, sesame, storage

INTRODUCTION

Sesame (*Sesamum indicum* L.), also known as sesamum or benniseed and a member of the family Pedaliaceae, is one of the most ancient oilseeds crops known to mankind. Sesame presents ample adaptability to various conditions of climate and soil, resistance to drought and ease of cultivation; characteristics that make it an excellent option for agricultural diversification and of great economic potential in domestic and international markets. Sesame plays an important role in human nutrition due to its high medicinal properties. Most of the sesame seeds are used for oil extraction and the rest are used for edible purposes (El Khier *et al*., 2008). Annual *Sesamum indicum* has a long history of cultivation, mostly for high oil yield. The oil plant has been grown since the beginning of arable cultivation, and originates from the dry bush savannah of tropical Africa, and spread from there to India and China, where it is still widely cultivated (Naturland, 2002).

Seed is one of the most vital and critical input for increasing productivity. High quality seed is essential for better field establishment and productivity of sesame (Biswas *et al.*, 2020). In India there is a big gap between production of oilseeds necessitating the import to meet the domestic demand (Govindaraj *et al.*, 2016). The main purpose of traditional seed storage is to secure the supply of good quality seed for planting programme whenever needed. Seed deterioration begins immediately after physiological maturity and is reflected in terms of loss in viability and vigour. The viability and vigour largely depend on the genotypes, location, mechanical injury to the seed, initial seed quality, seed treatment, packaging material and storage conditions. Sesame seeds deteriorate more rapidly after harvest, which reduce the quality of seeds (Prakash *et al.,* 2018). The ability of seeds to maintain their quality during storage is influenced by several factors, including moisture content, temperature and relative humidity of air and the packaging materials used for the seeds (Toledo *et al*., 2009). Seed priming stimulates various metabolic processes in seed that improve germination and early seedling vigour, leading to better stand establishment and yield. Not only that, the quality of produced seed is also influenced by the different seed priming treatments. Seed priming was effective in promoting seed germination, enhancing seedling growth of rice (*Oryza sativa* L.) under chilling (Hussain *et al*., 2016a; Wang *et al*., 2016), drought (Zheng *et al*., 2016), and waterlogging stresses (Hussain *et al*., 2016b). The seed longevity is influenced by several factors such as temperature, oxygen, relative air humidity and seed moisture content (Rajjou and Debeaujon, 2008). The influence of temperature, relative humidity and oxygen concentration on the longevity of normal seeds during storage have widely been studied for several years. However, research concerning the changes of α-amylase activity, total soluble sugar content and ultra-structure of primed seed in response to different storage conditions and storage durations is lacking. The effect of these environmental factors on the longevity of primed sesame in response to different packaging material seeds has rarely been studied. Considering the above facts, the present work was aimed to investigate invigoration of sesame before sowing to produce quality seeds.

MATERIALS AND METHODS

Field experiments were conducted in two consecutive *kharif* seasons of 2017-18 and 2018-2019 at AB Block farm, BCKV, Kalyani, West Bengal, India. Sesame variety 'Savitri' was collected from Pulse and Oilseed Research Station, Baharampur, Murshidabad, West Bengal, India and several seed priming chemicals were assessed at RKVY Laboratory, Department of Seed Science & Technology, BCKV, Nadia, West Bengal. The experiment comprised of 11 treatments using various organic and inorganic chemicals for seed priming including a control *viz* (KNO_3 @ 10 mM, KNO_3 @ 20 mM, KNO_3 @ 50 mM, KH_2PO_4 @ 50 mM, KH_2PO_4 @ 100 mM, KH_2PO_4 @ 200 mM, polyethylene glycol (PEG) 6000 @ -0.4 MPa, PEG 6000 @ -0.3 MPa, PEG 6000 @ -0.2 MPa, distilled water treatment (hydropriming) along with a untreated control (dry seeds). The experiment was conducted in a complete randomized design with each treatment replicated three times. The seeds were soaked separately in above aqueous solutions for 6 h, followed by drying back to its original moisture content (7%), except control. Four types of packaging like aluminum foil, plastic packet (40 µ, sealed), brown paper packet and cloth bag were provoked for storing of collected fresh seeds under ambient conditions which were estimated at an interim of two months considering 0, 2, 4, 6 and 8 months from initial storage. The seed quality parameters *viz*., germination (using moist germination paper in Petri-plate method, ISTA, 2018), vigour index (Abdul Baki and Anderson, 1973) and α-amylase activity (Bern Field, 1955) were assessed in addition to the electrical conductivity (ISTA, 2006). The data was statistical analysis at 5% level of significance through application of OPSTAT software (Sheoran *et al.,* 1998).

RESULTS AND DISCUSSION

Germination test is performed to compare the quality of different seed lots. Although, it is the most common and practical seed viability test, the germination percentage indicates only the potential of a seed lot to establish seedlings under favourable conditions. After 8 months of storage, aluminum

Table 1: Effect of packaging materials and storage period on germination percentage of primed sesame (Average pooled data)

	Aluminum foil	Plastic packet	Brown paper packet	Cloth bag
Treatments (T)				
KNO_3 @ 10 mM	67 (84)	67(84)	66(83)	65(82)
KNO_3 @ 20 mM	63 (79)	64(80)	63(78)	63(79)
KNO_3 @ 50 mM	69 (86)	68(86)	68(85)	68(85)
KH_2PO_4 @ 50 mM	67 (84)	66(83)	66(83)	65(82)
KH_2PO_4 @ 100 mM	63 (79)	63(79)	62(78)	63(79)
KH_2PO_4 @ 200 mM	64 (80)	64(80)	63(79)	63(79)
PEG 6000 @ -0.4 MPa	69 (86)	68(85)	68(85)	68(85)
PEG 6000 @ -0.3 MPa	69 (87)	68(85)	68(86)	68(85)
PEG 6000 @ -0.2 MPa	70 (88)	70(87)	70(86)	69(86)
Control (hydropriming)	63 (78)	63(79)	63(79)	63(79)
Control (dry seed)	64 (80)	64(80)	64(80)	64(80)
SEm (±)	0.64	0.56	0.59	0.55
$CD_{0.05}$	1.80	1.56	1.66	1.55
Storage period in months (S)				
0	69 (87)	69 (87)	69 (87)	69 (87)
2	67 (84)	67 (84)	67 (83)	66 (83)
4	66 (83)	65 (82)	65 (82)	65 (81)
6	65 (81)	64 (80)	64 (80)	64 (80)
8	64 (80)	63 (79)	63 (79)	63 (78)
SEm (±)	0.43	0.38	0.40	0.37
$CD_{0.05}$	1.21	1.06	1.12	1.04
Treatment x storage period interaction (T×S)				
SEm (±)	1.43	1.25	1.32	1.23
$CD_{0.05}$	ns	ns	ns	ns

PEG = Polyethylene glycol; Germination data in parentheses are transformed values.

foil treatment gave maximum germination percentage followed by plastic packet. Among different treatments, polyethylene glycol (PEG) 6000 @ -0.2 MPa recorded maximum germination, irrespective of storage containers. The effect of storage containers on germination showed lowest percentage was in cloth bag (Table 1). The results are in accordance with Monira *et al*. (2012), Meena *et al*. (2017) and Lambat *et al*. (2015). Interactions between treatments and duration of storage period was non-significant. During storage, the changes in seed moisture content and temperature which may affect seed germination. Low air movement in stored seeds lowers their quality due to heat accumulation during respiration (Chattha *et al*., 2012). Longer seed storage period increases seed aging intensity (Oyekale *et al*., 2012) which lowers germination percentage.

Seed lots with high germination capacity show better seedling establishment than those with low germination capacity, especially under suboptimal conditions. Higher germination along with high vigour index increases the potentiality of crop performance. The study revealed significant variation in different treatments and different storage periods but the interactions were non-significant (Table 2). Maximum vigour index was found immediately after harvest before storage (1008). Mean vigour index continued to be lower with advancement of storage period. After 8 months storage the mean vigour index was highest in aluminum foil (798), followed by plastic packet (789), brown paper packet (776) and cloth bag (758). Chuasin *et al.* (2006) found that seed stored in metalized film bags and aluminum foil bag had high standard germination and vigour index. Among the treatments, PEG 6000 @ -0.2 MPa maintained maximum vigour index in aluminum foil and brown paper packet (984 and 976, respectively). KNO_3 @ 50 mM, followed by PEG 6000 @ -0.2 MPa had maximum vigour index in plastic packet and cloth bag.

Table 2: Effect of packaging materials and storage period on vigour index of primed sesame

	Aluminum foil	Plastic packet	Brown paper packet	Cloth bag
Treatments (T)				
KNO_3 @ 10 mM	922	917	892	879
KNO_3 @ 20 mM	793	796	781	790
KNO_3 @ 50 mM	976	978	963	958
KH_2PO_4 @ 50 mM	909	897	904	882
KH_2PO_4 @ 100 mM	880	891	858	874
KH_2PO_4 @ 200 mM	854	846	840	832
PEG 6000 @ -0.4 MPa	906	885	880	867
PEG 6000 @ -0.3 MPa	942	911	916	896
PEG 6000 @ -0.2 MPa	984	962	976	935
Control (hydropriming)	845	846	824	829
Control (dry seed)	841	831	819	805
SEm (±)	12.52	11.20	22.84	10.83
$CD_{0.05}$	35.13	31.44	33.23	30.40
Storage periods in months (S)				
0	1008	1008	1008	1008
2	943	936	926	920
4	892	875	865	849
6	839	828	813	805
8	798	789	776	758
SEm (±)	8.44	7.55	7.98	7.30
$CD_{0.05}$	23.68	21.10	22.40	20.49
Treatment x storage period interaction (T×S)				
SEm (±)	27.99	25.05	26.47	24.22
$CD_{0.05}$	ns	ns	ns	ns

Electrical conductivity test is commonly used for the assessment of deterioration pattern of quality seed under storage conditions. There was significant variation in electric conductivity among the seed priming treatments as well as duration of storage period (Table 3). Minimum electrical conductivity (2.35 dSm^{-1}) was recorded in aluminum foil under different packaging materials after 8 months storage. Seed membrane becomes more permeable with age, resulting in leaching of sugar, free amino acid and organic acids from seed. Electrical conductivity of leachates after 8 months storage period followed the order of cloth bag> brown paper packet> plastic packet> aluminum foil. Seed deterioration during storage was due to damage of cell membrane and thereby increasing the value of electrical conductivity under ambient conditions (Oyekale *et al.*, 2012). Interaction between treatments and storage duration had non-significant effect. Similar trend was reported by Chandran and Rajgopal (2002) and reported that lower electrical conductivity in tri-aluminum foil pouches.

The major source of energy for seed germination and seedling establishment is the degradation of stored starch in endosperm. Complete starch hydrolysis is achieved by the combined action of α-amylase, β-amylase, debranching enzyme and α-glucosidase. α-amylase is synthesized *de novo* during seed germination in the presence of endogenous GA (gibberellic acid) from embryo (Sugimoto *et al*., 1998). Among the different containers aluminum foil recorded maximum α-amylase activity followed by plastic packet (Table 4). A significant variation was observed among the treatments and duration of storage under different containers. Seed stored in different containers recorded different α-amylase activity. Among the treatments PEG 6000 @ - 0.4 MPa recorded maximum α-amylase activity under all containers after 8 months storage. Higher α-amylase activity observed may be due to higher enzyme concentration, which was produced during seed development and maturation. Cloth bag recorded minimum mean value among the different containers. Interaction between treatments and duration of months recorded non-significant variation.

Table 3: Effect of packaging materials and storage period on electrical conductivity (dSm^{-1}) of primed sesame

Treatments (T)	Aluminum foil	Plastic packet	Brown paper packet	Cloth bag
KNO_3 @ 10 mM	1.76	1.82	1.76	1.75
KNO_3 @ 20 mM	1.81	1.81	1.88	1.92
KNO_3 @ 50 mM	1.64	1.75	1.73	1.74
KH_2PO_4 @ 50 mM	1.89	1.92	1.93	1.94
KH_2PO_4 @ 100 mM	2.15	2.06	2.12	2.17
KH_2PO_4 @ 200 mM	1.71	1.71	1.72	1.77
PEG 6000 @ -0.4 MPa	2.01	2.14	2.12	2.15
PEG 6000 @ -0.3 MPa	2.12	2.16	2.15	2.16
PEG 6000 @ -0.2 MPa	1.84	1.86	1.77	1.79
Control (hydropriming)	2.06	2.08	2.01	2.07
Control (dry seed)	1.92	1.84	1.90	1.95
SEm (±)	0.05	0.04	0.05	0.04
$CD_{0.05}$	0.14	0.12	0.14	0.12
Storage period in months (S)				
0	1.48	1.48	1.48	1.48
2	1.65	1.68	1.67	1.66
4	1.90	1.92	1.91	1.94
6	2.13	2.17	2.16	2.22
8	2.35	2.36	2.38	2.43
SEm (±)	0.01	0.03	0.03	0.03
$CD_{0.05}$	0.09	0.08	0.10	0.08
Treatment x Storage period interaction (T×S)				
SEm (±)	0.11	0.09	0.11	0.09
$CD_{0.05}$	ns	ns	ns	ns

Table 4: Effect of packaging materials and storage period on α-amylase activity ($\mu g\ min^{-1}\ g^{-1}$) of primed sesame

Treatments (T)	Aluminum foil	Plastic packet	Brown paper packet	Cloth bag
KNO_3 @ 10 mM	56.03	54.34	54.08	53.25
KNO_3 @ 20 mM	57.13	54.67	54.62	53.55
KNO_3 @ 50 mM	57.65	55.21	54.68	54.01
KH_2PO_4 @ 50 mM	55.65	53.39	52.23	51.38
KH_2PO_4 @ 100 mM	56.87	56.85	57.07	55.06
KH_2PO_4 @ 200 mM	54.38	52.57	51.69	50.61
PEG 6000 @ -0.4 MPa	61.13	59.74	58.30	56.67
PEG 6000 @ -0.3 MPa	60.73	59.02	57.98	56.38
PEG 6000 @ -0.2 MPa	53.11	52.74	50.70	50.03
Control (hydropriming)	57.32	56.42	54.87	53.52
Control (dry seed)	58.50	57.22	55.54	54.80
SEm (±)	0.60	0.59	0.51	0.59
$CD_{0.05}$	1.67	1.65	1.44	1.67
Storage period in months (S)				
0	74.10	74.10	74.10	74.10
2	66.31	65.72	65.41	63.45
4	56.56	53.43	54.03	52.03
6	46.71	44.20	41.01	41.23
8	41.99	40.81	38.97	37.03
SEm (±)	0.40	0.40	0.35	0.40
$CD_{0.05}$	1.13	1.12	0.97	1.12
Treatment x Storage period interaction (T×S)				
SEm (±)	1.33	1.32	1.15	1.33
$CD_{0.05}$	ns	ns	ns	ns

Conclusions: Seed quality deterioration is an inevitable process. The study revealed that the seeds stored in aluminum foil remain safe for longer period with least deterioration. Polyethylene glycol (PEG) 6000 @ -0.2 MPa is the most promising seed priming chemicals to produce quality seeds and the seed quality may be properly maintained up to eight months of storage.

REFERENCES

Abdul Baki, B.A.A. and Anderson, J.D. 1973. Relationship between decarboxylation of glutamic acid and vigour in soybean seed. *Crop Science*, **13**: 222-226.

Almeida, F. de. A.C, Fonseca, K.S. and Gouveia, J.P.G. de. 1999. Effect of packaging and storage location on the physiological quality of sesame seeds. *Brazilian Magazine of Agricultural and Environmental Engineering*, **3**(2): 195-201.

Azevedo, M.R. de. Q.A., Gouveia, J.P.G. de., Trovao, D.M. de. M. and Queiroga, V. de. P. 2003. Influence of packing and storage conditions on the vigour of sesame seeds. *Brazilian Journal of Agricultural and Environmental Engineering*, **7**(3): 519-524.

Bern field, P. 1955. Amylase alpha and beta assay methods. pp. 149-151.**In:** *Method of Enzymology* (eds. S. Colowick and N.O. Kalpan). Academic Press, New York, USA.

Biswas, U., Das, R. and Dutta, A. 2020. Pattern of capsule and seed development in sesame (*Sesamum indicum* L.) as influenced by seed priming. *International Journal of Environment and Climate Change*, **10**(4): 1-7.

Chandran, K. and Rajgopal, K. 2002. Influence of packaging media on the storability of groundnut (*Arachis hypogaea* L.) germplasm. *Plant Genetic Resources Newsletter*, **130**: 62-64.

Chattha, S.H., Jamali. L.A., Ibupoto, K.A. and Mangio, H.R. 2012. Effect of different packing materials and storage conditions on the viability of wheat seed (TD-1 variety). *Science, Technology and Development*, **31**(1): 10-18.

Chuasin, S., Vearasilp, S., Srichuwong, S. and Pawelzik, E. 2006. Selection of packaging materials for soybean seed storage. **In**: *Conference on International Agricultural Research for Development*. University of Bonn, Bonn, Germany.

Deepa, G.T., Chetti, M.B., Khetagoudar, M.C. and Adavirao, G.M. 2013. Influence of vacuum packaging on seed quality and mineral contents in chilli (*Capsicum annuum* L.). *Journal of Food Science and Technology*, **50**: 153-158.

Govindaraj, G.N., Suryaprakash, S., Sivaramane, N. and Murali, P. 2016. Changes in edible oil preference and present-day consumption status of households: A case of Tamil Nadu State, India. *Journal of Oilseeds Research*, **33**(3): 178-184.

Harrington, J.F. and Douglas, J.E. 1970. *Seed Storage and Packaging Application for India*. National Seed Corporation with the Rockfeller, New Delhi, India.

Hussain, S., Khan, F., Hussain, H. and Nie, L. 2016a. Physiological and biochemical mechanisms of seed priming induced chilling tolerance in rice cultivars. *Frontiers in Plant Science*, **7**: 116. [*https://doi.org/10.3389/fpls.2016.00116*].

Hussain, S., Yin, H., Peng, S., Khan, F., Sameeullah, M. and Hussain, H. 2016b. Comparative transcriptional profiling of primed and non-primed rice seedlings under submergence stress. *Frontiers in Plant Science*, 7: 1125. [*https://doi.org/10.3389/fpls.2016.01125*].

Hussain, S., Zheng, M., Khan, F., Khaliq, A., Fahad, S. and Peng, S. 2015. Benefits of rice seed priming are offset permanently by prolonged storage and the storage conditions. *Scientific Reports*, **5**: 8101. [*https://doi.org/10.1038/srep08101*].

ISTA 2014. *Seed Vigour Testing. International Rules for Seed Testing*. International Seed Testing Association, Zurich, Switzerland.

ISTA. 2006. *International Rules for Seed Testing*. International Seed Testing Association, Zurich, Switzerland.

Khier, El., M.K.S., Ishag K.E.A. and Yagoub, A.E.A. 2008. Chemical composition and oil characteristics of sesame seed cultivars grown in Sudan. *Research Journal of Agriculture and Biological Sciences*. **4**(6): 761-766.

Kyrychenko, O.V. 2014. The effect of specific plant exogenous lectin on the symbiotic potential of soybean-rhizobium system and lectin activity of soybean seeds. *Scientia Agriculturae*, **2**: 1-7.

Lambat, A, Charde, P.N., Lambat, P., Gadewar, R. and Charjan, S. 2015. Effect of storage containers on mycoflora and germinability of til. *International Journal of Research in Bioscience and Agriculture Technology*, **2**(3): 10-12.

Meena, M.K., Chetti, M.B. and Nawalagatti, C.M. 2017. Influence of different packaging materials and storage conditions on the seed quality parameters of groundnut (*Arachis hypogaea* L.). *International Journal of Pure and Applied Bioscie*nces, **5**(1): 933-941.

Miller, G.L. 1959. Use of dinitrosalicyIic acid reagent for determination of reducing sugar. *Analytical Chemistry*, **31**(3): 426-428.

Monira, U.S., Amin, M.H.A., Aktar, M.M. and Mamun, M.A.A. 2012. Effect of containers on seed quality of storage soybean seed. *Bangladesh Research Publications Journal*, **7**(4): 421-427.

Naturland. 2002. *Organic Farming in the Tropics and Subtropics: Sesame*. 21/07/11. Accessed in [*www.naturland.de/fileadmin/MDB/documents/Publication/English/sesame.pdf*].

Oyekale, K.O., Nwangburuka, C.C., Denton, O.A., Daramola, D.S., Adeyeye, J.A. and Kinkuotu, A.O. 2012. Comparative effects of organic and inorganic seed treatments on the viability and vigour of sesame seeds in storage. *Journal of Agricultural Science*, **9**(4): 187-195.

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical Methods for Agricultural Workers*. ICAR, New Delhi, India.

Pontes, C.A., Borges Corte, V., De Lima, E., Borges, E.E., Gomes Da Silva, A. and De Cássia Gonçalves Borges, R. 2006. Influence of storage temperature on the quality of *Caesalpinia peltophoroides* Benth seeds. *Sibipiruna*, **30**: 43-48. [*https://doi.org/10.1590/S0100-67622006000100006*].

Prakash, M., Sathiya, Narayanan. G., Anandan, R. and Sunil, Kumar. B. 2018. Effect of organic seed treatment and foliar spray on growth, yield and resultant seed quality in sesame (*Sesamum indicum*. L.). *Journal of Oilseeds Research*, **35**(4): 234-298.

Raikar, S.D., Vyakarnahal, B.S., Biradar, D.P., Deshpande, V.K. and Janagoudar, B.S. 2011. Effect of seed source, containers and seed treatment with chemical and biopesticide on storability of scented rice cv. Mugadsugandha. *Karnataka Journal of Agricultural Science*, **24**(4): 448-454.

Rajjou, L., and Debeaujon, I. 2008. Seed longevity: Survival and maintenance of high germination ability of dry seeds. *Comptes Rendus Biologies*. **331**: 796–805. [*https://doi.org/10.1016/j.crvi.2008.07.021*].

Sugimoto, N., Takeda, G., Nagato, Y. and Yamaguchi, J. 1998. Temporal and spatial expression of the α-amylase gene during seed germination in rice and barley. *Plant Cell Physiology*, **39:** 323-333.

Toledo, M.Z., Fonseca, N.R., Cesar, M.L., Soratto, R.P., Cavariani, C. and Crusciol, C.A.C. 2009. Physiological quality and storage of bean seeds as affected by late side dressing with nitrogen. *Pesquisa Agropecuaria Tropical*, **39**: 124-133. [*www.agro.ufg.br/pat*].

Wang, W., Chen, Q., Hussain, S., Mei, J., Dong, H. and Peng, S. 2016. Pre-sowing seed treatments in direct-seeded early rice: consequences for emergence, seedling growth and associated metabolic events under chilling stress. *Scientific Reports*, **6**: 19637. [*https://doi.org/10.1038/srep19637*].

Wani, A.A, Joshi, J., Titov, A. and Tomar, D.S. 2014. Effect of seed treatments and packing materials on seed quality parameters of maize (*Zea mays* L.) during Storage. *Indian Journal of Applied. Research*, **4**: 102- 108.

Zheng, M., Hussain, S., Tao, Y., Jiang, Q., Peng, S. and Huang, J. 2016. Seed priming in dry seeded rice: Consequences for emergence, seedling growth and associated metabolic events under drought stress. *Plant Growth Regulation*, **78:** 167-178.