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Full Length Research Paper

The effects of pruning and fertilization applications on yield and some fruit characteristics of pistachio nuts (*Pistacia vera L.)*

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This research was carried out on "Kırmızı" pistachio nut cultivar in order to determine the effects of different pruning and fertilization treatments on yield, and also some nut characteristics in pistachio (*Pistacia vera* L.). Nitrogen and phosphorus were applied using ammonium sulphate and TSP at the rate of 0 (Control-N_0), 800 (N_1), 1000 (N_2) and 1200 (N_3) g tree^{-1}, and 0 (Control-P_0), 200 (P_1), 400 (P_2) and 600 (P_3) g tree^{-1}. The trees were pruned by 2 different methods such as traditional pruning that is commonly applied in this region (PR_1), and cutting of apical flower buds besides traditional pruning (PR_2). At each harvest season, yield per tree, nut weight, nut splitting rate, empty nut rate and flower bud abscission rate were recorded. Differences in yield values obtained from trees, which were treated with different fertilization and pruning treatments were not significant. The interactive effects of fertilization doses and pruning treatments were significant on nut weight, nut splitting, and empty nut rates in all years, and on fruit bud abscission ratio only in the 'on' year. In relation to yield and all other characteristics, higher values were obtained from applied PR_2 trees, as well as the trees on which nitrogen and phosphorus fertilization was treated.

Key words: Pruning, fertilization, yield, nut size, nut splitting, empty nut, flower bud abscission, pistachio.

INTRODUCTION

The irregular yield caused by alternate bearing and low yield are among the major issues that are faced in pistachio growing. As a consequence of the inadequate and unbalanced nutrition of plant, the plant cannot develop satisfactorily and some problems like low yield and insufficient nut quality are observed. In the struggle for obtaining the nutrient that takes place between the fruit, the fruit bud and the leaves, the fruit takes the lead. Thus, the buds and leaves cannot nourish themselves sufficiently and drop. Consequently, that becames the main source for alternate bearing (Crane and Nelson, 1971). Apart from that, the basic cultural managements like fertilization, pruning and irrigation in pistachio orchards are not performed regularly and that becomes another important factor in low yield. In numerous studies, it was indicated that fertilization and irrigation practices have a significant role in acquiring high, regular and quality yield. Additionally, these practices reduce the severeness of alternate bearing (Kanber et al., 1993; Weinbaum et al., 1994; Rosecrance et al., 1998; Zeng et al., 1998; Vemmos, 1999; Goldhamer and Beede, 2004; Ünlü et al., 2005; Apaydın, 2006; Güneş et al., 2010). However, there is a limited numbers of the studies that focused on the effects of pruning on yield and fruit quality.

The effects of pruning on the tree's physiological equilibrium have been defined implicitly. In pruning practices, the main purpose is to provide early bearing of fruiting of trees and to keep their productivity period for a long time. In the other words, pruning develops and maintains physiological equilibrium of trees in the shortest time. Also, having regular annual yield by preventing or decreasing periodicity is one of the important advantages of pruning (Hill, 1986; Westwood, 1993a, b). In several

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researches, it was asserted that apart from alternate bearing characteristic of the species, its strong apical dominance should also be taken into consideration in the pruning of pistachio trees. It was also indicated that the pruned trees grow more strongly and regularly, the severeness of apical dominance and periodicity are decreased, and the yield fluctuations between the years are prevented (Ferguson et al., 1995; Beede and Ferguson, 2005). In the research performed by Arpacı et al. (1995), the effects of heavy pruning, which involved the removal of the two thirds of vegetative shoots and one third of mixed branches, and light pruning, which involved the removal of one third of all branches, on yield were compared with the traditional method that comprises only the cutting out of dead branches. The different pruning methods had no significant effect on yield. However, heavy pruning provided the lowest kernel/shell ratio, the heaviest 100 nut weight and the highest split percentage. Both experimental pruning techniques gave better shoot growth than the traditional method. Ferguson et al. (1995) investigated the effects of mechanical pruning treatments (hedding, topping, hedding/topping and hand-pruning) on yield, nut quality, alternate bearing and growth of Kerman cultivar. Researchers indicated that the yields of hedged/topped and topped trees were equal to those of control trees, while hedged trees produced significantly less. The incidence of nonsplit shells and blank nuts was not affected by pruning. Nuts weighed more in all years for hedged/topped and topped trees than for the others. Hedged/topped and topped trees had significantly less alternation in annual girth growth than control or hedged trees. Thus, severe annual hand-pruning could be used to prevent or minimize alternate bearing of pistachios. Boler (1998) also investigated the effect of fruit bud thinning and pruning on biennial bearing and nut quality of the pistachio cultivars, 'Kırmızı, and 'Keten Gömlek'. Fruit-bud thinning was carried out during two years when dormant fruit buds were removed from the branches in March to leave 1 or 2 fruit buds on each shoot. The pruning experiment was conducted during three years when the trees were topped and hedged with shoots being headed back to 40 - 50 cm. Thinning improved yield and nut quality. Nut size was also larger on treated trees, with a higher proportion of split nuts than on untreated trees. Pruning produced similar effects on yield, nut size and proportion of split nuts as fruit bud thinning. Pruning also affected shoot growth compared to untreated trees; annual shoots were thicker and new shoots emerged from the centre of the canopy. Pruned trees had larger leaves of a darker green colour than unpruned trees. Similarly, Küden et al. (1998) also reported that in pistachios, autumn (August) and winter (November) pruning induced poor shoot development. However, fruit drop was observed on poorly developing one-year-old shoots, which resulted in a high rate of fruit set. This self-thinning decreased the rate of alternate bearing and a regular crop was obtained the following year. Additionally, splitting rate and fruit size were increased. Autumn pruning in November caused increased shoot development and a decrease in fruit bud drop. The preventive and regulatory effect of pruning on periodicity was also defined in some almond cultivars. Regular pruning increased the yield in the year when yield was low to a certain extent, and also increased the nut size (Kruger et al., 1998; Arquero et al., 2006; Lovera et al., 2006).

The single effect of each cultural management like pruning, irrigation and fertilization in pistachio orchards was defined in previous studies. However, the collaborative and/or reciprocal effects of these practices have not been explicated clearly. By taking this perspective into consideration, this research seeks to define the reciprocal effects of different nitrogen and phosphorus fertilization doses and pruning applications on yield of some fruit characteristics in the widely cultivated "Kırmızı" cultivar, which shows genetically strong alternate bearing.

MATERIALS AND METHODS

This research was conducted in a commercial pistachio orchard located in the Fırat valley in the district of Nizip of the province of Gaziantep where pistachio nut growing is very common. 'Kırmızı' pistachio nut cultivar trees that are 35 to 40 years old and grafted on *P. vera* L. were used as plant material. In the research, which was performed according to completely randomized design with three repetitions, nitrogen and phosporus fertilization and pruning applications were implemented on all parcels of land during three consequent years. The 1^{st} and 3^{rd} years of the study were for bearing (heavy crop year, 'on' year) and the 2^{nd} year was for non-bearing (subsequent light cropping year, 'off' year). During the experimental period (3 years), irrigation was done as flooding began in the second half of July, and continued until harvest time with the intervals of 20 days.

Fertilizer applications

Nitrogen was applied in March and April at two times as ammonium sulfate at 0 (Control, N_0), 800 (N_1), 1000 (N_2) and 1200 (N_3) g.tree^{-1} doses, while phosphorus fertilization was applied at doses of 0 (Control, P_0), 200 (P_1), 400 (P_2) and 600 (P_3) g.tree^{-1} only once in February, in 25 to 30 cm in depth of soil only by using triple super phosphate. While nitrogen was applied by spreading it on the soil surface, phosphorus was treated as a basal dressing.

Pruning applications

Two different types of pruning applications were implemented on the trees. In the first application, all trees were pruned by being based on the traditional pruning technique (Pruning 1, PR_1), which is common in the region. Traditional pruning was performed during the winter dormant period (December) by paying attention in protecting and maintaining the central leader, and by cutting out the old and weakly developed 3 to 4 years old branches and by thinning the dead branches. In the second pruning application, cutting of apical flower buds was also performed besides traditional pruning (Pruning 2, PR^2).

Nut characteristics

In this research, yield per tree for each fertilizer and pruning application was determined by weighing of red, fresh and unshelled

Table 1. The effects of different nitrogen, phosphorus and pruning applications on yield (fresh, red, unshelled kg.tree^{-1}) of pistachio nut trees.

[1]Fertilizer applications		1st year ('ON')		2nd year ('OFF')		3rd year ('ON')	
Nitrogen	Phosphorus	[2]PR_1	[2]PR_2	PR_1	PR_2	PR_1	PR_2
N_0	P_0	[3]2.10	14.70	1.50	10.23	3.91	30.60
	P_1	9.18	7.33	4.93	5.73	11.89	9.87
	P_2	9.77	10.80	6.35	7.17	11.03	12.67
	P_3	12.75	6.43	8.14	5.50	16.40	7.53
N_1	P_0	6.28	3.57	4.42	2.73	7.58	4.83
	P_1	3.33	14.18	2.73	9.28	1.99	15.55
	P_2	7.37	8.13	5.27	5.97	8.75	8.55
	P_3	11.63	5.20	7.98	3.75	15.23	7.03
N_2	P_0	3.60	12.02	2.77	8.63	5.40	14.73
	P_1	6.22	1.65	4.85	1.65	5.75	3.27
	P_2	9.85	7.88	7.47	5.37	12.60	9.70
	P_3	5.58	8.13	4.02	6.03	6.08	9.28
N_3	P_0	10.13	8.45	6.78	6.62	13.92	11.83
	P_1	7.58	8.52	5.83	5.92	12.15	11.97
	P_2	4.00	8.42	3.57	5.48	6.63	12.08
	P_3	11.45	4.08	7.32	3.78	15.68	7.98

[1]Nitrogen doses (g.tree^{-1}): 0 (N_0, control), 800 (N_1), 1000 (N_2), 1200 (N_3); Phosphorus doses (g.tree^{-1}): 0 (P_0, control), 200 (P_1), 400 (P_2), 600 (P_3); [2] Pruning applications: PR_1 (Traditional pruning); PR_2 (Traditional pruning+cutting of apical flower buds); [3] Non significant at $p \leq 0,05$ error level.

nuts. Nut weight was measured based on 100 in-shell nuts. The splitting rate and empty nut rate were measured in 100 nuts with three replicates as percentages.

Flower bud abscission

For this parameter, all flower buds on shoots marked at the beginning of the vegetation period on four directions of each tree were counted at the beginning of June and also in November. Flower bud abscission was calculated by subtracting flower bud number in November from that of June. Counted flower bud number changed based on the shoots and years.

Statistical analysis

The research results were evaluated according to a completely randomized design with three factors in each year, separately. Nitrogen, phosphorus doses and pruning applications were taken into consideration as variables for nut characteristics and flower bud abscission criteria. Means were compared by Duncan's Multiple Range Test ($p \leq 0.05$). Arcsin transformations were used for all percentage data.

RESULTS

Yield

For all 3 years, there was no significant effect of fertilizer and pruning applications on yield ($p \leq 0.05$). When both fertilizing and pruning applications are evaluated separately, it is observed that the yield decreased in the second year to a certain extent, and increased in the subsequent year. In the traditionally pruned trees (PR_1) during the 1st and 2nd years of the research, the lowest (2.1 and 1.5 kg, respectively) and highest (12.75 and 8.14 kg, respectively) yields were observed at control trees (N_0-P_0) and N_0-P_3 treatments, respectively. During the same years, the lowest yields in PR_2 pruning (1.65 kg) were on N_2-P_1 application. Despite the fact that it changed according to fertilizer doses in almost all years, it was observed that the yield in trees on which PR_2 pruning application was implemented was partially higher (Table 1).

Nut weight

For the 1st and 2nd years of the research, the interactions among nitrogen x phosphorus x pruning, and for the 3rd year, the interactions among nitrogen x phosphorus and nitrogen x pruning were observed to be separately significant ($p \leq 0.05$). The highest nut weights during the 1st and 2nd years (89.33 g and 93.50 g respectively) were defined in N_2-P_1-PR_2 combination. The highest nut weights in the 3rd year were detected in N_1-P_2 (89.42 g), and N_0-PR_2 (87.40 g) applications. The lowest fruit weights

Table 2. The effects of different nitrogen, phosphorus and pruning applications on nut weight (g) of pistachio nut trees.

[1]N	[1]P	[2]PR	1st year ('ON')		2nd year ('OFF')		3rd year ('ON')			
							N	P		
N_0	P_0	PR_1	[3]82.93	a, ab, a	[3]90.43[4]	a, a, a	N_0	P_0	[4]82.57	a, a
		PR_2	74.80	b, b, b	82.73	a, a, a		P_1	83.63	a, a
	P_1	PR_1	81.27	a, a, a	88.60	a, a, a		P_2	76.97	a, b
		PR_2	77.60	a, b, ab	84.37	a, ab, a		P_3	83.87	a, a
	P_2	PR_1	67.40	b, c, c	73.50	b, b, b	N_1	P_0	80.07	b, a
		PR_2	81.53	a, a, a	90.57	a, a, a		P_1	81.53	b, a
	P_3	PR_1	74.47	b, b, b	84.50	a, a, ab		P_2	89.42	a, a
		PR_2	81.53	a, ab, a	92.00	a, a, a		P_3	82.37	b, ab
N_1	P_0	PR_1	79.07	a, b, b	82.87	a, ab, a	N_2	P_0	83.48	a, a
		PR_2	80.87	a, a, a	83.83	a, a, a		P_1	83.72	a, a
	P_1	PR_1	84.40	a, a, a	87.67	a, a, a		P_2	81.13	ab, b
		PR_2	74.03	b, b, b	79.60	a, b, a		P_3	75.38	b, b
	P_2	PR_1	86.47	a, a, a	88.93	a, a, a	N_3	P_0	84.00	a, a
		PR_2	82.93	a, a, a	88.07	a, a, a		P_1	77.17	a, a
	P_3	PR_1	76.70	b, b, b	80.80	a, a, a		P_2	81.00	a, b
		PR_2	83.40	a, a, a	88.90	a, ab, a		P_3	78.98	a, ab
N_2	P_0	PR_1	87.57	a, a, a	77.43	b, b, a	LSD		6.911	
		PR_2	81.60	b, a, b	90.53	a, a, a				
	P_1	PR_1	85.37	a, a, a	81.83	b, a, a				
		PR_2	89.33	a, a, a	93.50	a, a, a	N	PR		
	P_2	PR_1	77.83	a, b, b	81.57	a, ab, a	N_0	PR_1	[5]76.12	b, b
		PR_2	82.40	a, a, b	86.73	a, a, a		PR_2	87.40	a, a
	P_3	PR_1	75.73	a, b, b	80.53	a, a, a	N_1	PR_1	82.53	a, a
		PR_2	80.00	a, ab, b	88.87	a, ab, a		PR_2	84.17	a, ab
N_3	P_0	PR_1	84.53	a, a, a	92.13	a, a, a	N_2	PR_1	78.60	a, ab
		PR_2	80.07	a, a, ab	83.27	a, a, ab		PR_2	83.26	a, ab
	P_1	PR_1	75.80	a, b, b	78.67	a, a, b	N_3	PR_1	80.05	a, ab
		PR_2	77.47	a, b, b	84.37	a, ab, ab		PR_2	80.53	a, b
	P_2	PR_1	84.60	a, a, a	90.23	a, a, ab	LSD		4.887	
		PR_2	84.20	a, a, a	91.70	a, a, a				
	P_3	PR_1	82.63	a, a, a	89.63	a, a, ab				
		PR_2	77.87	a, b, b	78.87	a, b, b				
	LSD		4.974		11.00					

[1] Nitrogen doses (g.tree^{-1}): 0 (N_0, control), 800 (N_1), 1000 (N_2), 1200 (N_3); Phosphorus doses (g.tree^{-1}): 0 (P_0, control), 200 (P_1), 400 (P_2), 600 (P_3); [2] Pruning applications: PR_1 (Traditional pruning); PR_2 (Traditional pruning+cutting of apical flower buds), [3] First letter: Differences between pruning applications (PR_1, and PR_2) for each N-P fertilizer doses; Second letter: Differences between N fertilizer doses (N_0, N_1, N_2, and N_3) for each P fertilizer dose–pruning application; Third letter: Differences between P fertilizer doses (P_0, P_1, P_2, and P_3) for each N fertilizer dose-pruning application ($p \leq 0{,}05$), [4] First letter: Differences between P fertilizer doses (P_0, P_1, P_2, and P_3) for each N fertilizer dose; Second letter: Differences between N fertilizer doses (N_0, N_1, N_2, and N_3) for each P fertilizer dose ($p \leq 0{,}05$), [5]First letter: Differences between pruning applications (PR_1, and PR_2) for each N fertilizer dose; Second letter: Differences between N fertilizer doses (N_0, N_1, N_2, and N_3) for each pruning application ($p \leq 0.05$).

were in N_0-P_2-PR_1 in the 1st and 2nd years (67.40 and 73.50 g, respectively) and in N_2-P_3 (75.38 g) and N_0-PR_1 (76.12 g) in the 3rd year (Table 2).

The significant combinations from the perspective of the differences among pruning applications in each nitrogen-phosphorus fertilizer level were N_0-P_0, N_0-P_2, N_0-P_3, N_1-P_1, N_1-P_3 and N_2-P_0 in the 1st year and N_0-P_2, N_2-P_0 and N_2-P_1 in the 2nd year. In both years, the nut sizes of the trees on which PR_2 application was implemented were bigger (except N_0-P_0 and N_1-P_1 applications in the 1st year). In each phosphorus-pruning application, in relation to the differences between the nitrogen fertilizer doses, these doses had a significant statistical effect on nut weights in all applications except P_2-PR_2, during the research's 1st year. The observed significant combinations in the 2nd year were P_0-PR_1, P_1-PR_2, P_2-PR_1 and P_3-PR_2. Despite the fact that the nitrogen dose changes according to the combinations that provide the highest nut weight, it was detected that the increasing doses of nitrogen generally had a more positive effect. The phosphorus fertilizer doses in each nitrogen-pruning application affected the nut weight in all combinations on a significant statistical level in the 1st year. In most of the combinations, high nut weights on P_2 and P_3 phosphorus doses were obtained. In the 2nd year, only during N_0-PR_1, N_3-PR_1, N_3-PR_2 applications, P_0, P_1 and P_2 phosphorus fertilizer doses affected the nut weight on a statistically significant level, respectively. In the 3rd year, in relation to nitrogen x phosphorus interaction, P_2 only in N_1 dose, P_0 and P_1 applications in N_2 dose and N_1 in P_2 dose, and N_0, N_1, N_3 applications on P_3 dose are important. In relation to nitrogen x pruning interaction, a statistically significant level of high nut weights was detected in PR_2 pruning of the trees on which nitrogen fertilizers were not used (N_0). Except N_0 in the traditionally pruned trees (PR_1) and N_3 in the PR_2 applied trees, the nut weights are significantly high in all nitrogen doses (Table 2).

Split nut ratio (%)

The nitrogen x phosphorus x pruning interactions on split nut ratio was statistically important for all years ($p \leq 0.05$). The highest split nut ratios were observed in N_1-P_0-PR_2 applications in the 1st and 3rd years (70.33 and 64.67%, respectively) and in N_2-P_3-PR_2 applications in the 2nd year (83.33%). The lowest split nut ratios were detected in N_2-P_2-PR_1 applications in the 1st and 2nd years (22.67 and 23.67%, respectively) and in N_0-P_0-PR_2, N_0-P_2-PR_2, N_3-P_3-PR_2 applications in the 3rd year (23.00%) (Table 3).

The statistically significant combinations in the research's three years from the perspective of the differences between prunings on each nitrogen-phosphorus levels were N_0-P_1, N_1-P_0, N_1-P_2, N_2-P_1, N_2-P_2, N_2-P_3 and N_3-P_0. In all combinations, the split nut ratios of the PR_2 applied trees were higher. In each phosphorus-pruning application, in relation to the differences between nitrogen fertilizer doses in all years of the research, the split nut ratios were relatively high N_1, N_2, N_3 in P_0-PR_2 application, N_0, N_2, N_3 in P_1-PR_2 application, N_3 in P_2-PR_1 application, N_1, N_2 in P_2-PR_2 application and N_2 dose in P_3-PR_2 application. Additionally, the differences between the N_1, N_2, N_3 doses in P_0-PR_1 application in the 2nd year were also important. In relation to differences among phosphorus doses in each nitrogen-pruning application, the splitting ratios in all years of the research were significantly high in P_1 and P_3 doses of N_0-PR_2, P_0 and P_2 doses of N_1-PR_2, and P_0 dose of N_3-PR_2 applications. In addition, P_0 dose in N_0-PR_1 combination in the 1st year, P_0, P_1 and P_3 doses in N_2-PR_1 in the 2nd year and in N_2-PR_2 in the 3rd year increased the splitting ratio significantly (Table 3).

Empty fruit ratio (%)

Nitrogen x phosphorus and nitrogen x pruning in the 1st year, and nitrogen x pruning interactions in the 3rd year were individually significant. The differences between phosphorus doses and pruning treatments in the 2nd year were observed to be significant,separately ($p \leq 0.05$). The highest empty nut ratios were detected in N_3-P_3 (10.00%) and N_3-PR_2 (10.67%); in P_1 (5.83%) and PR_2 (5.30%); and in N_3-PR_2 (6.75%) in the 1st, 2nd and 3rd years, respectively. The lowest empty nut ratios were observed as N_1-P_0 (1.00%) and N_2-PR_2 (3.50%) in the 1st year; as P_2 (3.46%) and PR_1 (3.67%) in the 2nd year and as N_2-PR_1 (6.75%) treatments in the 3rd year (Table 4).

In the 1st year of the research, in relation to the nitrogen x phosphorus interaction, the empty nut ratios were significantly higher in P_2 and P_3 in N_0, and in P_1, P_2, P_3 doses in N_2 application. For phosphorus doses, the empty nut ratios were significantly high in all nitrogen doses except N_2 in P_0 and P_2, and N_1 and N_2 in P_3 applications. In terms of nitrogen x pruning interaction, the empty nut ratios in apical flower buds cutted trees (PR_2) were significantly high in N_3 in the 1st year (10.67%), in N_2 and N_3 nitrogen doses in the 3rd year (6.50 and 6.75% respectively). In the 2nd year, a significantlly high empty nut ratio was detected in P_1 phosphorus dose (5.83%) and PR_2 pruning applications (5.30%) (Table 4).

Flower bud abscission ratio (%)

For the 1st year of the research, nitrogen x phosphorus interaction was important. For 2nd and 3rd years, there was no significant effect of fertilizer and pruning applications on flower bud abscission ratio ($p \leq 0.05$). The highest fruit bud abscission ratios were inspected in N_1-PR_2 (47.42%), N_0-P_0-PR_2 (86.70%) and N_1-P_0-PR_2 (38.74%) applications in the 1st, 2nd, and 3rd years, respectively. The lowest fruit bud abscission ratios were observed in N_0-PR_1 (14.33%) in the 1st year, and in N_0-P_0-PR_1 (12.50 and 11.11%, respectively) in the 2nd and 3rd years (Table 5).

In the trees on which nitrogen fertilizers on N_0 and N_1 doses were applied, significantly high fruit bud abscission ratios were observed in PR_2 application. The fruit bud abscission ratios were significantly high in all nitrogen doses except N_0 in traditionally pruned trees (PR_1) and N_2 in apical flower buds cutted trees (PR_2) (Table 5).

DISCUSSION

Despite the fact that no significant statistical difference

Table 3. The effects of different nitrogen, phosphorus and pruning applications on splitted nut ratio (%).

[1]N	[1]P	[2]PR	1st year ('ON')		2nd year ('OFF')		3rd year ('ON')	
N_0	P_0	PR_1	[3]28.00	a, a, a	[3]30.67	a, b, a	[3]27.33	a, a, a
		PR_2	23.67	a, b, bc	25.00	a, b, c	23.00	a, b, b
	P_1	PR_1	29.33	b, a, a	31.67	b, a, a	28.00	b, a, a
		PR_2	53.67	a, ab, a	61.00	a, ab, a	48.00	a, ab, a
	P_2	PR_1	34.67	a, b, a	38.33	a, b, a	33.00	a, b, a
		PR_2	18.00	a, c, c	29.67	a, b, bc	23.00	a, b, b
	P_3	PR_1	25.67	a, a, a	26.00	a, a, a	24.00	a, a, a
		PR_2	42.00	a, bc, ab	47.67	a, b, ab	39.67	a, b, ab
N_1	P_0	PR_1	44.00	b, a, a	49.67	b, ab, a	41.33	b, a, a
		PR_2	70.33	a, a, a	76.00	a, a, a	64.67	a, a, a
	P_1	PR_1	36.00	a, a, a	39.33	a, a, a	34.00	a, a, a
		PR_2	39.67	a, bc, c	44.00	a, bc, c	37.33	a, bc, c
	P_2	PR_1	25.67	b, b, a	27.33	b, b, a	24.67	b, b, a
		PR_2	61.00	a, a, ab	67.67	a, a, ab	56.67	a, a, ab
	P_3	PR_1	31.00	a, a, a	34.00	a, a, a	29.67	a, a, a
		PR_2	44.00	a, b, bc	49.67	a, b, bc	41.33	a, b, bc
N_2	P_0	PR_1	45.67	a, a, a	54.33	a, a, a	42.67	a, a, a
		PR_2	51.67	a, a, a	59.00	a, a, b	48.00	a, a, b
	P_1	PR_1	32.67	b, a, ab	36.33	b, a, ab	31.33	b, a, a
		PR_2	68.00	a, a, a	76.67	a, a, ab	63.00	a, a, ab
	P_2	PR_1	22.67	b, b, b	23.67	b, b, b	25.67	b, b, a
		PR_2	62.67	a, a, a	72.33	a, a, ab	58.00	a, a, ab
	P_3	PR_1	36.67	b, a, ab	40.33	b, a, ab	34.67	b, a, a
		PR_2	67.67	a, a, a	83.33	a, a, a	68.00	a, a, a
N_3	P_0	PR_1	36.67	b, a, a	40.67	b, ab, a	34.67	b, a, a
		PR_2	62.67	a, a, a	72.33	a, a, a	58.00	a, a, a
	P_1	PR_1	36.67	a, a, a	40.67	a, a, a	34.67	a, a, a
		PR_2	31.33	a, c, b	34.00	a, c b	29.67	a, c, b
	P_2	PR_1	53.33	a, a, a	61.00	a, a, a	49.67	a, a, a
		PR_2	40.33	a, b, b	45.33	a, a, b	38.00	a, b, b
	P_3	PR_1	36.67	a, a, a	40.67	a, a, a	36.33	a, a, a
		PR_2	23.67	a, c, b	25.00	a, c, b	23.00	a, c, b
	LSD		18.35		20.84		16.48	

[1] Nitrogen doses ($g.tree^{-1}$): 0 (N_0, control), 800 (N_1), 1000 (N_2), 1200 (N_3); Phosphorus doses ($g.tree^{-1}$): 0 (P_0, control), 200 (P_1), 400 (P_2), 600 (P_3), [2] Pruning applications: PR_1 (Traditional pruning); PR_2 (Traditional pruning+cutting of apical flower buds), [3] First letter: Differences between pruning applications (PR_1, and PR_2) for each N-P fertilizer doses; Second letter: Differences between N fertilizer doses (N_0, N_1, N_2, and N_3) for each P fertilizer dose–pruning application; Third letter: Differences between P fertilizer doses (P_0, P_1, P_2, and P_3) for each N fertilizer dose-pruning application ($p \leq 0.05$).

was examined, the yield values of the pruning and fertilization applications in the 2nd year of the research were lower than in the first and the 3rd year (Table 1). This situation could result from the common periodicity in pistachio. Apart from that, the yield values of the applications with low doses of nitrogen were the lowest for all years of the research. Moreover, a similar situation was observed in high phosphorus-low nitrogen doses. This situation corresponds with the findings of the researchers who indicate that fertilization and especially nitrogen have a positive effect on yield in pistachio (Weinbaum et al., 1995; Rosecrane et al., 1998; Ünlü et al., 2005; Güneş et al., 2010).

In our research, cutting of apical flower buds provided a high yield in nitrogen-phosphorus combinations in all years (Table 1). As an outcome of the apical dominance that was observed in pistachio, the terminal bud of the highest shoot keeps the axillary buds under pressure by obstructing the development of shoots (Crane and Iwakiri, 1985). Since pistachio nuts develop on one-year old shoots, the number of the shoots on the tree needs to be increased (Ferguson et al., 1995; Beede and Ferguson,

Table 4. The effects of different nitrogen, phosphorus and pruning applications on empty fruit ratio (%).

1st year ('ON')							
[1]Nitrogen	**[1]Phosphorus**			**Nitrogen**	**[2]Pruning**		
N_0	P_0	[3]4.17	b, ab	N_0	PR_1	[4]6.17	a, a
	P_1	3.33	b, a		PR_2	4.83	a, b
	P_2	6.33	ab, ab	N_1	PR_1	5.00	a, a
	P_3	8.17	a, ab		PR_2	3.75	a, b
N_1	P_0	5.00	a, a	N_2	PR_1	4.58	a, a
	P_1	6.17	a, a		PR_2	3.50	a, b
	P_2	3.50	a, b	N_3	PR_1	5.50	b, a
	P_3	2.83	a, c		PR_2	10.67	a, a
N_2	P_0	1.00	b, b	LSD		2.547	
	P_1	4.67	a, a				
	P_2	4.83	a, ab				
	P_3	5.67	a, bc				
N_3	P_0	7.67	a, a				
	P_1	6.33	a, a				
	P_2	8.33	a, a				
	P_3	10.00	a, a				
LSD		3.601					

2nd year ('OFF')			3rd year ('ON')			
Phosphorus			**Nitrogen**	**Pruning**		
P_0	[5]4.79	ab	N_0	PR_1	[4]3.08	a, a
P_1	5.83	a		PR_2	2.58	a, c
P_2	3.46	b	N_1	PR_1	3.75	a, a
P_3	3.83	b		PR_2	4.17	a, bc
LSD	1.789		N_2	PR_1	2.00	b, a
				PR_2	6.50	a, ab
Pruning			N_3	PR_1	2.17	b, a
PR_1	[5]3.67	b		PR_2	6.75	a, a
PR_2	5.30	a	LSD		2.411	
LSD	1.265					

[1] Nitrogen doses (g.tree^{-1}): 0 (N_0, control), 800 (N_1), 1000 (N_2), 1200 (N_3); Phosphorus doses (g.tree^{-1}): 0 (P_0, control), 200 (P_1), 400 (P_2), 600 (P_3), [2] Pruning applications: PR_1 (Traditional pruning); PR_2 (Traditional pruning+cutting of apical flower buds), [3] First letter: Differences between P fertilizer doses (P_0, P_1, P_2, and P_3) for each N fertilizer dose; Second letter: Differences between N fertilizer doses (N_0, N_1, N_2, and N_3) for each P fertilizer dose ($p \leq 0.05$), [4] First letter: Differences between pruning applications (PR_1, and PR_2) for each N fertilizer doses; Second letter: Differences between N fertilizer doses (N_0, N_1, N_2, and N_3) for each pruning application ($p \leq 0.05$), [5] Differences between P fertilizer doses (P_0, P_1, P_2, and P_3) and pruning applications (PR_1 and PR_2) are statistically important separately ($p \leq 0.05$).

2005). Cutting of apical flower buds weakens the apical dominance on the tree and hence, causes an increase in the number of annual shoots and enhances yield.

Nut weight is often parallel to fruit size. The highest nut weight was observed in the 2nd year ('off' year) (Table 2), and this result is parallel to Westwood's finding (1993b, c), who reported that generally, in most of the fruit trees, the fruit size tends to decrease in heavy crop years and sometimes fruit thinning is required not only to decrease the crop load, but also to increase the fruit size. In all years of the research, the nitrogen-phosphorus interaction with the nut weight was considered to be important. With the increase in nitrogen and phosphorus doses, nut weight also increases. Our results are parallel

Table 5. The effects of different nitrogen, phosphorus and pruning applications on flower bud abscission ratio (%).

1st year ('ON')				N	[1]P	2nd year ('OFF')		3rd year ('ON')	
[1]N	[2]PR					PR_1	PR_2	PR_1	PR_2
N_0	PR_1	[3]14.33	b, b	N_0	P_0	[4]12.5	86.7	[4]11.11	37.11
	PR_2	46.23	a, a		P_1	43.4	29.17	24.6	28.4
N_1	PR_1	29.90	b, a		P_2	47.2	59.5	16.5	32.34
	PR_2	47.42	a, a		P_3	12.5	29.2	20.11	18.09
N_2	PR_1	28.45	a, a	N_1	P_0	17.8	26.1	14.88	38.74
	PR_2	30.99	a, a		P_1	44.7	37.7	24.51	31.43
N_3	PR_1	34.86	a, a		P_2	47.3	27.3	23.33	22.25
	PR_2	34.48	a, a		P_3	56.3	57.9	34.52	28.15
				N_2	P_0	41.7	31.1	25.06	27.3
					P_1	32.8	30.9	25.08	29.78
					P_2	35.2	38.4	23.52	22.87
					P_3	45.6	68.3	29.77	26.98
LSD		12.69							
				N_3	P_0	33.94	47.2	29.71	28.47
					P_1	21.00	37.00	22.72	27.78
					P_2	40.9	44.8	29.13	21.56
					P_3	55.6	41.7	24.02	25.42

[1] Nitrogen doses (g.tree^{-1}): 0 (N_0, control), 800 (N_1), 1000 (N_2), 1200 (N_3); Phosphorus doses (g.tree^{-1}): 0 (P_0, control), 200 (P_1), 400 (P_2), 600 (P_3), [2] Pruning applications: PR_1 (Traditional pruning); PR_2 (Traditional pruning+cutting of apical flower buds), [3] First letter: Differences between pruning applications (PR_1, and PR_2) for each N fertilizer doses; Second letter: Differences between N fertilizer doses (N_0, N_1, N_2, and N_3) for each pruning application ($p \leq 0{,}05$), [4] Non significant at $p \leq 0.05$ error level.

with the findings of other researchers who reported that nitrogen increased the nut weight in pistachio (Kanber et al., 1993; Weinbaum et al., 1995; Zeng et al., 2001). Moreover, this could demonstrate that fertilization does not affect alone the nut size, some other factors, such as rootstocks, nut load, irrigation and pruning mostly affect the nut size in pistachio (Crane, 1978; Bilgen, 1982; Kuru, 1993; Köroğlu and Köksal, 1999). The nut sizes of the trees treated with PR_2 pruning were found to be bigger and not only in pruning, but also nitrogen and phosphorus significantly affected this parameter. For trees fertilized with low or no nitrogen, PR_2 application caused higher nut weight values. This result could be related with increase in one year shoot number, which bears healthy nuts.

In pistachio, splitting is a genetic characteristic, however, it has been reported that some factors such as rootstock, cultivar, plant nutrition, alternate bearing, climatic conditions, cultural management and pollen source could affect the splitting ratio of nuts (Crane and Takeda, 1979; Crane et al., 1982). In this current research, the effect of nitrogen and phosphorus doses, and pruning treatments on split nut ratio was significant for all years (Table 3). Pontikis (1977) stated that higher nitrogen doses caused an increase in shoot growth, but also a decrease in nut growth and delay in the splitting of pistachio. In addition, Zheng et al. (2001) determined that application of potassium obviously improved nut quality in pistachio, with increased percentages of split nuts and nut weight and reduced percentages of blank and stained nuts. The split nut ratios in PR_2 applied trees were found to be higher (Table 3). The nut weights of those trees were also higher (Table 2). As an outcome of the increase in nut size, it can be stated that the split nut ratios also increased.

In relation to empty nut ratio, in spite of the changes that were seen in different years, it was observed that the difference between nitrogen x phosphorus, nitrogen x pruning interactions and pruning applications was important. In high nitrogen and phosphorus doses with cutting of apical flower buds, empty nut ratios were detected to be higher (Table 4). There is a dearth of study regarding the effect of nutrition and pruning on the formation of empty nuts. Although in some researches, it was indicated that nutrition and irrigation affect kernel formation and growth (Kanber et al., 1993; Kuru 1993), it is a widely known fact that unsufficient pollination and fertilization are mostly responsible for empty nut formation (Lin et al., 1984; Ayfer et al., 1990). As a matter of fact, in the research conducted by Ferguson et al. (1995), it was indicated that pruning did not have a statistical effect on empty nut formation. In our research, the yield, nut weight, split and empty nut ratio values that were examined, PR_2 applied trees corresponded with the findings of other researchers (Arpacı et al., 1995; Ferguson et al., 1995; Boler, 1998; Küden et al., 1998).

In relation to fruit bud abscission, the interaction between the fertilization doses only during the 1st year, was significant (Table 5). It was generally stated that fruit bud abscissions that are inspected in pistachios, form the basis of periodicity. Because of the lack of cultural managements like irrigation, fertilization and pruning of pistachios, alternate bearing is regarded to be related to the lack of carbohydrate accumulation in plant tissues. Accordingly, after the 'on' year, it cannot nourish the flower buds, which will be the products of the subsequent year as an outcome of the lack of carbohydate accumulation and drops them. Thus, the tree cannot give a yield in the following year and shows periodicity (Crane and Nelson, 1971; Ak and Kaşka, 1992). It is also asserted that the irrigated trees accumulate carbohydrate and have a positive effect on the prevention of the drop of fruit buds (Kanber et al., 1993). The fruit bud abscission ratio in trees cutted apical flower buds (PR_2) were also discovered to be higher (Table 5). Küden et al. (1998) claims that the pruning of pistachio trees decreased fruid bud abscission. When fruit bud abscission ratios (Table 5) and yield value per tree (Table 1) were compared, it was observed that the 2nd year of the research was 'on' year and the fruit bud abscission ratios of the 1st year were generally at lower levels. The 3rd year of the research is the 'off' year, and among the fruit buds of this year, which were going to give a yield, the flower bud abscission was detected to be more severe in the 2nd year compared to the previous one.

Conclusion

Despite the fact that it does not have a statistical significance, it was observed that when the amount of fertilizer used on the trees decreased, the yield also declined. It has been seen that nitrogen and phosphorus fertilization, as well as pruning applications, played an important role on nut weight, empty nut and splitting ratio, The effects of the applications had a statistical importance on fruit bud abscission ratio only for the first year ('on' year) of the research; it did not affect fertilization and fruit bud abscission during the remaining years. From the perspective of the yield and all other characteristics that were studied during the research, higher values were obtained in the PR_2 applied trees. This situation demonstrates that pruning could be a factor that has a significant effect on yield and nut characteristics.

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