P L A N T B R E E D I N G A N D S E E D S C I E N C E
Volume 81 2020

DOI: 10.37317/ pbss-2020-0003

Kutay Coşkun Yildirim[1,*], Ibrahim Demir[2]

[1]Department of Vegetable Agronomy, Ataturk Horticultural Central Research Institute, Yalova, Turkey;
[2]Department of Horticulture, Faculty of Agriculture, University of Ankara, Ankara, Turkey;
*Correspondence author's e-mail address: kutaycoskun.yildirim@tarimorman.gov.tr;
[1]ORCID: 0000-0002-5762-8128, [2]ORCID: 0000-0003-4515-0689

THE EFFECT OF MATURATION STAGE AND AFTER-RIPENING ON SEED QUALITY IN ORGANICALLY- AND CONVENTIONALLY PRODUCED PEPPER (*CAPSICUM ANNUUM* L.) SEEDS

ABSTRACT

High-quality seed production is essential in organic production as well as in conventional production. Fruit maturity can be observed at different times due to the continuous flowering of pepper plant. Consequently, seeds with different maturity stages were obtained as the fruits were collected during once over-harvesting period. Immature seeds collected in once over-harvest may cause quality losses in the seed lot. Hence, this study was conducted to determine the effect of after-ripening on mature and immature pepper seeds produced in organic and conventional production systems. To see the effect of after-ripening treatment, seeds were harvested in two different periods (immature 45-50 days after anthesis(DAA) and mature 60-65 DAA). After-ripening (AR) was performed by keeping the seeds in fruits for 7 days after harvesting the fruits. Effect of production systems and after-ripening on immature and mature pepper seed lots were assessed for four cultivars harvested in 2015 and 2016. After-ripening increased germination (AR:76.3%, C:28% for organic and AR:88%, C:53.8% for conventional), seedling emergence (AR:70.8%, C:44.3% for organic and AR:82.5%, C:53.8% for conventional) percentages and mean weight of 1000 seeds (AR:6.5, C:6.0g for organic and AR:6.5, C:6.2g for conventional) in both production systems of immature seed lots compared to control (C)($P<0.05$) but did not have a similar effect on mature ones. Moreover, organically-produced seed lots have the same quality as conventionally-produced seeds. Consequently, obtained results indicate that after-ripening can be used to enhance the quality of immature seeds of pepper cultivars and seeds can be produced organically without any loss of quality.

Key words: after-ripening, germination, harvesting periods, organic seed, pepper

INTRODUCTION

Seed is one of the most important elements in terms of increasing yield and obtaining high quality crops. Organic crop growing systems may claim to produce even higher quality reproduction material compared to conventional growing methods

Communicated by Grzegorz Żurek

(Sripathy *et al.*, 2012). Seeds and other production materials used in organic farming should be produced organically (Anonymous, 2005). Thus, organic seed is the initial material for organic plant production. The demand for organic seed has grown rapidly in recent years. Accordingly, sales of organic products were worth nearly $43 billion in 2015, an 11% increase compared to 2014. The food share of this amount was $39.7 billion (Anonymous, 2016). Accelerated understanding of health and environmental matters accompanied by the intense use of chemicals attracted attention to different methods of agriculture in the world. Organic farming is defined as a production method that protects the natural balance and includes human and environmentally friendly production systems, ensuring soil has sustainable efficiency, increasing the resistance of the plant, and recommending biological methods in plant protection (Tasbasli *et al.*, 2003).

Organic seed production usually involves higher costs than conventional seed production because of losses throughout the seed production period or inadequate quality of seed production (van der Zeijden, 2003). When research about organic vegetable seed production is examined, it was observed that the studies were limited to some vegetable species and this was related to the vegetation period (Bonina and Cantliffe, 2004). The longer vegetation period in vegetable seed production causes the plants to be exposed to ecological conditions for a longer period of time. Hence, research is required to handle these problems and support seed companies in advancing their organic seed production and seed treatment techniques (Groot *et al.*, 2004).

Determination of appropriate harvest time during seed development for high quality is of great importance for seeds that contain high seed moisture during maturation (Vidigal *et al.*, 2006). Pepper (*Capsicum annuum* L.) seeds contain seed moisture at maturity (Demir and Ellis, 1992a) and a high germination rate is not easily achieved due to the indeterminate flowering seed maturation on the plant. For this reason, the ideal harvest time in terms of fruit maturation directly affects the seed quality of the pepper seed lots (Sinniah *et al.*, 1998; Demir and Samit, 2001; Dias *et al.*, 2006; Vidigal *et al.*, 2011; Caixeta *et al.*, 2014; Nogueira *et al.*, 2017; Demir *et al.*, 2018).

Fruit maturity can be observed at different times due to the continuous flowering of the pepper plant. As a result, seeds with different maturity are obtained as the fruits are collected during one over-harvesting period in commercial seed production. When the seeds with different maturity are mixed, the immature seeds may cause a decrease in the quality of the seed lots by adversely affecting seedling emergence and uniformity (Demir and Ellis, 1992a). For this reason, pepper seed lots can be composed of immature, mature, and over mature seeds due to differences in flowering time and one over-harvesting.

Earlier studies indicate that seed quality was enhanced by keeping seeds in harvested fruits for a while (Edwards and Sundstrom, 1987; Sanchez *et al.*, 1993; Desai *et al.*, 1997; Vidigal *et al.*, 2006; Dias *et al.*, 2006; Vidigal *et al.*, 2009; Passam *et al.*, 2010; Kalyanrao and Singh, 2014; Santos *et al.*, 2015). Accordingly, if the vigor potential of the immature seeds is increased, it may have a positive effect on the overall quality of the seed lot (Vidigal *et al.* 2009). This may be more important when seed harvesting is done during once-over (harvesting all fruits at different maturation stages due to sequential flowering).

In previous reports, the effect of after-ripening treatment on seed quality was determined under conventional production conditions. However, to the best of our knowledge, there were no studies found about the effects of organic seed production system with after-ripening treatment on seed quality development and seed vigor performance. Hence, this study was carried out to assess the effect of after-ripening treatment linked to the maturation levels on organically- and conventionally-produced pepper seed lots. In addition, organic and conventional production systems were compared in terms of seed quality criteria.

MATERIALS AND METHODS

Plant cultivation and seed harvest in organic and conventional production systems

The study was conducted in 2015 and 2016 in the organic and conventional production parcels of Atatürk Horticultural Central Research Institute – Yalova / TURKEY. “Surmeli”, “Kandil Dolma”, “Yaglik” and “Corbaci” open-pollinated pepper cultivars were used as plant materials.

During the vegetation period for seed production, different fertilizers were used depending on plant growth periods and the amount of plant nutrients in the soil. 'Gentasol' (30% total organic matter, 5% N, 3% K_2O, 2% P_2O_5), 'Ormin K' (30% K_2O, %5 organic matter), and 'Biofarm' organic fertilizers were used in organic seed production parcels and 20:20:20 (NPK), potassium sulfate (50% K_2O) and 15:15:15 (NPK) compound fertilizers were used in conventional seed production parcels.

Table 1

Soil properties of organic and conventional seed production parcels in 2015-2016

Parameter	Year	Production system	
		Organic	Conventional
Depth [cm]		0-30	0-30
Water holding capacity [%]	2015	53	59
	2016	52	56
EC25 [1:2.5] [mmhos × cm^{-1}]	2015	0.10	0.11
	2016	0.07	0.10
pH	2015	7.73	7.79
	2016	7.28	7.09
Lime [%]	2015	0.40	0.40
	2016	0.40	0.40
Organic matter [%]	2015	2.03	3.51
	2016	1.41	2.22
Available phosphorus [ppm]	2015	20.0	17.0
	2016	8.0	7.2
Exchangeable potassium [ppm]	2015	233.0	310.0
	2016	202.5	232.5

According to the results of soil analysis, the soil structures of the production parcels belonging to both vegetation periods (2015-2016) have a clayey structure. The soil pH was determined to be between 7.09-7.79. Therefore, the structures of the production parcels have slightly alkaline character. Soil salinity is between 0.07% and 11.11%, while the available phosphorus values in the soil range from 7.2 to 20.0 ppm. The amount of organic matter in parcels was found to be between 1.41-3.51% and the amount of exchangeable potassium in the parcels was between 202.5-310.0 ppm (Table 1).

Seeds of four different pepper cultivars were sown in the second week of March in both vegetation periods. The medium used for seedling production is organic origin and contains 1:1:1 burned sheep manure, loam soil, and biofarm chicken manure. These materials were steam sterilized before use. The study was conducted according to the randomized complete block design with 4 replicates and each replicate contained 150 plants. Seedlings were planted in organic and conventional production fields in the second week of May in both seasons. Plant spacing was 0.8 m between rows and 0.4 × 0.5 m between plants with double rows. Before planting, biofarm chicken manure at a rate of 50 kg per 1000 m^2 was added to the organic parcels and 15:15:15 NPK at a rate of 50 kg per 1000 m^2 was applied to conventional parcels. Weekly fertilization was done depending on the plant growth and the amount of plant nutrients in the soil. "Gentasol" 20 L per 1000 m^2 was applied to the organic seed production parcels and 20:20:20 (N-P-K) 2 kg per 1000 m^2 of compound fertilizer was given by drip irrigation to the conventional seed production parcels. Potassium fertilization was done during the fruit phase. Accordingly, "Ormin K" 2 kg per 1000 m^2 was used in organic production parcels and potassium sulfate 1.5 kg per 1000 m^2 was given to conventional production parcels.

Plants began flowering in June in both production systems and both vegetation periods. Flowers were labeled on the day of flowering and fruits were harvested with two different maturities; 45-50 (immature) and 60-65 (mature) days after anthesis for each cultivar in both vegetation periods. The seeds from each harvest were kept in the fruits for 7 days under indoor conditions (about 23 °C and 70% RH). Afterward seeds were extracted and dried at 30 °C until the seed moisture content declined to 8%. Moisture content of dried seeds was determined according to the ISTA (2016) method. The mean weight of 1000 seeds was determined after the drying process. The dried seeds were kept in the dark at 4 °C in hermetically-sealed aluminum foil packets until use.

Seed viability and vigor tests

Germination test

The experiment was established with 4 replicates and each replicate had 50 seeds for each production system, after-ripening and harvest periods (i.e. 4 cultivars = 2 production systems × 2 harvests × 1 after-ripening and 1 control). Two pieces of Whatman No: 1 blotting paper were placed in 9 cm Petri dishes. Then 4 ml of 0.2% KNO_3 solution was added after the seeds were placed in the Petri dishes (ISTA, 2016). The germination test was carried out at 25 ºC in the dark and the percentage of germination was calculated using daily counts for 14 days. The germination papers were moistened as needed. Normal and abnormal seedlings were determined at the end of the germination experiment. Mean germination time was calculated based on the daily counts made during the experimental period (Ellis and Roberts, 1980).

Seedling emergence test

The seedling emergence test was conducted with the same protocol as the germination test (described above). Seeds from organic and conventional systems were sown in vials at a depth of 2 cm including a mixture of peat and perlite (1:0.5). The vials were put in a climate-controlled chamber at 23 ± 2 °C and 60-70% relative humidity with 16 hours of light and 8 hours dark conditions. Emergence counts were made daily for 25 days. The seedling emergence percentages (the appearance of hypocotyls at the surface) were determined after 25 days. Mean emergence time was recorded by virtue of the daily counts made during the experimental period (Ellis and Roberts, 1980).

Weight of 1000 seed

Using a seed counting machine, 1000 seeds from each seed lot were counted with four replicates and subjected to statistical analysis.

Statistical analysis

The laboratory tests in the study were established in accordance with the experimental randomized parcel design. Field trials were conducted according to the randomized complete block design. The percentage of values obtained from these tests were subjected to $\sqrt{n}$ transformation. JMP 8.0 Statistical package program was used for analysis. Data were assessed with analysis of variance for the main effects, whereby the means of values were compared using the Duncan Multiple Range Test and Least Significant Difference test (p=0.05).

RESULTS

There were statistically triple interactions found between production systems, harvest periods and after-ripening treatment for all viability and vigor tests. The difference between organic and conventional production systems was found to be statistically insignificant using germination and seedling emergence tests in consecutive years.

The mean germination rate (all cultivars) of after-ripening (AR) treated seeds belonging to immature harvests were 76.3% and 86.5% for the organic production system and 88.8% and 91.5% for the conventional production system in 2015 and 2016, respectively (Table 3). Nevertheless, control seed lots from immature harvests were 28 and 64.3% for the organic system and 53.8 and 70.3% for the conventional system in both years, respectively. In accordance with these results, AR treatment increased germination percentages compared to the control group of immature seed lots up to 48.3% and 22.2% for the organic system and 35% and 21.2% for the conventional system in subsequent years (P<0.05). AR treatment was found to be statistically insignificant for mature seed lots regardless of the production system in both vegetation periods. The mean germination percentages of the organically-produced control group of mature seed lots were 90.8% and 90.3 and seeds of a conventional production system were 92% and 90.3% in 2015-2016, respectively, while AR-treated seed lots from the organic system were 89.3% - 90% and 91.5% - %88 for the conventional production system.

Table 3

Germination percentages for four cultivars of after-ripening(AR) and control(C), immature and mature pepper seeds belonging to organic and conventional production systems. Means with different letters in the same line (i.e. cultivars and production systems) are significantly different at 5% level with Duncan's multiple range test(P<0.05). Values are means ± S.D. (n = 4)

Year	Cultivars	Organic				Conventional				CV	LSD
		Immature		Mature		Immature		Mature			
		AR	C	AR	C	AR	C	AR	C		
2015	Surmeli	55±5.7b	34±3.3c	89±1.7a	89±1.5a	89±3.0a	49±4.4b	86±1.4a	91±2.1a	5.23%	9.4
	Kandil D.	85±3.2a	10±2.3c	84±2.8a	88±1.7a	89±3.0a	28±2.2b	93±0.6a	90±1.0a	4.69%	6.9
	Yaglik	84±1.4b	33±3.7d	93±0.5a	91±2.2ab	83±2.4b	63±5.8c	91±1.7ab	94±1.2a	3.45%	6.9
	Corbaci	81±1.9b	35±3.7d	91±1.7a	95±0.6a	94±1.4a	75±2.2c	96±0.8a	93±1.3a	2.51%	5.1
2016	Surmeli	76±2.2bc	37±4.4d	85±2.9ab	87±1.7a	88±1.9a	70±2.6c	85±1.7a	87±3.6a	4.12%	8.1
	Kandil D.	91±1.0ab	57±1.8d	96±1.3a	91±2.1ab	91±2.7ab	72±1.8c	95±1.0a	89±1.7b	2.02%	5.0
	Yaglik	92±2.1ab	82±1.2c	87±1.7b	89±1.0ab	91±1.0ab	62±1.0e	76±1.2d	94±2.5a	1.82%	4.6
	Corbaci	87±3.3bc	81±1.7cd	92±1.0ab	94±0.8a	96±1.0a	77±2.4d	96±0.8a	91±3.1ab	2.31%	5.9

Table 4

Emergence percentages for four cultivars of after-ripening(AR) and control(C), immature and mature pepper seeds belonging to organic and conventional production systems. Means with different letters in the same line (i.e. cultivars and production systems) are significantly different at 5% level with Duncan's multiple range test(P<0.05). Values are means ± S.D. (n = 4)

Year	Cultivars	Organic				Conventional				CV	LSD
		Immature		Mature		Immature		Mature			
		AR	C	AR	C	AR	C	AR	C		
2015	Surmeli	53±2.5b	42±5.3b	69±4.7a	73±1.9a	79±3.4a	44±4.9b	84±6.7a	82±5.3a	7.34%	13.4
	Kandil D.	79±6.4a	24±5.9c	77±4.4a	77±5.3a	84±5.9a	38±1.2b	72±4.9a	80±2.3 a	7.86%	13.8
	Yaglik	77±1.9bc	53±3.0d	86±6.0ab	87±3.0ab	72±2.8c	52±2.8d	86±2.6ab	93±4.4a	4.66%	10.3
	Corbaci	74±2.6cd	58±2.6f	90±3.5ab	76±4.3cd	95±3.5a	81±1.9bc	64±4.0ef	69±3.8de	4.28%	9.5
2016	Surmeli	79±5.3bc	39±2.7d	90±3.5a	86±1.2ab	86±3.0ab	75±3.0c	81±3.9bc	84±1.6ab	3.75%	8.5
	Kandil D.	88±5.4a	65±1.9d	86±3.8ab	72±6.3cd	85±5.0a-c	72±2.8b-d	77±6.0a-d	79±5.0a-c	6.13%	13.9
	Yaglik	92±2.3ab	73±5.0c	94±3.5a	90±3.5ab	89±3.0ab	80±2.3bc	62±6.0d	89±4.1ab	4.97%	11.5
	Corbaci	86±2.0c	62±2.0e	93±1.9ab	90±1.2a-c	91±3.4a-c	75±2.7d	95±1.9a	87±1.0bc	2.35%	6.0

Table 5

Mean germination time (day) for four cultivars of after-ripening(AR) and control(C), immature and mature pepper seeds be longing to organic and conventional production systems. Means with different letters in the same line (i.e. cultivars and production systems) are significantly different at 5% level with Duncan's multiple range test(P<0.05). Values are means ± S.D. (n = 4)

Year	Cultivars	Organic				Conventional				CV	LSD
		Immature		Mature		Immature		Mature			
		AR	C	AR	C	AR	C	AR	C		
2015	Surmeli	53±2.5b	42±5.3b	69±4.7a	73±1.9a	79±3.4a	44±4.9b	84±6.7a	82±5.3a	7.34%	13.4
	Kandil D.	79±6.4a	24±5.9c	77±4.4a	77±5.3a	84±5.9a	38±1.2b	72±4.9a	80±2.3 a	7.86%	13.8
	Yaglik	77±1.9bc	53±3.0d	86±6.0ab	87±3.0ab	72±2.8c	52±2.8d	86±2.6ab	93±4.4a	4.66%	10.3
	Corbaci	74±2.6cd	58±2.6f	90±3.5ab	76±4.3cd	95±3.5a	81±1.9bc	64±4.0ef	69±3.8de	4.28%	9.5
2016	Surmeli	79±5.3bc	39±2.7d	90±3.5a	86±1.2ab	86±3.0ab	75±3.0c	81±3.9bc	84±1.6ab	3.75%	8.5
	Kandil D.	88±5.4a	65±1.9d	86±3.8ab	72±6.3cd	85±5.0a-c	72±2.8b-d	77±6.0a-d	79±5.0a-c	6.13%	13.9
	Yaglik	92±2.3ab	73±5.0c	94±3.5a	90±3.5ab	89±3.0ab	80±2.3bc	62±6.0d	89±4.1ab	4.97%	11.5
	Corbaci	86±2.0c	62±2.0e	93±1.9ab	90±1.2a-c	91±3.4a-c	75±2.7d	95±1.9a	87±1.0bc	2.35%	6.0

Table 6

Mean emergence time (day) for four cultivars of after-ripening(AR) and control(C), immature and mature pepper seeds belonging to organic and conventional production systems. Means with different letters in the same line (i.e. cultivars and production systems) are significantly different at 5% level with Duncan's multiple range test($P<0.05$). Values are means ± S.D. (n = 4)

Year	Cultivars	Organic				Conventional				CV	LSD
		Immature		Mature		Immature		Mature			
		AR	C	AR	C	AR	C	AR	C		
2015	Surmeli	7.4±0.29b	7.5±0.13ab	7.4±0.09b	7.5±0.03ab	6.9±0.11c	7.8±0.12a	6.2±0.08d	7.0±0.05c	2.87%	0.30
	Kandil D.	7.8±0.10c	8.4±0.14b	8.7±0.08a	8.0±0.08c	8.0±0.13c	8.5±0.06ab	8.7±0.09ab	8.7±0.14ab	2.54%	0.31
	Yaglik	6.0±0.05e	7.1±0.10c	5.3±0.13f	6.3±0.09d	7.5±0.07b	8.0±0.10a	5.2±0.16f	6.1±0.04de	2.97%	0.28
	Corbaci	7.6±0.17bc	7.7±0.21bc	7.8±0.16b	8.3±0.12a	7.7±0.12bc	7.8±0.03b	7.3±0.08c	7.7±0.17bc	3.69%	0.42
2016	Surmeli	7.2±0.15e	8.7±0.07b	6.9±0.13f	7.5±0.03d	7.9±0.14c	9.2±0.09a	5.9±0.08h	6.5±0.03g	2.60%	0.28
	Kandil D.	8.8±0.09e	10.4±0.13b	9.5±0.10cd	9.9±0.09c	9.6±0.10cd	10.8±0.14a	9.2±0.14d	9.8±0.19c	2.60%	0.37
	Yaglik	6.0±0.12e	7.2±0.04b	5.8±0.05e	6.5±0.08d	6.5±0.07d	7.7±0.05a	5.8±0.11e	6.8±0.11c	2.58%	0.25
	Corbaci	7.3±0.05b	7.9±0.23a	7.3±0.10b	7.3±0.06b	7.3±0.08b	8.1±0.17a	7.1±0.13b	7.4±0.06b	3.03%	0.33

Table 7

Mean weight of 1000 seed (g) for four cultivars of after-ripening(AR) and control(C), immature and mature pepper seeds belonging to organic and conventional production systems. Means with different letters in the same line (i.e. same year, cultivar and production systems) are significantly different at 5% level with Duncan's multiple range test($P<0.05$). Values are means ± S.D. (n = 4).

Year	Cultivars	Organic				Conventional				CV	LSD
		Immature		Mature		Immature		Mature			
		AR	C	AR	C	AR	C	AR	C		
2015	Surmeli	6.4±0.02bc	6.1±0.02e	6.4±0.04bc	6.7±0.04a	6.5±0.01b	6.3±0.01d	6.4±0.04c	6.4±0.02bc	%0.74	0.08
	Kandil D.	6.3±0.02c	5.8±0.01d	6.7±0.06a	6.8±0.08a	6.5±0.02b	5.9±0.03d	6.5±0.01b	6.6±0.03b	%1.10	0.12
	Yaglik	6.5±0.04bc	6.1±0.04e	6.5±0.04b	6.7±0.04a	6.4±0.05cd	6.2±0.02e	6.3±0.03d	6.7±0.01a	%0.95	0.11
	Corbaci	6.6±0.02c	6.1±0.04e	6.7±0.01b	6.9±0.02a	6.4±0.00d	6.2±0.02e	6.9±0.04a	6.8±0.05b	%0.81	0.09
2016	Surmeli	6.8±0.02e	6.5±0.04f	7.0±0.01bc	7.1±0.05a	7.0±0.04ab	7.0±0.01ab	6.9±0.01cd	6.9±0.02de	%0.70	0.08
	Kandil D.	7.4±0.02bc	7.3±0.04c-e	7.1±0.02f	7.2±0.09ef	7.6±0.06a	7.5±0.08ab	7.2±0.02d-f	7.4±0.06 b-d	%1.30	0.17
	Yaglik	7.4±0.04a	7.3±0.03a	7.1±0.03c	7.4±0.04a	7.4±0.05a	7.2±0.03b	7.4±0.02a	7.4±0.03a	%0.80	0.10
	Corbaci	6.8±0.02b	6.8±0.04b	7.0±0.01a	7.0±0.03a	6.8±0.06b	6.8±0.05b	7.1±0.03a	7.0±0.03a	%0.94	0.11

Similar results were obtained from the seedling emergence test. AR treatment improved seedling emergence performance in terms of immature seed lots of both production systems ($P<0.05$). Emergence percentages of organically-produced AR-treated immature seed lots were 70.8% and 86.3%, whereas the control groups were 44.3% and 59.8% in 2015 and 2016. Corresponding findings were seen in conventionally-produced immature seed lots. Accordingly, AR treatment increased the mean emergence percentages (all cultivars) of immature seeds compared to the control group from 53.8% to 82.5% in 2015 and 75.5% to 87.8% in 2016. However, mature seed lots from both production systems were not affected by AR treatment (Table 4).

Evaluation of seed vigor with the mean germination and emergence times gave analogous outcomes to the germination and seedling emergence percentages. AR treatment for immature seed lots shortened the germination and emergence time in both production systems and years (Table 5 and 6). Consequently, seed vigor of immature seed lots was enhanced by AR treatment in organic and conventional production systems. On the other hand, mature seed lots were not affected by AR treatment in both production systems. The mean germination times for AR-treated immature seed lots were 4.9 and 4.2 (days), while it was 5.8 and 5.4 (days) in the control group for the organic system in 2015 and 2016. AR-treated immature seed lots were 4.6 and 4.3 (days), whilst the control group was 6.0 and 5.5 (days) for the conventional system.

There was no statistical difference found between organic and conventional production systems in terms of mean germination and emergence times for all the cultivars in both years (Tables 5 and 6).

The mean weight of 1000 seed (all cultivars) values remained constant for AR-treated mature seed lots from organic and conventional systems (6.6 -7.1 and 6.5-7.2 g respectively) compared to control groups (6.8-7.2 and 6.6 -7.2 g respectively) in 2015-2016 (Table 7). Yet, AR treatment significantly improved the accumulation of dry matter content in immature seed lots for both production systems (C: 6.0, AR: 6.5 for organic and C: 6.2, AR: 6.5g for conventional) in the first year ($P<0.05$). But, this influence was not seen statistically in seed lots from the second year (C: 7.0, AR: 7.1 for organic and C: 7.1, AR: 7.2 g for conventional).

There was no statistical difference found between organic and conventional production systems for the means of the weight of 1000 seeds for all the cultivars in subsequent years as well.

DISCUSSION

Our research study examined the effect of AR treatment for different seed maturity levels from organically- and conventionally-produced pepper seed lots. In addition, the comparison was made with a conventional production system in order to determine whether the organic production system has an effect on quality of pepper seeds.

Each species and cultivars has specific needs for seed germination including certain features of seeds and environmental conditions (Baskin and Baskin, 1998). Our study indicates that similarities were recorded in the responses of all the cultivars to AR treatment, harvest periods, and production systems. This trend is seen in the results obtained by Yanmaz *et al.* (1994), Mavi *et al.* (2010), Kenanoglu *et al.* (2013), Demir *et al.* (2016), and Demir *et al.* (2018) who worked with more than one cultivar to see the influence of different treatments on these cultivars.

Many studies have been done to reveal the effect of after-ripening treatment on many species under conventional production conditions. Seed maturation of these species can continue for some time especially when harvested in the green fruit phase (Barbedo *et al.*, 1994; Dias *et al.*, 2006; Vidigal *et al.*, 2009; Passam *et al.*, 2010; Kalyanrao and Singh, 2014; Kumar *et al.*, 2014; dos Santos *et al.*, 2016). Yet, seed production using organic growing methods may influence seed quality (Yildirim and Demir, 2018). Thus, evaluating the treatment under organic production conditions has to be considered. Our findings indicate that the after-ripening treatment enhanced the germination and seedling emergence percentages and decreased the mean germination and emergence time of immature seed lots of all the cultivars belonging to organic and conventional production systems in both harvest years compared to the control group ($P<0.05$). However, the same effect was not monitored in mature seed lots. It was observed that the application of after-ripening had no effect on the mature pepper seed lots in both production systems. This could be due to the continuous growth of immature embryos reaching the physiological maturity of seed during after-ripening (Weston *et al.*, 1992).

There was no statistical difference found between organic and conventional production systems in terms of germination and seedling emergence tests. Consequently, Duman (2009) reported similar results that differences between seeds produced in organic conditions and conventionally-produced seeds were insignificant according to viability tests.

Seeds achieve their maximum quality some days after the maximum seed dry weight is reached (Welbaum and Bradford, 1988; Demir and Ellis, 1992b). Therefore, maximum seed germination and vigor is observed some days after maximum dry weight in fleshy-fruited species such as pepper. In our study, the data for the mean weight of 1000 seeds states that AR treatment slightly increased the seed weight of all the cultivars from the immature harvest period in both production systems in the first year. But this effect was not seen in the second year. Carvalho and Nakagawa (2000) reported that owing to high moisture content when seeds are stored in fleshy fruits, they are prone to respire more by consuming the endosperm; hence decreasing dry matter content. Conversely, some other reports suggest that considerable enhancement was recorded for a dry matter of seeds through nutrient transfer from fruit to seed during storage in fleshy fruits (Passam *et al.*, 2010; dos Santos *et al.*, 2016). It can also be claimed, and our results indicate that this may be the case, that it is caused by the climatic differences between the vegetation periods (Table 2).

Table 2

Changes in air temperature values during vegetation periods of 2015 and 2016

Month	Average temperature [°C]		Average highest temperature [°C]		Average lowest temperature [°C]		Instant highest temperature °C]		Instant lowest temperature [°C]	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	**2016**
March	9.0	11.3	12.5	15.4	5.5	6.7	20.5	24.9	-1.1	1.8
April	11.9	16.0	16.9	21.2	7.0	10.3	27.2	27.9	1.6	4.5
May	18.5	18.3	23.4	22.4	13.4	13.9	28.4	30.4	9.1	10.0
June	21.3	23.5	25.5	28.4	17.1	18.1	31.1	34.3	12.1	11.2
July	24.9	25.1	30.1	30.0	19.3	19.9	36.9	33.1	15.8	16.3
August	25.9	25.5	30.9	29.9	21.4	21.4	33.5	33.2	17.9	15.8
September	23.4	21.2	27.8	26.4	19.5	16.5	35.9	31.0	17.1	9.5
October	18.2	19.1	21.7	24.8	15.0	12.2	27.3	30.7	12.1	11.0

CONCLUSION

In this study, triple interaction of production systems, harvesting periods and after-ripening treatment on the quality of pepper seed lots was demonstrated. It is suggested that the production of pepper seeds consider these interactions. It was concluded that pepper seed production can be done effectively with the use of organic inputs and there will be no significant losses in the viability and quality characteristics of the seed lots compared to the conventional production systems. AR treatment induced the development of immature seeds to a certain level, but the same effect was not seen in mature seed lots. Therefore, in order to improve the overall quality of pepper seed lots, the harvested fruits should be left for 7 days of after-ripening treatment before seed extraction in both production systems.

ACKNOWLEDGEMENTS

This study was funded by the Ministry of Agriculture and Forestry association with Degirmen Eco-Investment Company–Turkey (Project No: TAGEM/ BBAD/16/A09/P06/01).

REFERENCES

Anonymous, 2005. Implementing Regulation on Principles and Application of Organic Agriculture. No: 25841. Date of access: 21.03.2019.

Anonymous, 2016. State of Organic Seed. http://stateoforganicseed.org/wp-content/uploads/2017/01/SOS-2016-report-FINAL-DIGITAL.pdf. Date of access: 25.03.2019.

Barbedo, C.J., Coelho, A.S., Zanin, A.C.W. and Nakagawa, J. 1993. Influence of age of cucumber fruits on seed quality. Horticultura Brasileira, 11; 18-21.
Barbedo, A.S.C., Zanin, A.C.W., Barbedo, C.J. and Nakagawa, J. 1994. Efeitos da idade e do periodo de repouso pós-colheita dos frutos sobre a qualidade de sementes de berinjela. (Effects of age and post-harvest storage of eggplant fruits on seed quality). Horticultura Brasileira, 12; 18-21.
Baskin, C.C., Baskin, J.M. 1998. Seeds. Ecology, Biogeography, and Evolution of Dormancy and Germination. San Diego, Academic Pres, 666 pp.
Bonina, J. and Cantliffe, D.J. 2004. Seed production and seed sources of organic vegetables. University of Florida, IFAS Extension, USA.
Caixeta, F., von Pinho, V.R.É., Guimarães
R.M., Pereira, P.H.A.R. and Catão, H.C.R.M. 2014. Physiological and biochemical alterations during germination and storage of habanero pepper seeds. African Journal of Agricultural Research, 9(6); 627-635.
Carvalho, N.M. and Nakagawa, J. 2000. *Sementes: ciência, tecnologia e produção*. Seeds science technology and production, 4 ed. Funep, Jaboticabal, 588 p.
Demir, I. and Ellis, R.H. 1992a. Development of pepper (*Capsicum annuum* L.) seed quality. Annual Application Biology, 121; 385-399.
Demir, I. and Ellis, R.H. 1992b. Changes in seed quality during seed development and maturation in tomato. Seed Science Research, 2; 81-87.
Demir, I., Kara, F., Ozden, E. and Hassanzadeh, M. 2016. The effects of seed moisture content and regional storage temperature on the longevity of two onion cultivars. VII International Symposium on Edible Alliaceae, 21-25 May, ActaHorticulturae, 1143-1148, Niğde, Turkey.
Demir, I., Ozden, E., Yıldırım, K.C., Sahin, O. and Van Staden, J. 2018. Priming with smoke-derived karrikinolide enhances germination and transplant quality of immature and mature pepper seed lots. South African Journal of Botany, 115; 264–268.
Demir, I. and Samit, Y. 2001. Seed quality in relation to fruit maturation and seed dry weight during development in tomato. Seed Science and Technology, 29; 453-462.
Desai, B.B., Kotecha, P.M. and Salunkhe, D.K. 1997. Seeds handbook: biology, production, processing and storage. Marcel Dekker Inc., New York, 627p.
Dias, D.C.F.S., Ribeiro, F.P., Dias, L.A.S., Silva, D.H. and Vidigal. D.S. 2006. Tomato seed quality in relation to fruit maturation and post-harvest storage. Seed Science and Technology, 34; 691-699.
Duman, I. 2009. Determination of Yield and Quality Characteristics in Organic Pepper (*Capsicum annuum* L.) Seed Production. Ege University Journal of Agriculture Faculty, 46(3), pp. 155-163.
Edwards, R.L. and Sundstrom, F.L. 1987. After ripening and harvesting effects on tobasco pepper seed germination performance. Hortscience, 22; 473-475.
Ellis, R.H. and Roberts, E.H. 1980. Towards a rational basis for seed testing in seed production. Ed. P.D. Hebblethwaite, Butterworths, London, 605-635.
Groot, S.P.C., van der Wolf, J.M., Jalink, H., Langerak, C.J. and van den Bulk, R.W. 2004. Challenges for the production of high quality organic seeds. Seed Testing International No. 127, p:12-15.
ISTA, 2016. International Rules for Seed Testing. Edition 2016. International Seed Testing Association, Bassersdorf, Switzerland.
Kalyanrao, B.S.T. and Singh, B. 2014. Effect of stage of harvest and post harvest ripening on hybrid seed yield and quality in bottle gourd. Indian Journal of. Horticulture, 71(3); 428-432.
Kenanoğlu, B.B., Demir, I. and Jalink, H. 2013. Chlorophyll fluorescence sorting method to improve quality of Capsicum pepper seed lots produced from different maturity fruits. HortScience, 48(8).
Kumar, V., Tomar, B.S., Singh, B. and Kumar, S. 2014. Effect of post-harvest ripening and drying methods on seed quality and storability in pumpkin cv Pusa Hybrid 1. Indian Journal of Agricultural Sciences, 84 (9); 1144-1148.
Mavi, K., Demir, I. and Matthews, S. 2010. Mean germination time estimates the relative emergence of seed lots of three cucurbit crops under stress conditions. Seed Science and Technology, 38; 14-25.
Nogueira, J.L., da Silva, B.A., Mógor, Á.F., Grzybowski, C.R.S. and Panobianco, M. 2017. Quality of organically produced bell pepper seeds. Journal of Seed Science, 39 (2); 100-105.
Passam, H.C., Theodoropoulou, S., Karanissa, T. and Karapanos, I.C. 2010. Influence of harvest time and after-ripening on the seed quality of eggplant. Scientia Horticulturae, 125; 518-520.
Sanchez, V.M., Sundstrom, F.J., McClure, G.N. and Lang, N.S. 1993. Fruit maturity, storage and postharvest maturation treatments affect bellpepper (*Capsicum annuum* L.) seed quality. Scientia Horticulturae, 54 (3); 191-201.
Santos, H.O., Von Pinho, E.V.R., Von Pinho, I.V., Dutra, S.M.F., Andrade, T. and Guimarães, R.M. 2015. Physiological quality and gene expression during the development of habanero pepper (*Capsicum chinense* Jacquin) seeds. Genet. Mol. Res 14(2):5085-5098.
dos Santos, H.O., Dutra, S.M.F., Raquel, R.W.P., Pires, M.O., von Pinho, É.V.R., da Rosa, S.D.V.F. and de Carvalho, M.L.M. 2016. Physiological quality of habanero pepper (*Capsicum chinense*) seeds based on development and drying process. African Journal of Agricultural Research, 11(12); 1102-1109.
Sinniah, U.R., Ellis, R.H. and John, P. 1998. Irrigation and seed quality development in rapid-cycling brassica: soluble carbohydrates and heat-stable proteins. Annals of Botany, 82; 647–655.

Sripathy, K.V., Hosamani, J., Bellundagi, A. and Prabhakar, I. 2012. Organic Seed Production. Environment & Ecology 30 (1) : 102-105.

Tasbasli, H., Zeytin, B., Aksoy, E. and Konuskan, H.M. 2003. General Principles of Organic Agriculture. T.C. Ministry of Agriculture and Rural Affairs, Research, Planning and Coordination Board, Ankara,118p.

Vidigal, D.S., Dias, D.C.F.S., Dias, L.A.S. and Finger, F.L. 2011. Changes in seed quality during fruit maturation of sweet pepper. Science Agricola, 68(5); 535-539.

Vidigal, D.S., Dias, D.C.F.S., Naveira, D.S.P., Rocha, F.B. and Bhering, M.C. 2006. Qualidade fi siológica de sementes de tomate em função da idade e do armazenamento pós-colheita dos frutos. (Physiological quality of tomato seeds in relation to fruit age and post-harvest storage). Revista Brasileira de Sementes, 28; 87- 93.

Vidigal, D.S., Dias, D.C.F.S., von Pınho, E.R.V. and Dias, L.A.S. 2009. Sweet pepper seed quality and lea-protein activity in relation to fruit maturation and post-harvest storage. Seed Science and Technology, 37; 192-201.

Welbaum, G.E. and Bradford, K.J. 1988: Water relations of seed development and germination in muskmelon (*Cucumis melo* L.). I. Water relations of seed and fruit development. Plant Physiology, 86; 406-411.

Weston, L.A., Geneve, R.L. and Staub, J.E. 1992. Seed dormancy in *Cucumis sativus* var. hardwickii (Royle) Alef. Scientia Horticulturae 50; 35–46.

Yanmaz, R., Demir, I. and Ellialtıoglu, S. 1994. Effect of PEG (Polyethylene Glycol 6000) treatment on the germination and emergence of pepper and eggplant seeds at low temperatures. ISTA/ISHS Symposium, Technological Advances in Variety and Seed Research 31 May-3 June 1994, Wageningen/Netherlands.

Yildirim K.C., Demir I. 2018. Effects of organic and conventional cultivation systems and different harvest periods on seed quality development in pepper (*Capsicum annuum* L.). International Participant Turkey 6th Seed Congress, 10-13 September 2018, Niğde, Proceedings of Congress: 195-201p.

van der Zeijden, D. 2003. The economics of Bejo's organic seed programme. In: Organic Seed Production and Plant Breeding - Strategies, problems and perspectives. Proceedings of ECO-PB 1st International symposium on organic seed production and plant breeding, Berlin, Germany 21-22 November 2002, (Eds. E.T. Lammerts van Bueren and K-P. Wilbois): pp 55-58.