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Evaluation of growth rates of *Bt* cotton (*Gossypium hirusutum* L.) hybrid RCH-799 as influenced by time of fertilizer application and farm yard manure levels under rainfed condition

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Abstract
Growth of crop may differ with fertilizer application time and farm yard manure levels practices. Hence a field experiment was conducted at Experimental farm, Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.) during *kharif* 2021-2022 season to study the response of *Bt* cotton to time of fertilizer application and farm yard manure levels under *rainfed* condition. The experiment was laid out in split plot design with three replications. The present investigation consisted of sixteen treatment combinations. Treatments details consist of time of fertilizer application in main plot and in sub plot four levels of FYM. The treatments were allotted randomly in each replication. Result of study revealed that among different time of fertilizer application (T_1) application of basal dose at sowing, splitting of N as per recommendation resulted maximum AGR for plant height (cm day^{-1} plant^{-1}) and dry matter (g day^{-1} plant^{-1}). Among different levels of FYM application (M_2) application of hill placement of 75% FYM at sowing resulted maximum AGR for plant height (cm day^{-1} plant^{-1}) and dry matter (g day^{-1} plant^{-1}). Mean Crop Growth Rate (CGR), Relative Growth Rate (RGR) were also maximum with (T_1) application of basal dose at sowing, splitting of N as per recommendation and (M_2) hill placement of 75% FYM at sowing.

Keywords: Time of fertilizer application, FYM levels, growth rates

Introduction
Cotton is one of India's most significant cash crops and source of fiber. It is crucial to the nation's industrial and agricultural economics. Since the beginning of the 21st century, Asian countries have experienced a faster increase in cotton production and processing than the rest of the world. In the inevitable future, too, the tendency is anticipated to continue. Cotton is grown in around 80 different nations, although only six of them; China, India, The United States, Pakistan, Brazil and Uzbekistan contributes to 85% of the world's supply. It is grown on 32.19 M ha worldwide, of which 12.95 M ha, or roughly 40% of the total, are in India (AICRP on Cotton, 2021) [1] during the 2020-21 growing season. India produces 371 lakh bales of cotton lint compared to the 1451 lakh bales produced globally.

It is grown on 32.19 M ha worldwide, of which 12.95 M ha, or roughly 40% of the total, are in India (AICRP on Cotton, 2021) [1] during the 2020-21 growing season. India produces 371 lakh bales of cotton lint compared to the 1451 lakh bales produced globally. It is one of the few commodity crops that has a significant chance of bringing farmers, traders, and entire countries long-term success.

The main states that grow cotton on a substantial scale are Maharashtra, Gujarat, and Telangana (68 per cent of the national area and 64 per cent production). With an area of 39.36 lakh hectares, or almost one third of the country's cotton area in 2021-22, Maharashtra state contributes to the largest area in the nation. Only 71.66 percent (388 kg ha^{-1}) of the nation's productivity comes from the state's production, which amounts to 89.86 lakh bales (AICRP on Cotton, 2022) [2]. The Marathwada region has 12.85 lakh ha of cotton area and produced 19.64 lakh bales in the 2021–22 season with a meagre output of 245 kg ha^{-1}.

In general, the organic manures recorded higher gross monetary returns compared with inorganic fertilizers and have positive residual effects on succeeding crop (Blaise *et al*., 2005) [4], which leads to an increase in the soil organic carbon, and reduction of soil erosion (Iqbal, 2017) [6]. Furthermore, they also help in improving the soil productivity, and also at same time protecting the soil environment from nitrate (NO_3) pollution and soil degradation

(Nyakatawa *et al*., 2001; Ali *et al*., 2017) [7, 3]. The useful effects of combined use of organic manures and inorganic improve crop yield as well as keeping soil health. Looking the economic importance of cotton crop and maintenance of fertility and nutrients status of soil, the importance of organic sources effect on cotton growth and to determine the best timing of fertilizer application on seed cotton yield, the purpose of this research was to assess the appropriate levels of FYM with NPK, to optimize the best time of fertilizer application on cotton growth parameters, seed cotton yield, lint yield, and yield components, and to find the optimal time of fertilizer application and level of FYM.

Materials and Methods

A field experiment was conducted during *kharif* 2021-22 at Experimental farm, Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in Marathwada region of Maharashtra state to evaluate the effect of time of fertilizer application and farm yard manure levels on *Bt.* cotton (*Gossypium hirsutum* L.). The field's topography was reasonably level and homogeneous. The soil was medium black cotton belonging to vertisol. The soil was a slightly alkaline reaction, low levels of organic carbon, the soil available nitrogen was low (159.90 kg ha^{-1}), available phosphorus was medium (12.10 kg ha^{-1}), available potassium was high (449.10 (kg ha^{-1}) and soil organic carbon of 0.55%.

The experiment was laid out in split plot design with three replications. The gross and net plots sizes were 38.88 and 21.60 square meters, respectively. Treatment consists of sixteen treatment combinations comprising four time of fertilizer application (T_1 - basal dose at sowing, splitting of N as per recommendation, T_2 - basal dose at 15 DAS, splitting of N as per recommendation, T_3 - basal dose at 30 DAS, splitting of N as 30% each at 45 DAS and 75 DAS and T_4 - basal dose at 30 DAS, splitting of N as 30% each at 60 DAS and 75 DAS) as in the main plot and four levels of FYM application (M_1 - recommended dose of FYM by broadcasting before last harrowing, M_2 - hill placement of 75% FYM at sowing, M_3 - hill placement of 50% FYM at sowing and M_4 - control (without FYM) as the sub plot treatments.

The *Bt* cotton was sown by dibbling method on 30-06-2021 after receipt of sufficient monsoon rains. During the experimentation year total quantity of 1604.4 mm of rainfall was received. During the experimental period, the mean relative humidity in the morning and evening hours varied from 79 to 96% and 29 to 79% respectively. During the crop growth period, mean maximum and mean minimum temperature range was 30.5 °C and 19.2 °C. Mean wind velocity during the crop growth season ranges between 2.1 km hr^{-1} to 5.8 km hr^{-1}, respectively with bright sunshine hours ranging between 2.2 to 9.4 hours day^{-1}, respectively. Evaporation ranging from 1.1 to 5.5 mm day^{-1}. At various growth stages, observations on plant growth character were recorded.

Absolute growth rate for plant height (cm day^{-1} $plant^{-1}$)

The Absolute Growth Rate (AGR) is the total gain in plant height by the plant within the specific time interval. Absolute growth rate for plant height is expressed as cm day^{-1} $plant^{-1}$ and is calculated by the formula given by Richards (1969) [8] as follows.

$$AGR = \frac{(H_2-H_1)}{(t_2-t_1)} \times 100$$

Where,

H_2 and H_1 are plant height (cm) at time t_2 and t_1, respectively.

Absolute growth rate for dry matter (g day^{-1} $plant^{-1}$)

The Absolute Growth Rate (AGR) is the total gain in dry matter by the plant within the specific time interval and expressed as g day^{-1} $plant^{-1}$ for dry matter accumulation $plant^{-1}$ and is calculated by the formula given by Richards (1969) [8] as follows.

$$AGR = \frac{(W_2-W_1)}{(t_2-t_1)} \times 100$$

Where,

W_2 and W_1 are the dry weight (g) plant at time t_2 and t_2, respectively.

Relative Growth Rate (RGR)

Increase in dry matter of plant is a process of continuous compound interest wherein the increment in any interval adds to the 'capital' for subsequent growth. This rate of increment is called as Relative Growth Rate (RGR), which was worked out as per formula given by Fisher (1921) [5] and expressed in g g^{-1} day^{-1} $plant^{-1}$.

$$RGR\ (g\ g^{-1}day^{-1}) = \frac{Log_e\ W_2 - Log_e\ W_1}{t_2 - t_1}$$

Where,

W_1 and W_2 are the weights of dry matter in g per plant at times t_1 and t_2, respectively and t_2 - t_1 is the time interval in days.

Log_e = natural logarithm to the base 'e' = 2.3026.

Crop Growth Rate (g m^{-2} day^{-1})

Crop Growth Rate (CGR) is the rate of dry matter production per unit ground area per unit time. It was calculated by using the following formula given by Watson (1952) [9] and is expressed as g m^{-2} day^{-1}.

$$CGR = \frac{(W_2-W_1)}{(t_2-t_1)} \times \text{Number of plants } m^{-2}$$

Where

W_1= Dry weight of the plant (g m^{-2}) at time t_1

W_2= Dry weight of the plant (g m^{-2}) at time t_2

t_2-t_1=Time interval in days

Results and Discussion

The results and discussion of the present study have been summarised under following heads.

Absolute Growth Rate (AGR) for plant height

Among different time of fertilizer application AGR of plant height was higher in (T_1) application of basal dose at sowing, splitting of N as per recommendation at all the stages followed by (T_2) application of basal dose at 15DAS, splitting of N as per recommendation. The higher mean AGR values of 2.2389 were recorded by (T_1) application of basal dose at sowing, splitting of N as per recommendation at 31-60DAS. Lowest AGR values recorded with (T_4) application of basal dose at 30 DAS, splitting of N as 30% each at 60 DAS and 75 DAS.

Among the levels of FYM application (M_2) of hill placement of 75% FYM at sowing recorded higher AGR values (2.2223 at 31-60DAS) it was followed by (M_3) application of hill placement of 50% FYM at sowing and recorded lowest mean AGR values with (M_4) control (without FYM) at all the growth stages.

Absolute growth rate of dry matter

Among different time of fertilizer application AGR for dry matter was higher in (T_1) application of basal dose at sowing, splitting of N as per recommendation at all the stages followed by (T_2) application of basal dose at 15DAS, splitting of N as per recommendation during 2021-2022. Among different time of fertilizer application, the higher mean AGR values of 2.6810 g day^{-1} plant^{-1} at 91-120 DAS were recorded by (T_1) basal dose at sowing, splitting of N as per recommendation and it was recorded lowest AGR values with (T_4) application of basal dose at 30 DAS, splitting of N as 30% each at 60 DAS and 75 DAS during the years of study.

Among the levels of FYM application (M_2) application of hill placement of 75% FYM at sowing recorded higher AGR values of for dry matter (2.6926 at 91-120 DAS) it was followed by (M_3) application of hill placement of 50% FYM at sowing and lowest mean AGR values recorded with (M_4) control (without FYM) at all the growth stages during experimentation.

Relative growth rate (g g^{-1} day^{-1})

Greater RGR was in (T_1) application of basal dose at sowing, splitting of N as per recommendation at 0-30, 31-60, and 121-150 DAS and (T_2) application of basal dose at 15DAS, splitting of N as per recommendation recorded greater RGR at 61-90 and 91-150 DAS. Lowest RGR values with (T_4) application of basal dose at 30 DAS, splitting of N as 30% each at 60 DAS and 75 DAS at 0-30,31-60, and 121-150 DAS and (T_3) application of basal dose at 30 DAS, splitting of N as 30% each at 45 DAS and 75 DAS recorded lowest RGR at 61-90 and 91-150 DAS during both the years of experimentation.

Among different levels of FYM application practices, greater RGR was in (M_2) application of hill placement of 75% FYM at sowing at 0-30, 31-60, 61-90 and (M_3) application of hill placement of 50% FYM at sowing recorded highest RGR at 91-120DAS. Lowest RGR recorded with (M_4) control (without FYM).

Crop growth rate (g day^{-1} m^{-2})

Among different time of fertilizer application crop growth rate for dry matter was higher in (T_1) basal dose at sowing, splitting of N as per recommendation at all the stages followed by (T_2) basal dose at 15DAS, splitting of N as per recommendation during 2021-2022 and 2022-2023. Among different time of fertilizer application, the higher mean CGR values of 4.9599 g day^{-1} m^{-2} at 91-120 DAS were recorded by (T_1) basal dose at sowing, splitting of N as per recommendation and lowest CGR values recorded with (T_4) basal dose at 30 DAS, splitting of N as 30% each at 60 DAS and 75 DAS during both the years of experimentation.

Among different levels of FYM application higher crop growth rate was calculated in (M_2) application of hill placement of 75% FYM at sowing at all the crop growth stages during the years of study. It was followed by (M_3) application of hill placement of 50% FYM at sowing. Among different levels of FYM application the higher mean CGR values of 4.9812 g day^{-1} m^{-2} at 91-120DAS were recorded by (M_2) application of hill placement of 75% FYM at sowing. The (M_4) control (without FYM) recorded lower crop growth rate values during the year of experimentation.

Application of fertilizer at sowing which leads to availability of nutrients to crop from initial growth period might have resulted in increasing plant growth**.** As hill placement of FYM supplied the crop with considerable amounts of different essential macronutrients and small amounts of micronutrients. Hence, spot application of FYM might have resulted in increasing growth attributes. Thus, higher plant height as well as dry matter accumulation, the growth rates were higher.

Conclusion

Application of basal dose at sowing, splitting of N as per recommendation resulted in maximum AGR for plant height (cm day^{-1} plant^{-1}), dry matter (g day^{-1} plant^{-1}) and Mean Crop Growth Rate (CGR). AGR for plant height (cm day^{-1} plant^{-1}), dry matter (g day^{-1} plant^{-1}) and Mean Crop Growth Rate (CGR) and Relative Growth Rate (RGR) were also maximum with application of hill placement of 75% FYM at sowing.

Table 1: Absolute growth rate for height (cm day^{-1} plant^{-1}) of *Bt.* cotton as influenced by different treatments at various crop growth period

Treatments	AGR (cm day^{-1} plant^{-1})				
	0-30 DAS	31-60 DAS	61-90 DAS	91-120 DAS	121-150 DAS
Main plot: Time of fertilizer application					
T_1: Basal dose at sowing, splitting of N as per recommendation	0.8043	2.2389	1.5002	0.6015	0.5553
T_2: Basal dose at 15 DAS, splitting of N as per recommendation	0.7637	2.1431	1.4271	0.6008	0.5554
T_3: Basal dose at 30 DAS, splitting of N as 30% each at 45 DAS and 75 DAS	0.7237	2.0335	1.2786	0.5606	0.5263
T_4: Basal dose at 30 DAS, splitting of N as 30% each at 60 DAS and 75 DAS	0.7226	2.0099	1.2506	0.5599	0.5387
Sub plot: Levels of FYM application					
M_1: Recommended dose of FYM by broadcasting before last harrowing	0.7487	2.0872	1.3684	0.5765	0.5431
M_2: Hill placement of 75% FYM at sowing	0.7863	2.2224	1.4774	0.5993	0.5626
M_3: Hill placement of 50% FYM at sowing	0.7730	2.1729	1.4757	0.5850	0.5492
M_4: Control (without FYM)	0.7061	1.9431	1.1350	0.5619	0.5208
GM	0.7582	2.1225	1.3837	0.5831	0.5469

Table 2: Absolute growth rate for dry matter (g day^{-1} plant^{-1}) of *Bt.* cotton as influenced by different treatments at various crop growth period

Treatments	AGR (g day^{-1} plant^{-1})				
	0-30 DAS	31-60 DAS	61-90 DAS	91-120 DAS	121-150 DAS
Main plot: Time of fertilizer application					
T_1: Basal dose at sowing, splitting of N as per recommendation	0.4439	1.4297	2.4247	2.6810	1.0225
T_2: Basal dose at 15 DAS, splitting of N as per recommendation	0.4292	1.3065	2.3568	2.6571	0.9447
T_3: Basal dose at 30 DAS, splitting of N as 30% each at 45 DAS and 75 DAS	0.4147	1.2463	1.8494	2.6416	0.9182
T_4: Basal dose at 30 DAS, splitting of N as 30% each at 60 DAS and 75 DAS	0.4100	1.1883	1.7917	2.6165	0.8771
Sub plot: Levels of FYM application					
M_1: Recommended dose of FYM broadcasting before last harrowing	0.4253	1.2667	2.0423	2.6613	0.9321
M_2: Hill placement of 75% FYM at sowing	0.4389	1.4174	2.3590	2.6926	0.9756
M_3: Hill placement of 50% FYM at sowing	0.4333	1.3891	2.2731	2.6860	0.9472
M_4: Control (without FYM)	0.4003	1.0976	1.7482	2.5564	0.9074
GM	0.4270	1.3092	2.1373	2.6584	0.9450

Table 3: Relative growth rate for dry matter (g g^{-1} day^{-1}) of *Bt.* cotton as influenced by different treatments at various crop growth period

Treatments	RGR (g g^{-1} day^{-1})				
	0-30 DAS	31-60 DAS	61-90 DAS	91-120 DAS	121-150 DAS
Main plot: Time of fertilizer application					
T_1: Basal dose at sowing, splitting of N as per recommendation	0.0863	0.0480	0.0277	0.0162	0.0046
T_2: Basal dose at 15 DAS, splitting of N as per recommendation	0.0852	0.0466	0.0286	0.0167	0.0044
T_3: Basal dose at 30 DAS, splitting of N as 30% each at 45 DAS and 75 DAS	0.0840	0.0463	0.0249	0.0187	0.0046
T_4: Basal dose at 30 DAS, splitting of N as 30% each at 60 DAS and 75 DAS	0.0837	0.0454	0.0251	0.0191	0.0045
Sub plot: Levels of FYM application					
M_1: Recommended dose of FYM by broadcasting before last harrowing	0.0849	0.0460	0.0264	0.0179	0.0045
M_2: Hill placement of 75% FYM at sowing	0.0859	0.0481	0.0273	0.0165	0.0044
M_3: Hill placement of 50% FYM at sowing	0.0855	0.0479	0.0270	0.0168	0.0044
M_4: Control (without FYM)	0.0829	0.0440	0.0258	0.0194	0.0048
GM	0.0848	0.0465	0.0266	0.0174	0.0045

Table 4: Crop Growth Rate (CGR) (g day^{-1} m^{-2}) of *Bt.* cotton as influenced by different treatments at various crop growth period

Treatments	CGR (g day^{-1} m^{-2})				
	0-30 DAS	31-60 DAS	61-90 DAS	91-120 DAS	121-150 DAS
Main plot: Time of fertilizer application					
T_1: Basal dose at sowing, splitting of N as per recommendation	0.8212	2.6450	4.4858	4.9599	1.8916
T_2: Basal dose at 15 DAS, splitting of N as per recommendation	0.7939	2.4170	4.3601	4.9157	1.7477
T_3: Basal dose at 30 DAS, splitting of N as 30% each at 45 DAS and 75 DAS	0.7672	2.3057	3.4214	4.8870	1.6986
T_4: Basal dose at 30 DAS, splitting of N as 30% each at 60 DAS and 75 DAS	0.7585	2.1984	3.3147	4.8405	1.6226
Sub plot: Levels of FYM application					
M_1: Recommended dose of FYM by broadcasting before last harrowing	0.7867	2.3434	3.7783	4.9235	1.7244
M_2: Hill placement of 75% FYM at sowing	0.8120	2.6222	4.3642	4.9812	1.8049
M_3: Hill placement of 50% FYM at sowing	0.8016	2.5698	4.2053	4.9690	1.7524
M_4: Control (without FYM)	0.7405	2.0306	3.2342	4.7293	1.6788
GM	0.7852	2.3915	3.8955	4.9008	1.7401

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