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Dynamics of phenological stages of BT cotton based cropping system under different nutrient levels

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Abstract
The study was conducted at the Department of Agronomy, Dr. PDKV, Akola, during 2020-21 and 2021-22 to evaluate different Bt cotton-based cropping systems under varying fertilizer levels applied to rabi crops. The experiment was carried out on the same site with the same randomization across both years. Findings indicated that the cropping systems had significant effects on plant height (cm), number of functional leaves, and leaf area of cotton, except at 30 DAS, in both years. With respect to nutrient management, the effects were non-significant in the first year but became significant in the second year for plant height, number of functional leaves, and leaf area, again with the exception of 30 DAS.

Keywords: Cotton, morphological study, Bt cotton, nutrient levels, cropping system

Introduction

According to United Nations estimates, India became the most populous country in the world in 2023, with a population of 1.42 billion. Projections suggest that the population will rise to 1.5 billion by 2030 and 1.67 billion by 2050 (United Nations, 2019). Consequently, the country will require about 311 million tonnes of food grains by 2030 and 350 million tonnes by 2050 to meet the growing demand.

Cotton (*Gossypium hirsutum* L.) is one of the most important fibre and cash crops, with a significant role in human history and civilization. Globally recognized as the most widely grown and profitable non-food crop, cotton is referred to as the "King of Fibre Crops" for its industrial and commercial value, and as "White Gold" by the farming community. It is a multipurpose crop providing five major products: lint, oil, seed meal, hulls, and linters. With vast potential in the textile industry, cotton serves as a livelihood source for millions of farmers and those engaged in trade, processing, manufacturing, and allied sectors. In India, the textile industry accounts for about 5% of the GDP, 14% of industrial production, and 11% of total export earnings. It is also the country's second-largest employer after agriculture, directly employing over 51 million people and indirectly providing jobs to another 68 million, including a large proportion of unskilled women.

However, cotton cultivation faces several challenges, particularly from insect pests such as sucking pests and bollworms. Among them, the pink bollworm is a major concern, causing significant yield and quality losses. Other emerging threats include erratic monsoon patterns, high labour costs, thrips, boll rot, and bollworm infestation (Prasad, 2016). Crop rotation is a key agronomic practice that helps mitigate these problems by disrupting pest and disease cycles. It influences insect populations by modifying the microclimate and by promoting the activity of natural enemies within the cropping system.

Methodology

A field experiment was carried out at the Agronomy Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Field No. 98-99) during the *kharif* and *rabi* seasons of 2020-21 and 2021-22. The site was uniformly levelled with medium black cotton soils classified as Vertisols. The study was conducted in a Split Plot Design (SPD) with ten treatments and three replications. The main treatments consisted of five crop sequences: sole Bt cotton, mid-late duration (C1); Bt cotton (early duration)-wheat (C2); Bt cotton (early duration)-chickpea (C3); Bt cotton (early duration)-linseed (C4); and Bt cotton (early duration)-onion

(C5). These were compared under two nutrient management levels, i.e., 75% RDF and 100% RDF applied to the *rabi* crops.

Plant height was measured from the basal node to the base of the uppermost unfolded leaf on five randomly selected plants per net plot, and the mean was expressed in centimetres. The number of functional leaves per plant was also recorded at different crop growth stages, with averages computed by dividing the total by five. Functional leaves sampled for dry matter studies were categorized as small, medium, or large. Leaf area of one representative leaf from each category was estimated using the formula proposed by Ashley *et al*. (1963). The total leaf area per plant was calculated by multiplying the number of leaves in each category with their respective leaf areas, and then summing the values.

Leaf area = (L x W x 0.771) x n

Where,
L-Maximum length of leaf
W-The maximum breadth of the leaf was measured at one-third of its length from the base.0.771-leaf area constant
n-Number of leaves per plant

Result and Discussion

The data on mean plant height (cm) of cotton at different growth stages as influenced by various treatments are presented in Table 1. The observations on the number of functional leaves per plant at 30, 60, 90, and 120 DAS during both years of experimentation are given in Table 2. The results pertaining to mean leaf area per plant (dm^2) of cotton, recorded at periodic intervals under different treatments, are presented in Table 3.

Cropping System

The data in Table 1 indicate that the effect of different treatments on plant height of cotton was significant at all growth stages, except at 30 DAS, during both 2020-21 and 2021-22. The treatment C1 (sole Bt cotton, mid-late duration) recorded significantly higher plant height compared to all other treatments in both years of experimentation. However, the various cotton-based cropping systems did not differ significantly from each other with respect to plant height at any growth stage. The greater height observed in sole Bt cotton (mid-late) can be attributed to varietal characteristics, while the lack of significant differences among cropping systems was due to the use of the same cotton variety across treatments. Similar findings were reported by Kumbhar *et al*. (2008) [2].

The data in Table 2 reveal that the number of functional leaves per plant was significantly influenced by treatments at all crop growth stages, except at 30 DAS, during both years of study. Sole Bt cotton (mid-late) (C1) produced significantly more functional leaves than all other treatments in both years. However, the cropping system treatments were statistically at par with each other at all growth stages. The increase in the number of functional leaves in sole Bt cotton (mid-late) was associated with greater plant height, which contributed to the development of more monopodial and sympodial branches and enhanced photosynthetic activity. The absence of significant differences among the cropping systems can be explained by the uniform use of a single cotton variety across treatments.

The data in Table 3 show that leaf area per plant varied significantly among treatments at different crop growth stages during both years of study, except at 30 DAS in 2020-21. Sole Bt cotton (mid-late) (C1) consistently recorded a significantly larger leaf area compared to all other treatments across both years. In contrast, the cotton-based cropping system treatments remained statistically at par with one another in terms of leaf area at all growth stages. A similar trend was observed in both 2020-21 and 2021-22.

Nutrient management

The data in Table 1 show that nutrient management applied to *rabi* crops had no significant effect on the plant height of cotton at any growth stage during 2020-21. However, in 2021-22, significant differences were observed due to nutrient levels applied to *rabi* crops. The residual effect of 100% RDF resulted in significantly greater plant height compared to 75% RDF. This increase may be attributed to the higher addition of organic matter from *rabi* crops under higher nutrient levels, which enhanced nutrient availability for the succeeding cotton crop, thereby improving growth. These findings are consistent with the results of Kumbhar *et al*. (2008) [2], Turkhede *et al*. (2017) [5], and Sanjiv Kumar *et al*. (2022) [4].

The results in Table 2 indicate that nutrient management in *rabi* crops did not significantly affect the number of functional leaves per plant during 2020-21. In contrast, during 2021-22, significant differences were observed, with 100% RDF applied to *rabi* crops producing the highest number of functional leaves compared to 75% RDF. This improvement can be explained by the greater biomass of *rabi* crops under 100% RDF, which added more organic matter to the soil. Upon mineralization, this organic matter increased nutrient availability to cotton, while the residual N and P from the preceding *rabi* crops further contributed to growth enhancement. Similar results have been reported by Turkhede *et al*. (2017) [5], Chaudhari *et al*. (2022) [1], and Sanjiv Kumar *et al*. (2022) [4].

The data in Table 3 reveal that nutrient management in *rabi* crops had no significant effect on cotton leaf area during 2020-21. However, in 2021-22, significant differences were recorded at 60, 90, and 120 DAS. Application of 100% RDF to *rabi* crops consistently resulted in the highest leaf area per plant compared to 75% RDF. This response may be attributed to greater organic matter addition under higher nutrient levels, which improved plant height, branch number, and overall growth, ultimately leading to increased leaf area. These findings are in agreement with those of Turkhede *et al*. (2017) [5], Sanjiv Kumar *et al*. (2022) [4], Chaudhari *et al*. (2022) [1], and Kumbhar *et al*. (2008) [2].

Table 1: Plant height (cm) of cotton as influenced by as influenced by different cropping systems and nutrient management treatments (2020-21 & 2021-22)

Treatments	Height of cotton (cm)							
	2020-21				2021-22			
	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
Main plot-Cropping System								
C_1 Sole *Bt* Cotton (mid-late)	33.68	87.21	116.04	123.67	39.90	90.50	119.53	136.28
C_2 *Bt*-Cotton (Early)-Wheat	28.08	77.28	104.75	113.22	37.23	80.62	109.17	118.60
C_3 *Bt*-Cotton (Early)-Chickpea	31.03	79.28	107.76	115.53	38.42	82.86	110.68	120.33
C_4 *Bt*-Cotton (Early)-Linseed	30.92	78.53	107.26	114.92	37.90	80.92	109.34	119.25
C_5 *Bt*-Cotton (Early)-Onion	29.88	77.93	105.36	113.57	37.08	79.68	103.18	117.90
SE	1.92	0.64	1.21	0.85	1.10	0.96	1.04	0.95
CD	NS	2.09	3.95	2.77	NS	3.11	3.38	3.09
Sub plot-Nutrient Management (*Rabi* crops)								
N_1 75% RDF	29.52	79.65	107.41	115.25	37.51	81.37	109.05	121.03
N_2 100% RDF	31.92	80.44	109.05	117.11	38.70	84.46	111.71	123.91
S.E. (m)±	0.95	0.43	0.55	0.61	0.61	0.68	0.41	0.26
C.D. at 5%	NS	NS	NS	NS	NS	2.13	1.30	0.81

Table 2: Number of functional leaves of cotton as influenced by different cropping systems and nutrient management treatments (2020-21 & 2021-22)

Treatments	Number of functional leaves of cotton							
	2020-21				2021-22			
	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
Main plot-Cropping System								
C_1 Sole *Bt* Cotton (mid-late)	19.87	108.57	177.63	99.08	23.20	117.16	204.37	125.39
C_2 *Bt*-Cotton (Early)-Wheat	17.93	101.42	148.49	73.98	21.14	110.17	183.17	104.10
C_3 *Bt*-Cotton (Early)-Chickpea	18.52	104.77	154.25	78.25	23.82	111.17	185.70	105.15
C_4 *Bt*-Cotton (Early)-Linseed	16.98	102.74	150.40	75.79	21.46	110.68	184.13	104.59
C_5 *Bt*-Cotton (Early)-Onion	17.32	102.02	149.56	74.26	20.19	109.10	182.24	103.58
SE	0.85	1.08	1.77	1.42	1.58	1.45	1.97	1.55
CD	NS	3.53	5.77	4.64	NS	4.73	6.42	5.07
Sub plot-Nutrient Management (*Rabi* crops)								
N_1 75% RDF	17.64	102.90	154.57	79.59	21.25	108.14	184.85	104.95
N_2 100% RDF	18.61	104.90	157.56	80.96	22.67	115.17	190.99	112.18
S.E. (m)±	0.68	0.73	0.96	0.68	0.70	0.42	0.90	0.57
C.D. at 5%	NS	NS	NS	NS	NS	1.34	2.82	1.80

Table 3: Leaf area plant^{-1} (dm^2) of cotton as influenced by different cropping systems and nutrient management treatments (2020-21 & 2021-22)

Treatments	Leaf area plant^{-1} (dm^2) of cotton							
	2020-21				2021-22			
	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
Main plot-Cropping System								
C_1 Sole *Bt* Cotton (mid-late)	6.78	58.75	92.06	62.72	7.32	65.77	99.27	67.08
C_2 *Bt*-Cotton (Early)-Wheat	6.11	47.71	78.80	52.01	6.97	58.86	88.76	58.19
C_3 *Bt*-Cotton (Early)-Chickpea	6.86	50.01	82.11	56.18	6.89	60.14	91.25	60.48
C_4 *Bt*-Cotton (Early)-Linseed	6.41	49.96	80.49	53.97	7.23	59.12	89.88	59.50
C_5 *Bt*-Cotton (Early)-Onion	6.16	48.60	79.21	53.28	6.93	58.22	88.10	57.79
SE	0.23	0.73	1.03	1.65	0.10	0.66	0.98	1.08
CD	NS	2.36	3.34	5.38	NS	2.14	3.19	3.53
Sub plot-Nutrient Management (*Rabi* crops)								
N_1 75% RDF	6.33	49.85	80.77	55.08	6.94	58.36	89.97	58.44
N_2 100% RDF	6.60	52.16	84.29	56.19	7.19	62.48	92.93	62.79
S.E. (m)±	0.10	0.92	1.16	0.61	0.09	0.77	0.80	0.46
C.D. at 5%	NS	NS	NS	NS	NS	2.43	2.52	1.46

Conclusion

Based on the results of the two-year investigation, it can be concluded that sole *Bt* cotton (mid-late) (C1) consistently recorded significantly higher plant height, number of functional leaves, and leaf area compared to all other treatments. The superiority of this treatment can be attributed to varietal characteristics, which enhanced vegetative growth, branching, and photosynthetic activity. However, the various cotton-based cropping systems remained statistically at par with each other due to the uniform use of the same cotton variety. With respect to nutrient management, no significant residual effects of rabi crop fertilization were observed in 2020-21, whereas in 2021-22, 100% RDF applied to rabi crops significantly improved plant height, functional leaves, and leaf area compared to 75% RDF. This improvement was due to higher organic matter addition and nutrient availability under full fertilization. Overall, the study highlights the importance of varietal selection and balanced nutrient management for enhancing cotton growth and development.

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