Bulgarian Journal of Agricultural Science, 26 (No 6) 2020, 1171–1178

Macronutrient contents of eggplant seeds with different ages and postharvest resting times

Ariel Santivañez Aguilar[1], Henrique Vasque[1], Ricardo Adriano Felito[1], Andres Felipe Gaona Acevedo[1], Estefânia Martins Bardiviesso[1], Raíra Andrade Pelvine[1], Antonio Ismael Inácio Cardoso[1] and Ernane Miranda Lemes[2*]

[1]*São Paulo State University (UNESP), Department of Horticulture, School of Agriculture (FCA), Botucatu, São Paulo State, Brazil. Postal code: 18610-034*
[2]*Federal University of Uberlândia (UFU), Agrarian Science Institute (ICIAG), Uberlândia, Minas Gerais State, Brazil. Postal code: 38410-337*
[*]*Corresponding author:* ernanefito@gmail.com

Abstract

Aguilar, A. S., Vasque, H., Felito, R. A., Acevedo, A. F. G., Bardiviesso, E. M., Pelvine, R. A., Cardoso, A. I. I. & Lemes, E. M. (2020). Macronutrient contents of eggplant seeds with different ages and postharvest resting times. *Bulg. J. Agric. Sci., 26 (6)*, 1171–1178

The seed nutritional status is of essential importance to seed storage capacity and vigor, especially for horticultural crops, such as the eggplant. Thus, this study aimed to evaluate the macronutrient contents in eggplant seeds with different ages and times after the fruit harvest. Twelve treatments were evaluated - four fruit ages (40, 50, 60 and 70 days after anthesis), and three periods of resting after the harvest of the fruits (PRAHF) (0, 10 and 20 days). The experiment was conducted in a protected cultivating area. The dry biomass of 1000 eggplant seeds and contents of seed macronutrients were evaluated. The N concentration decreased with the increase of the fruit age, however, the PRAHF did not affect its content. The seed P content did not change with fruit age or PRAHF. For the seed K, Mg, S and Ca contents it was observed interaction between fruit age and PRAHF, and generally, the contents of these macronutrients decreased with fruit age and the PRAHF. The reductions in seed N, K, Ca and Mg contents correlate with the increase of the 1000 seeds dry mass, probably due to a dilution effect. The descending order of macronutrients contents in eggplant seeds is N>K>P>Mg>S>Ca.

Keywords: Solanum melongena L.; seed maturation; storage period; seed biomass; seed nutritional status

Introduction

Eggplant (*Solanum melongena* L.) belongs to the Solanaceae family and is well adapted to the hot and humid environments of the tropics, with the plant growth interrupted at temperatures below 10°C (Concellón et al., 2005; Padmanabhan et al., 2015; Gürbüz et al., 2018). Despite being classified as an autogamous plant, the eggplant presents a high rate of cross-fertilization and the presence of pollinating insects can increase seed production (Taher et al., 2017).

Seeds are the main way of eggplant propagation; thus, they are an input of great importance. However, there are few studies regarding eggplant seed production. The eggplant plant has indeterminate growth habit and continuous flowering, consequently, fruit ripening is not uniform and results in seeds of different maturation stages and it can reduce the quality of the seed lot.

In species with fleshy fruits, such as plant from the Solanaceae and Cucurbitaceae family, the storage, or post-harvest rest period, allows the seeds to complete the process of maturation, reaching high levels of germination and vigor as reported by Sanchez et al. (1993), Castro et al. (2008), Ricci et al. (2013), and Figueiredo Neto et al. (2015). However, those studies were evaluating the effects of age and post-harvest period of fruits on the physiological quality of the seeds, but there have been no studies regarding the contents of nutrients in seeds during the maturation and post-harvest rest period of fruits.

Some nutrients, such as Ca, are of low mobility in plants and perhaps during the post-harvest rest period, the seeds cease to receive the amount of nutrients needed to maintain viable for more time. Besides, the evaluation of nutrient contents in vegetables is of great importance to evaluate the removal of soil nutrients by plants (Kano et al., 2010).

The correct formation of the embryo and its reserves, as well as its chemical composition and, consequently, the metabolism and seed vigor, are directly related to the availability of nutrients. A nutritionally balanced seed has more chances of developing more vigorous plants (Carvalho & Nakagawa, 2012). However, the needs of nutrients to seed formation vary from one species to another; lettuce (*Lactuca sativa* L.) presents the following decreasing order of nutrient content: K>N>Ca>Mg>P>S (Kano et al., 2011), while in cauliflower (*Brassica oleracea* var. *botrytis*) the order is N>K>S>P>Ca>Mg (Cardoso et al., 2016b), demonstrating the differences observed among the nutrient concentration in seeds.

As they are formed at the end of the plant cycle, the seeds present different chemical composition in comparison to other plant organs (Cardoso et al., 2016a). Seeds are capable of reserving nutrients that are used in the initial stages of plant germination and also interfere with the storage capacity (Magalhães et al., 2015). Also, the understanding of the accumulation and of the rate of accumulation of nutrients during seed formation is important to prevent nutrient shortage during critical periods of absorption (Laviola et al., 2009).

The seed maturation is the plant stage with the greatest need for nutrients by the plant (Carvalho & Nakagawa, 2012). Some nutrients such as N, P and K are translocated from the vegetative part to the seeds in large quantities (Magro et al., 2010), however, the literature is scarce about the nutrient translocation from fruit to seeds after harvest and before seed extraction. The fruit post-harvest rest period is beneficial because it allows the early harvest and, therefore, reduces the exposure of fruits to climatic factors that might interfere with and compromise the seed quality (Castro et al,. 2008; Nakada-Freitas et al., 2018).

Considering the situation presented, a study was conducted aiming to evaluate the macronutrient contents in eggplant seeds with different ages and fruit post-harvest rest time.

Material and Methods

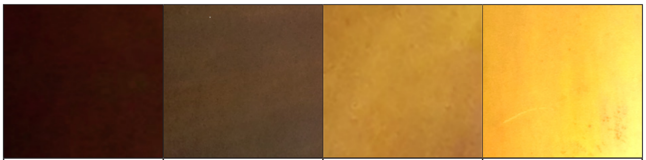
The eggplant frits and seeds used in this study were collected of plants cultivated in the São Manuel Experimental Farm (22°46’ S, 48°34’ W and altitude of 740 m) of the School of Agriculture (FCA) of the São Paulo State University (UNESP). The climate is of type *Cfa*, temperate hot (mesothermal) humid climate, according to the classification of Köppen (Cunha & Martins, 2009). The average monthly temperature (°C), relative humidity (%) and accumulated monthly rainfall (mm) was: August = 22.4, 54.1, 0; September = 24.6, 52.1, 27.9; October = 23.3, 72.6, 145.5; November = 22.6, 74.5, 163.3; December = 24.9, 77.4, 155.6; January = 23.8, 81.5, 176.0, and February = 23.45, 76.71, 94.9, respectively.

The eggplants were cultivated in a protected environment (type arc greenhouse) with 20 m length, 7 m width and 3 m height, covered with a polyethylene film of low density with 150 µm thick; the greenhouse sides were kept open to allow the entry of pollinator insects. The soil in the greenhouse is a Dystrophic Red Latosol (Embrapa, 2006). The soil chemical analysis (0-0.2 m soil layer) before the experiment installation were: pH ($CaCl_2$) = 6.0; soil organic matter = 10 g dm^{-3}; P = 166 mg dm^{-3}, H+Al = 19 $mmol_c$ dm^{-3}; K = 4.1 $mmol_c$ dm^{-3}, Ca = 52 $mmol_c$ dm^{-3}; Mg = 9 $mmol_c$ dm^{-3}; sum of bases (SB) = 65 $mmol_c$ dm^{-3}; cation exchange capacity (CEC) = 84 $mmol_c$ dm^{-3}, and base saturation (V) = 80%. Mineral fertilization was applied according to the recommendation (Raij et al., 1997).

Seeds of a line F6RC1 (“Napoli x (Kikushi x Napoli)”) of the breeding program of the FCA/UNESP was used. The sowing was made in polypropylene trays with 162 cells containing commercial substrate Carolina Soil®. Forty days after sowing the eggplant seedlings were transplanted (spacing 1 x 0.5 m) to beds in the greenhouse and all sprouts were removed until the first flower. The plant staking was made with bamboo. Drip irrigation was placed for each planting bed that was covered with black plastic (mulch). The fertilization was divided into six applications every 7 days; each application consisted of a liquid solution containing 1 g of urea and 1 g of potassium chloride per plant, starting at 14 days after transplanting.

The phytosanitary management included the application of Abamex®, Score® and Dithane NT® according to the need. The other crop management practices were carried out following the recommendation for the eggplant crop (Filgueira, 2013).

During the flowering stage, starting at 47 days after the seedling transplant, all flowers were labeled in the day of the anthesis. Twelve treatments were evaluated, resulting from the combination of four fruit ages (40, 50, 60 and 70 days after anthesis - DAA), and three periods of rest after the harvest of the fruits (PRAHF) (0, 10 and 20 days) before the seed extraction. As the maturation occurs the color of the eggplant fruit was determined according to the Munsell Scale of Color for soils (Munsell Soil Color Charts, 1954) (Figure 1). During the post-harvest rest, fruits were kept at 25°C. The experimental design was set as completely randomized, with four repetitions.



A - 40 DAA	B - 50 DAA	C - 60 DAA	D - 70 DAA
Dark gray	Dark nut-brown	Yelloish-brown	Yellow

Fig. 1. Coloring of eggplant fruits harvested at 40 (A), 50 (B), 60 (C) and 70 (D) days after anthesis (DAA)

Three fruits were left per plant that has been harvested according to age (DAA). In all treatments, the seed extraction followed the same methodology. The fruits were opened manually in the longitudinal direction, and the seeds were removed from the fruit, placed on a sieve and washed in tap water and distilled water. After washing, the seeds were left to dry in clay dishes. After seed cleaning to remove empty and damaged seeds - according to the methodology of Cardoso et al. (2016b) - they were packed in paper bags and dried in an oven with forced air circulation at 65°C until constant weight. After stabilization, the seeds were weighed, to obtain 1000 seeds weight, milled and forwarded to the laboratory for analysis to obtain macronutrients contents in the department of Soils and Environmental Resources of the FCA/UNESP. The methodology for the nutrients analysis followed the description found in Malavolta et al. (1997), using the sulfuric acid digestion to determine nitrogen, and nitric-perchloric digestion for phosphorus, potassium, calcium, magnesium, and sulfur. The results were expressed in g kg^{-1} of dry matter.

The results were submitted to analysis of variance and regression to verify the effect of the fruit age on the characteristics evaluated. To compare the post-harvest resting periods, the Tukey test ($p < 0.05$) was used. The data were processed using the statistical program Sisvar® 5.3 (Ferreira, 2011). Also, to establish relationships between the variables in this study, the Pearson's correlation was determined, and α = 5% was the significance level. The correlation was carried out by the InfoStat® software (Di Rienzo et al., 2011).

Results and Discussion

The dry mass of 1000 seeds presented significant interaction between the factors fruit age and post-harvest rest period. Regardless of the time after harvest, in the regression analysis, the data of fruit age adjusted to the quadratic model, with maximum values estimated at 5.40, 5.41 and 5.45 g for 64, 61 and 57 DAA, for 0, 10 and 20 days after the harvest of the fruits, respectively (Figure 2). According to Carvalho & Nakagawa (2012), as the seeds ripen within the fruit (even after harvest), the deposition of reserves occurs, increasing seed biomass, up to a maximum value that, probably, coincides with its physiological maturity. As the rest period after harvest increased, the age to achieve the maximum dry weight reduced, showing that, perhaps, it is possible to harvest the fruits earlier the longer the rest period. Also, Nascimento et al. (2000) reported low eggplant (hybrid Ciça) seed mass in low age eggplant fruits (30 to 40 DAA).

For the periods of rest after harvest, only for the first two ages (40 and 50 DAA) lower values were obtained for fruits without rest (PRAHF = 0 days) concerning 10 or 20 PRAHF; while for fruits with 60 and 70 DAA, the post-harvest rest did not affect the dry mass of 1000 seeds (Figure 2). The development of the seed is related to the maturation of the fruit, and even that eggplant is a no climacteric fruit, this does not mean that the seeds may not reach maturation within the harvested fruit (Passam & Karapanos, 2008; Passam et al., 2010; Rahman, 2015).

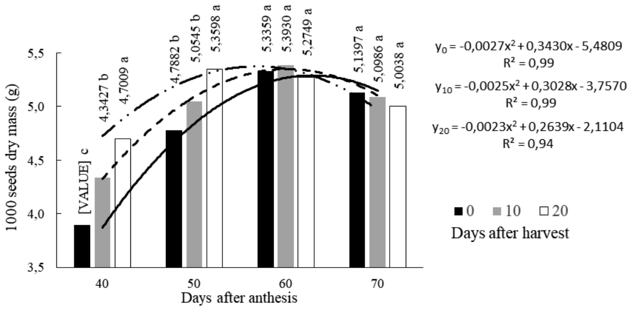


Fig. 2. The dry mass of 1000 seeds of eggplant according to fruit age and post-harvest rest periods

* Averages followed by the same lowercase letters in each age (days after anthesis) do not differ for the rest periods after harvest by the Tukey test ($P < 0.05$). Days of rest after harvest: 0 days = y_0 ─────; 10 days = y_{10} – – – –; 20 days = y_{20} – ● ● –

Interaction between the factors fruit age and post-harvest rest period was not significant for N content in seed. The fruit age factor indicated a linear reduction in seed N content with fruit age (Figure 3), with a great value at 40 DAA

(31.54 g kg^{-1}) and low N content at 70 DAA (29.26 g kg^{-1}), and an estimated reduction of 0.076 g kg^{-1} of N for each day the fruit remain attached to the plant. Despite the reduction has been relatively small (7.22%), it was significant and indicated that the increase in seed biomass was more pronounced than the capacity of the plant to absorb N and translocate it throughout the period of seed maturation, resulting in a dilution effect of the N concentration. The dilution of nutrients, according to Jarrell & Beverly (1981), is characterized when the growth rate of the dry biomass is greater than the rate of absorption of nutrients.

The rest period after harvest did not affect the seed N content; probably, this nutrient is translocated from the fruit to the seeds even after the cut (harvest) of the fruit from the plant. During the period after harvest, the fruits remained in the airy atmosphere, with temperatures below the greenhouse temperatures; thus, all the metabolic processes were reduced in comparison to the maturation period in the greenhouse, enabling the translocation of nutrients with the same intensity in which the seed biomass increased. The N is one of the nutrients more easily translocated from the leaves to the fruits (Tegeder & Masclaux-Daubresse, 2018), however, there are no studies on the N translocation from fruit to the seeds in post-harvest periods of storage, what probably happened in the present study.

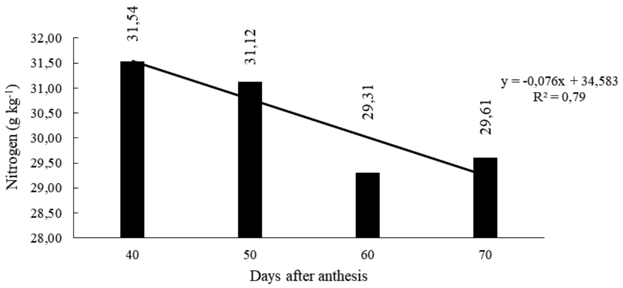


Fig. 3. Nitrogen content in the dry biomass of eggplant seeds according to fruit age and post-harvest rest periods

The P content in eggplant seed has not changed either by the fruit age or by the PRAHF. Therefore, the accumulation of P in seeds accompanied the increase of the seed dry biomass with fruit age and with the PRAHF. The average P content observed in the eggplant seeds was 4.6 g kg^{-1}, approximately 6.7 times lower than the content of Zucareli et al. (2011) observed that the phosphorus is required in quantity approximately 10 times smaller than the N in beans; however, the P deficiency reduced the viability, size, number and seed vigor. In seed, the phosphorus along with other nutrients is stored in salts of phytic acid, constituting the phytin, which during the germination is degraded and release these nutrients to be used in the development of the plant embryo and seedling (Carvalho & Nakagawa, 2012; Kano et al., 2012).

For the K, Ca, Mg and S contents in eggplant seeds the interaction between the factors fruit age and rest period after harvest was significant ($p < 0.05$). The contents of K (Figure 4) in eggplant seed adjusted to the quadratic model with minimum values of 4.98 and 5.37 g kg^{-1} to 64 and 60 DAA with 0 and 10 PRAHF, while with 20 PRAHF data adjusted to linear model, with a decrease of 0.0266 g kg^{-1} of K for each day the fruit remain attached to the plant.

The contents of Ca (Figure 5) in eggplant seed adjusted to the quadratic model, and the lowest values were estimated in 1.10, 1.09 and 1.12 g kg^{-1} at 59, 58 and 52 DAA, with 0, 10 and 20 PRAHF, respectively.

The seed K (Figure 4) and Ca (Figure 5) contents adjusted to the quadratic model (except for the K content in seeds from fruits with 20 days of rest after harvest), as well as the dry mass of 1000 seeds (Figure 2). The dry biomass of 1000 eggplant seeds increased to approximately 60 DAA, while the seed K (Figure 4) and Ca contents (Figure 5) reduced up to about 61 and 55 DAA, respectively. Therefore, it is clear that the seed dry mass increased faster than the plants can maintain the content of these nutrients, thus, diluting their concentration as the seed matures.

Calcium is an element commonly known by its reduced mobility in plants and, probably, all Ca in seeds is absorbed by the plant during the maturation of these and is forwarded

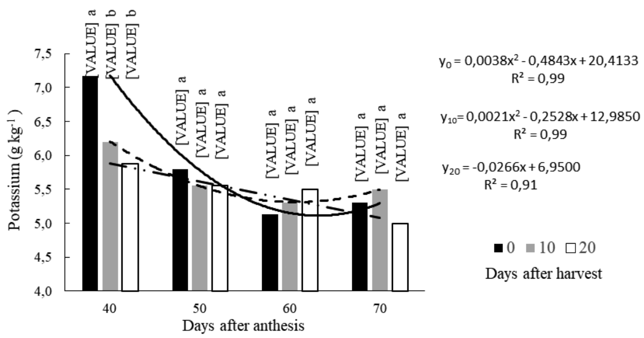


Fig. 4. Potassium content in the dry biomass of eggplant seeds according to fruit age and post-harvest rest periods

* Averages followed by the same lowercase letters in each age (days after anthesis) do not differ for the rest periods (days) after harvest by the Tukey test ($P < 0.05$). Days after harvest: 0 days = y_0 ———; 10 days = y_{10} –––; 20 days = y_{20} – ● ● –

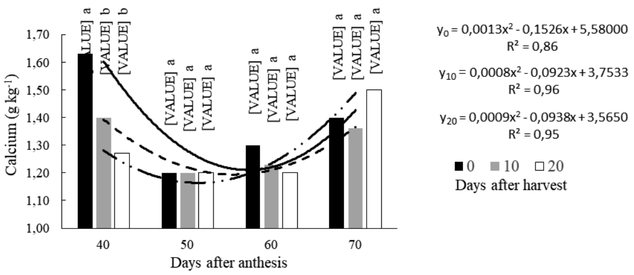


Fig. 5. Calcium content in the dry biomass of eggplant seeds according to fruit age and post-harvest rest periods

* Averages followed by the same lowercase letters in each age (days after anthesis) do not differ for the rest periods (days) after harvest by the Tukey test ($P < 0.05$). Days after harvest: 0 days = y_0 ―――――; 10 days = y_{10} ――――; 20 days = y_{20} – ● ● –

to the seeds without being immobilized in other parts of the plant (Kano et al., 2010). Therefore, the rapid development of the seeds inside the fruit and accelerated by high temperatures inside a protected environment was superior to the rate of Ca absorption. In Solanaceae plant family, the majority of the Ca accumulated is found in the leaves and stems and less in fruits and seeds (Marcussi et al., 2004; Marangon et al., 2016).

Potassium is a highly mobile nutrient in plants (Fernandes, 2006), and can be easily translocated from leaves to fruits and seeds; thus, the seed K content is not significantly affected even offering to plants different doses and sources of K (Kano et al., 2011; Quadros et al., 2012). Even so, a reduction in the K contents with the increase of the dry mass is expected as a dilution effect. Superior contents of K (Figure 4) and Ca (Figure 5) in eggplant seeds were observed in young fruits (40 DAA) when these nutrients were extracted immediately after harvest (PRAHF = 0) in relation to fruits stored for 10 or 20 days. In older fruits, the post-harvest rest period did not affect the contents of K and Ca in seeds. Again, on average, the effect was contrary to what was observed for the dry mass of 1000 seeds (Figure 2). The seed dry mass increment was more intense with the PRAHF than the transport of nutrients from the fruit to the seeds.

The effect of the fruit age in the Mg content in seeds was different for each period of post-harvest rest (Figure 6). In recently harvested fruits (PRAHF = 0), a linear reduction from 3.23 to 2.99 g kg^{-1} of Mg contents in fruits with 40 and 70 DAA, respectively, was observed, a reduction of 0.008 g kg^{-1} of Mg for each day the fruit remain attached to the plant, a similar effect that was observed for N (Figure 3). At 10 PRAHF, the quadratic effect was observed (Figure 6), similar to that observed for seed Ca content; in both cases (PRAHF = 0 and 10 days), a dilution effect of Mg in the seeds was observed. On the other hand, PRAHF of 20 days there was no difference in seed Mg contents, with an average of 3.07 g kg^{-1}. Probably, during post-harvest rest the translocation of Mg from fruit to the seeds occurs, being required great rest period to equalize the Mg contents in seeds. Magnesium is part of the chlorophyll and is a nutrient highly mobile in the plant vascular system, being easily translocated to reserve organs as seeds (Yan & Hou, 2018).

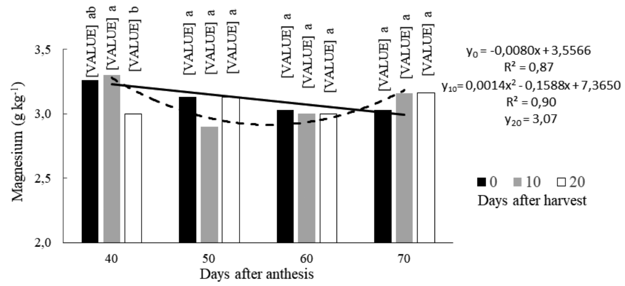


Fig. 6. Magnesium content in the dry biomass of eggplant seeds according to fruit age and post-harvest rest periods

* Averages followed by the same lowercase letters in each age (days after anthesis) do not differ for the rest periods (days) after harvest by the Tukey test ($P < 0.05$). Days after harvest: 0 days = y_0―――――; 10 days = y_{10}――――

The seed S content presented interaction between the factors (fruit age and post-harvest rest period). Only in younger eggplant fruits (40 and 50 DAA) presented a great concentration of S in seeds when extracted just after harvest (PRAHF = 0) compared to 20 days of post-harvest rest (Figure 7). Again, this effect was the inverse of the dry mass of 1000 seeds (Figure 2), characterizing the occurrence of the dilution effect during the post-harvest period. In older fruits

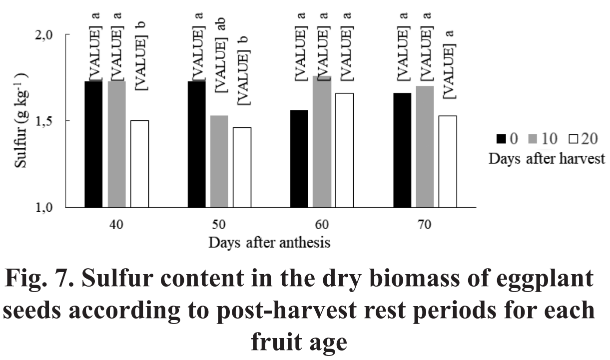


Fig. 7. Sulfur content in the dry biomass of eggplant seeds according to post-harvest rest periods for each fruit age

* Averages followed by the same lowercase letters in each age (days after anthesis) do not differ for the post-harvest rest periods by the Tukey test ($P < 0.05$)

Table 1. Estimation of simple correlation coefficients of Pearson between the dry weight of 1000 seeds and the contents of macronutrients in eggplant seeds with different ages and post-harvest rest periods

	Weight	N	P	K	Ca	Mg	S
Weight	1						
N	-0.63*	1					
P	-0.39	0.32	1				
K	-0.90**	0.55	0.44	1			
Ca	-0.66*	0.01	0.08	0.47	1		
Mg	-0.65*	0.48	0.30	0.55	0.67*	1	
S	-0.31	0.18	0.45	0.34	0.23	0.35	1

** Significant at $P < 0.01$; * Significant at $P < 0.05$

(60 and 70 DAA) there was no difference in seed S content (Figure 7), similar to the dry mass of 1000 seeds (Figure 2).

The correlations between the dry mass of 1000 seeds and the contents of macronutrients (Table 1) demonstrated that the dry mass is correlated negatively with the N, K, Ca and Mg nutrient contents in the eggplant seeds. The increase of seed mass is accompanied of reductions in nutrient contents if the nutrient is not mobilized to the seeds at the same intensity in which the seeds gain biomass, causing the mentioned dilution effect of these nutrients in the seeds (Jarrell & Beverly, 1981). Only for the seed P and S contents, no significant correlation was observed.

The descending order of the contents of nutrients in eggplant seeds was N>K>P>Mg>S>Ca. Hagg & Homa (1968) reported the following order of nutrients in eggplant plant K>N>Ca>Mg>P>S. Therefore, it can be observed the great importance of P to the seed and the lower relative importance of Ca. In the case of the Ca this is due to its low mobility (White & Broadley, 2003). According to Cardoso et al. (2016b), the Ca accumulation in seeds should only occur by absorption and transport during seed maturation, without redistribution of senescence leaves to the seeds. Phosphorus is of great importance to seeds and is part of the phytin, which during the germination is degraded and releases the P to be used in the development of the plant embryo and seedling (White & Veneklaas, 2012; Taliman et al., 2019).

In the present study, N is the nutrient with the greatest content in eggplant seeds, followed by K and P, confirming the results found by Cardoso et al. (2011) and Lott et al. (1995) who reported that N content in seeds of most vegetables is larger than any other nutrient. The same was observed by Kano et al. (2010) and Quadros et al. (2012) in the lettuce seeds, by Magro et al. (2010) in broccoli (*Brassica oleracea* var. *italica*) and by Cardoso et al. (2016b) in cauliflower.

This great N content in seeds is linked to the high levels of protein found in this plant organ (Tegeder & Masclaux-Daubresse, 2018). Also, the N content is important because it is related to proteins of storage (soluble peptides and free amino acids) that are translocated to the embryonic axis to provide energy during the germination process (Müntz et al., 2001). The speed of germination, the time of cotyledon fall and the emergence of leaves is determined by N concentration in the seed (Soriano et al., 2013).

However, the nutrient requirements to the appropriated seed formation may vary from one species to another; for example, the lettuce descending order of nutrients contents is K>N>Ca>Mg>P>S (Kano et al., 2011), while in cauliflower is N>K>S>P>Ca>Mg (Cardoso et al., 2016a), and the descending order of macronutrients found in the present study for eggplant seeds was N>K>P>Mg>S>Ca, thus, there are major differences in the seed composition among species.

Conclusions

The N content in seeds reduces with the age of the eggplant fruits and the contents of K, Ca, Mg and S reduce with the post-harvest rest period on young fruits (40 days after anthesis).

The P content in eggplant seeds is not altered with age or post-harvest rest period.

The reductions in N, K, Ca and Mg contents in eggplant seeds correlate with the increase in dry weight of 1000 seeds due to the dilution effect.

The descending order of the macronutrient contents in the eggplant seeds is N>K>P>Mg>S>Ca.

Acknowledgments

Coordination of Superior Level Staff Improvement (CAPES).

https://orcid.org/0000-0001-6807-0644

References

Cardoso, A. I. I., Claudio, M. de T. R., Magro, F. O. & Freitas, P. G. N. (2016a). Phosphate fertilization on the production and quality of cauliflower seeds. *Ciência Rural, 46(8),* 1337-1343. https://doi.org/10.1590/0103-8478cr20150664

Cardoso, A. I. I., Claudio, M. De T. R., Nakada-Freitas, P. G., Magro, F. O. & Tavares, A. E. B. (2016b). Phosphate fertilization over the accumulation of macronutrients in cauliflower seed production. *Horticultura Brasileira, 34(2),* 196-201. https://doi.org/10.1590/S0102-053620160000200008

Cardoso, A. I. I., Ferreira, K. P., Vieira Júnior, R. M. & Alcarde, C. (2011). Changes in soil properties managed with organic compost and its effect on lettuce seed quality. *Horticultura Brasileira, 29(4),* 594-599. https://doi.org/10.1590/S0102-05362011000400025

Carvalho, N. M. & Nakagawa, J. (2012). Seeds: Science, technology and production, 5th ed. Jaboticabal: FUNEP, 590.

Castro, M. M., Godoy, A. R. & Cardoso, A. I. I. (2008). Okra seed quality as a function of age and fruit post harvest rest. *Ciência e Agrotecnologia, 32(5),* 1491-1495.

Concellón, A., Añón, M. C. & Chaves, A. R. (2005). Effect of chilling on ethylene production in eggplant fruit. *Food Chemistry, 92(1),* 63-69. https://doi.org/10.1016/j.foodchem.2004.04.048

Cunha, A. R. & Martins, D. (2009). Climatic classification for the districts of Botucatu and São Manuel, SP. Irriga, *14(1),* 1-11. https://doi.org/10.15809/irriga.2009v14n1p1-11

Di-Rienzo, J. A., Casanoves, F., Balzarini, M. G., Gonzalez, L., Tablada, M. & Robledo, C. W. (2011). InfoStat. Córdoba: Grupo InfoStat FCA Universidad Nacional de Córdoba, Argentina.

EMBRAPA (2006). Brazilian System of Soil Classification. Empresa Brasileira de Pesquisa Agropecuária (Sistema brasileiro de classificação dos solos. Empresa Brasileira de Pesquisa Agropecuária). Rio de Janeiro.

Fernandes, M. S. (2006). Mineral plant nutrition (SBCS, ed.). Viçosa, MG., 432.

Ferreira, D. F. (2011). Sisvar: a computer statistical analysis system. *Ciência e Agrotecnologia, 35(6),* 1039-1042. https://doi.org/10.1590/S1413-70542011000600001

Figueiredo Neto, A., Almeida, F. A. C., Vieira, J. F. & Da Silva, M. F. (2015). Physiological maturity of pumpkin seeds. *African Journal of Agricultural Research, 10(27),* 2662-2667. https://doi.org/10.5897/AJAR2015.9522

Filgueira, F. A. R. (2013). New manual of olericulture: modern agrotechnology in the prodution and market of horticultures (Novo manual de olericultura: agrotecnologia moderna na produção e comercialização de hortaliças). (3. ed. rev). Viçosa, MG: Viçosa: UFV.

Foloni, J. S. S., Aranda, C. T., Barbosa, Moraes, A. de, Calonego, J. C. & Tiritan, C. S. (2016). Soil nutriente acumulation and C/N relation in diferente phenological stages of millet under nitrogen fertilization (Acúmulo de nutrientes e relação C / N em diferentes estádios fenológicos do milheto submetido à adubação nitrogenada). *Revista Agro@mbiente, 10(1),* 1-9. https://doi.org/10.18227/1982-8470ragro.v10i1.2798

Gürbüz, N., Uluişik, S., Frary, A., Frary, A. & Doğanlar, S. (2018). Health benefits and bioactive compounds of eggplant. *Food Chemistry, 268,* 602-610. https://doi.org/10.1016/j.foodchem.2018.06.093

Haag, H. P. & Homa, P. (1968). Mineral nutrition of horticultures - III Macronutrient deficiency in eggplant (Nutrição mineral de hortaliças - III Deficiências de macronutrientes em beringela). Anais da E.S.A. "Luiz de Queiroz".

Jarrell, W. M. & Beverly, R. B. (1981). The Dilution Effect in Plant Nutrition Studies In: *Advances in Agronomy.* New York, 197–224. https://doi.org/10.1016/S0065-2113(08)60887-1

Kano, C., Cardoso, A. I. I. & Villas Bôas, R. L. (2010). Macronutrient content in lettuce affected by potassium side dressing. *Horticultura Brasileira, 28*, 287-291.

Kano, C., Cardoso, A. I. I. & Villas Bôas, R. L. (2011). Nutrient accumulation by lettuce for seed production (Acúmulo de nutrientes pela alface destinada à produção de sementes). *Horticultura Brasileira, 29(1)*, 70-77.

Kano, C., Cardoso, A. I. I. & Villas Bôas, R. L. (2012). Phosphorus rates on yield and quality of lettuce seeds. *Horticultura Brasileira, 30,* 695-698.

Laviola, B. G., Martinez, H. E. P., Souza, R. B., Salomão, L. C. C. & Cruz, C. D. (2009). Macronutrient accumulation in coffee fruits at Brazilian Zona da Mata conditions. *Journal of Plant Nutrition, 32(6),* 980-995. https://doi.org/10.1080/01904160902872164

Lott, J. N. A., Greenwood, J. S. & Batten, G. D. (1995). Mechanisms and regulation of mineral nutrient storage during seed development. In: Kigel, J.; Galili, G. (eds.) *Seed development and germination,* 1. ed. New York: Dekker, 215-235.

Magalhães, W. de A., Megaioli, T. G., Freddi Onã, da S. & Santos Dos, M. A. (2015). Measurement of nutrient concentration in soybean seeds. *Revista de Ciências Agroambientais, 13(2),* 95-100.

Magro, F. O., Arruda, N., Casa, J., Salata, A. C., Cardoso, A. I. I. & Fernandes, D. M. (2010). Organic compost in broccoli seed yield and quality. *Ciência e Agrotecnologia, 34(3),* 596-602. https://doi.org/10.1590/S1413-70542010000300010

Marangon, C., Rizzatti, I., Souza, J., Santana, J. G. A. & Schveitzrt, B. (2016). Iron and calcium content of edible plants in non conventional family Solanaceae: A comparative analysis. *Periódico Tchê Química, 13*, 30-36.

Marcussi, F., Lyra Villas Bôas, R., José Grava de Godoy, L. & Goto, R. (2004). Macronutrient accumulation and partioning in fertigated sweet pepper plants. *Sci. Agric. (Piracicaba, Braz.), 61(1),* 62-68. https://doi.org/10.1590/S0103-90162004000100011

Munsell Soil Color Charts (1954). Baltimore, Md.: Munsell Color Company.

Müntz, K., Belozersky, M. A., Dunaevsky, Y., Schlereth, A. & Tiedemann, J. (2001). Stored proteinases and the initiation of storage protein mobilization in seeds during germination and seedling growth. *Journal of Experimental Botany, 52,* 1741-1752.

Nakada-Freitas, P. G., Ardoso, A. I. I., Lanna, N. B. L., Araujo, H. S., Santos, C. A. & Magalhaes, T. H. (2018). Maturation and resting of horticultural crops for seed production and qaulity (Maturação e repouso de frutos de hortaliças para produção e qualidade de sementes). In: Polycarpo, G. V. et al. (eds.). IMAST 2018: News in agrarian sciences: changes, trends and impacts (Atualidades nas ciências agrarias: mudanças, tendências e impactos). Drcena: *Cultura Acadêmica,* 76-101.

Nascimento, W. M., Lima, L. B. & Alvares, M. C. (2000). Eggplant hybrid seed maturation (Maturação de sementes híbridas de berinjela). *Horticultura Brasileira, 18, Supll,* 1041-1042.

Padmanabhan, P., Cheema, A. & Paliyath, G. (2015). Solanaceous fruits including tomato, eggplant and peppers. 1. ed. Guelph: Elsevier Ltd.

Passam, H. C. & Karapanos, I. C. (2008). Eggplants, peppers and tomatoes: factors affecting the quality and storage life of fresh and fresh-cut (minimally-processed) produce. *Eur. J. Plant Sci. Biotechnol, 2(1)*, 156-170.

Passam, H. C., Theodoropoulou, S., Karanissa, T. & Karapanos, I. C. (2010). Flowering, fruit set and fruit and seed development in two cultivar, of aubergine (*Solanum melongena* L.) grown under plastic cover. *Scientia Horticulturae, 125(3),* 518-520. https://doi.org/10.1016/j.scienta.2010.04.007

Quadros, B. R., Corrêa, C. V., Magro, F. O. & Cardoso, A. I. I. (2012). Infuence of organic compost and phosphorus on lettuce seeds. Semina:Ciencias Agrarias, 33(6), 2511-2518. https://doi.org/10.5433/1679-0359.2012v33Supl1p2511

Rahman, B. (2015). Physiological quality of eggplant seed as influenced by extraction method. *Advances in Crop Science and Technology,* s1. https://doi.org/10.4172/2329-8863.1000S1-005

Raij, B. Van, Cantarella, H., Quaggio, J. A. & Furlani, A. M. C. (1997). Recomendations of fertilization and lime to the São Paulo state (Recomendações de Adubação e Calagem para o Estado de São Paulo) 2 ed. rev.; Agronomic Institute of Campinas (IAC). Campinas: IAC.

Ricci, N., Pacheco, A. C., Conde, A. S. & Custódio, C. C. (2013). Seed quality of jalapeno pepper according to fruit maturation and post harvest rest. *Pesquisa Agropecuaria Tropical, 43(2),* 123-129. https://doi.org/10.1590/S1983-40632013000200008

Sanchez, V. M., Sundstrom, G. N., Mcclure, G. N. & Lang, N. S. (1993). Fruit maturity, storage and postharvest maturation treatments affect bell pepper (*Capsicum annuum* L.) seed quality. *Scientia Horticulturae, 54(3),* 191-201.

Soriano, D., Huante, P., Gamboa-de Buen, A. & Orozco-Segovia, A. (2013). Seed reserve translocation and early seedling growth of eight tree species in a tropical deciduous forest in Mexico. *Plant Ecology, 214(11),* 1361-1375. https://doi.org/10.1007/s11258-013-0257-z

Taher, D., Solberg, S. Ø., Prohens, J., Chou, Y., Rakha, M. & Wu, T. (2017). World vegetable center eggplant collection: origin, composition, seed dissemination and utilization in breeding. *Front. Plant Sci., 8,* 1484. https://doi.org/10.3389/fpls.2017.01484

Taliman, N. A., Dong, Q., Echigo, K., Raboy, V. & Saneoka, H. (2019). Effect of phosphorus fertilization on the growth, photosynthesis, nitrogen fixation, mineral accumulation, seed yield, and seed quality of a soybean low-phytate line. *Plants, 8,* 119. https://doi.org/10.3390/plants8050119

Tegeder, M. & Masclaux-Daubresse, C. (2018). Source and sink mechanisms of nitrogen transport and use. *New Phytologist, 217,* 35-53. https://doi.org/10.1111/nph.14876

Yan, B. & Hou, Y. (2018). Effect of soil magnesium on plants: a review. IOP Conference Series: *Earth and Environmental Science, 170(2),* 022168. https://doi.org/10.1088/1755-1315/170/2/022168

White, P. J. & Broadley, M. R. (2003). Caulcium in plants. *Annals of Botany, 92(4):* 487-511. https://doi.org/10.1093/aob/mcg164.

White, P. & Veneklaas, E. (2012). Nature and nurture: the importance of seed phosphorus content. *Plant and Soil, 357(1),* 1-8. https://doi.org/10.1007/s11104-012-1128-4

Zucareli, C., Prando, A. M., Junior, E. U. R. & Nakagawa, J. (2011). Phosphorus in the productivity and quality of premature *Carioca* bean seeds grown in the rainy period (Fósforo na produtividade e qualidade de sementes de feijão Carioca Precoce cultivado no período das águas). *Revista Ciencia Agronomica, 42(1),* 32-38. https://doi.org/10.1590/S1806-66902011000100005

Received: March, 11, 2020; *Accepted:* October, 7, 2020; *Published:* December, 31, 2020