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Effects of planting depth on agronomic performance of two potato varieties grown in the Sahel region of Tunisia

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Possibilities to enhance potato productivity in the Sahel region of Tunisia have been the domain of active investigation during the last several years. Many field experiments were carried out on the potential of using different plating depths to grow profitable potato crops. In the research station of the higher institute of agronomy of Chott-Mariem in the Sahel region of Tunisia, two varieties of potato: Alaska and Safrane, were mechanically planted at two different depths: 10 and 15 cm in a sandy loam soil. After three months of growth, the effect of planting depth was determined using fresh and dry weights of the above and below ground biomass as well as tuber yield. The results showed that in a light textured soil, plants of two potato varieties planted at 15 cm depth outperformed those planted at a 10 cm depth. In addition, for tuber yield, the Alaska variety was more productive than the Safrane variety with increasing yield of tubers than 2% for depths of 15 cm and 11, 9% for depths of 10 cm.

Key words: Potato, planting depth, light soil, agronomic parameters, Tunisia.

INTRODUCTION

The potato (*Solanum tuberosum* L.) belongs to the *Solanaceae* family, genus *Solanum* and is one of the most important food crops in Tunisia, as well as many other countries. It is a perennial that spreads by vegetative propagation and is grown as an annual species (Graham et al., 2001). However, tuber yield can be improved by choosing appropriate varieties and more rational cultivation techniques. Indeed, to obtain a homogeneous culture, the tubers should be distributed evenly with a specific spacing between rows and a uniform planting depth (Baarveld et al., 2002). Shallow planting is preferred in wet and heavy soils because in such soils deep planting of the tubers may lead to exhaustion of stored food before the sprouts emerge above the soil. Conversely, in light textured soils, where there is a risk of dehydration due to moisture stress, deep planting is essential. Deep planting has also advantage over shallow planting where temperatures are high.

In addition, Lambion et al. (2006) advocated that deeper planting may also limit the damage to tubers by certain pests. In addition to planting depth, crop yield is also influenced by variety, soil, temperature (Gopal et al., 1998), photoperiod (Pruski et al., 2001), light intensity (Gopal et al., 1998) nitrogen nutrition (Etemad and Sarajuoghi 2012) potassium (Naik and Sarkar, 1998) planting density, plant height, the number of stems on the surface, number of tubers formed by size. That depth of planting can be achieved through well-regulated machinery taking out a regular spacing of rows, a regular distribution of tubers in a planting depth and uniform coverage of land by ridging was reported by Haider et al. (2012). In the context of studies of the interaction of soil plant machine, we have found it useful to study the effects of mechanical planting depth on agronomic

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performance of two potato varieties grown in a sandy loam soil in the Chott Mariem region.

MATERIALS AND METHODS

Experimental site

The experiments were conducted from February to May in the research station of the agronomic height institute of Chott-Mariem (35° 54’ N 10° 36’ E), Sousse, Tunisia. The climate is Mediterranean, and is characterized by hot dry summers and moderate wet winters, an average annual precipitation of 230 mm and an annual mean temperature of 18.5°C. The area is located in an area under drip-irrigation, characterized by a sandy loam soil (52% silt, 29% sand and 19% clay). Previously, the soil was plowed to 28 cm depth with a moldboard plow and followed by plowing with a disc harrow and cultivar teeth.

Treatments and experimental design

The treatments consisted of two varieties (Safrane and Alaska) and two planting depth [T1 (10 cm) and T2 (15 cm)]. The experiment was laid out as a randomized complete block. The plot size was (30 x 50) m^2. Each plot consisted of 36 rows. Each row accommodated 178 plants. Plants in the central rows were used for determination of agronomic performance, leaving aside those in the two border rows as well as those at both ends of each row to avoid edge effects. Tubers of the two different potato varieties were planted at the spacing of 80 cm between rows and 28 between plants. For each depth the plants samples were allocated randomly to the treatments and the analysis was repeated three times for each sample. Therefore each depth was represented by 27 plants at 9 plants per elementary for each plot. For each variety, the effect of planting depth on agronomic parameters of the plant was considered at three growth stages (Stages 1, 2 and 3) corresponding, respectively to 60, 90 and 110 days.

Statistic

The statistical analyses were implementing with XLSTAT (2012). The analysis of variance ANOVA and post-hoc multiple comparisons Turkey’s test ($P < 0.05$) was used to examine the effects of depth and variety on the variation of agronomic parameters.

Fertilizer and pesticide treatments

Before planting each plot received 12.5 t/ha manure, 50 kg/ha triple superphosphate and 150 kg/ha potassium sulfate. After planting (one month later), an additional 150 kg/ha of ammonium nitrate was added. In addition, maintenance operations were conducted on plants at the Unilax (250 ha), at Gelben (250 g/hl) and C-Tattoo (150 cc/hl). Finally, the potatoes are manually picked from the field.

Measured parameters

Measurements on plants were recorded for above-ground (stem + leaf) and below-ground (root + stolon) fresh and dry weights. The weights were determined for three representative plants in each plot of each treatment. This was done three times during the growing cycle; at 60, 90 and 110 days after planting.

After determining the fresh weight of above- and below-ground portions, they plants samples were placed in an oven at 80°C for 24 h to determine dry weight. Tuber yield was determined at harvest. This measurement was made for the different plots by determining the average weight of 27 potato plants of each treatment at a rate of 9 plants per repetition.

RESULTS AND DISCUSSION

Fresh weight of aerial parts

From Table 1 it can be revealed that in sandy loam soil, the fresh above ground biomass increased between 60 and 90 days, and then decreased at 110 days after planting. Indeed, until the 90th day after planting, the plant formed its vegetation, and this fresh weight increased with time. In addition, after approximately 90 days, the photosynthetic products apparently began partitioning from the aerial portion to the tubers, which may explain the drop in fresh above-ground biomass between 90 and 110 days in both varieties.

It can be noted that, for both varieties, the best performance was obtained with plants planted at 15 cm depth. Indeed, after 90 days, fresh above ground biomass for potatoes planted at 15 cm depth was 29.9 and 10.7% greater than those planted at 10 cm depth for the Alaska and Safrane varieties, respectively. It seems that in light textured soil, planting deeper allows the crop to get more food reserves and water (McEwan, 2012) encouraging development and increasing fresh weight.

Dry weight of aerial parts

From Table 1, it can be seen that the dry above ground biomass for both varieties reached maximum approximately 90 days after planting and then began to decrease. This reduction in dry weight may be largely due to the effect of the state of ripening of the plant where a reduction in leaf area directly affects photosynthesis and, subsequently, carbon accumulation.

The latter in turn affects the rate of accumulation of dry matter in the various aerial organs. Moreover, it can be deduce that the dry weight of aerial parts evolved in the same direction as that of fresh weight with a better yield obtained with plants grown at 15 cm depth. Indeed, 90 days after planting, the dry weight recorded for plants grown at the depth of 15 cm depth was 50.6 and 35% greater than those grown at the depth of 10 cm for the Alaska and Safrane varieties, respectively.

Fresh below-ground biomass

The below ground portion is the most important part of the plant since it is the tubers that provide the nutritional value of potato (Le et al., 2002). It also bears many thin and fibrous roots that can penetrate deep into the soil if it

Table 1. Measured parameters.

Variable	Depth (cm)	Safrane variety			Alaska variety		
		Days after planting			Days after planting		
		60	90	110	60	90	110
Fresh weight of aerial parts (g/plant)	15	88.7 ± 2.8	215.8 ± 6	101.8 ± 7.6	202.8 ± 8.1	232.7 ± 9.8	98.7 ± 4.6
	10	84.3 ± 2.5	192.6 ± 4	79.6 ± 5.6	150.8 ± 7	162.9 ± 5.9	83 ± 5.5
Dry weight of aerial parts (g/plant)	15	13.9 ± 1.1	64 ± 3.9	39.4 ± 3.2	16.6 ± 2.6	66.3 ± 5.6	19 ± 2
	10	12.83 ± 0.9	41.6 ± 4	23.1 ± 1.9	12.8 ± 1.3	32.7 ± 4.1	15 ± 1.4
Fresh below-ground biomass (g/plant)	15	12.5 ± 1.7	19.1 ± 3	12 ± 1.8	17.7 ± 2.4	24 ± 3.6	18.5 ± 1.7
	10	11.22 ± 1.5	15 ± 2.4	11 ± 1.7	14.9 ± 1.8	17.5 ± 2.4	15.7 ± 1.5
Dry weight of under-ground parts (g/plant)	15	1.85 ± 0.04	3.16 ± 0.08	1.8 ± 0.03	2.92 ± 0.08	3.25 ± 0.86	1.9 ± 0.56
	10	1.76 ± 0.07	2.6 ± 0.05	1.7 ± 0.05	2.9 ± 0.1	2.82 ± 0.53	1.7 ± 0.78

is sufficiently soft (Soltner, 2005). From Table 1, the fresh below-ground (roots and tubers) biomass increase until 90th days after planting in both varieties.

It is similar to the aerial part, which allows us to deduce a similar correlation between the increases in fresh weight of aerial part and the underground part. This can be explained by the importance of metabolic processes at the plant and the immigration of the aerial part of assimilates to the underground.

In addition, the results of Table 1 show a steady increase in fresh weight for both depths of planting. However, plants grown at 15 cm depth are characterized by the greatest fresh weight for all stages. Indeed, for the variety Alaska, 90 days after planting, the below ground biomass grown at 15 cm depth had an average weight of 24 g/plant *vs*. 17.5 g /plant for crops at established at 10 cm depth, an increase of more than 33%. The fresh weight was lower for the Safrane variety where mean below ground biomass was 19.1 g/plant and 15 g/plant for 15 and 10 cm depths, respectively. It seems that in this light textured soil, planting depth was important to allow plants to get more food reserves and to promote their development and therefore yield higher fresh weights. Also, on the conditions of root growth which depend essentially on the structural state of topsoil and the presence of zones of compaction due to tillage in wet weather.

Dry weight of underground parts

From the results of Table 1, it can be deduced that the average weight of the underground part significantly ($P < 0.05$) increased during the crop cycle. In the early stages of development, this growth was rapid, peaked at about the 90th day after planting and then decreased. This was for the two planting depths tested. Indeed, for the Safrane variety for planting at 10 cm depth the lowest fresh weight was 2.6 and 1.7 g/plant, respectively 90 and 110 days after planting. A 15 cm depth, the weights were only 3.16 and 1.7 g/plant, respectively 90 and 110 days after planting.

For the Alaska variety, and for the same dates (90 and 110 days after planting) dry weights corresponded to 2.82 g/plant and 1.7 g/plant for the 10 cm depth and 3.25 g/plant and 1.9 g/plant for the 15 cm depths. This may be due to the change in reserve accumulation that starts fast but gradually decreases as the plant grows (Muhinyuza et al., 2008). Consistent with the results of this study, Marofi et al. (2013) and Snapp and Kravchenko (2010) reported that relative decreases in dry weights of underground parts are common after senescence of the plants. As measured by the variance at the 5%, we determined a significant difference in growth between the two varieties of potato. This difference recorded between the two varieties may be due to genetic effect as explained by the number of stems per unit area that emerged, and subsequently, increasing the size of plants or that of planting density, which generally leads to an increase in the average weight (Memari et al., 2011).

Tuber yield

According to Figure 1, both varieties produced the highest tuber yields when planted at 15 cm depth, 17.7 and 26% greater than those planted at 10 cm depth for the Alaska and Safran varieties, respectively. It appears that there is considerable interaction between the level of release of tubers in the soil and yield of the plant. Indeed, a major planting deepest germinates more slowly but their roots grow best laterally and at depth and make the most of available water and nutrients. By contrast, at shallower planting depths, plant biomass was relatively

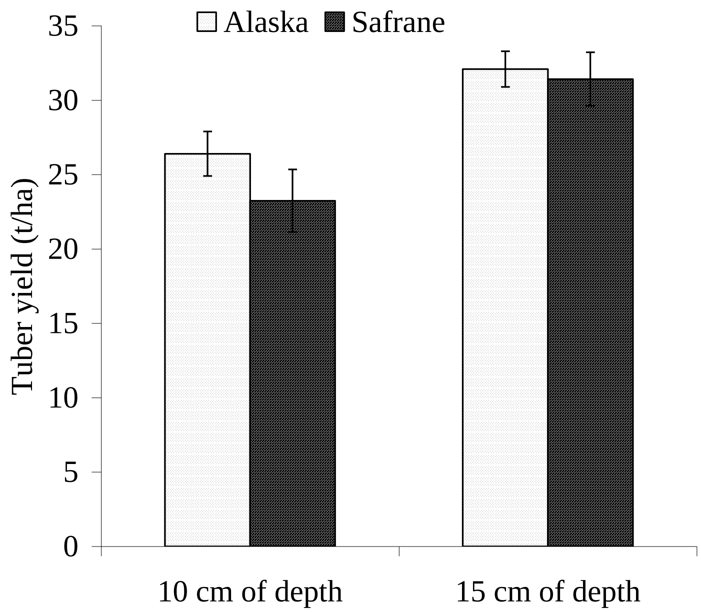

Figure 1. Tuber yield (t/ha).

less developed, leading to a lower tuber yield. Tuber weight depends primarily on the operating time of the leaf canopy (Snapp and Kravchenko, 2010), but also the conditions of operation and conditions of root growth. Studies of Abdulla et al. (1993) and Bohl and Love (2005) showed that potato yields increased when planting depth increased, but with a small tuber greening. Pavek and Thomotonr (2009) showed, in a study on the effects of planting depth, the performance of two commercial varieties of potatoes were lower for the reduced depth.

Similarly, Tamia et al. (1999) have indicated that in very compact horizons, root density can be higher than in the packed horizons, which directly affects performances. However, the complexity of the mechanisms of nutrition and plant growth and structural changes under the influence of climatic factors, biological and mechanical parameters are also of great influence.

Conclusion

At the end of this experimental work aimed to study the effects of planting depth on the mechanical performance of two varieties of potato, it appears that in the light soil, planting potatoes at 15 cm depth promoted better development of both below and above ground plant components as well as higher yields compared with potatoes planted at 10 cm depth. Indeed, plants grown at the shallower depth provided returns of 26.4 and 23.24 t/ha, respectively for the Alaska and Safrane varieties. By contrast, those grown at the greater depths resulted in yields of 32.09 t/ha for the Alaska variety and 31.42 t/ha for the Safrane variety.

From this, it appears that in light textured soil, planting potatoes at 15cm depth promotes better development of both above and below-ground organs of the plant. This may be due to the fact that in a light-textured soil with limited compaction, moisture conditions are typically better, which reduces the risk of dehydration and promotes normal development of roots, especially when the crop cycle coincides with the relativity warm months.

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