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Impact of mechanical planting depth and density on agronomic parameters of organic potato *Solanum tuberosum* L.

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Abstract

Demand for organic produce is expected to increase due to increasing concern in urban society about food quality. However, crop management options are extremely limited in an organic system, often leading to reduced yields. The objective of this study was to evaluate the effects of different mechanical planting densities (3.05 and 3.91 plant/m^2) and depths (0.07 and 0.12 m) on the agronomic parameters under organic culture. Field study was conducted at the Higher Institute of Agronomy of Chott Meriem, Tunisia from February to June. The results indicate that different treatment combinations could affect the vigor and growth of the plant, size of tubers and weight of fresh and dry matter of different plant organs, as well as the final yield. Moreover, it was shown that planting in-row spacing of 0.41 m and depth of 0.12 m improved the growth parameters of the plant. This study showed that there is a relationship between the number of plants per square meter and the crop yield. Indeed, yields with the density of 3.91plant/m^2 was higher than that of 3.05 plant/m^2 (13.75 and 10.83 t/ha, respectively).

Key words: Mechanical planting densities, mechanical planting depths, organic potatoes, yield, leaf area.

Introduction

With the increasing population pressure in tropical Africa, shifting cultivation is no longer sustainable and the length of traditional bush fallowing for maintaining the productivity of the soil is becoming shorter (Mbah and Mbagwu, 2006). Organic production practices maximize the use and recycling of on farm nutrient sources, including animal and green manures. Techniques such as accurate soil analyses and nutrient crediting help producers in avoiding excess fertilizer applications. Sustainable farming methods include soil-building and conserving practices such as adding organic matter and minimum-tillage approaches. Prices for certified organic produce may be considerably higher than conventionally produced crops. In Tunisia, potato is grown in three growing seasons and is considered a major vegetable crops from viewpoint of production area. Extended cultivation of potatoes was about 25 thousand hectares per year, equivalent to nearly 17 % of total spaces for the cultivation of vegetables and occupies the second place after tomatoes. However, despite the control of inputs *viz.*, choice of variety, physiological stage of the plant, germination and pre-treatment plant, planting date and circumstances, soil temperature, the quantities and their positioning, irrigation system, yields remain below expectations (Fraser, 2000). This is because the plantation requires a lot of manual labor and time. These limitations alone absorb the largest share of the cost price of products (Vergniaud, 1996; Vedie *et al.*, 2009). Preparing the soil for organic potato is similar to that of conventional farming. The density is of 29000 to 55000 plants/ha depending on the variety. The distance between ridges, depends on the equipment, is 0.75 to 0.9 m. However, the spacing of 0.9 m can be most suitable for mounds, which affect the success of weed control, tuber quality and protection against mildew. A deep planting reduce the risk of contamination of tubers by mildew, but increase the risk of *Erwinia* development in poorly drained soil (De Reycke *et al.*, 2005). In addition, lower plant density and orient ridges in the direction of the prevailing wind can limit the moisture level of culture. The contamination of tubers from foliage can be reduced by planting deep and creating a mound sharp enough that can allow rainwater to drain (Lambion, 2006). There are numerous organic potato production manuals that are specific to regions within the United States (Dufour *et al.*, 2009).

This paper evaluate many of the practices used in organic potato production in Tunisia and the effect of mechanical planting densities and depths on the agronomics parameters of organic potato crop. Because each farm is a unique combination of soil, climate, environment, management and marketing techniques, it is important to plan and assess which practices described here are appropriate for a particular farm.

Materials and methods

Experimental site: The experiment was conducted at the Higher Institute of Agronomy of Chott Mariem, Tunisia (Longitude 10°38E, Latitude 35°55N, altitude 15 m) from February to June 2009. The climate is typically Mediterranean with 230 mm annual rainfall and an average of 6 mm day^{-1} evaporation from a free water surface (Douh and Boujelben, 2010). In winter, the average minimum temperature is of 6 °C and the average maximum is of 18 °C, while in summer average minimum is of 23 °C and average maximum is of 38 °C. The soil is sandy loam with average basic infiltration rate of 14 mm h^{-1}. Bulk density (Bd) of soil was found to be 1.40 g cm^{-3} for the layer 0-60 cm. Porosity was calculated assuming a soil particle density (dp) of 2.65 mg m^{-3} for mineral soils. Porosity = 1 - (Bd/dp). The field was precision graded to approximately 1 mm m^{-1} slope. Potato variety "Spunta", was seeded on 24th of February with row spacing of 80 cm and plant spacing of 32 cm with a density of 3.91 plant/m^2. Another spacing treatment had 80 cm row spacing and plant to plant spacing of 41 cm with a density of 3.05 plant/m^2. The whole planting area was 539 m^2 (19.6 x 27.5 m).

Experimental design and measurements: The potato crop was drip irrigated during the growing season. Drip tubing (GR type, 16 mm diameter) with 40 cm emitter spacing was used (each delivering 4 L/h at 1 bar pressure). Weather data were obtained from a weather station located adjacent to the experimental area. For this study, we used four combinations of two densities and two planting depths. Such combinations are used to plant a crop of potatoes in season. The treatments were: D1P1: spacing between plants 32 cm (D1) with a planting depth of 7 cm (P1); D1P2: spacing between plants 32 cm (D1) with a planting depth of 12 cm (P2); D2P1: spacing between plants 41 cm (D2) with a planting depth of 7 cm (P1); D2P2: spacing between plants 41 cm (D2) with a planting depth of 12 cm (P2). Planting tubercles was carried out mechanically by means of a double row planter "Gruse" with automatic dispensing and manual adjustment. Three plants per plot and nine plants per treatment were chosen to determine the fresh weight of leaves, stems and roots. A sample of 50 g of leaves, stems or roots, taken from each plant, cut into pieces were placed in an oven at a temperature of 80 °C. When the weight stabilized, the dry weight was measured.

Three plants were randomly selected per plot for the determination of growth and yield parameters. Nine plants per treatment were removed in order to measure the leaf area with the help of an analog leaf area meter LI-3100.

Statistical analysis: The data collected were subjected to analysis of variance (ANOVA) procedure of Statistical Analysis System PROC GLM. The treatment means were separated using Duncan's multiple range test at *P*=0.05 with least significant difference (LSD).

Results and discussion

Plant emergence: Data presented in Fig. 1 show the percentage of emergence over time. The treatments, D1P1 and D2P1 emergence peaked 100 %, 35 days after planting. While for the treatment D1P2 and D2P2 maximum value were 86 and 95 % at 42 days after planting, respectively. It appears that the percentage of sprout emergence not only increased with time but also influenced by the planting depth. The results revealed that for a quick emergence, it is advantageous to reduce the depth of planting. Baarveld *et al.* (2002) reported that surface planting is preferred in heavy soils, where the mother tuber may run out before the seeds can reach the soil surface. In contrast, in light textured soils, where the risk of drying out is expected, a deep planting is desirable, especially in case of high temperatures (Chibane, 1999; Baarveld *et al.*, 2002). In addition, Lambion *et al.* (2006) advocated plantation deep enough to limit the damage of certain pests on tubers, making them more difficult to access.

Leaf area: The data depicted in Fig. 2 indicate the mean leaf area for each treatment and the mean values of the leaf area per plant are similar for treatments, with a slightly higher value recorded in D2P2 and D1P2 (1666±288 and 1610±239 cm^2/plant, respectively). Whereas it didn't exceed 1360±433 and 1349±244 cm^2/plant for D1P1 and D2P1. This also show the effect of the planting depth on the leaf area of the potato crop. Data show significant interactions between leaf area and density-planting depth.

Fresh weight: Table 1 show the root, leaf and stem fresh weight for the different treatments. The data indicated that P2 (12 cm) had the highest values irrespective of the planting density.

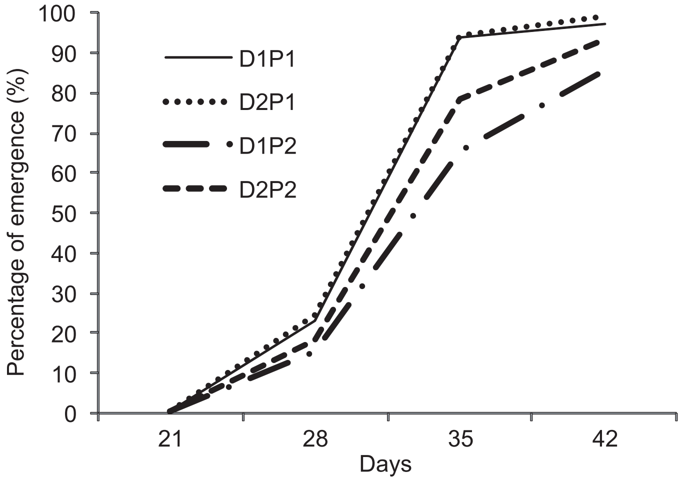

Fig. 1. Percentage of emergence under different planting depths and densities

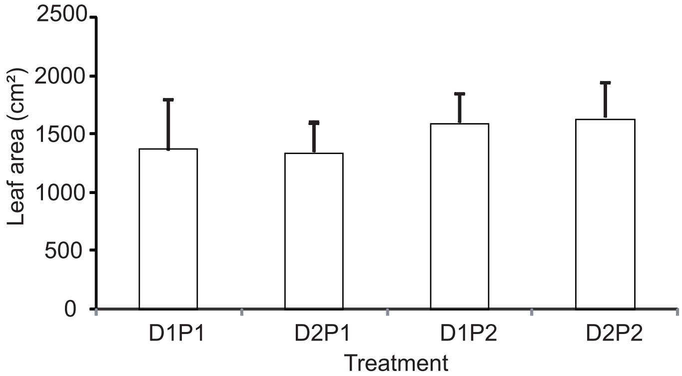

Fig. 2. Leaf area under different planting depths and densities

Table 1. Fresh weight under different planting depths and densities

Treatment	Root fresh weight (g)	leaf fresh weight (g)	Stem fresh weight (g)
D1P1	28.33±11.7	121.67±24.1	32.78±15.8
D2P1	26.67±5.9	128.33±24.9	32.78±6.2
D1P2	31.11±7.8	136.67±34.4	38.33±10.9
D2P2	30.00±10.0	135.56±25.8	47.78±15.6

Calibration of tubers: Table 2 summarizes the tubers' calibration for each treatment. For the planting depth of 7 cm (D2P1 and D1P1 treatments) 63 % of tubers were characterized by a medium size, 23 % large tubers and the rest of tubers were of small size. In contrast, depth of 12 cm (D1P2 and D2P2), resulted less than 57 % of tubers of medium size, 37 % large tubers.

Yield: Fig. 3 depicts the effect of different planting depths and density on the organic potatoes yield and indicate that the planting depth had a highly significant effect on the plant yield. Certainly, the highest values were registered on the 7 cm depth and the density of 3.9 m^2/plant. Indeed, the mean yield was 13.75±0.8 t/ha for D1P1, 8.2±1.2, 10.2±0.5 and 7.2±2 t/ha, respectively for D2P1, D1P2 and D2P2. Data show that the interactions between yield and treatments were highly significant, at 5 % level, and allowed the classification of treatments into three groups. Cambouris *et al.* (1996) showed that soil type influence significantly the yield and potential productivity of soils is an important component to include in the specific management of potatoes. Bouchard (1992) reported that the planting method of

Table 2. Calibration of tubers under different planting depths and densities

Caliber (%)	D1P1	D1P2	D2P1	D2P2
Small	11.50	5.31	7.58	9.17
Medium	63.39	57.44	68.70	51.69
Large	25.00	37.2	23.26	39.13

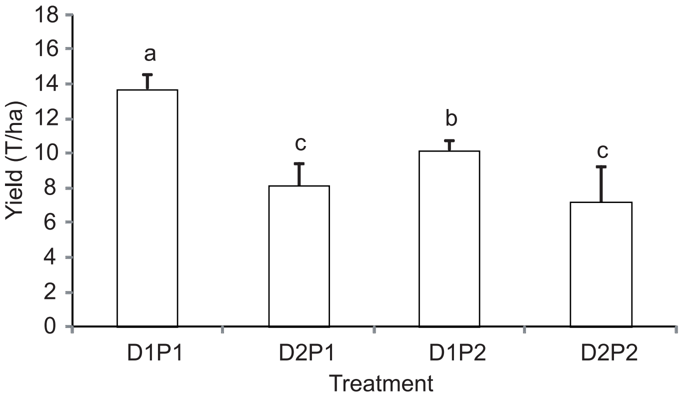

Fig. 3. Organic potato yield under different planting depths and densities

the potato is an important step that influence the amount and quality of the crop produced. Factors that have the greatest impact are the planting season, density and planting depth.

This study aimed the mechanical planting effect of densities (3.05 and 3.9 plant/m^2) and depths (7 and 12 cm) on agronomic parameters of organic potato. It appears that the performance of the plant depends on the depth-density planting combination. It was shown that planting in-row spacing of 0.41 m and depth of 0.12 m improved the growth parameters of the plant. This study showed that there is a relationship between the number of plants per square meter and the crop yield. Indeed, yields with the density of 3.91 plant/m^2 was higher than that of density 3.05 plant/m^2 (13.75 and 10.83 t/ha, respectively) an improvement of 27 % was recorded.

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