Evaluation of Tillage Methods under Rainfed Cultivation of Cotton-Pulses Crop Rotation

ABSTRACT

Aims: To evaluate the effect of tillage methods on soil moisture storage, grain yield, economics and rain water use efficiencyin semi-arid region

Study design: Four tillage methods viz. conventional tillage, Rotovator ploughing + chisel ploughing, chisel ploughing + tiller ploughing, conservation tillage (Minimum tillage with retention of crop residue) at different time of ploughing.

Place and Duration of Study: Kovilpatti, a representative location of semi-arid regions of Southern Tamil Nadu. This study was conducted from 2015 to 2021 with the alternate years of crop rotation of cotton and greengram.

Methodology: The field experiments werein cotton and greengram in black soil under rain fed situations. Soil samples were collected at different depths to assess the soil moisture storage. Yield was recorded and cost of cultivation was worked out. Rainwater used for obtaining higher yield was calculated..

Results: Soil moisture storage in subsurface soil layers was higher in conservation methods of tillage followed by rotatvator and chisel ploughing method. For both crops, Rotovator plough followed by chisel plough recorded the higher rain water use efficiency, yield and net return.

Conclusion: This study clearly indicated that Rotovator ploughing once followed by chisel ploughing once could be adopted as a promising strategy to retain soil water availability and boost crop productivity in semiarid regions of Tamil Nadu.

Keywords: Chisel plough, Clay, Rainwater use efficiency, Rainfed, Tillage method

1. INTRODUCTION

Field preparation is a fundamental and essential practice for improving desired crop production in rainfed regions. The favorable environment for increasing crop production requires a suitable soil condition, which can be produced by good tillage method because tillage has beneficial effect on plant growth. Kepner (1982) defined tillage as the mechanical manipulation of soil. The best tillage method is necessary to provide a suitable environment for seed germination, normal moisture availability and reduction of surface runoff by increasing infiltration (Kepner, 1982). Tillage methods reduce weed growth, controls soil erosion and maintain adequate soil moisture (Koller, 2003). Tillage creates an ideal seedbed condition for seedling emergence, development and unimpeded root growth (Licht and Kaisi, 2005). Tillage treatments directly or indirectly influence soil hydraulic properties such as water infiltration, hydraulic conductivity, and water retention which determine the ability of the soil to capture and store water through rainfall or irrigation. Tillage changes water flow rate and path by modifying aggregate size distribution. Therefore, tillage methods conserve water in soil and are important for plant growth under arid and semiarid conditions (Blanco, 2017). Some studies have revealed that tillage can reduce infiltration by reducing soil aggregate stability and macroporosity, increasing surface crusting, and causing soil consolidation after tillage in the absence of crop residues on the soil surface (Unger, 1992).

Different tillage methods have made significant contribution in crop production and yield. Arora et al. (1991) reported that deep tillage is useful for maize cultivation. Different methods of tillage operations, time of tillage along with incorporation of crop residue in soil greatly influence crop productivity. Long term tillage operation leads to form a plough pan or compact soil which hinders root growth and seed emergence (Shafique, 2011). Conservation tillage method has a greater potential for providing retained soil water to crops. Beneficial effects of the crop residue maintenance on the soil surface includes the reduction of soil erosion and runoff, an increase soil water conservation and soil aggregation (Nesmith *et al.,*1987; Nakamoto *et al.,* 2006). In order to combat soil loss and preserve soil moisture, a more attention has been focused on conservative tillage involving soil management practices that minimize the disruption of the soil structure (Samarajeewa et

al., 2006). Sessiz, *et al*.(2010) reported that conventional and conservation tillage has made significant improvement on soil physical properties, seedling emergence rate, yield and yield components in southeastern of Turkey conditions.

Selection of an appropriate tillage practice for crop production is very important for optimum growth and yield and even an increase of organic matter (Wright et al., 2008). Most of the farmers use iron plough continuously which leads to form a hard pan which hinders root growth and seed emergence. No measures have been taken up by the farmers to break hard pan in subsoil layers. Under this circumstances, use of chisel plough for breaking hard pan, rotary plough for preparing fine tilth, incorporating crop residues with minimum tillage in conservation tillage, conventional tillage practiced by farmers are to be tested to identify appropriate tillage practice in rainfed regions.

The main objective of the study is to evaluate the effect of different tillage methods under crop rotation on soil moisture, grain yield, economics and rain water use efficiency.

2. MATERIAL AND METHODS

2.1 Field Experiment

This research was conducted in Agricultural Research Station, Kovilpatti, Tamil Nadu, India from 2015 to 2021. Kovilpatti is the unique representative location for dryland agriculture in Tamil Nadu. Vertisols constitutes nearly 70 per cent of the total area. The soil depth varies from 110 to 150 cm with the infiltration rate of 0.9 cm hr-1. Soil develops typical cracks with at least one cm wide and reaches a depth of more than 50 cm during the period moisture stress. Considering the mechanical fraction, the soil is clayey with the clay content of 46.4 to 61.2 per cent, 10.0 to 17.5 per cent silt and 12.6 to 24.5 per cent coarse sand. The soil bulk density varied from 1.21 to 1.36 kg m^{-3} with a field capacity of 35 per cent and permanent wilting point of 14 per cent.

The soil has sub angular blocky structure with pH generally neutral to a tendency towards alkalinity at lower depths (7.8 to 8.2). Soil is low in available KMnO4¬-N, low to medium in available Olsen's-P and high in available NH4OAc-K. This soil is taxonomically classified under USDA system as fine, smectitic, isohyperthermic family of TypicHaplusterts.

This location received the normal rainfall of 699.1 mm in 42 rainy days. Seasonal rainfall, the North East monsoon (Oct - Dec) season (cropping season of Kovilpatti) recorded a normal rainfall of 390.6 mm, South West monsoon season (Jun - Sep) of rainfall of 145.0 mm and the summer (Mar - May) rainfall was 134.7 mm. The agroclimate of the Agricultural Research Station, Kovilpatti is characterized by semi-arid tropics. Maximum and minimum temperature is 35.4°C and 22.4°C.

2.2 Treatments details

Keeping in view the objectives of the study, the experiment was conducted with the following treatments.

Table 1: Method of tillage and timing

S. No.	Method of tillage	Time of tillage
1.	T1 - Conventional tillage (Disc ploughing once + tiller ploughing twice)	Disc ploughing once during the month of April on receipt of summer showers followed by tiller ploughing twice during August and September
2.	T2 –Rotavatorploughing once + Chisel ploughing	Rotovatorploughing during the month of April to incorporate the previous season crop residue and chisel ploughing once during the month of September before the commencement of sowing
3.	T3 - Chisel ploughing once + Tiller ploughing once	Chisel ploughing during the month of April and tiller ploughing during the month of September before the commencement of sowing
4.	T4 - Conservation tillage (Minimum tillage + retention of crop residues on the surface + following crop rotation)	Tilling the seed bed zone without soil inversion at the time of sowing (during second fortnight of September or first fortnight of October) with retention of crop residues on the surface.

Cotton (KC3) was grown with the seed rate of 20 kg/ha and spacing followed was 45 x 15 cm. The special feature of KC3 variety is, it is resistant to leafhoppermedium staplecotton – 26.4 mim, suitedto southern districts ofTuticorin, Tirunelveli

and Virudhu Nagar district.Greengram (CO 8) was sown at the seed rate of 20 kg/ha with crop spacing of 30 x 10 cm. Crops were cultivated in a gross plot size of 450 m^2 and net plot of 364 m^2. The duration of the variety is 55 – 60 days. Ridges and furrows were formed for 10 m long with 45 cm spacing using ridger. Seeds were hand dibbled at 3-5 cm depth on the side of the ridge 2/3 height from the top keeping row to row distance and seed to seed distance as per recommendations. Crops were cultivated and all the practices were followed as per the crop production guide. Soil samples were collected before starting the cultivation and initial physical and chemical properties were analyzed (Table - 2).

Table 2: Initial soil properties

Soil physical properties			**Soil chemical properties**		
Texture	:	Clayey	pH	:	8.0
Depth (cm)	:	0-15	EC	:	0.19
Field capacity (%)	:	35	Av. N (kg ha^{-1})	:	115-136
Wilting point (%)	:	14	Av. P (kg ha^{-1})	:	10.2 -11.2
			Av. K (kg ha^{-1})	:	410 -472
			Ogranic carbon (g kg^{-1})	:	2.8

2.3 Soil moisture storage

To study the effect of tillage methods on soil moisture content at vegetative (1-44 days), flowering (45-87) and maturity stages (88-145 days) of the cotton, soil samples were collected at 0-15, 15-30 and 30-45 cm depth on mid period of each stages without matching with rainy day. For greengram, soil samples were collected at 0-15 and 15-30 cm depth on mid period of sowing stage and maturity stage (60 days). Soil moisture content was determined gravimetrically by measuring the initial weight and final weight of the soil sample after the samples were oven dried.Data obtained from the analysis were processed for obtaining subsoil soil moisture and rainwater retaining capacity of soil.

2.4 Yield and Economics

For all the years, yield of the cotton and greengram was recorded. Cost of cultivation was worked out for all field operations viz. field preparation by adopting tillage methods as per the treatments, sowing, weeding, plant protection chemicals and harvesting. The economics of different tillage methods could be assessed based on the cost of cultivation (Rs/ha) incurred, gross and net economic returns (Rs/ha) attained. Benefit-Cost ratio (BCR) was determined by taking the ratio of gross economic returns and cost of cultivation in each year for cotton and greengram.

2.5 Rainwater use efficiency

Since the crops are grown in rainfed regions, there was no irrigation to the crop other than rain water, an indicator called rainwater use efficiency (RWUE) would represent the water productivity or water use efficiency of a particular tillage method.RWUE would specify the yield attained by a treatment per millimeter of rain water received during the study period. The details of total rainwater utilized by the crop and its impact on crop yield for a particular tillage method wereused for calculating rainwater use efficiency. Rain water use efficiency (RWUE) can be computed by

RWUE (kg/ha/mm) = Yield (kg/ha) / Cumulative rainfall (mm) from sowing to harvest.

3. RESULTS AND DISCUSSION

3.1 Effect of tillage methods on soil moisture content at different crop growth stages and depth

Effect of tillage methods on soil moisture content at different crop growth stages and depth for rainfed cotton is presented in Figure 1 (a, b) and Figure 2 (a, b).The essentiality for producing good yield in rainfed crop is to retain enough sub soil moisture throughout its crop period. Compared to other tillage methods, higher soil moisture content was recorded in conservation tillage method at 0 -15, 15 - 30 cm and 30 - 45 cm soil depths at different crop stages.

Sampling depth appreciably affected the soil moisture content. Higher losses of soil water was observed from the surface to the depth upto 15 cm due to high rate of water evaporation from the surface layer, which was exposed to evaporation factors than subsurface layers. Higher soil moisture content was observed at 15-30 cm soil depth for all tillage methods. The high moisture content under conservation tillage as compared to other methods of ploughing, was attributed to the decrease in evapotranspiration from the soil. Among the different tillage treatments, conservation tillage method has a greater potential for providing retained soil water to crops. Cracks to a depth of 30 cm in blacksoil were noticed when dry spell was increasing. This was managed by making soil disturbance through weeding tools, hence soil water in subsoil layers were retained in soil considerably.

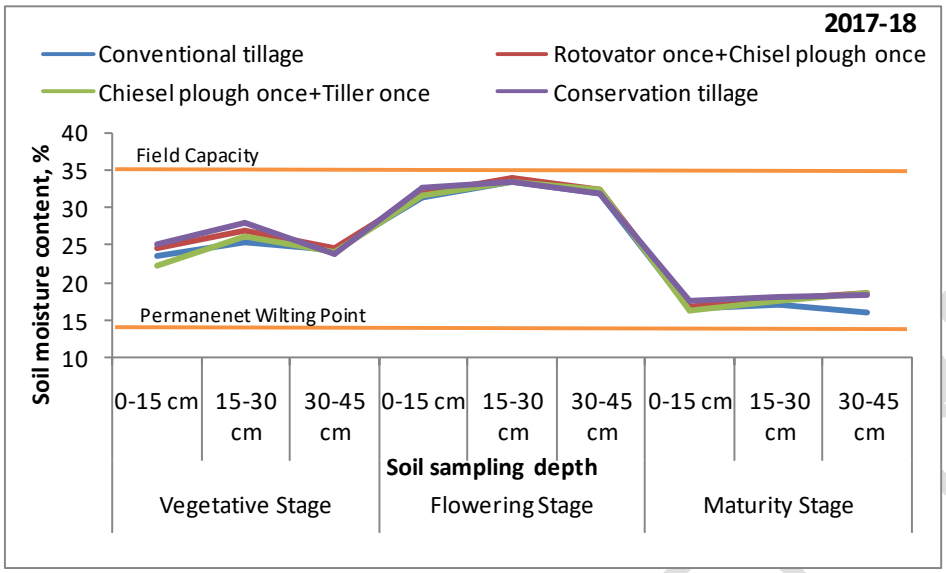

Figure 1a. Soil moisture content at different crop stages & sampling depths in cotton for 2017-18

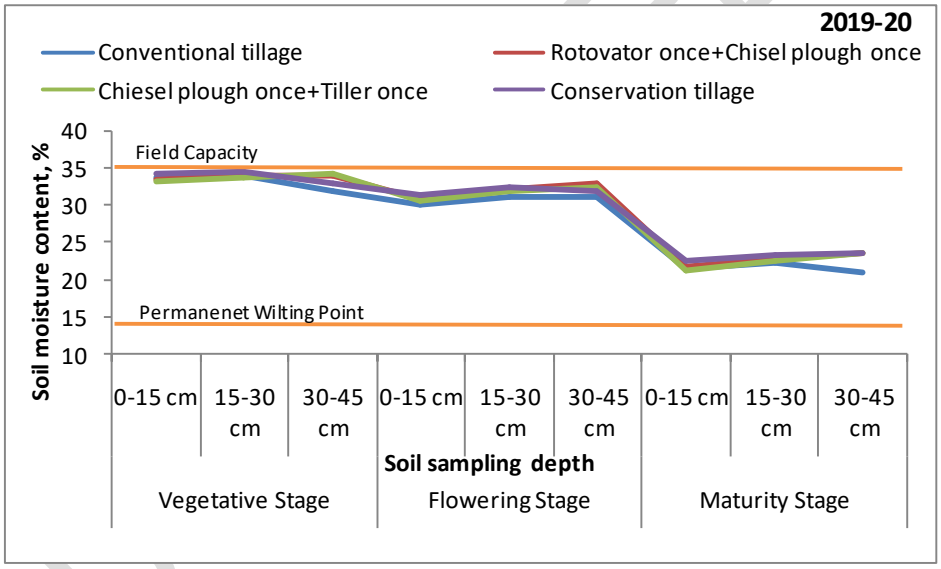

Figure 1b. Soil moisture content at different crop stages & sampling depths in cotton for 2019-20

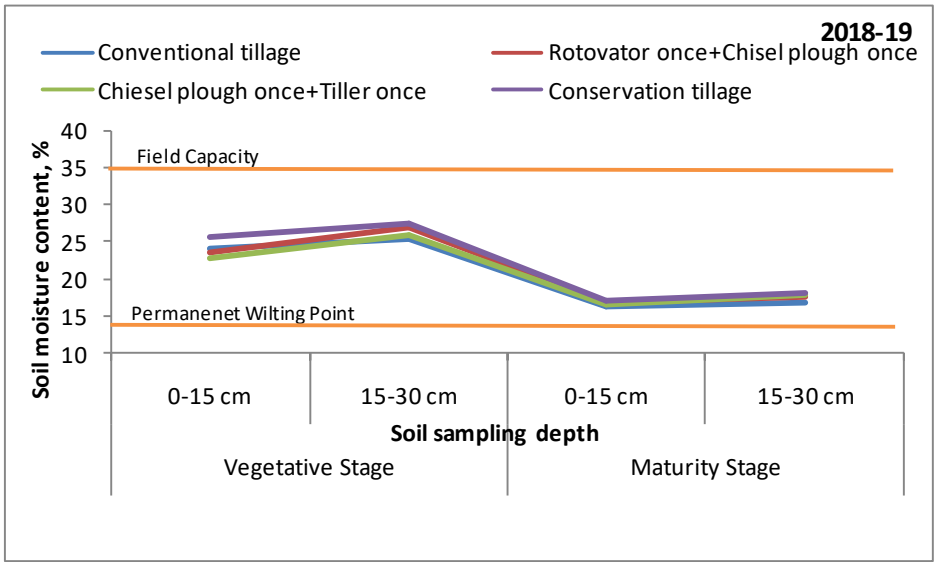

Figure 2a. Soil moisture content at different crop stages & sampling depths in greengram for 2018-19

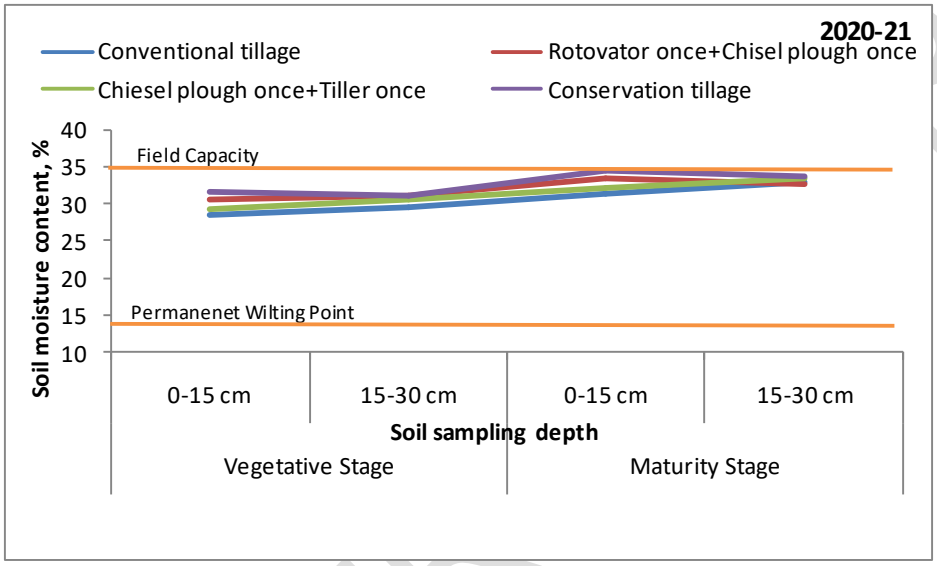

Figure 2b. Soil moisture content at different crop stages & sampling depths in greengram for 2020-21

3.2 Effect of tillage methods on yield and economic of cotton and greengram

Cotton yield, net returns and Benefit-Cost ratiorecorded during 2015-16, 2017-18, 2019-20 and mean values for different tillage methods are presented in Table 3. Rotovator ploughing once + chisel ploughing once (T2) recorded the higher yield of cotton (996 kg/ha) which was 12 per cent higher than the conventional tillage (Disc ploughing once + tiller ploughing twice).Conventional tillage recoded higher yield of 7 per cent over Chisel ploughing once + Tiller ploughing once. Fine tilth of soil by rotavator ploughing method and braking of hard layer by chisel plough has improved the water retaining capacity of soil. This effect has reflected in yield, net return and B-C ratio of cotton. Higher Benefit cost of 1.40 was recorded in Rotavator ploughing once + Chisel ploughing once followed by Conservation tillage.

Table 3: Yield, net return and B-C ratio of cottonfor different tillage methods

Treatment	2015-16			2017-18			2019-20			Mean		
	yield(kg/ha)	Net return (Rs./ha)	B-C ratio	yield (kg/ha)	Net return (Rs./ha)	B-C ratio	Yield(kg/ha)	Net return (Rs./ha)	B-C ratio	yield (kg/ha)	Net return (Rs./ha)	B-C Ratio
Conventional tillage	880	7600	1.24	863	5,746	1.19	924	11,751	1.38	889	8984	1.27
Rotavatorploughing once + Chisel ploughing once	974	11330	1.35	965	9,530	1.31	1048	16,874	1.54	996	13178	1.40
Chisel ploughing once +	805	6725	1.23	817	6,314	1.23	878	10,320	1.34	833	7923	1.27

Tiller ploughing once												
Conservation tillage	921	10195	1.33	904	8,218	1.28	955	15,053	1.51	927	11814	1.37

Table 4 presents the yield and economics of greengram for the effect of different tillage practices. Rotovator ploughing once + chisel ploughing once (T2) recorded the higher yield of greengram CO8 (470 kg/ha) which was 26 per cent higher than the conventional tillage.During the first year (2018-19) study yield and economics was lower than second year (2020-21). The excessive rainfall at maturity stage of the crop during 2018-19 damaged the crop and reduced the yield of greengram. However retaining higher soil moisture in the subsoil throughout the crop season reflected its impact on yield. Moreover breaking of subsoil hard pan through chisel plough and preparationof favorable seed bed by rotavator has improved water hydraulic properties of soil.These effects have reflected in yield, net return and B-C ratio of greengram. Conservation tillage method has registered remarkable yield over conventional tillage method.

Table 4: Yield, net return and B-C ratio of greengramfor different tillage methods

Treatment	2018-19			2020-21			Mean		
	yield (kg/ha)	Net return (Rs./ha)	B-C ratio	yield (kg/ha)	Net return (Rs./ha)	B-C ratio	yield (kg/ha)	Net return (Rs./ha)	B-C Ratio
T1 - Conventional tillage	358	-1520	0.54	388	280	1.01	373	-620	0.78
T2 - Rotavator ploughing once + Chisel ploughing once	461	4,160	0.68	479	5240	1.22	470	4700	0.95
T3 - Chisel ploughing once + Tiller ploughing once	398	1,630	0.61	425	3250	1.15	412	2440	0.88
T4 - Conservation tillage	442	4,770	0.70	434	4290	1.20	438	4530	0.95

3.3 Effect of tillage methods on rainwater use efficiency (kg/ha-mm) of cotton and greengram

Effective utilization of rainwater by crop in rainfed areas for producing higher yield in cotton and greengram was assessed through rainwater use efficiency and it is presented in Table 5. Higher rain water use efficiency of 2.05, 2.29 and 2.46 kg/ha mm was recorded in cotton for rotovator ploughing once + chisel ploughing once for 2015-16, 2017-18 and 2019-20 respectively. Incorporation of previous season crop residue through Rotovator ploughing during the month of April and breaking of subsoil hard pan by chisel ploughing once during the month of September before the commencement of sowing has increased remarkable water retaining capacity of soil. Hence rainwater received during crop period has improved biological characters of crop which was reflected in yield and RWUE. Conservation tillage has recorded considerable RWUE after T2 treatment because of minimum manipulation of soil and retaining crop residues on the surface. Disc ploughing once followed by tiller ploughing twice manipulated soil very well, could not retain enough soil water content in subsoil layers for crop production, hence lower RWUE was recorded in conventional tillage method. Similar pattern of RWUE was also recorded in green gram for 2018-19 and 2020-21. Continuous rainfall at maturity stage of greengram in 2020-21 reduced the yield and lowered RWUE. Crop rotation has improved water retaining capacity of soil, consequently it reflected in RWUE for entire study period.

Table 5 Effect of tillage methods on rainwater use efficiency (kg/ha-mm) of cotton and greengram

Treatments	Cotton			Greengram	
	2015-16	2017-18	2019-20	2018-19	2020-21
Seasonal Rainfall (mm)	475.8	421.4	213.9	426.4	473.3
T1 - Conventional tillage	1.85	2.05	2.17	2.17	0.82
T2 – Rotavator ploughing once + Chisel ploughing once	2.05	2.29	2.46	2.46	1.01
T3 - Chisel ploughing once + Tiller ploughing once	1.69	1.94	2.06	2.06	0.90
T4 - Conservation tillage	1.93	2.15	2.24	2.24	0.92

4. CONCLUSION

Different tillage practices were tested in the rainfed cotton and greengram crop rotation from 2015 to 2021. The conclusions drawn from this research are (i) Conservation tillage (minimum tillage along with retaining crop residue for higher soil moisture content at sub surface depth. (ii) Rotovator ploughing during the month of April to incorporate the previous season crop residue and chisel ploughing once during the month of September before the commencement of sowing for higher yield and economics.

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COMPETING INTERESTS

"Authors have declared that no competing interests exist.".

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