Evaluation of a Combined Reservoir Tillage System for Soil and Water Conservation in Rainfed Farming Land

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High rates of runoff and soil erosion from farms as a result of torrential rains and fragile soil structure are the major environmental concerns in semi-arid farmlands. Under these conditions, farmers face the challenge of retaining soil moisture for crop production. Conservation tillage is an option to solve this problem by using crop residue cover to prevent excessive evaporation and reduce soil erosion. However, in semi-arid areas crop residues are used to feed livestock. Consequently, developing new systems or techniques for conserving moisture becomes necessary. An alternative approach to increase soil and water conservation in bare cropland soils in semi-arid areas is the reconfiguration of soil structure and roughness conditioning. The integrated mechanical components to achieve this condition are also referred to as a Reservoir Tillage System. This approach was developed under the assumption that tillage can increase surface water storage, and it may represent one of the most effective means of controlling both high runoff rates and excessive soil erosion (Salem et al., 2014).

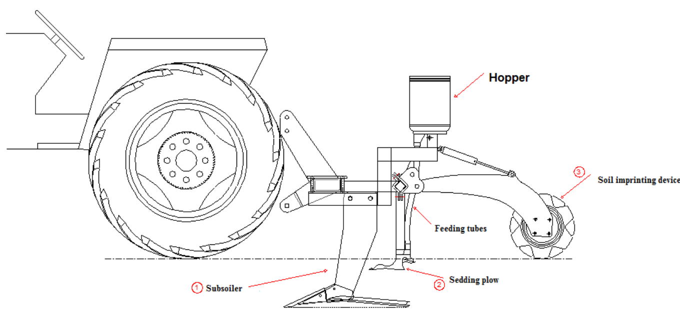

Figure 1. Combined Reservoir Tillage System.

The more relevant results of RTS development and its evaluation in semi-arid croplands based on the concept of vertical tillage, the precise placement of seed in the soil seedbed, and the soil surface conditioning, are presented in this work. The RTS was evaluated and compared with two reference treatments: Compacted Control (CC) and Conventional Tillage (CT) in soil erosion/runoff plots. The treatments were subjected to simulated rainfall, and resulting runoff, soil erosion, and soil water content were measured. The Combined Reservoir Tillage System (Figure 1) combines tools for soil surface conditioning and consolidation, precise seed placement, and the creation of a Geometrically Orderly Roughness (GOR). These three components help to mitigate and reduce soil compaction problems and

Figure 2. Components of combined RTS (Vertical Tillage + Seed + GOR).

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increase crop yields in semi-arid areas. The combined RTS consists of the following components: i) Multiplow, ii) Seed placement tool (coulter), iii) GOR roller formed from sprockets (Figure 2).

Experimental results for the first scenario of bare soil and constant rainfall intensity showed that the RTS reduced runoff 93.2% compared to 50% and 72.8% for the CC and CT treatments, respectively (Table 1). For the second scenario at flowering stage (55 days into the crop cycle), the RTS reduced runoff by nearly 100% compared to 61.4% and 57.3% for CC and CT, respectively. The configuration of the RTS treatment enhanced the development of crop canopy, which protected the soil from the erosive effects of rainfall, reduced runoff volumes, and increased crop yield due to intercepted rain water.

Similarly, increments in infiltration rate of water into the soil and water storage capacity have been reported by using similar tillage techniques (Pikul and Aase, 2003). However, the efficiency of these procedures is decreased by subsequent operations, breaking the vertical continuity of the pores. In contrast, the structured small depressions created by the RTS on the soil surface retain water longer, allowing a higher amount of infiltration (Granada et al., 2012).

For the first rainfall simulation, soil loss from the RTS was 3.0 and 1.5 times lower than from the CC and CT treatments, respectively (Table 1). For the second rainfall simulation the soil erosion rate greatly decreased for the RTS treatment with total losses of only 0.07 g m^{-2}, compared with soil loss of 663.7 g m^{-2} for CT and 547.1 g m^{-2} for CC (Table 1).

Table 1. Rainfall simulator experiment runoff and soil loss; and crop yields from treatments.

Treatment	Bare Soil		Crop Flowering Stage		
	Total runoff (mm/m^2)	Total soil loss (g/m^2)	Total runoff (mm/m^2)	Total soil loss (g/m^2)	Crop Yield (kg/ha)
CC	24.0	168.6	36.7	547.1	1400
CT	12.9	73.2	40.6	663.7	600
RTS	3.2	55.5	0.002	0.07	3250

Crop monitoring of green beans began when a total of 61, 123 and 108 plants emerged in the CC, CT, and RTS treatments, respectively. Crop harvest took place at the appropriate growth stage of green beans and was divided into three collection periods. Yields for the RTS treatement were 44% higher than for CC, and 67% higher than for CT (Table 1). The RTS improved the hydrophysical soil properties, reduced resistance, runoff, and erosion levels and increased infiltration and soil moisture content, which resulted in a higher crop yield. Crop yield will always be an indicator of the soil's physical conditions and the effect of practices to manage it.

Further evaluation of the RTS in field conditions is needed, as well as its the effectiveness in different types of soils and topographic conditions. Also, a long-term study of the physical and economic effects when using vertical tillage and GOR is one of the next steps in this work.

References

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