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Tillage and weed management influence on physico-chemical and biological characteristics of soil under cotton-greengram cropping system

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ABSTRACT

A field experiment was conducted during *Kharif*-Summer season of 2016-17 at research farm of AICRP-Weed Management, Anand Agricultural University, Anand, Gujarat to study the effect of different tillage and weed management options on physico-chemical and biological properties of soil under cotton-green gram cropping system. The tillage and weed management treatments did not show any significant effect on various physico-chemical properties of soil after harvest of cotton and greengram except on organic carbon content and available phosphorus. The tillage did not influence the microbial population in cotton but weed management options, IC + HW at 15, 30 and 45 DAS showed significant impact on total bacterial count and dehydrogenase activity in soil. The tillage had significant effect on actinobacteria count and dehydrogenase activity in greengram while weed management options exhibited significant effect on all the microbial observations except on total PSM count. It is inferred that combination of zero tillage + residue incorporation along with IC + HW at 15, 30 and 45 DAS in cotton and zero tillage + residue incorporation along with IC + HW at 20 and 40 DAS in green gram were most suitable option for cotton-greengram cropping system in Middle Gujarat condition.

INTRODUCTION

Cotton-greengram system is one of the major cropping system component adopted in Middle Western plains of Gujarat. Therefore, the role of tillage in this cropping system can play a substantial factor to minimize yield gap. Improved management practices such as reduced or no tillage management, addition of crop residue, crop rotation and balanced nutrient application improves agricultural sustainability (Six *et al.* 2002, West and Post 2002 and Vanden Bygaart *et al.* 2003). Conservation agriculture (CA) increases productivity and helps in improving soil health (Fowler and Rockstrom 2001, Hobbs 2007, Giller *et al.* 2009) and hence, there has been a positive shift towards the promotion of CA throughout the world (Melander *et al.* 2005, Sharma and Singh 2014 and Bajwa 2014).

To promote capture and conservation of water and nutrients in agricultural systems under arid and semi- arid regions, CA practices are important, because they can contribute to avoid soil degradation by compaction (Fernandez-Ugalde *et al.* 2009 and Kuzucua and Dokmenb 2015). Balancing of soil property is the core area to be taken care by the agriculturist or user of it. This study was conducted to assess effects of various tillage and weed management practices on physic-chemical and biological properties of soil in cotton-greengram cropping system.

MATERIALS AND METHODS

The present investigation was carried out during *Kharif*-summer season of 2016-17 at AICRP on Weed Management farm, Anand Agricultural University, Anand, Gujarat. The soil of the experimental field was sandy loam in texture with pH, EC, organic carbon, available nitrogen, phosphorus and potash of the soil ranged to 7.80, 0.17/dSm, 0.27% (low), 342.0 (medium), 48.0 (medium) and 298.0 (high) kg/ha, respectively. The soil samples from each plot were collected after harvest of the crop and analyzed for physico-chemical properties of soil using standard laboratory procedure.

The experiment was conducted in strip plot design wherein, cotton was grown in *Kharif* and *Rabi* season while greengram was grown in summer. In the first crop, the treatments were conventional tillage (CT), conventional tillage (CT), zero tillage

(ZT), zero tillage (ZT) and zero tillage + residue (ZT+R) were relegated to main plots while pendimethalin 900 g/ha pre-emergence treatment (PE) at 0-3 days *fb* IC + HW at 30 and 60 DAS, quizalofop-ethyl 50 g/ha post-emergence treatment (PoE) at 20 days *fb* IC + HW at 30 DAS and IC + HW at 15, 30 and 45 days after seeding (DAS) in subplot as a treatment. In second crop, the treatments were conventional-tillage (CT) followed by conventional tillage, conventional tillage (CT) followed by zero tillage (ZT), zero tillage (ZT) followed by zero tillage (ZT), zero tillage (ZT) followed by zero tillage + residue (ZT+R) and zero tillage + residue (ZT+R) followed by zero tillage + residue (ZT+R) relegated to main plot while pendimethalin 500 g/ha PE *fb* IC+HW at 30 DAS, imazethapyr 75 g/ha PoE *fb* IC + HW at 30 DAS and IC + HW at 20 and 40 DAS in sub-plots as a treatment. In *Kharif* season, cotton cultivar Guj. Cot. Hy. 8 (BG II) was sown the seed rate of 4.0 kg/ha at 120 cm row to row and 45 cm plant to plant distance. The crop was fertilized with 280 kg N/ha urea only. One fourth quantity of nitrogen (70 kg/ha) was applied as a basal and remaining quantity of nitrogen was applied in equal split at different growth stages of cotton, *viz.* square formation, flowering and boll formation stages as top dressing.

Similarly, in summer season, greengram cultivar '*GAM 5*' was sown using 20.0 kg/ha seed with 45 cm row to row spacing. The crop was fertilized with 20 kg N/ha and 40 kg phosphorus/ha. Entire quantity of nitrogen and phosphorous were applied using urea and single super phosphate as basal dose, respectively. The herbicides were applied as per the treatment in respective crop by knapsack sprayer fitted with flat-fan nozzle using 500 litres/ha water. All the recommended package of practices were followed to grow cotton and greengram crop.

The soil samples from each plot were collected before sowing of greengram and after harvest of cotton. These samples were analyzed for total soil bacteria, fungi, actinobacteria, diazotrophs, phosphate solubilizing microbial (PSM) populations and dehydrogenase activity in soil samples using standard laboratory procedure. For total count, soil samples were serially diluted and inoculated on respective agar media *i.e.* for bacteria nutrient agar, for fungi MRB agar, for actinomycetes agar and for PSM, PKVK agar medium were used. After incubation, microbial count in terms of CFU was recorded (Bera and Ghosh 2013). The overall data recorded for various parameters were statistically analyzed by the procedure described by Chochran and Cox (1957).

RESULTS AND DISCUSSION

Effect on weed dry biomass

At harvest, weed dry biomass (31.1 g/m^2) of total weed recorded significantly the highest under zero tillage treatment in cotton (**Table 1**). While the lowest total weed dry biomass was recorded under zero tillage practices. Dry biomass of monocot weeds at harvest was found significantly lower under zero tillage + residue when compared with conventional tillage treatment and at par with all other. Zero tillage and conventional tillage remain at par with each other but found significantly superior over other treatments for dry biomass of dicot weed (**Table 1**). Weed dry biomass of monocot, dicot and total were recorded significantly the lowest under IC + HW carried out at 15, 30 and 45 DAS except for dicot weed, which was at par with application of pendimethalin 900 g/ha PE *fb* IC + HW at 30 and 60 DAS. These results are in agreement with those reported by Patel *et al*. (2013). Least dry weight of sedges was recorded under application of quizalofop-ethyl 50 g/ha PoE *fb* IC + HW at 30 DAS at harvest in cotton.

Data presented in **Table 1** indicated that significant differences were achieved due to different tillage practices on weed density and dry biomass of monocot, dicot, sedges and total weeds at 30 DAS. The highest dry biomass of monocot weeds (11.7 g/m^2) was recorded under zero tillage followed by zero tillage + residue treatment. Similarly, dry biomass of dicot weed was recorded the highest under conventional tillage (3.49 g/m^2) treatment. Total weed dry biomass was recorded significantly the highest under zero tillage (12.5 g/m^2) followed by zero tillage + residue (10.2 g/m^2). Weed dry weight of monocot, sedges and total were found to be non significant due to different weed management practice. However, application of imazethapyr 75 g/ha PoE *fb* IC + HW at 30 DAS and IC + HW at 20 and 40 DAS remain at par with each other but found significantly superior over pendimethalin 500 g/ha PE *fb* IC + HW at 30 DAS with respect to dry weight of dicot weeds at 30 DAS.

Effect on yield

The highest seed cotton yield was achieved under conventional tillage treatment (2.52 t/ha) while the lowest seed cotton yield (1.88 t/ha) was recorded under zero tillage practices **(Table 1)**. Schwab *et al.* (2002) indicated that conventional tillage might have eliminated compaction of sub-surface soil due to deep tillage, which may enhanced root growth and subsequent nutrient and water uptake thereby produced higher seed cotton yield. Stalk yield was found non significant due to different tillage treatment (**Table 1**). Significant differences in seed cotton yield were not found due to different weed management practices. However, maximum and minimum seed cotton yield was recorded under application of pendimethalin 900 g/ha PE *fb* IC + HW at 30 and 60 DAS and IC+ HW at 15, 30 and 45 DAS, respectively.

Different tillage practices showed significant differences with respect to seed yield of greengram (**Table 1**). Significantly the highest seed and haulm yields were recorded under zero tillage + residue followed by zero tillage + residue treatment (0.68 t/ha) whereas, significant differences among other treatment were not found. Application of pendimethalin 500 g/ha PE *fb* IC + HW at 30 DAS recorded significantly the highest seed (0.720 t/ha) and haulm (1.11 t/ha) yields. The higher yield may be due to effective weed control which resulted in increased the yield attributes and thereby yield. While application of imazethapyr 75 g/ha PoE *fb* IC + HW at 30 DAS recorded significantly the lowest seed (0.413 t/ha) and haulm (0.718 t/ha) yield.

Effect on physico-chemical properties of soil

Different tillage and weed management treatments had no effect on soil characteristics except on organic carbon and available phosphorus, respectively (**Table 2**). However, zero tillage with residue incorporation has enhanced organic carbon content in soil with no treatments in zero tillage treatment alone and interaction of all other treatments were statistically at par with each other.

Alam *et al*. (2014) observed that zero tillage along with addition of organic matter and crop residues in the cropping systems reported increased soil organic matter (SOM) significantly in the 0–25 cm soil layer compared to deep tillage after 4 years. Similarly, Zhu *et al*. (2014) also noticed similar result

Table 1. Effect of tillage and weed management practices on weed dry biomass, seed cotton yield and seed yield of greengram

Treatment	Weed dry biomass (g/m^2) at harvest in cotton				Seed cotton yield (t/ha)	Stalk yield (t/ha)
	Monocot	Dicot	Sedges	Total		
Tillage and crop residue management practices in cotton (T)						
CT	23.7(569)	8.69(108)	3.41(13.2)	25.9(690)	2.52	5.14
CT	25.6(703)	8.48(84.2)	4.80(27.3)	27.5(815)	2.48	5.13
ZT	23.7(642)	6.71(49.1)	2.31(4.52)	25.0(695)	1.88	4.90
ZT	30.4(949)	4.79(25.5)	3.06(10.4)	31.1(985)	1.95	4.36
ZT+R	22.4(572)	4.23(17.0)	2.65(6.84)	23.1(596)	2.19	4.98
LSD (p=0.05)	2.99	0.50	0.27	2.92	0.17	NS
Weed management practices in cotton (W)						
Pendimethalin 900 g/ha PE *fb* IC + HW at 30 and 60 DAS	23.2(570)	5.65(36.0)	4.53(23.0)	24.5(629)	2.33	5.08
Quizalofop-ethyl 50 g/ha PoE *fb* IC + HW at 30 DAS	32.7(1086)	8.48(102)	2.31(5.14)	34.4(1194)	2.12	4.47
IC + HW at 15, 30 and 45 DAS	19.5(405)	5.62(31.8)	2.90(9.24)	20.5(446)	2.17	5.16
LSD (p=0.05)	3.75	0.44	0.23	3.57	NS	0.27
Interaction M x W	4.51	0.73	0.53	4.47	NS	NS
Treatment	**Weed dry biomass (g/m^2) at 30 DAS in greengram**				**Seed yield (t/ha)**	**Haulm yield (t/ha)**
	Monocot	Dicot	Sedges	Total		
Tillage & crop residue management practices in greengram (T)						
CT	5.45(30.7)	3.49(11.6)	2.54(5.59)	6.90(47.8)	0.587	0.927
ZT	7.95(80.2)	2.28(4.36)	3.28(10.4)	9.12(94.9)	0.547	0.898
ZT	11.7(139)	2.79(7.26)	3.16(9.30)	12.5(156)	0.551	0.901
ZT + R	9.17(88.0)	2.00(3.29)	3.91(15.7)	10.2(107)	0.560	0.923
ZT + R	8.37(69.5)	2.08(3.46)	2.99(8.14)	9.02(81.1)	0.677	1.064
LSD (p=0.05)	0.62	0.19	0.19	0.60	0.067	0.060
Weed management practices in greengram (W)						
Pendimethalin 500 g/ha PE *fb* IC + HW at 30 DAS	8.79(81.4)	2.77(6.94)	3.14(9.05)	9.68(97.4)	0.720	1.112
Imazethapyr 75 g/ha PoE *fb* IC + HW at 30 DAS	8.04(73.6)	2.41(5.56)	3.32(10.4)	9.16(89.6)	0.413	0.718
IC + HW at 20 and 40 DAS	8.80(89.6)	2.41(5.46)	3.07(9.99)	9.83(105)	0.620	0.998
LSD (p=0.05)	NS	0.12	NS	NS	0.038	0.029
Interaction M x W	0.76	0.22	0.27	0.67	NS	NS

Note: Data subjected to $(\sqrt{x+1})$ transformation. Figures in parentheses are means of original values; CT=Conventional tillage - conventional tillage; ZT=Conventional tillage - zero tillage; ZT=Zero tillage - zero tillage; ZT+R=Zero tillage - zero tillage + residue; ZT+R=Zero tillage + residue - zero tillage + residue where, zero tillage had 4.3% SOM in the 0–30 cm soil layer compared to traditional tillage after 4 years. The zero tillage + residue treatment has also recorded higher available phosphorus and potassium compared to rest of the treatment.

Similarly, under sub-plot treatments, available phosphorus was found to be significantly higher only with application of quizalofop-ethyl 50 g/ha PoE *fb* IC + HW at 30 DAS (51.3 kg/ha) than in other weed management treatments. Other soil characteristics were not affected by weed management treatments.

In greengram, also significantly higher organic carbon (0.40%) content was recorded under zero tillage + residue treatment compared with rest of the treatments except zero tillage + residue (0.36%) **(Table 3)**. Thus, the residue incorporation slightly helped in increasing the organic carbon in soil. Luo Youjin *et al.* (2011) found the highest organic carbon in 0-10 cm soil layer under NT-rr (no-till and ridge culture with rotation of rice and rape) and the least was found in 20-30 cm soil layer under CT-r (conventional tillage with rotation of rice and winter fallow system). Urioste *et al.* (2006) reported that frequent and excessive tillage and residue removal in conventional tillage and deep tillage by chiseling resulted in significant loss of soil organic matter. Treatment of conventional tillage followed by conventional tillage (CT-CT) did not show any uniform trend on any of the soils physico-chemical properties. Amongst weed management treatments, higher available phosphorus (50.0 kg/ha) and available potassium (209 kg/ha) were significantly recorded only with imazethapyr 75 g/ha PoE *fb* IC + HW at 30 DAS.

Effect on microbial properties of soil

Among all the treatments tested, only total bacteria count and dehydrogenase activity were

Table 2. Effect of tillage and weed management treatments on physico-chemical characteristics of soil at cotton harvest

Treatment	pH	EC (dS/m)	Organic Carbon (%)	Available Nitrogen (kg/ha)	Available Phosphorus (P_2O_5) (kg/ha)	Available Potassium (K_2O) (kg/ha)
Tillage and crop residue management practices in cotton						
CT	8.2	0.31	0.31	333	44.9	181
CT	8.0	0.34	0.32	310	40.6	175
ZT	7.9	0.35	0.29	338	43.2	189
ZT	8.0	0.35	0.33	332	45.5	197
ZT + R	7.9	0.41	0.37	306	46.4	207
LSD (p=0.05)	NS	NS	0.04	NS	NS	NS
Weed management treatments in cotton						
Pendimethalin 900 g/ha PE *fb* IC + HW at 30 and 60 DAS	8.1	0.36	0.32	320	39.7	188
Quizalofop-ethyl 50 g/ha PoE *fb* IC + HW at 30 DAS	7.9	0.34	0.32	321	51.3	204
IC + HW at 15, 30 and 45 DAS	7.9	0.35	0.33	330	41.2	178
LSD (p=0.05)	NS	NS	NS	NS	2.66	NS
Interaction T X W	NS	NS	NS	NS	Sig.	NS

Table 3. Effect of tillage and weed management treatments on physico-chemical characteristics of soil at greengram harvest

Treatment	pH	EC (dS/m)	Organic Carbon (%)	Available Nitrogen (kg/ha)	Available Phosphorus (P_2O_5) (kg/ha)	Available Potassium (K_2O) (kg/ha)
Tillage and crop residue management practices in greengram (T)						
CT	7.9	0.31	0.32	367	46.4	197
ZT	8.0	0.34	0.35	396	45.5	207
ZT	7.9	0.39	0.34	414	43.2	182
ZT + R	7.9	0.31	0.36	377	40.6	181
ZT + R	8.0	0.40	0.40	370	44.9	180
LSD (p=0.05)	NS	NS	0.04	NS	NS	NS
Weed management treatments in greengram (W)						
Pendimethalin 500 g/ha PE *fb* IC + HW at 30 DAS	7.9	0.37	0.35	376	39	181
Imazethapyr 75 g/ha PoE *fb* IC + HW at 30 DAS	7.9	0.36	0.35	380	50	209
IC + HW at 20 and 40 DAS	8.0	0.32	0.36	400	42	178
LSD (p=0.05)	NS	NS	NS	NS	2.66	25.5
Interaction T X W	NS	NS	NS	NS	Sig.	NS

found significant under different weed management options (**Table 4**). The zero tillage + residue system helped in maintaining higher total bacteria, actinobacteria, total PSM and dehydrogenase activity in the soil wherein, IC + HW at 15, 30 and 45 DAS sustained all microbial properties in higher range. Lal *et al*. (2007) also suggested that improved SOC accumulation in soil is associated with a greater microbial and root growth, nutrient and water supply, soil aggregation and better pH and temperature regulation. The IC + HW at 15, 30 and 45 DAS treatment significantly affected total bacteria count (91.7 10^6 CFU/g soil) and dehydrogenase activity (23.0 µg TPF/g soil/24 hr.) Thus, there was no adverse effect due to different weed management treatments on microbial properties of soil and non-chemical weed management option helped in sustaining higher microbial counts and activity in soil without hampering their proliferation rate. Wardle and Parkinson (1990) observed that some herbicide may even stimulate the growth and activities of the microbial activities. However, some herbicides may affect non-target organisms including micro-organisms (Latha and Gopal 2010). Thus, combination of zero tillage + residue and IC + HW at 15, 30 and 45 DAS was found as the best combination with less soil disturbance, greater availability of soil moisture and nutrients due to residue incorporation which encouraged higher microbial counts in soil.

In succeeding crop, greengram encountered the similar results where total actinobacteria (76.7 10^4CFU/g soil) and dehydrogenase activity (22.7 µg TPF/g soil/24 hr.) were significantly influenced by ZT + residue practices **(Table 5)**.

In comparison to previous crop the overall activity of total bacteria, fungi and actinobacteria decreased while remaining microbial observations increased their counts in soil samples of succeeding greengram crop, may be due to change in weed management options (**Table 4**). This decrease in the population of total bacteria, fungi and actinobacteria may be due to competitive influence and toxic effect of different herbicides applied in soil environment.

Table 4. Effect of tillage and weed management treatments on soil microbial characteristics at cotton harvest

Treatment	Total bacteria (10^6 CFU/g soil) Initial: 64 X 10^5	Fungi (10^4 CFU/g soil) Initial: 45 X 10^3	Actinobacteria (10^4 CFU/g soil) Initial: 50 X 10^3	Total Diazotrophs (10^3 CFU/g soil) Initial: 25 X 10^3	Total PSM (10^3 CFU/g soil) Initial: 18 X 10^3	Dehydrogenase (µg TPF/g soil/24 h) Initial: 18
Tillage and crop residue management practices in cotton (T)						
CT	88.7	55.7	69.3	85.6	90.0	22.4
CT	89.0	55.3	69.4	85.2	89.6	22.3
ZT	90.0	56.3	71.2	86.6	91.5	22.6
ZT	90.1	56.3	71.3	86.0	91.5	22.6
ZT + R	90.1	56.2	71.8	86.1	91.7	22.8
LSD (p=0.05)	NS	NS	NS	NS	NS	NS
Weed management treatments in cotton (W)						
Pendimethalin 900 g/ha PE *fb* IC + HW at 30&60 DAS	89.4	55.13	70.1	85.2	90.5	22.4
Quizalofop-ethyl 50 g/ha PoE *fb* IC+HW at 30 DAS	87.6	54.6	70.4	85.7	90.1	22.2
IC + HW at 15, 30 and 45 DAS	91.7	58.2	71.3	86.7	91.9	23.0
LSD (p=0.05)	1.61	NS	NS	NS	NS	0.49

Table 5. Effect of tillage and weed management treatments on soil microbial characteristics at greengram harvest

Treatment	Total Bacteria (10^6 CFU/g soil) Initial: 70 X 10^5	Fungi (10^4 CFU/g soil) Initial: 85 X 10^4	Actinobacteria (10^4 CFU/g soil) Initial: 95 X 10^3	Total Diazotrophs (10^3 CFU/g soil) Initial: 43 X 10^3	Total PSM (10^3 CFU/g soil) Initial: 50 X 10^3	Dehydrogenase (µg TPF/g soil/24 h) Initial: 14
Tillage and crop residue management practices in greengram (T)						
CT	41.9	28.9	72.0	95.8	94.8	18.3
ZT	42.2	30.2	72.6	96.1	95.9	19.7
ZT	42.9	31.4	73.6	96.1	96.6	20.3
ZT + R	43.3	31.6	74.4	97.0	96.7	20.6
ZT + R	44.2	33.3	76.7	98.3	98.6	22.7
LSD (p=0.05)	NS	NS	2.3	NS	NS	1.8
Weed management treatments in greengram (W)						
Pendimethalin 500 g/ha PE *fb* IC + HW at 30 DAS	42.0	30.7	73.7	95.9	96.3	19.9
Imazethapyr 75 g/ha PoE *fb* IC + HW at 30 DAS	41.9	29.8	72.3	94.6	95.6	19.2
IC + HW at 20 and 40 DAS	44.8	32.8	75.5	99.5	97.5	21.9
LSD (p=0.05)	2.5	1.73	2.55	2.82	NS	2.12
Interaction T X W	NS	NS	NS	NS	NS	NS

Amongst various weed management options, IC + HW at 20 and 40 DAS recorded significantly higher activity of total bacteria, fungi, actinobacteria, total diazotrophs and dehydrogenase activity except total PSM **(Table 5)**. Treatment of IC + HW at 20 and 40 DAS recorded higher microbial activity followed by pendimethalin 500 g/ha PE *fb* IC+ HW at 30 DAS and the lowest under imazethapyr 75 g/ha PoE *fb* IC + HW at 30 DAS.

The pre-emergence herbicide pendimethalin 500 g/ha *fb* IC+ HW at 30 DAS and post-emergence herbicide imazethapyr 75 g/ha *fb* IC + HW at 30 DAS were found to be statistically at par with each other; on the other hand post-emergence herbicide imazethapyr 75 g/ha *fb* IC + HW at 30 DAS and IC + HW at 15, 30 and 45 found to be statistically at par with each other.

It may be concluded that impact of zero tillage + residue incorporation with IC + HW at 15, 30 and 45 DAS in cotton and zero tillage + residue incorporation with IC + HW at 20 and 40 DAS in greengram found to be most suitable option for cotton green cropping system of middle Gujarat in sustaining the maximum gain of all physico-chemical and microbial properties of soil along with yield profit.

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