Research Article

Influence of Tillage Practices and Supplemental Irrigation Options on Growth, Yield and Soil Biological Properties of Rainfed Bt Cotton

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Abstract

A field experiment was conducted in two consecutive growing seasons at Agricultural Engineering College and Research Institute, Kumulur, Tamil Nadu to evaluate the tillage practices, crop residue and supplemental irrigation through drip irrigation in Bt cotton under rainfed condition. The experiment was laid out in strip plot design with three replications. The soil type of the experimental field was sandy loam in texture with pH 7.71. The fertility status of the soil was low, medium and high in the available N, P_2O_5, and K_2O; the values are 212, 20 & 575 kg ha^{-1} respectively. The main plot treatments were conventional tillage, minimum tillage without crop residue, minimum tillage with crop residue @ 5 t ha^{-1} and minimum tillage with crop residue @ 10 t ha^{-1}. The sub plot treatments were control (without irrigation), supplemental drip irrigation 4, 6, 8 and 10 times during the cropping period. Tillage practices and crop residue with supplemental drip irrigation practices could potentially lead to significant difference in growth parameters, microbes populations, yield attributes and maximum yield 2947, 2923 kg ha^{-1} of Bt cotton in both the seasons by application of minimum tillage with crop residue 10 t ha^{-1} + supplemental drip irrigation ten times. Therefore, minimum tillage (one pass of mouldboard plough followed by two passes of disk harrow) with crop residue 10 t ha^{-1} + supplemental irrigation through drip irrigation ten times was found to be more appropriate and profitable to improving yield of Bt cotton under rainfed condition.

Keywords: Soil health, cotton, supplemental irrigation, tillage and yield

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Introduction

Nature is comprised of biological diversity. A single gram of soil has been estimated to contain several thousand species of microbes. Traditional intensive agricultural practices deteriorate soil health [1].

Soil organisms are important elements for preserved ecosystem biodiversity and services thus assess functional and structural biodiversity in arable soils is interest. Main threats to soil biodiversity occurred by mechanical impacts (soil compaction, soil tillage) and chemical stress (plant protection measures) in agricultural management.

A wide range of sustainable agricultural practices improve soil quality. For example reducing tillage, increasing organic content in the soil by adding local available organic wastes and crop residues and ensuring sufficient ground cover to protect soil from erosion during off season etc.

Tillage systems influence physical, chemical and biological properties of soil and have a major impact on soil productivity and sustainability. It alters the organic matter content in soil, which ultimately affects the microbial population and their activity. Conventional tillage practices may adversely affect long–term soil productivity due to erosion and loss of organic matter in soil. Suitable soil management can be practiced through conservation tillage (including zero tillage), high crop residue return and crop rotation. Minimum-tillage (MT) is the most adapted conservation tillage system, which involves minimal disturbance of the surface residue.

Soil quality can be described as the integration of the physical, chemical and biological properties of the soil for productivity and environmental quality [2]. Fertile and high quality soil will sustain long-term agricultural production by supporting the production capacity of the system [3]. However, conventional agricultural practices have diminished soil productivity at such a frightening pace [4], that many agricultural soils are depleted of nutrients and unable to naturally sustain crops [5]. Under current conditions, unproductive soils have to be actively rehabilitated into fertile and healthy soil in order to increase yields [6]. This conversion process gave rise to the three main principles applied in ecological-oriented conservation agriculture (CA): crop diversification, minimum soil

disturbance, and permanent soil cover; all aiming to increase and sustain soil organic matter (SOM) [7]. Subsequent advantages such as increased infiltration, aggregate stability, increased water holding capacity, etc., are also associated with a higher SOM content

Cropping systems that return crop residues to the field significantly increase the activity of a wide range of soil enzymes, compared to unamended soils, due to the stimulation of microbial activity [8].

In dry areas mostly shortage of soil moisture occurs during the most sensitive growth stages like flowering and grain filling stage of the crops. As a resulting is poor crop growth and yield. Supplemental irrigation (SI), with limited amount of water, when applied during the critical crop growth stages, can result in substantial improvement in yield and water productivity. Hence SI is an effective method to alleviate the adverse impact of soil moisture stress during dry spells on the yield of rainfed crops [9].

Cotton is an important commercial crop, contributing to 65 per cent requirement of Indian Textile Industries. In India, cotton is currently cultivated in 9.37 million ha with the production of 29.0 million bales and the productivity is 526 kg ha^{-1} [10]. In order to increase production further there is no other option except to increase productivity by using available resources most efficiently.

Keeping this in view, the present investigation was undertaken to study the combined effect of tillage, crop residue incorporation and supplemental irrigation methods on the growth, biological population and yield of Bt cotton in Tamil Nadu.

Materials and Methods

A field experiment was carried out for two consecutive growing seasons at Agricultural Engineering College and Research Institute, Kumulur, Tamil Nadu. The experimental site is geographically situated at 10.56^0 North latitude and 78.49^0 East longitudes and at an altitude of 78 m above MSL. The soil was sandy loam in texture with pH 7.71. The fertility status of the soil was low, medium and high in the available N, P_2O_5, and K_2O, with the values of 212, 20 & 575 kg ha^{-1} respectively. The main plot treatments were conventional tillage, minimum tillage without crop residue, minimum tillage with crop residue @ 5 t ha^{-1} and minimum tillage with crop residue @ 10 t ha^{-1}. The sub plot treatments were (without irrigation) control, supplemental drip irrigation 4, 6, 8 and 10 times during the cropping period. The experiment was laid out in a strip plot design with three replications.

Conventional tillage included one pass of mouldboard plough to a depth of 15 cm and was followed by two passes of disk harrowing. Minimum tillage included only one pass of disk harrowing. The treatments were carried out on the same plots in the growing seasons. In both growing seasons, one of the most commercial Bt cotton RCH 2 was sowing manually on paired row spacing of 120 + 30 x 60 cm (totally there were two rows per plot). Before sowing a uniform fertilizer schedule was followed at the rate of 90:45:45 kg of N, P_2O_5 and K_2O ha^{-1}. Nitrogen was applied in three splits as 25: 50: 25 per cent as basal, at 35 and 55 DAS, respectively. The entire dose of phosphorus was applied basally. The potassium was applied in two equal split doses *viz*., basal and at 55 DAS. Pendimethalin @ 1.0 kg a.i ha^{-1} was also applied for weed control after sowing of cotton seed. During the growing season, the insecticides and fungicides were applied according to recommendations by the state agricultural university (SAU). All other necessary operations except those under study were kept normal and uniform for all the treatments.

The supplemental irrigation was given to the crop at the time of moisture stress period, which was determined based on the visual symptom (Wilting of plants). In study period four, six, eight and ten supplemental irrigations were given at various time period. The water was pumped by motor from farm pond and supplied to crops through drip irrigation system at a depth of 3 cm.

Observations on growth characters such as plant height and dry matter production were recorded at 40, 80, 120 DAS and at harvest from five randomly selected plants in each plot. The samples were collected from sampling rows in each plot for dry matter production and were used for the estimation of DMP. The population density of bacteria, fungi and actinomycetes were enumerated using serial dilution plate technique. The data on yield parameters and yield were also recorded.

Result and Discussion

Effect of treatments on plant height

Growth and development in plants are a consequence of excellent coordination of several processes operating at different growth stages of plant. The growth of cotton influenced by various tillage treatments has been elucidated through the positive response on plant height.

The growth parameters of Bt cotton were significantly influenced by tillage and crop residue with supplemental

irrigation through drip irrigation. The growth parameters were not influenced by treatments at 40 and 80 DAS. Among tillage and crop residue treatments, minimum tillage with crop residue 10 t ha^{-1} recorded significantly higher plant height (**Table 1**) (128, 143 cm and 112, 127 cm at 120 DAS and at harvest during 2012 and 2013, respectively). Regarding irrigation practices, supplemental irrigation at 10 times was recorded higher plant height than without supplemental irrigation plot.

With regard to interaction effect, in a given tillage with crop residue treatment and supplemental drip irrigation, minimum tillage with crop residue 10 t ha^{-1} + supplemental drip irrigation 10 times registered distinctly higher plant height at 120 DAS and at harvest during both the years.

Table 1 Effect of tillage, crop residue and supplemental drip irrigation on plant height (cm) of Bt cotton

Treatments	**120 DAS**					**At harvest**				
	M_1	**M_2**	**M_3**	**M_4**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**Mean**
2012										
S_1	103	105	108	113	107	112	118	126	126	120
S_2	108	108	116	124	114	114	124	135	138	128
S_3	112	114	120	128	118	120	128	138	142	132
S_4	113	117	121	135	121	125	129	140	150	136
S_5	116	118	126	142	126	127	133	148	157	141
Mean	110	112	118	128		120	127	137	143	
2013										
S1	91.3	92.3	96.4	99.2	94.8	103	105	107	111	107
S2	95.4	94.5	99.1	104.0	98.3	109	111	114	118	113
S3	97.4	97.4	102.5	110.2	101.9	114	115	121	124	119
S4	100.3	100.5	107.2	116.4	106.1	120	118	128	132	125
S5	107.3	106.2	117.3	129.4	115.1	125	122	135	149	133
Mean	98.3	98.2	104.5	111.9		114	114	121	127	

	S Ed	**CD (P=0.05)**	**S Ed**	**CD (P=0.05)**	**S Ed**	**CD (P=0.05)**	**S Ed**	**CD (P=0.05)**
M	3.63	8.87	3.10	7.59	3.11	7.61	3.79	9.28
S	3.31	7.63	3.70	8.53	3.49	8.04	3.97	9.15
M at S	4.15	9.83	3.96	9.30	3.88	9.14	4.96	11.69
S at M	3.85	8.87	4.40	10.15	4.15	9.58	5.03	11.61

M_1- Conventional tillage; M_2- Minimum tillage without crop residue; M_3- Minimum tillage with crop residue @ 5 tons ha^{-1}; M_4- Minimum tillage with crop residue @ 10 tons ha^{-1}.
S_1-Control; S_2- Supplemental drip irrigation four times; S_3- Supplemental drip irrigation six times;
S_4- Supplemental drip irrigation eight times; S_5- Supplemental drip irrigation ten times

Effect of treatments on dry matter production

Tillage and crop residue with supplemental irrigation through drip irrigation significantly influenced the dry matter production (**Table 2** and **3**). Among tillage and crop residue treatments, minimum tillage with crop residue 10 t ha^{-1} recorded significantly higher dry matter production (4966, 5278 kg ha^{-1} and 5053, 5279 kg ha^{-1}) at 120 DAS and at harvest during 2012 and 2013, respectively. Among irrigation practices, supplemental irrigation at 10 times was recorded higher dry matter production in respective stages during both the seasons and it was comparable with supplemental irrigation at 8 times was recorded higher dry matter production than that in without supplemental irrigation plot.

With regard to interaction effect, in a given tillage with crop residue treatment and supplemental drip irrigation, minimum tillage with crop residue 10 t ha^{-1} + supplemental drip irrigation 10 times registered significantly higher dry matter production at 120 DAS and at harvest during both the years of study. Interaction effect was not significant at 120 DAS during 2012.

This might be due to the reason that minimum tillage conserved more soil moisture and crop residues have potential to increase of soil organic matter and nutrient levels, moderation of soil temperature and augmented soil biological activity, which provided better growing environment for increased plant height. Minimum tillage indirectly defines the species composition of the soil microbial community by improving retention of soil moisture and modifying soil temperature [11].

Table 2 Effect of tillage, crop residue and supplemental drip irrigation on dry matter production (kg ha^{-1}) of Bt cotton 2012

Treatments	120 DAS					Harvest				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	4356	4217	4314	4524	4353	4302	4412	4564	4726	4501
S_2	4103	4387	4487	4706	4421	4497	4658	4667	4975	4699
S_3	4298	4562	4594	4987	4610	4725	4799	4783	5103	4853
S_4	4412	4787	4703	5124	4756	4884	4934	5075	5468	5090
S_5	4627	4965	5098	5487	5044	5001	5102	5542	6124	5442
Mean	4359	4584	4639	4966		4682	4781	4926	5279	
	S Ed		CD (P=0.05)			S Ed		CD (P=0.05)		
M	128.8		315.2			147.5		361.1		
S	152.7		352.1			177.6		409.5		
M at S	190.9		NS			175.8		412.9		
S at M	204.7		NS			200.2		461.7		

Table 3 Effect of tillage, crop residue and supplemental drip irrigation on dry matter production (kg ha^{-1}) of Bt cotton 2013

Treatments	120 DAS					Harvest				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	4215	4131	4457	4672	4369	4545	4634	4628	4739	4637
S_2	4388	4357	4758	4897	4600	4723	4739	5010	5192	4916
S_3	4574	4521	4897	4967	4740	4813	4938	5034	5291	5019
S_4	4814	4774	5012	5102	4925	4783	5120	5213	5345	5115
S_5	4934	4834	5089	5627	5121	4952	5213	5534	5821	5380
Mean	4585	4523	4843	5053		4763	4929	5084	5278	
	S Ed		CD (P=0.05)			S Ed		CD (P=0.05)		
M	124.3		304.2			134.1		328.2		
S	146.8		338.5			157.9		364.1		
M at S	139.7		328.3			165.1		387.8		
S at M	159.3		367.3			183.3		422.7		

Microbiological population

Tillage and crop residue with supplemental irrigation through drip irrigation obviously influenced the microbe's population. Soil organic matter distribution, nutrient cycling and microbial activity are influenced by the type and the degree of soil tillage [12]. The influence of tillage and supplemental irrigation on the soil biological properties was studied through the assessment of soil microbial population. Practice of different tillage systems and supplemental irrigation significantly energized the soil microbial load at early stages during both the years of experimentation. The fluctuation in the microbial load in the soil is based on the availability of carbon source in the soil and enhanced microbial activity stimulated by crop residues and manures [13].

Among tillage and crop residue treatments, minimum tillage with crop residue 10 t ha^{-1} recorded significantly higher population (**Tables 4-7**) at 80 and 120 DAS during both the years of study. Among irrigation practices, supplemental irrigation at 10 times was recorded higher number of bacteria, fungal and actinomycetes at 80 and 120 DAS during both the years than that in without supplemental irrigation plot (**Figure 1**). With regard to interaction effect, in a given tillage with crop residue treatment and supplemental drip irrigation, minimum tillage with crop residue 10 t ha^{-1} + supplemental drip irrigation 10 times had higher influence on the population of bacteria, fungal and actinomycetes at 80 and 120 DAS during both the years than others both the years of study.

Effect of treatments on yield attributes and yield

Yield attribute like number sympodial branches per plant and number of bolls per plant and yield of Bt cotton was significantly influenced by tillage, crop residue and supplemental irrigation through drip irrigation. Among tillage and crop residue treatments, minimum tillage with crop residue 10 t ha^{-1} recorded significantly higher sympodial branches per plant and number of bolls per plant and yield (**Tables 8** and **9**) (21.3 branches plant^{-1}, 57.1 bolls plant^{-1}, 2436 kg

ha^{-1} and 21.2 branches plant^{-1}, 58.2 bolls plant^{-1}, 2547 kg ha^{-1} during 2012 and 2013, respectively) Regarding irrigation practices, supplemental irrigation at 10 times was recorded higher sympodial branches per plant and number of bolls per plant and yield (20.9 branches plant^{-1}, 61.4 bolls plant^{-1}, 2514 kg ha^{-1} and 21.1 branches plant^{-1}, 62.7 bolls plant^{-1}, 2508 kg ha^{-1} during 2012 and 2013, respectively) than that in without supplemental irrigation plot.

Table 4 Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on microbial population (cfu g^{-1} of soil) of Bt cotton at 80 DAS during 2012

Treatments	Bacteria x 10^5 cfu g^{-1} of soil					Fungi x 10^3 cfu g^{-1} of soil					Actinomycetes x 10^4 cfu g^{-1} of soil				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	47.5	51.7	53.9	61.3	53.6	11.3	13.3	15.4	16.7	14.2	16.4	18.5	20.0	22.2	19.3
S_2	48.1	49.2	58.9	67.4	55.9	12.8	14.5	16.5	17.3	15.3	17.4	18.0	22.1	23.6	20.3
S_3	51.0	53.7	64.2	70.3	59.8	14.2	15.8	17.8	18.5	16.6	18.4	19.6	22.9	24.5	21.4
S_4	52.0	59.3	68.9	76.7	64.2	15.2	16.3	18.5	20.1	17.5	19.5	20.7	23.4	25.0	22.2
S_5	54.0	65.4	74.5	85.3	69.8	15.8	16.9	18.4	22.0	18.3	19.1	21.1	23.0	25.4	22.2
Mean	50.5	55.9	64.1	72.2		13.9	15.4	17.3	18.9		18.2	19.6	22.3	24.1	
	SEd		CD (P=0.05)			SEd		CD (P=0.05)			SEd		CD (P=0.05)		
T	1.5		3.6			0.4		1.0			0.5		1.2		
S	1.6		3.7			0.4		1.0			0.5		1.2		
T at S	1.6		3.8			0.6		1.3			0.6		1.4		
S at T	1.7		4.0			0.6		1.3			0.6		1.4		

Table 5 Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on microbial population (cfu g^{-1} of soil) of Bt cotton at 120 DAS during 2012

Treatments	Bacteria x 10^5 cfu g^{-1} of soil					Fungi x 10^3 cfu g^{-1} of soil					Actinomycetes x 10^4 cfu g^{-1} of soil				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	28.6	31.3	35.0	37.0	33.0	9.2	10.2	11.5	12.4	10.8	7.5	10.7	14.5	17.3	12.5
S_2	30.1	32.5	37.8	37.6	34.5	10.3	11.6	12.6	13.5	12.0	8.0	11.2	15.2	17.0	12.9
S_3	31.1	33.6	39.4	38.3	35.6	11.0	12.3	12.0	13.7	12.3	8.1	10.0	15.5	16.8	12.6
S_4	33.2	34.4	38.5	39.4	36.4	11.4	11.9	12.9	13.0	12.3	10.5	12.5	16.3	19.5	14.7
S_5	33.5	36.3	40.2	40.1	37.5	11.6	12.5	13.4	14.1	12.9	11.9	14.5	17.5	20.3	16.1
Mean	31.3	33.6	38.2	38.5		10.7	11.7	12.5	13.3		9.2	11.8	15.8	18.2	
	SEd		CD (P=0.05)			SEd		CD (P=0.05)			SEd		CD (P=0.05)		
T	0.8		2.0			0.3		0.8			0.4		1.0		
S	0.9		2.0			0.3		0.7			0.4		1.0		
T at S	1.2		2.8			0.4		1.0			0.5		1.2		
S at T	1.2		2.8			0.4		1.0			0.5		1.2		

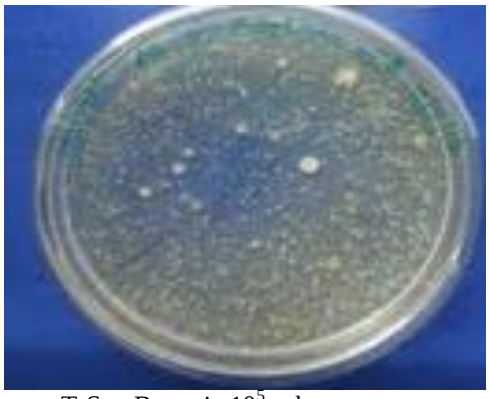
Table 6 Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on soil microbial population (cfu g^{-1} of soil) of Bt cotton at 80 DAS during 2013

Treatments	Bacteria x 10^5 cfu g^{-1} of soil					Fungi x 10^3 cfu g^{-1} of soil					Actinomycetes x 10^4 cfu g^{-1} of soil				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	40.1	45.6	52.2	58.5	49.1	10.3	12.3	16.2	17.5	14.1	14.3	18.4	22.3	24.6	19.9
S_2	43.5	47.2	53.5	62.2	51.6	12.2	14.3	18.1	19.2	16.0	15.4	20.2	23.5	25.2	21.1
S_3	45.5	48.6	55.6	64.5	53.6	13.1	15.2	19.2	20.2	16.9	16.3	20.3	24.6	26.2	21.9
S_4	48.2	53.2	59.6	69.1	57.5	13.3	15.6	18.8	21.2	17.2	17.2	21.5	24.6	25.8	22.3
S_5	50.2	54.2	64.3	72.3	60.3	14.0	16.8	19.5	21.9	18.1	18.6	20.9	25.2	26.4	22.8
Mean	45.5	49.8	57.0	65.3		12.6	14.8	18.4	20.0		16.4	20.3	24.0	25.6	
	SEd		CD (P=0.05)			SEd		CD (P=0.05)			SEd		CD (P=0.05)		
T	1.3		3.3			0.4		1.0			0.5		1.3		
S	1.2		2.9			0.5		1.2			0.6		1.3		
T at S	1.6		3.7			0.5		1.1			0.7		1.5		
S at T	1.5		3.4			0.6		1.3			0.7		1.6		

Table 7 Interaction effect of tillage practice with crop residue and supplemental irrigation through drip system on microbial population (cfu g^{-1} of soil) of Bt cotton at 120 DAS during 2013

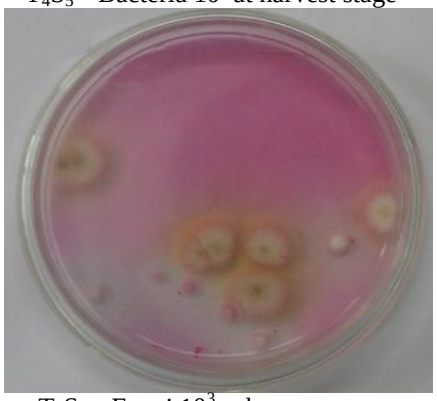
Treatments	Bacteria x 10^5 cfu g^{-1} of soil					Fungi x 10^3 cfu g^{-1} of soil					Actinomycetes x 10^4 cfu g^{-1} of soil				
	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
S_1	25.5	28.3	31.9	34.4	30.0	10.7	11.9	13.5	12.2	12.1	6.3	8.9	10.5	12.7	9.6
S_2	27.2	30.2	33.2	36.2	31.7	10.0	12.5	14.2	13.5	12.6	6.6	9.2	11.3	13.1	10.1
S_3	27.5	32.2	36.2	35.4	32.8	11.5	13.2	14.0	14.1	13.2	7.2	9.5	12.2	13.8	10.7
S_4	28.6	32.8	36.5	38.2	34.0	12.2	13.6	15.2	15.2	14.1	8.1	11.2	13.2	15.6	12.0
S_5	28.3	33.5	38.2	40.2	35.1	13.3	14.2	15.5	16.2	14.8	9.3	12.3	13.0	17.3	13.0
Mean	27.4	31.4	35.2	36.9		11.5	13.1	14.5	14.2		7.5	10.2	12.0	14.5	
		SEd	CD (P=0.05)			SEd	CD (P=0.05)				SEd	CD (P=0.05)			
T		0.7	1.8			0.34	0.8				0.3	0.7			
S		0.8	1.9			0.32	0.7				0.3	0.7			
T at S		1.0	2.3			0.43	1.0				0.5	1.2			
S at T		1.0	2.4			0.42	1.0				0.5	1.1			

T_4S_5 – Bacteria 10^5 at growth stage

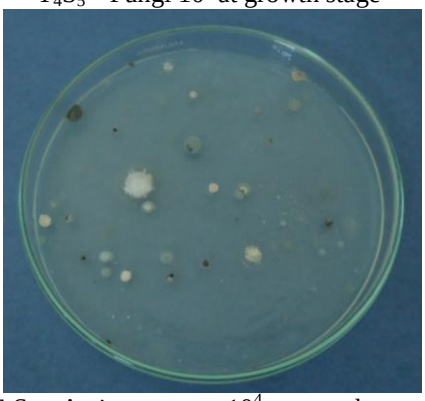


T_4S_5 – Bacteria 10^5 at harvest stage

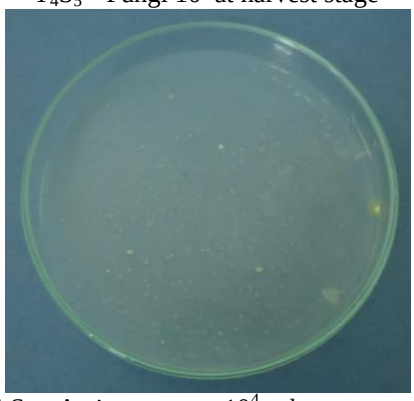
T_4S_5 – Fungi 10^3 at growth stage



T_4S_5 – Fungi 10^3 at harvest stage



T_4S_5 – Actinomycetes 10^4 at growth stage



T_4S_5 – Actinomycetes 10^4 at harvest stage

Figure 1 Microbial population

Table 8 Effect of tillage, crop residue and supplemental drip irrigation on yield attributes and yield of Bt cotton 2012

Treatments	Sympodial branches plant^{-1}					Number of bolls plant^{-1}					Yield (kg ha^{-1})				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	17.9	18.4	18.4	18.5	18.3	38.4	38.0	41.0	43.2	40.1	1794	1903	1975	2046	1930
S_2	18.0	19.5	19.5	20.8	19.5	45.2	48.3	54.2	55.3	50.7	1924	2064	2145	2245	2094
S_3	18.4	19.7	20.0	21.1	19.8	50.2	53.2	57.3	59.3	55.0	1985	2194	2298	2394	2218
S_4	18.5	19.5	19.3	22.0	19.8	54.2	57.4	58.3	61.3	57.8	2048	2285	2375	2547	2314
S_5	18.7	20.1	20.5	24.1	20.9	57.4	59.3	62.3	66.5	61.4	2187	2358	2564	2947	2514
Mean	18.3	19.4	19.5	21.3		49.1	51.2	54.6	57.1		1988	2161	2271	2436	
		S Ed	CD (P=0.05)			S Ed		CD (P=0.05)			S Ed		CD (P=0.05)		
M		0.55	1.34			1.58		3.88			82.3		201.3		
S		0.62	1.44			1.81		4.18			106.4		242.3		
M at S		0.85	1.99			1.85		4.36			103.9		243.6		
S at M		0.88	2.03			2.04		4.70			122.9		283.3		

Table 9 Effect of tillage, crop residue and supplemental drip irrigation on yield attributes and yield of Bt cotton 2013

Treatments	Sympodial branches plant^{-1}					No.of. bolls plant^{-1}					Yield (kg ha^{-1})				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	16.5	16.5	17.4	17.5	17.0	35.3	38.4	40.0	41.0	38.7	1731	1810	1967	2056	1891
S_2	17.4	17.5	18.7	19.3	18.2	44.7	49.2	55.2	58.2	51.8	2008	1903	2134	2345	2097
S_3	18.0	18.3	19.5	20.5	19.1	49.3	56.2	59.2	60.1	56.2	2019	2068	2312	2678	2269
S_4	18.2	18.6	20.2	23.4	20.1	54.7	57.1	61.2	63.2	59.1	2089	2268	2432	2735	2381
S_5	18.3	19.2	21.6	25.2	21.1	58.0	59.2	65.2	68.3	62.7	2120	2329	2658	2923	2508
Mean	17.7	18.0	19.5	21.2		48.4	52.0	56.2	58.2		1993	2076	2301	2547	
	S Ed		CD (P=0.05)			S Ed		CD (P=0.05)			S Ed		CD (P=0.05)		
M	0.49		1.20			1.49		3.64			90.8		222.1		
S	0.73		1.68			1.80		4.14			104.4		240.8		
M at S	0.75		1.74			1.93		4.53			96.1		226.1		
S at M	0.91		2.10			2.15		4.97			108.8		251.0		

With regard to interaction effect, in a given tillage with crop residue treatment and supplemental drip irrigation, minimum tillage with crop residue 10 t ha^{-1} + supplemental drip irrigation 10 times registered laudably higher sympodial branches per plant and number of bolls per plant and yield during both the years.

This might be due to the reason that the minimum tillage plots had more main stem nodes, numbers of fruiting sites than those on conventional tillage. Consequently, the number of bolls retained was greater under the minimum tillage than under the conventional tillage system. Enhanced boll retention in the minimum tillage treatments could be due to other factors such as less competition from weeds, differences in nutrient supply and conserved soil moisture. Greater boll numbers on the minimum tillage plots contributed to yield improvements compared to the conventional tillage [14]. [15] concluded that minimum tillage with residue retention increased yield particularly when crop faced terminal drought.

Conclusion

From these experiments, it is concluded that practicing of minimum tillage and application of crop residue at 10 t ha^{-1} + supplemental drip irrigation 10 times was found to be the promising agronomic practice for enhancing growth, microbial population and productivity of Bt cotton under rainfed situation.

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