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Influence of Mechanical Planting Depth on the Agronomic Behavior of a Potato Crop Conducted on Two Soil Types

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ABSTRACT

The effect of planting depth of the potato variety 'Safrane' at 8 and 15 cm was studied on two types of soil, a sandy loam and a loam clayey soil tilled with deep plowing using a moldboard plow and two tillage resumptions with a disc harrow. Planting was carried out mechanically at a density of 4.46 plants/m^2. Results showed that best yields in aerial and subterranean biomass and tubers were obtained for plants cultivated at 15 cm of depth in the sandy loam soil. The final yield of tubers increased 35.2% compared to plants cultivated 8 cm deep. However, for the loam clayey soil, plants cultivated 8 cm deep presented the best results for the different studied parameters. The increase in the final yield of tubers compared to plants cultivated at 15 cm of depth was 23%.

Keywords: mechanized planting, planting depth, Potato crop, soil texture, tubers yield

INTRODUCTION

Potato is one of the most important and popular vegetables in the world (Kashyap and Panda 2003). World production is around 311 million of tons of tubers for an area of 19.2 million ha (FAO 2004). In Tunisia, the average consumption per year and per habitant increased from 25 kg in 1994 to 32 kg currently. Its cultivation covers 21.600 ha for an annual production of 330.000 tons, a yield of 15 tons/ha (Ferjaoui 2002). However, this yield is still low but it can be improved by an adequate choice of varieties and more rational cultivation techniques. Indeed, tillage mechanization (Chehaibi and Hannachi 2005) and the choice of resumption tools improve tuber yield (Chehaibi and Hannachi 2008).

Moreover, the success of a potato culture requires mechanical planting allowing high regularity of depth and density of plantation (Ducattillon *et al.* 2007). Otherwise, Cambouris *et al.* (1996) showed that soil type significantly influences the yield and potential productivity of soils is an important component to integrate into the specific management of potato. Bouchard (1992) reported that potato planting is an important step that will influence the volume and the crop quality. Factors which have the greatest impact are the planting season, the density and the planting depth. He also reported that planting depth varies with the type of the soil. In a sandy soil, tubers will be planted deeper than in heavy or wet soil. The objective is to promote the rapid emergence of plant seeds to limit infections caused by bacteria and fungus. Late rising may cause a growth delay during the season and, consequently, a yield reduction. According to Harris (1978), the planting depth is one of the main factors affecting yield and tubers quality. The choice of the planting depth depends on the soil nature. In light soils, planting at important depths is possible and even sought because of its limited needs of energy. Moreover, Baarveld *et al.* (2002) reported that surface planting is preferred in heavy soils, where mother tubers may be exhausted before the seeds can reach the soil surface. On the other side, in sandy soils, where the risk of drying is expected, deep planting is desired, especially with high temperatures (Chibane 1999; Baarveld *et al.* 2002). Furthermore, Lambion *et al.* (2006) preconized that deep planting of potato, from 12 to 15 cm, limits the damage of certain pests on tubers. Rousselle *et al.* (1992) recommended an average planting depth to avoid a delayed emergence and a possible exposition of germs to *Rhizoctonia* attacks. A superficial planting is not recommended because the mounding is more difficult and the greening risk increases.

Regarding yields, they remain below expectations because of manual plantation system that requires much manual labor and time without ensuring regular depth distribution and tubers spacing between rows and on the ranks. These constraints affect yields and lead to an increase in the cost price of products (Vergniaud 1996).The yield of potato cultures is related to the variety, the planting density, the tuber size, the number of stems per unit of area and the number of tubers produced per stem and size (Struik *et al.* 1990; Baarveld *et al.* 2002). The success of potato cultivation, involves a mechanical planting allowing great regularity of depth and density (Ducattillon *et al.* 2007). Planting depth varies from 5 to 15 cm depending on several conditions and may be assured through well regulated machines with regular spacing of the ranks, regular distribution of tubers at uniform planting depths and good soil coverage by mounding (Baarveld *et al.* 2002).

In this context, we found useful to study the effect of mechanical planting depth on the agronomic behaviour of potato cultivated in two types of soil, a sandy loam soil and a loam clayey soil.

MATERIALS AND METHODS

Presentation of tests

The objective of this work is to study the effect of the mechanical planting depth on the potato yield, variety 'Safrane', cultivated on two soil types, located in the region of Chott-Mariem Tunisia. Tillage was performed on two plots with an average depth of 24 cm and two tillage resumptions. Planting was performed mechanically

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by a manual alimentation planter and mechanical distribution at a density of 4.46 plants/m^2 (distance between tubers of the same rank = 28 cm, distance between ranks = 80 cm). The first plot was characterized by a sandy loam soil (52% loam, 29% sand and 19% clay) and the second was formed by a clayey loam soil (55% clay, 30% loam and 15% sand). The two plots were treated, especially against mildew, *Phytophthora infestans*, using the following fungicides: Unilax (Syngenta, France) at 250 g/ha, Gelben (Tradi-Agri, UK) at 250 g/hl and Tattoo C (Bayer-Agri, Germany) at 250 cc/hl. Three repetitions and two treatments or planting depths of 8 and 15 cm was adopted for the experimental layout.

Measured parameters

Measurements of the following parameters were made:
- Emergence rate: it is the number of lifted plants divided by the number of planted seeds; it evaluates the germination quality of seeds by counting the emerged plants. It was performed weekly on each plot for one month:
- The fresh and dry weight of aerial part (stems + leaves), and the underground part (roots + stolons) determined on nine plants in each elementary plot of each test. This parameter was evaluated three times during the vegetative cycle of the plant, 60, 90 and 110 days after planting. The dry weight of different plant organs is determined by drying in an oven at 80°C for 24 h;
- Tuber yield was assessed on 27 plants/treatment (9 plants/replication).

Statistical analysis of the different measurements was based on analysis of variance (ANOVA) using software SPSS 13. The comparison between means was performed according to the Duncan's multiple range test at 5%.

Table 1 Emergence rate of potato plants.

	Depth	Measurement dates (weeks)			
		1	2	3	4
Sandy loam soil	8 (cm)	60	84	94	99
	15 (cm)	38	80	88	93
Loam clayey soil	8 (cm)	45	74	90	99
	15 (cm)	29	65	81	93

Table 2 Biomass yield of potato crop variety 'Safrane' in a sandy loam soil.

Depth (cm)	Days after planting	FWUP	DWUP	FWAP	DWAP
8	60	124.9	19	150.8	12.8
	90	566	76.8	161.9	32.7
	110	683.4	97.7	62.2	23.5
15	60	137.7	28.4	175.8	16.6
	90	815.6	84.6	243.8	57.8
	110	883.4	113.9	83.5	39

FW, fresh weight; DW, dry weight; UP, underground part; AP, aerial part

Table 3 Biomass yield of potato crop variety 'Safrane' in a loam clayey soil.

Depth (cm)	Days after planting	FWUP	DWUP	FWAP	DWAP
8	60	719.8	122	491	49.8
	90	1814.8	272	674	107.8
	110	1948.6	292	434.7	69
15	60	644.6	109	471	43.8
	90	1316	171	513.7	77.8
	110	1687.6	219	347.8	50.3

FW, fresh weight; DW, dry weight; UP, underground part; AP, aerial part

RESULTS AND DISCUSSION

Crop emergence

The obtained results show the presence of two distinct groups of plants for the sandy loam soil (**Table 1**): The first corresponds to plants cultivated at 8 cm and lifted rapidly; the second group is represented by plants cultivated at 15 cm of depth and lifted later than the first. However, for the loam clayey soil, plants buried at 8 cm of depth were characterized by a faster emergence, while those buried at 15 cm of depth were marked by a delayed emergence (**Table 1**). However, the emergence rates observed in the heavy soil are lower than those recorded in the light one. This difference seems related to soil texture. These results confirm those of Chibane (1999). Abdulla *et al*. (1993) showed that the planting depth affected the emergence rate of season and rear season potato. Our results are also consistent with those of Jablouski (1990) who noted that deep planting of potato tubers delays crop emergence.

Fresh and dry weight of aerial and underground parts

Examination of **Table 2** shows that for sandy loam soil, the fresh weight of aerial part increases from the stage of 60 days to 90 days after planting, and then it decreases at the stage of 110 days after planting. Indeed, until the 90th day after planting the plant forms its vegetation and increases with time. Beyond, begins the migration of photosynthesis products from aerial part to tubers. This explains the drop in fresh and dry weights of aerial part, however, we note an increase in these parameters for the underground part (roots and tubers). However, plants cultivated at 15 cm of depth are characterized by the most important fresh weight at all stages. Indeed, 90 days after planting, these plants presented an average weight of 243 g/plant against only 161 g/plant for plants cultivated at 8 cm of depth, an increase of more than 33%. Otherwise, the dry weight of aerial part evolved in the same way as the fresh weight with better yield obtained with plants cultivated at 15 cm of depth. Indeed, the increase in the dry weight for plants cultivated at 15 cm of depth 90 days after planting compared to those cultivated at 8 cm, is 43%. It seems that in the sandy loam soil, planting at important depth allows plants to receive more nutrient and water reserves promoting their development and consequently a high yield of fresh material.

Regarding the root part, results show a continuous increase in fresh and dry weight for the two planting depths. Indeed, for plants cultivated at 15 cm of depth, the fresh weights of the roots measured at 60, 90 and 110 days after planting are respectively 137, 815 and 883 g/plant. Corresponding dry weights are 28.4, 84.6 and 114 g/plant. This is related to the migration of assimilates from the aerial part to the underground part. However, comparison of fresh and dry weight of underground parts of the plant shows an increase of 9.4, 30 and 22.7% for fresh weight and 33; 9.4 and 14% for dry weight at 15 cm of depth, respectively 60, 90 and 110 days after planting.

It appears that for a sandy soil, potato planting at important depth promotes the development of underground and aerial organs of the plant. This could be explained by the fact that, in light soil, water reserves, enough high in depth, limit soil compaction. With the terminal drought advent, risks of drying are limited. Development of aerial and underground biomasses is thus favoured.

Analysis of obtained results for loam clayey soil (**Table 3**) shows an increase in fresh and dry weight of aerial part until the stage of 90 days after planting for the two tested depths. These weights fall at the stage of 110 days after planting. Indeed, for the lowest planting depth the fresh weight is respectively 674 and 434 g/plant at 90 and 110 days after planting. At 15 cm this weight measures only 513 and 348 g/plant respectively at 90 and 110 days after planting. The corresponding dry weight is 108 and 69 g/plant and 78 and 50 g/plant respectively for 8 and 15 cm of depth.

However, the underground part shows a continued increase in fresh and dry weights during all stages of measurement. This increase is valid for the two planting depths. At 90 and 110 days after planting, the average fresh weight per plant cultivated at 8 cm of depth is respectively 1814 and 1948 g, it represents 1316 and 1687 g for plants cultivated at 15 cm of depth. The corresponding dry weight is respectively 272 and 292 g/plant and 171 and 219 g/plant

Table 4 Mean squares and *F* test of fresh and dry weights (g) of aerial and underground parts of the plant.

Source	ddl	FWUP	DWUP	FWAP	DWAP
Soil	1	6078033***	146153***	1054592***	11360***
Depth	1	32304***	5898***	4853***	44.7***
date	2	2677183***	39695***	83156***	4446***
Soil × depth	1	412335***	12144***	39151***	2312***
CV		0.8	1.6	0.19	2.9

***: significant at the 1‰ level.
FW, fresh weight; DW, dry weight; UP, underground part; AP, aerial part

Table 5 Means comparisons of fresh and dry weights (g) of aerial and underground parts of potato plants as a function of soil type and planting depth (LSD test at the 5% level).

	Depth (cm)	FWUP	DWUP	FWAP	DWAP
Sandy loam soil	8	458 d	65 d	125 d	24 d
	15	612 c	76 c	168 c	37.8 c
Loam clayey soil	8	1494 a	229 a	533 a	75.6 a
	15	1220 b	166 b	444 b	57.3 b

Means followed by the same letters are not significantly different according to Duncan test at 5% level.
FW, fresh weight; DW, dry weight; UP, underground part; AP, aerial part

Table 6 Tubers yield of potato crop variety 'Safrane'.

	Depth (cm)	Tuber yield (tonnes/ha)
Sandy loam soil	8	24.41
	15	35.2
Loam clayey soil	8	39.06
	15	29.77

Table 7 Mean squares and *F* test of potato tubers yield (tonnes/ha).

Source	ddl	Tubers yield
Soil	1	64.4**
Depth (cm)	1	2.08*
Soil * Depth	1	298**
Error	6	0.263
CV		1.6

Table 8 Variations of tubers yield (tonnes/ha) as a function of soil type and planting depth.

Variable		Average yield
Soil	1	29.8 b (24.41+35.2)/2
	2	34.4 a (39.06+29.77)/2
Depth (cm)	8	31.7 b (24.41+39.06)/2
	15	32.5 a (35.2+29.77)/2

Means followed by the same letters are not significantly different according to Duncan test at 5% level

for the planting depths of 8 and 15 cm.

It should be noted that low planting depths provided best yields for the two parts of the plant. Indeed, 110 days after planting, we recorded a respective increase of fresh and dry matter of 13.4 and 25%. These results agree with those of Pangaribuan (1994) who showed a significant effect of the potato planting depth on the dry weight of the organs, the length of the roots and the number of tubers per plant.

Analysis of variance showed highly significant effects (P <1 ‰) of soil type, the planting depth, the measurement date and the interaction (soil × depth) on fresh and dry weights of aerial and underground parts of the plant. The coefficient of variation is between 0.8 and 2.9 (**Table 4**).

FWUP: Fresh weight of underground part; DWUP: Dry weight of underground part; FWAP: Fresh weight of aerial part; DWAP: Dry weight of aerial part.

The comparison of means showed that loam clayey soil provided fresh and dry weights of aerial and underground parts clearly higher than those obtained for the sandy loam soil (**Table 5**).

Tuber yield

According to **Table 6**, cultivated plants at15 cm of depth in a sandy loam soil gave the best tubers yield (31 t/ha). An increase of 35.2% compared to plants cultivated at a depth of 8 cm. It appears that there is a considerable interaction between the degree of tubers release in soil and the yield of the plant. Indeed, at significant planting depth (15 cm), plants germinate more slowly but their roots are well developed laterally and in depth. Therefore, a better exploitation of water reserve and fertilizers. However, at low planting depth, plant biomass is relatively less developed, leading to a lower tubers yield.

Studies of Abdulla *et al*. (1993) and Bohl and Love (2005) showed that potato yield is improved when the planting depth increases, but with limited greening of tubers. In addition, Pavek and Thornton (2009) showed in a study on the effects of planting depth, that commercial yield of two potato varieties was lower for reduced depth.

Despite the importance of this culture and the control of its inputs, yields remain below expectations (Fraser 2000). This is the result of a problem with the plantation system that requires a lot of manual labor and time, a uniform distribution of depth and spacing between the pads. These limitations alone absorb the largest share of the cost price of products (Védie *et al*. 2009). Referring to **Table 6**, it appears that in heavy soil, low planting depths provided the best tubers yield. Indeed, we record 39 tonnes/ha for low planting depth against almost 30 tonnes/ha for high planting depth, a yield increase of 23%. This can be explained by the fact that in heavy soils, root development is easier in the upper horizons where soil particles are less compacted. This development would undoubtedly have a positive effect on other plant parameters especially the tubers. Tamia *et al*. (1999) showed that in less compacted horizons, root density may be higher than in compacted horizons, which directly affects the yield. However, the complexity of nutrition and plants growth mechanisms and structural changes under the impact of climatic, biological or mechanical factors, have also great effect. Martin *et al*. (2009) reported that the impact of compaction depends on plant sensibility, especially the potato plant, to the presence of compacted areas.

Analysis of variance showed highly significant effects (*P* <1 ‰) of soil type and the planting depth on tubers yield of the plant. The coefficient of variation was 1.6 (**Table 7**).

Comparison of the means of potato tubers yield showed significant differences between soil and the planting depths (**Table 8**). Heavy soil (2) and the planting depth of 15 cm are indicated by the high means.

CONCLUSION

The agronomic behaviour of a potato crop is closely related to tubers planting depth and soil type. Indeed, in light soil, the best results of biomass were obtained with the most important planting depth (15 cm) which led to an improvement in tubers yield of 35%. However, in heavy soil low planting depth of 8 cm led to better effects, and improved, therefore, tubers yield of 23%. Soil texture significantly influenced the yields showing that this parameter is an important component to integrate in the potato specific management.

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