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# Improving Watermelon Growers Efficiency By Grafting Under A Water Scarcity Context

Abdelhafidh H[1*]., Fouzai A[1]., Rekik S[2]., Farjallah. M[1]., Cherif R[1]. And Ben Brahim M[1].

*1. Higher School of Agriculture of Mograne, University of Carthage. Tunisia*
*2. Faculty of Economic Sciences of Tunis, University of Manar. Tunisia*
*Corresponding Author; Ben Brahim M*

***Abstract:*** *Grafting has many agronomic advantages. However, there are concerns regarding the higher costs associated with the use of grafted plants in Tunisia. Limited information is available as to whether grafting can be used economically in open field production or not? The objective of this study was to determine the effects of the watermelon grafting on farms' productivity and water resource use efficiency. Using Data Envelopment Analysis (DEA), this paper evaluates the performance of a sample of watermelon growers. A comparative analysis of technical efficiency was conducted for grafted plants vs non grafted plants to assess the effect of grafting by using a Tobit model. Results indicated that watermelon growers have a poor productivity (53% on average). However, farms growing grafted watermelon are largely more efficient than those adopting non-grafted plants. The technical efficiency is about 63% in grafted mode while it is about 30% in the non grafted one. Results indicated also, that the use of grafted plants may largely save irrigation water because grafting enhances root water uptake. Efficient farms using grafted plants may save 1250m$^3$/ha. The results suggest that using grafted watermelon plants may enhance technical efficiency by 20% in watermelon farming. It can be concluded that grafting in watermelon plants positively affects farms' economic performance and Water use efficiency.*

***Keys words:*** *Watermelon, Grafting; Technical efficiency; Tunisia*

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## I. Introduction

Grafting has been used successfully in vegetable production for disease control and yield improvement in many parts of the World, especially in Asia and Europe (Lee and Oda, 2003; Lee et al., 2010). In the latest decades, vegetable grafting has also been performed to enhance tolerance to abiotic stresses, increase the efficiency of water and nutrient uptake, and improves fruit yield and quality (Bletsos & Passam, 2010; King et al., 2010). This technique offers resistance/tolerance to biotic and abiotic stressors in a variety of cucurbitaceous and solanaceous crops (Kubota et al., 2008; Lee et al., 2010; López-Pérez et al., 2006; Louws et al., 2010; Rivard et al., 2010; Venema et al., 2008). The yield increase provided by the grafted plants is a typical result of increased fruit size (Pogonyi et al. 2005), this is due to the vigorous root system of the rootstocks. Grafted plants usually show increased uptake of water and minerals when compared with self-rooted plants (Lee, Oda 2003).

In Tunisia, where land use is very intensive and continuous cropping is a common practice, vegetable grafting is considered as an innovative technique increasingly demanded by farmers. However, grafting has not been yet practiced enough by farmers as a control for soilborne pathogens and nematodes. Grafting may be a valuable tool for vegetable growers to cope with pest management challenges in the production of cucurbits and solanaceae crops. In addition, grafting may also cope with water shortage, a situation that Tunisia usually faces and which is a major limiting factor for crop productivity in this country. Grafting elite commercial cultivars on to selected vigorous rootstocks is considered as a useful strategy to alleviate the impact of environmental stress. In fact, the grafted plants have significantly higher values for vegetative growth, yield and Water Use Efficiency (WUE) in comparison with the non-grafted plants (Mahmoud A., 2014). Despite the fact that grafting improves crop resistance to pathogens diseases, it has also been utilized to increase plant resistance to temperatures variations (Tachibana, 1982, 1988, 1989).

The rootstock is essential in determining the response of the scion to drought (Soar et al., 2006). This is resulting in the potential that the breeding or selection of improved rootstocks offers for improving water use efficiency and drought tolerance of crops. Since, it is approved that grafting has many agronomics advantages. However, there are concerns regarding the higher costs associated with the use of grafted plants in Tunisia. Limited information is available as to whether grafting can be used economically in open field production or not. Considering the numerous benefits of vegetable grafting, a comprehensive approach involving production efficiency is needed to evaluate the economic benefits of using grafted watermelon transplants as a sustainable component of field production systems. The purpose of this study was to determine the effects of the watermelon grafting on farms' productivity and water resource use efficiency. The technical efficiency is a good tool to measure the farm productivity. A comparative analysis was conduct for grafted plants vs non-grafted plants to assess the effect of grafting on the technical efficiency.

## II. Theoretical framework

**Defining Efficiency**

The term "efficiency" implies the success with which a farm best utilizes its available resources to produce maximum levels of potential outputs (Dinc et al., 1998; Abdelhafidh and Bachta, 2017). A farm is efficient if, and only if, it is not possible to increase output (decrease inputs) without more inputs use (without decreasing output) (Cooper et al., 1995). Failure to obtain this potential maximum output results in inefficiency.

Michael Farrell (1957) first introduced the concept of productive efficiency. A farm is technically efficient if it produces a maximum output, given the level of inputs and technology. Thus, the production frontier is associated with the maximum obtainable level of output, given a level of inputs, or the minimum level of inputs required to produce a given output. Technical inefficiency is attributed to a failure of the farm to produce the frontier level of output, given the quantities of inputs (Kumbhakar, 1994).

In figure 1, it is assumed that there are two inputs (X1 and X2) used by a firm to produce a single output (Y) with the assumption of constant returns to scale. The II' curve represents the isoquant of fully efficient firms and could be used to measure TE. If the firm employs a given amount of inputs at point R to produce a unit of output, the technical inefficiency of that firm could be measured by the distance RS. This is the proportion by which the use of inputs could be reduced without a decrease in output. This is expressed in percentage terms by the ratio SR/OR, which stands for the percentage by which all inputs need to be reduced to gain production which is technically efficient. The TE of a firm is measured by the ratio: TE = OS/OR. If a firm has TE equal to 1, it is technically efficient. If its TE value is less than 1, then the firm is technically inefficient. When the TE is equal to 1, the firm produces with full technical efficiency. It's the case of the point S where the firm could gain full technical efficiency because point S is lying on the efficient production indifference curve.

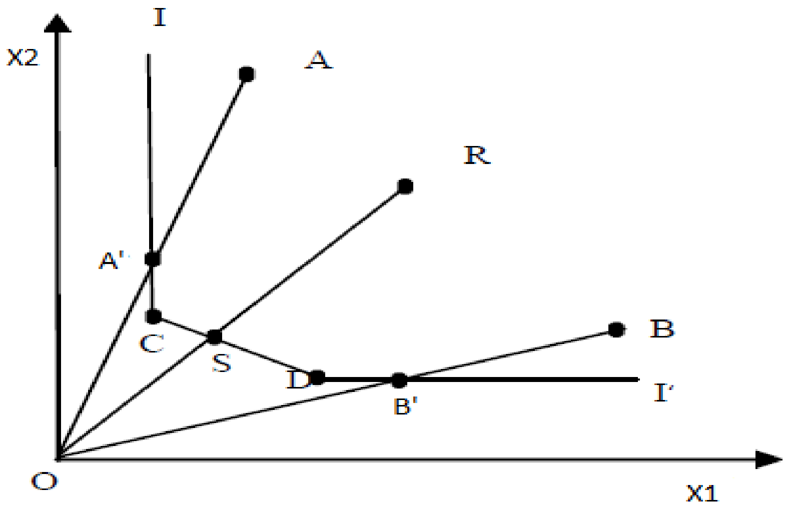


**Figure 1: Technical Efficiency, Radial adjustment, and slack identified in an input-oriented CRS DEA**

**Efficiency estimation**

The efficiency measures proposed by Farrell assume a known production function for the fully efficient decision-making unit (DMU). The production function of a DMU is generally unknown in practice, and relative efficiencies must be measured from the sample data available. Two approaches are used to estimate relative efficiency scores: the parametric or the stochastic frontier production approach (SFA) and the nonparametric or data envelopment analysis approach (DEA) (Coelli, 1995). The SFA assumes a functional relationship between outputs and inputs and uses statistical techniques to estimate parameters for the function. The disadvantage of SFA is that it imposes specific assumptions on both the functional form of the frontier and the distribution of the error term. In contrast, DEA uses linear programming methods to construct a piecewise frontier of the data. Because it is nonparametric, DEA does not require any assumptions to be made about functional form or distribution type. Second, it does not require the distributional assumption of the inefficiency term. It is thus less sensitive to misspecification relative to SFA.

Each one from these approaches has its limitations and advantages and the choice of which method to use isn't clear. Since, the choice of which method to use appears to be arbitrary, as is pointed out by Dhungana et al., (2004). We choose the DEA approach in this study since it doesn't impose a prior parametric restriction on the underlying technology (Chavas and Aliber, 1993; Fletschner and Zepeda, 2002; Wu and Prato, 2006).

## III. Methodology

**Measurement of Technical, Pure Technical, and Scale Efficiencies: CCR and BCC DEA models**

As noted above, we intend to apply the technique of DEA for computing the measures of technical, pure technical, and scale efficiencies for individual watermelon producers. In DEA, technical efficiency (TE) can be viewed from two perspectives. First, input-oriented TE focuses on the possibility of reducing inputs to produce given output levels. Second, output-oriented TE considers the possible expansion in outputs for a given set of input quantities. A measure of TE for a DMU can be defined as:

$\theta_{outpu}$t = actual output/ Maximum possible output in output-oriented context,

or $\theta_{input}$ =Minimum input possible / Actual input in input-oriented context.

To quantify a measure of TE, we need to find out the divergence between actual production and production on the boundary of the feasible production set. This set summarizes all technological possibilities of transforming inputs into outputs that are available to the organization. A DMU is technically inefficient if production occurs within the interior of this production set. A measure of scale efficiency (SE) can be obtained by comparing TE measures derived under the assumptions of constant returns-to-scale (CRS) and variable returns-to-scale (VRS). As noted above, the TE measure corresponding to the CRS assumption represents overall technical efficiency (OTE) which measures inefficiencies due to the input/output configuration and as well as the size of operations.

The efficiency measure corresponding to the VRS assumption represents pure technical efficiency (PTE) which measures inefficiencies due to only managerial underperformance. The relationship SE = OTE/PTE provides a measure of scale efficiency.

**Overall Technical efficiency :**

Under the non-parametric approach (DEA), to estimate the production frontier, we consider the "input oriented" model, according to Coelli (1996) : n farms (i=1,……n), each producing M outputs ymn (m=1,…M) by using K different inputs xkn(k=1,…..K), each farm becoming the reference unit. For the $i^{th}$ firm, we have vectors xi (K×1) and yi (M×1). For the entire data set, therefore, we have a K×N input matrix X and M×N output matrix Y. The technical efficiency (TE) measure is obtained by solving The CCR model which was initially proposed by Charnes et al., (1978). The CCR model is indicated in Eq. (1):

$$\begin{aligned} &\min_{\theta,\lambda} \theta_i \\ &\text{St} \\ &-y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \qquad (1) \\ &\lambda \geq 0 \end{aligned}$$

Where $\theta_i$ is a variable representing the efficiency of the Reference Farm i and hence the percentage of reduction to which each input must be subjected to reach the production frontier. λ is a vector of (k*1) elements representing the influence of each farm in determining the efficiency of the $i^{th}$ farm.

**Pure technical efficiency and Scale efficiency**

Pure technical efficiency is the technical efficiency of the BCC model. The BCC model was initially proposed by Banker et al. (1984). The input-oriented BCC model evaluates the efficiency of DMUj by solving the following program:

$$\begin{aligned} &\min_{\theta,\lambda} \theta_i \\ &\text{Sc} \\ &-y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \qquad (2) \\ &\sum_{i=1}^{N} \lambda_i = 1 \\ &\lambda i \geq 0 \end{aligned}$$

Based on the CCR and BCC scores, scale efficiency defined by (Cooper et al., 2006):

$$SE = \frac{TE_{CCR}}{TE_{BCC}} \qquad (3)$$

In other words, decomposition of Eq. (10) can be defined by:

$$TE_{CCR} = SE.TE_{BCC} \quad (4)$$

If the scale efficiency is less than 1, the DMU will be operating either at decreasing returns to scale (DRS) if a proportional increase of all input levels produces a less-than-proportional increase in output levels or increasing return to scale (IRS) at the converse case. This implies that resources may be transferred from DMUs operating at DRS to scale to those operating at IRS to increase average productivity at both sets of DMUs (Boussofiane et al., 1992).

**Slacks and radial adjustments**

DEA identifies the most efficient point on the frontier as a target for those inefficient. For the ith DMU, the distance from an inefficient point, where it is located, to the projected point on the frontier by radial adjusting the level of inputs, $(1-\theta_i) \cdot x_i$, is called "radial adjustment". Moreover, the mostly seen piecewise-linear form of the non-parametric frontier causes the second stage to shift from the projected point to a point at the practical minimum level of the inputs on the frontier. The distance of shifting along with the frontier in between is called "slack". How a point with a practical minimum level for inputs on the frontier can be identified in DEA is illustrated in Figure1 with a case of one output and two inputs. The maximum level Y output by the DMUs located on the frontier is normalized to unity and generated from the inputs which are also normalized by dividing Y. Point R is the actual input set and point S is the projected point on the frontier for DMU R as the target in order to improve its efficiency accordingly by reducing the radial adjustment RS.

Yet, as aforementioned, the practical frontier is a piecewise linear format that requires the second-stage adjustment to determine a practical minimum point for inputs. In Figure 1, point B' is the projected point on the frontier for another DMU B as the target to reach by reducing the radial adjustment BB'. Therefore the input level at point B' could be further reduced to the input level at point D while maintaining at the same time the same output level. The amount DB' that shall further be adjusted for the input level at point B' along with the frontier is called 'slack'.

The summation amount of slack (DB') and radial adjustment (BB') for inputs is called the level of total adjustments (DB), meaning that it is the total amount for inputs which should be adjusted by a DMU so as to reach its optimal production efficiency. The adjustments require both a promotion of technology level and an improvement in the production process so that OTE is optimized. The amount of total adjustments therefore decreases and the output level is maximized so that the DMU operates at the frontier position of production efficiency. The practical minimum input level is called the target input level for a DMU. Thus, for an input, the summation provides an "Input reduction target" (IRT) and for any input X the formula is as follows (Hu, 2006; Abelhafidh et al., 2017):

IRT(X) = Radial adjustment of input X + Slack of input X. (5)

Then an inefficient DMU can reduce the IRT without reducing its growth and so it can improve its efficiency. The CRS model of DEA suggests the slack and radical adjustment of the individual input and the amount of target input can be calculated accordingly. The 'total adjustment amount' is then obtained from the gap between the actual input level and the targeted input level.

The IRT computed by DEA shows a target amount of input to be reduced in a DMU or in a region to reach the optimal production efficiency at the frontier and therefore a simple index named the Input adjustment target ratio (IATR) is constructed as a ratio format of IRT to measure the ratio of IRT to the amount of total water use in the region (Hu, 2006). The IATR index is constructed below:

$$\text{Input Adjustment Target Ratio (IATR)} = \frac{\text{Input Reduction Target}}{\text{Actual Input}}$$

The IATR reflects what ratio of Input use is able to decrease without affecting the regional economic output level.

**Tobit Model**

The present study uses the Tobit regression to analyze the role of farm attributes in explaining TE This approach has been used widely in efficiency literature (Speelman et al, 2008; Chebil et al.,2015; Abdelhafidh et al, 2018). In fact, the values of the dependent variable lie in the interval (0-1). The censored Tobit model can be then used to get a consistent estimation. The Tobit regression used in our study is specified as follows:

$$\theta_i = \begin{cases} \theta_i^* \text{ if } 0 < \theta_i^* < 1 \\ 0 \text{ if } \theta_i^* \leq 0 \\ 1 \text{ if } \theta_i^* \geq 1 \end{cases} \quad (6)$$

Where $\theta_i$ are technical efficiency scores used as dependent variables. $\theta^*$: is the value of an artificial variable (unobservable) that is related to explanatory variables ($X_i$) as the following relationship:

$$\theta_i^* = x_i \beta^* + \varepsilon_i \quad (7)$$

Where: $\varepsilon_i$ error term and β are parameters to be estimated.
The estimation of the Tobit model is based on maximum likelihood procedures. For Tobit estimates to be consistent, it is necessary that residuals are normally distributed (Holden, 2004).

**Data and empirical procedures**
**Study area**

The data used in the current study is about the production structure of 57 farms over two geographic regions with different climatic conditions. Heterogeneity is likely to characterize the sample (different farm sizes, uneven management skills, etc.). Farm-level data are obtained by interviewing farmers who produce watermelon crops. The sample was compounded by 32 farms located at the province of Jendouba in the sub-humid bioclimatic stage with annual precipitation of 800 mm and 25 farms located in the province of Nadhour in the higher semi-arid bioclimatic stage with an annual precipitation of 450mm.

**Variables**

Data include farm production, input use, and socioeconomic characteristics. The survey was conducted during the planting season in 2016. Inputs included in the analysis are; total area (ha) of watermelon planted land ; crop-specific inputs (mechanization, hired and family labor, and fertilizers and crop protection products in monetary units).

**Table 1:** Summary statistics of the variables used in the analysis of efficiency

| Variables | | Mean | S.D | MIN | Max |
|---|---|---|---|---|---|
| output | Output value(TND) | 36226 | 26013 | 7500 | 122500 |
| inputs | Water melon planted area(ha) | 2,8 | 1,4 | 1,0 | 6,0 |
| | Irrigation water expenses (TND) | 532 | 354 | 50 | 1530 |
| | Machinery expenses (TND) | 1637 | 1183 | 240 | 5800 |
| | Labour expenses(TND) | 1290 | 1027 | 250 | 5000 |
| | Fertilizers and protection expenses(TND) | 12438 | 6737 | 3770 | 36750 |
| Specifics factors | Age (years) | 41 | 10 | 25 | 64 |
| | Education level: NI (1 if the education level was up to primary , 0 otherwise) | 0,63 | 0,49 | 0 | 1 |
| | Main Occupation ( 1 if the famers has agriculture as main occupation, 0 otherwise) | 0,88 | 0,33 | 0 | 1 |
| | Water source (1 if the farmer uses two sources, 0 if he uses only one) | 0,63 | 0,49 | 0 | 1 |
| | Grafting (1 if farmer uses grafted plants, 0 otherwise) | 0,58 | 0,50 | 0 | 1 |
| | Vulgarization(1 if farmers receive vulgarization support, 0 otherwise) | 0,58 | 0,50 | 0 | 1 |
| | Location (1 if farms are located in Jendouba province, 0 otherwise) | 0,44 | 0,50 | 0 | 1 |

Regarding technical efficiency determinants, we integrated age, Education level, and location, agriculture as the main activity, irrigation water source, grafting, and vulgarization services as related factors. Table 1 provides descriptive statistics of the mains used variables

## IV. Empirical Results

**Efficiency scores results**

The estimation of efficiency scores through DEA models was conducted using the DEAP (Data Envelopment Analysis Program) software. Distribution of PTE, SE, and OTE of watermelon farms considered in our sample are summarized in Table 2.

For the SE, results show that 84% of farms are experiencing increasing returns to scale; while 4%of them have decreasing returns to scale and only 12% are scale efficient. We also note that 80% of grafted watermelon farms are experiencing increasing returns to scale against 94% of non-grafted watermelon farms; Since the majority of farms can increase their production efficiency by increasing their input use.

The analysis shows that the average OTE is about 53%. This reflects that the current level of output can be achieved using 47 % fewer inputs on average. OTE varies between a minimum of about 16% and a maximum of 100%. We note that 35% of farms have OTE scores less than or equal to 40%; about 35% of them are of an efficiency ranging between 40% and 60%, and only 18% of farms have an OTE strictly greater than 80%. These results provide information on the heterogeneity of the farm's performances and the potential for increasing watermelon production in the regions of Jendouba and Nadhour.

**Table2:** Frequency of distribution of PTE, SE, and OTE estimates.

| | Grafted Watermelon | | | N.Grafted Watermelon | | | Over All sample | | |
|---|---|---|---|---|---|---|---|---|---|
| | PTE | SE | OTE | PTE | SE | OTE | PTE | SE | OTE |
| Average (%) | 76 | 83 | 63 | 62 | 53 | 30 | 72 | 74 | 53 |
| Min (%) | 40 | 38 | 36 | 36 | 25 | 16 | 36 | 25 | 16 |
| Max (%) | 100 | 100 | 100 | 100 | 96 | 54 | 100 | 100 | 100 |
| Std.Dev. (%) | 20 | 17 | 22 | 20 | 23 | 9 | 21 | 23 | 24 |
| Efficiency ≤ 40% (%) | 0 | 3 | 10 | 12 | 35 | 94 | 4 | 12 | 35 |
| 40<Efficiency ≤60%(%) | 28 | 8 | 48 | 41 | 35 | 6 | 32 | 16 | 35 |
| 60<Efficiency ≤ 80% (%) | 28 | 28 | 18 | 24 | 18 | 0 | 26 | 25 | 12 |
| Efficiency > 80% (%) | 45 | 63 | 25 | 24 | 12 | 0 | 39 | 47 | 18 |
| IRS (%) | 80 | | | 94 | | | 84 | | |
| DRS (%) | 2 | | | 6 | | | 4 | | |
| CRS(%) | 18 | | | 0 | | | 12 | | |

Regarding the cultural mode (grafted and non grafted watermelon) the results show that the OTE is about 63% in grafted while it is about 30% in the non grafted mode. This shows the great effect of grafting on watermelon farms' productivity. The marginal effect of grafting will be more discussed and determined by the Tobit model later.

The calculated IRT and IATR are presented in table 3. The results show the inputs reduction target, so no input is used at the optimal level. The results signify that if farmers were to operate efficiently (i.e. have zero inputs slacks), the present inputs level should be reduced by 35%, 30%, 34% , 42% and 29% respectively for area, irrigation water, machinery, labour and fertilizers and protection expenses for the grafted watermelon plants versus 56%, 67%, 55%, 70% and 47% for the non-grafted watermelon plants.

**Table 3**: Inputs target, Adjustments, and IATR

| Inputs | Watermelon Plants | Area (ha) | Irrigation Water expenses (TND) | Machinery expenses (TND) | Labor expenses (TND) | Fertilizers and protection expenses (TND) |
|---|---|---|---|---|---|---|
| Actual | Grafted | 113 | 51350 | 21990 | 48990 | 516800 |
| | Non grafted | 48 | 40880 | 8360 | 24760 | 193700 |
| Target | Grafted | 73,5 | 35699 | 14502 | 28230 | 310926 |
| | Non grafted | 21 | 13371 | 3722 | 7403 | 83930 |
| Radial Ajustments | Grafted | -32,5 | -15567 | -6453 | -14545 | -149762 |
| | Non grafted | -21,5 | -17601 | -3759 | -11124 | -90766 |
| Slacks | Grafted | -7,0 | -14 | -1081 | -6045 | 0 |
| | Non grafted | -5,5 | -9878 | -835 | -6183 | 0 |
| IRT | Grafted | -39,5 | -15581 | -7533 | -20590 | -149762 |
| | Non grafted | -27,0 | -27479 | -4593 | -17307 | -90766 |
| Inputs Adjustments Target Ratio | Grafted | -35% | -30% | -34% | -42% | -29% |
| | Non grafted | -56% | -67% | -55% | -70% | -47% |

It's clear that in non grafted cropped watermelon plants mode, inputs were more inefficiently used than in the grafted plants mode and the gap between the IART in the two modes is very large. The consequence of overutilization of inputs increases the production costs, which results in low profit for farmers and ultimately low standard of living.Regarding the water shortage in the county, cropping grafted watermelon plants can reduce largely water consumption. To be efficient, farmers in grafted mode have s to reduce irrigation water consumption by only 30% versus 67% in non grafted mode. Moreover, the target irrigation water consumption/ha is about 4048m3/ha in the grafted mode versus 5300m3/ha in the non grafted mode. Hence grafting enhances irrigation water use and can reduce the consumed quantities by more than 20% which contributes to water saving.

**Determinants of the efficiency**

Tobit regression explaining efficiency, as defined in equation 6 is estimated using Stata package. The results of the Tobit model estimation by maximum likelihood are shown in Table 4.

**Table 4:** Tobit estimation results of factors affecting efficiency scores

| Variables | Coefficient | t-Statistic | P>t |
|---|---|---|---|
| Age | 0.002 | 0.57 | 0.574 |
| Education | 0.090 | 1.63 | 0.11 |
| Main occupation | 0.133 | 1.78 | 0.082 |
| Water source | 0.140 | 2.12 | 0.039 |
| Grafting | 0.200 | 3.38 | 0.001 |
| Vulgarization | 0.116 | 2.02 | 0.049 |
| Location | -0.179 | -2.71 | 0.009 |
| Constant | 0.099 | 0.7 | 0.484 |
| LR chi2 | 48.57 | | |
| Prob> chi2 | 000 | | |
| Log-likelihood | 10.55 | | |

Regarding the Tobit model results, the likelihood ratio test rejects a null hypothesis that all slope parameters are simultaneously nil. This confirms that the Tobit model is statistically valid. Overall technical efficiency is positively affected by all explaining factors except the location with a coefficient of -0.179 which indicates that farms located in the province of Jendouba are more efficient than those in the province of Nadhour. This may be explained by the irrigation water quality. Farms in this province usually use surface water with very low salinity whereas farms located in Nadhour usually use groundwater which has poorer quality regarding the salinity charges caused by the over exploitation of the aquifers.

The Tobit model results also indicated that grafting has the most marginal effect on technical efficiency with a coefficient of 0.2 and significant at the 1% level. This implies that farms that adopt grafting are able to enhance their efficiency by 20%. Results also show that water source which is a proxy of water availability positively affects technical efficiency; since the corresponded coefficient is 0.14 and significant at the 5% level. This means that farms which have access to more than one irrigation water source can improve their efficiencies by 14%. In addition, the type of the main occupation (agricultural or otherwise) seems to affect productivity positively, and is significant at the 10% level. While education level and age tend to increase efficiency but are not significant at the 10% level. The adoption of new agricultural technology as grafting is assumed to lead to higher growth in both the productivity and the production of watermelon. Thus, farmers would be able to utilize the agricultural production factors at an optimal level, alongside technical knowledge diffusion. Finally, based on the empirical results, some suggestions and policy recommendations can be raised such as encouraging technological package and supporting the use of grafted watermelon plants for enhancing productivity and saving irrigation water especially in a water scarcity context.

## V. Conclusion

Watermelon is an important vegetable in Tunisia and it's being cultivated in a wide area throughout the country. Soil-borne diseases may cause a decrease in the cultivated area of this important crop. Yield and quality may heavily be affected in infested soils. Thus, the selection of rootstocks resistant to soil pathogens seems to be an effective solution. This study has focused on the technical efficiency of the watermelon growers. A key underlying motivation for the study has been to identify the effect of grafting on farms' productivity. To ensure that grafting has an economic enhancement in watermelon production, it is important that the maximum output from the use of inputs (Soil, water, machinery, etc.) is achieved and to compare the efficiency of farmers who are adopting grafting versus those who do not. Overall technical, pure technical and scale efficiencies have been estimated for a sample of 57 watermelon growers in Jendouba and Nadhour regions (North Ouest and Central Tunisia) using Data Envelopment Analysis method. The factors, which influence the overall technical efficiency scores in watermelon production, have been also determined using a Tobit model. The main results that can be retained from this analysis indicate the existence of low efficiency for both types of growers. It's about 53% on average for the entire sample. However, farms growing grafted watermelon plants are largely more efficient than those adopting non-grafted plants. The technical efficiency is on average 63% in the grafted mode while it is about 30% in the non-grafted. Results indicated that the use of grafted plants may largely save irrigation water because grafting enhances root water uptake and efficient farms using grafted plants may save 1250$m^3$/ha than efficient farms using non-grafted plants. The Tobit model results, also, showed that grafting might enhance technical efficiency by 20%. It can be concluded that grafting in watermelon plants positively affects productivity. Consequently, the government should support farms to use grafted plants in order to raise the current level of productivity, food security and hence development sustainability.

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