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# BEAN YIELD AND ROOT DEVELOPMENT IN DIFFERENT SOIL MANAGEMENTS UNDER A CENTER PIVOT SYSTEM

Leonardo Pretto de Azevedo[1]
João Carlos Cury Saad[2]
Marcelo Augusto de Aguiar e Silva[3]

## ABSTRACT

The bean culture is part of crop rotation used by irrigators from the southwestern region of the state of São Paulo, who perform the no-tillage soil management as a form of sustainable soil use. The effect of this conservationist practice on soil compaction, root development and bean culture production components in relation to the conventional management was the objective of this work. The experiment was conducted at the Buriti-Mirim Farm, Angatuba, SP, Brazil, using an 18ha area irrigated through center pivot system divided into two types of soil managements: conventional management and no-tillage management. Crop production components, soil cone index and root development components (distribution in the soil profile, length, surface, diameter and dry matter) were evaluated. Although the no-tillage management had presented lower compaction at the most superficial layers and more uniform root distribution in the soil profile, the managements evaluated were not significantly different in relation to crop productivity.

## INTRODUCTION AND BACKGROUND

### Soil management

The different management systems affect soil density and porosity, directly influencing the root system development and crop productivity. The incorrect use of machines and agricultural accessories leads to increases on the soil density at the sub superficial layer and has been pointed as one of the main causes for deterioration of the soil structure and reductions on the crop productivity (Campos et al., 1995). According to Pedroso & Corsini (1983) and Silva et al. (1986), alterations on the soil structure due to conventional management practices also affect its drainage in function of the reduction on the volume of macropores, modifying the diffusion of water and gases and making the plant root development difficult. If intensive tillage is responsible for the soil deterioration, its reduction and the accumulation of organic residues at the soil surface could probably change this condition (Silveira Neto et al., 2006). The adoption of rational techniques for soil and water conservationist management is vital for sustainability so that these resources will be preserved along time with sufficient quantity and quality for the maintenance of satisfactory productivity levels (Wutke et al., 2000).

[1]Graduate, Agricultural Science School, São Paulo State University, Rua José Barbosa de Barros, 1780, Botucatu, SP, 18610-307, Brazil; pretto@fca.unesp.br
[2]Professor, Agricultural Science School, São Paulo State University, Rua José Barbosa de Barros, 1780, Botucatu, SP, 18610-307, Brazil; joaosaad@fca.unesp.br
[3]Graduate, Agricultural Science School, São Paulo State University, Rua José Barbosa de Barros, 1780, Botucatu, SP, 18610-307, Brazil; aguiaresilva@fca.unesp.br

In this context, the no-tillage technique has been recommended as alternative to avoid the undesirable effects of inadequate and repetitive soil preparation (Chan et al., 1992). It deals a management system where the sowing is performed on the remainders of the previous culture without drastic soil mobilization, in other words, without its preparation or mobilization before sowing (Stone and Silveira, 1999). Although this technique could increase the volume of water stored and available to plants, Klein and Libardi (1998) explain that the soil management under no-tillage system also increases the soil density and penetration resistance. According to Silveira Neto et al. (2006), this increase on the soil density at the most superficial layers has led some farmers from the Brazilian Cerrado vegetation to use plow or scarifier in areas so far conducted under no-tillage system, also acting in the nutrients redistribution in the soil profile. According to Silveira et al. (1998), such procedure does not affect the soil management conservationist aspect at all, once the no-tillage system is again employed in subsequent tillages. The use of no-tillage system and irrigation as conjugate techniques has shown to be promising considering the improvement of the soil exploitation and its maintenance. Stone & Moreira (2000; 2001) verified that the no-tillage system provided higher water economy when compared to other soil management systems; besides, this system would improve the soil physical characteristics along the years, once the increase on the organic matter content on the soil surface layer may reduce its density.

## Root development

Since the no-tillage system improves the soil structure and water availability, a higher root development and hence a higher productivity are expected for this type of soil management; however, the effects of different soil management on root development and bean plant yield are not yet well determined. In general, root elongation is only possible when the root growth pressure is higher than the soil mechanical resistance to penetration (Passioura, 1991). According to Freddi et al. (2006), this resistance exerts great influence on the vegetal development, once the root growth and crop yield change is inversely proportional to their value. Mechanical resistance to penetration values ranging from 1000 to 3500kPa may generally restrict or even hinder the root development and growth. (Canarache, 1990; Merotto & Mundstock, 1999). According to Arshad et al. (1996), these values may range from 2000 to 4000kPa. More specifically for bean crop, Carvalho et al. (2006) concluded that soil mechanical resistance to penetration values ranging from 1290 to 2870 kPa are not restrictive to productivity. Richther et al. (1990) worked with different cultures and obtained higher root production using no-tillage system than in conventional management system; however, the highest amount of roots obtained with the no-tillage system was found at the first 15 cm of soil. Stone & Silveira (1999) studied the effect of different soil managements on productivity, water availability and root development of bean crops and verified that the no-tillage system presented higher productivity with higher water economy; however, the root system depth distribution was more uniform in plow-prepared soils. Stone (2002) worked with bean crop for four consecutive years using three soil preparation systems (no-tillage, plowing with plowing grid and moldboard plow) and observed that from 76 to 90% of roots were found at the first 30 cm deep in the soil.

**Bean yield**

In relation to bean yield, Knavel & Herron (1986), Mullins & Straw (1988), Sampaio et al. (1989) and Siqueira (1989) verified higher productivities in conventional management when compared to no-tillage system. In the study of Stone (2002), the no-tillage system presented lower number of pods per plant and lower mass of 100 grains and hence lower productivity in relation to the other soil management systems; however, the author attributed the lower bean yield to the lower N content in plants and concluded that the bean plant yield under no-tillage system increases with the adoption time of this system. Other important aspects are related to reductions on productivity in the no-tillage system. Arf et al. (2004) observed that soils prepared with moldboard plow and with plowing grid produced higher amount of grains in relation to the no-tillage system, once the dead coverage of this system provided higher humidity in the soil surface, thus favoring the attack of the “white mould”. Mullins et al. (1980) and Zaffaroni et al. (1991), however, found no differences in the bean plant yield between no-tillage system and conventional management. According to Lopes et al. (2004), no significant differences in relation to water storage and grain productivity between no-tillage system and conventional management were found either.

**Objectives**

Due to the economic and environmental importance that the conventional management and the no-tillage systems represent for farmers from the southwestern region of the state of São Paulo, the objective of this work was to evaluate how these systems influence the compaction (soil cone index), root development and yield of beans irrigated through central pivot system.

## MATERIAL AND METHODS

The experiment was conducted in an 18ha area irrigated through center pivot system at the Buriti-Mirim Farm, Angatuba, SP, Brazil during the second semester of 2003. The culture used was bean (*Phaseolus vulgaris* L.) cultivar Rubi, which sowing occurred at August 2 and the harvest at November 25, 2003, summing up 116 days of culture cycle. The experimental design was fully randomized with two treatments: the no-tillage and conventional managements with 13 parcels each. The averages of the results obtained were compared through the Tukey test at 5% probability. The conventional management was performed by means of the use of plow and grid, while the no-tillage management was characterized by sowing under remainders of the previous culture with no soil revolving. The denomination “no-tillage” was used in this experiment, but the parcel with no soil revolving does not characterize a continuous no-tillage system, once operations such as soil preparation aimed at eliminating the cotton stump and subsoiling for the elimination of compacted soil layers and redistribution of nutrients along the soil profile are periodically performed. Before the experiment was installed, soil non-deformed samples were collected with the aid of volumetric rings. The samples were led to the Soils Physics Laboratory of the Department of Natural Resources – Agricultural Sciences School, UNESP, Botucatu, Brazil, for the attainment of the water retention characteristic curve in relation to both soil managements adopted. Water was supplied to the culture by means of a central pivot irrigation system. Irrigation was monitored by means of three tensiometer batteries in each soil management treatment: conventional and no-tillage managements. Each battery was composed of two tensiometers installed at 15 and 30 cm of depth, where the first one defined the irrigation moment and the second one was used to control the amount of water applied (Saad & Libardi, 1992). The irrigations were performed whenever the average value read in tensiometer placed at 15 cm of depth reached 35 kPa (Silveira & Stone 1994; Moreira et al., 1999). For the determination of the soil cone index (soil mechanical resistance to penetration), a hydraulic-electronic penetrometer according to Lanças and Santos (1998) was used. The hydraulic-electronic penetrometer, assembled on a cart for haulage and application in tractors with hydraulic system, presents a cone with base area of 320 $mm^2$, solid angle of 30º and soil penetration constant velocity of 30 mm $s^{-1}$ according to ASAE S313.2 (1991). The electronic system presents a data acquisition system (Microlloger 23X, Campbell), power sensor (load cell of 10000 N) and depth sensor (rotational potentiometer). The depths used for the determination of the soil cone index were 0-5; 5-10; 10-20 and 20-40cm in both treatments. The root development was evaluated when 50% of plants were found at full flowering stage and its sampling was performed using a galvanized steel auger with diameter of 4.5 cm. The soil collection for the root analysis occurred at days 3 and 4 of November in four layers (0-5; 5-10; 10-20 and 20-40cm). The samples were removed from the tillage line between one plant and another with four repetitions per parcel, summing up 52 samples from each layer per treatment. Later, the roots were separated from the soil through washing in running water with the aid of a 0.5 mm sieve. After separated and washed, the root samples were conditioned in universal collectors with alcohol solution 70% and placed into freezer at 4°C. The variables that characterize the root development were determined in a Scanner coupled to a computer equipped with WinRhizo software, which uses the method proposed by Tennant (1975) as principle. This equipment determined length (Km $m^{-3}$), surface ($m^2$ $m^{-3}$) and root diameter (cm). After these evaluations, the samples were dried in stove at 65°C until reaching constant weight for the determination of the root dry matter production (g $m^{-3}$). On the occasion of the bean culture harvest, 10 sequential plants in pre-determined site in the useful area of each parcel were collected, summing up 130 samples per treatment. These plants were led to the laboratory for the determination of the number of pod/plant, number of grains/plant, average number of grains/pod and mass of 100 grains, determined through random collection and weighting of two samples of 100 grains per parcel.

## RESULTS AND DISCUSSION

The soil cone index values showed increase trend up to the layer of 10-20 cm for both treatments. In this layer, the highest values for no-tillage and conventional management systems were observed, 3254kPa and 3310kPa, respectively (Table 1). Physically, the root elongation is only possible when the root growth pressure is higher than the soil mechanical resistance to penetration (Passioura, 1991), which may be characterized by the soil cone index. According to Carvalho et al. (2006), the maximum soil cone index value for adequate root development in bean plants is of 2870 kPa, showing that values obtained were restrictive in layer of 10-20 cm. According to Canarache (1990), Arshad et al. (1996) and Merotto & Mundstock (1999), the soil cone index values found in this work can also be restrictive to the root development in most cultures.

Table 1. Soil cone index values (kPa) for no-tillage management (NM) and conventional management conditions (CM) at the different soil layers evaluated.

| Soil Management | 0-5cm | 5-10cm | 10-20cm | 20-40cm |
|---|---|---|---|---|
| NM | 1104 | 2736 | 3254 | 2335 |
| CM | 1095 | 3161 | 3310 | 2702 |

Thus, the bean plant root system was found at the most superficial soil layers (0-5cm and 5-10cm), presenting total length of 93% at the first 10 cm of the soil profile in the conventional management system and 84% in the no-tillage management system (Table 2). The most uniform root distribution in the no-tillage management system may be related to soil cone index values of layer 5-10 cm. In this layer, the soil cone index in the no-tillage management system (2736 kPa) was lower than that considered restrictive for this culture (2870 kPa), what was not observed for the conventional management system (3161 kPa). One yet observes that layers of 5-10 and 10-20 cm in the conventional management system presented values quite close to each other, 3161kPa and 3310kPa respectively, what might have been caused by adjustment problems of the agricultural accessories work effective depth, thus evidencing alterations at the depth of the compacted subsuperficial layers.

Table 2. Distribution of the bean plant root length along the soil profile at no-tillage (NM) and conventional (CM) management systems for depths evaluated.

| Soil layer (cm) | NM | CM |
|---|---|---|
| 0-5 | 38% | 61% |
| 5-10 | 46% | 32% |
| 10-20 | 11% | 6% |
| 20-40 | 5% | 1% |

The layer of 5-10 cm also presented significant differences in the dry weight of roots (Table 3), of 898.35 $g.m^{-3}$ in the no-tillage management system and of 598.59 $g.m^{-3}$ in the conventional management system. For the other root development variables, no significant differences between treatments were observed. The most uniform root distribution results in no-tillage management are not in agreement with Stone & Silveira (1999), who obtained better distribution in plow-prepared soil.

Table 3. Length ($km\ m^{-3}$), surface ($m^2\ m^{-3}$), dry weight ($g\ m^{-3}$) and root diameter (cm) of the bean plant in no-tillage management system (NM) and conventional management system (CM) at the different layers evaluated.

| Soil layer (cm) | Length ($km\ m^{-3}$) | | Surface ($m^2\ m^{-3}$) | | Dry Weight ($g\ m^{-3}$) | | Diameter (cm) | |
|---|---|---|---|---|---|---|---|---|
| | NM | CM | NM | CM | NM | CM | NM | CM |
| 0-5 | 9,04a | 16,66a | 14,37a | 22,35a | 733,15a | 924,55a | 0,054a | 0,046a |
| 5-10 | 10,98a | 8,67a | 19,93a | 11,82a | 898,35a | 598,59b | 0,059a | 0,048a |
| 10-20 | 2,68a | 1,53a | 5,28a | 3,26a | 339,38a | 263,67a | 0,056a | 0,059a |
| 20-40 | 1,11a | 0,28a | 1,72a | 0,44a | 93,53a | 74,70a | 0,048a | 0,042a |

Values followed by same letter are not significantly different at 5% probability through the Tukey test.

However, distribution differences in the root system and dry weight of roots were not sufficient to influence the bean yield of bean plants between treatments (Table 4). These results are similar to those obtained by Mullins et al. (1980) and Zafarroni et al. (1991), who also found differences in bean yield between no-tillage and conventional management systems.

Table 4**.** Number of grains per plant, pod per plant, grains per pod, mass of 100 grains and bean yield in function of the different soil preparations, conventional management (CM) and no-tillage management system (NM).

| Soil management | Grains/plant | Pod/plant | Grains/pod | Mass of 100 grains (g) | Bean Yield (Kg $ha^{-1}$) |
|---|---|---|---|---|---|
| NM | 83,48a | 15,22a | 5,14a | 18,02[a] | 3360a |
| CM | 78,41a | 16,22a | 5,16a | 19,47[a] | 3330a |

Values followed by same letter are not significantly different at 5% probability through the Tukey test.

## CONCLUSIONS

The root system distribution in the 0-40cm layer was more uniform in no-tillage management system in relation to the conventional one. The no-tillage management system presented higher root dry weight value than the conventional management system at layer of 5-10 cm. No significant difference in relation to bean yield between soil managements evaluated was observed.

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