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Effect of removing the spring flush and phosphor-nitrogenous fertilizing on fruit yield and quality of the late fruiting of cactus pear *Opuntia ficus-indica* (L.) Mill

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Abstract

The aim of this work was to study the effect of removing the spring flush (scozzolatura practice) and phosphor-nitrogenous fertilizing on fruit yield and quality of the late fruiting of cactus pear *Opuntia ficus-indica* (L.) Mill. To meet this objective, trials were carried out on an adult plantation of 'Aissa' cv in the experimental station of Hassan II Institute of Agronomy and Veterinary Medicine in Agadir. The scozzolatura practice consisted of removing the whole spring flush of flowers and cladodes during full blooming (50% flowers in bloom). The amount of fertilization provided are: 0-0, 120-18 and 195-33 kg N-P_2O_5 ha^{-1}. The soil of the site of trials contains a reserve of 30-12 kg N-P_2O_5 ha^{-1} and the treatments of fertilization studied are: (T0) (control without supply, only the reserve of soil) 30-12 kg N- P_2O_5 ha^{-1}, (T1) 150-30 kg N-P_2O_5 ha^{-1} and (T2) 225-45 kg N-P_2O_5 ha^{-1}. Obtained results showed that the scozzolatura practice reduced fruit yield, while it improved fruit size. Nitrogen and phosphorus (N-P) fertilizing increased fruit yield and size of scozzolaturated and not scozzolaturated plants with more effect on scozzolaturated plants and T2 treatment yielded more than the other treaments of fertilization. Interaction of the two factors scozzolatura practice and N-P fertilizing does not affect ($p > 0.05$) fruit yield and size of scozzolaturated plants.

Keywords: Cactus pear; *Opuntia ficus-indica*; Scozzolatura practice; Late fruiting; Fruit yield; Fruit quality

1. Introduction

Removing the spring flush (known as scozzolatura practice) between mid-May and mid-June results in the emission of a second flush of flowers (or reflowering) and cladodes 30 to 40 days later [1]. The late fruits resulting from the second flush of flowers are usually ripened between September and December [2, 3, 4] and their ripening can sometimes extend to May or June, depending on the climatic conditions of the year, including temperature [2, 4]. Although the yield of this off-season production is low (20-30% of the seasonal production), its fruits are larger and tastier than the seasonal fruits. The pulp fruit is spongy, the skin is thick, and the fruits are of higher commercial value than the seasonal fruits [2, 3, 5, 6]. The late ripening fruits also contain more flesh and less seeds than the seasonal fruits [7, 8]. They are characterized by high firmness, more intense pulp coloration [9] and higher content of sugars [3]. However, Inglese [2] reported that fruit pulp of the off-season fruits is less sweet and less colored than the seasonal fruits.

The removing period of the spring flush affects the number of yielded fruits, fruit development, and the ripening period [5, 10]. The fertilization of crops improves fruit yield and avoid the lack of nutrients in the plants. Cactus pear is a crop, which also responds well to soil fertilization, and its fertilization depends on its system of production. In the system production of cactus pear, several authors reported that nitrogen and phosphorus fertilizing (N-P fertilizing) affect

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positively fruit yield and size in not scozzolaturated plants. Moreover, treatments providing high amounts of nitrogen and phosphorus affect more fruit yield and size than other treatments of fertilization [11, 12, 13, 14, 15, 16, 17, 18]. Some other authors indicated that mineral fertilization of cactus pear improved fruit yield. However, it did not affect fruit size [14, 19, 20], and the organoleptic parameters of the fruit (The contents of juice and sugars in the fruit and titratable acidity and the pH of juice) [16, 17]. While Ahmed et al. [18] reported that N-P-K mineral fertilizing improved the organoleptic parameters of the fruit in cactus pear.

The goal of this work was to study the effects of removing the spring flush and phosphor- nitrogenous fertilization on fruit yield and quality of the late fruiting of cactus pear, which is to sell fruits with an interesting price on the local market. The effect of these parameters on the reflowering and late ripening of cactus pear is the subject of another paper under consideration in another journal.

2. Materials and methods

Experiments were set up in the experimental station of Hassan II Institute of Agronomy and Veterinary Medicine, Horticultural Complex of Agadir: 30° 22' N, 9° 39' W and 32 m altitude. The site of trials is characterized by a mean temperature of 9 °C during the coldest month (January) and 30 °C during the warmest month (August), and rainfall rarely exceeds 250 mm. The texture of the soil of trials consists of 19.55% coarse sand, 30% fine sand, 20.6% coarse silt, 24.4% fine silt and 5.45% clay. The pH of the soil is 8.6 and its content in active limestone is 5.78 %. The parcel of trials is equipped with drip irrigation system and trials are carried out on an 18-year-old plantation of cactus pear 'Aissa' of *Opuntia ficus-indica* (L.) Mill. . The mean width and height of the plants of trials are respectively 1.6 and 2 m. Plant spacing is 3 x 2 m, i.e. 1666 plants per hectare. The amounts of nitrogen provided (0-0, 120-18 and 195-33 kg N-P_2O_5 ha^{-1}) are based on Nerd and Mizrahi [1] by using higher amounts they used.

Phosphorus is supplied with nitrogen to study the effect of this nutrient on the emission of the second flush of flowers and cladodes, while knowing that trials carried out on not scozzolaturated plants showed that supplying phosphorus with nitrogen affects beneficially the emission of shoots and flowers [16, 17]. Fertilizers are supplied with irrigation, nitrogen supplies are divided into three inputs with the first three irrigations and phosphorus is supplied in one input with the first irrigation. Plants are watered six times once a week and 10 mm per supply for a period of five weeks and the first irrigation took place just after the scozzolatura practice. The amounts of fertilizers supplied and the dates of their supply are shown in Table 1.

Table 1 Amounts of supplied fertilizers on cactus pear 'Aissa' of *O. ficus-indica* after the scozzolatura practice and dates of their supply in the Agadir region, Morocco

			Date of supply of the fertilizers		
			May 20 2018	**May 27 2018**	**Jun 4 2018**
Supplied amount of nitrogen per ha (kg)	120	Supplied amount of nitrogen per plant (g)	24.00	24.00	24.00
	195		39.01	39.01	39.01
Supplied amount of P_2O_5 per ha (kg)	18	Supplied amount of phosphorus per plant (g)	10.80	-	-
	33		19.81	-	-
Supplied amount of the fertilizer Ammonium nitrate (33.5%) per plant (g)			65,22	71,64	74,64
			104.62	116.45	116.45
Supplied amount of the fertilizer Monoammonium phosphate per plant (g)			18	-	-
			33.01	-	-

We have two factors to study: the scozzolatura practice and N-P fertilizing, adopted experimental design is a split plot with four blocks where the treatments of fertilization are the large parcels and the scozolatura practice treatments are the small parcels or experimental units (24 experimental units in total). Supplied amounts of fertilization are: 0-0, 120-18 and 195--33 kg N-P_2O_5 ha^{-1}. Before the fertilizers are supplied, the soil of trials contains 30 kg nitrogen and 12 kg phosphorus available per hectare. The treatments of fertilization really applied in our trials are: T0 (control without supply, contains only the soil reserve in N-P: 30-12 kg N-P_2O_5 ha^{-1}), T1: 150-30 kg N-P_2O_5 ha^{-1} (120 + 30 N and 18 + 12 P_2O_5), and T2: 225-45 kg N-P_2O_5 ha^{-1} (195 + 30 N and 33 + 12 P_2O_5). Scozzolaturated plants and not scozzolaturated

ones are the parameters studied among the factor scozzolatura practice, which consisted of removing the whole spring flush of flowers and cladodes during the full blooming stage (50% flowers in bloom), it was carried out on May 17, 2018.

2.1. Measures and observations realized

Fruit yield was determined on the whole plants (4) of each treatment of fertilization and scozzolatura practice. Fruit quality was determined on a sample of 20 ripe fruits (5 fruits on each orientation of the plant) which are randomly selected on each treatment of fertilization and scozzolatura practice. Studied qualitative parameters included the fresh mass of the fruit, pulp and skin, fruit dimensions (fruit length and diameter), skin thickness, the number of seeds per fruit, the content of juice and sugars (or degree Brix) in the fruit and the titratable acidity and pH of the juice. The mass of the fruit, pulp and skin are measured with an electrical balance with a precision of 0.01 g. Fruit dimensions and skin thickness are measured with a caliper. The number of seeds per fruit is determined on a 10 g portion of pulp and the content of juice in the fruit is determined according to the following formula:

$$\text{Juice \%} = \text{Juice mass}/\text{Pulp mass} \times 100$$

The content of sugars in the fruit or degree Brix is determined with a refractometer and the pH of juice is determined with a pH meter. The titratable acidity of the juice is determined by titrating the juice solution, which consists of 10 g juice diluted in 10 ml of distilled water. The titration of the juice solution is made with 0.1 N NaOH solution, using phenolphthalein as the color indicator, until the color changes to pink. Titratable acidity of the juice is determined according to IFU [21]; it is expressed in g of citric acid per liter of juice.

$$ACA = 0.64 \times V(NaOH)$$

ACA: Amount of citric acid expressed in g citric acid per liter of juice.

V(NaOH): Volume of 0.1 N NaOH solution used (ml).

3. Results and discussion

3.1. Effect of removing the spring flush and N-P fertilizing on fruit yield and quality

3.1.1. Effect on the yielded fruits per plant

Table 2 shows the effect of the scozzolatura practice and N-P fertilizing on the yielded fruits per plant. The scozzolatura practice affects significantly ($p \leq 0.001$) the number of yielded fruits per plant. Not scozzolatured plants yielded a mean number of 192 fruits per plant, while scozzolatured plants yielded only 133 fruits per plant, a decrease of 59 fruits per plant (- 45%) compared to not scozzolaturated plants. Nitrogen and phosphorus fertilizing also affects significantly ($p \leq 0.001$) the number of yielded fruits per plant. In scozzolaturated plants, T2 treatment of fertilization (225-45 kg N-P_2O_5 ha^{-1}) yielded 187 fruits per plant; T1 treatment (150-30 kg N- P_2O_5 ha^{-1}) yielded 131 fruits per plant and unfertilized plants yielded only 82 fruits per plant (Table 2).

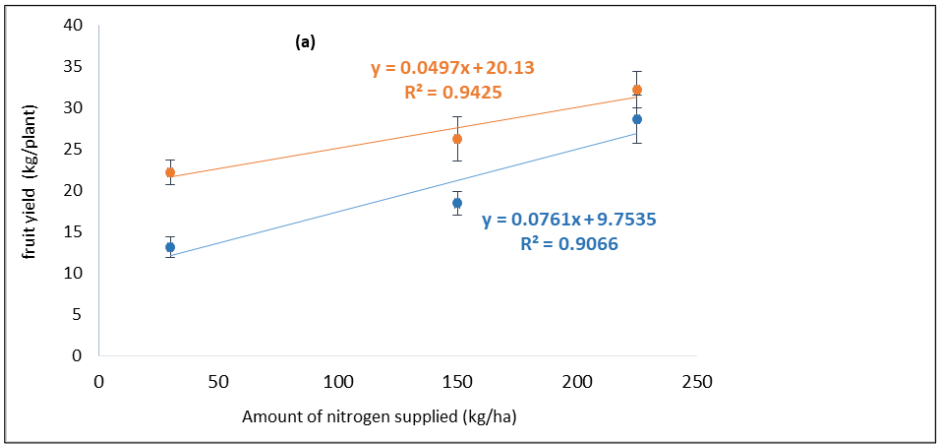
Table 2 Effect of the scozzolatura practice and N-P fertilizing on yielded fruits per plant and fruit yield of cactus pear 'Aissa' of *O. ficus-indica* in the Agadir region

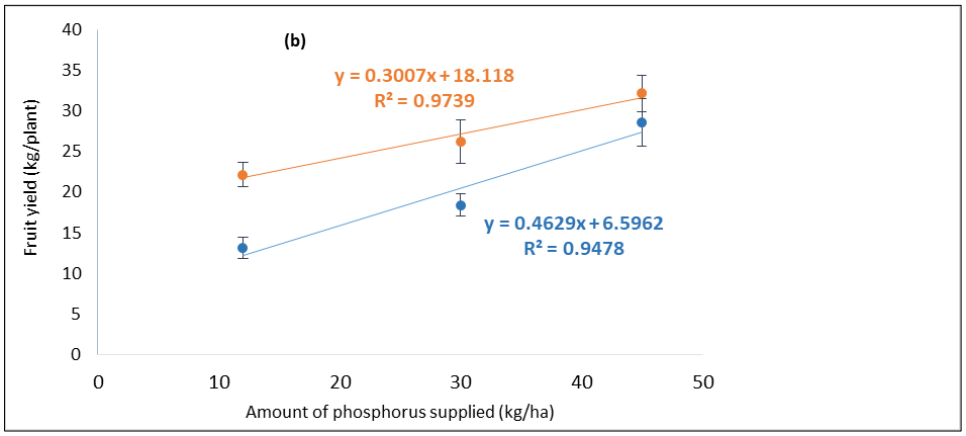
Treatment of scozzolatura practice	**Treatment of N-P fertilizing**		
	T0	**T1**	**T2**
	Number of yielded fruits per plant		
Not scozzolaturated plants	170.33	190.00	217.33
Scozzolaturated plants	81.83	130.75	186.52
	Fruit yield (Kg plant^{-1})		
Not scozzolaturated plants	22.15	26.20	32.16
Scozzolaturated plants	13.09	18.41	28.56

Interaction of the two factors scozzolatura practice and N-P fertilizing also affects significantly ($p \leq 0.05$) the number of yielded fruits per plant. In scozzolaturated plants, T2 treatment of fertilization yielded the highest number of fruits per plant (188) with an increase of 9.5% over the unfertilized and not scozzolaturated plants (Table 2).

3.1.2. Effect on fruit yield

The scozzolatura practice affects significantly ($p \leq 0.001$) the fruit yield of cactus pear. Not scozzolaturated plants yielded a mean of 26.84 kg per plant, while scozzolaturated plants yielded a mean of 20.02 kg per plant, a decrease of 34.06% compared to not scozzolaturated plants (Table 2). Nitrogen and phosphorus fertilizing also affects significantly ($p \leq 0.001$) the fruit yield of cactus pear. T2 treatment of fertilization (225-45 kg N-P_2O_5 ha^{-1}) yielded the highest in scozzolaturated plants (28.56 kg per plant) and not scozzolaturated plants (30.36 kg per plant). In scozzolaturated plants, T2 treatment yielded an increase of 15.47 kg per plant over the unfertilized plants and 10.15 kg per plant over the fertilized plants with T1 treatment. In not scozzolaturated plants, T2 treatment yielded an increase of 12.74 kg per plant over the unfertilized plants (Table 2). Interaction of the two factors scozzolatura practice and treatment of fertilization does not affect ($p > 0.05$) fruit yield.





Legends: Linear regeression in not scozzolaturated plants; Linear regression in scozzolaturated plants

Figure 1 Correlation and linear regression relationship between supplied amounts of nitrogen (a) and phosphorus (b) and fruit yield per plant in scozzolaturated and not scozzolaturated plants of cactus pear 'Aissa' of *O. ficus-indica* in the Agadir region

Advanced statistical analysis of data using correlation and regression methods showed a significant linear regression relationship ($p \leq 0.001$) between the amount of nitrogen and phosphorus supplied and fruit yield of scozzolaturated and not scozzolaturated plants, and the coefficient of correlation R^2 of these linear regressions is close to 1 (Figure 1a and b). A strong positive linear relationship exists between fruit yield and the amount of nitrogen and phosphorus supplied. This means also that fruit yield increases with the increase in the amounts of nitrogen and phosphorus supplied, whether in scozzolaturated or not scozzolaturated plants. This may also justify the economic use of large amounts of nitrogen and phosphorus such as T2 treatment, especially in scozzolaturated plants where the effect of N-P fertilizing is more beneficial than in not scozzolaturated plants. In scozzolaturated plants, T2 treatment of fertilization

increased fruit yield with 15 kg per plant over the unfertilized plants, whereas in not socozzolaturated plants this treatment of fertilization increased fruit yield with only 10 kg per plant over the unfertilized plants.

3.2. Effect of removing the spring flush and N-P fertilizing on fruit quality

3.2.1. Effect on the fresh mass of the fruit, pulp and skin

The scozzolatura practice affects significantly ($p \leq 0.001$) the fresh mass of the fruit, pulp and skin of cactus pear. The fresh mass of the fruit, pulp and peel of scozzolaturated plants, whether fertilized or not, are higher than those of not scozzolaturated plants (Table 3). Nitrogen and phosphorus fertilizing also affects significantly ($p \leq 0.001$) the fresh mass of the fruit, pulp and skin. The mean fresh mass of the fruit, pulp and peel are higher in T2 treatment of fertilization, followed by T1 treatment of fertilization and unfertilized plants (T0 treatment) are the latest (Table 3). However, N-P fertilizing does not affect ($p > 0.05$) the fresh mass of the fruit, pulp and peel. The mean fresh mass of these parameters in unfertilized plants is higher than that in fertilized plants (Table 3). Interaction of the two factors the scozzolatura practice and N-P fertilizing does not affect ($p > 0.05$) the fresh mass of the fruit, pulp and peel of cactus pear. The highest fresh mass of these parameters is obtained in scozzolaturated and unfertilized plants (Table 3). The small number of yielded fruits in scozzolaturated plants may explain this.

Table 3 Effect of the scozzolatura practice and N-P fertilizing on the fresh mass of the fruit, pulp and skin, on the peel thickness and fruit length and diameter of cactus pear 'Aissa' of *O. ficus-indica* in the Agadir region

Treatment of scozzolatura practice	**Treatment of N-P fertilizing**			**Treatment of N-P fertilizing**		
	T0	**T1**	**T2**	**T0**	**T1**	**T2**
	Fruit fresh mass (g)			**Skin thickness (mm)**		
Not scozzolaturated plants	130,82 f	137,18 e	146,63 c	3,9 f	4,1 e	4,6 c
Scozzolaturated plants	161,96 a	143,02 d	153,32 b	5,1 a	4,3 d	4,8 b
	Pulp fresh mass (g)			Fruit length (cm)		
Not scozzolaturated plants	70,06 e	74,18 d	77,90 c	7,1 e	7,3 d	7,5 c
Scozzolaturated plants	87,80 a	77,95 c	82,66 b	7,9 a	7,5 c	7,7 b
	Peel fresh mass (g)			Fruit diameter (cm)		
Not scozzolaturated plants	60,89 f	62,94 e	68,87 c	5,3 e	5,5 d	5,6 c
Scozzolaturated plants	74,25 a	65,16 d	70,85 b	5,8 a	5,6 c	5,7 b

a, b, c, d, e and f: Comparison groups according to Tukey test (Confidence level: 95%).

3.2.2. Effect on the skin thickness and fruit size

The scozzolatura practice also affects significantly ($p \leq 0.05$) the skin thickness and fruit size (fruit length and diameter) of cactus pear. Skin thickness and fruit size of scozzolaturated plants are higher than those of not scozzolaturated plants, whether fertilized or unfertilized (Table 3). Nitrogen and phosphorus fertilizing also affects significantly ($p \leq 0.05$) the peel thickness and fruit size of not scozzolaturated plants and T2 treatment of fertilization yielded fruits with higher skin thickness and fruit size than those of T1 treatment and unfertilized plants are the latest (Table 3). However, N-P fertilizing does not affect ($p > 0.05$) the skin thickness and fruit size of scozzolaturated plants, and unfertilized plants yielded fruits with higher skin thickness and fruit size than those of fertilized plants (Table 3). Interaction of the two factors the scozzolatura practice and N-P fertilizing does not affect ($p > 0.05$) skin thickness and fruit size (Table 3). This probably because the small number of yielded fruits in scozzolaturated plants, as explained below for the other morphological parameters of the fruit (fresh mass of the fruit, pulp and skin).

Our results on fruit yield and size in scozzolaturated plants are consistent with those of several authors who reported that fruit yield of scozzolaturated plants is lower than that of the seasonal yield of not scozzolaturated plants. However, the fruits of scozzolaturated plants are particularly larger than the seasonal fruits [3, 4, 5, 7, 8]. Obtained results on fertilized and not scozzolaturated plants are also consistent with those of several authors who showed that mineral fertilization improved fruit yield and size [11,12, 13, 14, 15; 16, 17, 18].

3.2.3. Effect on the organoleptic parameters of the fruit

Except for the content of juice in the fruit, the scozzolatura practice affects significantly ($p \leq 0.001$) the other organoleptic parameters of the fruit (the content of sugars and seeds in the fruit and the pH and titratable acidity of the juice) (Table 4). The content of sugars in the fruit (14.80 °Brix) and the pH of juice (6.43) of scozzolatured plants are higher than those of not scozzolatured plants (13.43 °Brix and 6.28 respectively for the content of sugars and the pH of juice) (Table 4).

However, the content of seeds in the fruit and the titratable acidity of juice are lower in scozzolaturated plants than in not scozzolaturated plants (Table 4). Regarding nitrogen and phosphorus fertilizing, it does not affect ($p > 0.05$) the organoleptic parameters of the fruits of scozzolaturated and not scscozzolaturated plants of cactus pear.

Table 4 Effect of the scozzolatura practice on the organoleptic parameters of the fruits of cactus pear 'Aissa' of *O. ficus-indica* in the Agadir region

The organoleptic parameters of the fruit	Not scozzolaturated plants	Scozzolaturated plants	
The content of juice in the fruit (%)	73.81	74.90	ns
The content of sugars in the fruit (°Brix)	13.43	14.80	*
Titratable acidity of the juice (g l^{-1})	0.78	0.69	*
The pH of juice	6.36	6.42	*
Number of seeds per 10 g pulp	44.18	42.83	*

ns: No significant difference; *: Significant difference at $p \leq 0.001$

Our results on the organoleptic parameters of the fruit of scozzolaturated plants are similar to those of several authors who reported that the late fruits of scozzolaturated plants are of better quality than the seasonal fruits. The late fruits of scozzolaturated plants are larger, tastier, sweeter, and contain less seeds than the seasonal fruits [3, 4, 5]. Obtained results on the organoleptic parameters of the fruits of fertilized and not scozzolaturated plants are consistent with those of several authors who indicated that N-P fertilizing did not affect the organoleptic parameters of the fruit [16, 17]. While Ahmed et al. [18] showed that N-P-K mineral fertilization improved the organoleptic parameters of the fruits (the content of juice and sugars in the fruit and titratable acidity and the pH of juice). This is probably because the young plants they studied (5-year-old) responded better to fertilization than the older plants such as those they are used in the studies of Arba [16] and Arba et al. [17].

3.3. Economic study on the gain of the late fruiting compared to seasonal fruiting

To study the benefit of the late fruiting of scozzolaturated plants compared to seasonal fruiting of summer, we carried out an economic study with the aim of comparing the selling prices of the seasonal fruits with those of the late fruits.

Obtained results on fruit yield showed that not scozzolaturated and unfertilized plants yielded a mean of 36,652 kg ha^{-1} and not scozzolaturated and fertilized plants with T2 treatment yielded 53,312 kg ha^{-1}. While scozzolaturated and unfertilized plants yielded a mean of 21,658 kg ha^{-1} and scozzolaturated and fertilized plants with T2 yielded 46,648 kg ha^{-1}. During the summer season, the seasonal yield of cactus pear in Morocco (July-August) far exceeds the consumer demand for the fruit and the selling prices of the fruit in the local market are low and do not exceed 1.50 MAD kg^{-1}. While during the late production period, supply is low and the demand is high, leading to a remarkable increase in the selling prices of the fruit in the local market where they can reach a mean of 5.00 MAD kg^{-1}. The selling price of one hectare unfertilized seasonal production is 54,978 MAD (36,652 kg x 1.5 MAD kg^{-1}) and that of one hectare fertilized seasonal production with T2 treatment is 79,968 MAD (53,312 kg x 1.50 MAD kg^{-1}). While the selling price of one hectare unfertilized late production is 108,290 MAD (21,658 kg x 5.00 MAD kg^{-1}) and that of one hectare late production fertilized with T2 treatment is 233,240 MAD (46,648 kg x 5.00 MAD kg^{-1}). The gain of unfertilized late production over unfertilized seasonal production is 53,312 MAD ha^{-1} (108,290 – 54,978 MAD ha^{-1}) (5,337 $US) and that of fertilized late production with T2 treatment over fertilized seasonal production with T2 is 153,272 MAD ha^{-1} (233,240 – 79,968 MAD ha^{-1}) (15,353 $US). The gain of late production fertilized with T2 treatment over unfertilized seasonal production is 178,262 MAD ha^{-1} (233,240 – 54,978 MAD ha^{-1}) (17,844 $US).

4. Conclusion

The scozzolatura practice reduced fruit yield, the number of yielded fruits per plant, the content of seeds in the fruit and the titratable acidity of the juice. However, it increased the content of sugars in the fruit and the pH of juice compared to not scozzolaturated plants. Nitrogen and phosphorus fertilizing improved fruit yield, the number of yielded fruits per plant, and fruit size of scozzolaturated and not scozzolaturated plants and higher amount of supplied fertilization such as T2 treatment affects much these yield parameters than the other treatments of fertilization. A positive linear regression relationship exists between fruit yield and the amount of nitrogen, phosphorus fertilizers provided, and fruit yield increases with the increase for fertilization provided. However, N-P fertilizing did not affect the organoleptic parameters of the fruits of scozzolaturated and not scozzolaturated plants.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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