

Analytical and Techno-Economic Diagnosis of a Rosehip Plantation on Sandy Soil in Semi-Arid Zone of Tunisia

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Abstract: To study the effect of the sandy texture and the plantation density on rosehip production, the soil of a plot of 1ha area located in a semi-arid region of Tunisia, previously divided into three zones with variable densities of shrubs, was sampled at three points in each unit, on 90 cm deep. During flowering period, samples of flowers and leaves were collected to determine the concentration of dry matter in N, P and K. The production was assessed by counting the flowers on each sampled shrub of the three densities. The results confirmed the sandy particle size of the soil and its contents of elements which are low for mineral N, modest for available P and sufficient for exchangeable K. Plants have removed still, higher quantities even of those taken by other species that have better nutritional conditions. Flowers have accumulated more P and K but less N than the leaves. The soil available P was significantly related to flowers yield. The agro-economic study showed that the rosehip culture is profitable regardless of the planting density adopted on sandy soil, but the 500 plants per hectare was the most profitable. Indeed, it has provided the best performance with the highest gross and net margins and the most important economic efficiency. The rosehip culture is possible in all types of aerated and not salted soils, even in the absence of significant humus reserves. It can be a source of income for many farmers having limited land space.

Keywords: rosehip, sandy soil, flowers, leaves, yield, profitability.

1. Introduction

The rosehip or wild rose or *Rosa canina* is a bushy shrub with thorny stems pushing as tillers whose lengths can reach several meters. In Tunisia, it, naturally, grows in the higher rainfall areas or under semi-arid to sub-humid climate. It was even identified in wet highlands, northwest of Tunisia (Ghazghazi et al, 2010). In Mediterranean areas, it adapts to ecosystems where thrive species as *Cistus laurifolius*, *Pyrus elaeagnifolia*, *Quercus vulcania* and *Amelanchier rotundifolia*; *Rosa canina* can therefore be considered as a species for land restoration and protection against degradation factors of such ecosystems (Guner et al, 2011).

It is cultivated mainly for the extraction of its floral water that has medicinal benefits. According Chrubasic et al (2008), the rosehip water has antioxidant properties. It tones heart, burns visceral fat and has a vasodilator effect, in addition to its high content of vitamin C that stimulates the body's defenses against flu and rheum (Ghazghazi et al, 2013). The essential oils extracted from leaves of *Rosa canina* possess antioxidant activity which is greater in extracts of carotenoids (Ghazghazi et al, 2010). Rosehip fruits have also antiseptic and antioxidant properties (Montazier et al, 2011; Fattahi et al, 2012). It can too, be used as a rootstock for roses.

Cultivated on highly calcareous and clayey soils, it provided enough important flowers yield to form respectable annual revenue for the operator (Hajji and Bayounès, 2011). It is commonly known that it adapts well to humiferous and well-drained soils, which explains the need for a certain chemical fertility and good circulation of air in the soil porosity. Its culture in sandy soils with little or no humus is not known and has not been tested. The current study aims

to diagnose the nutritional elements N, P and K of soil and their uptake by the plant firstly, and secondly to assess the profitability of the rosehip culture planted in different densities on a sandy and slightly humiferous soil, not or very little fertilized. This required a physicochemical analysis of the soil and determination of concentrations of the elements N, P and K in flowers and leaves of shrubs aged five.

2. Materials and Methods

Experimental Protocol

The plot where rosehips are planted covers an area of 1 hectare and is located in an alluvial valley of low slope, near the bed of the wadi Rmel, at 10 km east of Zaghouan city in north-east of Tunisia. It is covered by a thick sandy soil classified as "not developed, not climatic soil of alluvial deposits" (CPCS, 1967), typic xerofluent (SMSS, 1985) and juvenile FLUVIOSOL (AFES, 2008). The plot was divided into three portions in which, different planting densities were adopted: D₁ (5 mx 4 m); D₂ (3m x 8m); D₃ (5m x 8 m).

Shrubs in the plot are five years old, their branches lengths exceed 2.5 m and volumes, treated as hemispheres, reach 10 m³. They were fertilized at planting period with an amino-phosphate mineral fertilizer and growth depended of soil mineral reserves. The experimental protocol consisted of the sampling of soil and plant at each density. To the soil, three points adjacent to three successive shrubs were sampled by auger every 30 cm to 90 cm deep; this made 3 samples per point, 9 for each density and 27 in total. For the plant at flowering stage, in May 2014, samples of 100 flowers and 100 leaves was taken from each plant in a row of three

adjacent plants in each density, to determine the dry matter content and concentrations of N, P and K. In addition, counting flowers has been achieved, to evaluate the production of flowers in each sampled shrub.

Analysis Methods

Analyses of soil: soil samples, once dried, crushed and sieved to 2 mm, have been analyzed with following physicochemical methods (Naanaa and Susini, 1988):

- Particle size: method of Robinson pipette.
- pH: measured by the pH-meter on a soil/water extract = 1/2.5.
- Electrical conductivity (EC): measured on a saturated paste extract by the conductivimeter.
- Total limestone: determined by the method of calcimeter of Bernard.
- Active limestone: evaluated by attack of 2.5 g of soil with a solution of 0.2 N ammonium oxalate and dosage of excess oxalate with potassium permanganate 0.1 N.
- Organic matter: extraction of organic C with potassium bichromate to 8% by cold, in sulfuric ambience (Walkley and Black), colorimetric dosage at the wavelength 600 nm.
- Total nitrogen: mineralization in sulfuric ambience in the presence of selenium catalyzer and distillation with an excess of NaOH (Kjeldahl method); distillate reception in a boric acid solution at 2% and dosage by HCl 0.01 N.
- Available phosphorus: extraction by a 0.5 N Na bicarbonate solution (Olsen), colorimetric dosage at the wavelength 660 nm, after developing the blue color of

ammonium molybdate in the presence of ascorbic acid 1%.

- Exchangeable potassium: extraction with 1 N ammonium acetate, dosage by flame photometry.

Analyses of plant material (De Saint Amand and Case, 1967): after drying at 70-80 °C, the flowers and the leaves sampled were weighed to determine the dry matter content, then crushed in powder.

- Total Nitrogen: N extraction and distillation of 0.4 g of plant powder by Kjeldahl method, distillate received in a boric acid solution at 2% and dosage by HCl 0.1 N.
- Phosphorus and potassium: calcination of 1 g of plant powder at 550 °C, dissolving the ashes by HCl 1/5 and filtering with distilled water. Determination of P in filtrate by colorimetry at the wavelength 660 nm and K by flame photometry.

3. Results

Results of soil analysis

Physicochemical parameters

The largest size fraction is the fine sands with values higher than 50% and may even exceed 60% in some horizons. The other fractions are variable but values almost never exceeding 20%; the clay fraction is not negligible and often exceeds 10%. The textures are either sandy loam or sandy clay with dominance of fine sands compared to coarse sands (Figure 1).

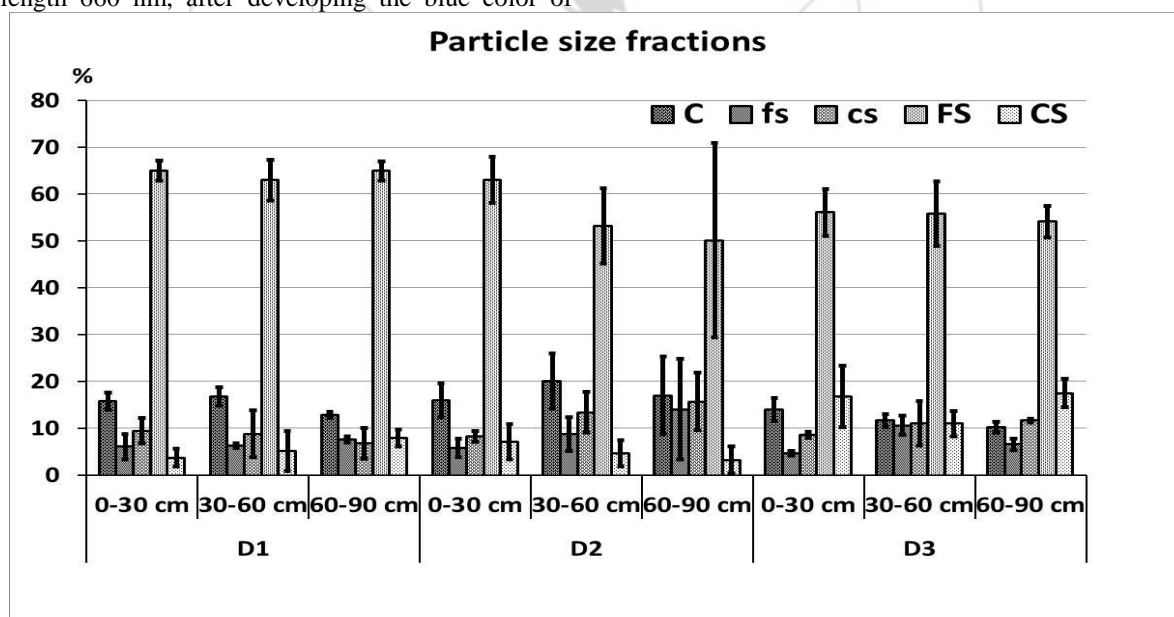


Figure 1: Distribution of particle size fractions according to the depth and the plantation zone (D₁, D₂, D₃) (C: clay; fs: fine silt; cs: coarse silt; FS: fine sand; CS: coarse sand)

The average electrical conductivity tends to increase as a function of depth in the areas D₁ and D₂ and remains weak and homogeneous in the D₃ zone (Table 1). The origin of the salts is irrigation water pumped from a surface well located close to the plot; irrigation has been practiced daily after planting in summer 2009 and irregularly during the following years. The salts are partially driven deep by rainwater in D₁ and D₂. D₃ area has received less irrigation

water, which is reflected by the low values of the electrical conductivity.

The pH presents homogeneous alkaline values which are close to 8 in all horizons and in the three planting areas (Table 1). This moderate alkalinity is due to the presence of limestone in modest amounts. The values of the total limestone are generally between 10 and 15% and have a heterogeneous distribution in function of depth; the active

part of this limestone is low and varies from 0 to 7% (Table 1).

Table 1: Average values and their standard deviations of electric conductivity (EC), pH, total and active limestone, of soil horizons of the three plantation densities

| Density | Depth (cm) | EC (mS/cm) | | pH | | Total CaCO ₃ | | Active CaCO ₃ | |
|----------------|------------|------------|------|------|------|-------------------------|------|--------------------------|------|
| | | M* | SD** | M* | SD** | M* | SD** | M* | SD** |
| D ₁ | 0-30 | 0.62 | 0.30 | 7.81 | 0.06 | 8.20 | 3.12 | 1.50 | 2.60 |
| | 30-60 | 2.29 | 1.14 | 7.93 | 0.11 | 15.47 | 1.80 | 4.50 | 0.87 |
| | 60-90 | 3.59 | 1.62 | 7.95 | 0.06 | 11.40 | 3.33 | 2.83 | 2.57 |
| D ₂ | 0-30 | 3.98 | 5.18 | 7.86 | 0.01 | 13.20 | 1.13 | 6.50 | 4.27 |
| | 30-60 | 2.71 | 2.45 | 7.90 | 0.06 | 13.47 | 1.54 | 7.00 | 1.80 |

| | | | | | | | | | |
|----------------|-------|------|------|------|------|-------|------|------|------|
| | 60-90 | 5.06 | 3.88 | 7.86 | 0.04 | 12.53 | 5.32 | 1.67 | 2.89 |
| D ₃ | 0-30 | 0.87 | 0.52 | 7.93 | 0.11 | 9.60 | 2.61 | 1.83 | 3.18 |
| | 30-60 | 0.70 | 0.26 | 7.91 | 0.03 | 13.73 | 6.98 | 3.33 | 5.77 |
| | 60-90 | 0.73 | 0.26 | 7.92 | 0.03 | 9.60 | 2.67 | 5.00 | 4.36 |

* M : mean ; ** SD : standard deviation

The total organic matter content is low, not exceeding 1%, and is divided into a descending gradient except for the density D₂ where it increases between 30 and 60 cm (Figure 2). These levels reflect, firstly the character weakly fixer of organic matter by sandy texture and secondly the frequent passages of the working tools of the soil because it is a cultivated plot.

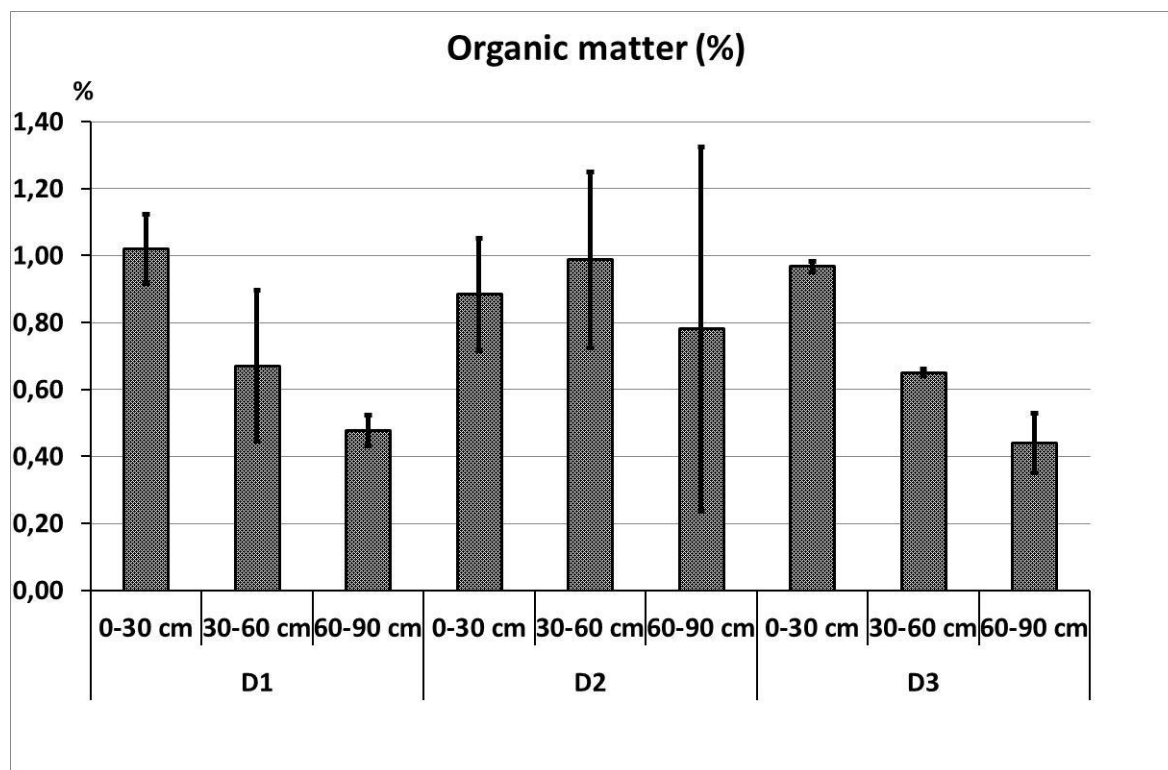


Figure 2: Average contents (%) of organic matter of soil horizons of the three plantation areas

The elements N, P and K

The mineral nitrogen was calculated from the total N by the expression of Roy et al (2005). Its values are low and do not exceed 7 mg kg⁻¹; they are relatively homogeneous in the different horizons and in the different planting densities except the surface horizon of density 1, wherein the content is only 2 mg kg⁻¹ (Figure 3). This mobile element has insufficient fixing sites in the sandy soil; it should be easily leached even in its ammonium form. Moreover, its low values are due to the lack of sources such as mineral fertilizer that is not practiced and the reserve too insufficient of organic matter to release this element in sufficient quantities by mineralization.

Available phosphorus is characterized, also, by its very modest levels particularly at the D₂ and D₃ densities. D₁ zone has the highest values with 25.5 mg kg⁻¹ in the surface layer, 20.6 mg kg⁻¹ in average depth and 8.8 mg kg⁻¹ at the bottom of the soil profile. In the other areas, the values are much lower, despite a tendency to a higher concentration of this element in the surface horizon (Figure 4). Soil supply sources of this element are also reduced and essentially come from the mineralization of organic matter and the dissolution of the few primary phosphate minerals that may exist in such material.

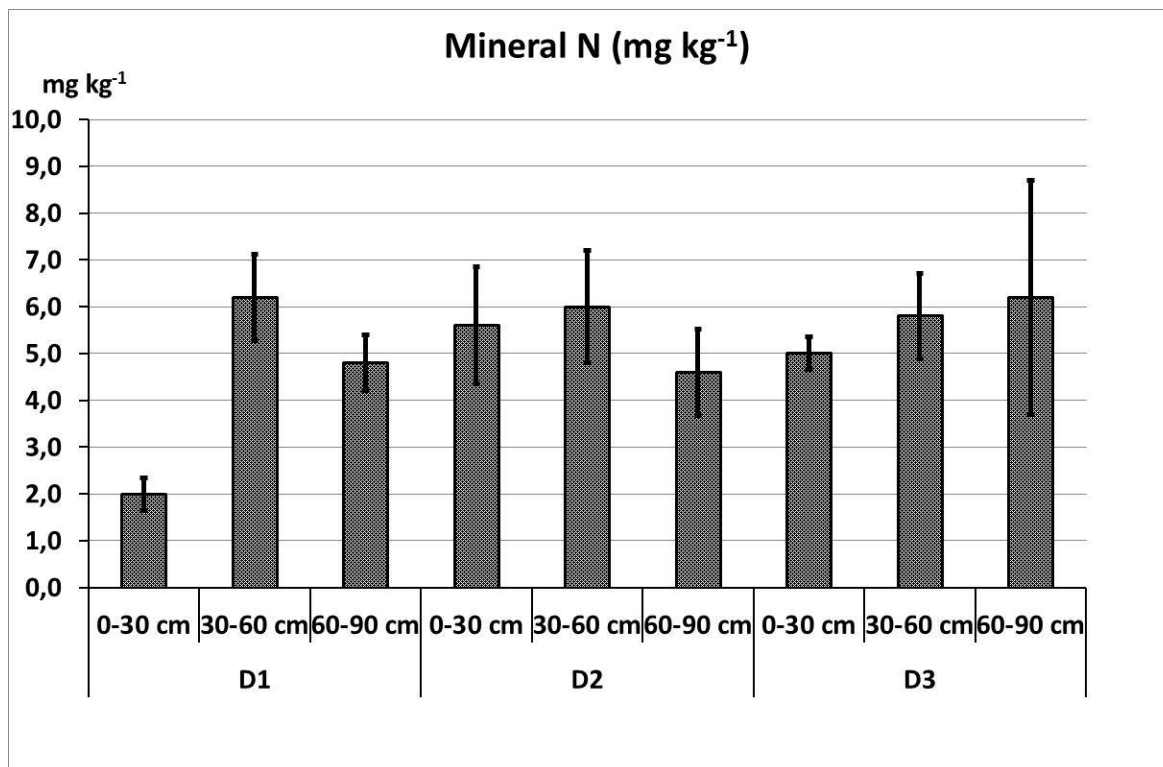


Figure 3- Average contents (mg kg⁻¹) of mineral nitrogen of soil horizons of the three plantation areas

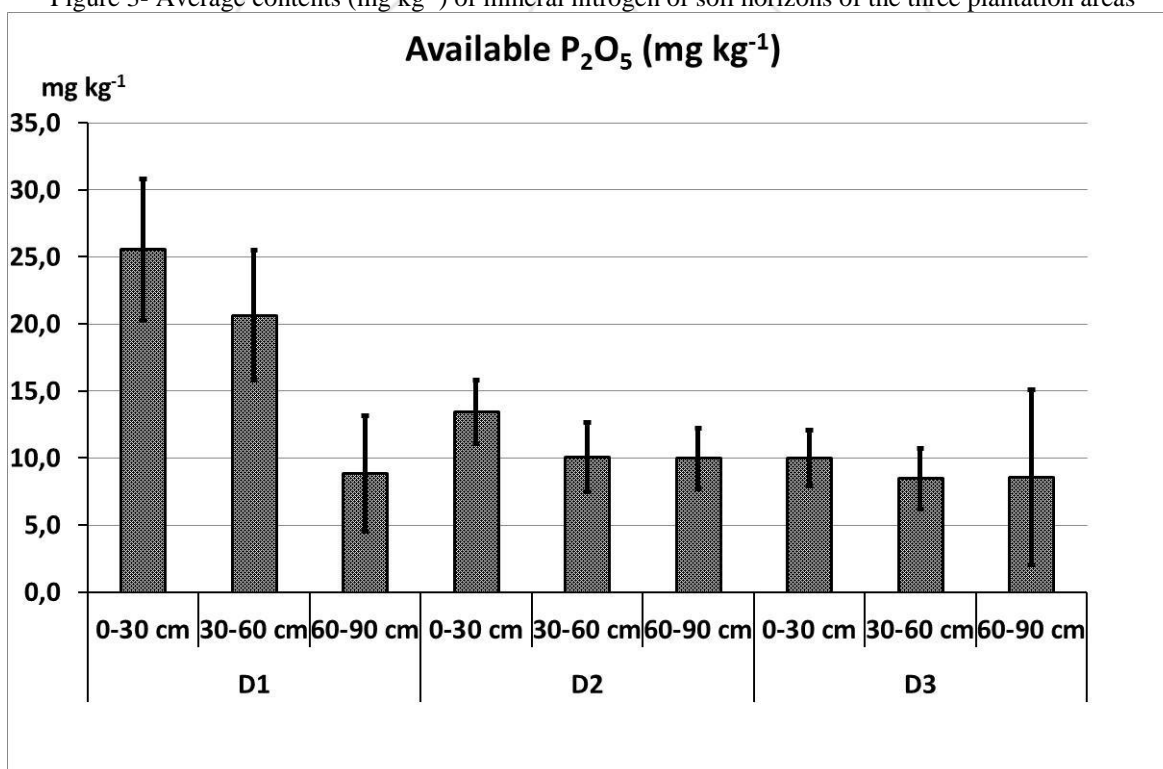


Figure 4: Average contents (mg kg⁻¹) of available P₂O₅ of soil horizons of the three plantation areas

The exchangeable potassium is, the opposite of the other two elements, sufficiently abundant especially in surface horizons where its values are of the order of 245.3 mg kg⁻¹ in the D₁ zone, 282.2 mg kg⁻¹ in the area D₂ and 220.5 mg

kg⁻¹ in the area D₃ (Figure 5). Despite their decrease in subsurface horizons of D₁ zone, reserves always exceed 100 mg kg⁻¹.

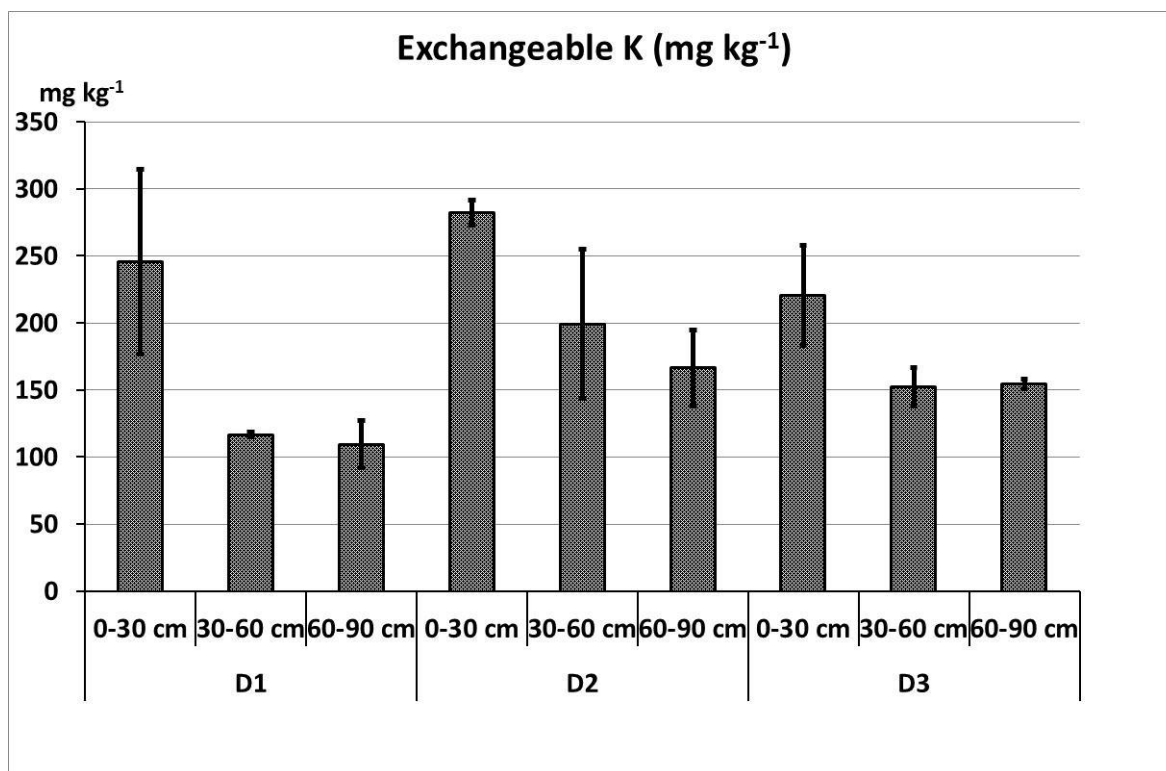


Figure 5: Average contents (mg kg⁻¹) of exchangeable K of soil horizons of the three plantation areas

This element mainly come from the mineral fraction on which it is or exchangeable (clays) or detached by weathering of other potassic minerals (micas, feldspars, ...). Its liberation by the mineralization of organic matter is also a hypothesis that we don't exclude, since it is more abundant in the surface horizons, more provided with organic matter.

Analysis results of N, P and K in plant organs

The parameters determined in aerial plant organs of this species are the dry matter contents and concentrations of N, P and K. The results obtained are shown in Table 2. Leaves nitrogen contents are close to 2.5% of dry matter and we found no significant difference between the three values; they exceed approximately 1% of flowers concentration in this element. Such a result is predictable since the nitrogen is part of the chlorophyll molecules which obviously are in the leaves and not in the flowers. Phosphorus, expressed in

P₂O₅, is more concentrated in the flowers than in the leaves and it is noted that, for all three cases, the flowers concentration in P₂O₅ is greater than that in the leaves by 1500 mg kg⁻¹. Potassium comports in a similar manner to that of the phosphorus in the two organs: it has values ranging between 8000 and 8900 mg kg⁻¹ in leaves and between 9700 and 10450 mg kg⁻¹ in flowers; there was therefore, a difference of 1500 to 1700 mg kg⁻¹ of K between the two organs. However, it is the phosphorus which presents the highest difference if we consider the differences in the proportions viewpoint. The flowers are, therefore, accumulators organs of phosphorus and potassium and not nitrogen. The edaphic parameter that showed positive correlation, but still slightly below the level of significance ($r = 0.659$) with 6 degrees of freedom, with flowers P₂O₅ content is available P₂O₅ in soil.

Table 2: Average concentrations of the dry matter of *Rosa canina* leaves and flowers in N (%), P₂O₅ (mg kg⁻¹) and K (mg kg⁻¹)

| Elements | Density 1 | | | | Density 2 | | | | Density 3 | | | |
|-------------------------------|-----------|---------|---------|--------|-----------|---------|---------|--------|-----------|--------|---------|--------|
| | Leaves | | Flowers | | Leaves | | Flowers | | Leaves | | Flowers | |
| | M* | SD** | M* | SD** | M* | SD** | M* | SD** | M* | SD** | M* | SD** |
| N | 2.29 | 0.15 | 1.61 | 0.09 | 2.52 | 0.19 | 1.61 | 0.26 | 2.36 | 0.28 | 1.40 | 0.35 |
| P ₂ O ₅ | 2960.67 | 567.24 | 4525.33 | 640.27 | 2648 | 1191.76 | 4066.67 | 286.81 | 2808 | 249.93 | 4440 | 407.29 |
| K | 7978.1 | 1335.48 | 9772.1 | 692.27 | 8868.6 | 996.79 | 10454.6 | 454.12 | 8290.1 | 604.6 | 9687.6 | 137.89 |

* M : mean ; ** SD : standard deviation

The yield of flowers and influencing factors

To assess the flowers yield, we performed by the collection of 100 flowers of each shrub, we weighed them in fresh state then counted the flowers number on each shrub. The weight of flowers per shrub is then multiplied by the number of plants per hectare which varies depending on the plant density: 500 units for D₁, 416 for D₂ and 250 for D₃. The

results obtained are shown in Table 3. We note that for the shrub 3 in the planting area D₃, production was zero because the development was stunted due to severe competition through spontaneous parasite species. The mean and standard deviation were, therefore, calculated for D₃ on two values.

Production was better in the higher planting density area (D_1) with an average of 957.77 kg of fresh flowers per hectare. It is followed by the D_2 planting zone with an average of 670.31 kg ha⁻¹. D_3 area is obviously the one with the lowest yield (566.08 kg ha⁻¹) despite higher production per unit (Table 3). Reducing the planting density, thus, increases the yield per unit but significantly decreases it per hectare.

Table 3: Flowers yield according to the plantation density

| Densities | Shrubs | Weight of 100 flowers in g | Number of flowers per shrub | Yield by shrub in g | Yield in kg ha ⁻¹ |
|---------------------------|--------------------|----------------------------|-----------------------------|---------------------|------------------------------|
| D_1 500 units per ha | 1 | 42.44 | 5170 | 2194.148 | 1097.74 |
| | 2 | 36.38 | 4990 | 1815.362 | 907.681 |
| | 3 | 32.05 | 5420 | 1737.11 | 868.55 |
| | Mean | | | | 957.77 |
| | Standard deviation | | | | 122.22 |
| D_2 416 units | 1 | 21.77 | 7240 | 1576.15 | 655.68 |
| | 2 | 25.06 | 5690 | 1425.91 | 593.18 |

| | | | | | |
|---------------------------|--------------------|-------|------|---------|--------|
| per ha | 3 | 27.84 | 6580 | 1831.87 | 762.06 |
| | Mean | | | | 670.31 |
| | Standard deviation | | | | 85.38 |
| D_3 250 units per ha | 1 | 36.79 | 5600 | 2060.24 | 513.0 |
| | 2 | 43.32 | 5740 | 2486.57 | 619.16 |
| | 3 | 0 | 0 | 0 | 0 |
| | Mean | | | | 566.08 |
| | Standard deviation | | | | 75.07 |

The only edaphic factor which positively acts, significantly and in the threshold 0.05 to 6 degrees of freedom (n-2), on the yield, is available phosphorus calculated by the average of the three soil horizons (Figure 6). This element could have affected the yield, due to its rarity in sandy soil, chemically poor and very little fertilized. For other factors, only the parameter "clay content" presented a relatively high correlation coefficient ($r = 0.551$) which remains insignificant to n-2 degrees of freedom.

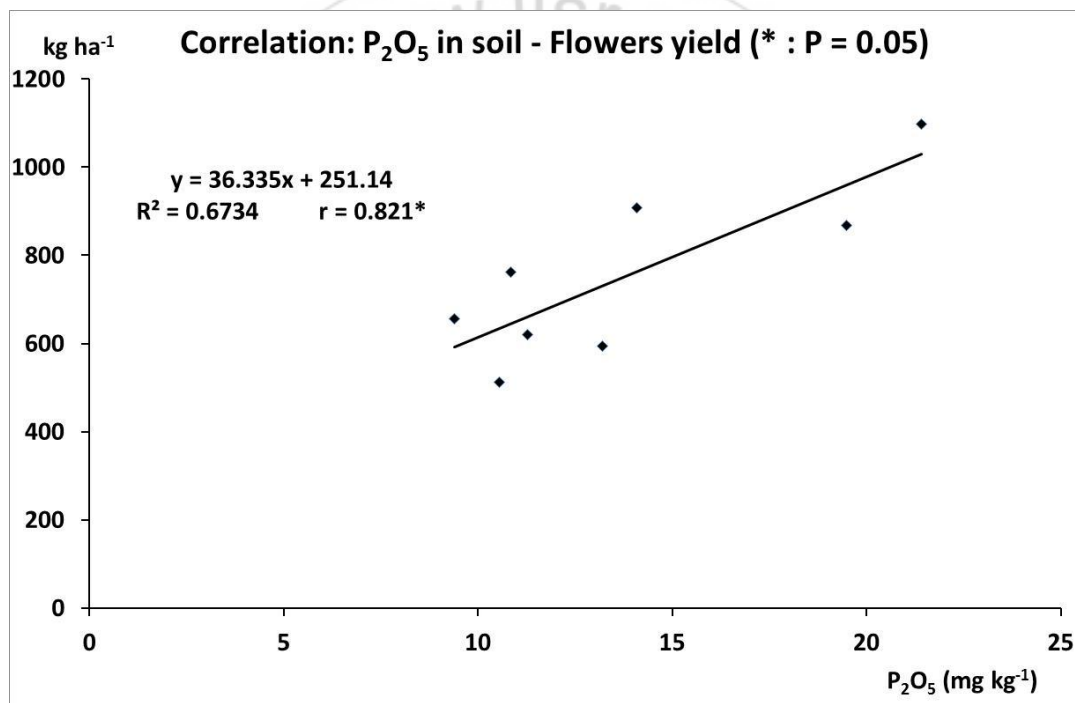


Figure 6: Simple linear regression between soil available phosphorus (P_2O_5 in mg kg⁻¹) and the fresh flowers yield (kg ha⁻¹)

Economic profitability

The profitability is linked to production costs and the income generated. It can be defined in many different ways, such as the difference between earnings and costs, or as the ratio between earnings and costs.

If the profitability of the rosehip crop has already been proven in carbonated silty clay soil (Hajji and Bayounès, 2011), the production of this species and its profitability remain unknown in sandy soil. The opportunity came here to assess the following economic parameters:

1) The raw product is the value of product sales (rosehip roses). It is calculated on the basis of an average selling price of 16 Tunisian dinars per kg of roses. Tunisian Dinar is the equivalent of 0.54 \$.

- 2) Variable expenses are the expenses related to the use of operational inputs. These are variable loads that appear, disappear or vary along activity. They include casual labor, irrigation, tillage and transport costs.
- 3) Fixed costs or expenses structures are independent productions. They include permanent workforce, amortization of shrubs, amortization of working material of the soil and the rental value of the land.
- 4) Gross margin is defined as the difference between the gross proceeds and variable loads. According Lassègue (1975), it is also called gross profit. In terms unit, it is called contribution margin, which is equal to the selling price reduced by the average variable cost.
- 5) Net margin is the difference between gross margin and fixed costs. It allows appreciating the final profitability of the business. If we admit that the structure charges are independent productions, profit will be even larger than

the gross margin will be high. In principle, it is necessary to maximize the gross margin, regardless of overheads, for maximum profit (Tournier, 1986).

- 6) Economic efficiency is measured by the coefficient of economic efficiency which is the ratio of overall expense coverage by product value. This must be greater than 1 for an operator making a profit. The most is this indicator, the higher the activity is economically efficient.
- 7) The breakeven value, also called sales critical case, is defined as the ratio between the gross product multiplied by the fixed cost and contribution margin.

Table 4: Economic analysis results of 1 hectare of rosehip (*Rosa canina*) flowers, planted in sandy soil

| Parameters | Density D ₁ | Density D ₂ | Density D ₃ |
|--------------------------------------|---------------------------|---------------------------|---------------------------|
| Average yield in kg ha ⁻¹ | 957.77 | 670.31 | 566.08 |
| Gross product in DT | 15324.32 | 10724.06 | 9057.28 |
| Variable charges in DT | 2652.8 | 1945.19 | 1536.4 |
| Fixed charges in DT | 647.59 | 631.38 | 601.2 |
| Gross margin in DT | 12671.52 | 8779.77 | 7520.88 |
| Net margin in DT | 12023.93 | 8148.39 | 6919.68 |
| Coefficient of economic efficiency | 4.6 | 4.1 | 4.2 |
| Breakeven value in DT | 783.18 | 771.26 | 724.02 |

According to the results in Table 4, the D₁ planting density with 500 plants per hectare is the density of the highest values of economic parameters evaluated. The gap is very large compared to the D₂ and D₃ densities, especially for the parameter "net margin" which represent the net profit. Economic efficiency is good for the three planting zones of that the coefficient of economic efficiency is greater than 1; however, the density D₁ is the most profitable because of the highest value of this coefficient (4.6). This allows concluding that the densification planting even in sandy soil is the most economically viable. For the breakeven value that represents the level of gross product from which the operation begins to make a profit, it is not very different for the three planting zones. We can relate this result to the fact that fixed costs do not increase greatly, if we intensify the number of plants per hectare; rosehip is not a culture that demands high fixed costs even stronger planting densities.

4. Discussion

The rosehip plantation, in the studied plot, is five years old. Shrubs have, therefore, more or less reached adult age production. The soil of the plot is sandy texture and contains a proportion close or slightly higher than 10% clay. Its contents of organic matter, N and P were low in contrast potassium whose reserves are more than sufficient. Because of its rarity, P was a limiting factor, character explained by the close correlation between the reserves of this element in the soil and yield of fresh flowers. The soil levels in all three elements have been no obvious impact on their dry matter concentration of leaves and flowers. Leaves more concentrate nitrogen while flowers accumulate more phosphorous and potassium; they, thus, constitute storage and reserve organs in these two elements (P and K). Compared to those of citrus (Ben Hassine et al, 2013; Junior et al, 2012; Koo et al, 1984; Sauls, 2007), concentrations of leaves of *Rosa canina* are almost similar to N with 2.3 to

2.5% and P with 0.12 to 0.13%; rosehips leaves appear more concentrated in K, with 0.8 to 0.9%, than those of citrus leaves whose content is of the order of 0.65%. The rosehip flowers are more concentrated in phosphorus and nitrogen and have almost similar values of K than the citrus fruit (Ben Hassine et al, 2013).

This species considered rustic, happens to get its needs of the three elements, even in sandy soil, chemically poor and not provided in organic matter. Better maintenance practices of fertilization and tillage have more favorable impacts on production and performance.

The variation of plant density seems to have had no impact on the assimilation of elements N, P and K from the soil; of this aspect, there is interest in increasing the density as plants show almost no physiological difference in the ability to absorb nutrients.

In agro-economic viewpoint, rosehip culture in sandy soil proved a profitable investment regardless of the planting density adopted. However, the density D₁ presented the best performance in terms of gross and net margins and also in terms of economic efficiency. The economic efficiency coefficient is, indeed, higher for D₁ density (500 units ha⁻¹) than D₂ density (416 plants ha⁻¹) and D₃ (250 units ha⁻¹). Values and actual gross margins could be increased by introducing the technique of distillation in the farm. The price of a liter of water rosehip produced by 1 kg of fresh flowers is almost double.

5. Conclusion

Rosa canina is not a wild plant without agronomic and economic interest; the current study confirmed that it can be planted, even in sandy soil, to produce either flowers, either wild rose water extracted from roses but also leaves; rosehip is also used in various culinary and medicinal uses. In semi-arid Mediterranean climate with a long dry season, this species has reached the adult stage after five years of culture without intensive farming techniques. It accumulates the elements N, P and K in the leaves but also, in higher contents in its flowers, especially for P and K, despite the insufficiency of mineral nitrogen reserves and available phosphorus in the soil. Its cultivation does not require a lot of investment and is profitable regardless of the planting density. The highest density (500 plants per hectare) showed, however, the greatest economic profitability and provided the best values of gross and net margins and economic efficiency coefficient. Just have two hectares of rosehips planted in 5 mx 4 m to reach the average annual income of a state employee with university level. This is a culture to encourage in all types of soils unaffected by waterlogging in semi-arid rainfed conditions firstly for its medicinal benefits and secondly for its economic profitability.

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