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# Effect of Phosphorus and Nitrogen on the Growth and Productivity of Jojoba Shrubs (*Simmondsia chinensis* L. Schneider)

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**Abstract:** Nutritional status improvement is a surrogate approach to overcoming undesirable soil conditions and under the newly reclaimed lands in Egypt. This investigation aimed to study of independent effects of phosphorus nutrition as mono ammonium phosphate (MAP) at (30, 45 and 60 P units) and nitrogen as ammonium nitrate 33.5% at (50, 70 and 90 N units) on growth and productivity of 8 years old jojoba shrubs propagated by leafy cuttings selection from the most promising individual plant during two consecutive seasons 2021/2022 and 2022/2023 in a private orchard located at Cairo-Alexandria desert road, Egypt (about 64 km from Cairo). Results revealed a positive effect of fertilizing jojoba shrubs with a rate of 90 units of nitrogen and 30 units of phosphorus for improving vegetative growth, fruit characteristics and productivity without significant differences with that fertilized by using 70 units of nitrogen and 30 units of phosphorus in most cases. Leaf mineral content of jojoba leaves was enhanced by various nitrogen and phosphorus treatments, the overall better performance was obtained by addition of 50 units N:60 unit's P (T3), 70 units N:30 unit's P (T4) and 90 units N:30 unit's P (T5) help to compensate the depletion of mineral nutrient and enhancing tree yield and fruit characters.

**Kew words:** Jojoba · Nitrogen · Phosphorus · Nutrition · Productivity

## INTRODUCTION

Egypt intends to reclaim and cultivate 1.5 million acres as part of its sustainable development plan, taking into account the problems related to water scarcity, Egypt's declining share of the Nile River's water and the high rate of water scarcity, which rises at a rate of 7 billion cubic meters per year. Jojoba is one of the most well-known plants whose climate, water needs and terrestrial requirements are appropriate for Egyptian conditions. [1, 2].

Jojoba (*Simmondsia chinensis* L. Schneider) is an evergreen shrub belonging to family of *Simmondsiaceae* [3]. Jojoba is native to the deserts of North America, particularly Arizona, California and Mexico. It's renowned for its seeds which it used for producing oil (liquid-wax) [4]. Jojoba liquid-wax is a highly antioxidant compound because it contains less than 3% of triglycerides [5]. Also, jojoba liquid-wax consists of an alcohol and mixture of an ester of long chain fatty acids. jojoba oil is highly valuable and used in medicines, cosmetics, petrochemicals and lubricants and it has a great economic value equivalent to the value of whale oil.

Jojoba nutrition is one of the factors that affect seeds and oil productivity [6]. Even so, little information is available about the role of nutrients in the growth and productivity of jojoba shrubs.

Phosphorus (P) is one of macro-nutrients essential for plant growth and production. Numerous chemical molecules, including nucleic acids, enzymes and phosphate compounds with high energy content (ADP and ATP), are synthesized with phosphorus. Apart from the inorganic phosphate ion, P is moved to other sections of the plant to be utilized in subsequent processes [7]. The application of phosphorus enhanced plant morphology, including root surface area and length [8]. In addition, numerous studies have addressed the significance that phosphorus plays in improving growth and productivity [6, 9-12].

Nitrogen (N) is crucial nutrient for plants, particularly those used to extract oil [13]. This is because nitrogen is required for the synthesis of amino acids, which serve as

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a basic unit in building proteins [6]. Consequently, nitrogen deficiency has an impact on many vital processes within plant, which has an impact on the productivity and overall health of the plant. Many researchers indicted the effect of nitrogen nutrition on growth and productivity in jojoba and olive [9, 10, 14, 15].

In general, Khattab *et al*. [16] explained that, increasing phosphorus nutrition beside nitrogen and boron improved the productivity of jojoba shrubs. Furthermore, Ahmed *et al.* [6] showed that, 320 kg/ha $P_2O_5$, 400 kg/ha $K_2O$ and 40 ton/ha compost enhanced jojoba seed production. While, Hegab *et al.* [9] said that, jojoba shrubs irrigated by industrial wastewater gave their heights growth and production when fertilized with 240 kg N/ha, 150 kg $P_2O_5$/ha + 120 kg $K_2O$/ha.

The aim of this study was to determine the optimal rate of phosphorus and nitrogen for enhancing growth and productivity of jojoba shrubs.

## MATERIALS AND METHODS

**Field Practices:** The field experiment was conducted during two growing seasons (2021/2022 and 2022/2023) on eight years old of jojoba shrubs propagated by leafy cutting selection from the most promising jojoba individual plant grown in a private orchard at (64 km from Cairo)- Cairo-Alexandria desert road, situated (30.2674617) N latitude, (30.8047994) E longitude. Jojoba shrubs were cultivated at 2 x 4 m spacing in sandy soil under drip irrigation. The mechanical and chemical characteristics of the experimental soil and irrigation water were determined according to Chapman and Pratt [17] and Page *et al.* [18] in Tables (1 & 2).

**Experimental Material and Treatments:** The experiment designed as a randomized complete block design. Thirty of mature Jojoba shrubs were selected and divided into 5 treatments represented by 3 replicates (2 trees per each). The tested Jojoba shrubs were fertilized with different additions of phosphorus as mono Ammonium Phosphate (MAB) and nitrogen as Ammonium Nitrate 33.5%.

The treatments were arranged as followed:

T1-(control) 50 units' nitrogen: 30 units' phosphorus.
T2- 50 units' nitrogen: 45 units phosphorus.
T3- 50 units' nitrogen: 60 units phosphorus.
T4- 70 units' nitrogen: 30 units phosphorus.
T5- 90 units' nitrogen: 30 units phosphorus.

The selected shrubs received monthly doses according to morphological activities (Table 3) during the period from February to June in the first and second seasons of the study (Table 4). All treatments received equal dose of potassium ($K_2O$) 30 units distributed on the growing season and a dose of micronutrient (Fe, Zn, Mg and boron) 0.5 g/L during the period of active growth and before flowering.

Jojoba seeds were picked in August, to determine the yield and oil%. The responses of the tested jojoba shrubs to treatments were estimated through the following parameters:

**Vegetative Growth:** At the end of the growing seasons (September) twelve healthy shoots from selected shrubs were labeled to determine shoot length (cm), number of leaves/shoot, leaf length (cm), leaf width (cm) and weight of 10 leaves (g).

**Fruit Characteristics:**

- The average number of fruits/shoot were counted at the end April.
- At harvest time ten fruits were randomly selected to evaluate fruit length, width (cm) and weight (g).

**Yield and Oil Productivity:**

- Yield/tree the average for each treatment was calculated as kg/tree.
- Oil content (%) in dried seeds were evaluated by Soxhlet apparatus and petroleum ether (60-80 °C) for extraction as described by Hassan *et al.* [19].
- Oil productivity = Yield/tree x Oil content (%).

**Leaf Mineral Content:** Sample of twenty leaves for each replicate were taken from non-fruiting shoots in September of each season. /eaves were cleaned and washed with tap water, distilled water and oven-dried at 70°C until constant weight than finely ground.

Total nitrogen content was evaluated by modified micro-Kjeldahl method as outlined by Wilde *et al.* [20].

Phosphorus content was determined according to Chapman and Pratt [17].

Potassium content by using flame photometer as explained by Browen and Lilleland [21].

**Nutrition Use Efficiency:** Nutrition use efficiency Were calculated according to the equation that described by Dobermann [22] as follow:

Table 1: Chemical and mechanical characteristics of tested soil.

| Chemical analysis | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Soluble cations (meq/ L) | | | | Soluble anions (meq/ L) | | | |
| PH (1:2.5) | E.C. $dsM^{-1}$ (1:5) | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ | $CO_3^{=}$ | $HCO_3^{-}$ | $Cl^{-}$ | $SO_4^{=}$ |
| 7.20 | 2.68 | 7.89 | 2.97 | 12.90 | 0.26 | - | 2.83 | 14.41 | 6.78 |

| Mechanical analysis (%) | | | | |
|---|---|---|---|---|
| Coarse sand % | Fine sand % | Silt % | Clay % | Textural classes |
| 38.40 | 43.30 | 13.00 | 5.30 | Sandy |

Table 2: Chemical characteristics of tested irrigation water collected from tested area

| | | | Cations (meq/l) | | | | Anions (meq/l) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Characters | EC $dsM^{-1}$ (1:5) | pH (1:2.5) | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{2+}$ | $K^{2+}$ | $CO_3^{-}$ | $HCO_3^{-}$ | $Cl^{-}$ | $SO_4^{2-}$ | SAR |
| Value | 7.1 | 8.3 | 16.1 | 11.7 | 38.3 | 0.2 | 0.0 | 1.8 | 29.2 | 35.3 | 10.3 |

Table 3: Morphological activities of jojoba shrubs during months of experiments

| | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Morphological Activity | Jan | Feb | March | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Vegetative growth | | ? | ? | ? | ? | ? | ? | ? | ? | | | |
| Flowering growth | | ? | ? | | | | | | | | | |
| Fruiting growth | | | | ? | ? | ? | ? | ? | ? | | | |

Note: These distributions could change according on the climate and environmental factors in the jojoba cultivation zones.

Table 4: The distribution of phosphorus and nitrogen units during months of experiments

| | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nutrient | Jan | Feb | March | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
| Phosphorus | 3 | 4 | 4 | 4 | 4 | 2 | 2 | 2 | 2 | 1 | 2 | 0 | 30 |
| | 4 | 6 | 6 | 6 | 6 | 3 | 3 | 3 | 3 | 2 | 3 | 0 | 45 |
| | 6 | 8 | 8 | 8 | 8 | 4 | 4 | 4 | 4 | 2 | 4 | 0 | 60 |
| Nitrogen | 5 | 3 | 3 | 7 | 7 | 3 | 3 | 6 | 6 | 4 | 3 | 0 | 50 |
| | 7 | 4 | 4 | 10 | 10 | 5 | 5 | 8 | 8 | 5 | 4 | 0 | 70 |
| | 9 | 6 | 6 | 12 | 12 | 6 | 6 | 10 | 10 | 8 | 5 | 0 | 90 |

Nitrogen use efficiency (NUE) = Jojoba productivity/ Nitrogen units
Phosphorus use efficiency (PUE) = Jojoba productivity/ Phosphorus units

**Statistical analysis:** The collected data were analyzed using analysis of variance (ANOVA) according to Snedecor and Cochran [23]. treatment means were compared using New LSD method at 5% of probability.

## RESULTS AND DISCUSSION

**Vegetative Growth:** The vegetative growth of jojoba shrubs was significantly impacted by the rates of nitrogen and phosphorus supplied in the first and second seasons. Data in (Table 5) demonstrated that, the treatment with 90 units N: 30 units P (T5) achieved the highest values for shoot length (24.00 & 26.75 cm), number of leaves (22.00 & 21.75) and leaf weight (2.35 & 2.84 g), while the control treatment gave the lowest values. Moreover, a narrow variation was obtained in leaf length and width as the effect of additions by 70 units N:30 units P (T4) and 90 units N:30 units P (T5) in both seasons, respectively.

This could be due to the role of nitrogen in both cell division and the formation of new cells [24]. According to Masclaux-Daubresse *et al.* [25] and Fathi [26] nitrogen is one of nutrients that plants required in abundance, since it plays a crucial part in photosynthesis process and synthesis of amino acids. Moreover, Nelson and Watson [27] proposed that, the response of jojoba trees to nitrogen addition depends on many factors, including the heavy fruit load on jojoba trees in some years.

**Fruit Characteristics:** According to the presented data in Table (6), it could be noticed that, treatment with 90 units N: 30 units P produced the greatest numbers of fruit (6 and 7.33) in both seasons. Similarly, each of treatments with 70 units N:30 units P(T4) and 90 units N:30 units P(T5) were superiority in fruit length, width and weight than other treatments during two investigated seasons. Otherwise, the control treatment exhibit marks a minimum fruit characteristics records in both studied seasons respectively.

These findings went parallel with those obtained by Elbadawy *et al.* [28] and Rosati *et al.* [29] on olive, Dhillon *et al.* [30] and Davarpanah *et al.* [31] on pomegranate they attributed the increase in fruit weight to

Table 5: Effect of phosphorus and nitrogen nutrition on vegetative growth of jojoba during two growing seasons (2021/2022 and 2022/2023)

| | Shoot Length (cm) | | Number of leaves | | Leaf Length (cm) | | Leaf Width (cm) | | Weight of 10 leaves | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| T1 (Control) | 17.50 | 16.25 | 15.00 | 13.00 | 3.70 | 3.20 | 1.47 | 1.55 | 1.58 | 1.35 |
| T2 | 18.50 | 20.00 | 20.00 | 14.50 | 3.75 | 3.47 | 1.73 | 1.60 | 1.97 | 1.76 |
| T3 | 18.75 | 23.75 | 17.00 | 20.50 | 4.00 | 3.73 | 1.67 | 1.75 | 2.27 | 1.66 |
| T4 | 20.00 | 18.50 | 18.75 | 15.00 | 4.70 | 4.97 | 2.00 | 2.15 | 1.85 | 2.25 |
| T5 | 24.00 | 26.75 | 22.00 | 21.75 | 4.45 | 4.83 | 2.07 | 2.20 | 2.35 | 2.84 |
| Mean | 19.75 | 21.05 | 18.55 | 16.95 | 4.12 | 4.04 | 1.788 | 1.85 | 2.00 | 1.97 |
| LSD 5% | 4.54 | 5.25 | 2.60 | 6.81 | 0.82 | 0.35 | 0.37 | 0.39 | 0.12 | 0.08 |

T1 Control= 50 N:30 P, T2= 50 N:45 P, T3= 50 N:60 P, T4=70 N:30 P, T5=90 N:30 P

Table 6: Effect of phosphorus and nitrogen nutrition on fruit characteristics of jojoba during two growing seasons (2021/2022 and 2022/2023)

| | Number of fruits / Shoot | | Length of 10 fruits | | Width of 10 fruits | | Weight of 10 fruits | |
|---|---|---|---|---|---|---|---|---|
| Treatment | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| T1 (Control) | 3.67 | 4.00 | 13.71 | 14.13 | 9.40 | 8.07 | 6.13 | 6.17 |
| T2 | 4.33 | 5.00 | 14.40 | 14.17 | 9.47 | 8.93 | 6.80 | 6.60 |
| T3 | 5.33 | 7.00 | 14.37 | 14.90 | 9.40 | 9.73 | 6.68 | 7.10 |
| T4 | 5.00 | 4.33 | 16.80 | 16.93 | 9.60 | 9.80 | 8.00 | 8.63 |
| T5 | 6.00 | 7.33 | 16.67 | 17.57 | 9.87 | 10.17 | 7.97 | 9.43 |
| Mean | 4.87 | 5.53 | 15.19 | 15.54 | 9.55 | 9.34 | 7.12 | 7.59 |
| LSD 5% | 1.63 | 1.76 | 0.31 | 0.90 | 0.16 | 1.20 | 0.28 | 1.33 |

T1 Control= 50 N:30 P, T2= 50 N:45 P, T3= 50 N:60 P, T4=70 N:30 P, T5=90 N:30 P

Table 7: Effect of phosphorus and nitrogen nutrition on yield and oil productivity of jojoba during two growing seasons (2021/2022 and 2022/2023)

| | Yield (Kg/Tree) | | Oil % | | Oil productivity | |
|---|---|---|---|---|---|---|
| Treatment | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| T1 (Control) | 1.62 | 1.90 | 47.26 | 47.96 | 0.78 | 0.91 |
| T2 | 2.04 | 2.41 | 48.65 | 49.51 | 0.99 | 1.22 |
| T3 | 2.26 | 2.57 | 50.93 | 50.77 | 1.15 | 1.32 |
| T4 | 2.67 | 2.82 | 54.46 | 51.59 | 1.45 | 1.40 |
| T5 | 2.98 | 3.30 | 53.59 | 52.68 | 1.60 | 1.74 |
| Mean | 2.31 | 2.60 | 50.98 | 50.50 | 1.19 | 1.32 |
| LSD 5% | 0.79 | 0.70 | 4.77 | 2.79 | 0.45 | 0.35 |

T1 Control= 50 N:30 P, T2= 50 N:45 P, T3= 50 N:60 P, T4=70 N:30 P, T5=90 N:30 P

Table 8: Effect of phosphorus and nitrogen nutrition on leaf mineral content of jojoba during two growing seasons (2021/2022 and 2022/2023)

| | N (%) | | P (%) | | K (%) | |
|---|---|---|---|---|---|---|
| Treatment | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| T1 (Control) | 1.89 | 1.83 | 0.28 | 0.26 | 1.68 | 1.39 |
| T2 | 2.12 | 2.05 | 0.40 | 0.38 | 2.01 | 1.68 |
| T3 | 2.45 | 2.15 | 0.44 | 0.39 | 2.22 | 2.04 |
| T4 | 2.33 | 2.17 | 0.46 | 0.35 | 2.12 | 1.77 |
| T5 | 2.18 | 2.24 | 0.39 | 0.41 | 2.09 | 1.75 |
| Mean | 2.19 | 2.09 | 0.39 | 0.36 | 2.02 | 1.73 |
| LSD 5% | 0.47 | 0.14 | 0.14 | 0.07 | 0.44 | 0.64 |

T1 Control= 50 N:30 P, T2= 50 N:45 P, T3= 50 N:60 P, T4=70 N:30 P, T5=90 N:30 P

Table 9: Effect of phosphorus and nitrogen nutrition on nutrition use efficiency of jojoba during two growing seasons (2021/2022 and 2022/2023)

| Treatment | NUE | | PUE | |
|---|---|---|---|---|
| | 1st | 2nd | 1st | 2nd |
| T1 (Control) | 0.0157 | 0.0180 | 0.0260 | 0.0303 |
| T2 | 0.0200 | 0.0243 | 0.0223 | 0.0270 |
| T3 | 0.0233 | 0.0263 | 0.0190 | 0.0220 |
| T4 | 0.0207 | 0.0197 | 0.0480 | 0.0467 |
| T5 | 0.0177 | 0.0197 | 0.0533 | 0.0580 |
| Mean | 0.019 | 0.022 | 0.034 | 0.037 |
| LSD 5% | 0.007 | 0.007 | 0.006 | 0.012 |

T1 Control= 50 N:30 P, T2= 50 N:45 P, T3= 50 N:60 P, T4=70 N:30P, T5=90 N:30 P

the amount of nitrogen available in the soil, which led to an increase in the effciency of metabolic processes dry matter accumulation in fruits. Cheng *et al.* [32] explained that, fruit cells during division process need a large amount of carbon and nitrogen.

**Yield and Oil Productivity:** Results presented in (Table 7) showed, a vast variability among tested treatments. Both additions of 70 units N:30 units P (T4) & 90 units N:30 units P (T5) gave the highest yield (kg/tree), oil % and productivity in both seasons. The lowermost values of jojoba yield and oil productivity were recorded by control treatment. Moreover, the treatment with 50 units N:60 units' P (T3) gave an intermediate value during the 1st and 2nd seasons, respectively.

The aforementioned results agree with Nelson and Watson [27] and Ahmed *et al.*[6] they found that, seed yields of jojoba trees were increased linearly by nitrogen supply. Moreover, Swetha and Saritha [33] gave evidence that, during the fruit growth stage, N and P are transported to the fruiting part, where they are required in high quantities for the synthesis of protein and lipids. In addition, Nelson and Watson [27] illustrated that, the rise in nitrogen addition causes a decrease in the amount of seed wax (oil) in jojoba. Also, Dag *et al*. [34] cleared that, nitrogen nutrition did not affect wax content in jojoba seeds.

**Leaf Mineral Content:** Presented data in Table (8) indicated that, nutrition treatments induced significant increases in jojoba leaf mineral content (N, P and K %). Generally, N content in jojoba leaves was ranged from (1.89 to 2.45%), P content was from (0.28 to 0.46%) and (1.68 to 2.22%) for K content in first season. In the second one this values were ranged between (1.83 to2.24%) for N content, (0.26 to 0.41%) for P content and (1.39 to 2.04%) for K content. The highest significant values of (N, P and K %) were differ from first and second one. The maximum recorded of (N&P) by both applications with 50 units N:60 units P (T3) & 70 units N:30 units (T4) in the first season. While in the second one the treatment with 90 units N:30 units P was superiority. The maximum record of K content attained by the treatment with and 50 units N:60 units P (T3) in both seasons, respectively. Conversely, the lowest values of mineral contents were obtained by control treatment.

The increasing in leaf mineral content may be due to the enhanced effect of nitrogen on plant growth, which can lead to changes in the concentrations of phosphorus and potassium in leaves. Liu *et al*. [35] mentioned that, increased nitrogen availability can hasten the cycling of phosphorus, influencing the absorption and translocation of both potassium and phosphorus.

**Nutrition Use Efficiency:** Data in Table (9) demonstrate the significant influence of phosphorus and nitrogen on nutrition use efficiency of the tested jojoba trees during 2022 and 2023 seasons; nitrogen use efficiency (NUE) ranged from (0.0157 to 0.0233) in first season and (0.0180 to 0.0263) in the second one. The greatest number of NUE were obtained by 50 units N:60 units P (T3) than other treatments, while the least records was obtained by control.

With regard to the phosphorus use efficiency (PUE) in Table (9), it was ranged from (0.0190 to 0.0533) in the first season and from (0.0220 to 0.0580) in the second one. Both additions of (70 units N:30 units P and 90 units N:30 units P) induced statistically highest PUE in both seasons, respectively. On the other hand, the control treatment gave statistically the lowest values in this concern.

Numerous investigations have demonstrated the linear relationship between phosphorus and nitrogen [36, 37]. In addition, Marklein and Houlton [38] said that, the amount of nitrogen present in a plant can affect how quickly phosphorus cycles through it. In contrast, phosphorus regulates biological nitrogen fixation, which transforms atmospheric nitrogen into a form that plants can use [39]. Meanwhile, Krouk and Kiba [40] illustrated that, the relationship between nitrogen (N) and phosphorus (P) is neither simple nor linear. The biological activity within the plant is influenced by various factors in its surrounding environment, which can affect the plant's response to N and P. Aulakh and Malhi [41] reported that, the application of nitrogen alone has minimal impact on crop output; however, application of both nitrogen and phosphorus can greatly boost productivity and the efficacy of applied fertilizers. In addition, Tan *et al.* [42] mentioned that, tree demand and N supply must be coordinated to guarantee sufficient uptake and utilization as well as maximum production.

## CONCLUSION

Results of present study showed considerable variation in the vegetative growth, fruit characteristics, yield, oil productivity, leaf mineral content and Nutrition use efficiency of tested Jojoba shrubs as the effect of different fertilization levels of nitrogen and phosphorus. The best fertilizer rates of N and P obtained by each of treatments with 70 units N:30 units P and 90 units N:30 units P that considered preferable for helping to compensate the depletion of mineral nutrient and enhances fruiting that refers to the productivity. Thus, we can recommend the growers to apply either of these treatments that showed a good performance in increasing seed yield subsequently increase the economic return.

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