DOI: http://doi.org/10.4038/tare.v24i3.5552

Tropical Agricultural Research & Extension 24 (3): 2021

RESEARCH ARTICLE

IMPACT OF HARVESTING TIME AND POSTHARVEST RIPENING DURATION ON THE SEED QUALITY OF *Solanum melongena* L. (EGGPLANT)

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Received: 2021.05.20, Accepted: 2021.09.04

Abstract

The best harvesting stage of eggplant (*Solanum melongena* L.) to obtain quality seeds has not been given due attention under local seed production programs. The present practice is to allow fruits to ripen on the plant, however, it is believed that it may result in fewer fruits and low-quality seeds. Therefore, an experiment was conducted to identify the best maturity stage and the effect of postharvest ripening on the quality of eggplant seeds. Two eggplant varieties; *Thinnavelli purple* and *Padagoda* were grown and fruits were harvested at 35, 42 and 49 days after pollination (DAP) to determine the optimum harvesting time. Three postharvest ripening (PHR) periods (0, 1 and 2 weeks after harvesting) were also employed. Seeds from the fruits harvested at 35 DAP showed less germination %, vigour index and longer duration for 50% germination (T50). Germination percentage was increased up to 89% (*Thinnavelli purple*) and 72% (*Padagoda*) in seeds from fruits harvested at 35 DAP followed by 2 weeks PHR duration. Moreover, T50 was decreased from 1.74 to 0.94 days in *Thinnavelli purple*. The assessed seed quality parameters were much poorer in seeds from fruits harvested at 42 and 49 DAP. The results revealed that postharvest ripening enhances the seed quality of eggplant when fruits are harvested at the early ripened stage.

INTRODUCTION

Eggplant (*Solanum melongena* L.), also known as brinjal or aubergine, is the fourth most important vegetable (Collonnier *et al.* 2003) throughout the world, notably in tropical and subtropical areas due to its low-caloric content and other nutritional benefits (Gürbüz *et al.* 2018). The International Treaty on Plant Genetic Resources for Food and Agriculture has identified eggplant as one of the 35 most valuable vegetables for food security. Eggplant is cultivated on more than 1.86 million hectares, with an annual yield of more than 54 million tons (FAO 2020). Furthermore, eggplant is a hardy crop as compared to the other vegetables, hence it can be successfully grown in dry regions under minimum irrigation practices or rain-fed conditions by tolerating drought conditions (Aujla *et al.* 2007).

Eggplant is growing throughout the year in all agro-climatic regions except up country-wet zone in Sri Lanka. It can be grown well up to an elevation of about 1300 m in the low country wet zone, intermediate, up-country intermediate and dry zone (Department of Agriculture, 2021). According to the Department of Census and Statistics in 2020, the total eggplant production in the country was around 141,881 metric tons, with a total area of 11,109 hectares. Sri Lankan farmers are familiar with F1 hybrids (Anjalee and Amanda), open-pollinated varieties, SM164, *Thinnavelli purple*, and *Padagoda*, due to their high yielding ability and other yield-

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related characters; including resistance to the bacterial wilt.

To attain sustainable production and resilience to climate change challenges, farmers require genetically improved high yielding eggplant varieties. Hence, breeding programs have been conducted throughout the eggplant growing countries aiming to develop improved varieties (F1 hybrids) with high yield and fruit quality, extended shelf-life, and tolerance to abiotic stresses such as drought and salinity, along with resistance to major biotic factors; mainly diseases and pests (Daunay and Hazra 2012; Ranaweera *et al*. 2020). The provision of quality seeds to the farmers is the ultimate target of these programmes and one of the prime areas of interest of these programmes is to establish the best time to harvest the ripened fruits to extract high-quality seeds. Sękara and Bieniasz (2012) have shown that pollen viability, pollinator behaviour, stigma receptivity, ovule fertilization, set efficiency, growth, and ripening have an impact on fruit productivity and seed quality. In addition, Abdul-Baki and Stommel (1995) reported that an influence of various climatic conditions in the region affects the seed quality. Nevertheless, the best maturity stage for obtaining quality seeds of eggplant has not been studied under local conditions though some work has been conducted elsewhere (Alves et al. 2017; Franquera 2015). The seeds obtained from fruits that were not fully ripened was reported to have either low or zero germination. If the seed maturation goes beyond maximum dry mass, deterioration of the seed will be initiated (Bareke 2018). The physiological quality of seeds of some species occurs simultaneously at the time which seeds reached their maximum mass (Villa *et al*. 2019). Besides, Martins *et al*. (2012) reported that deterioration of the seed is initiated after the maximum quality is reached and then leading to the gradual reduction of the quality. Takac *et al*. (2015) reported that high-quality eggplant seeds can be produced by harvesting during 60-70 days after flowering while some authors were in the opinion that better quality seeds could be obtained from fruits harvested between 50-55 days after fertilization and according to Barbedo *et al*. (1999) fruits harvested at 50 days after anthesis gave better quality. In eggplant, usually, once harvesting started, it can be continued at a regular interval to encourage the development of more fruits. Fruits left on the mother plant to mature tend to reduce flower production which in turn result in lower fruit production and delay the development of new fruits. Even though eggplant is a non-climacteric species, or its fruits do not ripen after harvest, the seeds within the harvested fruits may continue to develop and mature, resulting in better germination, viability, and vigour (Passam *et al*. 2010). Fruits compete with each other throughout their growth and maturation leads to lower seed number, seed size, and vigour and also there are hormonal effects for plants to discontinue reproductive growth (Passam *et al*. 2010). Therefore, it is an advantage for seed producers to harvest the ripened fruits as early as possible after anthesis which will allow plants to retain a lower number of fruits at a given time and to continue with reproductive growth to produce new flowers and more fruits. According to Passam *et al*. (2010), eggplant fruits are allowed to ripen even after harvesting, seeds continue to achieve maximum levels of germination and vigour. Therefore, an experiment was conducted to identify the best maturity stage of fruits to harvest and the effect of postharvest ripening to produce quality seeds in two eggplant varieties (*Thinnavelli purple* and *Padagoda*) under local conditions.

MATERIALS AND METHODS

The experiment was carried out at the experimental station, Meewathura (WM2b) belongs to the University of Peradeniya from August 2020 to January 2021. Seeds of two recommended eggplant varieties, *Thinnavelli purple* and *Padagoda* obtained from the Horticultural Crop Research and Development Institute (HORDI), Department of Agriculture (DOA), Gannoruwa, were used for the experiment. Seeds of two eggplant varieties were sown in nursery trays and 4 weeks old seedlings were transplanted in individual pots (25 cm x 35 cm) filled with the media of topsoil, compost, coir dust, and half burn paddy husk at a 5:3:2:1 ratio. Plants were kept under greenhouse conditions at a spacing of 60 cm x 90 cm using a completely randomized design with three replications and each replicate consisted of 4 plants. The plants were managed as per the recommendations of the Department of Agriculture, Sri Lanka.

Self-pollination was facilitated during the flowering stage by shaking each flower. The flower buds which had been already pollinated were then tagged with the date of pollination to determine the age of the fruits at each harvest stage and allow for fruit development. Only the flowers that were formed on the main stem were allowed to set fruits while all flowers developed on secondary branches were removed. Harvesting was done at 35, 42 and 49 days after pollination (DAP) to identify the best harvesting stage for quality eggplant seed production. The harvested fruits from each date were subjected to three postharvest ripening durations (PHR); i.e. 0 (seeds extracted immediately after harvesting), 1, and 2 weeks after harvesting where fruits were kept under room temperature. Seeds were extracted according to the dry seed extraction procedure and air-dried under shade to remove excess moisture. Subsequently, electrical conductivity (EC), germination %, time taken for 50% of seed germination (T50), vigour index and, thousand seed weight (TSW), were measured. The EC of seeds was measured as per the method reported by Alves and de Sá, (2009). From each plant, the batch of 50 seeds was selected and replicated 12 times. Thereafter, selected seeds were placed in beakers filled with 25 ml distilled water. The EC was measured after 24 hours at 25˚C using a conductivity meter.

The germination tests were conducted with batches of 50 seeds in 12 replicates. The seeds were sown on filter papers moistened with deionized water in the petri dishes. The temperature of the germination chamber was maintained at 25˚C. The number of germinated seeds was counted daily until the count becomes constant. The emergence of the radicle with a length higher than 2 mm was taken as the indicator of germination. The germination percentages (GP) of seeds were calculated based on the equation given below (equ 1).

$$GP = \frac{\mathrm{n}}{\mathrm{N}} \times 100 \ldots \ldots \ldots \ldots \ldots \mathrm{equ}\ 1$$

Where n denotes the number of seeds that have germinated and N denotes the total number of seeds.

The time taken for 50% of seed germination (T50) was calculated by using the formula introduced by Coolbear *et al*. (1984) and modified by Farooq *et al*. (2005), in equ 2.

$$T50 = ti + \left(\frac{N}{2} - ni\right) + \frac{(ti - tj)}{(nj - ni)} \ldots\ldots \mathrm{equ}\ 2$$

Where N represents the final number of germination and ni and nj cumulative number of seeds germinated by adjacent counts at times ti and tj when ni < N/2 < nj.

The vigour index of seeds was calculated using the method proposed by Abdul-Baki and Anderson (1973), (equ 3).

$$VI = (\mathrm{RL} + \mathrm{SL})\mathrm{GP} \ldots \ldots \ldots \mathrm{equ}\ 3$$

Where RL stands the root length (cm), SL is the shoot length (cm) and GP is the germination percentage. Finally, TSW was measured using three replicates.

Data analysis

Data were subjected to Multivariate Analysis of Variance (MANOVA) and means were separated by the Turkey Post Hoc test at P = 0.05 significance level using the SPSS (Version 22) statistical program.

RESULTS AND DISCUSSION

Electrical Conductivity (EC)

EC can be used as an indicator of seed viability which is a non-destructive technique compared to conventional tests, further rapid and reliable results could be obtained (Mara *et*

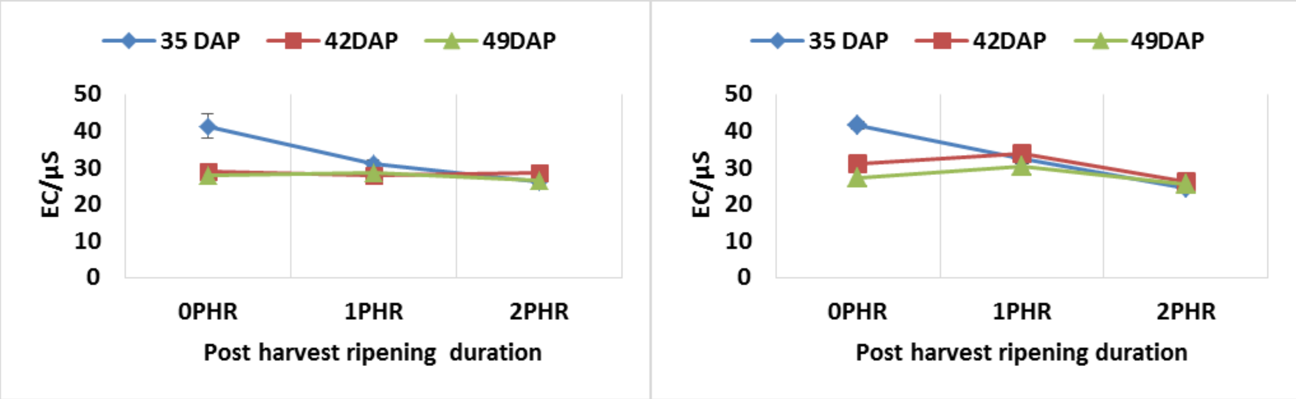

Figure 1. The variation of EC (µs) of (A) *Thinnavelli purple* and (B) *Padagoda* seeds with postharvest maturity duration of each harvesting stage

al. 2012). The EC of tested seeds was significant between varieties, harvesting stages and the postharvest ripening durations (PHR). The EC of seeds that were harvested at 35 DAP was significantly higher than 42 DAP and 49 DAP harvesting stages at 0 PHR (Fig. 1) in both varieties. In addition, data showed a decreasing trend with increased PHR for fruits harvested at 35 DAP for both varieties (Fig. 1). As reported by Bewley *et al*. (2013), this could attribute to the loss of solutes such as sugars, amino acids, fatty acids, proteins, enzymes, and inorganic ions to the external environment during the germination process. Hence, the primary objective of measuring EC is to identify the seed vigour, as the EC of seeds inversely proportionate to the seed vigour, as such less vigorous or more deteriorated seeds, show a lower speed of cell membrane repair during hydration (Alves & de Sá 2009). According to Martins *et al*. (2012), the plasma membrane of seeds, not well structured and efficient at the early stage of seed development resulted in high EC value. On other hand, later stages of harvesting (42 DAP) obtained lower EC values as their membranes are well structurally organized, so not having a great influence on increasing EC values. The seeds harvested at 35 DAP are at the early stage of maturity and cell membranes are not structured well, which was advanced with the maturation of the fruit, therefore, the current study's findings are in agreement with the findings of Alves *et al*. (2017); Marcos Filho (2015) and Martins *et al*. (2012).

Thousand Seeds Weight (TSW)

Thousand seeds weight is an important parameter in seed quality determination. Seeds with high mass have more stored reserves which could be used during germination and emergence, therefore, can withstand stress conditions (Takac *et al*. 2015). In the present experiment, TSW showed a significant difference between varieties and the harvesting stages, where fruits harvested at 35 DAP (2.72±0.04 g) reported less weight than 42 DAP (3.24±0.04 g) and 49 DAP (3.30±0.03 g) for *Thinnavelli purple*. In addition, the results of this study showed that there was no interaction between time of harvesting × PHR and both varieties did not show significant differences for postharvest ripening durations at 35 and 42 DAP harvesting stages. According to Demir *et al*. (2002) and Passam *et al*. (2010), a significant difference in postharvest ripening duration for seed weight can be seen before 25 days after anthesis, and they also reported that a lack of significant effect beyond that stage. Thus, the present study results are in agreement with those results as no seed size increment was shown with postharvest ripening at 35 and 42 DAP. However, some authors were in the opinion that seed filling could take 45-65 days to complete the process (Demir *et al*. 2002; Yogeesha *et al*. 2006). If there are many fruits on the plant, it may lead to a reduction of seed mass and size because of competition for photosynthates among fruits. This is important to be considered in the quality seed production process of eggplant and the fruit can be harvested at their botanical maturity stage (Passam & Khah 1992).

Germination Percentage (GP)

The GP of the seeds were also significantly affected by the harvesting stage and the postharvest ripening duration. The results indicated that the GP was increased along with the harvesting stage proceed for the variety *Thinnavelli purple*. The postharvest ripening duration significantly increased the GP of fruits harvested at 35 DAP and 42 DAP in both varieties. GP could be increased up to 89% (*Thinnavelli purple*) and 72% (*Padagoda*) by harvesting fruits at 35 DAP following 2 weeks of PHR. These values were significantly higher than the GP values of fruits harvested at 49 DAP and when seeds were extracted immediately after harvest i.e without postharvest ripening, for both the varieties (Table 1).

Vigour Index (VI)

The VI also significantly varied among harvesting and postharvest ripening stages. The variety *Thinnavelli purple* showed a significant higher VI (1040.45±30.12) at 49 DAP but it was highest at 42 DAP (549.54±25.76) in *Padagoda*. However, the subsequent postharvest ripening also seemed to enhance the vigour of the seedlings of seeds of fruits harvested at 35 DAP and 42 DAP of both varieties (Table 2).

Time to 50% germination (T50)

The T50 was varied significantly between the harvesting stage and postharvest ripening duration for both eggplant varieties tested. Both varieties had shown a significant interaction between DAP×PHR. However, seeds extracted at 49 DAP in the variety *Thinnavelli purple* (1.00±0.05) and 42 DAP in the *Padagoda* (1.23±0.04) recorded significantly less time to attain 50% germination (Table 2). Moreover, T50 exhibited a decreasing trend with the postharvest ripening duration of fruits harvested at 35 DAP and 42 DAP in both varieties.

At the time of physiological maturity, seeds germinate to their full potential, vigour, and viability% because of settling the formation of the morphological, biochemical and structural systems (Rao *et al*. 2017). In facts seeds with fleshy fruits such as eggplant, the maximum germination, vigour, and dry matter accumulation levels occur when the seeds achieve physiological maturity. Early harvest and much later harvest cause the loss of physiological qualities such as viability and vigour of the seeds of eggplant. High vigorous

Table 1: The effect of postharvest ripening duration on seed germination and seed weight at different harvesting stages.

Variety	PHR	Germination % ±SE			Thousand seed weight± SE(g)		
		35DAP	42DAP	49DAP	35DAP	42DAP	49DAP
Thinnavelli purple	0PHR	$56.96±4.56^{b}$	$68.43±4.26^{b}$	$89.58±2.89^{ab}$	$2.64±0.07^{a}$	$3.12±0.09^{a}$	$3.32±0.05^{a}$
	1PHR	$81.25±2.25^{a}$	$84.44±5.37^{a}$	$95.33±1.19^{a}$	$2.82±0.08^{a}$	$3.24±0.08^{a}$	$3.30±0.04^{a}$
	3PHR	$89.84±3.07^{a}$	$87.74±2.90^{a}$	$81.83±4.44^{b}$	$2.69±0.09^{a}$	$3.36±0.04^{a}$	$3.29±0.08^{a}$
Padagoda	0PHR	$44.54±1.69^{b}$	$54.86±2.02^{b}$	$67.27±2.75^{a}$	$2.46±0.07^{a}$	$2.63±0.05^{a}$	2.36±0.07b
	1PHR	$66.25±3.59^{a}$	$66.28±3.08^{ab}$	$59.26±3.31^{ab}$	$2.35±0.05^{a}$	$2.64±0.03^{a}$	$2.44±0.05^{ab}$
	3PHR	$72.59±4.38^{a}$	$77.32±5.31^{a}$	$52.91±1.72^{b}$	$2.45±0.04^{a}$	$2.70±0.04^{a}$	$2.65±0.04^{a}$

Note: The different superscripts within column indicate statistical significance of each post ripening durations at a p=0.05 significant level.

Table 2. The effect of postharvest ripening on the vigour of seedlings and time of 50% germination at different harvesting stages

Variety	PHR	Vigour Index % ±SE			T50± SE(g)		
		35DAP	42DAP	49DAP	35DAP	42DAP	49DAP
Thinnavelli purple	0PHR	325.60±56.01[b]	693.28±57.30[b]	1042.52±49.32[ab]	1.74±0.17[a]	1.27±0.09[a]	0.99±0.06[b]
	1PHR	882.51±38.29[a]	870.50±91.37[ab]	1176.65±49.36[a]	1.14±0.04[b]	0.97±0.06[b]	0.86±0.01[b]
	3PHR	792.37±35.55[a]	922.14±47.71[a]	901.76±47.43[b]	0.94±0.06[b]	1.00±0.05[b]	1.16±0.14[a]
Padagoda	0PHR	378.07±29.96[b]	385.80±21.57[b]	544.54±30.98[a]	1.49±0.05[a]	1.39±0.06[a]	1.28±0.05[b]
	1PHR	598.61±49.34[a]	648.93±49.86[a]	393.43±36.06[b]	1.24±0.06[b]	1.22±0.06[ab]	1.34±0.06[ab]
	3PHR	592.66±55.70[a]	635.33±41.32[a]	316.19±23.77[b]	1.18±0.08[b]	1.01±0.07[b]	1.56±0.07[a]

Note: The different superscripts within column indicate statistical significance of each post ripening durations at a p=0.05 significant level.

seeds have a well structurally organized membrane system and the whole apparatus is ready for germination which has a direct relationship with germination energy (Marcos -Filho 2015).

CONCLUSIONS

Seed quality is one of the prime factors in crop production and food security. The results of the study revealed that the optimum harvesting stage is affected by the variety of eggplant. However, fruits subjected to postharvest ripening for approximately 2 weeks after early harvesting enhanced the overall quality of the eggplant seeds under the conditions that the experiment was conducted. As the seed is a costly input in eggplant cultivation, the findings of this study could pave the way to enhance the quality seed production of self-seed producers and commercial seed producers. However, this study needs to be conducted in different agro-ecological zones and the results need to be compared with some other recommended varieties.

AUTHOR CONTRIBUTION

GKMMKR and RMF and HF designed the study. GKMMKR and KATH performed the greenhouse experiment and pollination and KATH performed seed extraction and laboratory data collection. Data analyzed by GKMMKR. GKMMKR, RMF, HF written the manuscript.

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