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Growth and yield attributes under different cotton (*Gossypium hirsutum*) management systems

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Abstract
A field investigation was conducted to compare cotton (*Gossypium hirsutum*) growth and yield attributes under organic, bio-dynamic, Bt-conventional, and non-Bt conventional management systems during the kharif season of 2020–21 at the bio Re-FiBL research trails farm, run by the bioRe Association in Kasrawad, Khurgone, Madhya Pradesh. Five distinct crop management techniques were used in the field experiment, each replicated four times, and the study was set up using a randomized block design. The treatments were distributed at random to different plots. The five approaches are: organic cotton management, biodynamic cotton management, conventional non-Bt cotton management, conventional Bt cotton management, and absolute control (without fertilizers). Regarding the emergence (%) and final plant population, it was determined that none of the treatments were statistically significant. The treatment with conventional Bt had the highest plant height and plant dry matter per hectare whereas the control had the lowest. The Conventional Bt treatment had the greatest observed open and closed boll count at the time of first and second picking, whereas the Control treatment had the lowest. Additionally, it was discovered that treatments with conventional Bt and control had the highest and lowest seed cotton yields per plant and per hectare, respectively. From the experiment, it can be inferred that the Conventional management of Bt cotton had considerably higher maximum growth and yield characteristics than the others.

Keywords: Bio-dynamic, Bt, conventional, cotton, growth, organic, yield

Introduction
Cotton is a substantial cash crop on a global scale that provides millions of farmers with their main source of income and is crucial to the textile industry. However, the conventional farming methods used for cotton production have given rise to concerns about long-term productivity, environmental sustainability, and human health (Tadesse *et al*., 2020) [12]. Alternative management strategies, like organic, biodynamic, and genetically modified (GM) Bt (*Bacillus thuringiensis*) cotton, have gained popularity recently in response to these worries. Making assessments on sustainable cotton farming practices requires having a thorough understanding of the development and yield characteristics of cotton under various management systems.

Chemical pesticides, fertilizers, and herbicides are a few examples of the synthetic inputs that cotton cultivation has historically relied largely on. These inputs have a deleterious influence on biodiversity, soil degradation, and water contamination (Grassini *et al*., 2015) [2]. Alternative management approaches have come to light as viable remedies to the problems caused by conventional cotton cultivation in terms of the environment and human health.

Organic cotton management systems prioritize the use of natural and organic inputs while avoiding synthetic chemicals. These systems have a strong emphasis on biodiversity, soil health, and minimal environmental effect. Organic cotton cultivation has the ability to increase soil fertility, encourage beneficial insect populations, and lessen the dangers brought on by pesticide residues by concentrating on regenerative techniques (Kaur *et al*., 2018) [6]. Biodynamic farming takes the principles of organic agriculture a step further by incorporating holistic practices and a spiritual understanding of the ecosystem (Dogan and Erdal, 2016) [1]. Genetically modified Bt cotton has been developed to address pest pressures by incorporating a gene from the soil bacterium *Bacillus thuringiensis* (Bt) that produces a toxin harmful to specific pests. Due to this genetic change, Bt cotton may fend off some pests without using a lot of pesticides. Bt cotton has gained popularity in areas with serious pest problems because it may help with pest control and minimize the need for chemical pesticides (Huang *et al*., 2018) [5].

To assess the effectiveness and sustainability of these various cotton management systems, it is crucial to evaluate the growth and yield attributes of cotton under different conditions. Growth and yield attributes serve as key indicators of crop performance, productivity, and quality. Factors such as plant height, plant dry matter, boll development and lint yield provide valuable insights into the impact of different management systems on cotton growth and productivity. (Marques *et al*., 2020) [7].

In this experiment we compared the growth and yield parameters of all the five treatments i.e., organic, biodynamic, conventional Bt, conventional non-Bt farming systems of cotton and the control.

Materials and Methods

The current study was conducted at the bioRe-FiBL research trails farm, bioRe Association, Kasrawad, Khurgone, Madhya Pradesh State, India in the Nimar Valley at 22.83°N 75.45°E and at approximately 200-300 m above mean sea level, during the kharif season of 2020-21. The semi-arid environment receives 800 mm of precipitation on average year, with the peak monsoon season often lasting from mid-June to September. Highest and lowest temperatures are between 15 and 49 °C and occur in May and June, respectively. throughout the south-west monsoon, relative humidity reaches its highest point (70-90%) and its lowest point (20-30%) throughout the summer. The current test site was part of the FiBL Sys-Com project, which started a long-term experiment (LTE) in 2007 to examine various farming techniques over the course of 10 to 20 years. In a two-year crop rotation, cotton, soybean, and wheat output were compared. Five distinct crop management techniques were used in the field experiment, each duplicated four times, and the experiment was set up using a randomized block design. The treatments were distributed at random to different plots. The treatments included organic, biodynamic, conventional with genetically engineered Bt cotton, and control (Table 1). These representations illustrate local farming systems and the predominant issues facing farmers, agricultural groups, and politicians.

The current test site is located in a fertile vertisol area. The soil has a low level of available nitrogen (159.3 kg ha^{-1}), a medium level of phosphorus (15.5 kg ha^{-1}) and organic carbon (0.71%), a high level of potassium (672.4 kg ha^{-1}) that is readily available, and a somewhat alkaline reaction (7.75). Cotton cultivars 'Narmada shakti silver' (non-Bt) and 'Rasi-659' (Bt) were employed in the trial, and they were seeded at a seed rate of 0.128 kg $plot^{-1}$ (5 kg ha^{-1}) with a spacing of 106 × 53 cm. For the duration of the experiment, four 1 m × 1 m (1 m^2) quadrants were randomly placed on each experimental plot's four sides, and different biometric observations were recorded from each quadrant according to its treatment.

Results and Discussion

The findings and the discussion related to the present investigation as influenced by different treatments was as follows.

Plant stand

According to the emergence (%), it was determined that none of the treatments—T_1 Organic, T_2 Biodynamic, T_3 Conventional non-Bt, T_4 Conventional Bt, and T_5 Control—were statistically significant. Regarding the final plant population, it was discovered that none of the treatments T_1 Organic, T_2 Biodynamic, T_3 Conventional non-Bt, T_4 Conventional Bt, and T_5 Control were statistically different from each other. This may be because all of the seed treatments conducted before to sowing stopped biological elements from attacking the seed. The materials utilized in the organic and conventional treatments, however, are different. In order to treat seeds, it was necessary to utilize Imidachloropid 70% SL (Gaucho) @ 3ml/kg seeds for conventional seeds and Beejamrit + Hing, Trichoderma viridae, Blue Vitriol (Nila Thota or copper sulphate) for organic seeds.

Crop growth studies

The treatment T_4-Conventional Bt had the tallest plants at all of the intervals, which included 30 DAS, 60 DAS, 90 DAS, 120 DAS, and at harvest. The treatment T_5-Control had the lowest plant height. The findings indicate that the conventional treatments produced the tallest plants, whereas organic and biodynamic treatments produced the shortest ones. The development of the cotton crop's plants is significantly influenced by weed competition. The height of the plant will decrease as weed competition increases. (Sandhu and Bhatia, 1992) [10].

The treatments with conventional Bt and conventional non-Bt, respectively, had the maximum plant dry matter per hectare with no discernible difference. With no significant difference, Control, Organic, and Biodynamic had the lowest plant dry matter. The organic and biodynamic treatments were found to have less biomass, which may be related to the greater weed populations and biomass. Due to weeds not being controlled, the weed-free check (control) had the least amount of plant dry matter. (Snipes *et al.*, 1982; Mohammed and Bhanumurthy, 1985) [11, 8].

Yield contributing characters

The treatment T_4-Conventional Bt has the highest open boll count at the time of first picking, whereas the treatment T_5-Control has the lowest open boll count. The treatment T_4-Conventional Bt likewise has the highest closed boll count, while the treatment T_5-Control has the lowest closed boll count. The treatment T_4-Conventional Bt shows the highest open boll count at the time of second picking, whereas the treatment T_5-Control shows the lowest open boll count. The treatment T_4-Conventional Bt likewise has the highest closed boll count, while the treatment T_5-Control has the lowest closed boll count.

The T_4-Conventional Bt treatment showed the greatest Seed Cotton yield per plant. The treatments T_5-Control and T_3-Conventional non-, respectively, showed the lowest Seed Cotton yield per plant with no significant difference. The treatment T_4-Conventional Bt had the highest seed cotton yield per acre. The treatments T_5-Control and T_3-Conventional non-Bt, respectively, had the lowest Seed Cotton yield per hectare, with no discernible difference.

The aforementioned findings demonstrate that the Conventional Bt treatment greatly increased the Seed Cotton yield and Total Boll Count. The Bt-Cotton cultivar's widespread use and superiority may be responsible for this (Hebbar, 2007; Hlophe and Mavuso, 2018) [3, 4]. In India, cotton has a very high incidence of boll worms, which results in a high rate of boll loss and boll damage. Compared to regular cultivars, the Bt cultivars had a much lower level of

aforementioned damages. The treatment Conventional non-Bt compared to organic showed the lowest weight of seed cotton per hectare outside of the control. This can be as a result of the cultivar's poor reaction to the implemented management strategy.

Table 1: Plant stand and Crop growth attributes as influenced by different treatments

Treatment Details	Emergence (%)	Per Hectare population	Plant height (cm)					Final plant dry matter (kg/ha)
			30 DAS	60 DAS	90 DAS	120 DAS	At harvest	
Organic farming cotton	92.68	16475	34.78	80.55	100.44	137.5	138.54	2482.5
Bio-dynamic farming cotton	93.26	16579	34.65	81.31	99.91	140.43	141.45	2610.1
Conventional farming non-Bt cotton	94.82	16857	35.11	91.81	131.16	153.51	155.21	4114.3
Conventional farming Bt cotton	95.41	16961	35.53	93.5	132.22	156.45	157.76	4551.3
Absolute Control (without fertilizers)	90.33	16058	34.16	78.8	98.92	134.64	136.41	2057.1
SE(m)±	1.31	233.17	0.13	2.23	1.99	1.93	1.99	238.79
CD at 5%	NS	NS	0.40	6.88	6.14	5.94	6.14	735.67
GM	93.30	16586	34.85	85.14	112.53	144.50	145.87	3163

Table 2: Yield contributing characters as influenced by different treatments

Treatment Details	First Picking		Second Picking		Seed Cotton Yield	
	Open Boll	Closed Boll	Open Boll	Closed Boll	Per plant (g/plant)	Per hactare (kg/ha)
Organic farming cotton	9.08	11.84	12.35	7.10	110.8	1824.5
Bio-dynamic farming cotton	9.13	11.43	12.73	6.89	110.46	1764.2
Conventional farming non-Bt cotton	8.95	14.34	11.09	6.59	76.93	1217.6
Conventional farming Bt cotton	14.8	19.06	22.82	8.29	174.14	2841.8
Absolute Control (without fertilizers)	7.51	9.69	9.95	5.58	62.44	997.3
SE(m)±	0.50	1.29	1.17	0.44	10.25	131.90
CD at 5%	1.54	3.99	3.60	1.35	31.59	406.35
GM	9.8927	13.27	13.79	6.89	106.96	1729.1

Conclusion

According to the above data, conventional management of Bt cotton showed significantly higher maximum growth and yield characteristics than organic, biodynamic, conventional management of non-Bt cotton and control. Among all the interventions, conventional management of Bt cotton was determined to be the most effective. However, it was shown that organic cotton had higher growth and yield characteristics than conventionally managed non-Bt cotton.

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