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Soil Hydraulic and Strength Parameters as influenced by various Mechanized Rainwater Conservation Practices in Rainfed Groundnut Crop

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ABSTRACT

In India, rain fed agriculture constitutes to 60% of the net cultivated area and accounts for nearly 44% of the National food basket. 54.6% of the total workforce is engaged in agricultural and allied sector activities (Census, 2011) and accounts for 17.8% of the country's Gross Value Added (GVA) for the year 2019-20. Rain Water Harvesting (RWH) is a low-cost, easy-to-use, environmentally friendly way to recover a large part of this lost water. In India, the rainfed agriculture constitutes 60% of the total net sown area and Andhra Pradesh constitutes nearly 57% net sown area under rainfed agriculture. Groundnut (*Arachis hypogea*) occupies nearly 28.3% of the cultivated area under oil seed crops in India and the area under groundnut in the Country is 5.40 Mha with a total production of 6.57 Million Tonnes (MT) and with the productivity of 910 kg ha^{-1}. The area of groundnut crop in Andhra Pradesh is 7.47 Lakh ha whereas Ananthapuramu District occupied 6.71 Lakh ha. The study was carried out under different surface and subsurface rainwater conservation practices with the objective to study the soil hydraulic and strength parameters viz., soil moisture content in frequent intervals at 10 cm, 20 cm, 30 cm depth and bulk density, particle density and porosity at 20 cm depth. From the study, it was observed that, highest soil moisture content was observed in subsoiling at 1 m distance + broad bed and furrow system treatment at three different soil sampling depths of 10 cm, 20 cm and 30 cm as 25.40%, 31.20% and 27.50%, respectively at 40 Days After Sowing (DAS) and 29.74%, 34.71% and 22.38%, respectively at 80 Days After Sowing (DAS). The lowest bulk density and highest soil porosity were observed as 1.52 g cm^{-3} and 32.7% in subsoiling at 1 m distance + broad bed and furrow treatment than other practices.

Key words: *Rain fed Agriculture, Rainwater Harvesting, Hydraulic, and Strength*

Introduction

In India, rain fed agriculture constitutes to 60% of the net cultivated area and accounts for nearly 44% of the National food basket. Efficient water harvesting measures are the main issues in successful rain fed farming system (Dile *et al.*, 2013). Though, the *in-situ* rainwater conservation practices viz., subsoiling, trenching, bunding (contour, graded, compartmental), farm ponds, conservation and dead furrows between crop rows are effective but with intermittent draughts under scanty rainfall situations, it is not able to retain enough soil moisture at critical stages of the crop (Fowe *et al.*, 2015). Excessive water loss in smallholder farming areas reduces water availability and leads to loss of valu-

([1]Assistant Professor, [2]B.Tech (Agril. Engg.) Students) able nutrients from top soil (Biazin *et al*., 2012). *In-situ* rainwater harvesting can delay moisture stress in major crops with enhanced fertility, moisture and yields (Hensley *et al*., 2000; and Rockstrom *et al*., 2002). *In-situ* Rain Water Harvesting (RWH) techniques have been very instrumental in overcoming this crucial period. They also reduce nutrient loss from the fields by controlling leaching losses and managing soil erosion (Gebreegziabher *et al*., 2009).

Groundnut (*Arachis hypogea*) occupies nearly 28.3% of the cultivated area under oil seed crops and contributes 31.7% of the total oilseed production in the country (Patel *et al*., 2010). In India, groundnut is grown in an area of 6.45 million ha with a total production of 6.57 Million Tonnes (MT), contributing to 26.6% and 18.5% of world's groundnut area and production, respectively. Ananthapuramu district is one of the droughts- prone districts in the rain shadow area of Andhra Pradesh. The annual average rainfall of the district is 546 mm. The normal rainfall for the South West monsoon period is 338mm which forms about 61.2% of the total rainfall for the year. The rainfall for North East monsoon period is 156 mm, which forms 28.3% of annual rainfall (October to December). The remaining months of March, April and May are warm and dry (Sahadeva Reddy *et al*., 2013).

The importance of water conservation for agriculture has been recognized for centuries. In addition, reservoirs were constructed for retaining water for later use on agricultural land, terraces were constructed to reduce runoff, ploughed fallowing was promoted to conserve water, deep ploughing was used in some cases and contouring was used to retain water on land. The present study was carried out with the objective to study the soil hydraulic and strength parameters as influenced by various mechanized rainwater conservation practices. The various treatments adopted in the study are T_1: Control; T_2: Subsoiling at 1 m interval; T_3: Conservation furrow for every two rows of groundnut crop; T_4: Broad bed and Furrow system; T_5: Furrow diking; T_6: $T_2 + T_3$; T_7: $T_2 + T_4$ and T_8: $T_2 + T_5$.

Materials and Methods

The various*in-situ* mechanized rainwater conservation technologies viz., furrow diking, broad bed and furrow system, subsoiling, conservation furrow system and integrated approach ofsurface and subsurface rainwater conservation / management practices were studied at the College of Agricultural Engineering, Madakasira, Ananthapuramu District, Andhra Pradesh.

Experimental site characteristics and Design of the experimental field

The field experiment was located at 676 m above mean sea level, 13°92´ N latitude and 77°37´E longitude. The climate here was considered to be a local steppe climate. There was not much rainfall in Madakasira all year along and the annual mean rainfall was 594 mm. The experiment consisted of seven different *in-situ* rain water harvesting techniques in addition to control shown in Fig. 1.

Field preparation

Subsoiling operation was done in T_2, T_6, T_7 and T_8 treatments respectively with tractor drawn chisel plough prior to primary tillage to a depth of 45 cm in order to make favorable conditions for the rainwater to percolate into the deeper layers and to reduce runoff velocity of water. Sub soiling i.e., cutting soil strata up to the depth of 45 cm on the field was restricted the lateral movement of excess water as runoff.

Groundnut crop requires better tilth (fine texture) and congenial environment to extend roots proliferate crop. Since, the selected experimental field was not under cultivation for the past 5 years; primary tillage was done with mould board plough to break open hardpan of the soilto a depth of 25 cm. The secondary tillage was carried out by tractor operated rotavator to a depth of 20 cm to get better pulverization of soil. Since the rotovator consists of door in the

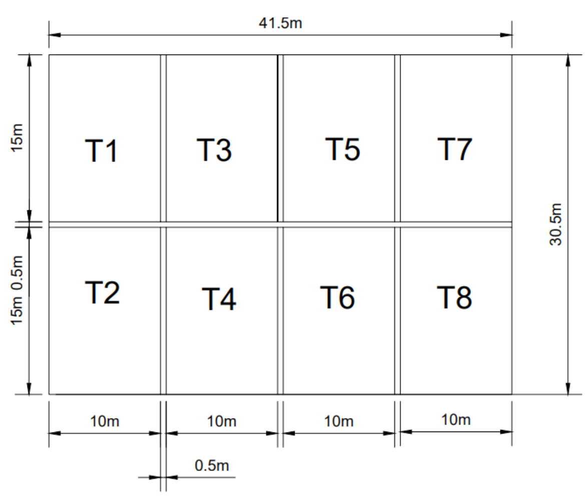

Fig. 1. Experimental Field Layout

rear side to adjust clod size of the soil in the operation and it helpful in making field level and clod free.

Seedbed preparation with tractor drawn blade harrow

The tractor drawn blade harrow is being attached with 3-point linkage system of tractor as integral part. This was used after primary tillage and at the end of secondary tillage operation for seedbed preparation. The blade of the implement cut undulating soil portions beneath the ploughed (or) tilled soil. The scraping of these undulating soil lumps will greatly help in uniform water distribution in entire field and avoid dry patches of crop in the field. The cutting of hidden bumps under soil is very much essential and provides uniform crop growth and maturity which improves water productivity.

Sowing of groundnut seed

Sowing of groundnut seed was taken up with tractor drawn seed cum fertilizer drill in T_1, T_2, T_3 and T_4 treatments, respectively. Groundnut seed of K6 variety was initially treated with Carbendazim 50 WP (Bavistin 50 WP) @ 2 g per 1 kg of seeds. This seed treatment gives protection to the seedlings up to 40 days from seedling diseases. Groundnut seed treated with chemical was filled in the hopper for sowing with tractor drawn seed cum fertilizer drill. The row to row and plant to plant spacing was maintained as 30 cm and 10 cm throughout the field. Groundnut seed was sown with mini tractor drawn seed cum fertilizer drill with diker attachment in T_5 (sole furrow diking) and T_8 (subsoiling + furrow diking) treatments, which made circular dikes at regular intervals for harvesting rainwater within the field as shown in Fig. 3 and 4. Broad bed and furrower cum planter was used to sow the groundnut seed in T_6 (sole broad bed and furrow system) and T_7 (subsoiling + broad bed and furrow system) treatments as shown in Fig. 5.

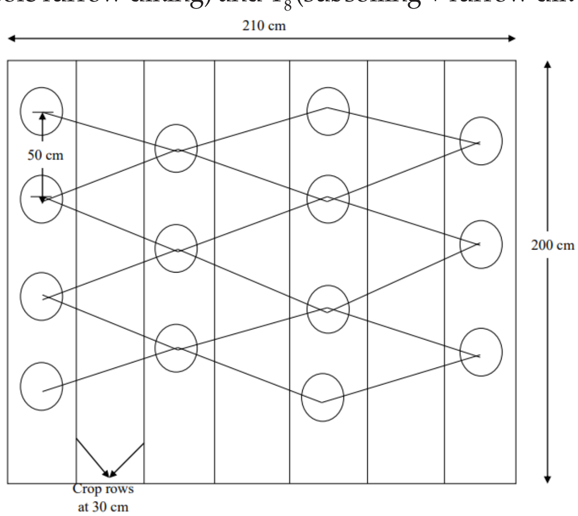

Fig. 3. Experimental plot layout after formation of dikes

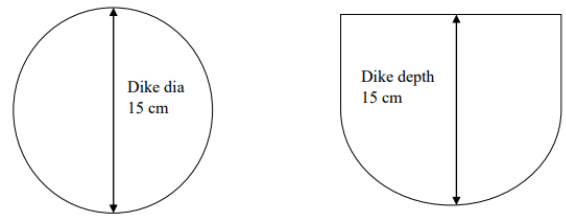

Fig. 4. Dimensions of dikes formed in the crop rows

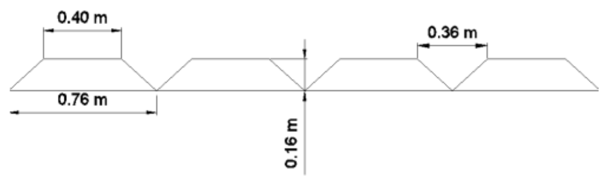

Fig. 5. Dimensions of broad bed and furrows

Harvesting of rainwater with different mechanised practices

Dikes in T_5 and T_8 treatments under furrow diking system; furrows in T_4 and T_7 treatments under broad bed and furrow system were formed while sowing operation itself. Conservation furrows were formed in T_3 (sole conservation furrows) and T_6 (subsoiling + conservation furrows) treatments for every 2 rows of groundnut at 30 DAS to enhance rainwater use efficiency with tractor drawn intercultivator. The intercultivator consisted of 4 shanks attached with shovels at bottom, which were mounted at front side

Fig. 6. Conservation of rainwater in broad bed furrow system

Fig. 7. Conservation of rainwater in conservation furrow system

Fig. 8. Conservation of rainwater in furrow diking system

and conservation furrower. The spacing between two conservation furrows was adjusted as 60 cm to form a conservation furrow for every 2 rows of groundnut crop during intercultural operation. It forms a furrow of depth 10cm and width of 22.5 cm without affecting the crop root zone. The harvested rainwater during the crop period by different treatments is shown in Fig. 6, 7 and 8 respectively.

Determination of soil strength parameters

Determination of Bulk density of soil

The bulk density of soil was determined by core sampler method. The core sample of the soil of known volume was collected and weighed. In its natural state, a soil's volume includes solids and pores; therefore, a sample must be taken without compaction or to correctly determine the soil bulk density. The bulk density of soil was determined for every 20 days from the date of sowing to harvesting time in each treatment. The soil bulk density was determined with the formula 2.1 (Pravin *et al.*, 2013).

$$\rho = \frac{M}{V} \quad \ldots \quad 2.1$$

Where, ρ = Bulk density of soil, g cc^{-1}

M = Mass of soil, g

V = Volume of soil, cm^3

Determination of Particle density of the soil

Particle density is the volumetric mass of the solid soil. It differs from bulk density because the volume used does not include pore spaces. Particle density is the ratio of oven-dry soil weight and volume of soil solids. The particle density of soil was determined for every 20 days from the date of sowing to harvesting time in each treatment. Particle density of the soil was determined with the formula 2.2 (Pravin *et al.*, 2013).

$$P = \frac{W}{\Delta V} \quad .. \quad 2.2$$

Where, P = Particle density, g cc^{-1}

W = Weight of oven dried soil sample, g

ÄV = Change in volume, cm^3

Determination of Soil porosity

Porosity is that portion of the soil volume occupied by pore spaces. This porosity does not have to be measured directly, since it can be calculated using the values determined for bulk density and particle density with the formula 2.3. Finding the ratio of bulk density to particle density and multiplying by 100 gives the percent of solid space.

$$\text{Porosity} = (1 - \frac{\rho}{P} \times 100) \quad .. \quad 2.3$$

Where, ρ = Bulk density, g cc^{-1}

P = Particle density, g cc^{-1}

Determination of soil moisture content

The moisture content of the soil was determined by oven drying method. In this method, wet soil sample of known weight (w_w) was kept in the thermostatically controlled oven at a temperature of 105°C for 24 hours. The dried soil was again weighed (w_d) and the moisture content was determined with the formula 2.4 (Pravin *et al.*, 2013).

$$W\ (\%\ \text{d.b.}) = \frac{w_w - w_d}{w_d} \quad .. \quad 2.4$$

Where, w_w = Weight of moist soil, g

w_d = Weight of dry soil, g

W = Moisture content, (% d.b.)

Results and Discussion

Measurement of rainfall distribution

As a part of the study, the amount of rainfall occurred during the crop period was measured. During the entire crop period of 120 days, the crop experienced long non-rainy days (dry spell) *i.e.*, from germination stage to vegetative stage. Another dry spell was observed from pod penetration stage to harvesting stage. A total of 406.8 mm rainfall was received on 28 rainy days during the crop period but the effective rainfall received was 396.2 mm (< 2.5 mm was considered as non-rainy day) on 21 effective rainy days. The cropped seasonal rainfall accounts for approximately 74.5% of total annual rainfall. Month wise rainfall distribution pattern during the groundnut crop period was plotted as shown in Fig. 9. Out of the total rainfall received during the crop period, 96% of rainfall was occurred on the months of October and November. The negative rainfall deviation (-100%) was observed in the months of August and September as the actual rainfall received was lower than the normal rainfall. The positive rainfall deviation (+41.86%, +82.65% and +39.26%) was observed during the months of October, November and December, respectively.

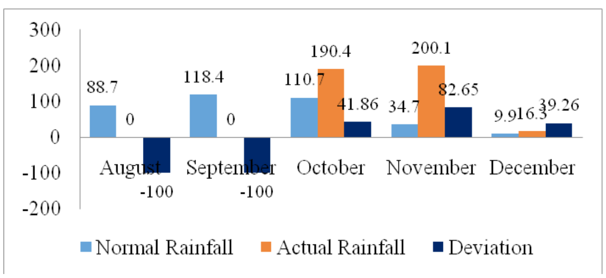

Fig. 9. Rainfall deviation during the crop period

Effect of *in-situ* rainwater conservation practices on soil bulk density

Bulk density is an indicator of soil compaction. It affects infiltration, available water capacity, rooting depth, etcwhich influences key soil processes and productivity. Fig. 10 shows the mean values of soil bulk density under different rainwater conservation practices for every 20-day interval from sowing to harvesting stage. Bulk density generally increases with depth and was significantly affected by different rainwater conservation practices.

Soil bulk density was significantly higher in control than in rainwater conservation practices (Fig. 10). The averages high bulk density was observed as 1.89 g cm^{-3} in controlas high bulk density impacts available water capacity, root growth, movement of air and water through soil (USDA – NRCS, 2019).

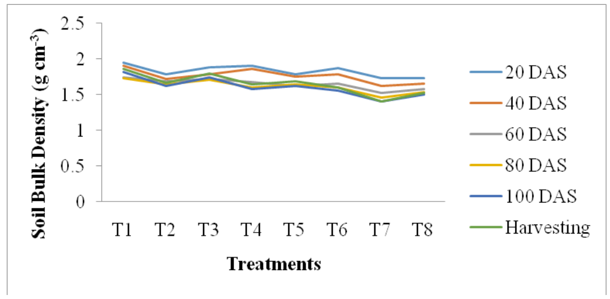

Fig. 10. Comparison of soil bulk density for different treatments

The bulk density was abruptly decreased in T_7 treatment (Subsoiling + Broad bed and furrow) and observed as 1.40 g cm^{-3} at the time of harvesting which satisfied the recommendations of USDA – NRCS (Ideal bulk density for plant growth in sandy loam soils is < 1.4 g cm^{-3}). Lowerbulk density of soil was observed in duel rainwater conservation practices (Wing *et al*., 2021; Fasinmirin and Reichert, 2011; Mitchell *et al*., 2012). Lower bulk density is preferred in agriculture because it increases water infiltration rate, promotes root growth and improves soil aeration (Jones *et al*., 1983). From the Fig. 10, it was observed that, bulk density was lower on rainy days as the rainwater conservation practice directly affects the soil moisture availability between the pores.

Effect of *in-situ* rainwater conservation practices on soil particle density

Particle density plays an important role in understanding and determination of physical properties including bulk density and porosity. Soil particle density was significantly higher in control than rainwater conservation practices. It was calculated as the dry weight of soil divided by its change in volume as mentioned in equation 2.2.

The higher average soil particle density was ob-

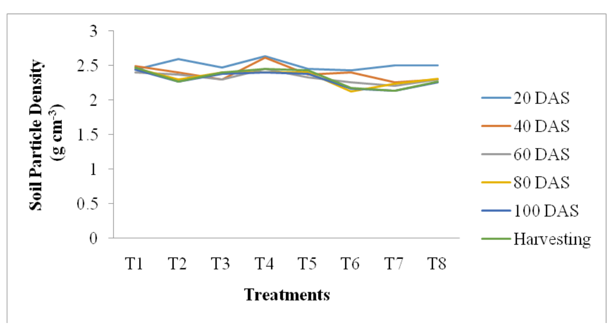

Fig. 11. Comparison of soil particle density for different rainwater conservation practices

served as 2.45 g cm^{-3} in control and lowest as 2.24g cm^{-3} in T_7 treatment (Subsoiling + Broad bed and furrow) followed by T_6, T_8, T_2, T_4, T_3 and T_5, respectively as the sandy loam soils particle density generally ranges from 2.60 g cm^{-3} to 2.78 g cm^{-3} as shown in Fig. 11. The lower particle density in subsoiled plots, broad bed and furrow and furrow diking is due to the capable of storing soil moisture at subsurface layers and availability of moisture content at the root zone. A low particle density indicates high organic matter content.

Effect of *in-situ* rainwater conservation practices on soil porosity

The porosity of soil determines the possibility of water binding, air movement, penetration of plant roots, etc. (Arvidsson, 1998 and Lipiec *et al*., 2006). The porosity results from bulk density and particle density of soil. Since porosity is calculated from the relation between bulk density and particle density of the soil from the equation 2.3. Porosity values of the soils varied during crop growth in each stage and ranged from 20 to 35% as shown in Fig. 12.

The treatments (T_7, T_8 and T_6) ploughed with the chisel plough showed the highest soil porosity as compared the treatments not ploughed with the chisel plough due to the lower bulk density achieved in deep tillage (Makki and Mohamed, 2008). The average soil porosity observed higher in T_7 (Subsoiling along with broad bed and furrow) treatment as 32.7% and was observed least in control as 25.1% (Fig. 12). The higher porosity in subsoiled treatments resulted in more available moisture content.

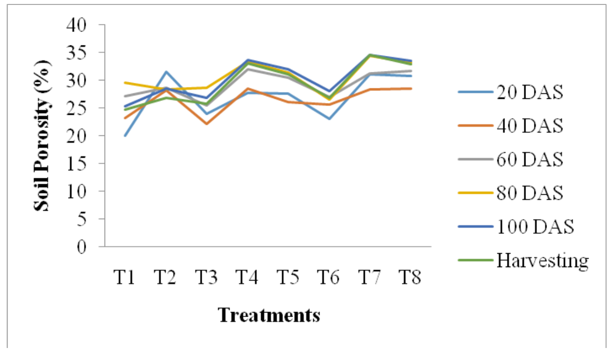

Fig. 12. Comparison of soil porosity for different rainwater conservation practices

Determination of moisture content of soil at 10 cm, 20 cm and 30 cm sampling depth

Soil moisture affects many parameters that are of interest to agricultural production and soil conservation. Moisture content of different rainwater conservation practices was determined at ten (10) day interval with gravimetric method at the soil profiledepth of 10 cm, 20 cm and 30 cm, respectively and shown in Table 1, 2 and 3. Soil moisture affects the wide range of soil properties and processes. From the results, the soil moisture content was decreased initially from the date of sowing to 30 DAS due to the dry spell for about 16 days (Table 1). The treatment Subsoiling + Broad bed and furrow system (T_7) conserved more moisture content on rainy days and non-rainy days as well followed by T_6, T_8, T_4, T_3, T_5, T_2 and T_1, respectively which satisfied with conservation tillage practice (Ferreras *et al*., 2000). The more moisture retention in T_7, T_6, T_8, T_4 and T_5

Table 1. Comparison of moisture content of soil of different *in-situ* mechanized rainwater conservation practices at 10 cm soil profile depth

Time	Sampling depth (cm)	Moisture content of different treatments (%) at 10 cm depth							
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
10 DAS	10 cm	9.93	9.45	9.55	12.10	11.20	9.77	13.80	11.90
20 DAS		7.56	7.62	7.55	9.88	8.56	7.74	10.64	9.08
30 DAS		5.00	5.24	6.10	8.12	6.46	6.28	8.93	7.33
40 DAS		16.30	17.42	21.86	20.40	20.56	22.30	25.40	22.12
50 DAS		12.87	13.37	14.94	15.62	15.88	16.14	16.85	16.03
60 DAS		11.24	11.65	12.24	12.70	12.55	13.02	13.65	12.86
70 DAS		8.65	9.11	9.37	9.37	9.61	10.26	11.18	10.10
80 DAS		20.56	21.37	24.73	24.88	23.69	27.83	29.74	25.39
90 DAS		14.01	14.53	16.26	16.66	15.06	18.30	19.48	16.62
100 DAS		9.65	9.25	10.53	10.92	9.14	11.81	12.90	11.31
110 DAS		6.46	6.32	6.85	6.92	6.51	7.22	8.36	6.50
Harvesting		4.26	4.95	5.38	5.45	5.25	6.52	6.72	5.45

treatments on non-rainy days is due to the deep tillage practices and formation of rainwater harvesting furrows and dikes between the crop rows.

The moisture storage capability of the treatment Subsoiling + Broad bed and furrow system (T_7) ranges from 17.65% to 44.0% than control during the crop period. Higher moisture content of 25.40% and 29.74% was observed in the treatment T_7 during the rainy days on occurrence of 87.5 mm and 169.4 mm cumulative rainfall at 40 DAS and 80 DAS, respectively. Conservation tillage thus seems to be more effective in improving soil water storage especially on non-rainy days (Hamblin 1987; Moreno *et al*., 1997).

From the Table 2, it is observed that, deep tillage showed significant influence in soil moisture content at deeper layers. The differences within the treatments occurred when soil water contents were highest shortly after the rains and the higher moisture content found under these treatments was attributed to higher infiltration rates (Gicheru *et al*., 2005).

The greater soil moisture content was observed in combination of subsoiling + broad bed and furrow system (T_7). These results are in agreement with those reported by (Shafiq *et al*., 1994; Boydas and Turgut, 2007; Rashidi and Keshavarzpour, 2008) for deep tillage. The study found that tillage implements had significant effect on soil moisture content with maximum moisture conservation in soil tilled with chisel plough. The moisture storage capability of the treatment Subsoiling + Broad bed and furrow system (T_7) ranges from 32.50% to 55.0% than control during the entire crop period. Higher moisture content of 31.20% and 34.71% was observed in treat-

Table 2. Comparison of moisture content of soil of different *in-situ* mechanized rainwater conservation practices at 20 cm soil profile depth

Time	Sampling depth (cm)	Moisture content of different treatments (%) at 20 cm depth							
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
10 DAS	20 cm	8.46	10.52	8.55	13.60	12.53	17.06	18.71	16.38
20 DAS		8.90	10.34	9.05	11.82	10.12	15.68	16.20	14.58
30 DAS		6.22	8.14	6.82	8.86	7.12	10.39	13.80	11.60
40 DAS		18.65	19.60	24.18	25.42	21.38	29.54	31.20	27.60
50 DAS		15.40	16.57	19.84	20.19	17.48	25.31	28.10	23.38
60 DAS		14.29	14.84	17.62	18.37	16.22	23.82	25.67	21.60
70 DAS		11.34	11.97	14.37	15.68	13.26	18.10	20.35	17.24
80 DAS		20.60	22.57	24.74	25.17	24.52	29.36	34.71	30.81
90 DAS		14.16	17.30	18.57	20.16	19.35	22.63	26.27	24.60
100 DAS		10.30	10.59	12.80	14.89	11.47	14.98	15.25	14.90
110 DAS		8.10	9.46	11.32	13.37	10.40	13.65	13.92	12.75
Harvesting		7.38	7.92	8.61	10.93	8.80	10.40	11.12	10.77

Table 3. Comparison of moisture content of soil of different *in-situ* mechanized rainwater conservation practices at 30 cm soil profile depth

Time	Sampling depth (cm)	Moisture content of different treatments (%) at 30 cm depth							
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
10 DAS	30 cm	8.62	9.67	8.80	12.37	12.00	14.74	16.28	14.30
20 DAS		7.69	9.34	8.90	10.83	9.71	10.31	11.33	10.07
30 DAS		5.60	7.40	6.40	7.91	6.72	9.80	11.90	10.30
40 DAS		14.37	17.3	20.50	21.60	17.40	22.30	27.50	24.50
50 DAS		13.30	14.60	15.41	18.30	21.80	25.40	26.70	20.20
60 DAS		12.70	13.80	14.30	16.70	14.22	21.35	23.42	19.72
70 DAS		9.80	10.41	12.51	13.40	11.73	16.51	18.34	15.79
80 DAS		14.62	15.30	16.71	18.24	17.37	19.83	22.38	21.78
90 DAS		10.16	11.30	11.70	12.09	11.30	14.73	15.45	14.57
100 DAS		7.36	8.21	10.24	11.62	9.31	11.35	12.42	11.85
110 DAS		6.33	7.20	8.57	9.30	8.37	10.50	10.64	9.40
Harvesting		6.92	7.13	7.83	9.19	8.20	9.82	10.12	9.21

ment T_7 during the rainy days on occurrence of 87.5 mm and 169.4 mm cumulative rainfall at 40 DAS and 80 DAS, respectively.

Highest soil moisture content at 30 cm sampling depth was observed at 40 DAS and 80 DAS in T_7 treatment during non-rainy days. The available soil moisture content decreased with depth due to more soil compaction in deeper layers which in turn influences the strength parameters like soil bulk density and soil porosity. The combinational surface and subsurface *in-situ* rainwater management practices retained more soil moisture sole management practices.

Conclusion

Based on the study, it can be concluded that, the lowest average bulk density; highest average soil particle density and soil porosity were observed in rainwater conservation practices than control.More soil moisture availability in subsoiled treatments influenced the on a par soil porosity in T_7 (Subsoiling + Broad bed furrow system) and T_8 (Subsoiling + Furrow diking) treatments.The soil moisture content was observed highest in T_7 treatments at three different soil sampling depths of 10 cm, 20 cm and 30 cm as 25.40%, 31.20% and 27.50%, respectively at 40 DAS and 29.74%, 34.71% and 22.38%, respectively at 80 DAS. Among the treatments, the combinational surface and subsurface rainwater conservation / management practices stored highest available soil moisture content during non-rainy days.

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