World Journal of Advanced Pharmaceutical and Life Sciences

Journal homepage: https://zealjournals.com/wjapls/

ISSN: 2799-0222 (Online)

(RESEARCH ARTICLE)

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# Effect of removing the spring flush and phosphor-nitrogenous fertilization on the reflowering and late ripening of cactus pear *Opuntia ficus-indica* (L.) Mill

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World Journal of Advanced Pharmaceutical and Life Sciences, 2023, 05(02), 005–012

Publication history: Received on 22 September 2023; revised on 11 November 2023; accepted on 14 November 2023

Article DOI: https://doi.org/10.53346/wjapls.2023.5.2.0078

## Abstract

The aim of this work was to study the effect of removing the spring flush (scozzolatura practice) and phosphor-nitrogenous fertilization on the refloring and late ripening of cactus pear *Opuntia ficus-indica* (L.) Mill. To meet this objective, trials were carried out on an adult plantation of cactus pear 'Aissa' in Agadir area during the 2018 season. The scozzolatura practice consisted of removing the whole spring flush of flowers and cladodes during full blooming (50% flowers in bloom). The fertilization doses 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) 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 delayed the reflowering for 44 days compared to the spring flowering and the late fruiting for 54 days compared to seasonal fruiting. However, phosphor-nitrogenous fertilization does not affect significantly ($p > 0.05$) the reflowering and late ripening of cactus pear. Appliying T2 treatment of nitrogen and phosphorus fertilization after the scozzolatura practice improved the number of flowers (194) and cladodes (160) emitted per plant.

**Keywords:** Scozzolatura practice; Flowering; Fruiting; Late fruiting

## 1. Introduction

Removing the spring flush known as scozzolatura practice results in the emission of a second flush of flowers and cladodes 30-40 days after this practice . The second flush of flowers produce an out of season late ripening between September and December. The flowering of the second flush or reflowering is related to the spring flush and the greater the spring flush, the higher the number of flowers emitted after the scozzolatura practice [1, 2]. The number of flowers emitted after the scozzolatura practice is positively related to the number of removed flowers and young cladodes per plant. Therefore, leaving more than 25% of the spring cladodes should be avoided in order to obtain an important second flush of flowers and to prevent the phenomenon of alternating production. Moreover, when the scozzolatura practice is applied later (after the end flowering stage or during the fruit growth stage) the reflowering is negatively affected [3]. Inglese [4] recommended avoiding the practice of the scozzolatura on young plantations under 4 years old in order to prevent the cycle disturbance of their vegetative development.

The period of removing the spring flush affects the reflowering and the ripening period of the late fruiting [1]. According to Barbera et al. [3], the full flowering stage (50% flowers in bloom) is the most suitable period for the scozzolatura practice under the climatic conditions of Sicily in Italy. This period can be extended until the late flowering stage and before the fall of the corollas in south Morocco [1]. These last authors showed that after this late flowering stage, removing the spring flush reduces the rate of reflowering for 50 to 70% and removing it before blooming leads to early

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fruit ripening for 15 to 20 days from a removing in full-flowering stage and 30 to 40 days from a removing in end flowering stage.

Cactus pear responds well to mineral fertilization, and phosphor-nitrogenous fertilization might affect the emission of flowers and shoots in cactus pear [5, 6]. Treatments providing 60 kg N $ha^{-1}$ or 60-80 kg N-$P_2O_5$ $ha^{-1}$ affect much the emission of shoots and flowers than other treatments used (0-80, 40-40 and 60-0 kg N-$P_2O_5$ $ha^{-1}$) [6]. The emission of flowers is also related to the content of nitrogen in the terminal cladodes [5, 6]. Nerd and Mizrahi [7] reported that the amounts of nitrogen they used after the scozzolatura practice (60 and 120 kg $ha^{-1}$) don't affect the reflowering of cactus pear, while they significantly affect the emission of shoots. Although the yield of the late fruiting is low (20 to 30% of the seasonal yield ), the commercial value of its production is higher than that of the seasonal fruiting [2, 4].

The goal of this work was to study the effects of the scozzolatura practice and nitrogen and phosphorus fertilizing on the late ripening of cactus pear, which is to sell fruits with an interesting price on the local market.

## 2. Material and methods

Experiments were set up in the experimental station of the Hassan II Institute of Agronomy and Veterinary Medicine in Agadir area (30° 22' N, 9° 39' W and 32 m altitude) during the 2018 season. The mean temperature in the site of trials is 9 °C for the coldest month (January) and 30 °C for the warmest month (August) and rainfall rarely exceeds 250 mm. The parcel of trials is equipped with a drip irrigation system and the soil of the parcel has a silty texture, consisting 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%. Trials are carried out on a 18-year-old plantation of cactus pear 'Aissa' of *Opuntia ficus-indica* (L.) Mill. . Plants have a mean width of 1.6 m and a mean length of 2 m. Plant spacing is 3 × 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 [7] by using higher amounts they used. Phosphorus is brought with nitrogen to study its effect on the emission of the second flush of flowers and cladodes, while knowing that trials we carried out on not scozzolaturated plants have shown that its contribution with nitrogen has a beneficial effect on the emission of shoots and flowers [6]. Fertilizers are supplied with irrigation, nitrogen supplies are divided into three inputs with the first three watering irrigations and phosphorus is supplied in one input with the first watering. Plants are irrigated 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 fertilizers brought to cactus *O. ficus-indica* pear after the scozzolatura practice in the Agadir region and dates of their supplies

| **Dates of the supplies** | | | **May 20 2018** | **May 27 2018** | **Jun 4 2018** |
|---|---|---|---|---|---|
| Amount of nitrogen supplied per ha (kg) | 120 | Amount of nitrogen supplied per plant (g) | 24.00 | 24.00 | 24.00 |
| | 195 | | 39.01 | 39.01 | 39.01 |
| Amount of $P_2O_5$ supplied per ha (kg) | 18 | Amount of phosphorus supplied per plant (g) | 10.80 | - | - |
| | 33 | | 19.81 | - | - |

We have two factors to study: the scozzolatura practice and N-P fertilizing, the experimental design used is a Split Plot with four blocks. The treatments of fertilization are the large parcels and the scozolatura practice the small parcels or experimental units (24 experimental units in total). The amounts of fertilization provided are: 0-0, 120-18 and 195-33 kg N-$P_2O_5$ $ha^{-1}$. Before the fertilizers are supplied, the soil of the parcel of trials contains 30 kg nitrogen and 12 kg phosphorus available per hectare. The treatments of fertilization really studied in our trials are T0: (control without supply, contains only the soil reserve in N-P: 30 kg N-12 kg $P_2O_5$ $ha^{-1}$), T1: 150 kg N-30 kg $P_2O_5$ $ha^{-1}$ (120 + 30 N and 18 + 12 $P_2O_5$) and T2: 225 kg N-45 kg $P_2O_5$ $ha^{-1}$ (195 + 30 N and 33 + 12 $P_2O_5$). Scozzolaturated and not scozzolaturated plants are the parameters used in the scozzolatura practice, which consisted of removing the whole spring flush of flowers and cladodes during full blooming stage (50% flowers in bloom), it was carried out on May 17, 2018. The periods of flowering and ripening phases extend from the start date of the flowering or ripening phases (5% flowers in bloom for flowering and 5% ripened fruits for ripening) until the end of the phenological phase (100% flowers in bloom for flowering and 100% ripened fruits for ripening). The date of full blooming or ripening stage corresponds to the date when 50% flowers in bloom are reached for flowering and 50% ripened fruits are reached for ripening. Observations began on March 2018 for the flowering and the emission of shoots and after fruit set for the ripening phase. They

consisted of counting the number of emitted flowers and shoots and the number of ripened fruits (Change in the bark color from green to yellowish-green) per plant of all the treatments of fertilization and scozzolatura practice. Observations are carried out on a sample of 20 cladodes per plant of the trials (10 cladodes of one year and 10 of two years), which are selected on the four orientations of the plant. They are done twice a week during the vegetative cycle of the plant, which extends from March 2018 until the ripening period of the scozzolaturated plants. The percentage of ripened fruits is determined according to Oelofse et al. [8].

% ripened fruits = Number of ripened fruits/Total number of fruits on the plant x 100

Statistical analysis of data is carried out with MINITAB software. It focused on the analysis of variance with two parameters, and data analysis was also completed with a comparison of means using Tukey test.

## 3. Results and discussion

### 3.1. Effect of removing the spring flush and N-P fertilization on the reflowering

The scozzolatura practice affects significantly ($p \leq 0.001$) the flowering and ripening phases of cactus pear. Scozzolatured plants gave a second flush of flowers (reflowering) and an off-season late fruiting, while not scozzolatured plants did not give a reflowering and a late fruiting (Figure 1). To reach the full flowering stage, for example, it takes 27 days after April 24 for not scozzolaturated plants and 71 days after the same date for scozzolaturated plants, a difference of 44 days between scozzolaturated and not scozzolaturated plants. A delay of 52 to 55 days exists between the ripening stage of not scozzolaturated plants and the ripening stage of scozzolaturated plants (Table 2). Our results are consistent with those of several authors who reported that the second flush of flowers and cladodes appears 30 to 40 days after the scozzolatura practice [1, 2, 9]. Nitrogen and phosphorus fertilizing does not affect significantly ($p > 0.05$) the flowering period of scozzolaturated and not scozzolatured plants. The reflowering period is similar for fertilized and unfertilized scozzolaturated plants.

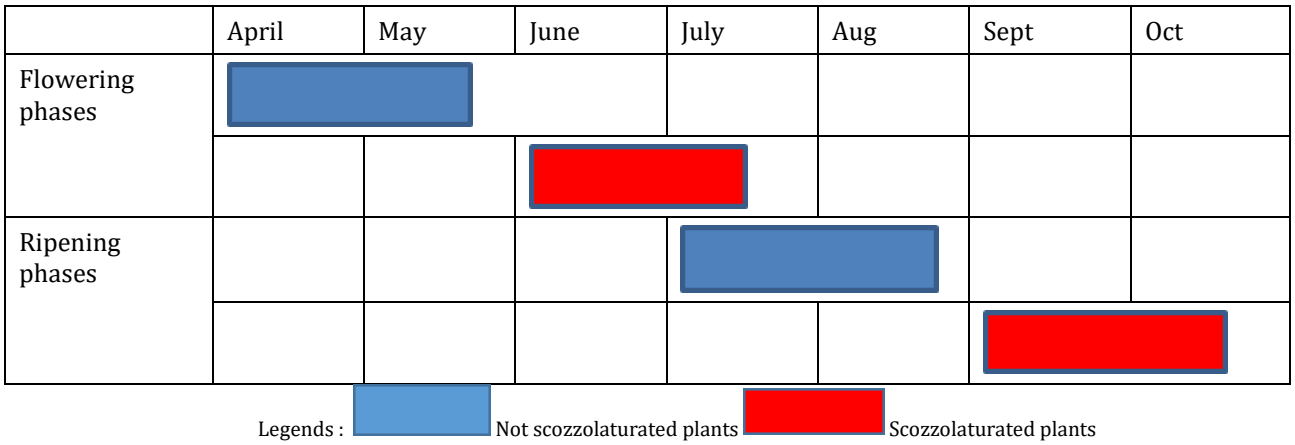



**Figure 1** Flowering and ripening phases of scozzolaturated and not scozzolaturated plants of cactus pear *O. ficus-indica* in the Agadir region

**Table 2** Dates of flowering and ripening and number of days required to reach a phenological stage from the start of a phenological phase of scozzolaturated and not scozzolaturated plants of cactus pear *O. ficus-indica* in the Agadir region

| | | **Not scozzolaturated plants** | **Scozzolaturated plants** | **Not scozzolaturated plants** | **Scozzolaturated plants** |
|---|---|---|---|---|---|
| | | Date of the flowering stage | | Date of the ripening stage | |
| | Early flowering or ripening | 24/04/2018 | 10/06/2018 | 09/07/2018 | 02/09/2018 |

| | | | | | |
|---|---|---|---|---|---|
| Flowering or ripening stages | stage (5% flowers in bloom or ripened fruits) | | | | |
| | Full flowering or ripening stage (50% flowers in bloom or ripened fruits) | 17/05/2018 | 30/06/2018 | 02/08/2018 | 25/09/2018 |
| | End flowering or ripening stage (100% flowers in bloom or ripened fruits) | 14/06/2018 | 24/07/2018 | 25/08/2018 | 16/10/2018 |

| | | | | | |
|---|---|---|---|---|---|
| | | Number of days required to reach a flowering or a ripening stage | | Difference number of days between scozzolaturated and not scozzolaturated plants | |
| Flowering stages | Early flowering | 0 | 47 | 47 | |
| | Full blooming | 23 | 67 | 44 | |
| | End flowering | 51 | 92 | 41 | |
| Ripening stages | Early ripening | 0 | 55 | 55 | |
| | Full ripening | 24 | 78 | 54 | |
| | End ripening | 47 | 99 | 52 | |

| **Emitted flush of flowers or of fruits per plant** | **flowers** | **cladodes** | **flowers** | **cladodes** |
|---|---|---|---|---|
| First flush of flowers and cladodes | 177.25 | 30.58 | 177.25 | 30.58 |
| Second flush of flowers and cladodes | 0 | 0 | 85.00 | 16.50 |
| First flush of fruiting (Seasonal fruiting) | 170 | | 170 | |
| Second flush of fruiting (Late fruiting) | 0 | | 82 | |

### 3.2. Effect of removing the spring flush and N-P fertilization on the emission of shoots and flowers

Application of NP fertilizing after the scozzolatura practice affects significantly ($p \leq 0.001$) the emission of shoots and flowers in scozzolaturated and not scozzolaturated plants. Fertilized and scozzolaturated or not scozzolaturated plants produced a higher number of flowers and cladodes than unfertilized plants. Moreover, fertilized plants with T2 treatment (195–45 kg N-$P_2O_5$ $ha^{-1}$) produced a higher number of flowers and cladodes per plant (194 flowers and 160

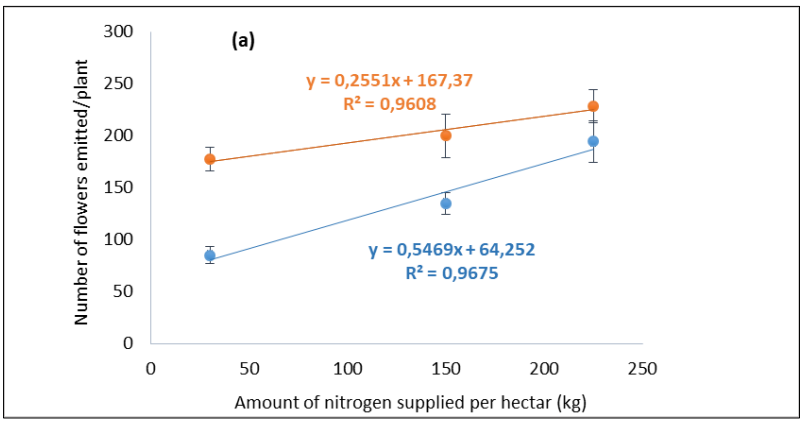
cladodes for scozzolaturated plants) than fertilized plants with T1 (135 flowers and 130 cladodes for scozzolaturated plants) (Table 3). The highest number of flowers and cladodes per plant in scozzolaturated and not scozzolaturated plants is obtained with T2 treatment (194 flowers and 160 cladodes, and 238 flowers and 120 cladodes respectively). While, the lowest number of flowers and cladodes per plant is obtained with T0 unfertilized treatment (85 flowers and 31 cladodes for scozzolaturated plants and 137 flowers and 17 cladodes for not scozzolaturated plants). However, in fertilized plants, the number of cladodes emitted per plant is higher in scozzolaturated plants (130 and 160 cladodes respectively for T1 and T2) than in not scozzolaturated plants (101 and 120 cladodes respectively for T1 and T2).

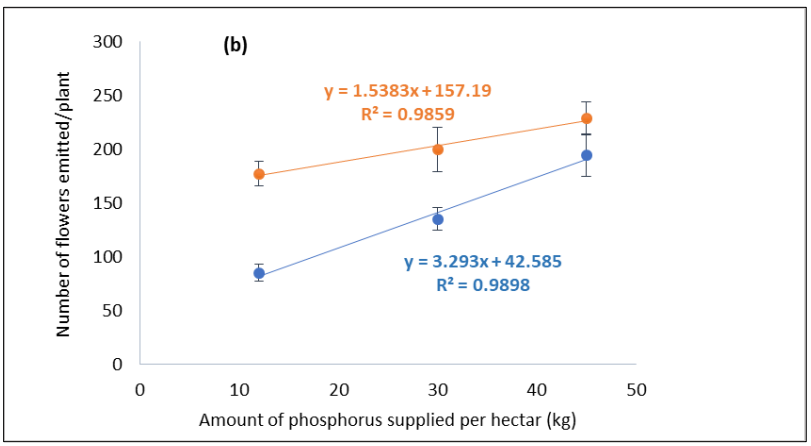
**Table 3** Effect of N-P fertilizing on the emission of shoots and flowers in scozzolaturated and not scozzolaturated plants of cactus pear *O. ficus-indica* in the Agadir region

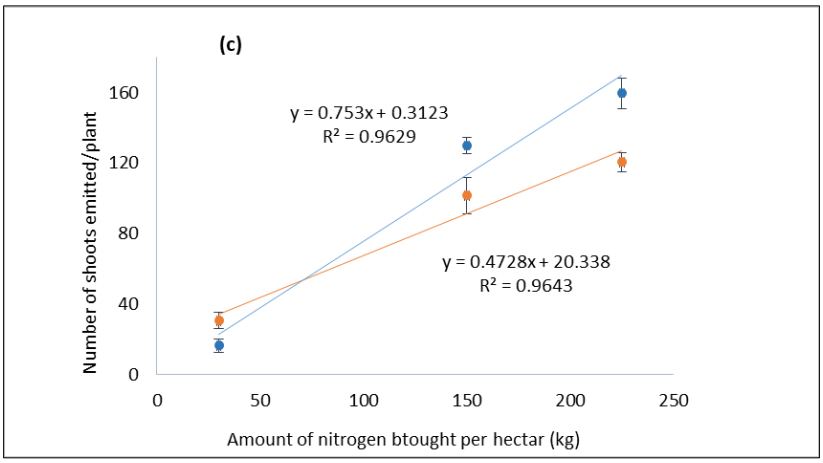
| **Number of flowers and shoots emitted per plant** | | **Treatments of N-P fertilizing** | | |
|---|---|---|---|---|
| | | **T0** | **T1** | **T2** |
| Number of flowers emitted per plant | Not scozzolaturated plants | 177.25 b | 199.06 ab | 228.33 a |
| | Scozzolaturated plants | 85.00 d | 135.09 c | 194.25 ab |
| Number of shoots emitted per plant | Not scozzolaturated plants | 30.58 e | 101.50 d | 120.42 b |
| | Scozzolaturated plants | 16.50 f | 129.92 c | 159.50 a |

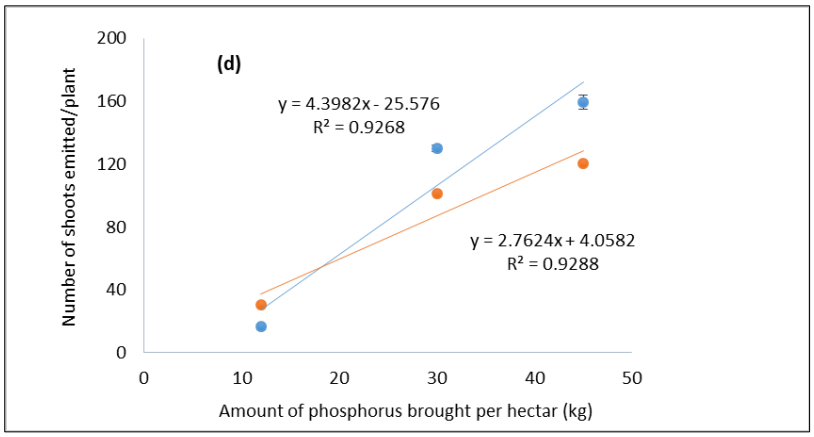
a, b, c, d, e and f : Homogenous groups according to Tukey test (confidence level: 95%).

Interaction of the two factors scozzolatura practice and N-P fertilizing affects significantly ($p \leq 0.05$) the emission of shoots and flowers. In scozzolaturated and fertilized plants, the number of flowers emitted per plant is 135 for T1 and 194 for T2, and the number of cladodes emitted per plant is 130 for T1 and 160 for T2. Whereas in not scozzolaturated and unfertilized plants, the number of flowers and cladodes emitted per plant is 177 and 31 respectively. A linear correlation exists between the amounts of nitrogen and phosphorus supplied and the emission of flowers and the correlation coefficient $R^2$ is 0.96 for nitrogen (Figure 2a) and 0.98 for phosphorus (Figure 2b). A linear correlation exists also between the amounts of nitrogen and phosphorus supplied and the emission of shoots and $R^2$ is 0.96 for nitrogen (Figure 2c) and 0.92 for phosphorus (Figure 2d).






Legends : Linear regression of scozzolaturated plants; Linear regression of not scozzolaturated plants

**Figure 2** Linear correlation between the amounts of nitrogen and phosphorus supplied and the emission of flowers (a and b) and shoots (c and d) in scozzolaturated and not scozzolaturated plants of cactus pear *O. ficus-indica* in the Agadir region

Application of correlation and regression methods showed that a significant linear regression relationship ($p \leq 0.001$) exists between the amounts of nitrogen and phosphorus supplied and the emission of shoots and flowers in scozzolaturated and not scozzolaturated plants (Figure 2). The coefficient of determination $R^2$ of this linear regression is close to one. This indicates that there is a strong positive linear relationship between the amounts of nitrogen and phosphorus supplied and the emission of shoots and flowers, whether for scozzolaturated or not scozzolaturated plants. It also maens that by increasing the amounts of nitrogen and phosphorus provided to the plants, whether scozzolaturated or not scozzolaturated, the emission of shoots and flowers increases. What confirms the economic profitability of supplying high amounts of nitrogen and phosphorus (such as T2 treatment) to farmers, since they increase the emission of flowers and shoots. Moreover, the effect of such high amounts of NP fertilizers seems to be more beneficial in scozzolaturated plants than in not scozzolaturated plants (Table 3). What also maens that the contribution of nitrogen and phosphorus fertilization is more cost-effective in scozzolaturated plants than in not scozzolaturated plants. Our results are consistent with those of several authors who reported that mineral nutrients, mainly nitrogen and phosphorus, have an influence on the vegetative and reproductive phenology of cactus pear [10, 11, 12, 13]. Large amounts of nitrogen fertilizing on scozzolaturated plants also leads to an increase in the emission of flowers [5]. Other authors have shown that the emission of shoots and flowers in cactus pear is positively correlated with the content of nitrogen and phosphorus in the upper cladodes [5, 6, 12, 14]. On an adult plantation of cactus pear in the same parcel where trials are set up, and which received an N-P fertilizing of 60-80 kg N-$P_2O_5$ $ha^{-1}$, the content of nutrients in one-year old cladodes is 10.5 g $kg^{-1}$ dry matter for N and 1.3 for P. However, the content of these elements in the cladodes of unfertilized plants is 9.8 g $kg^{-1}$ dry matter for N and 1.2 for P [6]. However, our results are different from those of Nerd and Mizrahi [7] who reported that application of nitrogen fertilizing on scozzolaturated plants affects the emission of shoots , but does not affect the emission of flowers . This may be explained by the lower amount of nitrogen they brought in (120 kg N $ha^{-1}$) in comparison with the amounts we used in our study. In addition to large

amounts of nitrogen we used, the phosphorus supply has contributed to the improvement of the emission of shoots and flowers. Our results on not scozzolaturated plants are also consistent with those of several authors who reported that N-P dressings providing 60 kg N $ha^{-1}$ or 60-80 kg N-$P_2O_5$ $ha^{-1}$ affects significantly the emission of shoots and flowers [6]. Potgieter and D'Aquino [12] suggested to consider the available nutrient reserves in the soil as well as the plant nutrient status of the terminal cladodes in order to make a fertilizer recommendation for cactus pear. They added that a production system with two crops in one year may require additional mineral supplies.

### 3.3. Effect of removing the spring flush and N-P fertilization on the ripening period

The scozzolatura practice affects significantly ($p \leq 0.001$) the ripening period of cactus pear. The ripening period of not scozzolaturated plants extends from July 9 to August 25, 2018, while that of scozzolaturated plants extends from September 2 to October 16, 2018 (Figure 1). The dates of the ripening stages of scozzolaturated and not scozzolaturated plants are presented in Table 2. Nitrogen and phosphorus fertilizing does not affect significantly ($p > 0.05$) the ripening period of the seasonal and late fruiting. Our results are consistent with those of several authors who reported that the scozzolatura practice leads to an out of season late fructifying, which is usually ripened between September and December [1, 2]. The ripening period of the late fruiting is also influenced by the removing period of the spring flush [3]. Nitrogen and phosphorus fertilizing does not affect significantly the ripening period of the late fruiting and the ripening period is similar for fertilized and unfertilized plants.

## 4. Conclusion

Removing the spring flush leads to an off-season late fruiting in cactus pear. Nitrogen and phosphorus fertilizing does not affect the late ripening of scozzolaturated plants. While it influence the emission of shoots and flowers of both scozzolaturated and not scozzolaturated plants and T2 treatment, (225-45 kg N-$P_2O_5$ $ha^{-1}$) gave the highest emission of shoots and flowers compared to other treatments of fertilization. The substantial removing of the spring flush requires appropriate nitrogen and phosphorus fertilizing of cactus pear, in order to increase the emission of shoots and flowers in scozzolaturated plants. A similar study by bringing potassium with nitrogen and phosphorus may be interesting in order to study the effect of this nutrient on the fruiting of scozzolaturated plants, although several authors indicated that cactus pear does not respond well to potassium fertilizing [11, 15]. Similar studies using separate nitrogen and phosphorus fertilizers may also be interesting in order to study the effect of each separate fertilizer on the reflowering and late fruiting of cactus pear.

## Compliance with ethical standards

*Acknowledgments*

Many thanks to Hassan II Institute of Agronomy and Veterinary Medicine, Horticultural Complex of Agadir for his support to our study

*Disclosure of conflict of interest*

The authors declare no conflict of interest

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