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Effects of hydrogen peroxide on yield and quality parameters of watermelon

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Abstract

The objective was of the study were to examine different concentrations of hydrogen peroxide on some fruit quality parameters and yield of watermelon from individual grafted and ungrafted seedlings. The field trials were performed in four concentrations of hydrogen peroxide (H_2O_2+ $C_2H_4O_2$) and in combination of phosphorus pentoxide (P_2O_5 + K_2O) in 2010 and 2011, consequently. In the experiment 300 ml/100 L and 400 ml/ 100 L H_2O_2+$C_2H_4O_2$ alone, and combination with 60 ml/100 L and 80 ml/100 L P_2O_5 + K_2O were used in flowering, first fruit setting and when fruit size was 10-12 cm in diameter for both years. The results revealed that combination of H_2O_2+$C_2H_4O_2$ and P_2O_5+K_2O foliar applications improved yield significantly both per plant and total in grafted and ungrafted plants in the two years. Besides, such combinations also enriched total soluble solid content in grafted and ungrafted plants. However, those increases appeared more comparable in grafted ones. In addition, fruit thickness, titratable acidity (TA) and flesh colour (a*/b*) were considerably affected by all applications of hydrogen peroxide.

Key words: Brix, fruit quality, hydrogen peroxide, watermelon, yield.

Introduction

Watermelon is widely cultivated in many countries in warm and temperate climatic zones. Turkey produces 4.5 million tons of watermelon annually, which is 4% of world total production. Consumption of watermelon is increased gradually throughout the world because of its content rich in vitamins, minerals and fiber. Watermelon has been recently included in diet program as well.

Use of grafted seedlings has become popular to produce the earliness, higher yields and resistance to diseases [1, 2], since 40-67% of field and greenhouses soils have been contaminated by soilborne pathogens in Turkey [3].

Varieties found to be resistant to pests and diseases are to be preferred to prevent yield losses and reduce amount of pesticides caused by pest control processes in disease-infected soils. However, most varieties from cultivated species cannot be made resistant to diseases/pests through breeding, and the problem can only be solved by grafting cultivated varieties on disease resistant rootstocks. Grafted seedlings have gradually been chosen in watermelon production for controlling soil-caused diseases, producing high and early yield and making the plant resistant to unavailable soil conditions [4-7]. Process of grafted seedlings in water melon growth uses different rootstocks (*Lagenaria siceravia, Benincasa hispida, C. maxima* and *C. moschata* hybrid varieties or inter-special hybrids). Earlier and higher harvests, bigger individual fruits and longer storage after harvesting were observed thanks to grafted watermelon seedlings as positive effects of the process, which is, however, accompanied by a series of complaints such as dissatisfaction of consumers with aroma and taste. One of the most important quality standards, sugar pass from leaves to fruits until fruit maturity or harvesting, when potentially positive effects of external applications as well as optimum care conditions should be taken into account. Ozaki *et al.* [8] reported that hydrogen peroxide applied to melon production could increase soluble sugar content in melon fruits. Considering complaints about low taste and aroma contents in watermelon fruits, we aimed to determine values of taste, aroma, color, scent and yield. Peracetic acid (PAA), the peroxide of acetic acid, is one of the most important organic peroxides with a wide range of antimicrobial activity. PAA was patented in 1950 to treat fruits and vegetables and reduce spoilage from bacteria and fungi destined for processing [9]. Peracetic acid is a mixture of acetic acid (CH_3COOH) and hydrogen peroxide (H_2O_2) in an aqueous solution [10]. H_2O_2 production is thought to be increased by various abiotic stresses and to enhance gene expression of active oxygen scavenging enzymes. In maize, H_2O_2 production was reported to increase in response to chilling stress, and exogenously applied H_2O_2 increased chilling tolerance [11].

Accordingly, efficiencies of some applications were also studied in grafted and ungrafted watermelon plants in the production process.

Material and Methods

The study was carried out in production areas of Horticultural Dept., Agricultural Fac., Ege University in 2010 and 2011, when grafted seedlings of ‘Crimson tide’ cultivar were applied on ‘Jumbo’ rootstock (*Cucurbita maxima* Duch. x *Cucurbita moshata* Poir hybrid) and ungrafted individuals (seeds) were used. Combinations of H_2O_2+$C_2H_4O_2$ and P_2O_5 + K_2O preparations by Timsel Kimya Ltd. were employed in terms of their expected or potential influences on yield and some quality properties in three different periods, namely flowering, first fruit setting and fruit growth to size of 10-12 cm in diameter [8] in both years (Table 1).

Grafted and ungrafted watermelon seedlings were planted in 2.5 m x 1.5 m and 1.40 m x 1.00 m, respectively, and looked after

Table 1. Preparations used in the trial process and their properties.

Category	Active ingredients
Fungicide	Hydrogen peroxide (H_2O_2) 260 g/L+ Acetic acid (CH_3COOH) 90 g/L
Foliar fertilizer	Phosphorus pentoxide (P_2O_5) 6% + Potassium oxide (K_2O) 15%

under Vural *et al.* [12]. The experiment of five applications (p300, p400, p300+60, p400+80 and control) including grafted, ungrafted and unapplied (control) plots was set under randomized block design with 3 replications each (Table 2), following which per plant and total yield values were established and fruits were mature in harvests of the two periods. The first harvest process determined fruit weight, total soluble solid matter (TSS), titratable acidity (TA), flesh fruit colour was measured with the Commision Internationale de I'Eclairage (CIE) system using a CR 300 colorimeter (Minolta, Osaka, Japan) (a*/b*) and firmness (N = Newton) using 11 mm tips. The data was assessed by SPSS (for windows 16.0) statistical packet program.

Table 2. Application properties used in the experiment.

Applications	Application rates (100 L)	
	H_2O_2+$C_2H_4O_2$	P_2O_5 + K_2O
p300	300 ml	-
p400	400 ml	-
p300+60	300 ml	60 ml
p400+80	400 ml	80 ml
Control	Water sprey	-

Results

First of all, findings from the study conducted to improve fruit quality properties and increase yield per unit area were separately examined for the experiment years. Table 3 presents yield values in 2010, the first experiment year.

Significant differences were seen between grafted and ungrafted applications in terms of values of yield from the plots ($p \leq 0.01$) with remarkably high per plant (kg) and total (ha) yields from grafted plots. It follows from the applied doses that their effects on both grafted and ungrafted plots were statistically significant ($p \leq 0.01$). Provided with p400+80, harvested yields of grafted plants were highest per plant and per ha by 25.67 kg/plant and 102,660 kg/ha, respectively. On the other hand, grafted plots supplied with p300+60 gave a yield of 25.95 kg/plant and total yield of 99,780 kg/ha, which are statistically significant in the second group. Of grafted plants in plots, control processes yielded a highest mean fruit weight (9935.09 g). Ungrafted plots harvested highest 7.75 and 7.39 kg/plant from p300+60 and p400+80, whereas total yield values (ha) of the same application were 77,510 and 73,940 kg/ha, respectively. In contrast to grafted plants, ungrafted ones gave highest fruit weights (12.390 and 10.500 g) from p400+80 and p300+60 applications, respectively. Table 4 shows some fruit quality properties of grafted and ungrafted plots as well as yield values.

Table 3. Effects of the applications on properties of yield from grafted and ungrafted seedlings (2010).

	2010	Yield per plant (kg)		Total yield (kg/ha)		Fruit weight (g)	
Ungrafted	Control	6.93	c[x]	69330	c	9303.0	c
	p300	6.93	c	69260	c	8713.0	c
	p400	7.03	c	69590	c	8787.0	c
	p300+60	7.75	a	77510	a	10500.0	b
	p400+80	7.39	b	73940	b	12390.0	a
		$LSD_{0.01}$:0.31		$LSD_{0.01}$:2750.2		$LSD_{0.01}$:703.4	
Grafted	Control	21.22	c	84890	c	9935.0	a
	p300	22.61	bc	90450	bc	9691.0	ab
	p400	22.72	abc	90890	abc	8783.0	c
	p300+60	24.95	ab	99780	ab	8883.0	c
	p400+80	25.67	a	102660	a	9170.0	bc
		$LSD_{0.01}$:2.87		$LSD_{0.01}$:1193.9		$LSD_{0.05}$:677.3	

x: Duncan's multiple range test, **significant p = 0.01, *significant p = 0.05, ns: not significant.

Effect of the applications on TSS values in water melons from plots of grafted plants was statistically significant, with applications of p300+60, p400+80 and p300 being included in the same effect group in terms of TSS varied from 11.40 and 11.67%. Ungrafted plots showed similar variations in TSS with highest value (11.93%) from p400+80 process (Table 4). Effects of the applications above in terms of TA value, which is effective in setting of fruit taste, were insignificant. Individual and combined applications of hydrogen peroxide did not have any impacts on TA values of grafted and ungrafted fruits. However, effects of the applications on fruit firmness from grafted plots were negligible, whereas those of p300 and p400 significantly increased fruit firmness in ungrafted plots ($p \leq 0.01$), which showed that such applications could be effective in regions where fruit firmness proves problematic.

It was clear from effects of the applications on fruit color that especially applications in grafted plant plots did positively influence color value (a*/b*) of the fruit which was significantly higher in all combinations of applications than in control. On the other hand, unlike grafted plant plots, grafted plant harvested highest a*/b* values from control plants. Table 5 presents yield values in the experimental study carried out under the same conditions to determine effects of the applications performed in 2011.

Statistically significant differences of $p \leq 0.01$ were found between the applications per plant and total yield values from grafted plots in the second year of the study. Application of p400+80 gave highest yield per plant (22.60 kg/plant) and that of p300 gave higher yield (21.07 kg/plant) than in control plots. Contrary to the first experiment year, it is interesting to note that lowest fruit weight was harvested from control of grafted plots, with highest total yield values of 100,900 and 96,667 kg/ha in the same applications. Highest fruit weights were obtained (9546.70 and 9516.70 g) by p300 and p400, respectively.

Statistically significant variations ($p \leq 0.01$) were found between the applications in terms of yield values from ungrafted plants. Application of p400+80 in ungrafted watermelon plants appeared as the highest yield, with per plant and total yields being 10.16 kg/plant and 90,060 kg/ha, respectively. In terms of mean fruit weight, plots of ungrafted plants with p400+80 and control presented highest yield values by 8636 and 8640 g, respectively (Table 5). It was observed that large fruits were obtained by p400 and p300+60 in the ungrafted plots in the second experiment year. Table 6 presents fruit quality properties in the second experiment year.

Effects of the applications on TSS values of fruits from grafted and ungrafted plots were statistically significant ($p \leq 0.01$). Highest TSS values (10.52%) were obtained from p400+80 applications in plots of plants grafted on squash rootstock. However, applications of p400 and p400+80 and p300+60 were those with similar effects in TSS values of ungrafted plots. The applications were found not to have a statistically significant impact on TA values in the second experiment year. Effects of the applications in grafted and

Table 4. Effects of the applications on fruit quality properties (2010).

	2010	TSS content (%)		TA (g/100 g)	Fruit flesh firmness (N)		Flesh colour a*/b*	
Ungrafted	Control	9.83	c[x]	0.17	18.64	ab	1.54	a
	p300	10.00	bc	0.16	21.29	a	1.21	bc
	p400	10.43	bc	0.16	21.09	a	1.21	bc
	p300+60	10.87	b	0.16	20.31	a	1.17	c
	p400+80	11.93	a	0.16	17.36	b	1.29	b
		$LSD_{0.01}$:0.92		ns	$LSD_{0.01}$:2.75		$LSD_{0.01}$:0.12	
Grafted	Control	9.53	c	0.17	28.15		1.08	c
	p300	11.40	a	0.17	27.57		1.19	b
	p400	10.73	b	0.17	25.21		1.36	a
	p300+60	11.67	a	0.17	25.60		1.32	a
	p400+80	11.60	a	0.17	26.98		1.26	ab
		$LSD_{0.01}$:0.56		ns	ns		$LSD_{0.01}$:0.104	

x: Duncan's multiple range test, **significant p = 0.01, *significant p = 0.05, ns: not significant.

Table 5. Effects of the applications on yields of grafted ad plants (2011).

	2011	Yield per plant (kg)		Total yield (kg/ha)		Fruit weight (g)	
Ungrafted	Control	9.47	ab[x]	84160	b	8640.0	a
	p300	8.30	d	77330	cd	7286.0	c
	p400	9.12	bc	74930	d	8293.0	ab
	p300+60	8.70	cd	80060	c	8106.0	b
	p400+80	10.16	a	90060	a	8636.0	a
		$LSD_{0.01}$:0.72		$LSD_{0.01}$:3114		$LSD_{0.01}$:510.3	
Grafted	Control	19.30	cd	88880	d	7440.0	b
	p300	21.07	b	96667	b	9546.7	a
	p400	18.70	d	87230	d	9516.7	a
	p300+60	19.93	c	91430	c	8223.0	b
	p400+80	22.60	a	100900	a	8453.0	ab
		$LSD_{0.01}$:1.04		$LSD_{0.01}$:1850.05		$LSD_{0.01}$:1149.8	

x: Duncan's multiple range test, **significant p = 0.01, *significant p = 0.05, ns: not significant.

Table 6. Effects of the applications on grafted and ungrafted fruit quality properties (2011).

	2011	TSS content (%)		TA (g/100 g)	Fruit flesh firmness (N)		Flesh colour a*/b*	
Ungrafted	Control	8.03	b	0.09	22.07	ab	1.06	b
	p300	7.20	c	0.09	19.62	b	1.12	a
	p400	9.70	a	0.08	25.01	a	1.11	a
	p300+60	8.03	b	0.09	20.50	b	1.04	b
	p400+80	8.10	b	0.09	23.84	a	1.08	ab
		$LSD_{0.01}$:0.059		ns	$LSD_{0.05}$:3.24		$LSD_{0.05}$:0.05	
Grafted	Control	7.07	c	0.08	30.90	bc	1.18	a
	p300	8.40	b	0.08	27.86	c	1.01	b
	p400	9.13	b	0.07	32.67	ab	1.03	b
	p300+60	8.80	b	0.07	31.39	bc	1.00	b
	p400+80	10.52	a	0.07	35.22	a	1.18	a
		$LSD_{0.01}$:0.98		ns	$LSD_{0.05}$:3.56		$LSD_{0.01}$:0.07	

x: Duncan's multiple range test, **significant p = 0.01, *significant p = 0.05, ns: not significant.

ungrafted plots on fruit firmness were statistically significant. Applications of p400+80 and p400 on fruits from grafted plots showed highest fruit firmness of 35.22 and 32.67 N and likewise those of p400+80 and p400 in ungrafted plots highest fruit firmness of 23.84 and 25.01 N, respectively.

Differences between the applications in terms of fruit color values (a*/b*) were statistically significant by $p \leq 0.01$ and $p \leq 0.05$ in grafted and ungrafted plots, respectively. P400+80 and control (1.18) showed best fruit color values in grafted plots, whereas highest a*/b* values of 1.12, 1.11 and 1.08 were obtained from p300, p400 and p400+80 applications, respectively.

It is clear from the evidence of both experiment years that applications to grafted and ungrafted watermelon plots tended to increase per plant and total (ha) yields with different rises in fruit weights. Therefore, both grafted and ungrafted plots showed yield increases in per plant and unit area parameters through the applications of p400+80 and p300+60. However, the same applications and those of p300 and p400 influenced performances of grafted and ungrafted plots to various extents based on years to finally increase fruit weights from the plots. Examination of effects of the applications on fruit quality properties indicated that highest TSS values were obtained from p400+80 in grafted and p400 and p400+80 in ungrafted plots in both experiment years. Treatments p300, p400, p300+60 and p400+80 led to increases in fruit firmness in various degrees based on years of experiment in grafted and ungrafted plots. Although p400 and p400+80 applications were found to be effective in terms of fruit colour (a*/b*) in grafted plots in particular, such effectiveness cannot be said to definitely exist. Likewise, any positive effects of the applications on TA content have yet to be found.

Discussion

Significantly higher yield values were obtained from grafted plant plots per plant and per ha yields in the two year study to improve quality properties of watermelons grafted especially considering complaints from consumers. It is reported that studies by various researchers showed similar findings as well [13-15]. The concerned studies report that use of grafted seedlings leads to early flowering, enlarged leaf area, higher solid matter in fruit [13], increased absorption of nutrients through soil [16] and greater tolerance of plant to salt [17] as well as to their resistance to extreme temperatures [18, 19] and efficient benefit from nutrition in the soil thanks to strengthened root system. Moreover, increases were reported in phosphorus, nitrogen, magnesium and calcium intakes thanks to grafting [20-24]. On the other hand, although Yetişir and Sarı [13] and Roberts *et al.* [14] report that heavier water melons grafted on squash rootstock have been obtained, the present study did not show any statistically significant differences in fruit weight from grafted plants, which is believed to be attributable to number of fruits per plant since high number of fruits from grafted plants is thought to reduce mean fruit weight. In contrast, applications above in grafted and ungrafted watermelon plots in the two years are assumed to have increased per plant and yield per hectare. Therefore, applications of p400+80 and p300+60 to both grafted and ungrafted plants increased yields per plant and per hectare as well. It was found that the applications to grafted plots in particular harvested yields ranging from 91,430 to 102,660 kg/ha, which varied between 84,890 and 88,810 kg/ha. However, the treatments applied to ungrafted plants harvested yields of 73,940-90,060 kg/ha whereas controls gave yields of 69,330-84,160 kg/ha, respectively. The evidence suggested that the applications in the study harvested significant increases of yield. Indeed, Ozaki *et al.* [8] reported that similar applications of hydrogen peroxide to melon production harvested significant improvements in yield, with the consequences consistent with those from the present study.

Applications of hydrogen peroxide and additional combinations of nutrients were found to increase TSS values in fruits in the two years. It is therefore interesting to note that effects are considerable in applications of p400+80 (11.93%) to grafted plots in particular and those of p400 and p400+80 (10.52 and 11.60%, respectively) to ungrafted plants. In fact, applications in grafted plants improved TSS values as compared to control in both years. Similarly, Ozaki *et al.* [8] reported that applications of hydrogen peroxide increased TSS values in melons significantly with outcomes consistent with those of the present study, which can be interpreted as TSS values associated with taste percentages in watermelons as Vural *et al.* [12] reported. On the contrary, the applications were not found to be statistically significant in TA, which is another parameter to influence taste in watermelons in two years.

Values of fruit firmness were found higher in grafted watermelons than those in ungrafted plants. Indeed, Yetişir and Sarı [13] and Roberts *et al.* [14] reported that firmer fruits appeared due to increased fibering related to grafting on squash rootstock with findings consistent with those from the study concerned. Applications of p400+80 and p400 in grafted plots and all treatments (p300, p400 and p400+80) in ungrafted plants tended to increase fruit firmness. Considering that fruit firmness is of great importance and providing added value in marketing, positive effects of the applications should be taken into account as well.

Fruit color values (a*/b*) showed a similarity in grafted and ungrafted plots in both years. Both p400+80 applied plots and control yielded high a*/b* values and p400+80, p300 and p400-applied ungrafted plots showed high a*/b* values. Thus, it seems not possible to clearly mention effects of the applications on fruit color (a*/b*).

It is reported that grafting decreases amount of TSS, increases yellow stripes in consumed parts and causes peel thickness, fiber density and quality of consumption as well as fruit firmness [6, 25-27] while other researchers reported positive effects of grafting on fruits to conclude that fruit firmness, brix and lycopene content increased. Salam *et al.* [28], Davis and Perkins-Veazie [29]; Yetişir and Sarı [13] found that brix, fruit firmness, peel thickness and shape of fruit depend on the rootstock used. Atasayar [30] discovered that brix values decreased and fruit flesh changed in taste and aroma in samples of watermelons grafted on squash (*L. siceraria*) rootstocks with brix and taste values increasing in *C.maxima* x *C. moschata* hybrids. Likewise, it was reported that values of TSS of rootstocks from *C.maxima* x *C. moschata* hybrids increased [16] and grafting increased fruit size [16, 28].

Conclusions

Conducted to improve quality properties of fruits from watermelon plants grafted on squash rootstock, applications of p400+80 positively influenced yield TSS values and fruit firmness especially in grafted plots. The increase in yield and TSS values must be a significant evidence for watermelon-producing nations, mainly for Turkey, since the higher fruit TSS values and firmness is the higher income per hectare. In addition, high content of TSS from p400+80 treatment has caused complaints from consumers about fruits of grafted watermelon plants to be somewhat eliminated.

It would be of great use to determine effects of rootstocks on the present study considering conduction of similar studies on different watermelon varieties and rootstocks.

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