Developing a combined machine for seedbed preparation

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Abstract: Soil preparation is a very important part of the grain production process as it is necessary to maximize the possible yield. The mechanical soil preparation assists better water, air circulation and fertilizer dissolving in soils, which can increase the grain yield. The aim of this investigation was to develop a new combined machine for seedbed preparation in one trip and assess its effect on some soil physical properties and crop yield. Field experiments were carried out on clay loam, three diverse tillage methods were conducted under the same conditions of soil moisture content, operating speed and plowing depth. The tillage methods were: new combined machine (NCM), traditional method (TM) and no tillage (NT) method. Results clarified that NCM achieved better values of the soil physical properties and increased onion yield compared to the other tillage methods. The NCM decreased soil bulk density by 19% based on NT method and 12% based on TM. It also increased soil total porosity by 35.16% based on NT method and 8% based on TM. The NCM maximized crop yield by 63.5% and 48.2% based on crop yield in NT and TM respectively. The obtained results recommended using NCM in seedbed preparation for onion crop which planted in clay loam soil under the studied conditions.

Keywords: seedbed preparation, combined machine, soil physical properties, onion yield, clay loam soil

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1 Introduction

Tillage as one of the most influential management practices affecting soil physical and hydraulic characteristics (Lal and Shulka, 2004). In simple terms, tillage involves the movement of soil from one place to another. The aim of tillage is to improve soil physical conditions for seed germination and crop growth (Walters, 2013). Over time, tillage equipment have been developed to meet specific requirements, for example, the plow was developed to invert the soil. Other systems have also been developed to meet the large variation in soil, climate and crop requirements (Morriset et al., 2010). Traditional or conventional tillage refers to the sequence of operations “most commonly or historically used in a given field to prepare a seedbed and produce a given crop (MWPS, 2000; ASAE, 2005).

The benefits of plowing on weed control and stand establishment are immediate, but it also has numerous long-term adverse impacts on soil and environments. For example, tillage rearranges the soil and affects the soil physical and chemical properties (Agbede, 2010; Alvarez and Steinbach, 2009). Nasr (2008) found that when machines moved on soil to prepare for planting, the soil was exposed to a number of stresses as a result of the movement of this equipment. Soil Structure is one of the most important soil dynamic properties affected by the seedbed preparation operations and influenced by the chemical and physical conditions as well as agricultural operations performed to prepare the soil for planting.

Nasr et al. (2016) found that using combined machines reducing fuel consumption and wheel slip. Javadi and Hajiahmad (2006) mentioned that using combined equipment and reducing the number of passes

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is getting popular due to its effect on time, efficiency and costs. Design and development of combined a machine were considered in both primary and secondary tillage operations from about hundred years ago.

Kęsik and Błażewicz-woźniak (2009) stated that onion plants grew best following traditional tillage. In those fields, the plants were the tallest and produced the most leaves. Conservation tillage reduced the vegetative growth of onion plants. After using spring rye, the plants were somewhat taller, but produced fewer leaves than after mulching with vetch. They also added that the most beneficial pre-sowing tillage method for onion was the traditional tillage method involving pre-winter ploughing and soil preparation treatments in the spring, without the use of any mulching plants. Pedersen et al. (2015) found that the average yield of marketable onions was significantly higher in the plots that were neither compacted nor sub soiled (no compaction treatment, no subsoiling treatment) compared to the plots with both treatments (compaction treatment, subsoiling (loosening) treatment). No significant differences were found in the percentage of onions in the different size classes, also the percentage of non-marketable onions due to size or disease infections was not different between the treatments.

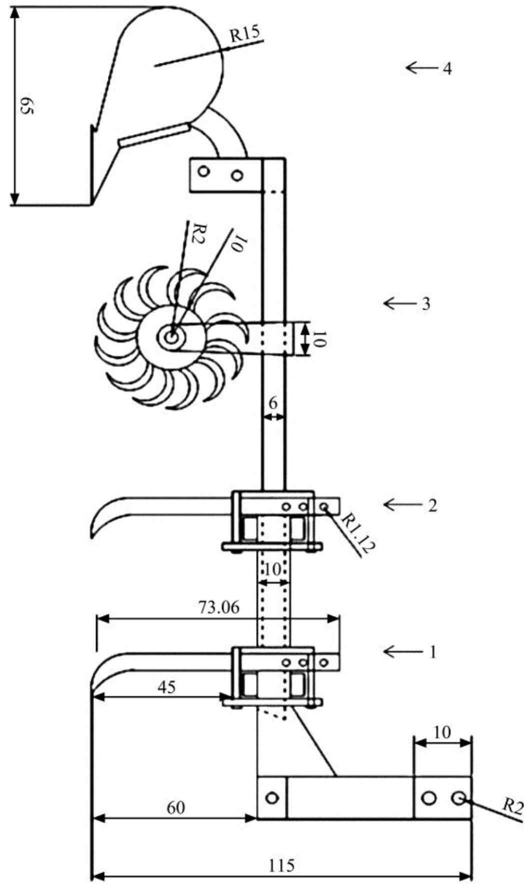
The present investigation aimed to (1) design a combined machine for seedbed preparation which preparing soil in one trip to reduce passes number of farm machinery unite on soil and (2) reducing soil compaction and (3) compared the new tillage equipment with the traditional systems and assess its effect on some soil physical properties and onion crop yield.

2 Materials and methods

2.1 Combined machine design and description

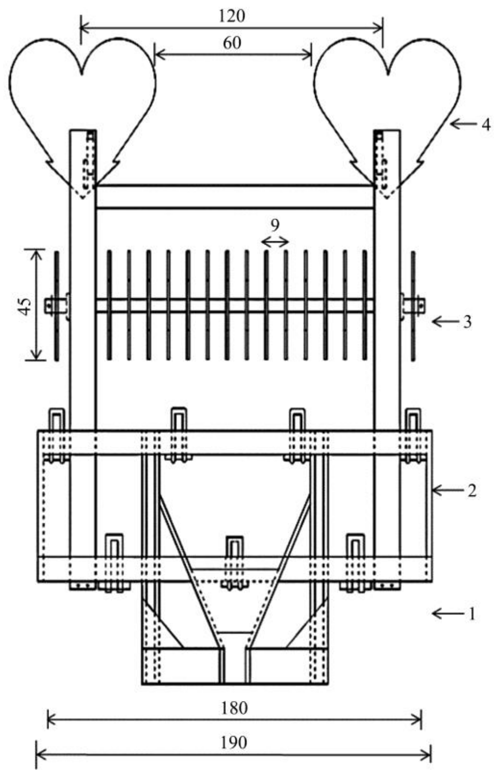
The combined machine consisted of a set of parts as shown in Figures (1, 2). The first part is Chisel plow with seven times, 170 cm working width which represents the primary tillage tool.

The second part is a packer roller which represents the secondary tillage tool with 180 cm axial with 16 circular toothed rotary tines, with space 9 cm between two tins. The inner diameter of the tins is 20 cm and the outside diameter at the edge of tins is 45 cm, respectively. Packer roller collects weeds and breaks the soil clods resulting from plowing process.



1. Main frame 2. Chisel plow 3. Pacher roller 4. Two blades ridger

Figure 1 Side view for the combined machine (dimension in cm).



1. Main frame 2. Chisel plow 3. Packer roller 4. Two blades ridger

Figure 2 Plan view for the combined machine (dimensions in cm)

The last part of the combined is two adjacent blades ridger that makes terrace 60 cm width. All these parts were linked together to one frame hitching with Belarus agriculture tractor (two wheels drive, four cylinders diesel engine and engine 90 HP at 2200 rpm). The total mass of the combined machine is 500 kg.

Design calculations were conducted for each part of the machine to determine the safety factor during operating of the machine. Bending moment and bending stress were determined for each part to get the factor of safety and compare it with the allowable safety factor of the metal that used in manufacturing.

The main frame of the combined machine was manufactured locally of steel structures of U cross section area (100×60×8 mm). The frame was incomplete rectangular shape with total length and wide 180 and 130cm. respectively. At a distance of 110 cm from the beginning of the frame two bars (30×10 cm) were welded with frame to attach the beam of secondary tillage tool with the frame. At end of the frame another two bars with dimensions (30×20 cm) were also welded to attach the two ridger.

2.2 Experiment layout

The experiments were carried out during the agricultural season of 2015-2016 in clay loam soil at the Experimental Station, Faculty of Agriculture, Cairo University, Giza, Egyptian cooperation with The National Research Center. Onions (Allium cepa) L. Beheri (red) cultivar were transplanted manually at late December 2015 in the winter planting season under surface irrigation. Onion crop was irrigated according to water requirements and fertilized according to the recommended doses during growing season.

Three tillage methods were conducted under 18% soil moisture content:

1. The new combined machine (NCM)
2. Traditional method (TM): Three passes (two passes chisel plow followed by ridger (one pass)).
3. No tillage treatment (NT).

Undisturbed soil samples were taken randomly from the experimental field area before and after the experiment to study soil physical properties and assess treatment effects on it. Soil samples were taken at depths of 15 cm and 30 cm in three replications. Onion crop yield was measured for each tillage method. The experimental data were analyzed using analysis of variance (ANOVA). The means were compared with LSD at 5% level significance for all study parameters. This analysis was performed by COSTAT program.

3 Measurements

3.1 Soil bulk density

Bulk density was measured according to Blake and Hartge (1986) Equation (1)

$$\delta b = \frac{M}{Vb} \tag{1}$$

where, δb is soil bulk density, g cm^{-3}; M is the oven dry weigh of soil in the container, g, and Vb is bulk volume of the soil in container, cm^3.

3.2 Total Soil porosity

Soil porosity % was calculated according to the following Equation (2). (Blake and Hartge, 1986):

$$\emptyset = \left(\frac{1-\delta b}{\delta r}\right) \times 100 \tag{2}$$

where, δr is real soil density (2.65 g cm^{-3}), and δb is soil bulk density (g cm^{-3}).

3.3 Soil hydraulic conductivity

Constant head method was used in determining soil hydraulic conductivity (K), using the following Equation (3). (Klute and Dirksen, 1986)

$$K = \frac{Q \cdot L}{A \Delta h} \tag{3}$$

where, K is hydraulic conductivity, cm h^{-1}; Q is rate of water flows via the column, cm h^{-1}; L is length of the column, cm; A is the Crosse section area of the core, cm^2; and Δh is the head difference causing the flow, cm.

3.4 Crop yield

Crop yield is an important indicator in the evaluating of the new combined machine. At the end of the season onion was harvested and measured the crop yield (tons fed^{-1}) (*fed*= 4200 m^2) for each treatment

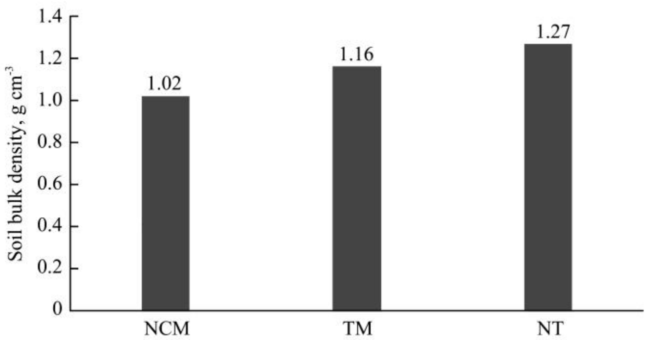
4 Results and discussion

Results showed that the NCM achieved positive changes concerning the soil physical properties under study and onion yield. It decreased soil bulk density by (19 and 12%) and increased total porosity by (35.16; 8%), soil hydraulics conductivity (70.8; 92.8%) and onion yield, and (63.5; 48.2%) relative to NT and TM methods, respectively.

4.1 Effect of tillage methods on soil physical properties

4.1.1 The effect of tillage methods on soil bulk density

Soil bulk density decreased after all seedbed preparation systems Abdel-Galil (2007). From Figure 3, it is clear that tillage methods affect soil bulk density. The NCM achieved lowest soil bulk density values compared to TM and NT system. This trend may be due to that the combined machine break up the soil and produced a good close packing for the fine aggregates. Also, the NCM prepared the seedbed in one pass instead of three ones and decreased tractor wheel slip relieving soil compaction Nasr et al. (2016).



Tillage systems: NCM is the new combined machine, TM is traditional method, NT is no tillage.

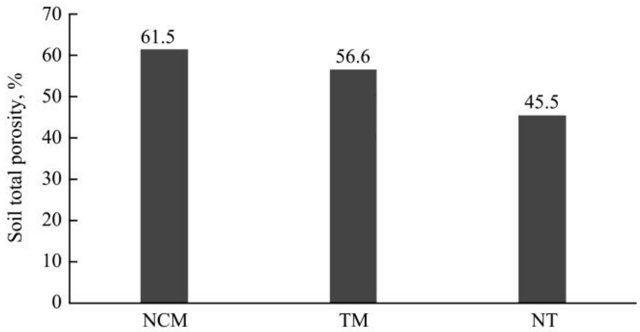
Figure 3 Effect of tillage methods on soil bulk density

4.1.2 The effect of tillage methods on total soil porosity

According to the change in soil bulk density, soil porosity showed a reverse behavior. This result agreed with Abdel-Galil (2007) who found that soil porosity values increased after all seedbed preparation treatments than those before treatments. Figure 4 showed total soil porosity values under experimental operating conditions. By using the NCM, total soil porosity increased compared with both NT and TM. The total soil bulk density values were 61.5% for the NCM while traditional method soil porosity value was 56.6% and no-tillage was 45.5%.

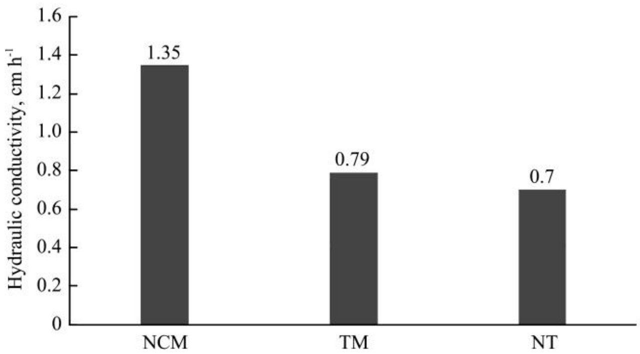
4.1.3 The effect of tillage methods on hydraulic conductivity

Hydraulic conductivity of the soil under experimental conditions is showed in Figure 5. Ahmadi and Ghaur (2015) found that hydraulic conductivity of the soil affected by tillage methods and plowing depth. Data trend showed the NCM had the highest hydraulic conductivity value compared to traditional method and no- tillage methods. This trend may be due to the greater values of soil total porosity. The hydraulic conductivity of soil was 1.35 cm h^{-1} for the NCM while traditional method value was 0.79 cm h^{-1} and no-tillage were 0.7 cm h^{-1}. The NCM increasing soil hydraulic conductivity by 70.8% and 92.8% based on TM and NT respectively.



Tillage systems: NCM is the new combined machine, TM is traditional method, NT is no tillage.

Figure 4 Effect of tillage methods on soil total porosity

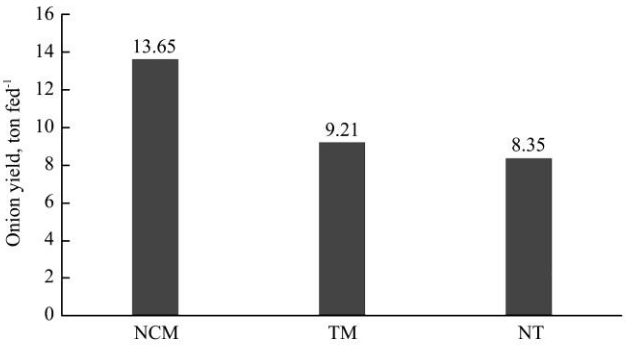


Tillage systems: NCM is the new combined machine, TM is traditional method, NT is no tillage.

Figure 5 Effect of tillage methods on hydraulic conductivity

4.2 Effect of tillage methods on onion yield

Swanton et al. (2004) found that onion yield was affected by tillage methods. They added that marketable yields of onion were greater when grown in the zone tillage system than under conventional tillage. Figure 6 represented onion crop yield under the different tillage methods. From data, it is clear that the NCM has achieved greater productivity compared to both traditional method and no- tillage treatments. The onion crop yield under the NCM, TM, and NT methods were 13.65; 9.21; and 8.35 ton fed^{-1}, respectively. The NCM increased crop yield by 63.5% and 48.2% based on crop yield of NT and TM, respectively.



Tillage systems: NCM is the new combined machine, TM is traditional method, NT is no tillage.

Figure 6 Effect of tillage methods on onion yield

5 Conclusion

All studied parameters were influenced by using different tillage methods (NCM; TM; and NT). According to the results, the NCM surpass other tillage methods in all measured soil physical properties. NCM increased soil total porosity and soil hydraulic conductivity compared to TM and NT but it decreased soil bulk density. The NCM increased onion yield compared to TM and NT. The obtained results recommended using NCM in seedbed preparation for onion crop which planted in clay loam soil under the studied conditions.

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