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Original Research Article

Correlation Study between Physiological Parameters and Seed Cotton Yield in *Bt* Cotton

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Correlation study, Physiological parameters and Seed cotton yield in *Bt* cotton

A B S T R A C T

A field experiment was conducted during rainy season of 2014 and 2015 at Mahatma Phule Krishi Vidyapeeth, Rahuri. The correlation studies between physiological parameters and seed cotton yield in Bt cotton was studied as one of aspect. The data revealed that the positive and highly significant correlation was observed between seed cotton yield and physiological parameters *viz.* photosynthetic rate, CO_2 concentration, stomatal conductance, transpiration rate and leaf temperature at all periodical growth stages during both the years. Whereas, negative correlation was noticed between seed cotton yield and stomatal resistance and leaf temperature at all growth stages during both years. This indicates that as the physiological parameters *viz.* photosynthetic rate, CO_2 concentration, stomatal conductance and transpiration rate increases the seed cotton yield also increase. Whereas, as the stomatal resistance and leaf temperature increases, the seed cotton yield decreases.

Introduction

Bt cotton (*Gossypium hirsutum* L.) has a pride of place among the cultivated plants that satisfy the material need of man because next to food, clothing is the prime need of life. Cotton plays a key role in the national as well as farmer's economy in terms of both employment generation and foreign exchange earnings. It generates employment for about 60 million people either directly or indirectly involved in the agricultural and industrial sectors of cotton production, processing, textiles and related activities (Chaudhary and Gaur, 2010).

Amongst the leading cotton growing countries in the world, India ranks first in area with 10.5 million hectares which is about 34 per cent of world's total but in production it contributes 40.0 million bales (170 kg each) next to China. Maharashtra leads the nation in respect of area as it occupies nearly 3.81 Million hectare, (Anonymous, 2016). The productivity of cotton can be improved by adopting suitable agronomic practices like maintenance of ideal plant density, use of optimum dose of fertilizer as well as proper water management practices. It is essential to find out suitable plant density for recently released Bt cotton hybrid to realize the maximum yield potential. There is a positive relationship between plant population and seed cotton yield in cotton crop (Bhalerao *et al.*, 2008). There are many reasons for decreasing productivity like decreasing soil fertility especially micronutrients, imbalanced use of fertilizer, occurrences of physiological disorders like square dropping, square drying, leaf reddening and climatic factors like temperature, wind, velocity, humidity, leaf temperature etc. Among these, imbalanced use of major and micro nutrients is the major problem. These nutrients are more important because in Bt cotton synchronized boll development altered the source-sink relationship due to rapid translocation of saccharides and nutrients from leaves to the developing bolls (Hebbar *et al.*, 2007). To overcome these constraints, additional nutrition through foliar feeding is required over and above the normal fertilizer recommendation. This is one of the most efficient ways of supplying essential nutrients to a growing crop. Fertigation is the

injection of fertilizers, soil amendments and other water-soluble products into an irrigation system. Through fertigation nutrients can be applied in correct doses and at appropriate stage of plant growth. In addition it improves fertilizer use efficiency, hastens the maturity of crop and improves the quality of produce.

In view to shrinking water resources and increasing cost of water soluble fertilizers and to exploit the yield potentiality of Bt cotton genotype by following important agro technique such as varied planting techniques and nutrient managements the efforts have been made to plan and conducted an experiment by considering deficit irrigation, planting techniques and nutrient management for enhancing the productivity and quality of Bt cotton during two consecutive season.

Materials and Methods

The present investigation was conducted at Post Graduate Institute Research Farm, MPKV, Rahuri. The soil of the experimental field was silty clay in texture. It was low in available nitrogen (175.61 kg / ha), medium in phosphorus (20.66 kg / ha) and high in potassium (448.11 kg / ha) with slightly alkaline in reaction (pH 8.10).The soil micronutrients were deficit in zinc (0.26 mg / kg) and ferrous (1.07 mg / kg) and high in manganese (15.92 mg / kg) and copper (2.06 mg / kg). The moisture content at field capacity and permanent wilting point was 36.49 per cent and 17.50 per cent, respectively. The present investigation was laid out in split plot design with three replications. The treatment comprising four irrigation regimes (I_1-0.6 ETc, I_2-0.8 ETc, I_3-1.0 ETc and I_4-Surface irrigation (Control) and two planting techniques (P_1-90 cm x 90 cm and P_2-150 cm x 60 cm) as main plot treatments and three levels of fertigation (F_1 -100% GRDF, F_2 -100% GRDF +$MgSO_4$ (20 kg / ha) and F_3-100% GRDF + $MgSO_4$ (20 kg / ha) + $ZnSO_4$ (25 kg / ha) and foliar spray of 1% Fe SO_4 (at flowering and boll development) + Boron @ 0.5 % (at flowering and boll development) as sub plot treatment. The surface irrigation with recommended dose of fertilizer was taken as control treatment. Fertigation was started at 10 days after sowing and scheduled at weekly interval in 12 equal splits upto boll development stage. In treatment F_2 and F_3, MgSO4 @ 20 kg / ha and $ZnSO_4$ @ 25 kg / ha was applied at weekly interval in 9 equal splits upto flowering, where as in control treatment, it was applied at sowing as a basal dose. In drip method, irrigation was applied at every alternate day based on pan evaporation data and in surface irrigation method irrigation was applied at 75 mm CPE with 7.5 cm of irrigation depth at each irrigation turn. In drip irrigation method, scheduling of irrigation was done at every alternate day on the basis of pan evaporation (PE) and crop coefficient (Kc). The scheduling of irrigation was done by using following formula.

$$\text{(lit. plant}^{-1}\text{ alternate}^{-1}\text{ day)} = \frac{\text{Epan x Kpan x Kc x } S_1 \text{ x } S_2 \text{ x Wa}}{\text{System efficiency (\%)}}$$

Volume of water

Where,

Epan = Pan evaporation (mm),

Kpan = Pan co-efficient (0.7)

Kc = Crop coefficient (as per growth stages),

S_1 = Inter row spacing (m)

S_2 = Intra row spacing (m),

Wa = Wetted area (%)

The operating time of system was calculated by using following formula.

$$\text{Time required (hours)} = \frac{\text{Total volume of water (lit.)}}{\text{Number of emitters x Emitter discharge (Lph)}}$$

The farmyard manure was applied common to all the treatments @ 10 t ha^{-1} well before the dibbling of the cotton seeds. Before application of farmyard manure in the field it was analyze for nutrient contents by using standard analytical method. The seed material of Bt cotton hybrid Ajeet-155BG-II was planted on 10.06.2014 and 18.06.2015. The total precipitation received during the crop growth period was 456.20 mm in 27 rainy days during first season and 285.2 mm in 25 rainy days during second season. Four picking were done in each year and picking was started on 08.09.2014 and 19.10.2015.For controlling the sucking pest infestation recommended package of practices were adopted.

The various growth and yield observations as well as physiological observations were recorded by selecting five observational plants from each treatment and tied a lable to each plant for identifications. The growth observations were recorded periodically at an interval of 28 days and physiological observation were recorded at an interval of 14 days during the growth period.

Results and Discussion

Irrigation regimes

Maximum photosynthetic rate (19.91 and 23.93 µ mol CO_2 $m^{-2}s^{-1}$), CO_2 concentration (396.45 and 365.08 µ mol CO_2 $m^{-2}s^{-1}$), transpiration rate (6.69 and 6.29 µ mol H_2O $m^{-2}s^{-1}$) and stomatal conductance (0.49 and 0.51 m mol $m^{-2}s^{-1}$) in Bt cotton leaves were observed at 98 DAP under 1.0 ETc irrigation regime through drip as compared to rest of irrigation regimes and surface irrigation method.

This might be due to soil remains always at field capacity in root rhizosphere which is a congenial condition for absorption of more moisture and nutrients by crop resulted in increasing cell turgidity because of that stomata remains open for longer period for enhancing transpiration rate and intake of carbon dioxide which increase the stomatal conductance and photosynthetic rate. The reverses trend was noticed under deficit irrigation i.e. at 0.6 ETc irrigation regime where the moisture intake rate of crop was less than the evaporative demand of crop because of that crop experience the moisture stress which leads to partially close the stomata and reduce the transpiration rate thereby increase leaf temperature and stomatal resistance. These results are in the line of Liu *et al.*, (2008). This might be due to continuous availability of moisture in the root rhizosphere increase the uptake of moisture and nutrients which leads to luxurious growth of crop in terms of plant height, number of sympodial branches $plant^{-1}$, leaf number $plant^{-1}$ and leaf area $plant^{-1}$ resulted in more interception of solar radiation for physiological activities. Whereas, in deficit irrigation treatment (0.6 ETc) the vegetative growth was inhibited due to inadequate moisture availability at all the crop growth stages. These results are inconfirmity with those reported Yeates *et al.*, (2010) and Evangelos *et al.*, (2011).

Planting techniques

Maximum photosynthetic rate (17.10 and 21.44 µ mol CO_2 $m^{-2}s^{-1}$), CO_2 concentration (386.58 and 353.32 µ mol CO_2 $m^{-2}s^{-1}$), transpiration rate (5.78 and5.96 µ mol H_2O $m^{-2}s^{-1}$) and stomatal conductance (0.42 and 0.47 m mol $m^{-2}s^{-1}$) in Bt cotton leaves were observed at 98 DAP under 90 cm x 90 cm planting technique than rest of planting method. In case of stomatal resistance and leaf temperature 150 cm x 60 cm planting technique recorded maximum values than rest of planting techniques.

Fertigation (Nutrient management)

The physiological parameters *viz.*, photosynthetic rate, CO_2 concentration, transpiration rate, stomatal conductance, stomatal resistance and leaf temperature play important role in growth and development of crop.

Nutrient management through fertigation influences the physiological activities. Fertigation of 100 % GRDF upto 100 days + 20 kg $MgSO_4$ ha^{-1} and 25 kg $ZnSO_4$ ha^{-1} upto flowering at weekly interval + foliar spray of Fe (1.0 %) and B (0.5%) at flowering and boll development stages registered significantly higher photosynthetic rate (17.75 and 24.16 µmol CO_2 $m^{-2}s^{-1}$), CO_2 concentration (394.14 and 357.92 µmol CO_2 $m^{-2}s^{-1}$) transpiration rate (5.90 and 6.10 µmol H_2O $m^{-2}s^{-1}$) and stomatal conductance (0.42 and 0.48 m mol $m^{-2}s^{-1}$) was at higher magnitude at 98 DAP during the both years. The frequent application of major and micronutrients at weekly interval upto boll development stage and the foliar nutrition of Iron and Boron at flowering and boll development stage leads to luxurious growth of crop which increase the interception of solar radiation and accelerate the physiological activities. Similar results were reported by Zhao and Oosterhuis (2000). Fertigation of 100 % GRDF alone registered significantly higher stomatal resistance (2.60 and 2.27 µ mol $m^{-2}s^{-1}$) and leaf temperature (29.38 and 29.97 ^{0}C) at 98 DAPS during the both year of experimentation.

Interaction

The interaction effect between irrigation regimes, planting techniques and nutrient management through fertigation was found to be non-significant in all physiological parameters in Bt cotton at all the crop growth stages during both the years.

Correlation studies

The correlation coefficients between seed cotton yield and physiological parameters were assessed during both the years and presented in Table 4. Positive and highly significant correlation was observed between seed cotton yield and physiological parameters *viz.* photosynthetic rate, CO_2 concentration, stomatal conductance and transpiration rate at all growth stages during both years (Table 4) indicating as the rate of these physiological parameters were increased, the yield of seed cotton also increased.

Table.1 Periodical photosynthetic rate and CO_2 concentration in Bt cotton as influenced by different treatments 2014 and 2015

Treatment	Photosynthetic rate (µ mol co_2 m^{-2} s^{-1})						CO_2 concentration (µ mol co_2 m^{-2} s^{-1})					
	2014			2015			2014			2015		
	56 DAP	98 DAP	112 DAP	56 DAP	98 DAP	112 DAP	56 DAP	98 DAP	112 DAP	56 DAP	98 DAP	112 DAP
Irrigation regimes - I												
I_1: 0.6 ETc	7.91	14.06	12.90	9.07	15.77	13.37	324.74	368.50	342.45	307.08	336.58	320.47
I_2: 0.8 ETc	11.85	17.22	14.30	11.02	22.87	15.58	340.13	386.85	358.18	330.96	357.96	333.63
I_3:1.0 ETc	14.39	19.93	17.92	14.19	23.93	21.48	347.52	396.45	365.29	340.19	365.08	357.08
I_4:Surface irrigation (Control)	9.50	15.89	13.63	7.96	17.94	15.54	334.58	379.07	350.23	310.58	345.30	328.63
S.Em (±)	0.89	0.85	0.50	0.91	0.31	0.21	2.12	2.98	4.34	3.82	5.83	6.84
CD at 5%	3.12	2.94	1.73	3.17	1.09	0.71	7.32	10.41	15.01	13.22	20.16	23.69
Planting techniques - P												
P_1: 90 cm x 90 cm	11.49	17.10	14.86	11.35	21.44	16.87	339.54	386.58	356.14	324.29	353.32	336.76
P_1: 150 cm x 60 cm	10.33	16.45	14.52	10.12	19.82	16.11	333.95	378.85	351.94	320.11	349.14	333.14
S.Em (±)	0.37	0.24	0.57	0.42	0.51	0.29	1.77	1.49	2.25	1.66	1.45	1.81
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Fertigation (Nutrient management) - F												
F_1: 100% GRDF	8.85	15.61	11.30	9.19	17.03	14.55	331.44	373.46	344.91	316.90	346.48	331.65
F_2: 100 % GRDF + 20 kg $MgSO_4$ ha^{-1}	10.68	16.97	15.07	10.66	20.69	16.54	335.08	380.56	352.01	320.54	349.29	333.12
F_3: 100 % GRDF + 20 kg $MgSO_4$ + 25 kg $ZnSO_4$ + foliar spray of Fe (1 %) and B (0.5 %)	13.21	17.75	17.69	12.36	24.16	18.38	343.71	394.14	365.19	329.17	357.92	340.09
S.Em (±)	0.50	0.35	0.56	0.44	0.45	0.44	1.27	1.42	1.45	1.27	1.24	1.56
CD at 5%	1.44	1.00	1.61	1.26	1.29	1.26	3.65	4.08	4.19	3.65	3.58	4.49
Interactions	N.S.			N.S.			N.S.			N.S.		
General mean	10.91	16.77	14.69	10.73	20.63	16.49	336.74	382.72	354.04	336.74	382.72	354.04

Table.2 Periodical transpiration rate and stomatal conductance in Bt cotton as influenced by different treatments during 2014 and 2015

Treatment	Transpiration rate (m mol H_20 m^{-2} s^{-1})						Stomatal conductance (m mol m^{-2} s^{-1})					
	2014			2015			2014			2015		
	56 DAP	98 DAP	112 DAP	56 DAP	98 DAP	112 DAP	56 DAP	98 DAP	112 DAP	56 DAP	98 DAP	112 DAP
Irrigation regimes - I												
I_1: 0.6 ETc	2.99	5.16	4.93	4.24	5.36	5.01	0.22	0.35	0.29	0.29	0.40	0.33
I_2: 0.8 ETc	3.48	6.08	5.64	4.89	6.11	5.70	0.29	0.42	0.38	0.33	0.47	0.38
I_3:1.0 ETc	3.69	6.69	6.13	5.13	6.29	6.17	0.31	0.49	0.42	0.38	0.51	0.39
I_4:Surface irrigation (Control)	2.94	4.94	4.59	4.42	5.59	5.22	0.24	0.37	0.31	0.31	0.47	0.36
S.Em (±)	0.070	0.048	0.069	0.068	0.062	0.070	0.014	0.005	0.008	0.014	0.015	0.007
CD at 5%	0.244	0.167	0.238	0.244	0.216	0.244	0.049	0.019	0.029	0.050	0.050	0.030
Planting techniques - P												
P_1: 90 cm x 90 cm	3.30	5.78	5.35	4.73	5.96	5.57	0.27	0.42	0.36	0.34	0.47	0.38
P_1: 150 cm x 60 cm	3.25	5.65	5.30	4.63	5.87	5.48	0.26	0.40	0.34	0.32	0.45	0.35
S.Em (±)	0.029	0.045	0.044	0.034	0.040	0.034	0.006	0.006	0.005	0.009	0.009	0.014
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Fertigation (Nutrient management) - F												
F_1: 100% GRDF	3.21	5.53	5.13	4.51	5.69	5.30	0.25	0.39	0.33	0.31	0.45	0.35
F_2: 100 % GRDF + 20 kg $MgSO_4$ ha^{-1}	3.28	5.72	5.34	4.71	5.95	5.57	0.27	0.41	0.35	0.33	0.46	0.37
F_3: 100 % GRDF + 20 kg $MgSO_4$ + 25 kg $ZnSO_4$ + foliar spray of Fe (1 %) and B (0.5 %)	3.34	5.90	5.50	4.82	6.10	5.70	0.28	0.42	0.37	0.34	0.48	0.38
S.Em (±)	0.016	0.017	0.021	0.018	0.022	0.024	0.003	0.004	0.005	0.005	0.005	0.006
CD at 5%	0.046	0.049	0.059	0.053	0.062	0.068	0.010	0.011	0.015	0.016	0.016	0.017
Interactions	N.S.			N.S.			N.S.			N.S.		
General mean	3.27	5.72	5.32	4.68	5.91	5.52	0.26	0.41	0.35	0.26	0.41	0.35

Table.3 Periodical stomatal resistance and leaf temperature in Bt cotton as influenced by different treatments during 2014 and 2015

Treatment	Stomatal resistance						Leaf temperature (^{0}C)					
	2014			2015			2014			2015		
	56 DAP	98 DAP	112 DAP	56 DAP	98 DAP	112 DAP	56 DAP	98 DAP	112 DAP	56 DAP	98 DAP	112 DAP
Irrigation regimes - I												
I_1: 0.6 ETc	4.58	2.84	3.47	3.41	2.50	3.15	34.73	30.58	32.77	31.90	30.38	30.65
I_2: 0.8 ETc	3.52	2.38	2.63	3.14	2.17	2.69	31.17	27.64	29.21	30.34	28.99	29.47
I_3:1.0 ETc	3.24	2.07	2.39	2.65	2.00	2.60	30.68	27.08	28.34	29.36	28.82	29.41
I_4:Surface irrigation (Control)	4.29	2.72	3.33	3.29	2.15	2.83	34.08	29.94	31.78	31.42	29.99	30.25
S.Em (±)	0.19	0.04	0.10	0.14	0.07	0.07	0.24	0.15	0.18	0.31	0.18	0.21
CD at 5%	0.67	0.14	0.34	0.50	0.24	0.24	0.82	0.53	0.61	1.09	0.62	0.73
Planting techniques - P												
P_1: 90 cm x 90 cm	3.78	2.45	2.89	3.06	2.16	2.73	32.67	28.73	30.38	30.54	29.39	29.81
P_1: 150 cm x 60 cm	4.04	2.55	3.03	3.19	2.25	2.91	32.65	28.89	30.68	30.97	29.69	30.08
S.Em (±)	0.08	0.03	0.04	0.09	0.04	0.14	0.19	0.22	0.25	0.26	0.22	0.24
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Fertigation (Nutrient management) - F												
F_1: 100% GRDF	4.16	2.60	3.12	3.25	2.27	2.97	32.93	29.38	31.06	31.17	29.97	30.37
F_2: 100 % GRDF + 20 kg $MgSO_4$ ha^{-1}	3.87	2.48	2.95	3.13	2.21	2.77	32.85	28.75	30.53	31.02	29.87	30.31
F_3: 100 % GRDF + 20 kg $MgSO_4$ + 25 kg $ZnSO_4$ + foliar spray of Fe (1 %) and B (0.5 %)	3.69	2.43	2.80	2.98	2.13	2.71	32.21	28.30	29.99	30.08	28.79	29.15
S.Em (±)	0.05	0.03	0.06	0.05	0.03	0.07	0.21	0.21	0.20	0.25	0.29	0.28
CD at 5%	0.15	0.07	0.16	0.14	0.07	0.20	0.60	0.61	0.59	0.73	0.83	0.80
Interactions	N.S.			N.S.			N.S.					
General mean	3.91	2.50	2.96	3.12	2.2	2.82	32.66	28.81	30.53	30.76	29.54	29.94

Table.4 Correlation coefficients between seed cotton yield of Bt cotton and physiological parameters as influenced by different treatments during 2014 and 2015

Physiological parameters	Crop growth periods					
	2014			2015		
	56 DAP	98 DAP	112 DAP	56 DAP	98 DAP	112 DAP
Photosynthetic rate	0.812**	0.831**	0.553**	0.669**	0.736**	0.634**
CO_2 concentration	0.899**	0.884**	0.83**	0.832**	0.791**	0.73**
Transpiration rate	0.836**	0.716**	0.774**	0.739**	0.74**	0.718**
Stomatal conductance	0.9**	0.909**	0.902**	0.761**	0.762**	0.73**
Stomatal resistance	-0.916**	-.918**	-0.88**	-0.741**	-0.718**	-0.556**
Leaf temperature	-0.869**	-0.863**	-0.873**	-0.73**	-0.659**	-0.542**

*: 5 % level of significance **: 1 % level of significance

The enhancement of these parameters resulted in luxurious growth of crop which contributes more biomass accumulation and translocation of photosynthates towards reproductive organs resulted in increase the seed cotton yield. Whereas, negative correlation was noticed between seed cotton yield and physiological parameters *viz.,* stomatal resistance and leaf temperature at all growth stages during both years. This indicates that as rate of these parameters were increases, seed cotton yield decreases. Similar results were reported by Wang *et al.,* (2008) and Han *et al.,* (2011).

Thus, it could be concluded that, scheduling of irrigation at 0.8 ETc irrigation regime coupled with 90 cm x 90 cm planting technique and fertigation of 100 per cent GRDF upto 100 days +20 kg $MgSO_4$/ ha and 25 kg $ZnSO_4$ / ha upto flowering at weekly interval + foliar spray of ferrous sulphate (1.0 %) and borax (0.5%) at flowering and boll development stages along with favourable effect of physiological parameters recorded maximum growth, yield contributing characters and seed cotton yield in Bt cotton.

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