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Effect of Seed Maturity and Priming on Viability and Vigour in Tomato (*Lycopersicon esculentum* L.)

R. G. S. Rao, P. M. Singh and M. Rai
(Indian Institute of Vegetable Research, Varanasi, India)

Summary

The influence of seed maturity and osmopriming on germination and vigour variations in developing tomato seeds was analysed. Seeds were harvested at various maturity classes based on fruit colour. Results revealed that the physiologically mature seeds showed higher percentage germination, robust and healthy seedlings, greater seedling vigour index (SVI) and longer storability. Priming enhanced the germination behaviour of low vigour and ageing seeds. The seedling mortality and abnormal seedlings were higher in the overmature, mature and immature classes, respectively.

Zusammenfassung

Einfluss von Saatgutreife und Priming auf Keimfähigkeit und Vitalität von Tomaten (*Lycopersicon esculentum* L.). Gegenstand dieser Untersuchung war der Einfluss des Reifegrades und des osmotischen Primings auf die Keimung und die Vitalität von Tomatensaatgut. Die Samen wurden in unterschiedlichen, auf der Fruchtfarbe basierenden Reifeklassen geerntet. Die Ergebnisse zeigten, dass physiologisch reife Samen eine höhere Keimrate, widerstandsfähige und gesunde Sämlinge, einen höheren Sämlingsvitalitätsindex (SVI) und eine längere Lagerfähigkeit aufweisen. Das Priming verstärkte das Keimverhalten von wenig vitalem und älterem Saatgut. Die Rate absterbender und abnormaler Sämlinge war in der überreifen, reifen beziehungsweise unreifen Klasse höher.

Key words. accelerated ageing – germination – maturity – osmopriming – tomato – vigour

Introduction

Tomato (*Lycopersicon esculentum* L.) is one of the major vegetable crops of the world because it is the richest source of several nutrients and other applications. The growing importance of tomatoes has been thoroughly met with the exploitation of available genetic resources for developing promising new varieties and hybrids. Since the seed recovery (%) is very low, there is greater emphasis on each and every seed produced and also, tomato seeds have been categorized **as low volume-high cost input**. In the present context of advanced and commercial tomato cultivation, quality of seeds determines the expected returns from proportionate application of all other inputs. Thus, the production and making available good quality seeds to vegetable growers would be important from the breeding and seed technology point of view. However, seed germinability, and vigour grossly depends upon the extent of pollination, seed setting, seed development, and maturation besides, cultural and weather conditions during seed development, and post harvest handling etc. The seed harvest well before appropriate maturity and retention of seeds on the mother plant beyond physiological maturity leads to the development of hard, dead and diseased seeds, which result in maximum abnormal and low vigour seedlings (WELLINGTON 1956; BLACK 1983). The time of maturity and marketable yield in many vegetable crops could be influenced by the time taken for seeds to germinate and seedlings to establish (CURRAH 1978). Osmopriming of seeds regulates the physiological and biochemical activities besides also undertake repair processes affecting germination, thus resulting in uniform, vigorous and healthy seedling emergence. The hydrated/primed seeds are presumed to lose longevity, however, such seeds dried back to safe moisture contents could be stored for longer durations. Accelerated ageing has been a good indicator of vigour and storability since loss of vigour and viability could be assessed at regular intervals. The literature pertaining to the quality of tomato seeds harvested at various maturity stages, suitable priming treatments for enhancing the physiological potential of seeds to emerge and longevity is limited. Hence, the present investigations were conducted to evaluate the influence of seed maturity and priming on the germinability and vigour of tomato seeds

Materials and Methods

Seed crops of tomato cv. 'Sel-7' was raised during winter 2003/04. The fruits were harvested at three maturity stages i.e., breaker (S_1), mature (S_2) and over ripe (S_3) on the basis of fruit colour variations by visual observations. The seeds were extracted by fermentation method i.e., fresh fruits were collected in 700 gauge polyethylene bags, crushed and allowed to ferment for

36 h and later, transferred into clean tub wherein the supernatant material was decanted in running water. The extracted clean seeds were dried under shade for 24 h followed by oven drying at 35 °C for 72 h as to reduce the seed moisture content (SMC) to 6.5 % and data on 100 seed weight was noted. For priming, the dried seeds were uniformly spread over petri plates lined with filter papers, to which adequate amount of priming solutions were added, and whole uncovered and aerated apparatus was maintained at 20 °C in an incubator for 24 h. The priming solutions utilized in the present experiments were PEG (T_1: –1.0 M Pa) and KNO_3 (T_2: 150 ppm). After priming, the seeds were dried back to original SMC as described earlier. Both primed and control un-primed seeds were subjected to accelerated ageing under 45 °C and 75 % RH (saturated NaCl solution in a sealed desiccator) for a week and samples were collected regularly at one day interval. Observations were recorded on percent germination (ISTA 1999), abnormal seedlings (%), dead seeds (%), and seedling vigour index (ABDUL BAKI and ANDERSON 1973).

Results

Data on effect of maturity and priming showed significant variations for percent seed germination (Table 2). Among the maturity stages, seeds harvested from mature (S_2) fruits showed maximum germination (86.5 %) as compared to S_1 (63.5 %) and S_3 (68.0 %). Irrespective of maturity stage, seed priming with PEG (T_1) had improved the germination performance as well as decreased the rate of seed quality deterioration which otherwise implied that a satisfactory germinability (approximately 85 %) could be maintained up to 5, 6 and 3 days after accelerated ageing (DAA) in S_1, S_2 and S_3, respectively. Though the initial seed quality was relatively satisfactory (68.0 %), the loss of germinability was faster in S_3 seeds. The effect of KNO_3 treatment (T_2) was also significant wherein satisfactory germination could be achieved even after 3, 5 and 2 DAA in S_1, S_2 and S_3, respectively. However, the seed maturity, priming, and their interaction showed highly significant influence on germination and also on loss of germinability upon seed ageing. Conversely, the number of abnormal seedlings and dead seeds were maximum in S_2 seeds and continuously increased with accelerated ageing. However, more number of abnormal seedlings and dead seeds were seen in S_1 and S_3 classes, respectively (Table 3, 4). Data also confirmed significant interaction effect between maturity, priming and ageing treatments on number of abnormal seedlings and dead seeds.

Data on seed vigour was noted on the basis of germination (%) and seedling length (cm). Among the various classes, mature seeds exhibited maximum vigour followed by immature and overmature seeds (Table 5). Irrespective of maturity stage, PEG (T_1) treatment significantly enhanced the seed vigour and minimized the seed senescence. In case of S_2, the effects of PEG and KNO_3 are significantly different. Over all, the stage of maturity, priming, and their interaction effects significantly improved the seed vigour.

Table 1. Variation of seed weight (g) with stage of maturity.

Maturity stage	100 seed weight
S_1	2.43
S_2	2.01
S_3	1.86
Mean	2.10
S em (±1)	0.07
CD (0.05)	0.20

Discussion

Data on seed density showed significant variation with seed development and maturity (Table 1). The 100 seed weight of seeds harvested from breaker stage fruits was high (2.43 g) as compared to mature (2.01 g) and over

Table 2. Effect of maturity, priming and controlled ageing on seed germination (%).

	S_1				S_2				S_3			
	T_0	T_1	T_2	Mean	T_0	T_1	T_2	Mean	T_0	T_1	T_2	Mean
D_0	63.5	63.5	63.5	63.5	86.5	86.5	86.5	86.5	68.0	68.0	68.0	68.0
D_1	89.3	81.3	81.3	84.0	98.7	100.0	98.7	99.1	68.0	84.0	90.7	80.9
D_2	92.0	100.0	94.7	95.6	100.0	100.0	100.0	100.0	76.0	84.0	81.3	80.4
D_3	58.7	89.3	86.7	78.2	86.7	98.7	98.7	94.7	61.3	85.3	34.7	60.4
D_4	58.7	85.3	74.7	72.9	81.3	90.7	93.3	88.4	42.7	58.7	42.7	48.0
D_5	21.3	84.0	58.7	54.7	72.0	85.3	82.7	80.0	46.7	68.0	37.3	50.7
D_6	16.0	69.3	22.7	36.0	21.3	84.0	62.7	56.0	10.7	45.3	13.3	23.1
D_7	0.0	25.3	26.7	17.3	5.3	58.7	52.0	38.7	0.0	17.3	4.0	7.1
Mean	49.9	74.8	63.6	62.8	69.0	88.0	84.3	80.4	46.7	63.8	46.5	52.3

CD (0.05) for days after ageing (D)	1.71	CD (0.05) for (DxT) interaction	3.39
CD (0.05) for maturity stages (S)	1.94	CD (0.05) for (DxS) interaction	3.26
CD (0.05) for priming treatments (T)	1.04	CD (0.05) for (TxS) interaction	1.89
CD (0.05) for (DxSxT) interaction	8.26		

Table 3. Influence of maturity, priming and ageing on abnormal seedlings (%).

	S_1				S_2				S_3			
	T_0	T_1	T_2	Mean	T_0	T_1	T_2	Mean	T_0	T_1	T_2	Mean
D_0	29.5	29.5	29.5	29.5	2.5	2.5	2.5	2.5	8.5	8.5	8.5	8.5
D_1	10.7	17.3	16.0	14.7	0.0	0.0	0.3	0.1	2.3	2.7	0.7	1.9
D_2	6.7	0.0	4.3	3.7	0.0	0.0	0.0	0.0	3.3	1.3	0.0	1.6
D_3	40.7	10.0	11.3	20.7	0.7	1.3	0.0	0.7	5.3	0.7	17.3	7.8
D_4	38.0	4.7	19.3	20.7	0.7	2.7	0.0	1.1	2.0	6.7	6.7	5.1
D_5	58.0	5.3	26.0	29.8	6.7	6.7	13.3	8.9	22.0	7.3	9.3	12.9
D_6	65.3	25.3	56.7	49.1	18.0	8.0	8.7	11.6	24.0	12.7	12.0	16.2
D_7	88.0	66.0	64.0	72.7	16.7	7.3	23.3	15.8	0.0	35.3	10.0	15.1
Mean	42.1	19.8	28.4	30.1	5.6	3.6	6.0	5.1	8.4	9.4	8.1	8.6

CD (0.05) for days after ageing (D)	1.59	CD (0.05) for (DxT) interaction	3.15
CD (0.05) for maturity stages (S)	1.17	CD (0.05) for (DxS) interaction	2.95
CD (0.05) for priming treatments (T)	0.97	CD (0.05) for (TxS) interaction	1.76
CD (0.05) for (DxSxT) interaction	7.69		

Table 4. Influence of maturity, priming and ageing on dead seeds (%).

	S_1				S_2				S_3			
	T_0	T_1	T_2	Mean	T_0	T_1	T_2	Mean	T_0	T_1	T_2	Mean
D_0	7.0	7.0	7.0	7.0	11.0	11.0	11.0	11.0	23.5	23.5	23.5	47.0
D_1	0.0	1.3	2.7	1.3	1.3	0.0	1.0	0.8	29.7	13.3	8.7	34.5
D_2	1.3	0.0	1.0	0.8	0.0	0.0	0.0	0.0	20.7	14.7	18.7	36.0
D_3	0.7	0.4	2.0	1.0	12.7	0.0	1.3	4.7	33.3	14.0	48.0	63.6
D_4	3.3	10.0	6.0	6.4	18.0	6.7	6.7	10.4	55.3	34.7	50.7	93.8
D_5	20.7	10.7	15.3	15.6	21.3	8.0	4.0	11.1	31.3	24.7	53.3	72.9
D_6	18.7	5.3	20.7	14.9	60.7	8.0	28.7	32.4	65.3	42.0	74.7	121.3
D_7	12.0	8.7	9.3	10.0	78.0	34.0	24.7	45.6	100.0	47.3	86.0	155.6
Mean	8.0	5.4	8.0	7.1	25.4	8.5	9.7	14.5	44.9	26.8	45.4	78.1

CD (0.05) for days after ageing (D)	1.27	CD (0.05) for (DxT) interaction	2.52
CD (0.05) for maturity stages (S)	0.78	CD (0.05) for (DxS) interaction	2.36
CD (0.05) for priming treatments (T)	1.14	CD (0.05) for (TxS) interaction	1.41
CD (0.05) for (DxS xT) interaction	6.15		

ripe seeds (1.86 g) because of reduction in seed moisture, high rate of respiration, anabolism of seed reserves, deposition of polymeric reserves and desiccation during maturation drying and after-ripening processes and so, seed density is negatively correlated with seed maturity.

Seed maturity significantly affected germination potential with maximum germinability (86.5 %) in mature (S_2) seeds, while poor germination of 63.5 and 68.0 % was recorded in S_1 and S_3, respectively. The results of our study also emphasized that seeds with good initial quality could perform better under field conditions and also store for longer periods. Certain earlier reports also revealed that the seed germinability, seedling vigour, and storability would be superior in physiologically mature seeds (DOIJODE 1988; PALLAIS et al. 1989). However, appropriate indices to assess seed vigour need to be critically standardized for each seed type and crop. Accelerated ageing tests offered relative advantages as an indicator of seed vigour (ARGERICH and BRADFORD 1989) because, it is rapid and simulates various physiological and biochemical changes associated with germination process and also, loss of vigour. Both primed and un-primed seeds showed significant initial increase in germinability and vigour followed by steep reduction with ageing. The detrimental effects of ageing was more significant in S_1 and S_3 classes, whose germination fell to < 60 % after 3 days accelerated ageing (DAA) whereas 72 % germination was observed after 5 DAA in case of mature seeds (Table 2). Seeds and seedlings of S_2 were least infected and / or colonized by fungi as compared to S_1 and S_3 seeds. The seedling mortality was higher in overmature seeds (Table 3) while more abnormal seedlings were produced in immature seed class (Table 4). In majority of seeds, a des-

Table 5. Variations in seed vigour (SVI) with seed maturity, priming and ageing.

	S_1				S_2				S_3			
	T_0	T_1	T_2	Mean	T_0	T_1	T_2	Mean	T_0	T_1	T_2	Mean
D_0	1111.3	1260.5	1317.6	1229.8	1712.7	2119.3	1885.7	1905.9	1275.0	1286.6	1389.2	1316.9
D_1	1428.7	1111.3	1152.0	1230.7	1613.3	1716.7	1760.0	1696.7	1189.3	1146.7	1440.0	1258.7
D_2	1253.3	1700.0	1230.0	1394.4	1833.3	1883.3	1800.0	1838.9	1235.3	1216.7	1219.3	1223.8
D_3	877.3	1206.6	971.3	1018.4	1079.3	1858.0	1875.3	1604.2	566.7	1125.3	194.7	628.9
D_4	716.0	937.3	1056.0	903.1	1468.7	1375.3	1587.3	1477.1	490.0	770.7	472.0	577.6
D_5	172.0	1277.3	670.6	706.6	1027.3	1392.7	1251.3	1223.8	508.1	1061.1	545.3	704.8
D_6	80.7	861.3	174.0	372.0	180.7	1104.7	559.1	614.8	49.3	549.3	138.7	245.8
D_7	0.0	126.6	110.6	79.1	17.3	477.6	456.7	317.2	0.0	152.0	20.7	57.6
Mean	646.9	1031.5	766.4	814.9	1031.4	1401.2	1327.1	1253.2	577.0	860.3	575.8	671.0

CD (0.05) for days after ageing (D)	78.96	CD (0.05) for (DxT) interaction	128.11
CD (0.05) for maturity stages (S)	38.87	CD (0.05) for (DxS) interaction	156.48
CD (0.05) for priming treatments (T)	48.35	CD (0.05) for (TxS) interaction	87.44
CD (0.05) for (DxSxT) interaction	381.28		

iccation period i.e., a switch in cellular activities from an exclusively developmental program to an exclusively germination / growth-oriented program is essential as a part of seed development and maturation for seeds to mature and germinate. Though, immature embryos have the capacity to precocious germination in response to certain 'germination cues' but can't undergo necessary developmental metabolism as occurs in normal mature seeds and thus, often results in abnormal seedling growth (KERMODE 1990). Various investigations have suggested that certain fungal species viz., *Aspergillus flavus* invade and infect the growing embryo, which ultimately damages the embryo thereby reducing seed vigour and viability. Mostly, its severity and inoculum depends on the prevailing environmental conditions (AGARWAL and SINCLAIR 1987). However, in case of overmature seeds, combining certain chemical treatments (systemic fungicides) along with the priming would collectively reduces the seed infections and mortality, thus increasing the planting value (viability and vigour) of seeds. Conclusively, the plant stand variations would be attributed to existing differences in seed maturity classes within the seedlots.

Overall, enhanced germinability and vigour was observed in seeds treated with PEG (T_1) followed by KNO_3 (T_2). Results of the present investigation revealed that priming improved the germination performance of S_1 and S_3 seeds to a tune of 100 and 90 %, respectively. Among the priming treatments, maximum germination (100 %) was attained with PEG (–1.0 M Pa) in S_1 class. In addition, satisfactory germinability (80 %) could be maintained in primed S_1 seeds after 3 to 5 DAA with T_2 and T_1, respectively. Overmature seeds showed appreciable sensitivity to KNO_3 priming (T_2) while storability could be satisfactory with osmopriming (T_1). In case of primed mature seeds, satisfactory germinability and vigour could be retained even after 5 to 6 DAA. Pre-sowing priming of seeds considerably increased the performance of poor quality seeds extracted from sun scalded tomato fruits (SINGH et al. 2001). Similarly in muskmelon, seeds harvested at mature and fully mature stages primed with KNO_3 and PEG showed similar germinability but reduced mean germination rate (inverse of time to germination) i.e., enhanced seedling vigour and seedling ability to emerge under unfavourable conditions. Overall, priming significantly improved the performance of mature seeds, but had less effect on maturing and overmature seeds (WELBAUM and BRADFORD 1991). The seed priming with suitable osmotica under optimum conditions regulates the rate and degree of seed imbibition, retains seeds in phase II for longer time enabling all seeds in a seedlot to initiate and complete essential pre-germinative metabolic events uniformly, thus culminating in rapid radicle emergence, uniform germination and stand establishment (BROCKLEHURST et al. 1987). Priming efficiently improved eggplant seed performance in terms of laboratory germination, radicle length, biomass accumulation, and field emergence (TRIGO and TRIGO 1999).

However, there have been conflicting reports that osmopriming effects the seed storability, but our results confirmed that priming followed by drying seeds back to safe SMC had increased the ability of seed to withstand the adverse factors affecting the senescence. Nascimento and West (2000) compared the effects of drying immediately after seed priming or after 12 months of storage in muskmelon and found beneficial effects of priming after dehydration while drying temperature did not affect seed germination. However, seed germination and vigour of primed seeds decreased after 12 months of storage. BROCKLEHURST et al. (1987) illustrated the beneficial effects of completely dried onion seeds after priming treatments, which could be stored for 12 months after priming with no significant loss of beneficial effects of treatments. Results of our accelerated ageing experiments also suggested that the priming might delay the onset of deterioration in seeds.

Apparently, priming did not improve the germination of fresh seeds but, PEG and KNO_3 did improve

the viability and vigour of seeds subjected to accelerated ageing (Table 5). PANDITA et al. (2000) also reported that priming did not effect the germination of fresh tomato seeds but improved that of ageing seeds. However, the sensitivities of seeds to priming showed varietal differences when seeds of several cultivars were primed with PEG and water, dried back to 6.5 % SMC and stored in sealed aluminum foil bags followed by accelerated ageing. This appeared to be an interesting observation. However, looking for the reasons for such behaviour of seeds, it was felt that the fresh seeds were unable to germinate and establish into a vigorous seedling because of several innate factors, which might be physical, physiological, and biochemical manifestations culminating in the poor and irregular radicle emergence and seedling development. In tomato, X-ray photographs and longitudinal sections revealed the formation of free space surrounding the embryo in dry primed seeds, which was not evident in un-primed or aged seeds thus, priming increased the rate of germination while ageing decreased it (ARGERICH and BRADFORD 1989). When the seeds were aged, the necessary physiological, biochemical and molecular changes required for successful germination viz., increased levels of α-amylase and RNAs, nuclear replication activities etc might have occurred contributing towards cell division, elongation, organellar differentiation and ultimately radicle protrusion, and enhanced performance of primed seeds. TOORN and TOORN (1990) improved the quality of low vigorous celery seeds after gravity separation by priming in water and PEG due to which embryos doubled in length and embryo growth rate was faster. Priming of pepper seeds induced enhanced DNA replication and synthesis in the embryo root tips, thus reducing the mean germination time whereas the amount of priming-induced DNA synthesis was lower in aged/deteriorated seeds (LANTERI et al. 1997). Similarly, matriconditioned pepper seeds showed a significant increase in the speed of emergence, capability of emergence, vigour of seedlings and the content of DNA in seedlings (DABROWSKA et al. 2000). Considering the lipid peroxidation hypothesis of seed ageing, priming treatments might have minimized seed membrane disintegrations and cell detoxifying systems etc by preventing accumulation of toxic forms of oxygen and increasing activities of certain free radical scavenging enzymes (BAILLY et al. 1996).

Conclusions

The enhancement of quality of immature and overmature seeds by osmopriming treatments and loss of vigour with ageing could be suitably confirmed by the seedling growth tests supplemented by accelerated ageing. Incidentally, it is critically important that the seeds should be harvested at optimum fruit and seed maturity stages of the plant. Otherwise, pooled seedlots possess varying seed germination and vigour. However, priming treatments (hydration in water or osmotic solutions followed by drying) could improve the short-term seed performance but often improper drying might result in reduced seed longevity wherein both temperature and duration of drying affect the seed vigour after storage.

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Addresses of authors: Rao, R.G.S., P.M. Singh, P.M., and Mathura Rai, Indian Institute of Vegetable Research, P.B. 5002, P.O. BHU, Varanasi - 221 005 (U.P.), India, e-mail: gowri_iivr@yahoo.com.