EFFECT OF SEED PRIMING TREATMENT ON THE PHYSIOLOGICAL QUALITY OF NATURALLY AGED ONION (*ALLIUM CEPA* L.) SEEDS

BRAR, N. S.[1] – KAUSHIK, P.[2,3*] – DUDI, B. S.[4]

[1]*Department of Vegetable Science, Punjab Agricultural University, Ludhiana 141 004, India*

[2]*Instituto de Conservación y Mejora de la Agrodiversidad Valenciana, Universitat Politècnica de València, Valencia 46022, Spain*

[3]*Nagano University, 1088 Komaki, Ueda, Nagano 386-0031, Japan*

[4]*Department of Vegetable Science, CCS Haryana Agricultural University, Hisar 125001, India*

**Corresponding author*
e-mail: prakau@doctor.upv.es, prashantumri@gmail.com; phone: +34-96-387-7000

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Abstract. The experiment was conducted to investigate the effect of priming treatments on the physiological parameters of naturally aged onion (*Allium cepa* L.) seed, six seed priming treatments viz., Control, Hydro priming followed by dry dressing with Thiram (2 g/kg), Hydration with GA_3 (50 ppm), Hydration with KNO_3 (0.5% solution), Hydration with KH_2PO_4 (0.5% solution), and Biofertilizer (*Azotobacter*) were analyzed to identify the most suitable priming treatment. The standard seed germination, seedling length, seedling dry weight, seed vigour index-I & II and viability test (Tz test), decreased significantly, while electrical conductivity increased with the advancement of the ageing period. The field parameters viz., seedling emergence index and seedling establishment also decreased significantly with the natural ageing of seeds. The seed quality improvement through seed priming was noticed more in marginal seed lot, i.e., one-year-old seed lot. Among various priming treatments, hydration with GA3 @ 50 PPM followed by biofertilizer, (*Azotobacter*) performed best in enhancing all seed vigour and viability characteristics and lowering the electrical conductivity of naturally aged onion seeds. In conclusion, the present study revealed that onion seed loses its viability rapidly under ambient storage conditions. Therefore, seed priming with GA_3 @ 50 ppm and biofertilizer, (*Azotobacter*) can be used effectively to enhance its vigour and viability. These priming treatments can aid to improve the quality of seed stored for one year, thus ensuring good plant stands from the stored seed of a poor storer crop.
Keywords: *onion, GA_3, Azotobacter, germination, viability, seedling emergence index*

Introduction

Onion (*Allium cepa* L.) is a bulb crop of worldwide importance. India ranks first in the cultivated area with 1.31 million ha but ranks second in terms of total production (22.42 million tons) after China (FAO, 2017). Most crucial input for improving the yield is the use of good quality seeds. However, onion seeds exhibit some poor attributes like inferior longevity and storability, which ultimately result in rapid loss of viability (Khan et al., 2004). Furthermore, low-quality seeds result in low and asynchronous germination and high numbers of abnormal seedlings under stress conditions in early spring planting (Borowski and Michalek, 2006). Ultimately, quality of onion seed is dependent on several factors, some of which are surrounding environment during plant growth and seed development, location of seeds on plant, time of seed harvest, seed harvesting techniques, storage conditions and seed treatment before sowing. In the case of onions, where seed size is small, and seed establishment is

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poor, seed priming is the most promising method to improve seed establishment. Seed priming is a pre-sowing, controlled hydration treatment where physiological and biochemical activities are stimulated in the seed, but radicle protrusion is prevented (Khan, 1992). Bosland and Votara (2000) were of the view that priming leads to enhanced and uniform germination. Moreover, primed onion and leek seeds maintained viability after one year when stored at 10 °C (Drew et al., 1997). Similar results have been reported in the case of tomato, asparagus and canola (Argerich et al., 1989; Owen and Pill, 1994; Basra et al., 2003). Many researchers have studied effect of seed priming on enhancement of germination, morphological characters, yield, etc. (Thejeshwini et al., 2019; Muruli et al., 2016; Saranya, 2017; Patil and Manjare, 2013; Arin et al., 2011; Selvarani and Umarani, 2011; Nego et al., 2015).

Seed priming (pre-sowing hydration treatments of seeds) is widely used for enabling better crop establishment (Taylor et al., 1998). Priming is a process in which seeds are imbibed in either water or osmotic solution or a combination of solid matrix carrier and water in specific proportions followed by drying before radicle emergence. In several studies, an increase in the nuclear DNA contents of radicle meristem cells from the G1 to the S or G2 phases of the cell cycle was noticed. The recorded effects of priming treatments on the storability of seeds are contradictory. The advancement of the germination process during priming continuously consumes stored substances and consequently may shorten seed longevity. However, the repair of DNA damage will increase longevity (Osborne, 1983). The results obtained so far are few, limited, contrasting because of the variability of the response to treatments of cultivars and even seed lots (Bradford, 1986) which require a careful choice of the compounds to proper standardization of the seed priming method and methodology for individual crops is the most critical determinant of success of the seed priming treatment.

In storage, the viability and vigour of the seeds not only vary from genera to genera and variety to variety, but is also regulated by many physicochemical factors like moisture content, atmospheric relative humidity, temperature, initial seed quality, physical and chemical composition of seed, gaseous exchange, storage structure, packaging materials etc. (Doijode, 1988). It will be of immense use to seed industry and farming community that how best the seeds can be stored by treating the seeds with chemicals and inert matter at relatively low cost under ambient storage and refrigerated conditions, with minimum quantitative and qualitative losses. As the quality, seed plays an important role in obtaining higher returns, as it is expected to perform well under any given environmental conditions.

Keeping in view the above facts, the present study was conducted with the objective of determining the most appropriate seed priming treatment and its physiological effects in differentially aged onion seeds.

Materials and methods

Experimental layout

The freshly harvested seed of three onion cultivars viz., Hisar-2 (V1), Hisar Onion-3 (V2) and Hisar Onion-4 (V3) were brought to the laboratory and stored in cloth bags under room temperature conditions (27 ± 1 °C, relative humidity (RH) 54 ± 3%) with seed moisture 7-8%. The seed lots of each of the three varieties were stored under ambient conditions in the laboratory of Seed Science and Technology, Haryana Agricultural University), Hisar, India This seed was used for further studies according

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to different years of natural seed ageing. These varieties were selected based on their extensive cultivation and popularity among Haryana farmers. Details of the experimental material are provided in *Table 1*.

Table 1. *Differentially aged seedlot during the two years of study*

Year of study	Lots	Year of production	Age of seed lot/seed age
2013	A	2013	Fresh
	B	2012	1 years old
	C	2011	2 years old
2014	A	2014	Fresh
	B	2013	1 year old
	C	2012	2 years old
	D	2011	3 years old

Treatments

Six seed priming treatments were compared with untreated control. The treatments are detailed in *Table 2*.

Table 2. *Details of priming treatments under study*

Hydro-priming followed by dry dressing with Thiram (2 g/kg)	Hydration with distilled water and followed by dry dressing of seeds by thiram fungicides (2 g/kg seed)
Hydration with GA_3 (50 ppm)	50 mg of gibberellic acid (GA_3) was dissolved in 2 L of water to make solution of concentration of 50 ppm. One to three drops of acetone were also added as GA_3 cannot dissolve in distilled water
Hydration with KNO_3 (0.5% solution)	5 g of potassium nitrate ($KN0_3$) was dissolved in 1 L of distilled water
Hydration with KH_2PO_4 (0.5% solution)	5 g of potassium dihydrogen phosphate (KH_2PO_4) was dissolved in 1 L of distilled water
Biofertilizer (*Azotobacter*)	Seeds were first treated with 2% jaggary solution and then with *Azotobacter* strain HT-57. The strain was taken from the biofertilizers unit of CCS HAU, Hisar

The seed of each lot was soaked in a sufficient amount of solution for 16 h in each treatment. Then the seed was dried in the shade at 20 °C to attain the initial seed weight to maintain original or near to safe moisture content.

Observations

Germination and seed viability determination

Germination assays were determined according to the procedure described by International rules for seed testing (ISTA, 2015) by placing seeds in Petri plates for germination at 20-22 °C and 90 ± 2% RH (100 sterilized seeds per Petri plate in four replicates) in a germination chamber. Germination (%) was scored at radicle growth of 2 mm, or more and counting of normal and abnormal seedlings was started on the 5^{th} day

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and continued up to the 20th day (final count) followed by calculation of germination percentage. After the germination test, seedling length, dry seedling weight and seed vigour index were measured and calculated as per the standard procedure. Seedling length (cm) was measured from 20 randomly selected healthy seedlings at the time of final count of germination. These selected seedlings were then kept in a hot air oven at 60 °C for 48 h for the recording of seedling dry weight (mg). Based on the seed germination, seedling length and seedling dry weight data, seed vigour index-I (SV-I) and seed vigour index-II (SVI-II) were calculated (Abdul Baki and Anderson, 1972). To evaluate the viability, 25 seeds were soaked in 50 ml water and kept in the incubator at 30 ± 1 °C (in three replicates) for 24 h. After incubation, seeds were cut longitudinally and maintained in 1% staining solution of 2,3,5-triphenyl tetrazolium chloride (TTC) for 4 h at 38 ± 1 °C under dark conditions (Moore, 1973). During the staining period, only viable part of the seed is converted into red colour due to the formation of triphenyl formazon from TTC solution.

Electrical conductivity test (EC)

The electrical conductivity of seed leachates was measured for seeds of different age. Fifty seeds were soaked in 75 ml deionised water and incubated at 25 °C for 24 h. Seed leachates were collected, and conductivity (dS/cm/seed) was recorded by using digital conductivity meter (Model 304, Systronics, Ahmedabad, India) along with deionised water as a control (Dadlani and Aggarwal, 1987).

Field parameters

Seedling emergence index (SEI)

The number of seedlings emerged under field conditions were counted daily from 1st day to 20th day, and the seedling emergence index was calculated as described by (Maguire, 1962).

$$\text{SEI} = \frac{\text{No. of seedlings emerged on the first day}}{\text{Day of the first count (1st)}} + \cdots + \frac{\text{No. of seedlings emerged on last day}}{\text{Day of the last count (20th)}}$$

Seedling establishment (%)

Seedling establishment was estimated under field conditions by including the total number of seedlings after emergence or when there was no further addition to the total emergence.

Statistical analyses

The statistical analysis was carried out for each observed character under the study using MS-Excel and SPSS Statistics 20. The means of the treatments were compared using Duncan's Multiple Range Test (DMRT). Besides, the linear regressions were determined with the help of data analysis tool pack in MS Excel.

Experimental results

Results of the study showed that the effect of priming, seed age and their interaction were significant at $p < 0.05$ for all the seed quality parameters studied. Therefore, the seed lots of different ages were analysed separately for all the parameters. The

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laboratory parameters study was laid in completely randomized design CRD (*Table 3*), and field parameters were laid in randomized block design RBD (*Table 4*). During the second year of study, an additional seed lot of three-year-old seed was also studied.

Table 3. *Analysis of variance for seed quality characteristics of onion seed as affected by different priming treatments*

Source of variation	df	Germination	SL	SDW	SVI-I	SVI-II	Viability	EC
Seed lot (L)	2	20,143.92*	432.81*	37.97*	16,315,106.15*	859,446.45*	20,447.85*	6.42*
Priming (P)	5	259.64*	126.96*	0.27*	846,361.19*	8,555.79*	111.45*	0.21*
L*P	10	13.03*	10.66*	0.02**	99,516.17*	747.50*	3.51*	0.16*
Error	108	1.99	0.69	0.01	6,374.95	139.23	1.40	0.002

*Significant at 1% level of significance; **Significant at 5% level of significance; SL- seedling length; SDW- seedling dry weight; SVI-I- Seed vigour index-I; SVI-II- seed vigour index-II; EC- electrical conductivity

Table 4. *Analysis of variance for field parameters of onion seed as affected by different priming treatments*

Source of variation	df	SEI	SE
Seed age (L)	2	267.71*	18,413.84*
Priming (P)	5	6.05*	101.54*
L*P	10	0.20**	17.57*
Error	105	0.13	0.79

*Significant at 1% level of significance; **Significant at 5% level of significance; SEI- seedling emergence index; SE- seedling establishment

Seed priming has significant influence ($p < 0.05$) on the different traits of onion seed. Among the different seed priming treatments, hydration with GA_3 (50 ppm) was most effective in enhancing different traits followed by treatment with biofertilizer *Azotobacter*. Other treatments in declining order of seed quality are, hydro priming followed by dry dressing with Thiram (2 g/kg), hydration with KH_2PO_4 (0.5%) and hydration with KNO_3 (0.5%). Priming of seeds with various treatments was found competent to improve the quality in fresh and marginal seed lots. Out of the differentially aged seed lots, fresh seed performed the best, and the seed quality tends to decline with the ageing of the seed. Fresh seed lot was characterized by a high number of germinating seeds, exceeding 80% even in unprimed seed (*Table 5*). GA_3 emerged as the most effective priming treatment as it registered 11.23% increase in germination over control. After a year of storage, germination under different priming treatments dropped by 12.45 (*Azotobacter*), 13.11 (GA_3), 17.55 (Thiram), 20.1 (KH_2PO_4) and 20.45% (KNO_3), while unprimed seed recorded a reduction of 21.45%. A decline in germination in all the treatments was above 40% after three years of storage when compared with germination after two years of storage. The decrease in germination after three years of storage was below 10%. A similar trend was observed in the case of seed viability, where there was a steep decline after one year of storage (*Table 5*).

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Table 5. *Germination (%) and viability (%) of differentially aged onion seed lots under different priming treatments*

Priming treatment	Germination (%)				Viability (%)			
	Lot1	Lot2	Lot3	Lot4	Lot1	Lot2	Lot3	Lot4
Thiram	88.43b	70.88c	27.20a	20.11a	88.41a	67.43b	22.26b	19.44b
GA_3	91.32a	78.21a	27.16a	20.67a	89.41a	70.71a	24.98a	22.89a
KNO_3	84.88c	64.44d	21.73b	13.33b	84.26c	63.05c	18.37c	14.78c
KH_2PO_4	85.43c	65.33d	22.05b	14.33b	83.26c	64.16c	19.01c	15.67c
Azotobacter	88.88b	76.43b	26.10a	18.89a	86.21b	68.18b	24.76a	21.89ab
Control	82.10d	60.53e	17.47c	8.56c	83.02c	61.33d	17.89c	14.11c

Means under same parameter sharing letters are not significantly different at α = 0.05; Lot1: Fresh seed; Lot2: One-year old seed; Lot3: Two-year old seed; Lot4: Three-year-old seed

Seed priming with GA_3 in fresh seed was the best combination followed by priming with Thiram. More than 70.71% GA_3 primed seed was viable in the one-year-old seed lot. Viability of seed was below 25% in the primed and non-primed seed of two and three-year-old seed lot. A gradual decline in seedling length (cm) and seedling dry weight (mg) was observed in all the priming treatments with the progression of storage period (*Table 6*). In all of the aged seed lots, priming with GA_3 improved both seedling characteristics over other priming treatments in differentially aged seed lots. Seed vigour index- I (SVI-I) was highest in GA_3 primed seed in case of fresh, one year old and three-year-old seed lots (*Table 7*). While SVI-I was highest in Thiram primed seed that has been stored for two years.

Table 6. *Seedling length (cm) and dry weight (mg) of differentially aged onion seed lots under different priming treatments*

Priming treatment	Seedling length (cm)				Seedling dry weight (mg)			
	Lot1	Lot2	Lot3	Lot4	Lot1	Lot2	Lot3	Lot4
Thiram	16.45c	14.16b	12.47b	10.98b	3.57bc	2.76ab	1.77bc	0.95ab
GA_3	18.98a	16.70a	14.53a	13.18a	3.75a	2.79a	1.94a	1.12a
KNO_3	14.34d	10.82d	8.75d	6.46cd	3.49bc	2.49c	1.71c	0.98ab
KH_2PO_4	16.12c	11.61c	10.01c	8.08c	3.49bc	2.71b	1.72c	0.90c
Azotobacter	17.63b	9.94e	8.34d	11.19b	3.62ab	2.73ab	1.86ab	1.00ab
Control	13.78d	9.26f	8.17d	5.91d	3.43c	2.53c	1.70c	0.89c

Means under same parameter sharing letters are not significantly different at α = 0.05; Lot1: Fresh seed; Lot2: One-year-old seed; Lot3: Two-year-old seed; Lot4: Three-year-old seed

On the other hand, seed vigour index- II (SVI-II) was highest in *Azotobacter* primed two-year-old seed (*Table 7*). GA_3 priming recorded highest SVI-II in other aged seed lots. Electrical conductivity (EC) of GA_3 primed seed was lowest among the all priming treatments in the four seed lots studied (*Table 8*). This was followed by priming treatments of *Azotobacter* and Thiram, while the oldest aged seed had the highest EC values. The field parameters, i.e., seedling emergence index (SEI) and seedling establishment (SE) were also high in the fresh and one-year-old seed lot and followed a

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steep decline in two and three-year-old seed lot (*Table 9*). GA_3 primed seed also performed best in case of the field parameters followed by treatment with *Azotobacter*.

Table 7. *Seed vigour index-I (SVI-I) and seed vigour index- II (SVI-II) of differentially aged onion seed lots under different priming treatments*

Priming treatment	Seed vigour index- I				Seed vigour index- II			
	Lot1	Lot2	Lot3	Lot4	Lot1	Lot2	Lot3	Lot4
Thiram	1459.38bc	1001.14b	342.31b	224.47b	316.54bc	196.07c	48.47a	19.51b
GA_3	1738.16a	1302.87a	398.71a	276.76a	343.33a	219.09a	53.01a	23.25a
KNO_3	1219.68d	694.64d	191.20c	86.40d	296.96cd	160.93e	36.94b	13.03c
KH_2PO_4	1380.20c	756.47c	222.86c	118.62c	298.60cd	177.32d	38.29b	13.12c
Azotobacter	1570.35b	743.70cd	203.20c	214.69b	322.21b	209.04b	48.78a	19.06b
Control	1132.59d	59.96e	146.28d	52.28e	281.77d	153.52f	29.84c	7.95d

Means under same parameter sharing letters are not significantly different at α = 0.05; Lot1: Fresh seed; Lot2: One-year old seed; Lot3: Two-year-old seed; Lot4: Three-year-old seed

Table 8. *Electrical conductivity (dS/cm/seed) of differentially aged onion seed lots under different priming treatments*

Priming treatment	Electrical conductivity (dS/cm/seed)			
	Lot1	Lot2	Lot3	Lot4
Thiram	0.256bc	0.721cd	0.830c	1.34bc
GA_3	0.246c	0.714d	0.798c	1.29c
KNO_3	0.276a	0.732bc	0.865c	1.39bc
KH_2PO_4	0.265ab	0.739b	1.08b	1.60b
Azotobacter	0.256bc	0.714d	0.862c	1.35bc
Control	0.278a	0.757a	1.47a	2.02a

Means under same parameter sharing letters are not significantly different at α = 0.05; Lot1: Fresh seed; Lot2: One-year-old seed; Lot3: Two-year-old seed; Lot4: Three-year-old seed

Table 9. *Seedling emergence index and seedling establishment (%) of differentially aged onion seed lots under different priming treatments*

Priming treatment	Seedling emergence index				Seedling establishment (%)			
	Lot1	Lot2	Lot3	Lot4	Lot1	Lot2	Lot3	Lot4
Thiram	6.89abc	5.66c	2.39c	1.98c	68.39bc	63.16b	11.61bc	5.94ab
GA_3	7.39a	6.31a	3.14a	2.75a	71.28a	65.93a	12.78a	6.39a
KNO_3	6.64bc	5.61c	2.10d	1.71cd	66.50cd	58.49d	10.01d	4.28c
KH_2PO_4	6.66bc	5.66c	1.91e	1.46d	65.61d	60.38c	10.97c	5.28b
Azotobacter	7.12ab	5.88b	2.74b	2.34b	69.06b	65.49a	12.04b	5.94ab
Control	6.27c	4.75d	1.38f	0.95e	64.50d	49.05e	9.38d	3.72c

Means under same parameter sharing letters are not significantly different at α = 0.05; Lot1: Fresh seed; Lot2: One-year-old seed; Lot3: Two-year-old seed; Lot4: Three-year-old seed

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Based on the effectiveness for enhancement of germination, vigour and storage potential, the best priming treatment is GA_3 @ 50 ppm followed by Biofertilizer *Aztobacter*. While the least effective treatment was KNO_3. Priming of the seeds with various treatments was found competent to improve the seed quality in fresh as well as marginal (one-year-old) and sub-marginal (two-year-old) seed age. No doubt performance of fresh seed was found better over all the other lots but, the improvement was comparatively more in marginal seed age, i.e., one-year-old seed lot (Lot1) because in this lot seed germination achieved up to 70% as per Indian minimum seed certification standards (IMSCS) standards.

Linear regression analysis revealed that germination and SE exhibited significant positive relationship ($p < 0.05$) in one-year-old seed lot, where germination explained 81% variation in SE (*Fig. 1*). Successful SE depends on several factors and ability of seeds to germinate is one of them. Present studies reveal that higher germination capacity under laboratory conditions is quite apparent through better establishment of seedlings under field conditions. These two parameters had a high positive correlation ($r = 0.90$), which indicates that priming in the one-year-old seed can result in good performance in field conditions. Similarly, both the vigour indices, i.e., SVI-I ($p < 0.01$) and SVI-II ($p < 0.05$) also had a positive association with SEI in one-year-old seed lot. SVI-I and SVI-II explained 89 and 73% variation in SEI, respectively (*Fig. 2*). Correlation of SVI-I and SVI-II with SEI had high positive values of 0.94 and 0.85, respectively. Vigour indices are based on germination, seedling length and seedling dry weight, and high values of these indices indicate fast-growing seedlings with good quality characteristics which are ultimately reflected in SEI. Fast-growing and healthy seedlings (which are a basis for vigour indices) lead to the higher values of SEI. Overall, it could be said that priming of onion seed stored for one year has good performance under heterogeneous field conditions leading to a good plant stand.

Discussion

Seed priming was identified to improve the germination and seedling establishment in some of the critical field crops like soybean, wheat, maize, sunflower and sugarbeet (Singh, 1995; Khajeh-Hosseini et al., 2003; Sdeghian and Yavari, 2004). The improved performance and quality of seed after is due to several processes like DNA repair, activation of enzymes and endosperm weakening in primed seeds (Osborne, 1983; Dell'Aquilla et al., 1998; Moosavi et al., 2009). Also, priming enhances antioxidant activity in the seeds, which results in reduced lipid peroxidation, improves seed quality (Hsu et al., 2003; Chiu et al., 2006). Davison and Bray (1991) have observed some changes in the protein pattern in the primed seeds. Vigorous crops grown from primed seeds were able to capture more nitrogen than plants grown from non-primed seeds, thus utilising nitrogen before leaching or volatilization losses (Byrum and Copland, 1995). Ramadevi and Gopalkrishan (2001) are of the view that enhanced hydration of all seed parts leading to reduced damage to the embryonic axis could be the reason behind the increased speed of emergence and seedling establishment. Toxic effect of potassium salts on the germinating seeds is the reason behind KNO_3 being the least effective treatment. Toxic effect of KCL has been reported by some workers where it has a negative effect on germinating embryos which leads to a reduction in germination and seedling death (Giri and Schillinger, 2003; Yari et al., 2011).

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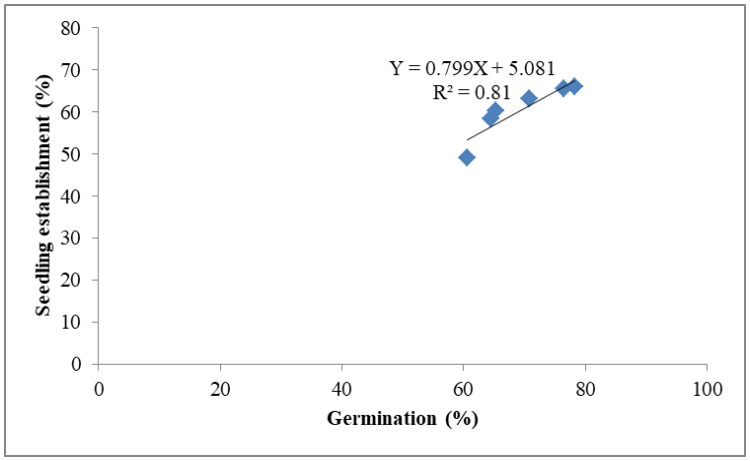

Figure 1. *Relationship between seedling establishment (%) and germination (%) in one-year-old seed*

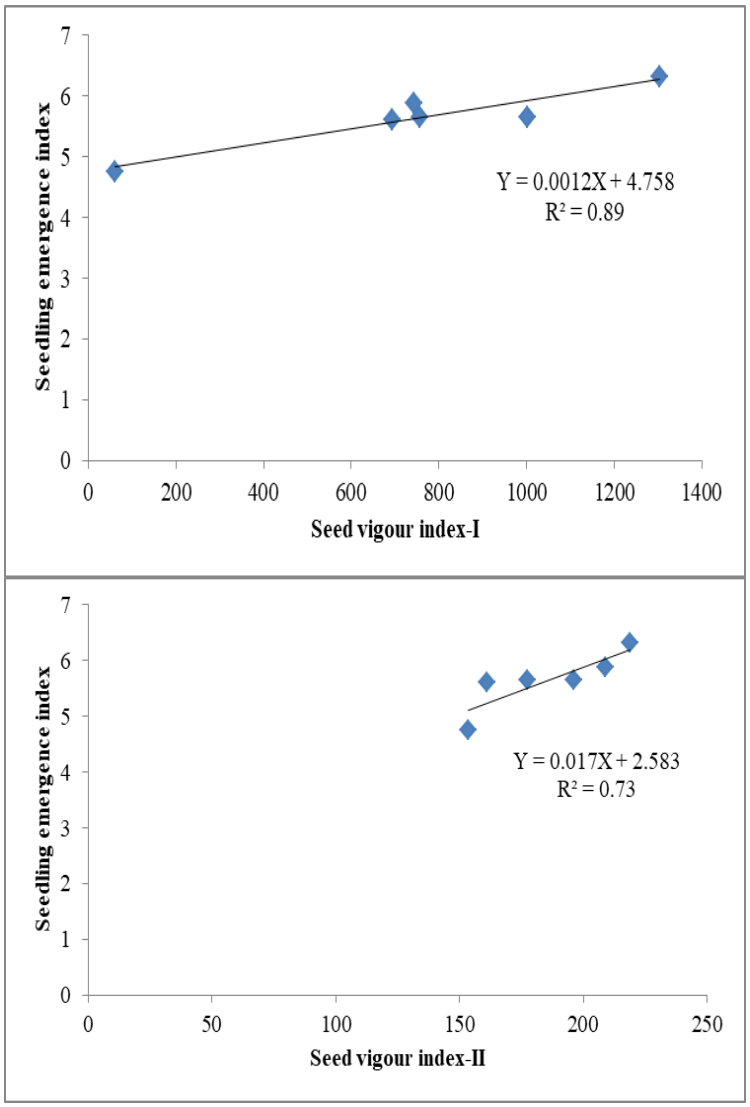

Figure 2. *Relationship between seedling emergence index (SEI) and seed vigour index-I (SVI-I) and seed vigour index-II (SVI-II) in one-year-old seed*

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Gibberellic Acid (GA_3) is an essential growth regulator, which aids in breaking seed dormancy, promoting germination, internodal length, growth of hypocotyl and cell division in the cambial zone and enlargement of leaf size. GA_3 degrades cells surrounding the radicle by stimulating hydrolytic enzymes, which ultimately speeds germination (Rood et al., 1990). GA_3 also plays a vital role in the mobilization of endosperm reserves during germination of seeds (Weiss and Ori, 2007). During the germination process, GA_3 is released from an embryo, which activates genes responsible for alpha-amylase mRNA transcription (Taiz and Zeiger, 1991). Exogenous application of GA_3 might lead to activation of such genes in seeds, thus improving germination. Increased vigour characteristics elevated peroxide scavenging enzymes activities and decline in lipid peroxidation some of the possible reasons behind enhanced seed germination. Higher metabolic activity in primed seeds causes efficient food mobilization during early hours of germination, which leads to increased shoot and root lengths (Brar et al., 2019).

Consequently, it results in higher seedling dry weight (Bailly et al., 2002; Jett et al., 1996). Priming of fresh and aged onion seed with GA_3 (50 ppm) resulted in favourbale impact on the germination ability and seed vigour. Also the aged seed was more responsive to priming as compared to the fresh seed (Muruli et al., 2016). Yarnia et al. (2012) determined the effect of hormonal treatments i.e., IAA, GA_3 and kinetin on germination and seedling growth of onion. Of these priming treatments GA_3 and IAA led to improved attributes such as germination, seedling length, root length, seedling dry weight etc. Helaly et al. (2016) also reported highest germination, seed yield and weight of thousand seeds in GA_3 (1000 ppm) primed onion seeds. In case of shallots also GA_3 priming significantly enhances the germination, speed of germination, seedling vigour and rate of seedling emergence (Agung and Diara, 2017).

GA_3 priming was followed by bio-priming with *Azotobacter*, which is known to promote plant growth through indole-3-acetic acid (IAA) production and nitrogen fixation (Hafeez et al., 2004). *Azotobacter* inoculations are known to produce GA_3, IAA and cytokinins (Barea and Brown, 1974), which enhances seedling development and plant growth (Brown, 1982). Bacteria produce plant growth regulators which alter morphology and metabolism of the plant, yields more extended root systems and improves absorption of water and minerals (Bashan et al., 2004; Lai et al., 2008; Fibach-Paldi et al., 2012). *Azotobacter* enhances germination in rice and cotton by the synthesis of growth promoters and antifungal antibiotic production, which ensure seed safety during germination (Shende et al., 1977). Inoculation with *Azotobacter* increases shoot, and root length in maize and sorghum and pre-soaking of seed improves germination and seedling establishment (Ahmed et al., 1998). Bio-agents are also more effective as compared to synthetic chemicals as they improve seed quality characteristics while providing tolerance to other toxic agents. Brar et al. (2015) reported improved seed quality characteristics in tomato with the supply of biofertilizers like *Azotobacter*. Treatment with biofertilizers also enhanced the seed yield and improved the fertility status of the soil by nitrogen fixation.

Lower EC for primed seed may be due to improved plasma membrane structure as a result of slow hydration in the priming treatments (McDonald, 1980). Kumar (2004) reported that onion seeds treated with GA_3 recorded the maximum decline in seed leachates in comparison to control. Improvement of germination at high levels of ageing was not achieved through priming as the irreversible damage could not be repaired (Butler et al., 2009). During the programmed cell death (PCD), catalase rate and

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sensitivity reduce, which indicates that the ageing causes PCD and subsequent the reduction of seed viability.

Conclusion

It is concluded that the standard germination, vigour indices and EC tests could be used as reliable predictors of seed quality because of easiness, quickness and accuracy in their execution. Further, various seed priming treatments can be used for enhancing seed quality of marginal seed lot. GA_3 (50 ppm) was found to be best priming treatment for improving the seed quality followed by biofertilizer (*Azotobacter*), hydro priming and dry dressing with Thiram (2 g/kg), KH 2 PO 4 (0.5%) and KNO 3 (0.5%), respectively. Overall, the priming technology was found useful and beneficial for enhancing the physiological, biochemical and storage potential of onion seed**.** Indeed, in the case of these onion varieties, we recommend the priming treatment for getting a bumper harvest.

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