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POSTHARVEST TECHNOLOGY AND SEED GERMINATION AND STORABILITY OF TOMATO (*SOLANUM LYCOPERSICUM* L.)

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ABSTRACT
Postharvest technology for quality seed production in tomato was standardized in the parentage (Pusa slection 120 and Chikoo) of Pusa Hybrid-4 in the Division of Seed Science and Technology at Indian Agricultural Research Institute, New Delhi. Initially, high seed germination percentage was recorded with male parent (93), open field crop (94), turning stage (92), acid method of seed extraction (96) and shade drying (93). Among combinations, high seed germination percentage was recorded with turning stage and acid method (95); turning stage and shade drying (93); acid method and shade drying (98). Twelve months of storage, high tomato seed germination (percentage) was observed with male parent (88), green house grown crop (88), red ripe stage (88) and acid method (88). Among combinations, turning stage and acid method (88); turning stage and shade drying (88); acid method and shade drying (88) recorded good storability. Tomato fruits harvested at turning stage followed by acid method of seed extraction and shade drying recorded high initial seed quality with 96 per cent seed germination. But fruits harvested at red ripe stage, acid method of seed extraction and sun drying recorded high storability with 89% seed germination.

INTRODUCTION

Tomato (*Solanum lycopersicum L.*) is the second major vegetable crop in India grown on an area of 0.882 million hectares with annual production of 18.7 million tones and average productivity of 19.5 t ha^{-1} and the share of tomato in total vegetable production in India is 11.3% (National Horticulture Board, 2015). However, this productivity is far less than the world's productivity of 32.8 m ha^{-1} (FAO, 2015). Moreover, major loss in tomato occurs during post harvest handling (Monika *et al.,* 2015). Hence, the availability of quality seed is important for increasing the production and productivity of tomato. The seed quality of tomato is affected by factors like seed maturation (Dias et al., 2006 and Kailappan and Karunanithy, 2006), seed extraction (Ghosh and Syamal, 1997 and Kailappan and Karunanithy, 2006) and seed drying in chilli (Chakradhar et al., 2016). These factors also determine vegetable seed quality by influencing seed germination and seedling emergence (Demir and Ellis, 1992). The information on the combined effect of these factors on tomato seed quality and storability is meager. Postharvest quality and shelf life of the fruit in part will depend on some postharvest handling practices and treatments carried out after harvest quality of the harvested fruit can be maintained and shelf life extended by using appropriate postharvest handling practices and treatment methods (Issac *et al.,* 2016)

With this, the present project was planned to bridge this gap by standardizing best combinations of growing conditions, stage of fruit picking, method of seed extraction and method of seed drying as an efficient tomato seed production and postharvest technology for producing good quality tomato seed with longer seed storability and good seed germination. This study was conducted to verify the influence of fruit maturity stage and post-harvest technology on tomato (*Solanum lycopersicum* Mill.) seed quality.

MATERIALS AND METHODS

Tomato seed production was carried out in two types of growing conditions viz., protected condition (green house) and unprotected condition (open field) at the Centre for Protected Cultivation and Technology (CPCT), IARI, New Delhi (India). The seedlings of two parents of hybrid tomato "Pusa Hybrid-4" (Pusa Selection 120 and Chikoo) were raised in the multi-celled plastic plug trays having cell volume of 20 cm^3 by using soil less media consisting of coco-peat,vermiculite and perlite in 3:1:1 ratio (v/v). Fertigation in the nursery was done once a day and the concentration of NPK plus micronutrients used was from 20 to 80 ppm depending upon the growing stage of the nursery. Thirty day old tomato seedlings were transplanted in greenhouse and open field at a planting spacing of 50 x 60 cm and stacking was provided throughout the crop growth period.

Tomato fruits of both the parents of Pusa Hybrid-4 were picked at two different stages, red ripe stage (S1) i.e., more than 90 percent of the surface shows red colour and turning stage (S2) i.e., more than 10 percent but not more than 30 percent of the surface, shows a definite change in colour from green to yellow, pink, red, or a combination of these colours (CFR, 1991 and Choi *et al.,* 1995). In the Division of Seed Science and

Technology, IARI, New Delhi, tomato seed was extracted from the harvested fruits by following three methods viz., manual crushing and extraction (E1) by crushing harvested fruits along with seeds and pulp in nylon bags or polyethylene bags in order to remove the mucilage that is present around the seeds and the seed was separated from pulp by 3-4 times washing with water; fermentation method (E2) by allowing a measured quantity of crushed fruit pulp to ferment without adding water for 48 hours in poly bags at ambient temperature (25-30^{0}C) and acid method (E3) by adding concentrated hydrochloric acid to the pulp @ 100 ml for every 14 kg of pulp, acid and pulp was continuously stirred for 15-20 minutes and the seed was separated by thorough washing in running water (Nemati *et al.,* 2010). Extracted seeds were dried by following two methods viz., sun drying (D1) by draining off water completely from the seed and spreading them on blotting paper and were dried under sun till the moisture content reached around 8-10 percent and shade drying (D2) by drying the drained seed under shade (Ravi Hunje *et al.,* 2007 and Chakradhar *et al.,* 2016). Treatments were formed in twelve combinations as red ripe stage -manual extraction - sun drying (S1E1D1); red ripe stage - fermentation extraction - sun drying (S1E2D1); red ripe stage - acid extraction - sun drying (S1E3D1); red ripe stage -manual extraction - shade drying (S1E1D_2); red ripe stage - fermentation extraction - shade drying (S1E2D_2); red ripe stage - acid extraction - shade drying (S1E3D2); turning stage - manual extraction - sun drying (S2E1D1); turning stage - fermentation extraction - sun drying (S2E2D1); turning stage - acid extraction - sun drying (S2E3D1); turning stage -manual extraction - shade drying (S2E1D2); turning stage -fermentation extraction - shade drying (S2E2D2) and turning stage - acid extraction - shade drying (S2E3D2).

The standard germination test was conducted as per ISTA rules (2007). Four replications of 100 seeds each were placed on the top of paper in petri dishes and were kept in germinator at 25+ 1^{o}C. The evaluation of normal seed and abnormal seedlings, fresh ungerminated and dead seeds was done on 14th day. Germination percentage is expressed on the number of normal seedlings.

The 450 g seeds of each treatment in three replications were packed in paper bags and kept at room temperature for twelve months using CRD (Completely Randomized Design) techniques, as described by Panse and Sukhatme (1985). The data were statistically analyzed using analysis of variance (Gomez and Gomez, 1984). Wherever, necessary the data was transformed to angular (arc sine) values before subjecting them to statistical analysis. The storability of seeds was studied using seed germination test.

RESULTS AND DISCUSSION

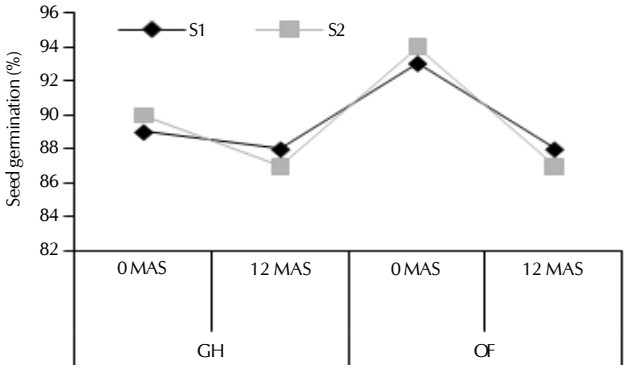
Parental response

The data pertains to the effect of seed crop growing conditions, stage of fruit picking, methods of seed extraction and drying on the seed germination and storability of the parents of Pusa hybrid 4 is presented in the table 1. Initially, in both the parents statistically significant difference was observed among the treatments but this difference was non-significant among the treatments after 12 months of storage. Among the parents, male parent (Chikoo) recorded high initial seed germination (93%) when compared to female parent (Pusa selection 120) as 91%. But no significant difference in seed storability was observed among the parents (87-88% seed germination) after 12 months of storage and this might be affected by genetic

Table 1: Effect of growing conditions, stage of fruit picking, seed extraction and drying methods on germination on female parent (Pusa Selection-120) of Pusa Hybrid-4 before and after seed storage

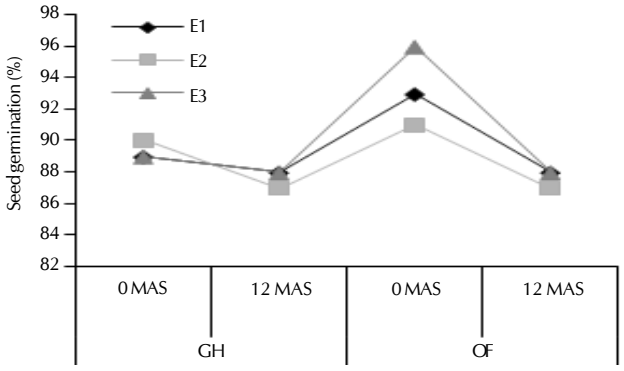
Treatment	Pusa Selection-120 (Female parent of Pusa hybrid 4)								Chikoo (Male parent of Pusa hybrid 4)							
	Green House				Open field				Green House				Open field			
	0MAS		12 MAS		0MAS		12 MAS		0MAS		12 MAS		0MAS		12 MAS	
S1E1D1	87	(69)	87	(70)	92	(76)	90	(72)	90	(72)	87	(69)	97	(80)	88	(69)
S1E2D1	90	(72)	87	(70)	87	(70)	86	(68)	92	(76)	87	(69)	91	(72)	87	(69)
S1E3D1	89	(71)	89	(71)	88	(71)	88	(69)	93	(75)	88	(70)	89	(70)	87	(69)
S1E1D2	89	(71)	89	(71)	93	(77)	87	(68)	89	(70)	87	(69)	92	(76)	87	(69)
S1E2D2	90	(72)	87	(70)	98	(86)	87	(69)	89	(71)	89	(71)	94	(76)	87	(69)
S1E3D2	88	(70)	86	(68)	98	(82)	87	(69)	95	(76)	87	(69)	96	(80)	87	(69)
S2E1D1	89	(71)	86	(68)	89	(71)	87	(69)	90	(72)	90	(71)	95	(78)	88	(70)
S2E2D1	90	(72)	86	(68)	89	(71)	86	(68)	90	(73)	90	(71)	98	(81)	88	(70)
S2E3D1	88	(70)	88	(70)	98	(86)	88	(70)	88	(70)	87	(69)	99	(82)	88	(70)
S2E1D2	89	(71)	89	(71)	97	(81)	86	(68)	93	(75)	88	(70)	92	(76)	86	(68)
S2E2D2	89	(71)	87	(69)	90	(72)	87	(69)	91	(72)	87	(69)	95	(76)	86	(68)
S2E3D2	92	(74)	87	(69)	98	(82)	87	(69)	96	(79)	88	(70)	98	(82)	87	(69)
Mean	89	(71)	87	(70)	93	(77)	87	(69)	91	(72)	88	(70)	95	(64)	87	(69)
CD at 5%																
Stage of picking	1.53		NS		4.28		NS		2.96		NS		2.70		NS	
Extraction method	1.88		NS		5.24		NS		2.96		NS		2.70		NS	
Drying method	1.53		NS		4.28		NS		4.19		NS		3.83		NS	
Stage x Extraction	2.66		NS		7.42		NS		3.63		NS		3.31		NS	
Stage x Drying	2.17		NS		6.06		NS		5.13		NS		4.69		NS	
Extraction x Drying	2.66		NS		7.43		NS		5.13		NS		4.69		NS	
Stage x Drying x Extraction	3.77		NS		10.49		NS		7.26		NS		6.63		NS	

Note: MAS- Months After Storage; Stages of fruit picking: Red ripe stage (S1), Turning stage (S2); Methods of seed extraction: manual crushing and extraction (E1), fermentation method (E2), acid method (E3); Methods of seed drying: sun drying (D1), shade drying (D2); Arc sine transformed values in parenthesis.



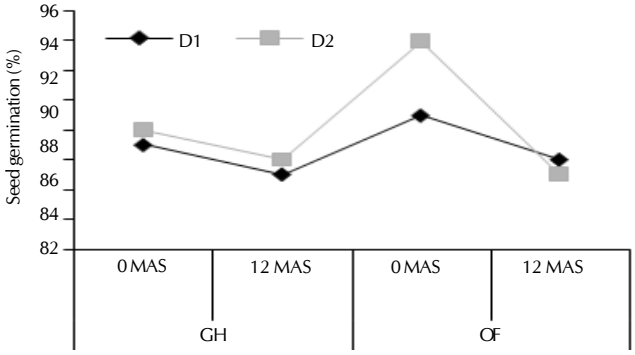
Note: GH- Green House; OF- Open Field; MAS- Months After Storage; S1-Fruits harvested at red ripe stage; S2 - Fruits harvested at turning stage

Figure 1: Effect of stage of fruit picking on tomato seed germination (%) and storability of Pusa selection-120



Note: E1-Manual crushing and extraction; E2- Fermentation method; E3- Acid method

Figure 2: Effect of method of seed extraction on tomato seed germination (%) and storability of Pusa selection-120



Note: D1-Sun drying; D2 - Shade drying

Figure 3: Effect of method of seed drying on tomato seed germination (%) and storability of Pusa selection-120

factors pertains to the crop.

Effect of crop growing conditions

Among the growing conditions, seed produced under open field condition showed high seed germination with an average of 94% (95 and 93%, respectively for male and female parents) compared to green house grown crop seed with an average of 90% (91 and 89% respectively, for male and female parents). Seed produced from both the growing conditions showed similar storage behavior with regard to germination (87%) even after 12 months of storage. This might be due to the fact that green house grown seed crop showed certain extent of seed dormancy (8-10 %) (Sujatha *et al.,* 2015a, Sujatha *et al.,* 2015b and Sujatha *et al.,* 2013) which was decreased with the advancement of seed storage period when compared to open field grown seed crop.

Effect of stage of fruit picking

Illustration from Fig. 1 reveals that the fruits harvested at turning stage (S2) showed slightly high initial seed germination (94 and 90%, respectively for open field and green house conditions) compared to fruits harvested at red ripe (S1) stage (93 and 89%, respectively for open field and green house conditions). Fruits harvested at turning stage might be in physiological maturity stage with high seed germination capacity and this might have decreased with the delay in the harvesting in red ripe stage. But a reverse trend was observed with regard to seed storability i.e., fruits harvested at red ripe stage (S1) showed comparatively good storability (88%) than the fruits harvested at turning (S2) stage (87%). It was also reported that germination potential of seeds reduced with the advanced stages of fruit maturity (Basave Gowda *et al.,* 2007) by reporting in tomato that 100 seed weight, germination and vigour index remained almost same upto sixth picking, thereafter, the values decreased with the further pickings for quality seed production. Usually the ethylene production rate increases with ripeness, injury incidence, disease and temperature increase (Yahia *et al.,* 2012 and Barry and Giovannoni, 2007 and Pech *et al.,* 2002).

Effect of method of seed extraction

Seeds produced from open field crop (Fig. 2) extracted by acid method (E3) showed high seed germination (96%) compared to fermentation (E2) method (91%). Whereas, green house grown seed extracted by fermentation method showed good germination (90%). Acid method of extraction might have remove mucilaginous substance around the seed in addition to the removal of dormancy that might have enhance percent seed germination. Seed extracted by manual crushing & extraction (E1) showed comparatively good storability with 88% germination followed by acid method and fermentation and this might be due to the fact that manual crushing might not have any mechanical injury or pathogen infection to the seed. These findings are in similar with Nemati et al., (2010) who have reported that seed quality decreased with increasing temperature and duration of fermentation and the fermentation duration from 24 to 48 h at temperature 25 degrees C. They have also reported that different extraction methods had not detrimental effect on percentage germination, but acid treatments produce very bright clean seeds in compare to other treatments.

Effect of method of seed drying

Data presented in Figure 3 reveals that irrespective of seed crop growing conditions, seed dried by shade drying (D2) showed more initial seed germination (96 and 90%, respectively for open field and green house conditions)

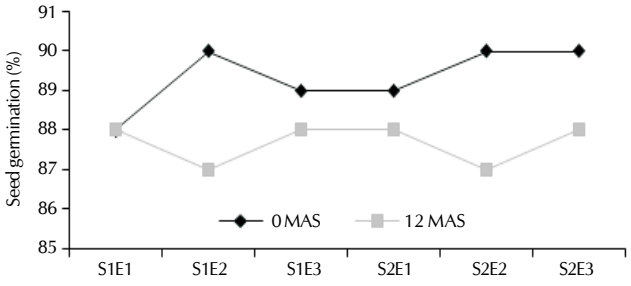


Figure 4A: Green house condition

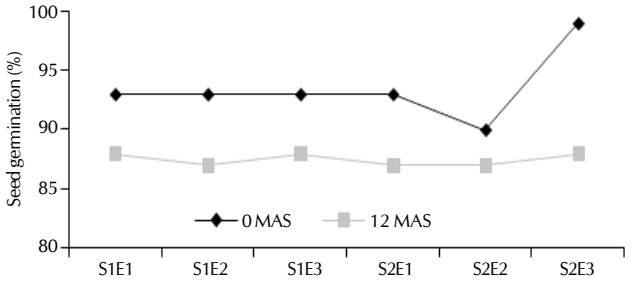


Figure 4B: Open field condition

Note: MAS- Months After Storage; S1E1- Fruits harvested at red ripe stage & manual crushing and extraction ; S1E2- Fruits harvested at red ripe stage & fermentation method ; S1E3- Fruits harvested at red ripe stage & acid method; S2E1- Fruits harvested at turning stage & manual crushing and extraction ; S2E2- Fruits harvested at turning stage & fermentation method ; S2E3- Fruits harvested at turning stage & acid method

Figure 4: Effect of stage of fruit picking and method of seed extraction on tomato seed germination (%) and storability

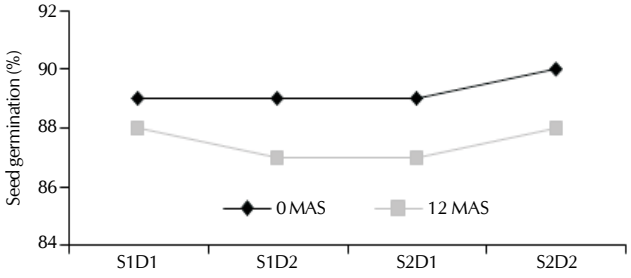


Figure 5A: Green house condition

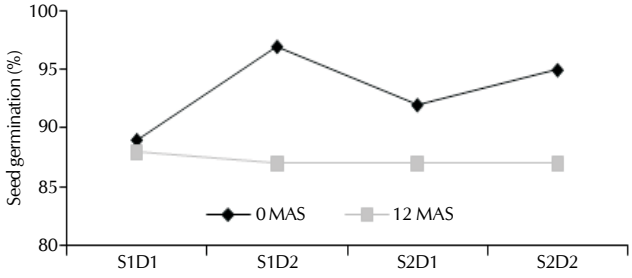


Figure 5B: Open field condition

Note: MAS- Months After Storage; S1D1- Fruits harvested at red ripe stage & sun drying; S1D2- Fruits harvested at red ripe stage & shade drying; S2D1- Fruits harvested at turning stage & sun drying ; S2D2- Fruits harvested at turning stage & shade drying

Figure 5. Effect of stage of fruit picking and method of seed drying on tomato seed germination (%) and storability

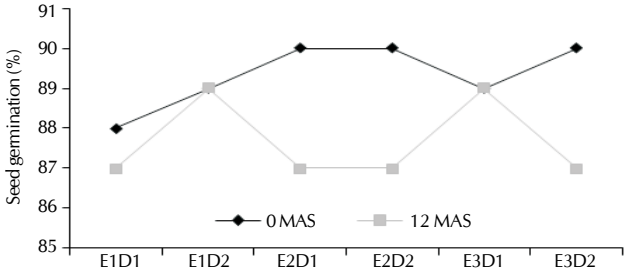


Figure 6A: Green house condition

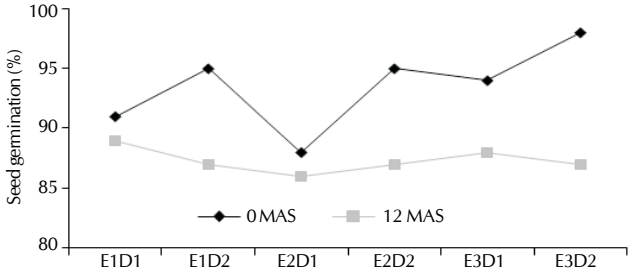


Figure 6B: Open field condition

Note: MAS- Months After Storage; E1D1- Manual crushing and extraction& sun drying ; E1D2- Manual crushing and extraction& sun drying;E2D1- Fermentation method& sun drying ; E2D2- Fermentation method& shade drying ; E3D1- Acid method& sun drying ; E3D2- Acid method& shade drying

Figure 6: Effect of methods of seed extraction and drying on tomato seed germination (%) and storability

compared to sun (D1) drying (91 and 89%, respectively for open field and green house conditions). No significant difference was observed among the drying methods with regard to seed storability. This might be due to the fact that shade drying might dry the seed at lower temperatures and does not cause any damage either to seed or to embryo. This finding was in conformity with the findings of Chakradhar et al., (2016) who have reported that shade drying was significantly better than other drying methods in chilli.

Combined effect of stage of fruit picking and extraction methods

Combinational effect of stage of fruit picking and extraction methods were presented in the Figure 4. Among the six combinations, fruits harvested at turning stage and seed extracted by acid method (S2 E3) showed high initial seed germination (99 and 90%, respectively for open field and green house conditions) and their combination also showed high seed storability (88%) even after 12 months of storage. This might be due to the fact that these two combinations might be compatible in enhancing seed germination by removing dormancy from seed. It was in conformity with the findings of Valdes and Gray, 1998 who have reported that the

maximum per cent of seed germination was obtained as early as breaker stage of fruit and thereafter they did not change as the fruit ripened.

Combined effect of stage of fruit picking and method of drying

Among the four combinations (Fig. 5), fruits harvested at turning stage and shade drying (S2 D2) recorded good seed germination (95 and 90% respectively for open field and green house conditions) and good seed storability with 88% germinated even after 12 months of storage under green house conditions. Shade drying might have preserved the physiological potential of the seed by removing moisture from the seed at very slow rate without causing any injury to the seed.

Combined effect of methods of seed extraction and drying.

Data pertains to the effect of six combinations of methods of seed extraction and drying was presented in the Fig. 6. The open field grown crop seed recorded good seed germination (98%) with acid method of seed extraction and shade drying (E3 D2) followed by E3 D1 and E1 D2 with 95% germination. Under both the growing conditions E3 D2 followed by E3 D1 and E1 D2 recorded good initial seed germination and high seed storability even after 12 MAS. In other findings it was reported that when fermentation is not complete, it suppresses seed germination and long period of fermentation is not advisable because it reduces seed quality such as seed germination per cent, vigour index and field emergence (Rajan and Markose, 2007).

Combined effect of three combination of treatments

Data from the Table 1 reveals that among twelve treatments, irrespective of seed crop growing conditions, fruits harvested at turning stage, seed extracted by acid method followed by shade drying (S2 E3 D2) recorded high initial seed germination (99 and 92%, respectively for open field and green house conditions). But with regard to seed storability, fruits harvested at red ripe stage, acid method of seed extraction and sun drying (S1 E3 D1) combinations recorded high seed storability with high seed germination (88 and 89%, respectively for open field and green house conditions) even after 12 of months of storage. These findings are in accordance to the findings of Ravi Hunje *et al*. (2007) who have reported in chilli that red ripe fruits dried under sun with better seed quality parameters, but lower seed quality parameters were recorded in shade drying.

It is to conclude that the seed produced from open field showed high initial seed germination than green house produced seed due to presence of more dormancy in green house grown seed. Seed obtained from fruits picked at turning stage showed high initial seed germination but fruits picked at red ripe stage showed high seed storability at 12 months after storage. Acid method of seed extraction showed high initial seed germination and seed storability. Seeds dried by shade drying showed high initial seed germination but there was significant difference among methods of seed drying with regard to seed storability. With regard to two combinations, turning stage of picking and acid method of seed extraction and turning stage of picking and shade drying, acid method of seed extraction and shade drying recorded good seed germination and storability. With regard to three combinations, turning stage of picking, acid method and shade drying showed high initial seed germination but fruits harvested at red ripe stage, acid method of seed extraction and sun drying recorded high tomato storability.

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