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1. PLANT PRODUCTION

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RESERVOIR TILLAGE TECHNIQUE

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Abstract

Many countries located in arid and semi-arid regions have water scarcity problems due to low rainfall and uneven distribution throughout the season. On the other hand, soil erosion is a serious environmental problem in some region of the world due to intensive rainfalls and the arid and semi-arid regions. Therefore, soil and water conservation is so important in these areas. Different type of soil tillage techniques such as reduced tillage, mulch tillage, ridge tillage, strip tillage, no-till, direct seed and reservoir tillage had been developed to conserve soil and water. Reservoir tillage has been defined as a system in which a large number of depressions or small reservoirs are formed to hold rain or sprinkler applied water. Reservoirs are formed on whole soil surface, between rows or in furrows using different types of equipment or equipment combinations. These equipment are commercially available and their prices are reasonable. Reservoir tillage is used to control both runoff and soil erosion. It can be used with many crops such as potato, corn, sugar beet, cotton, sunflower, sorghum, tomatoe and wheat. Studies have showed that reservoir tillage could increase soil water content, enhance infiltration, reduce soil erosion and increase crop yield. The purpose of this paper is to explain reservoir tillage technique and introduce equipment used for this technique.

Keywords: *Reservoir tillage technique, Runoff, Soil erosion, Soil and water conservation.*

Introduction

Approximately 40% of the world's agricultural land is seriously degraded (Anonymous, 2016a). Each year, 75 billion tons of soil is removed due to erosion largely from agricultural land, and about 20 million-ha of land is already lost (Pandey et al., 2009). Drought is an other important proplem except for erosion. Drylands cover about 41% of earth’s land surface and about one third of world population is affected from drought (Safriel and Adeel, 2005). Approximately 6.6%, 10.6%, 15.2% and 8.7% of drylands are consisted of hyper-arid, arid, semiarid, and dry subhumid, repectively. In dry farming regions, total annual rain is low than 500 mm and distributed unevenly throughout the season.

Soil tillage is a method of soil preparation for seeding and planting. Moulboard plow, disc harrow, field cultivator and other mechanical implements are used to prepare the field for crop production in conventional tillage. However, most of the crop residue are incorporated or burried into the soil. That’s why, conventional tillage leaves soils vulnerable to wind and water erosion and causes to the loss of soil moisture. Different type of soil tillage techniques such as reduced tillage, mulch tillage, ridge tillage, strip tillage, no-till, direct seed and reservoir tillage had been developed to conserve soil and water (Anonymous, 2013a; Dursun, 2015). The purpose of this paper is to explain reservoir tillage technique and introduce equipment used for this technique.

Reservoir Tillage and Its Advantages

Reservoir tillage is defined as a system in which a large number of depressions or small reservoirs are formed to hold and collect rain or sprinkler applied water and to prevent surface runoff from irrigation or rainfall (Longley, 1984; Hacweell *et al.* 1991; Anonymous, 2005a; Anonymous, 2013a; Salem *et al*. 2015). Figure 1 shows a reservoir tillage implement and reservoirs formed on soil surface. Reservoir tillage is applied in the regions where soil erosion is a problem, dry farming regions, and fields irrigated with low-pressure center pivots and lateral move irrigation systems. Distance between reservoirs or holes is 60-90 cm (Busch and Kincaid, 1995).

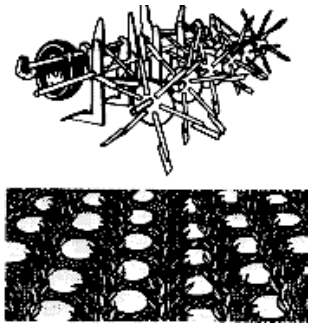

Figure 1. An equipment combination for reservoir tillage and reservoirs created on the soil surface after tillage (Kranz *et al.*, 1996).

Reservoir tillage has a lot of benefits. Small reservoirs or depressions created on the soil surface hold water and reduces surface runoff during irrigation or rainfall (Anonymous, 2016b). Particularly, reservoir tillage prevents soil erosion if there is not enough crop residue on the soil surface (Dursun, 2015). Reservoir tillage enables to in-situ water harvesting in dry farming regions and can increase level of surface storage. The surface area of the soil is increased due to small reservoirs or depressions created on the soil surface and thus infiltration of rain or applied irrigation water is increased. On the other hand, soil warms faster because of greater surface area (http://tillso.co.uk). Moreover, the loss of valuable soil, residual chemicals and nutrients could be reduced by small reservoir or depressions formed on soil surface in the fields irrigated with low-pressure center pivots and wheel-move irrigation systems (Anonymous, 2005a). Reservoirs could increase rainwater or applied irrigation water use efficiency and soil water content. As a result of this, crops could benefit from water more efficiently, crop yield could be increased and irrigation costs could be decreased.

Many research has been conducted on reservoir tillage. We noticed same variations in equipment and terminology interested with reservoir tillage when we examined these research. It is known under different names such as furrow diking, furrow damming, basin tillage, basin listing, microbasin tillage, and tied ridges (Hackwell *et al.*, 1991; Jones and Baumhardt, 2003). The shapes, dimensions and distributions of reservoirs, dikes, basins, dams and ridges created on the soil surface are different by mentioned tillage techniques. Furrow diking is not a new technology. It was used in the U.S.A., in the 1930s (Hasheminia, 1994; Jones and Baumhardt, 2003). But, reservoir tillage is a more new technique (Garvin *et al*., 1986).

Small earthen dams shaped rectangle are formed periodically between furrow ridges in furrow diking (Figure 2). Furrow diking can be adapted to both dryland and irrigated crop production. It is often used on gently sloping land in arid and semiarid areas (Anonymous, 2013b). This practice was mostly used for cotton production in Africa in 1940. But, the practice of furrow

diking for wheat production was abandoned because of slow operating speed of diking equipment, poor weed control, difficulty with seedbed preparation and subsequent tillage, and mainly little benefit in yield in U.S.A., in the 1950s. However, furrow diking had been widely adopted due to improved mechanical equipment for constructing the dikes, herbicide tolerant crops and more effective herbicides to control weeds (Jones and Baumhardt, 2003). It was reported that favorable responses were obtained with some kind of crops such as cotton, sorghum, corn and sunflower in field tests (Hasheminia, 1994; Anonymous, 2013b).



Figure 2. The view of furrow dikes created on the field (left) and the most common type of furrow diker (right) (Warrick *et al.*, 2002; Warrick, 2008).

Tied ridges is also known as furrow blocking, furrow damming, furrow diking, and basin listing. In this practice, ridges and furrows are made firstly and then dams that tied with small mounds are formed in furrows (Figure 3) (Hudson, 1987). This practice has been developed to prevent rain or irrigation water runoff from crops on sloping land (http://www. briggsirrigation.co.uk).



Figure 3. The practice of tied ridges (http://www.briggsirrigation.co.uk).

Basin tillage is also called reservoir tillage and more suitable to crop rows. In this practice, a series of micro-catchments between crop rows are created for retention of water under center pivots and lateral move irrigation systems (Figure 4). This practice is especially preferred when the applied water exceed intake rate of the soil**.** The basins lenght usually ranges from 60 to180 cm (Busch and Kincaid, 1995). It has been reported that this practice has been used successfully for runoff control on field slopes of less than 5 percent. The failure potential of individual basins in furrows is increased as field slope increased (Kranz *et al.*, 1996).

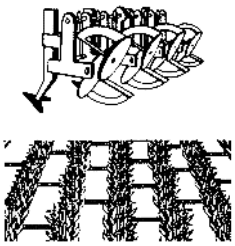

Figure 4. Basin tillage between crop rows (Kranz *et al.*, 1996).

The basins are constructed across the slope using a special implement called basin-lister in the method of basin listing. (Figure 5).This practice increases time to rain water for infiltration into the soil (Anonymous, 2005b).



Figure 5. The practice of basin listing for cotton field (http://agritech.tnau.ac.in)

In microbasin tillage, individual earth blocks or basins are created along furrows. The lenght of each block is about 65-75 cm (Figure 6). This practice has been used successfully on fields with slopes of 5-7 percent (Sui *et al*., 2016).



Figure 6. The practice of microbasin tillage (Sui *et al.*, 2016).

Equipment for Reservoir Tillage

There are three different application of reservoir tillage. In the first application, reservoirs are builded on whole soil surface. In the second application, reservoirs are only builded between rows. In the third application, reservoirs are only builded in furrows. The first application of reservoir tillage is called "New Reservoir Tillage System" (Ventura *et al.*, 2003).

Different equipment or equipment combinations are used for reservoir tillage depend on cultivated crop variety, soil condition and application region. The rollers or soil conditioners used for reservoir tillage have different forms and they are known under different names. The shapes and dimensions of reservoirs changes depend on constructional features of soil conditioners. One type of soil conditioner has durable rubber cones that fixed to a rubber carcase and forms reservoirs shaped in half cone. The other type of soil conditioner known "Imprinting roller" creates reservoirs that are narrow and long. The other soil conditioner has triangle prisms on its roller surface. This type of soil conditioner creates reservoirs shaped with triangle prism. The equipment combinations such as rotovator + soil conditionner, horizontal cut subsoiler + modified row planter + roller formed with plastic wheels, chisel plow + spike-tooth harrow + seed drill + spiked roller, potato planter + soil conditioner, subsoiler or chisel plow + soil conditionner can be used used for tillage (Figure 7) (Ventura *et al*., 2003; Salem *et al*., 2015; http://tillso.co.uk). The weight per unit working width of soil conditioner is about 80 daN/m for vegetable and root crops and 180 daN/m for grain crops (http://tillso.co.uk).



Figure 7. Three different types of soil conditioner used for reservoir tillage and soil surfaces after tillage (Ventura *et al.*, 2003; Anonymous, 2012; Anonymous, 2016c).

The reservoir tillage that including reservoirs only between rows is especially preferred at row crops irrigated with low-pressure center pivots and lateral move irrigation systems. The reservoirs between rows are formed using a soil conditioner roller or an equipment combination such as subsoiler (inter-row ripper) + multi-spoke "spider" or chisel + multi-spoke "spider". The reservoirs are formed by multi-spoke "spider" when using equipment combination (Figure 8) (Schneider *et al*., 2000; Ventura *et al*., 2003). Reservoirs can be created hoes or shovels placed at between coulters of spacing drill during sowing. The shapes and dimensions of reservoirs changes depend on constructional features of soil conditioners. It is reported that reservoirs or holes 15 to 25 cm in diameter, 15-20 cm deep, and spaced about 60 cm on center into the soil (Hansen ve Trimmer, 1997).



Figure 8. A hand type soil conditioner and a combination of inter-row ripper and multi-spoke "spider" (Geisel, 2012; Keith, 2016; http://www.Terramanustech.com; http://www.dammerdiker.com)

Reservoir tillage is widely used for potato grown in ridges and reservoirs are only formed in furrows. Different equipment combinations such as lister + chisel + multi-spoke "spider", subsoiler or chisel + multi-spoke "spider" and subsoiler or chisel + soil conditioner can be used. In these combinations, reservoirs are formed by multi-spoke "spider" or soil conditioner (Figure 9). Reservoirs could be formed before planting, during planting or after planting.



Figure 9. The application of ridge till and formation of reservoirs by an equipment combination (http://www.dammerdiker.com)

Conclusion

Reservoir tillage is a soil and water conservation practice. In this practice, a large number of depressions or small reservoirs are formed to hold rain water or sprinkler applied water and to prevent surface runoff from irrigation or rainfall. Reservoirs are formed on whole soil surface, between rows or in furrows using different types of equipment or equipment combinations. The practice of reservoir tillage can be used with many crops such as potato, corn, sugar beet, cotton, sunflower, sorghum, tomatoe and wheat. Studies on reservoir tillage have showed that it could increase soil water content, enhance infiltration, reduce soil erosion and surface runoff and increase crop yield. Whereas, it has some disadvantages such as difficulty in weed control, need a new equipment and being a new technique for farmers. However, it is reported that reservoir tillage or similar practices is widely used by farmers. Because, nowadays, the price of equipment used for reservoir tillage is resaonable and more effective herbicides is used to control weeds.

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