Greener Journal of Agricultural Sciences
ISSN: 2276-7770; ICV: 6.15
Vol. 4 (2), pp. 046-051, March 2014

http://gjournals.org/GJAS

Research Article (DOI: http://dx.doi.org/10.15580/GJAS.2014.2.020314087)

Soil Bulk Density and Potato Tuber Yield as Influenced by Tillage Systems and Working Depths

Abrougui K.[1]*, Chehaibi S.[2], Boukhalfa H.H.[3], Chenini I.[4], Douh B.[5] and Nemri M.[6]

Soil Bulk Density and Potato Tuber Yield as Influenced by Tillage Systems and Working Depths

ARTICLE INFO

Article No.: 020314087
DOI: 10.15580/GJAS.2014.2.020314087

Submitted: 03/02/2014
Accepted: 07/03/2014
Published: 13/03/2014

**Corresponding Author*
Abrougui K.
E-mail: khaoula_abr @yahoo.fr
Phone: (+216) 73 327 540, (+216) 73 327 591

Keywords:
Tillage systems, soil structure, bulk density, tubers size, potato yield

ABSTRACT

To evaluate the effects of tillage systems on soil bulk density, yield and quality of potato crop (*Solanum tuberosum* L.), three different tillage techniques were studied: reduced tillage using discs harrow (RT), medium tillage depth using discs plow (MT) and conventional deep tillage using moldboard plowing (CT) with three working depths of 10, 20 and 30 cm respectively. Tillage was followed by a first resumption after 10 days and a second one after 20 days. Soil structure was characterized by its bulk density and potato quality by tubers size and yield. Samples were collected from tilled plots at different dates spaced of 20 days. The obtained data were tabulated and analysed using IBM SPSS 17.0 version and Tukey test. Compared to MT and RT, CT decreased bulk density to 1.16 g cm^{-3} against 1.23 and 1.4 g cm^{-3} 60 days after tillage respectively for the two previous tillage systems and increased tubers size and consequently the potato yield to an average of 11 Mg ha^{-1} compared to 9 and 7 Mg ha^{-1} respectively for MT and RT. The statistical analyses of the data showed significant effects of the treatments and the measurement date on soil bulk density.

INTRODUCTION

Tillage aims to make the soil most favorable for the cultivation. All vegetables are concerned with the quality of the soil structure and thus with tillage (Abrougui et al., 2012b). The structure of the tilled layer of cultivated soil changes with times because of the tillage itself, compaction under traffic and as a result of natural processes (root growth, faunal activity and weather). Moldboard plow creates a desirable tillage, controls weeds, and buries fertilizers and residues of the preceding crops.

An important factor for the evaluation of an agricultural system's sustainability is the monitoring of soil quality via its physical attributes (Santos et al., 2012). It is therefore important to study the effect of tillage systems on soil structure (Abrougui et al., 2012b). Tillage practices involving annual plowing without other soil management practices are increasingly being recognized to have deleterious effects on soil conditions (Briggs et al., 1998). Conservation tillage could benefit agricultural production by controlling topsoil loss from wind erosion and conserving soil moisture as a reserve against common summer droughts. However, reduction in tillage does have the potential to negatively affect tuber production because of the potato plant sensitivity to soil physical conditions (Mundy et al., 1999). The main purpose of tillage in potato production is to control weeds, facilitate planting, and increase the ease of later cultivation and harvest (Prestt and Carr, 1984). No-till (NT) soils tend to have higher bulk densities than conventional-till (CT) soils (Naderman, 1991). Increased bulk densities can decrease potato yield (Blake et al., 1960) and make harvest more difficult (Grant and Epstein, 1973). According to Harris (1978), the planting depth is one of the main factors affecting yield and tubers quality. 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. 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 (Ducattillon et al., 2007). In this context, we consider revising useful to study the effect of tillage systems and planting depth on soil bulk density and biological potato yield.This paper describes a new comparison between three tillage systems that takes into account the changes in the structure of the tilled layer and the yield of biological potato crop at a plot scale, where the main factors responsible for change are tillage systems, working depths and natural conditions.

MATERIAL AND METHODS

Experiments were conducted at the Higher Institute of Agronomy in Sousse, on the east coast of Tunisia, for one production cycle on a sandy loam soil using a standard two-wheel-drive tractor equipped with single rear tires and having a total weight of 2,910 kg (1,715 kg on the rear axle) and a power of 59 Kw. This region is characterized by a typical Mediterranean climate, with an average temperature of 18.5 °C and an average monthly temperature ranging from 28 °C in August to 11.4 °C in January. The annual rainfall is 300 mm/year. To study the influence of tillage systems on soil physical properties and potato crop, soil bulk density, tubers size and yield of biological potato crop (*Solanum tuberosum* L.), were studied over time.

The experimental layout includes a studied factor: soil tillage under three different systems CT, MT and RT and three measured variables: dry bulk density, tubers size and potato yield. The statistical design was a randomized complete block. The main experimental plot area, 40 by 30 m, was split into three blocks; each area was then split into three sub-plots for the three tested systems.

Tillage resumption for the three treatments was achieved by two passages of disc harrow (offset) with three replications of measurements for each treatment.

- Treatment 1 = RT: reduced or minimum tillage using a disc harrow (Offset) at 8 cm of depth + 2 tillage resumptions spaced of 10 days, using a disc harrow;
- Treatment 2 = MT: medium tillage with disc plowing at a maximum depth of 20 cm + 2 tillage resumptions spaced of 10 days, using a disc harrow;
- Treatment 3 = CT: conventional deep tillage with moldboard plowing at a depth of 30 cm + 2 tillage resumptions spaced of 10 days, using a disc harrow.

Samples were collected from tilled plots at different dates spaced of 20 days to measure suggested physical indicator of soil quality, the bulk density.

Fertilization of the crop depends on organic manure (animal waste) before plowing with a dose of 15 Mg ha^{-1} and a compost juice (dilution of compost (straw and green leaves) in water (1 part compost / 5 parts water)), distributed to the plants once or twice a week. Planting was performed manually in mid-February 2013 with an average spacing of 30 cm between tubers and 80 cm between rows. The total number of rows was nine with three treatments and three repetitions per treatment. Irrigation was insured by drip system with a frequency of once a week. DITHANE and RIDOMIL (250 g 100 L^{-1}) and SENCOR (700 g ha^{-1}) were used as phytosanitary treatment against mildew and weed control respectively during the cycle. Maintenance operations were conducted on plants during the production cycle and finally the potatoes were manually snatched from the field.

Soil bulk density (g cm^{-3}) was measured on a soil cylindrical core (diameter = 5 cm, height = 5 cm) using a cylinder densimeter, the samples were taken every 10 cm to a depth of 30 cm for each treatment with three replications per treatment. Then we obtained the dry mass of the sample after drying it in an oven at a temperature of 105°C for 24 hours (Yoro and Godo, 1990). Measurements of soil bulk density were performed at initial state before tillage and 20, 40 and 60 days after tillage. According to Ben (2009), tubers developed by each plant were calibrated based on three categories of diameters:

1) small (diameter < 35 mm); 2) medium (35 < diameter < 55 mm); 3) large (diameter > 55 mm).

Tubers yield was determined at harvest. This measurement was made for the different plots by determining the average weight of 30 potato plants of each treatment at a rate of 10 plants per repetition.

Analysis of variance was performed at the 5% level of significance using the SPSS 17 software based on the variance-covariance structure. Multiple comparisons between significant parameters were carried out using the Tukey adjustment method.

RESULTS AND DISCUSSION

Figure 1 illustrated the comparison between initial state before tillage and the three tillage systems. Soil bulk density measured at initial state is the highest compared to values recorded after reduced, medium and conventional deep tillage and bulk density reached a maximum of 1.45 g cm^{-3} against 1.39 g cm^{-3} for superficial technique which may be explained by soil decompaction due to tillage effects. It decreases for the first technique to a depth of 10 cm and then increases at 20 cm which explains the disadvantage of reduced tillage. Results recorded for MT, showed that soil bulk density was lower than that obtained for RT except at 10 cm of depth. This difference can be explained by loosening provided by discs plow (Φ = 46 cm) most important than that provided by discs harrow (Offset). CT showed the lowest bulk density values with a maximum of 1.36 g cm^{-3} and a decrease of 0.9 g cm^{-3} compared to the initial state before tillage. Variation of bulk density as a function of depth was not significant statistically. However, differences can be explained by considerable soil decompaction after deep plowing. Indeed, conventional deep tillage provides a desired reversal of the plowed soil strip which leads to soil aeration and then a decrease in bulk density. The following practices can lead to poor bulk density: consistently plowing or disking to the same depth, allowing equipment traffic, especially on wet soil, using a limited crop rotation without variability in root structure or rooting depth. Conservation practices resulting in bulk density favorable to soil function include: conservation crop rotation, cover crop, deep tillage, prescribed grazing, residue and tillage management (Nyle, 2008).

Figure 2 showed the variation of bulk density as a function of time. We noted that from 0 to 30 days after tillage the most important values were recorded for treatment 2 (MT). 40 days after tillage, the highest values were recorded for treatment 1, the superficial or reduced tillage (RT). Soil bulk density recorded 60 days after tillage was 1.16 g cm^{-3} for deep plowing (CT), 1.23 g cm^{-3} for medium tillage and 1.38 g cm^{-3} for reduced tillage. This could be explained by the fact that in tilled soil, water reserves, enough high in depth and soil aeration, limit soil compaction and then decreases soil resistance to penetration and bulk density (Abrougui et al., 2012a). With the terminal drought advent, risks of drying are limited. Development of aerial and underground biomasses is thus favoured. Kanwar (1989) and Meek et al. (1992) reported that tillage systems have altered bulk density and porosity of soils. Higher bulk density values were obtained by decreasing the number, intensity and depth of tillage. The increases in bulk density of the soil with no-tillage treatments have previously been reported by Xu and Mermoud (2001). Contrasting results have been reported for the effects of soil tillage systems on bulk density. Tebrügge and Düring (1999) reported bulk density of 1.2 to 1.35 g cm^{-3} under inversion tillage and 1.4 to 1.5 g cm^{-3} under no-tillage.Statistical analyses of the data at * P <0.05 showed significant effects of the treatment and the measurement date on soil bulk density.

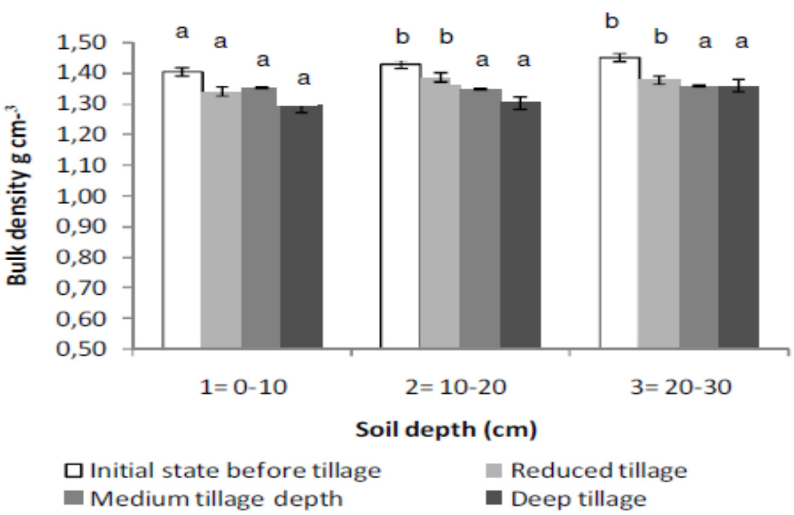

Fig. 1: Soil bulk density depending on tillage depth.

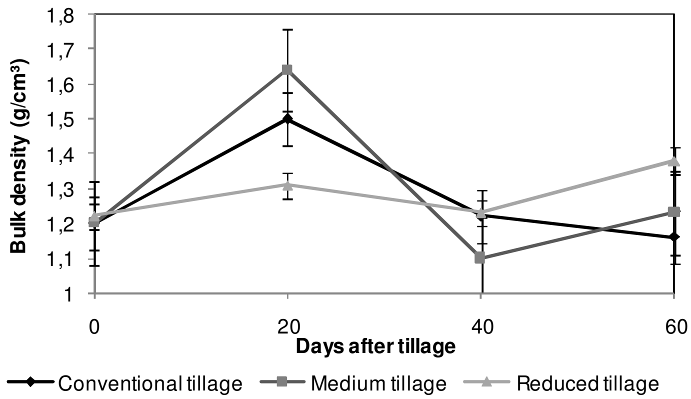

Fig. 2: Soil bulk density depending on measurement date.

Based on the different diameter categories, we conclude that conventional deep tillage presented the highest percentage of large tubers (56%). Medium and small tubers presented respectively an average of 33 and 10% of potato tubers (Table 1).

However, medium tillage presented 30% of large tubers and 37% of small tubers. Medium tubers presented an average of 32% of potato tubers. In fact, with highest tillage depth of 30 cm, we obtained the most important large tubers. Statistical analyses of the data at * P <0.05 showed significant effects of the treatment on the tuber size. It seems that a well tilled soil allows plants to receive more nutrient and water reserves promoting their development and consequently a high yield of fresh material (Abrougui et al., 2013; Chehaibi et al., 2013). 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.

Table 1: Measured tubers sizes

	Tillage system		
Tuber size (%)	Conventional tillage	Medium tillage	Reduced tillage
Small	10,13±0.33[a]	37,64±2.04[b]	61±1.73[c]
Medium	33,33±3.05[b]	32,23±1.96[b]	10±1[a]
Large	56,54±1.85[b]	30,13±0.22[a]	29±1.73[a]

Figure 3 showed that conventional deep tillage (CT) presented the highest tubers yield compared to other tillage techniques with an average of 11 Mg ha^{-1}, while reduced tillage (RT) presented the lowest yield of approximately 7 Mg ha^{-1}. The removed plough pan and the increased rooting might help the plant to avoid water stress. If this leads to improvements in tuber quality and quantity, it is important for the grower since it influence the economical outcome. It appears that there is considerable interaction between the tillage depth, the level of release of tubers in the soil and yield of the plant (Haider et al., 2012). Indeed, at shallower tillage, plant biomass was relatively less developed, leading to a lower tuber yield. 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 (Memari et al., 2011). Martin et al. (2009) reported that the impact of compaction depends on plant sensibility, especially the potato plant, to the presence of compacted areas.

Mohammadi and Shamabadi (2012) showed that tillage practices had significant influence on yield forming processes. Number of tubers per plant and tuber length was maximum in conventional planting. However, the difference of these parameters between conventional and minimum tillage was nominal. Ogbodo (2005) reported that plant shoot dry matter yield was significantly higher on the tilled plots by 16, 24, 27 and 39% for 10, 20, 30 and 40cm tillage depths respectively when compared with the untilled plots. The plants in the 40cm treated plots produced 23, 15, and 11% significantly higher dry matter yield than the plants on 10, 20 and 30cm tillage depth plots, respectively. The improved soil physical conditions due to reduced bulk density, and penetration resistance, could have positively influenced the crop growth. The direct implication was that root growth and plant nutrient uptake was increased on tilled plots, and this was reflected in the significantly higher plant growth on the tilled plots when compared with the untilled plots. Chandler et al. (1996) and Aina (1976) also reported higher yields of potato and cassava on tilled plots than the untilled plots. The former observed that higher plant shoot growth was enhanced by the increased root feeding area, created by increased depth of tillage.

Statistical analyses of the data at * P <0.05 showed significant effects of the treatment on the tuber yield (Fig 3). However, the difference of these parameters between conventional and minimum tillage was nominal. In this study, we found that the success, solely in terms of potato yield, of reduction of pre-plant tillage in potato production systems depended largely on the soil type and specific site of production. At the Higher Institute of Agronomy in Sousse, in a sandy loam soil, with low organic matter, potatoes did not produce well in reduced system. The difference in organic matter and fineness of soil texture between soils may mediate changes in bulk density and soil tilth to improve conditions for potato growth.

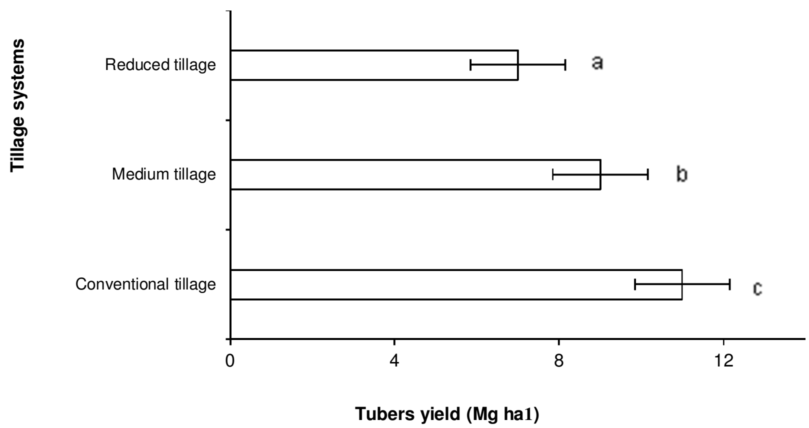

Fig. 3: Tubers yield (Mg ha^{-1})

CONCLUSION

At the end of this experimental work aimed to study the effects of three tillage techniques, on soil bulk density and on agronomic performance of potato crop conducted organically, conclusion was that deep plowing using discs plow followed by tillage resumption using "Offset", presented generally the lowest soil bulk density values. Soil bulk density recorded 60 days after tillage was 1.16 g cm^{-3} for T3, 1.23 g cm^{-3} for T2 and 1.38 g cm^{-3} for T1. Adopting the deep tillage technique, best results were obtained in terms of tuber size and potato yield. Conventional deep tillage presented the highest percentage of large tubers (56%). Medium and small tubers presented respectively an average of 33 and 10% of potato tubers. Plants under deep plowing with greater root area had higher soil feeding area than those under reduced depth of plowing.

Despite these limitations, RT in potatoes has the potential to be considered as a viable management option by potato growers in the east of Tunisia. Researches on zero tillage and subsurface tillage in potatoes should focus on production in different soil types to determine what soils are best suited for these production techniques.

ACKNOWLEDGMENTS

I like to extend my gratitude to Pr. S. Chehaibi and Dr. B. Dridi for their valuable comments during the whole process.

REFERENCES

Abrougui K., Chehaibi S., Dridi B. and Ben Mbarek K (2013). Influence of Mechanical Planting Depth on the Agronomic Behavior of a Potato Crop Conducted on Two Soil Types. The Afri J of Plant Sci and Biotech, 7 (1): 75-78.

Abrougui K., Chehaibi S. and Khelifi M (2012a). Impact of mechanical aeration on the soil resistance to penetration and density of a grassy sward. J. Environ. Sci. Eng (USA), A 1: 683-687.

Abrougui K., Chehaibi S., Louvet JN., Hannachi C. and Destain MF (2012b). Soil structure and the effect of tillage systems. Bulletin UASVM Agri, 69:11-16.

Aina PO (1976). Soil changes resulting from Long-Term Management Practices in Western Nigeria. Soil Sci. Soc. Amer. J, 44:827-837

Ben Hadj W (2009). Effet de la profondeur et de la densité de plantation mécanique sur le comportement d'une culture de pomme de terre conduite en mode biologique. Projet de fin d'études: ISA Chott Mariem Tunisia.

Blake GR., Boetler DH., Adams EP. and Aase JK (1960). Soil compaction and potato growth. Amer. Potato J, 37: 409-413.

Briggs SR., Ellis J. and Twomlow SJ (1998). Modern methods from traditional soil and water conservation technologies. In: Proceedings of the DFID Land Management Workshop. Kabale: Uganda; 1998.

Chandler JV., Costar RC. and Boneta EG (1996). High crop produced with and without tillage on three tropical soils of the humid region of Puerto Rico. Fac. Agric. Univ. of Puerto Rico bulletin, 50:146-150.

Chehaibi S., Hamdi W. and Abrougui K (2013). Effects of planting depth on agronomic performance of two potato varieties grown in the Sahel region of Tunisia. J of Dev and Agri Eco, 5(7): 272-276.

Ducattillon C., Donfut JR., Vandemeulebroecke K. and Blondiau L (2007). Avis pomme de terre 2. Centre pour l'agronomie et l'agro-industrie de la province de Hainaut: Belgique; 2007.

Grant WJ. and Epstein E (1973). Minimum tillage for potatoes. Amer. Potato J, 50: 193-203.
Haider M., Wasim A., Chaudhary M., Pervez MA., Asad HU., Raza SA. and Ashraf I (2012). Impact of foliar application of seaweed extract on growth, yield and quality of potato (Solanum tuberosum L.). Soil & Env, 31(2): 157-162.
Harris PM (1978). The potato Crop, the Scientific Basis for Improvement. Champan and Hall: London.
Kanwar RS (1989). Effect of tillage system on the variability of soil water tensions and water content.Trans. ASAE, 32(2): 605-610
Martin M., Royer C., Labreuche J., Boizard H. and Duparque A (2009). Le tassement des sols en régions de grande culture: enjeux et perspectives. Colloque SIM. ARVALIS-Institut du Végétal: Paris.
Meek BD., Rechel EA., Cater LM., DeTar WR. and Urie AL (1992). Infiltration rate of a sandy loam soil: effets of traffic, tillage, and plant roots. Soil. Sci. Soc. Am. J, 56: 908-913
Memari T., Elnaz F., Yarnia F. and Noshin A (2011). Effect of different irrigation level on yield potato. Ann. Biol. Res, 2(6): 269-273
Mohammadi A. and Shamabadi Z (2012). Evaluation the effect of conservation tillage on potato yield and energy Efficiency. Inter. J. Agr. Crop Sci, 4(23):1778-1785.
Mundy C., Nancy G., Carl R., George L. and Ronald D (1999). Soil Physical Properties and Potato Yield in No-till, Subsurface-till, and Conventional-till Systems. Hortechnology, 9(2): 240-247.
Naderman GC (1991). Effects of crop residue and tillage practices on water infiltration and crop production. In: Hargrove WL, editor. Cover crops for clean water. W. Tenn. Expt. Sta: Jackson; 1991.
Nyle C (2008). The Nature and Properties of Soils, Soil quality indicators. Macmillan Publishing Company: USA.
Ogbodo EN (2005). Effect of depth of tillage on soil physical conditions, growth and yield of sweet potato in an ultisol at Abakaliki, southeastern Nigeria. JASR, 5(1): 41-47
Pavek MJ. and Thorntonr RE (2009). Planting depth influences potato plant morphology and economic value. Amer J of Potato Res, 86(1): 56-67.
Prestt AJ. and Carr MVK (1984). Soil management and planting techniques for potatoes. Aspects Appl. Biol, 7:187-204.
Rousselle P., Robert Y. and Crosnier JC (1992). La pomme de terre: production, amélioration, ennemis et maladies. Ed. Inra: France.
Santos FL., De Jesus VAM. and Valente DSM (2012). Modeling of soil penetration resistance using statistical analyses and artificial neural networks. Acta Scientiarum. Agronomy, 34 (2): 219-224.
Snapp E. and Kravchenko A (2010). Potato yield variability across the Landscape. Agron. J, 102 (3): 885.
Tebrügge F. and Düring RA (1999). Reducing tillage intensity-a review of results from a long-term study in Germany. Soil Tillage Res, 53: 15-28
Xu D and Mermoud A (2001). Topsoil properties as affected by tillage practices in North China. Soil Tillage Res, 60(1): 11-19
Yoro G. and Godo G (1990). Les méthodes de mesure de la densité apparente: analyse de la dispersion des résultats dans un horizon donné. Cah. ORSTOM, sér. Pédol. 1990; XXV: 423-429.

Cite this Article: Abrougui K, Chehaibi S, Boukhalfa HH, Chenini I, Douh B, Nemri M, 2014. Soil Bulk Density and Potato Tuber Yield as Influenced by Tillage Systems and Working Depths. Greener Journal of Agricultural Sciences. 4(2):046-051, http://dx.doi.org/10.15580/GJAS.2014.2.020314087.