Effect of integrated reservoir tillage for in-situ rainwater harvesting on soil erosion control and climate change mitigation in arid region of Egypt

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Abstract

There is a need for in-situ soil moisture conservation in arid and semi-arid regions due to insufficient rainfall for agriculture. For this purpose, a combination implement [integrated reservoir tillage system (RT)] comprised of a single-row chisel plow, single-row spike tooth harrow, modified seeder, and spiked roller was developed and compared to the popular tillage practices, viz., minimum tillage (MT) and conventional tillage (CT) in an arid Mediterranean environment in Egypt. Some soil physical properties, runoff, soil loss, water harvesting efficiency and yield of wheat were evaluated. The different tillage practices caused significant differences in soil physical properties as the RT increased soil infiltration, producing a rate of 48% and 65% higher than that obtained in MT and CT, respectively. The lowest values of runoff and soil loss were recorded under RT as 4.91 mm and 0.65 t ha^{-1}, whereas the highest values were recorded under CT as 11.36 mm and 1.66 t ha^{-1}, respectively. In conclusion, the RT enhanced the infiltration rate, increased water harvesting efficiency, reduced runoff and achieved the highest yield of wheat.

Background

This study used Egypt as the focus region because it lies in the heart of the water scarcity problem. Current scenarios predict that climate change will increase water scarcity in Egypt. Climate change has the potential to affect agriculture through changes in temperature, rainfall timing and quantity. Changes in rainfall will be one of the most critical factors determining the overall impact of climate change. This problem indicate a need to design integrated technologies to increase agricultural water use efficiency through rainwater harvesting while conserving the soil in rainfed areas. Researchers in this region recognized the need to develop an alternative system that was energy, water and labor efficient that could also help sustain soil and environmental quality and produce more at a lower cost.

Materials and methods

The combination implement used in this study was manufactured from local materials to overcome the problems associated to the imported machines like cost and power requirements.

The main structure consisted of the parts defined in the following sections:

1- Chisel plow, 2- Spike-tooth harrow, 3- Seeding unit

4- Spiked roller (reservoir tillage tool)

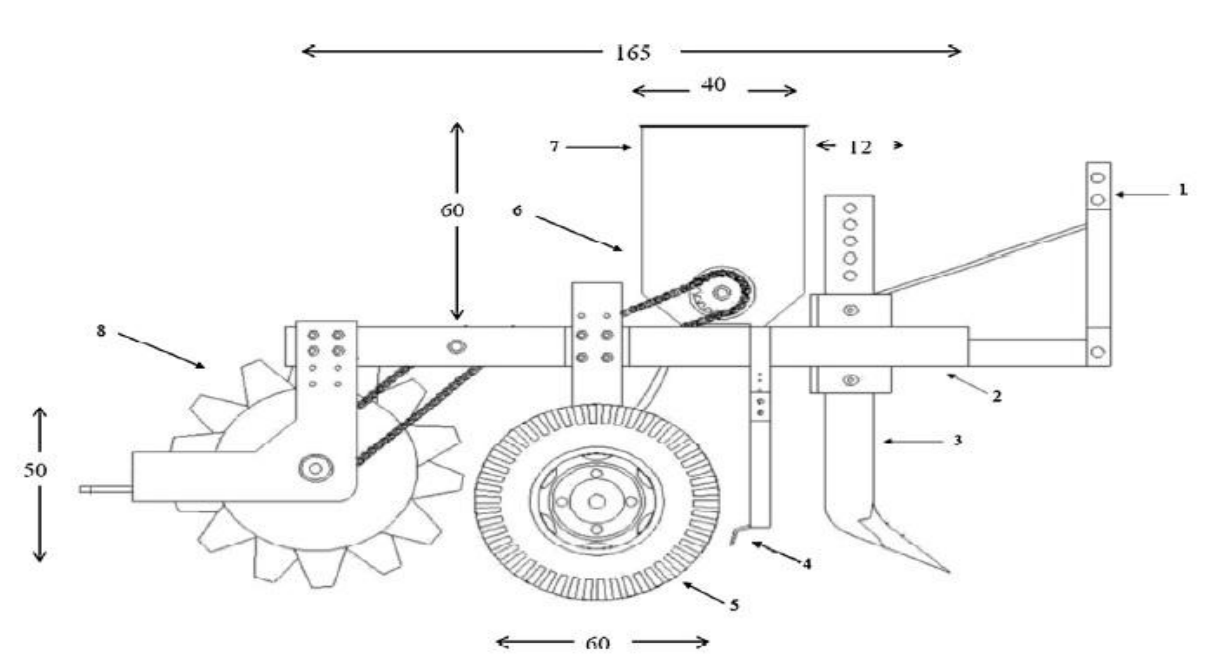

Fig. 1. Side view of the combination implement (integrated reservoir tillage system), (1) upper hitch point; (2) main frame; (3) chisel plow; (4) spike-tooth harrow; (5) ground wheel; (6) feeding mechanism; (7) seed hopper; (8) spiked roller. Dimensions in centimeters.

Fig. 2. The combination implement during carrying out experiments.

Results

1- Infiltration rate

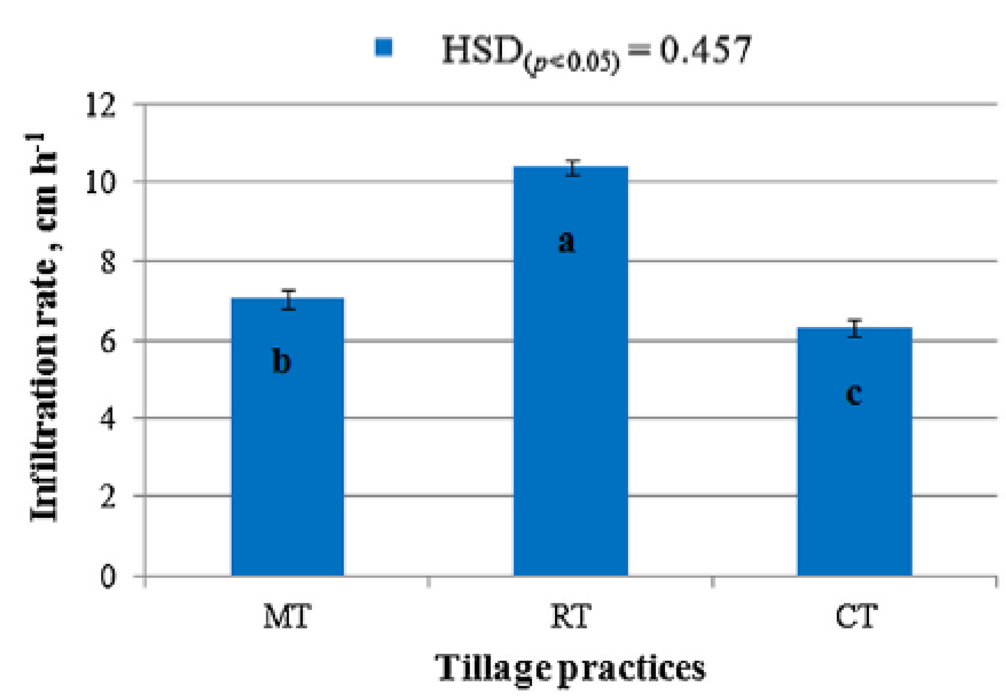

Fig. 3. Mean infiltration rate (cm h1), under tillage practices, MT: minimum tillage; RT: reservoir tillage; CT: conventional tillage . Different letters indicate significant differences (p < 0.05).

2- Runoff and soil loss

Treatments	Runoff (mm)	Runoff coefficient (%)	Soil loss (t ha^{-1})
MT	10.20 ±0.2 ^{b}	6.33 ±0.1 ^{b}	1.44 ±0.1 ^{b}
RT	4.91 ±0.2 ^{c}	3.04 ±0.1 ^{c}	0.65 ±0.1 ^{c}
CT	11.36 ±0.2 ^{a}	7.05 ±0.1 ^{a}	1.66 ±0.1 ^{a}
HSD ($p < 0.05$)	0.529	0.328	0.030

Table 1. Mean values ±standard error of runoff (mm), runoff coefficient (%), and soil loss (t ha^{-1}) for different tillage practices. Different letters in the same column indicate significant differences (*p < 0.05*).

3- Moisture storage

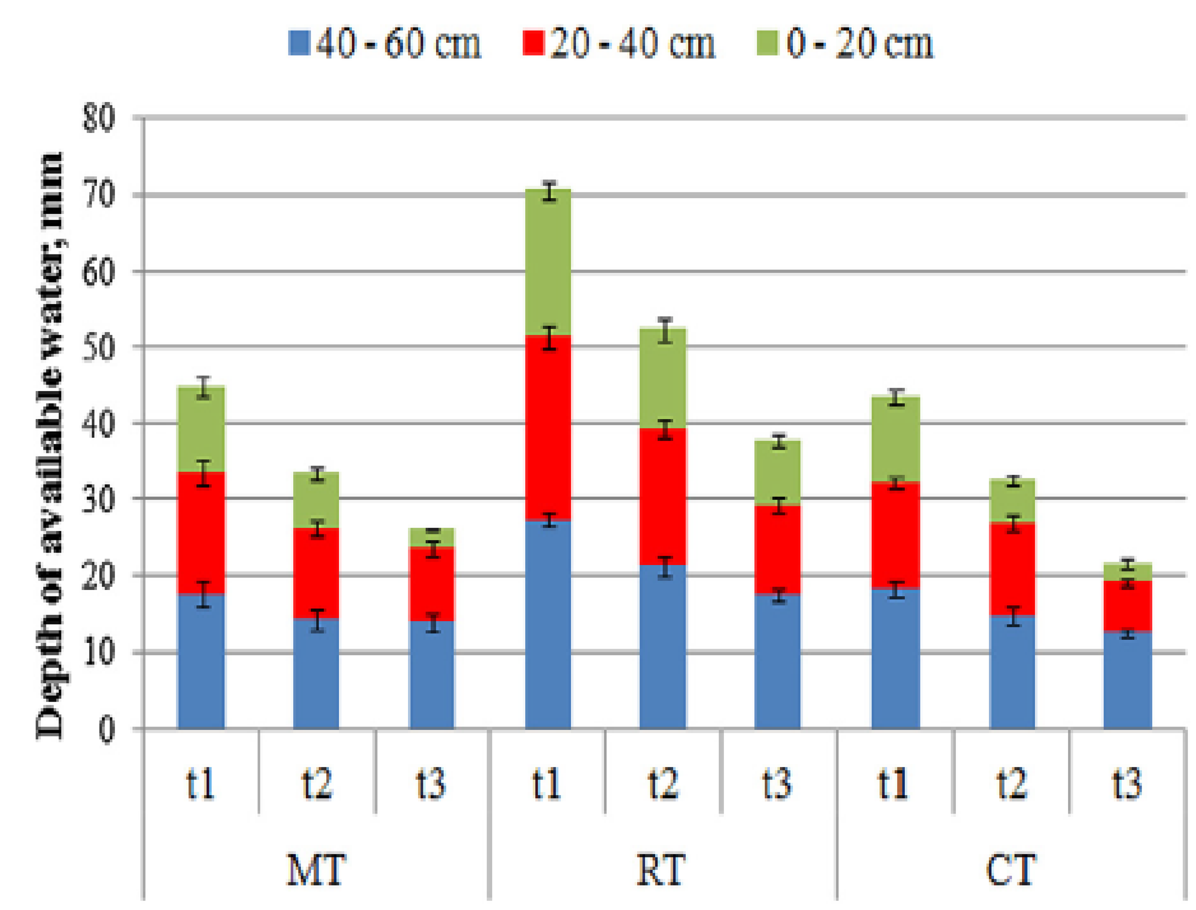

Fig. 4. Depth of available water as distributed in the soil layers (0–20, 20–40, and 40–60 cm), through the dry period of the growing season (t1, t2, t3, which correspond with 6, 40, and 63 days, respectively, after the last rainfall event); Line bars represent standard error.

4- Grain yield and water harvesting efficiency

Treatments	Grain yield (kg ha^{-1})	WHE (%)
MT	1323 ±19.8 ^{b}	41.3 ±0.4 ^{b}
RT	1864 ±29.2 ^{a}	57.5 ±0.4 ^{a}
CT	1237 ±21.6 ^{c}	26.9 ±0.4 ^{c}
HSD ($p < 0.05$)	74.7	1.36

Table 2. Mean values ±standard error of Grain yield (kg ha^{-1}), and water harvesting efficiency (WHE). Different letters in the same column indicate significant differences (*p < 0.05*).

Conclusions

The combination implement (integrated reservoir tillage system) enhanced infiltration rate, increased water harvesting efficiency, reduced runoff and soil losses, and exhibited the highest yield of wheat. The combination implement provided, therefore, a viable option that has positive effects on soil properties and increased crop yields compared to minimum tillage and conventional tillage and provided an opportunity to increase agricultural water use efficiency through rainwater harvesting. This system could be successfully utilized in the form of rainwater harvesting for sustainable climate change adaptation and mitigation. Furthermore, it could be useful in saving fuel, time and production costs due to the performance of multiple processes at the same time.

References

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