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Growth and yield of *Bt* cotton (*Gossypium hirsutum* L.) as influenced by tillage and weed management practices under rainfed condition

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Abstract
Growth and crop yield may differ with tillage and weed management practices. Hence a field experiment was conducted at experimental farm, AICRP on Integrated Farming Systems, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.) during *kharif* 2019-20 and 2020-21 seasons to study "Response of Bt cotton (*Gossypium hirsutum* L.) to tillage and weed management practices in vertisol". Treatment consisted of sixteen treatment combinations comprising four tillage practices (T1- Conventional tillage, T2- Rotary tillage, T3- Minimum tillage, T4- Zero tillage) in main plot, and four weed management practices (W1 - Weed check, W2 - Weed free, W3 – Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Quizalofop ethyl (5% EC)@ 50 g ha1(PoE) + Hoeing. and W4- Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE +Pyrithiobac-sodium (10% EC) @ 62.5 g ha-1 (PoE) + Straw mulching 2.5t/ha.). The result of the study revealed that among tillage practices conventional tillage (T1) recorded significantly higher growth, yield contributing characters and seed cotton yield than other treatments, but it was at par with the rotary tillage (T2). Among weed management practices weed free (W2) recorded significantly higher growth, yield contributing characters and seed cotton yield and it was at par with Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Pyrithiobac-sodium (10% EC) @ 62.5 gha-1 (PoE) + Straw mulching 2.5t/ha (W4).

Keywords: Seed cotton yield, bolls per plant, lint yield, growth, leaf area

Introduction
Cotton (*Gossypium hirsutum* L.) is a valuable cash crop and one of the oldest among the world's commercial crops, it is also a backbone of the textile industry, owing to its lint. Cotton is valued for its oil as well as its fibre, and cotton seed cake is an important livestock feed. Cotton seeds contain 15 to 20% oil, which can be used in the soap industry after refining.

India continues to have the largest cotton-growing area and is the world's second-largest cotton producer, after China, with 34% of global area and 21% of global production. World cotton area is estimated at 34.7 million ha with production of 125.8 million bales with an average productivity of 789.0 kg ha-1 (Anonymous, 2019a) [1]. Cotton is grown on 129.57 lakh ha in India, with 371 lakh bales produced and a productivity of 487 kg lint ha-1 (Anonymous, 2020b) [2] Maharashtra ranks first in both area and production in the country, covering 41.84 lakh ha and production 86.0 lakh bales with a productivity of 349 kg lint ha-1 (Anonymous, 2020c) [3].

Tillage is the process of mechanically manipulating soil to provide favourable conditions for crop development and, in most cases, crop nurturing. In the field, it is the most difficult and time-consuming process. Ploughing is the initial step in the seedbed preparation process. It makes a significant contribution to achieving good tilth and even moisture conservation. Tillage is the process of opening up the soil in order to lower soil strength and cover crop wastes. Deep ploughing, subsoiling, minimum tillage, zero tillage or no tillage, mulch tillage, and puddling are all examples of tillage. Deep ploughing varies depending on the type of plough and the amount of power available. Animal ploughing is commonly associated with shallow ploughing. Although tractor power allows for deeper ploughing, average ploughing depths are up to 20 cm. On many soils, deeper ploughing has been advocated to extend the depth of the root bed, both to increase root elongation and proliferation and to increase the average soil moisture. Deep ploughing is based on the nature of crop, climate, type of soil and the operation's economics.

The weeds (annual and perennial) in cotton can be effectively controlled by combining cultural method and pre or post emergence herbicides. Because of the economics of crop production

and regulatory mandates about environmental issues, conservation management production (e.g. zero tillage, minimum tillage) systems have become more popular in recent years. Herbicide treatment has been the basis for weed management in many developed countries for the last sixty years, both in conventional and conservation systems. Conservation practises often enhance and utilise soil and crop micro-environments to prevent weed germination, growth, and spread while reducing the need of synthetic herbicides. Conservation management systems, as described above, integrate those practices that conserve or improve natural resources like soil and water. Minimum tillage, cover crops, crop rotation, variable row spacing, and crop planting timing are some examples of conservation management strategies that can be used in weed management programmes.

Weed control is essential for successful cotton production. Because cotton grows more slowly early in the season and is less competitive with weeds, effective weed management has been more difficult in cotton than in other row crops such as maize and soybean. Early in the growth season, there is usually the most competition. The effects of weed competition at the square formation and flower development stages were found to be more harmful than the effects of weed competition at later stages (Farrell *et al.*, 2001) [5].

To see how different tillage practises, such as conventional tillage, rotary tillage, minimum tillage, and zero tillage, affect the performance of Bt cotton, as well as various weed management practises. Considering all of the above, as well as the decrease in production costs, such as the efficient use of expensive inputs. In this context, present study was carried out to study "Response of Bt cotton (*Gossypium hirsutum* L.) to tillage and weed management practices in vertisol", was taken up with the following objectives.

1. To study the effect of tillage and weed management practices on growth parameters of cotton.
2. To study the effect of tillage and weed management practices on yield and yield contributing characters of cotton.

Material and Methods

During the Kharif seasons of 2019-20 and 2020-21 a field experiment was conducted at experimental farm, AICRP on Integrated Farming Systems, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S., India). The site of experiment was clayey in texture with slightly alkaline pH of 8. The available nitrogen was in the range of low (222.40 kg ha-1), P2O5 medium (17.54 kg ha-1) and K2O was high (545.52 kg ha-1).

The experiment was laid out in split plot design with three replications. The gross and net plot size were 35.1 m2 and 17.82 m2, respectively. Treatment consists of sixteen treatment combinations comprising four tillage practices (T1- Conventional tillage, T2- Rotary tillage, T3- Minimum tillage, T4- Zero tillage) in main plot, and four weed management practices (W1 - Weed check,W2 - Weed free, W3 – Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Quizalofop ethyl (5% EC)@ 50 g ha1(PoE) + Hoeing. and W4- Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE+Pyrithiobac-sodium (10% EC) @ 62.5 g ha-1 (PoE) + Straw mulching 2.5t/ha.).

Recommended dose of fertilizers 120:60:60 NPK kg ha-1 was applied during both the years of study. The Bt cotton was sown by dibbling method at 120 cm x 45 cm spacing on 03-07-2019 and 02-07-2020 after receipt of sufficient monsoon rains. During the experimentation of first and second year total quantity rainfall received 936.7 and 857.0 mm respectively. The mean daily maximum temperature ranged from 30.8 ^{0}C to over 45 ^{0}C, while the mean daily minimum temperature ranged from 11.9 ^{0}C to 24.9 ^{0}C, respectively. The soil was medium deep black and well drained. The topography of the experimental field was fairly uniform and levelled. The 40 per cent of nitrogen and full dose of phosphorus and potash were applied as basal application at the time of sowing. At various growth stages, observations on plant growth and yield contributing characters were recorded.

Results and Discussion

The mean plant height (cm), number of functional leaves plant-1, leaf area (dm2), total dry matter (g) plant-1, number of monopodial and sympodial branches plant-1 of Bt cotton was influenced significantly due to different tillage and weed management practices are tabulated in Table 1,2,3. Significant increase in numbers of picked bolls per plant, seed cotton yield (kg ha-1) and lint yield (kg ha-1) was observed due to tillage and weed management practices (Table 4).

Table 1: Mean plant height (cm) and no of functional leaves plant-1 of *Bt* cotton hybrid as influenced by different treatments.

Treatments	Mean plant height (cm) 2019-20			Mean plant height (cm) 2020-21			No of functional leaves plant-1 2019-20			No of functional leaves plant-1 2020-21		
	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At Harvest
A) Main plot - Tillage practices												
T1 - Conventional tillage	58.15	85.80	115.63	60.10	88.16	117.34	35.66	77.09	50.94	39.64	80.73	53.15
T2 - Rotary tillage	55.79	82.15	110.34	57.15	84.20	112.42	34.53	74.74	47.56	37.51	77.83	50.41
T3 - Minimum tillage	50.03	76.03	99.78	52.89	78.20	102.36	32.13	69.41	42.22	33.51	71.62	45.04
T4 - Zero tillage	48.00	73.18	96.44	49.99	74.29	97.15	30.59	67.10	39.53	31.73	68.33	42.18
SE+	1.12	1.58	1.90	1.10	1.50	1.78	0.65	1.46	1.31	1.14	1.73	1.09
CD at 5%	3.89	5.48	6.58	3.80	5.19	6.14	2.24	5.04	4.54	3.94	5.98	3.78
B) Sub plot - Weed management												
W1 - Weedy check	43.76	69.33	86.60	46.60	72.27	88.42	28.07	63.53	35.71	29.26	65.70	37.54
W2 - Weed free	58.66	86.04	116.43	60.51	87.22	118.57	36.51	77.27	50.99	39.45	80.39	54.06
W3 - Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Quizalofop ethyl (5% EC) @ 50 g ha-1 (PoE) + Hoeing.	53.08	78.85	106.73	54.90	80.81	107.97	33.09	71.87	44.98	35.28	74.15	47.53
W4 - Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Pyrithiobac-sodium (10% EC)	56.47	82.94	112.43	58.12	84.56	114.31	35.25	75.67	48.58	38.40	78.27	51.64

@ 62.5 g ha-1 (PoE) + Straw mulching (2.5 t/ha).												
SE+	0.86	1.27	1.64	0.90	1.18	1.61	0.53	1.09	0.91	0.82	1.23	0.98
CD at 5%	2.50	3.70	4.80	2.62	3.45	4.70	1.53	3.18	2.65	2.40	3.60	2.86
Interaction (AxB)												
SE+	1.71	2.53	3.29	1.80	2.36	3.22	1.05	2.18	1.81	1.65	2.47	1.96
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
GM	52.99	79.29	105.56	51.65	81.21	107.32	33.23	72.08	45.06	35.60	74.63	47.69

Table 2: Mean leaf area (dm2) and mean total dry matter (g) plant-1 of Bt cotton hybrid as influenced by different treatments.

Treatments	Mean leaf area (dm2) 2019-20			Mean leaf area (dm2) 2020-21			Mean total dry matter (g) plant-1 2019-20			Mean total dry matter (g) plant-1 2020-21		
	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At Harvest
A) Main plot - Tillage practices												
T1 - Conventional tillage	36.55	59.79	39.13	38.39	62.53	40.60	38.18	76.33	127.78	42.19	79.63	126.61
T2 - Rotary tillage	34.28	57.28	37.52	36.06	60.05	38.72	36.25	74.07	123.04	39.61	76.43	122.86
T3 - Minimum tillage	31.31	51.56	34.12	32.07	55.99	35.18	32.11	69.53	113.95	34.44	70.37	113.02
T4 - Zero tillage	29.47	48.65	32.37	30.80	54.03	33.10	29.97	66.70	108.86	32.09	67.55	108.20
SE+	0.82	1.59	0.66	1.08	1.13	0.83	0.79	1.10	2.06	0.95	1.18	2.45
CD at 5%	2.85	5.50	2.29	3.72	3.91	2.87	2.74	3.79	7.13	3.30	4.08	8.48
B) Sub plot - Weed management												
W1 - Weedy check	25.27	44.09	29.86	27.05	46.83	31.81	28.93	59.37	103.19	26.95	56.57	101.26
W2 - Weed free	37.49	61.14	40.06	39.20	64.79	40.77	38.27	79.26	128.10	42.96	82.72	129.30
W3 - Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Quizalofop ethyl (5% EC) @ 50 g ha-1 (PoE) + Hoeing.	33.34	53.75	34.94	34.04	58.92	35.99	32.85	71.81	117.60	37.18	74.75	115.83
W4 - Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Pyrithiobac-sodium (10% EC) @ 62.5 g ha-1 (PoE) + Straw mulching (2.5 t/ha).	35.52	58.28	38.27	37.01	62.06	39.03	36.46	76.18	124.74	41.23	79.93	124.31
SE+	0.70	1.44	0.84	0.92	0.99	0.72	0.73	1.15	1.87	0.73	1.01	2.58
CD at 5%	2.05	4.20	2.45	2.68	2.89	2.11	2.13	3.35	5.47	2.13	2.96	7.52
Interaction (AxB)												
SE+	1.41	2.88	1.68	1.83	1.98	1.45	1.46	2.30	3.75	1.46	2.03	5.15
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
GM	33.90	54.32	35.78	34.33	58.15	36.90	34.12	71.66	118.41	37.08	73.49	117.67

Table 3: Mean number of monopodial and sympodial branches plant-1 of *Bt* cotton hybrid as influenced by different treatments.

Treatments	Monopodial branches plant-1 2019-20		Monopodial branches plant-1 2020-21		Sympodial branches -1			Sympodial branches -1		
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At Harvest
A) Main plot - Tillage practices										
T1 - Conventional tillage	1.25	1.77	1.29	1.81	7.08	11.30	13.20	7.29	11.46	13.51
T2 - Rotary tillage	1.22	1.73	1.27	1.78	6.97	11.07	12.93	7.21	11.28	13.35
T3 - Minimum tillage	1.05	1.58	1.09	1.60	6.47	9.67	11.01	6.55	10.25	12.03
T4 - Zero tillage	1.02	1.53	1.06	1.56	6.33	9.44	10.84	6.43	10.11	11.88
SE+	0.05	0.04	0.03	0.03	0.10	0.20	0.30	0.18	0.28	0.32
CD at 5%	0.16	0.12	0.10	0.09	0.34	0.68	1.05	0.61	0.95	1.11
B) Sub plot - Weed management										
W1 - Weedy check	0.95	1.47	0.99	1.49	5.78	8.20	9.26	6.06	8.71	10.56
W2 - Weed free	1.27	1.79	1.31	1.83	7.23	11.35	13.33	7.39	11.75	13.76
W3 - Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Quizalofop ethyl (5% EC) @ 50 g ha-1 (PoE) + Hoeing.	1.09	1.62	1.12	1.65	6.67	10.68	12.24	6.77	11.01	12.83
W4 - Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Pyrithiobac- sodium (10% EC) @ 62.5 g ha-1 (PoE) + Straw mulching (2.5 t/ha).	1.23	1.73	1.29	1.79	7.17	11.24	13.14	7.25	11.62	13.62
SE+	0.04	0.03	0.05	0.04	0.15	0.16	0.26	0.14	0.19	0.24
CD at 5%	0.12	0.09	0.14	0.11	0.45	0.47	0.76	0.42	0.57	0.72
Interaction (AxB)										
SE+	0.08	0.06	0.10	0.07	0.31	0.32	0.52	0.29	0.39	0.49
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
GM	1.13	1.65	1.18	1.69	6.71	10.37	11.99	6.87	10.77	12.69

Table 4: Number of picked bolls plant-1, Seed cotton yield (kg ha-1) and lint yield (kg ha-1) of *Bt* cotton hybrid as influenced by different treatments

Treatments	Number of picked bolls plant-1			Seed cotton yield (kg ha-1)			Lint yield (kg ha-1)		
	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean
A) Main plot - Tillage practices									
T1 - Conventional tillage	36.90	37.71	37.31	2092	2177	2134	725	752	739
T2 - Rotary tillage	35.25	36.32	35.79	1982	2073	2027	688	720	704
T3 - Minimum tillage	29.47	30.77	30.12	1649	1739	1694	559	592	575
T4 - Zero tillage	27.86	29.17	28.52	1541	1624	1583	514	543	528
SE+	0.97	0.64	0.85	45.76	52.72	29.99	24.05	18.18	14.57
CD at 5%	3.36	2.20	2.95	158.34	182.45	103.79	83.24	62.93	50.42
B) Sub plot - Weed management									
W1 - Weedy check	21.28	21.35	21.31	1126	1145	1135	369	376	372
W2 - Weed free	37.60	38.96	38.28	2150	2261	2205	748	785	767
W3 - Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Quizalofop ethyl (5% EC) @ 50 g ha-1 (PoE) + Hoeing.	34.23	35.77	35.00	1922	2028	1975	656	694	675
W4 - Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Pyrithiobac-sodium (10% EC) @ 62.5 g ha-1 (PoE) + Straw mulching (2.5 t/ha).	36.38	37.90	37.14	2067	2179	2123	712	753	732
SE+	0.68	0.53	0.47	41.91	33.37	31.16	19.56	17.08	15.55
CD at 5%	1.98	1.54	1.36	122.32	97.41	90.94	57.09	49.84	45.39
Interaction (AxB)									
SE+	1.35	1.05	0.93	83.81	66.74	62.31	39.12	34.15	31.10
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
GM	32.37	33.50	32.93	1816	1903	1860	621	652	637

Tillage practices

The growth characters *viz*. plant height (cm), number of functional leaves plant-1, leaf area (dm2), total dry matter (g) plant-1, number of monopodial and sympodial branches plant-1 were substantially influenced by tillage practices. Significantly taller plant was recorded with conventional tillage (T1) which was at par with the rotary tillage (T2) practices. Lowest growth characters of Bt cotton was noticed with the zero tillage (T4). The conventional tillage (T1) recorded maximum increased number of functional leaves plant-1, leaf area (dm2), total dry matter (g) plant-1, number of monopodial and sympodial branches plant-1 as compared to other tillage practices during both the years. These results are similar to those of Wesley *et al*., (2001) [20], Mandol (2006) [8], Manjith and Angadi (2016) [8] and Rajkumari *et al*., (2017) [14].

The conventional tillage (T1) recorded maximum numbers of picked bolls per plant which was at par with the rotary tillage (T2) during both the years of experimentation. The similar findings were observed by Wiatrak *et al*. (2005) [21] and Mandol (2006) [8].

Scrutiny of data presented in Table 4 stipulated that the seed cotton yield and lint yield ha-1 (kg ha-1) of Bt cotton was influenced significantly due to different tillage practices during both the years and in pooled analysis. The conventional tillage (T1) was found to be significantly superior over other tillage practices in recording significantly more seed cotton yield 2092 kg ha-1, 2177 kg ha-1 and 2134 kg ha-1 and lint yield ha-1 725 kg ha-1, 752 kg ha-1 and 739 kg ha-1 and however it was found at par with the rotary tillage (T2) during both the years and followed by in pooled analysis, respectively. The lowest seed cotton yield and lint yield ha-1 (kg ha-1) was recorded with zero tillage T4 during both the years and in pooled analysis. This might be due to more favoured overall growth due to favourable seed bed resulting from deceased bulk density, increased pore space, better aeration, increased infiltration rate, with scope for more space, light interception, benefit of more conserved moisture during dry spell period and its support at critical growth stages like flowering, numbers of bolls plant-1 and development. This ultimately resulted in higher values of yield attributing characters and which in turn resulted in higher yields of Bt cotton. This results correlate with the work of Gul *et al*. (2003) [6] and Manjith and Angadi (2016) [9].

Weed management

The growth characters *viz*. plant height (cm), number of functional leaves plant-1, leaf area (dm2), total dry matter (g) plant-1, number of monopodial and sympodial branches plant-1 were substantially influenced by weed management practices. Significantly taller plant was recorded with weed free (W2) which was at par with the Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Pyrithiobac-sodium (10% EC) @ 62.5 g ha-1 (PoE) + Straw mulching (2.5 t/ha) (W4). Lowest growth characters of Bt cotton was noticed with the weedy check (W1). The weed free (W2) recorded maximum number of functional leaves plant-1, leaf area (dm2), total dry matter (g) plant-1, number of monopodial and sympodial branches plant-1 as compared to other weed management practices during both the years. These results are conformation with the results of Sandangi and Barik (2007) [15], Hiremath *et al*., (2013) [12], Nadeem *et al*.(2013) [10], Veeraputhiran and Srinivasan (2015), Rajendra *et al*., (2016), Shivashankar *et al*., (2017) [19], Chauhan *et al*. (2018) [4] and Parshotamkumar (2018).

The weed free (W2) treatment recorded maximum numbers of picked bolls and at par with the Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Pyrithiobac-sodium (10% EC) @ 62.5 g ha-1 (PoE) + Straw mulching (2.5 t/ha) (W4). Lowest yield attributes of Bt cotton was noticed with the weedy check (W1) during both the years of experimentation. Similar results were also reported by Hargilas *et al*. (2015) [7],

Glimpse of data presented in Table 4 showed that, the mean

seed cotton yield and lint yield ha-1 (kg ha-1) was influenced significantly due to different weed management practices during both the years and in pooled data. The weed free (W2) treatment was found to be significantly superior over other weed management practices produced higher seed cotton yield of 2150 kg ha-1, 2261 kg ha-1 and 2205 kg ha-1 and lint yield ha-1 748 kg ha-1,785 kg ha-1 and 767 kg ha-1 and however it was found at par with Pendimethalin (30% EC) @ 0.75 kg ha-1 as PE + Pyrithiobac- sodium (10% EC) @ 62.5 g ha-1 (PoE) + Straw mulching 2.5t/ha (W4) during both the years and in pooled analysis, respectively. The weedy check (W1) recorded the lowest seed cotton yield and lint yield ha-1 (kg ha-1) during 2019-20, 2020-21 and in pooled analysis. The weed free (W2) treatment recorded significantly higher, number of bolls plant-1, weight of boll, weight seed cotton yield plant-1 indicating least competition offered by weeds for nutrients and moisture at crucial growth stages under this treatment ultimately improved all yield attributes besides increased rate of N, P and K absorption cumulatively helped the crop plants to produce more surface area for high photosynthetic rate as well as maximum translocation of photosynthesis from source to sink, subsequently resulted in improvement of all yield attributes. Because of synergist effect among the yield attributes they benefited each other. These findings are in accordance with those of Rajanand *et al*. (2013) [12], Hargilas *et al*. (2015) [7] and Singh and Rathore (2015) [18].

Interaction effect

The interaction effects between tillage and weed management did not reached to the level of significance during 2019-20, 2020-21 and pooled data.

Conclusion

It can be concluded that-

Among tillage practices conventional tillage (T1) recorded significantly higher growth, yield contributing characters and seed cotton yield than other treatments, but it was at par with the rotary tillage (T2).

Among weed management practices weed free (W2) recorded significantly higher growth, yield contributing characters and seed cotton yield and it was at par with 62.5 g ha-1 (PoE) + Straw mulching 2.5t/ha (W4).

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