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Effect of stage of harvest and post-harvest ripening of fruits on hybrid seed yield and quality in pumpkin (*Cucurbita moschata*)

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ABSTRACT

The effect of stage of harvest and post-harvest ripening of fruits on seed yield and quality in Pusa Hybrid 1 pumpkin (*Cucurbita moschata* Duchesne ex Poir) was studied during summer 2008 and 2009 at Seed Production Unit Farm, IARI, New Delhi. Among the six different treatments of harvesting and post-harvest ripening stages, viz. H1-50 DAA, H2 - 60 DAA, H3 - 70 DAA, H1P1 - 50 DAA + 10 PHR, H1P2 - 50 DAA + 20 PHR and H2P1 - 60 DAA + 10 PHR, the fruits harvested at H3 stage outperformed others in respect of fruit weight (3.77 kg), fruit diameter (22.34 cm), cavity length (16.22 cm) and cavity diameter (16.06 cm). However, fruits obtained from H2P1 (60 DAA + 10 PHR) recorded significantly higher number of filled seeds (489.85), total number of seeds (494.35), 100 seed weight (14.68 g) and other seed quality attributes, viz. germination (93.44 %), seedling length (31.26 cm), seedling dry weight (54.96 mg), vigour index - I & II (2921.65 and 5141.64) compared to other treatments. The seed obtained from H2P1 also showed superiority in seed anatomical attributes such as weight of the seed coat (0.294 g), embryo (0.024 g) and cotyledons (1.413 g) as well as protein (399.5 mg/g) and oil (45.5 %) content indicating highest level of development and metabolic gain of the seed.

Key words: Oil content, Post-harvest ripening, Protein content, Pumpkin, Seed anatomical studies, Seed quality, Seed yield, Stage of harvest

Pumpkin (*Cucurbita moschata* Duchesne ex Poir) occupies a prominent place among vegetables owing to its high productivity, nutritive value, good storability, long period of availability and better transport potentialities. Physiological maturity and harvesting time are the two major considerations in the production of quality seed in pumpkin. Harvesting either at an early or a late stage results in lower seed yield with poor quality. Generally, fruits harvested at physiological maturity produce high quality seeds in terms of viability and vigour compared to fruits harvested at early or later stages of field maturity (Chaudhari *et al.* 1992, Biradar 1994). The seeds obtained from fruits harvested even before attainment of physiological maturity but allowed for post-harvest fruit ripening for a few days may also produce good quality seeds since the seed development continues in fleshy fruits owing to the continuous supply of nutrients and food reserves from fruit to seed (Petrova *et al.* 1981). In fruit vegetables like pumpkin, harvesting of fruits at right stage of maturity is important to ensure maximum seed yield, quality and also prevents the field damage due to fruit rotting and adverse environmental conditions.

Therefore, the investigations were undertaken to standardize the stage of harvest and post-harvest ripening in pumpkin to obtain better quality seed in large quantities.

MATERIALS AND METHODS

The present experiment was carried out during summer 2008 and 2009 at seed production unit, IARI.The seedlings of the parental lines of Pusa Hybrid 1 were raised sown in soil- less medium consist of cocopeat, vermiculite and perlite (3:1:1 ratio) in plug trays (1½" cell size) at Center for Protected Cultivation Technology (CPCT), IARI. The 25 days old seedlings (two leaves stage) were transplanted in block method. The seed and pollen parent in separate block providing 5m isolation between the two and one seedling per hill was transplanted at a spacing of 3.5 m × 1 m. The crop was well managed and protected from pests and diseases following the recommended practices.

The female and male flowers were protected by covering with white paper bags were hand pollinated and tagged with date of pollination in order to monitor the fruits until the determined date for harvesting. The fruits were harvested at three stages of maturation, viz. 50 days after anthesis (DAA), where fruits stop growing, 60 DAA, the stage where fruits attain full ripe colour and 70 DAA which

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is a vine drying stage indicating the end of plant growth. Fruits harvested at 50 DAA were sub-divided into three lots and allowed to 0 days (H1), 10 days (H1P1) and 20 days (H1P2) post-harvest ripening under ambient conditions before seed extraction. Similarly, half of the fruits harvested at 60 days maturity were used for 0 days (H2) and 10 days (H2P1) post-harvest ripening beforeseed extraction. The fruits harvested at 70 DAA were used for seed extraction immediately after harvesting without post-harvest ripening (H3). Thus, in total, there were six treatments in the experiment.

For each of the six treatments, a minimum of five fruits were tagged. Observations were recorded on fruit development attributes, viz. fruit weight, fruit length, fruit width, cavity length, cavity size, flesh thickness immediately after harvest. The seeds extracted from each fruit of the respective treatments were separated into filled, unfilled seeds and the total number of seeds per fruit was counted before washing to avert the loss of seeds during washing. The seeds were washed under tap water for 10 minutes to remove mucilage tissue; the excess water on seeds was removed with paper towel and subjected to air drying at room temperature for a week. The dried seeds of different treatments were subjected to germination test (ISTA 2008), vigour Index-I & II (Abdul Baki and Anderson 1973), moisture content (ISTA 2008) and electrical conductivity of seed leachate (ISTA 2008), seed anatomical studies (weight of seed coat, embryo, cotyledons) and also for estimating the seed protein and seed oil contents.For studying the contribution of components of seed harvested at different maturity stages, ten seeds were taken from each replication. After recording the fresh and dry weights, each seed was partitioned into different components, viz. seed coat, cotyledons and embryo. Weight of individual components was measured and the mean was calculated and expressed in grams.The protein content in the embryo and cotyledons was estimated by following Lowry (1951) method using Folin - Phenol reagent (Lowry *et al.* 1951) and oil content in seed kernel was estimated by following Soxhlet extraction method.The data generated was subjected to statistical analysis by adopting Randomized Complete Block (RCB) design using SAS statistical package version 9.2. The percentage data were subjected to arcsine transformation before analysis.

RESULTS AND DISCUSSION

Fruit development attributes

The results of pooled data on the effect of stage of harvest and post-harvest ripening on fruit developmental characters, viz. fruit weight, length, diameter, cavity length and diameter are presented in Table 1. A significant difference in fruit weight was recorded between treatments ranging from 2.77 kg (H1P2) to 3.77 kg (H3) with overall mean value of 3.20 kg. The fruit weight was found decreasing with increase in duration of post-harvest ripening. With the advancement of maturity, the fruit length increased from 18.83 cm (H1P2) to 20.74 cm (H3). A marginal reduction in the fruit length was noticed in post-harvest ripening treatments.A significant effect of stage of harvest and post-harvest ripening was noticed on fruit diameter. Highest fruit diameter was recorded in H3 (22.34 cm), followed by H2 (21.63 cm) and H1 (20.66 cm). The lowest fruit diameter was recorded in H2P1 (19.83 cm) with an overall mean of 20.86 cm.

No significant difference for cavity length was recorded among treatments. However, there was a marginal increase in cavity length with increasing maturity of fruits from 13.91 cm (H1) to 16.22 cm (H3). Significant differences for cavity diameter was noticed and it was highest in H3 (16.06 cm). There was no definite effect of period of post-harvest ripening treatments on cavity diameter. A non-significant

Table 1 Effect of stage of harvest and post-harvest ripening on fruit development and seed yield attributes in pumpkin cv Pusa Hybrid 1 (Pooled data of 2008 and 2009 season)

Treatment	Fruit development attributes						Seed yield attributes			
	Fruit weight (kg)	Fruit length (cm)	Fruit diameter (cm)	Cavity length (cm)	Length diameter (cm)	Flesh thickness (cm)	Filled seeds	Unfilled seeds	Total number of seeds	100 seed weight (g)
H1	3.23 abc	19.16	20.66 ab	13.91	15.62 ab	3.18 ab	422.35 b	11.30 b	433.65 c	12.76 b
H2	3.39 ab	20.74	21.63 ab	15.01	14.26 b	3.46 a	468.35 ab	5.45 c	473.80 abc	13.46 ab
H3	3.77 a	20.39	22.34 a	16.22	16.06 a	3.25 ab	468.25 ab	16.35 a	484.60 ab	12.73 b
H1P1	2.94 bc	19.23	20.45 b	14.26	15.35 ab	2.89 b	436.70 b	7.10 c	443.80 bc	13.31 ab
H1P2	2.77 c	18.83	20.26 b	14.33	15.41 ab	2.81 b	445.35 ab	6.90 c	452.25 abc	13.77 ab
H2P1	3.16 bc	19.50	19.83 b	15.30	14.45 ab	2.90 b	489.85 a	4.50 c	494.35 a	14.96 a
Mean	3.20	19.63	20.86	14.83	15.19	3.07	455.13	8.60	463.74	13.50
SE(d)	0.19	0.87	0.60	0.68	0.58	0.16	17.10	1.23	16.85	0.64
Tukey's HSD at 5%	0.56	NS	1.79	NS	1.74	0.49	50.86	3.69	50.14	1.99

H1- 50 DAA+ 0 PHR, H2 - 60 DAA+ 0 PHR, H3 - 70 DAA+ 0 PHR, H1P1 - 50 DAA+ 10 PHR, H1P2 - 50 DAA+ 20 PHR, H2P1 - 60 DAA+ 10 PHR. DAA – Days after anthesis, PHR – Post harvest ripening. Means the data with the same letter are not significantly different difference was observed with respect to flesh thickness among all treatments though, it was numerically higher in H2 (3.46 cm) and lowest in H1P2 (2.81 cm).It is evident from the results that harvesting of fruits at 70 DAA resulted in higher fruit development attributes compared to other harvesting stages owing to accumulation of food reserves in fruits with the increase in period of harvest.

Seed yield attributes

The pooled data presented in Table 1 showed significant effect of stage of harvest and post-harvest ripening on the number of filled seed, unfilled seed, total number of seed and 100 seed weight (g).Significantly higher number of filled seeds were recorded in H2P1 (489.85) followed by H2 (468.35) and the lowest was recorded in H1 (422.35), with an overall mean value of 455.13. The highest number of unfilled seed was observed in H3 (16.35), followed by H1 (11.30), while it was lowest in H2P1 (4.50). H2P1 also showed superiority among all treatments with regard to total number of seeds (494.35) and 100 seed weight (14.68 g). The lowest number of total seed (433.65) and 100 seed weight (12.29 g) was observed in H1. The superior performance of H2P1 could be due to maximum accumulation of dry matter in seed at this stage which was supported by the view that seeds continue to develop and mature in the fleshy fruits until they got extracted from fruits (Ahmed *et al.* 1987).

Seed quality attributes

The pooled data presented in Table 2 on seed quality characters revealed that there was a significant difference between the treatments for germination (%), seedling length (cm), seedling dry weight (mg), vigour index –I and vigour index –II with mean values of 87.56, 29.89, 49.44, 2625.95 and 4344.22, respectively. Significantly highest values of percentage germination (93.44%), seedling length (31.26 cm), seedling dry weight (54.96 mg), vigour index–I (2921.65) and vigour index –II (5444.46) were recorded in H2P1, followed by H2 with respect to seedling dry weight (51.82 mg) and vigour index –II (4632.83) and H1P2 with respect to vigour index –I (2662.69). The lowest values of germination (82.15%), seedling length (28.36 cm), vigour index –I (2336.47) and vigour index –II (3816.62) were observed in treatment H1.The higher seed yield in H2P1 was due to the increased growth potential of embryo during post-harvest ripening which enhanced the capacity of radical to penetrate the seed coat. This is in conformity with the finding of Weston *et al*. (1992) in cucumber.

Significant differences for electrical conductivity (EC) of the seed leachate was observed among treatments, with lowest value for H2P1 (31.50), followed by H3 (34.90), while it was highest in H1 (47.15) (Table 2). Comparatively lowerseed quality at H1 may be ascribed to high rate of respiration during delayed harvest after physiological maturity thus leading to depletion of food reserves and also the disintegrated cell wall which was evident by the higher electrical conductivity of seed leachates. These results are in accordance with the findings of Alvarenga *et al.* (1984) in water melon, Barbedo *et al. (*1993), Nandeesh *et al.* (1995) in cucumber, Pandita and Nagarajan (2001) in Indian chilli and Hamsaveni *et al.* (2003), Dias *et al.* (2006) in tomato crops.Moisture content (%) on dry weight basis showed significant differences among the treatments with mean value of 8.33. Seeds harvested from H2 had the lowest moisture content (8.01), followed by H2P1 (8.17) and with highest moisture in H1P1 (8.75).

Seed components

The results of pooled data on fresh weight of seed, dry weight of seed, weight of seed coat, embryo and cotyledons of seeds are given in Table 3. The higher fresh and dry weight of seed were recorded in H2P1 (1.43 and 1.35), followed by H3 (1.37 and 1.31), with the lowest value in H1 (1.24 and 1.17, respectively).The mean weight of seed coat was 0.255 g while it was maximum in H2P1 (0.294 g), followed by H3 (0.290 g). The minimum weight was recorded in H1 treatment (0.198 g). Embryo and cotyledon weights also exhibited a similar trend showing significantly higher values in H2P1 (0.028 g and 1.413 g), followed by H3 (0.027 and 1.309 g) with lowest values in H1 (0.018 and

Table 2 Effect of stage of harvest and post-harvest ripening on seed quality attributes in pumpkin cv Pusa Hybrid 1 (Pooled data of 2008 and 2009 season)

Treatment	Germination (%)	Total seedling length (cm)	Seedling dry weight (mg)	Vigour Index - I	Vigour Index - II	EC (µmhos/cm/g)	MC (%)
H1	82.15 ^{b} (65.73)*	28.36 ^{b}	46.27 ^{b}	2336.47 ^{b}	3816.62 ^{b}	47.15 ^{a}	8.36^{bc}
H2	89.19^{ab} (71.42)	29.67^{ab}	51.82^{ab}	2645.96^{ab}	4632.83^{ab}	36.25^{c}	8.01 ^{c}
H3	85.60 ^{b} (68.42)	30.33^{ab}	50.20^{ab}	2613.03^{ab}	4294.34 ^{b}	34.90 ^{cd}	8.32^{bc}
H1P1	86.79^{ab}(69.17)	29.60^{ab}	45.46 ^{b}	2575.88^{ab}	3955.01 ^{b}	41.38 ^{b}	8.75 ^{a}
H1P2	88.17^{ab} (70.18)	30.12^{ab}	47.93^{ab}	2662.69^{ab}	4224.87 ^{b}	38.93^{bc}	8.38 ^{b}
H2P1	93.44 ^{a} (76.06)	31.26 ^{a}	54.96 ^{a}	2921.65 ^{a}	5141.64 ^{a}	31.50^{d}	8.17^{bc}
Mean	87.56 (70.16)	29.89	49.44	2625.95	4344.22	38.35	8.33
SE(d)	2.38	0.88	2.35	116.54	272.70	1.04	0.10
Tukey's HSD at 5%	7.16	2.68	7.09	350.21	819.42	4.44	0.35

*Data written within parenthesis indicates Arcsine transformation value

Table 3 Effect of stage of harvest and post-harvest ripening on weight of seed coat, embryo and cotyledons in pumpkin cv Pusa Hybrid 1 (Pooled data of 2008 and 2009 season)

Treatment	Seed coat weight	Embryo weight	Coty-ledon weight	Total seed weight (g)	Fresh weight of seed (g)	Dry weight of seed (g)
H1	0.198 c	0.018 e	1.045 d	1.260 d	1.24 b	1.17 b
H2	0.258ab	0.025bc	1.253bc	1.536bc	1.28 b	1.22ab
H3	0.290 a	0.027ab	1.309ab	1.626ab	1.37ab	1.31 a
H1P1	0.238bc	0.022 d	1.115 cd	1.375 cd	1.28 b	1.22ab
H1P2	0.255ab	0.024 cd	1.195bcd	1.474bc	1.34ab	1.26ab
H2P1	0.294 a	0.028 a	1.413 a	1.735 a	1.43 a	1.35 a
Mean	0.255	0.024	1.222	1.501	1.32	1.25
SE(d)	0.01	0.00	0.04	0.05	0.04	0.04
Tukey's HSD at 5%	0.04	0.003	0.15	0.16	0.14	0.13

Table 4 Effect of stage of harvest and post-harvest ripening on seed oil content and seed protein content (mg/g) in pumpkin cv Pusa Hybrid 1 (Pooled data of 2008 and 2009 season)

Treatment	Protein content (mg/g)			Total oil content in seed kernel (%)
	Embryo	Cotyledons	Total seed protein	
H1	180.63 b	150.06	330.69bc	41.67d
H2	212.81ab	169.63	382.44ab	44.72abc
H3	188.38 b	135.25	323.63c	45.17ab
H1P1	195.38 b	153.56	348.94abc	42.03cd
H1P2	213.19ab	143.88	357.06abc	42.45bcd
H2P1	237.88 a	162.08	399.95 a	45.50a
Mean	204.71	152.41	357.12	43.59
SE(d)	7.65	8.69	12.28	0.64
Tukey's HSD at 5%	32.66	NS	52.41	2.77

1.045 g). Similar findings of increasing embryo weight with fruit development and after-ripening period were reported in bottle gourd (Yoo *et al.* 1996). With the progress of maturity, the weight of different seed parts also increased and showed highest and lowest values at 70 DAA (1.735 g) and 50 DAA (1.260 g) respectively. On an average, the percent contribution of seed coat, embryo and cotyledons to total seed weight was 16.97, 1.60 and 81.43 % respectively and the testa weight accounts for almost one sixth of total seed weight.Maximum contribution of seed coat and embryo to total seed weight was observed in H2P1 (17.80% and 1.69%) and the minimum was recorded in H1 (15.68% and 1.39%). On the other hand, the contribution of cotyledons was maximum at H1 (82.91%) stage, with a minimum value at H2P1 (80.50%).Contrastingly, Ganar *et al*. (2004) reported that the testa (53 - 55%) contribution to seed weight was more than cotyledons in ash gourd which could be attributed to variation in species under study.

Protein and oil contents in seed kernels

The results on protein content in embryo and cotyledons revealed that there were significant differences in protein content in embryos and total seed protein among the treatments but a non-significant difference was observed in cotyledons (Table 4). Between embryo and cotyledons, higher amount of protein was recorded in the embryo (204.71 mg/g) than in cotyledons (152.41 mg/g).The embryonic protein reached highest concentration at H2P1 (237.88 mg/g of embryo) and lowest concentration at H1 (180.63 mg). Equal amounts of protein was recorded in H2 (212.81 mg) and H1P2 (213.19 mg) though marginally higher value was noted in H1P2. Significantly, higher amount of protein in seed kernel was observed in H2P1 (399.5 mg), followed by H2 (382.44 mg) and the minimum amount was noted in H1 (330.69 mg). The net increase in the amount of proteins could be due to the metabolic processes within the plant cells, which continues even after harvest by using the free amino acids. As in other oil rich seeds, the accumulation of proteins and oils follows the accumulation of carbohydrates in the maturing seed. The reduced activity of the hydrolytic enzymes such as protease also helps the fruit in accumulating the proteins during the later stages of ripening (Stanley 1998).

The oil content in seed kernels from the fruits harvested at 60 DAA and 10 days after ripening (H2P1) had significantly high quantities of oil (45.50 %), followed by H3 (45.17%) and H2 (44.72%) respectively with a mean value of 43.59 %. The lowest oil content was observed in H1 (41.67%) treatment. According to Martin (1984) the seeds of cucurbits contain up to 50% oil content and most of the oil present is made up of non-saturated fatty acids, thus of high nutritional values. Similar results were recorded in other cucurbits, viz. watermelon (Mabaleha *et al.* 2007), pumpkin (El-Adwy and Taha 2001 and Enujiugha and Ayodele-Oni 2003), musk melon (Mariod *et al.* 2009), *Cucumis sativus* (Fokou *et al.,* 2004) and ridge gourd (Ali *et al.* 2009). High levels of these two food reserves in the seed, particularly in the embryonic axis help in better performance of the mature seed. Hence, harvesting fruits at 60 DAA and allowing a period of 10 days of after ripening (H2P1) was found to be the most optimum stage for ensuring highest seed yield and quality.

From the present study, it can be concluded that the crossed fruits of pumpkin on the female parent of Pusa Hybrid 1 should be harvested at 60 days after anthesis and fruits should be allowed for 10 days post harvest ripening under Delhi conditions for higher hybrid seed yield and quality.

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