Motorization and small vegetable farms in the Tunisian Sahel: Performance and soil preparation costs

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Jel classification: Q120, Q180

Abstract

In this research work, we compare the small powers (two-wheeled tractor and small tractor) to the standard tractor in terms of hourly performance or field time, soil preparation costs and field yield. These machines have been used on three soil types with different textures (clayey-sandy, sandy-clayey and sandy) in the "Sahel", the Tunisian central coast area, characterized by small-sized farms producing vegetable crops. Results show that for all operations, the best hourly performance is obtained with the small tractor. Indeed, this performance equalled on average 5.5, 4.1 and 2.8 hours/ha, respectively for ploughing, for the first and the second shallow ploughing. Regarding the field yield, the two-wheeled tractor and the small tractor were more powerful. They got respectively 70 and 62% in ploughing, 76 and 70% in the first shallow and 68 and 65% in the second shallow ploughing. In terms of soil preparation costs, the small powers were the best and particularly the small tractor. The latter led to an average cost for the three soil categories of 75.1 TD/ha, against 132.2 TD/ha for the two-wheeled tractor and 211.4 TD/ha for the standard tractor.

Résumé

Les performances horaires ou temps de chantier, les coûts de préparation du sol et le rendement de chantier de la petite motorisation (motoculteur, petit tracteur) comparés à ceux du tracteur standard, ont été étudiés pour trois types de sol dans de petites exploitations maraîchères du Sahel tunisien de tex - ture argilo-sableuse, sablo-argileuse et sableuse. Les résultats montrent que les meilleures performances ont été réalisées par le petit tracteur pour l'ensemble des opérations. Ces performances étaient, en moyenne sur les trois sites, de 5,5 - 4,1 et 2,8 heures/ha respectivement pour le labour, le premier et le deuxième recroisement. Au niveau du rendement de chantier, le motoculteur et le petit tracteur sont plus performants. En effet, ils ont procuré respective - ment 70 et 62% en labour, 76 et 70% en premier recroisement et 68 et 65% en deuxième recroisement. En termes de coûts de préparation du sol, les plus faibles correspondent aux petites puissances. Plus précisément, c'est le petit tracteur qui est le plus avantageux et ce, pour les trois sols. Ce dernier en - gendre un coût moyen de 75,1 DT/ha contre 132,2 DT /ha pour le motoculteur et 211,4 DT /ha pour le tracteur standard.

Introduction

Increasing crop yields depend mainly on the optimisation of all techniques, the maintenance of their effectiveness and their adaptation to the land and farmer's ability. This increase could be possible through the adoption of more intensive production systems (FAO, 1996).

In Tunisia, the costs of mechanized services are increasing more than the agricultural output prices, reducing the profitability of the whole mechanization operation. Consequently, some adjustments should be applied to rationalize its density and to improve its effectiveness by setting suitable methods and appropriate materials (FAO, 1996).

Mechanization cost share ranges between 25 and 30% of the total farm costs. Those related to soil tillage are estimated between 50 and 70% of the mechanization costs (Vitlox, 1997). Thus, a cost-benefit analysis has to be performed before buying any material because the underuse of machines involves high fixed costs and reduces crop profitability (Anken et al., 1999).

The reduction in an expensive energy loss during soil preparation depends on the tractor-tool adaptation and on their operational characteristics. Several research works have been conducted to evaluate the tractor field performance (Ismail et al., 1981; Erickson and Larsen, 1983). This performance is closely related to the soil physical properties such as the apparent density, texture and water content which vary according to the soil type (ASAE, 1992).

Although the economic aspect is not the only factor behind the choice of some material, the inherent expenses related to the use of agricultural machinery cannot be overemphasized (Tissot, 1990). The mechanization loads are only a share of the whole operating expenditure, but they can increase quickly if one wants to intensify production (Bonnefond, 1970). Indeed, agricultural production intensification is characterized mainly by an increase in the mechanized soil tillage operations (Vitlox and Loyen, 2002). Thus, the material must be selected according to the available days for tillage, and the technical choices depend basically on the soil behaviour (Vitlox, 1997).

In the "Sahel" the Tunisian central coast area, characterized by small-sized farms producing vegetable crops, including 1207 ha of greenhouse crops, the use of large-sized machines poses serious technical and economic problems (Chehaibi et al., 2003). The aim of this work is to lead a comparative study in terms of time performance and soil preparation costs between different traction equipment (6 to 60 kW) on several soil categories of the area.

2. Material and methods

The performance of agricultural equipment used for the soil tillage trials was measured according to Tissot (1990)

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and Miserque et al. (2000), and interpreted based on the following criteria:

- Effective working time (Te: h/ha): the machine operating time, excluding corners' wasted time and any stop of any kind. The effective working time depends only on the tillage width and speed;
- Soil tillage time or time performance (TC: h/ha): it includes the effective tillage time and non-directly productive times (turns, stops, etc.), excluding products supply time, transfer from site to site or inside the farm, etc;
- Field yield ($\sum$C: %): ratio of the effective working time to the field time. This magnitude characterizes the effectiveness of the mechanical work in normal conditions.

$$\eta_c = 100 \cdot \frac{T_e}{T_c} with: \eta_c = \text{fieldy yield (\%)};$$

T_e = effective working time (h / ha)

T_c = Field time (h / ha)

The machine implementation costs (traction machines, harnessed tools) include fixed and variable costs. The fixed costs comprise depreciation, interest, housing, taxes and insurance. The variable costs include fuel, oil, lubricants, tires, repairs and labour.

The tillage average cost expressed in Tunisian Dinars per hectare (TD/ha) is calculated by adding ploughing to reprise costs (Tissot et al., 1997). The cost of a given operation is defined as the product of the hourly cost of the tractor-tool (TD/hour) and its time performance (hours/ha). Three categories of power tractions divided into two groups were used. The first was tested for two soil categories and included a two-wheeled tractor (trial 1), a small tractor (trial 2), and a standard tractor (trial 3) with a 6, 22 and 52 kW-power, respectively. The second, composed of a two-wheeled tractor (trial 4), a small tractor (trial 5), and a standard tractor (trial 6) with a 6, 22 and 60 kW-power respectively, was applied to another soil. Ploughing was carried out using ploughshare and mould boards. Their estimated work width is 0.27, 0.75, 1.05, 0.23, 0.75 and 0.9 meters, respectively. The ploughing reprise was carried out by rotary cultivators with the following work widths: 0.60, 1.20, 1.30, 0.50, 1.20 and 1.50 meters, respectively from trials T1 to T6.

The tillage experiments were run in three small-sized plots of different texture: Sandy-Clayey (SC), Clayey-Sandy (CS) and Sandy (S).

The first two plots, whose size was 50 X 60 m^2, were further divided into subplots of 5 x 50 m^2. The third plot had a size of 45 x 30 m^2 and was also divided into subplots of 5 x 30 m^2.

Plots characterized by a gentle slope (1.7% and less) were divided perpendicularly according to the slope direction. Each subplot was ploughed with a row plough and mould boards whereas for shallow ploughing a rotary cultivator was used.

Tab. 1. *Trial description on the SC and CS soils (Sous se region)*

Trial	Soil nature			
	SC		CS	
	ploughing depth [cm]	*water content [%]	ploughing depth [cm]	*water content [%]
T1	13		13,5	
T2	13	11,5	15	7,1
T3	21		17	

Average water content on the 0-30 cm horizon

Table 1 shows the trial schedule on soils SC and CS.

Table 2 describes the trials run on the sandy soil.

The experiments were conducted on the different sites according to a complete random block design with replicates on the three soil types. Statistical data were processed by the variance analysis, using the SAS software (Statistical Analysis System, 1990).

Tab. 2. *Trial description in sandy soil (Monastir region)*

Trial	Sandy soil	
	ploughing depth [cm]	water content [%]
T4	19	
T5	24	3,2
T6	43	

3. Results and Discussion

3.1 Hourly performance

Fig 1. *Machinesnhourly pernabce for soilks SC and CS respecti - vely*

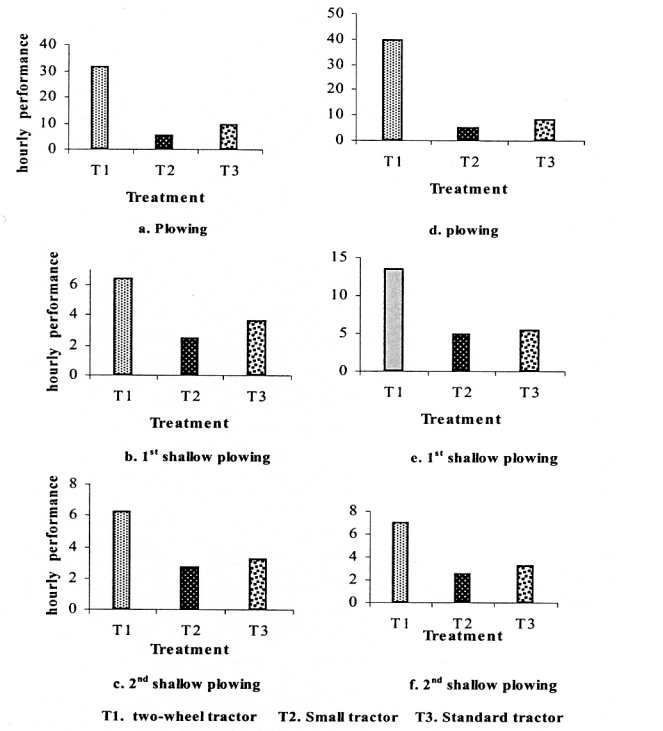


Fig. 2. *Machines hourly performances of the sandy soil*

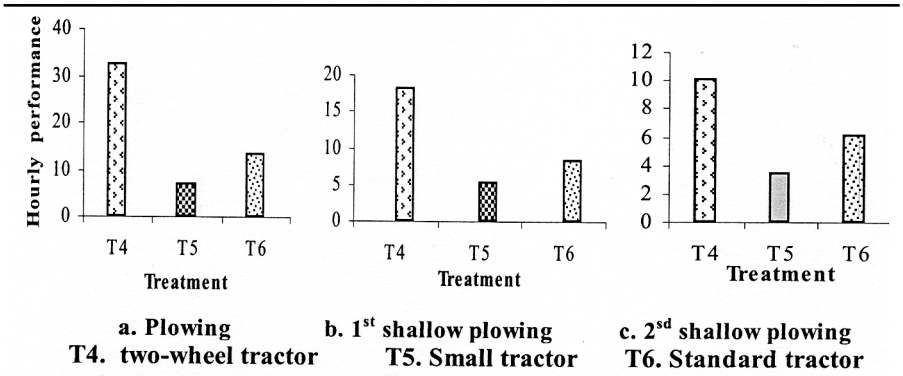


Figure 1_{abc} shows that for all operations, the small tractor and the two-wheeled tractor achieved respectively the best and the worst hourly performance. Indeed, to plough one hectare, the small tractor spent 5.2 hours as against 31.2 hours for the two-wheeled tractor and 9.5 hours for the standard tractor.

Regarding ploughing reprise, the machine hourly performance was similar (in direction) to that obtained during the ploughing operation. The small tractor gave the lowest averages (2.4 and 2.7 hours/ha) and the two-wheeled tractor the highest averages (6.4 and 6.2 hours/ha), respectively for the first and second shallow ploughing. However, the standard tractor spent 3.6 and 3.2 hours/ha respectively for the two operations.

In addition, on the CS soil (fig. 1def), the small powers (small tractor and two-wheeled tractor) also generated low and high time performance. They allowed 4.6 and 39.3 h/ha at ploughing, 4.8 and 13.4 h/ha at the first shallow ploughing and 2.5 and 6.9 h/ha at the second. On the other hand, for the same operations, the time performance of the standard tractor was 7.7, 5.3 and 3.2 h/ha.

Considering the sandy soil ploughing (fig. 2), results show that the best time performance is attained by the use of the small tractor (6.8 h/ha) while the lowest performance is recorded with the two-wheeled tractor (32.3 h/ha).

On the other hand, for shallow ploughing operations, this performance equals 5.2 and 3.4 h/ha for the small tractor, 8.4 and 6.1 h/ha for the standard one and 18.0 and 10.1 h/ha for the two-wheeled tractor, respectively in the first and second operation.

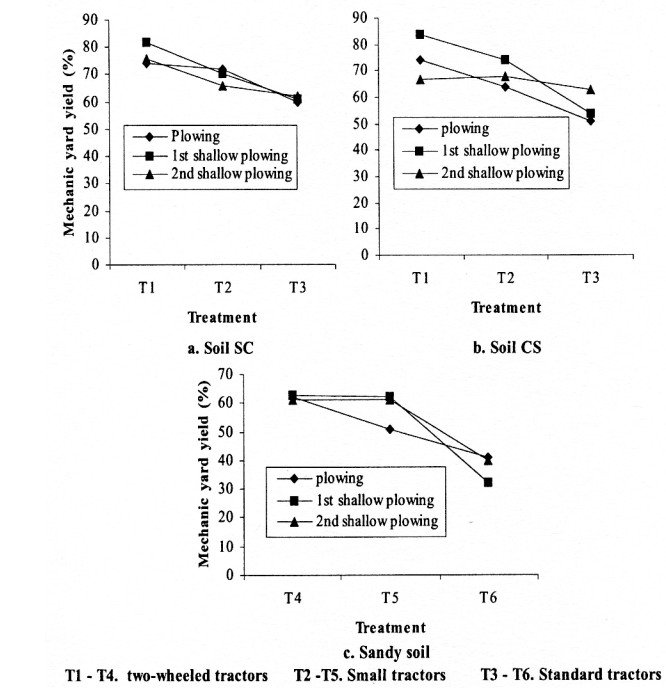
The hourly performance differences observed for the various machines applied to the various soil types depended on the soil texture, the available traction effort, the tool width, the working speed, the driver's ability, and especially on time waste caused by the corner operations and specific soil resistance which is related to water content at the intervention time.

For example, the SC soil ploughing at a low water content (7.3% on the 0-30 cm horizon) requested hard working of the plough parts and consequently of traction equipment. But, given the limited power of the two-wheeled tractor, wheel slipping was often observed. Consequently, its time performance was relatively high (39.5 h/ha). As for the sandy and sandy-clayey soils (water content at the ploughing time of 3.2 and 11.5%, respectively), the low performance of the two-wheeled tractor was attributed to the soil texture for the former and to the texture and water content for the latter (32.3 and 31.2 h/ha).

3.2. Mechanical field yields

Figure 3 shows that the best mechanical field yields for the three operations on the various soils were obtained with the two-wheeled tractor whereas the worst were recorded with the standard tractor. Indeed, as to SC soil, yields in terms of ploughing and first and second shallow ploughing were of 72.2%, 66% and 82.76% respectively for the small tractor and the two-wheeled tractor. On the other hand, the standard tractor yields were close to 61% for the three operations. The statistical processing highlighted significant differences between the small powers and the standard tractor for ploughing and first shallow ploughing operations. In contrast, regarding the second shallow ploughing, there was no significant difference between the three machines.

Fig 3. *Mechanic yard yekds of the different machines for tillage operations*



For the CS soil (fig.3b), the two-wheeled tractor yield came to 74%, 84% and 67%, respectively while the small tractor allowed yields of 64%, 74% and 68% respectively,

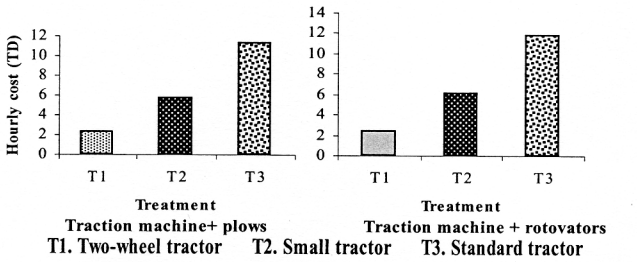
in ploughing, first and second shallow ploughing. Standard tractor yields were of 51%, 54% and 63% for the same operations. For the ploughing operation, there was a significant difference between the small powers and the standard tractor while for the first shallow ploughing, only the two-wheeled tractor significantly differed from the standard tractor. Finally, the three machines showed no significant differences in the second shallow ploughing.

Considering the sandy soil (Fig. 3_C), results show that the best mechanical field yields were also obtained by the small powers for all operations. The statistical data processing highlighted similar ploughing performance of the small tractor and the two-wheeled tractor. However, a significant difference was obtained between the last two and the standard tractor. More precisely, the small powers differed significantly from the standard tractor during the first reprise and became too much lower during the second reprise operation. Hence, the use of small powers allowed a better performance as regards the standard tractor. Furthermore, the best field yields were obtained with the two-wheeled tractor thanks to its small size which reduced waste of time when taking corners. However, for the limited size plots, the small tractor exhibited the best hourly performance due to its adaptability and high-speed manoeuvre operations. Indeed, compared to the two-wheeled tractor the small tractor was faster and had a higher traction effort reserve. The advantage of the small tractor compared to the standard one derived from its better adaptation and flexibility in limited space which allowed to till a larger area and to reduce waste of time in the corners.

3.3. Hourly costs

Figure 4 illustrates that the hourly cost of traction equipment is closely related to its nominal power. Indeed, the hourly cost of a standard 52 kW-power tractor is 11.0 TD[1]. However the cost of small pieces of equipments, with nominal power of 22 kW and 6 kW respectively, is 5.4 TD for the small tractor and 2.1 TD for the two-wheeled tractor.

Fig. 4. *Forecasted hourly costs of agricultural machines used in soils SC and CS*



It is worth noting that the hourly cost of the coupled tools depends on their size. Thus, for a given operation the hourly cost of all traction machines and their attachments is high and low respectively, for the big and small powers.

Concerning sandy soils (Fig. 5), similar results are obtained. Indeed, the use of a standard tractor implies a cost of 8.9 TD/hour while for the small powers, the cost amounts to 5.8 and 2.4 TD/hour, respectively for the small tractor and the two-wheeled tractor. Moreover, for the traction machines and their attachment combinations, the hourly cost for a given operation is also high for the standard tractor.

3.4. Soil preparation costs

Soil preparation costs are illustrated in figure 6. Results show that the small tractor allowed the lowest cost on average in the three soil categories. Indeed, the use of this machine costs 60.7, 70.2 and 94.5 TD/ha respectively for SC, CS and S soils. However, the use of a two-wheeled tractor for the same operations costs 101.3, 137.7 and 160.0 TD/ha, while for a standard tractor the costs come to 187.7, 186.3 and 260.3 TD/ha.

The statistical analysis indicated significant differences between the small tractor and the other machines in SC and CS soils, and between the two small powers and the standard tractor in the sandy soil.

Fig. 5. *Forecasted hourly costs of the agricultural machine used on the sandy soil S*

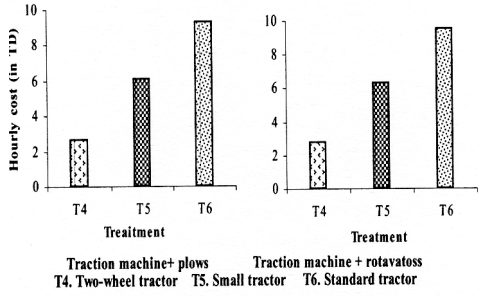
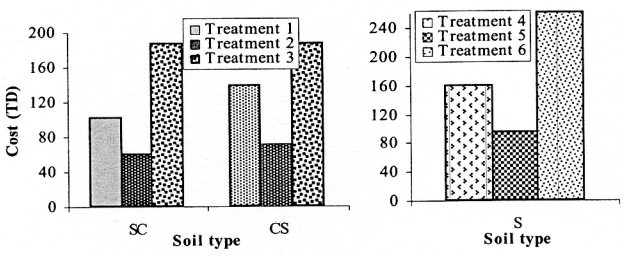


Fig 6. SOIL Costs preparatio og the various machines (TD/ha)



4. Conclusion

The objective of this work was to lead a comparative study, concerning time performance and soil preparation costs, between small powers and the standard tractor in the Tunisian central coast area, characterized by small-sized farms producing vegetable crops. Results show that small powers allowed several advantages compared to the standard tractor. The two-wheeled tractor provided the best field yields and the small tractor the lowest hourly costs. With regard to soil preparation costs, results show a considerable difference between the small powers and the standard tractor and the best performance was obtained with the small tractor. However, the use of the two-wheeled tractor

for ploughing operations displayed some disadvantages: a limited working speed even under favourable conditions, low traction capacity, particularly on hard soils, difficulties for the user, etc.

The main conclusion of this work is that, for a given small vegetable producing farm in the Tunisian "Sahel", the use of proper traction material would reduce the waste of time, limit the mechanical costs and contribute to the improvement of crop efficiency. Furthermore, improving the operating conditions of small equipment (a higher adaptation of traction machines and tools, the proper ploughing timing, skilful drivers etc.) could undoubtedly contribute to improve the general equipment performance and efficiency.

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