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Effect of fruit picking, extraction and drying on seed dormancy and storability in tomato (*Solanum lycopersicum* L.)

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Abstract
High per cent of seed dormancy was recorded with parents of Pusa Hybrid-4 (Pusa Selection 120 X Chikoo) under green house (9) compared to open field condition (6). Red ripe stage picking recorded more seed dormancy (8%) compared to turning stage (7%). High percentage of dormancy was observed with fermentation (8) followed by manual crushing and extraction (7) and acid method recorded lower seed dormancy (6). Even after twelve months of storage, manual crushing and extraction reported more dormancy (3%) compared to other extraction methods (2%). Sun drying recorded high percentage of dormancy (9) compared to shade drying. Among combinations, more seed dormancy was observed with red ripe stage and manual crushing (S1E1), red ripe stage and sun drying (S1D1) and fermentation and sun drying (E2D1). High seed dormancy was observed with combinations of red ripe stage either with manual crushing (green house) or fermentation method (open field) followed by sun drying.

Keywords: tomato, seed, picking, extraction, drying, dormancy

Introduction
The second major vegetable crop in India is Tomato (*Solanum lycopersicum* L.). It is 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) [5]. The information on post-harvest technology of tomato seed and its effect on seed dormancy and storability is meager. The present experiment was planned to known the effect of stage of fruit picking, method of seed extraction and method of seed drying and their various combinations on seed dormancy for producing good quality tomato seed with longer seed storability.

Material and Methods
The seedlings of both the 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) at the Centre for Protected Cultivation and Technology (CPCT), IARI, New Delhi (India). 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 both in greenhouse and open field at a spacing of 50 x 60 cm and stacking was provided throughout the crop growth period.
Tomato fruits were picked at red ripe stage (S1) and at turning stage (S2) and seed was extracted at Division of Seed Science and Technology, IARI, New Delhi, by 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. 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. Treatments were formed in twelve combinations as red ripe stage -manual extraction - sun drying ($S_1E_1D_1$); red ripe stage - fermentation extraction - sun drying ($S_1E_2D_1$); red ripe stage - acid extraction - sun drying ($S_1E_3D_1$) red;

ripe stage -manual extraction - shade drying ($S_1E_1D_2$); red ripe stage - fermentation extraction - shade drying ($S_1E_2D_2$); red ripe stage - acid extraction - shade drying ($S_1E_3D_2$); turning stage - manual extraction - sun drying ($S_2E_1D_1$); turning stage - fermentation extraction - sun drying ($S_2E_2D_1$); turning stage - acid extraction - sun drying ($S_2E_3D_1$); turning stage -manual extraction - shade drying ($S_2E_1D_2$); turning stage - fermentation extraction - shade drying ($S_2E_2D_2$) and turning stage - acid extraction - shade drying ($S_2E_3D_2$). The standard germination test was conducted as per ISTA rules (2007) [4]. Four replications of 100 seeds each were placed on the top of paper in petri dishes and were kept in germinator at 25± 1ºC. The evaluation of dormancy was done from counting the number of fresh ungerminated seeds was done on 14th day and the percentage dormancy was calculated. Dormancy percentage is expressed on the number of fresh ungerminated seeds. 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) [7]. The data were statistically analyzed using analysis of variance (Gomez and Gomez, 1984) [3]. Wherever, necessary the data was transformed to angular (arc sine) values before subjecting them to statistical analysis.

Results and Discussion

Effect of crop growing conditions on the seed dormancy and parental response

The data presented in the Table1 and Figures 1, 2 and 3 reveals the effect of post-harvest treatments on the extent of existence of dormancy. Both the parents showed similar extent of dormancy and no parental variation was observed with regard to dormancy. Among the growing conditions, seed produced under greenhouse condition showed high seed dormancy (8%) compared to open field grown crop seed (5%). Seed produced from both the growing conditions showed similar storage behavior with regard to dormancy (2%) even after 12 months of storage. This might be due to the fact that greenhouse conditions might have induced certain extent of higher dormancy compared to open field conditions.

Table 1: Effect of growing conditions, stage of fruit picking, seed extraction and drying methods on seed dormancy (Percentage of fresh ungerminated seed) in female (Pusa Selection-120) and male parents (Chikoo) 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	10	(19)	4	(11)	5	(13)	2	(8)	9	(17)	2	(7)	7	(15)	4	(11)
S1E2D1	9	(18)	4	(12)	11	(16)	3	(9)	7	(15)	2	(7)	7	(15)	2	(8)
S1E3D1	9	(18)	2	(8)	10	(15)	2	(7)	7	(15)	2	(7)	6	(19)	3	(10)
S1E1D2	9	(18)	3	(9)	5	(13)	3	(11)	11	(19)	4	(7)	8	(16)	2	(8)
S1E2D2	8	(16)	3	(9)	1	(5)	1	(6)	10	(19)	5	(12)	4	(12)	2	(7)
S1E3D2	8	(16)	3	(9)	1	(5)	1	(4)	4	(12)	4	(7)	3	(8)	2	(8)
S2E1D1	8	(16)	2	(7)	9	(15)	0	(0)	6	(14)	2	(7)	5	(19)	1	(6)
S2E2D1	8	(16)	2	(17)	10	(15)	2	(12)	9	(17)	4	(11)	2	(20)	3	(10)
S2E3D1	9	(18)	1	(6)	1	(5)	1	(8)	10	(17)	5	(13)	1	(4)	1	(6)
S2E1D2	9	(17)	1	(4)	2	(7)	1	(15)	6	(14)	5	(12)	6	(14)	4	(12)
S2E2D2	7	(15)	0	(0)	8	(17)	0	(12)	6	(14)	6	(14)	5	(13)	3	(10)
S2E3D2	7	(15)	2	(7)	1	(5)	1	(13)	3	(8)	4	(7)	1	(4)	1	(4)
Mean	8	(16)	2	(8)	5	(13)	2	(10)	8	(15)	3	(9)	5	(12)	2	(9)
CD at 5%																
Stage of picking	0.13		0.26		0.44		0.22		0.25		0.23		0.24		0.18	
Extraction method	0.17		0.32		0.54		0.27		0.25		0.23		0.24		NS	
Drying method	0.14		0.26		0.44		0.22		0.35		0.33		0.34		0.26	
Stage x Extraction	0.23		0.45		0.76		0.38		0.30		0.29		0.29		0.23	
Stage x Drying	0.19		0.37		0.62		0.31		0.43		0.41		0.41		0.32	
Extraction x Drying	0.24		0.45		0.76		0.39		0.43		0.41		0.41		0.32	
Stage x Drying x Extraction	0.34		0.64		1.08		0.55		0.61		0.58		0.59		0.45	

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.

Effect of stage of fruit picking, seed extraction methods and seed drying methods on the seed dormancy

Data presented in the Figure 1 reveal that the seeds from the fruits picked at red ripe stage (S_1) showed high initial seed dormancy of 8 percentage (9 and 6%, respectively for green house and open field conditions) compared to fruits harvested at turning (S_2) stage with an average of 7% (8 and 5%, respectively for green house and open field conditions). Decrease in the dormancy percentage was observed with the increase in the storage period, but even after 12 months of storage fruits picked at red ripe stage (S_1) showed high seed dormancy than turning stage. This might be due to increased ethylene production in red ripe fruits might have induced dormancy and this dormancy induction might be more under greenhouse conditions. This is in conformity with the findings that the ethylene production rate increases with ripeness, injury incidence, disease and temperature increase (Pech *et al.,* 2002 and Yahja *et al.*, 2012).

High seed dormancy of 9% was observed in the seeds that are produced from green house crop (Figure 2) with manual crushing (9%) followed by fermentation (E2) method (8%). Whereas, with open field grown crop, seed extracted by acid method showed less dormancy (3%). Acid method of extraction might have removed mucilaginous substance around the seed in addition to the removal of dormancy that might have enhanced the percent of seed germination. After twelve months of storage there was no significant difference in the dormancy among the different extraction methods. This

might be due to the fact that manual crushing might have not removed mucilaginous covering around seed which might have contributed to the dormancy and fermentation method through pathogen infection to the seed might have induced seed dormancy. These findings are in similar with Nemati *et al.*, (2010) who have reported that seed quality decreased with increasing temperature and duration of fermentation from 24 to 48 h at temperature 25 degrees C.

Irrespective of growing conditions and storage period (Figure 3), seeds dried by sun drying (D1) showed more seed dormancy (9 and 8%, respectively for green house and open field conditions) compared to shade (D2) drying (8 and 3%, respectively for green house and open field conditions). This might be due to the fact that sun drying with high temperature might have induced and retained more dormancy even after storage period.

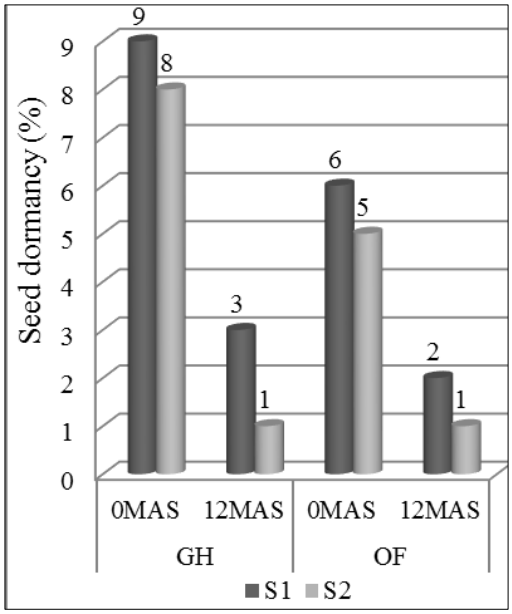

Fig 1: Effect of stage of fruit picking on tomato seed dormancy and storability of Pusa selection-120

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

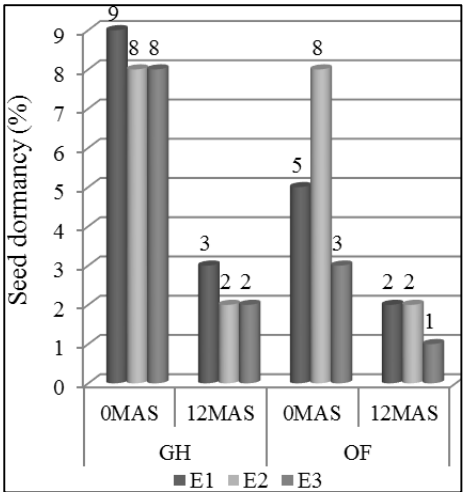

Fig 2: Effect of method of seed extraction on tomato seed dormancy and storability of Pusa selection-120

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

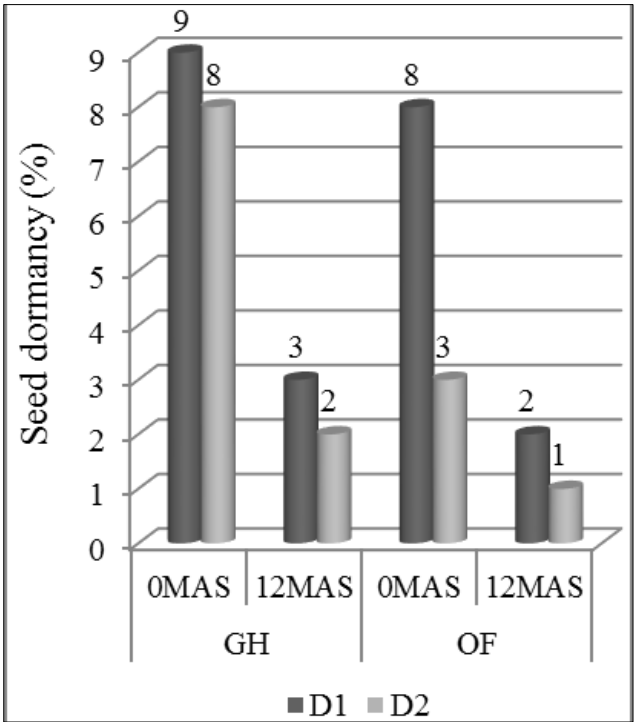

Fig 3: Effect of method of seed drying on tomato seed dormancy and storability of Pusa selection-120

Note: D1-Sun drying; D2 - Shade drying

Combined treatments effect on seed dormancy

Among the six combinations of stage of fruit picking and extraction methods (Figure 4: Figure 4A and Figure 4B), fruits harvested at red ripe stage and seed extracted by manual crushing (S1 E1) showed high initial seed dormancy (10 and 5%, respectively for green house and open field conditions) and their combination also showed high seed dormancy (4 and 3%, respectively for green house and open field conditions) even after 12 months of storage. This might be due to the fact that these two combinations might be compatible in enhancing and retaining seed dormancy (Valdes and Gray, 1998). Irrespective of growing conditions, among the four combinations of the effect of stage of fruit picking and method of drying (Figure 5: Figure 5A and Figure 5B), fruits harvested at red ripe stage and sun drying (S1 D1) recorded more seed dormancy (9%) and this combination also retained more percentage of dormancy even after 12 months of storage. Sun drying in combination with red ripe stage might have induced and retained more dormancy. Data pertains to the effect of six combinations of methods of seed extraction and drying was presented in the Figure 6 (Figure 6A and Figure 6B). The seed produced from the crop raised under greenhouse condition showed more seed dormancy than open field crop seed. Seed extracted by fermentation method and sun drying (E2D1) recorded more initial seed dormancy (9 and 11 %, respectively for green house and open field conditions). And seeds of this same combinations also recorded more seed dormancy even after 12 months of storage. These findings are in conformity with the report of Rajan and Markose (2007) [9] who have 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.

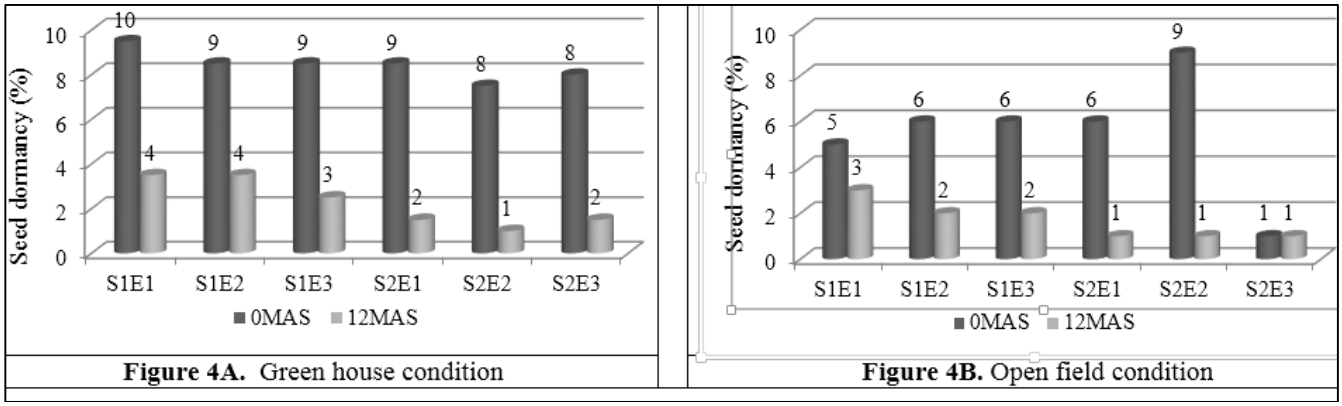

Fig 4: Effect of stage of fruit picking and method of seed extraction on tomato seed dormancy (%) and storability

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

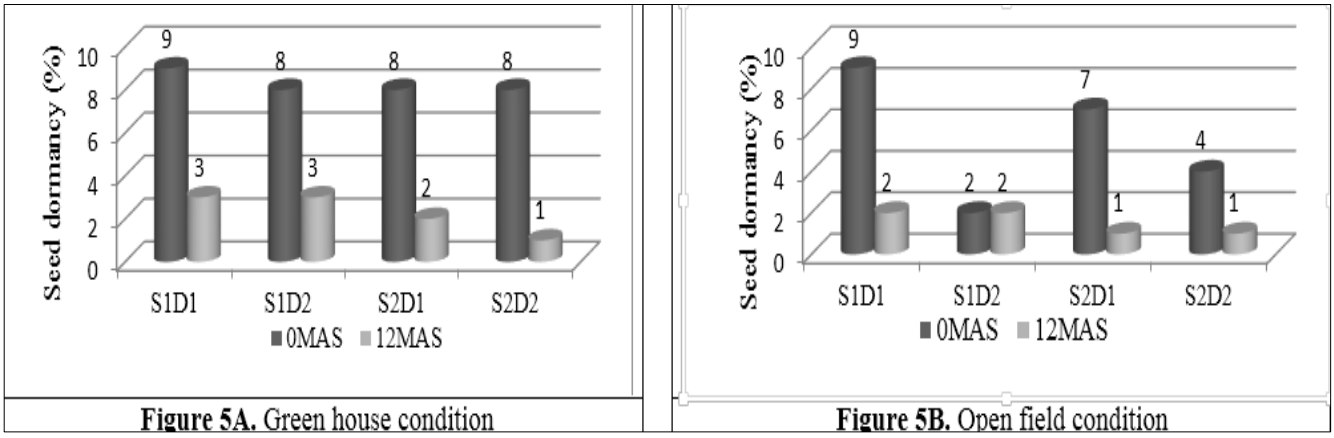

Fig 5: Effect of stage of fruit picking and method of seed drying on tomato seed dormancy (%) and storability

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

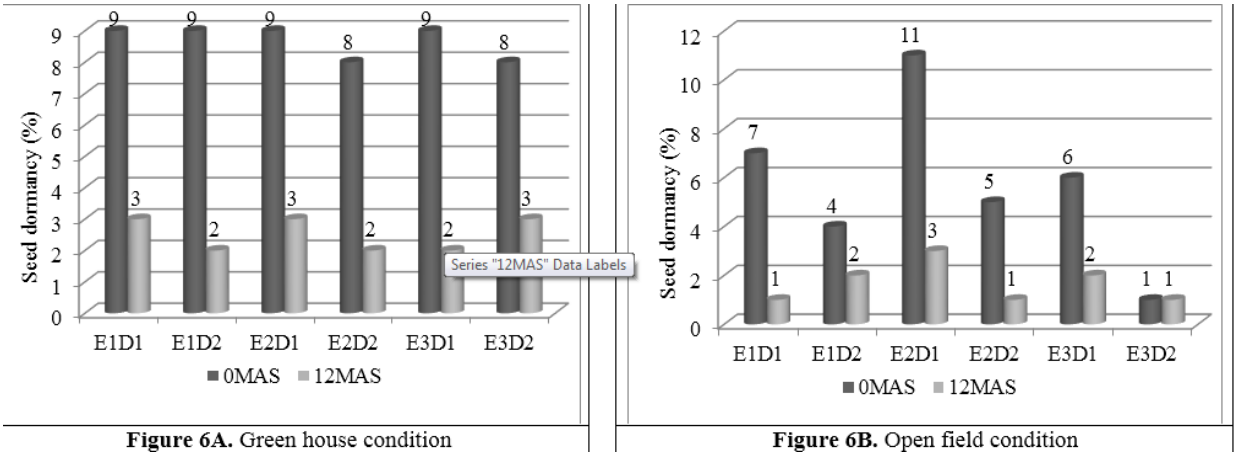

Fig 6: Effect of methods of seed extraction and drying on tomato seed dormancy (%) and storability

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

Effect of combinations of stage of fruit picking, methods of seed extraction and drying on seed dormancy

Data from the table 1 revealed that among twelve treatments, irrespective of seed crop growing conditions and parentage, fruits harvested at red ripe stage, seed extracted by fermentation method followed by sun drying (S1 E2 D1) recorded high percentage of initial seed dormancy (11 and 9%, respectively for open field and green house conditions). Seeds of this same combination recorded high seed dormancy (3 and 4%, respectively for open field and green house conditions) even after 12 of months of storage. This might be due to the fact that these combinations might have induced

and retained dormancy in the seed (Ravi Hunje *et al*., 2007) [9].

It is to conclude that more or less similar percentage of seed dormancy was recorded in the parentage of tomato hybrid, Pusa hybrid-4. Seed produced from green house condition showed high seed dormancy than open field condition. Seed obtained from fruits picked at red ripe stage, fermentation method of seed extraction and sun drying showed high initial seed dormancy and also more dormancy even after 12 months of storage. With regard to two combinations, red ripe stage and manual crushing, red ripe stage and sun drying recorded more seed dormancy. With regard to three combinations, red ripe stage of picking either with manual crushing (green house grown seed crop) or with fermentation (open field grown seed crop) and sun drying recorded high seed dormancy.

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