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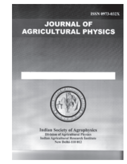

Research Article

Influence of Seed Hardening and Foliar Nutrition on Growth and Yield in Bt Cotton (*Gossypium hirsutum* L.)

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ABSTRACT

The present study was undertaken at Agricultural Research Station, Dharwad during the year 2011 to study the influence of seed hardening and foliar nutrition on growth and yield of Bt-Cotton under rainfed condition. The trial was laid under RBD with three replications**.** Significant enhancement in growth and yield attributes was observed among various treatments as compared to control. The morpho-physiological traits like plant height (112.7 cm), number of monopodial (2.94) and sympodial (18.8) branches, LAI (3.62), TDM (233.36 g plant^{-1}) and growth analysis parameters like AGR (4.64 g d^{-1}), CGR (8.59 g m^{-2} d^{-1}), NAR (0.89 g m^{-2} d^{-1}) and RGR (1.35 g g^{-1} d^{-1}) and yield (2276 kg ha^{-1}) and yield attributing characters like boll weight (5.12 g boll^{-1}) and number of bolls per plant (28) significantly increased on seed hardening and foliar spray with $CaCl_2$ @ 2% and 0.5%, respectively followed by seed treatment and foliar spray with $ZnSO_4$ @ 0.5% as compared with untreated control. Hence, these treatments could be used for boosting the yield of Bt-Cotton under the rainfed condition.

Key words: Seed hardening, Absolute growth rate, Total dry matter

Introduction

Cotton is the most important cash crop of India. It is the backbone of our sprawling textile industry contributing 7.0 per cent to our GDP, fetching an export earning besides providing employment in the production, promotion, processing and trade of cotton. The area under cotton during 2010-11 in India was 110.00 lakh ha with production and productivity of 325 lakh bales and 503 kg lint ha^{-1}, respectively. Even though, India ranks first in terms of area, it is relegated to fourth position in terms of production of cotton. Reasons for low productivity include (a) the area under rainfed cotton predominates over irrigated area and (b) more than 50 per cent of rainfed cotton is grown under low and erratic rainfall conditions, without adequate application of fertilizers and plant protection measures. The present day cotton varieties are of longer duration (>180 days) and are exposed to biotic risks like pest and disease incidence particularly to bollworms and abiotic stress like drought. In addition, the low yield levels could also be attributed to the genetic, physiological and agronomic factors involved in cotton production. Drought is the most common adverse environmental factor, which limits the productivity of crops under the rainfed and arid conditions. The water balance of a crop is upset by drought and as a consequence of this, the physiological function responsible for growth and yield are disarranged. The severity and extent of drought not only depends on low rainfall but also on other hydro-meteorological factors like soil moisture, infiltration and moisture-retention capacity of the soil. High temperature and low humidity during critical phases of the plant

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growth affect its metabolism. Hence there is a need for securing the crop varieties to cope up with the drought condition. In this regard the pre-sowing hardening of seeds is one of the best methods that results in modifying the physiological and biochemical nature of seeds. Pre-sowing hardening is the result of extensive physiological reorganization induced by dehydration process. The effect of pre-sowing hardening on crop plants involves the changes occurring in the physico-chemical properties of the cytoplasm such as the greater hydration of colloids, the higher viscosity and elasticity of the protoplasm, the greater amount of water, more intense metabolism, variations in xenomorphic structures and more intense transpiration. The ability to retain greater quantity of water associated with a more efficient root system is the results of these changes. This hardening accelerates rapid germination and growth rate of seedlings. It is an important morphological adaptation in plants that helps in drought resistance without loosing productivity. Though required in minute quantities, micro-nutrients play vital role in the growth of plant (Benepal, 1967). They improve general condition of plants and are known to act as catalysts in promoting organic reactions taking place in plant. Soil application of Ca, Zn and K is less efficient, as these nutrients remain inaccessible to plant roots due to higher soil pH (Singh *et al.,* 2015). In such circumstances foliar application becomes the alternative cost effective method. Since limited data is available on complementary effect of pre-hardening treatments and foliar application on growth and yield of *Bt* cotton, present study was undertaken to evaluate the influence of both on growth and yield in *Bt* cotton.

Materials and Methods

A field experiment was carried at Agricultural Research Station, Dharwad farm during the *kharif* season of year 2011 under rainfed condition. The trial was fourteen treatments laid under randomized complete block design with three replications. Seeds were sown by hand dibbling with a spacing of 90 cm × 60 cm. Prior to sowing, the seeds were subjected to pre-sowing treatments with water, $CaCl_2$ (2%), CCC (100 ppm), KNO_3 (0.5%), $ZnSO_4$ (0.5%) in the ratio of 2:1 solution to seeds for 8 h and seeds were dried under shade and then under sun. The foliar sprays were given for all the treatments at 70 and 90 DAS (days after sowing). Plant height, no. of monopodial and sympodial branches was recorded in five randomly selected plants in a plot of each treatment. The leaf area index was calculated by dividing the leaf area per plant by land area occupied by the plant and is defined as the assimilatory surface area per unit land area given by Sestak *et al.* (1971). The total dry matter and its distribution in leaf, stem and reproductive parts was worked out from the average of three randomly selected plants which were dried at 80^0C till a constant weight and is expressed as g/plant.

Absolute growth rate (AGR g d^{-1}), crop growth rate (CGR g m^{-2} d^{-1}) and net assimilation rate (NAR g m^{-2} d^{-1}) and relative growth rate (RGR g g^{-1} d^{-1}) were computed for 120-150 DAS.

Absolute growth rate (AGR) is the dry matter production per unit time (g day^{-1}), which was calculated by using the formula of Radford (1967).

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Crop growth rate (CGR) is the ratio of dry matter production per unit ground area per unit time, which was calculated by adopting the formula given by Watson (1952) and expressed as g m^{-2} day^{-1}.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

Relative growth rate (RGR) is the rate of increase in the dry weight per unit dry weight already accumulated and was calculated by using the formula of Blackman (1919).

$$RGR = \frac{Log_e W_2 - Log_e W_1}{t_2 - t_1}$$

Net assimilation rate (NAR) is the rate of dry weight increase per unit leaf area per unit time, which was calculated by the formula of Gregory (1926) and expressed as g m^{-2} day^{-1}.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1}$$

Specific leaf weight (SLW) indicates the average leaf thickness and was determined by the method of Radford (1967) and expressed as mg cm^{-2}.

$$SLW = \frac{\text{Leaf dry weight per plant (mg)}}{\text{Leaf area per plant (cm}^2\text{)}}$$

Results and Discussion

The seed hardening treatments, foliar spray and their application in combination had a significant influence on growth and development of Bt-cotton (Table 1). Highest (112.7 cm) plant height was recorded in treatment T_5 *viz.,* seed hardening @ 2% and foliar nutrition @ 0.5%. with $CaCl_2$ followed by seed treatment and foliar spray with $ZnSO_4$ at 0.5% (108.5 cm) and KNO_3 @ 0.5% (103.4 cm). Lowest plant height was recorded with application of foliar spray CCC@20ppm (80.6 cm) and control (86.4 cm).

Table 1. Influence of seed hardening and foliar nutrition on morpho-physiological traits in Bt-cotton (*RCH-2*)

Treatments		Plant height (cm)	Monopodial branches	Sympodial branches	Leaf area index 150 DAS	Total dry matter (g/plant) 150 DAS
T_1	Seed treatment with $CaCl_2$ @ 2%	100.3	2.42	17.49	2.91	192.65
T_2	Seed treatment with CCC @ 100 ppm	92.6	2.36	17.02	2.62	187.84
T_3	Seed treatment with KNO_3 @ 0.5%	96.0	2.32	16.91	2.50	184.93
T_4	Seed treatment with $ZnSO_4$ @ 0.5%	97.2	2.39	17.22	2.79	190.44
T_5	Seed treatment with $CaCl_2$ @ 2% and Foliar spray with $CaCl_2$ @ 0.5% at 70 and 90 DAS	112.7	2.94	18.80	3.62	233.36
T_6	Seed treatment with CCC @ 100 ppm and Foliar spray with CCC @ 20 ppm at 70 and 90 DAS	95.2	2.78	18.10	3.40	219.67
T_7	Seed treatment with KNO_3 @ 0.5% and Foliar spray with KNO_3 @ 0.5% at 70 and 90 DAS	103.4	2.72	17.80	3.26	211.32
T_8	Seed treatment with $ZnSO_4$ @ 0.5% and Foliar spray with $ZnSO_4$ @ 0.5% at 70 and 90 DAS	108.5	2.82	18.40	3.54	226.53
T_9	Foliar spray with $CaCl_2$ @ 0.5% at 70 and 90 DAS	94.2	2.66	17.50	3.20	192.56
T_{10}	Foliar spray with CCC @ 20 ppm at 70 and 90 DAS	80.6	2.63	16.70	2.92	187.70
T_{11}	Foliar spray with KNO_3 @ 0.5% at 70 and 90 DAS	92.2	2.68	16.00	2.80	184.77
T_{12}	Foliar spray with $ZnSO_4$ @ 0.5% at 70 and 90 DAS	92.9	2.64	17.10	3.07	190.45
T_{13}	Water soaking	90.1	2.20	15.80	2.28	163.67
T_{14}	Control	86.4	1.90	15.10	1.89	143.72
	Mean	95.9	2.53	17.14	2.91	193.54
	SEm+	4.0	0.12	0.64	0.12	8.11
	CD @ 5%	11.7	0.36	1.86	0.36	23.58

DAS-Days after sowing

This indicates that mode of action is quite different for different chemicals. Earlier workers also reported that pre-sowing seed hardening of ragi seeds in different chemical solutions increased the plant height significantly (Karivaratharaju and Ramakrishnan, 1985) and ragi seeds treated with potassium and distilled water produced distinctly more plant height (Misra and Dwivedi, 1980).

The number of monopodial and sympodial branches differed significantly with differential seed treatments (Table 1). The highest number of monopodial (2.94) and sympodial (18.8) branches were observed in seed hardening @2% and foliar nutrition @0.5% with $CaCl_2$ which were on par with $ZnSO_4$ @0.5% (2.82) as compared with control (1.9). Selvaraj *et al.* (1978) reported that the increment in number of monopodial branches beyond 3 per plant had adverse effect on seed yield of cotton. This might be because of maximum competition for interception and shading at lower position of the canopy, thus affecting potential yield. Sympodial branches form the principal segment of cotton plant on which the fruiting bodies develop. Higher number of sympodia indicated the formation of more fruiting points (Knorgade and Ekbote, 1980; Giri and Upadyay, 1980; Soomro *et al.*, 1982). Hence, the number of sympodial branches has a great role in yield determination. Many workers have reported significant correlation for number of sympodia per plant with yield (Chen and Zhao, 1991, Basu and Bhat, 1987; Channaveeraiah, 1983). Medium sized 22 sympodial branches were considered as important character among morphological parameters for high yielding cotton.

Cotton is an intermediate crop where the vegetative and reproductive phases overlap resulting in intra plant competition for photosynthesis between developing bolls and vegetative parts (main stem, lateral branches and leaves). It was observed that there was significant increase in dry matter production of leaf, stem and reproductive parts due to seed hardening and foliar spray treatments and use of chemicals at different concentrations.

Among the treatments, seed hardening with $CaCl_2$ at 2% and foliar spray at 0.5% followed by seed treatment with $ZnSO_4$ at 0.5% and foliar spray at 0.5% recorded significantly higher weight of leaf, stem and reproductive parts compared to control. The amount of total dry matter produced is an indication of efficient utilization of resources and better light interception. These results are in concurrence with Arjunan and Srinivasan (1989), whose results also revealed that seed treatment with $CaCl_2$ at 1% significantly increased total dry matter produced in groundnut.

Growth parameters like AGR, CGR, RGR and NAR have been extensively used for better understanding of the physiological basis of yield variation in crop plants, leaf photosynthetic rates and LAI appeared to be major determinants of crop growth rate. The data revealed significantly higher AGR (4.64 g d^{-1}), CGR (8.59 g m^{-2} d^{-1}), NAR (0.89 g m^{-2} d^{-1}) RGR (1.35 g g^{-1} d^{-1}) and SLW (12.24 mg cm^{-2}) in seed hardening at 2% and foliar spray at 0.5% with $cacl_2$ followed by seed treatment and foliar spray with $ZnSO_4$ @ 0.5% (4.55 g d^{-1}, 8.43 g m^{-2} d^{-1}, 0.88 g dm^{-2} d^{-1} $\times10^{-2}$, 1.34 g g^{-1} $d^{-1}\times10^{-2}$ and 12.18 mg cm^{-2}, respectively) (Table 2). The increase in the growth parameters may be attributed to increase in photosynthetic efficiency with retention of more chlorophyll content and efficient translocation of photosynthates. These treatments activated the synthesis of proteins, free amino acids and soluble sugars at the first phases of germination (Jyotsna and Srivastava, 1998). Various researchers have reported on the effectiveness of seed hardening on the growth analysis parameters. Maitra *et al.* (1998) revealed that seed hardening with $CaCl_2$ at 2% significantly increased CGR over control in finger millet. Eshanna and Kulkarni (1990) revealed that pre-sowing seed treatment with $CaCl_2$ (1:3 proportions) recorded maximum NAR over control in maize. Thirumalaiswamy and Rao (1977) reported that seed treatment with cycocel significantly increased RGR under moisture stress condition and also the size of the leaves was greatly influenced by cycocel.

Table 2. Influence of seed hardening and foliar nutrition on growth indices in Bt-cotton (*RCH-2*)

	Treatments	Absolute growth rate ($g\ d^{-1}$)	Crop growth rate ($g\ m^{-2}\ d^{-1}$)	Net assimilation rate ($g\ m^{-2}\ d^{-1}$)	Relative growth rate ($g\ g^{-1}\ d^{-1}$)	Specific leaf weight ($mg\ cm^{-2}$)
		120-150	120-150	120-150	120-150	120
		DAS				
T_1	Seed treatment with $CaCl_2$ @ 2%	3.80	7.03	0.87	1.34	11.75
T_2	Seed treatment with CCC @ 100 ppm	3.81	7.05	0.85	1.31	11.63
T_3	Seed treatment with KNO_3 @ 0.5%	3.72	6.89	0.85	1.30	11.60
T_4	Seed treatment with $ZnSO_4$ @ 0.5%	3.83	7.10	0.86	1.34	11.69
T_5	Seed treatment with $CaCl_2$ @ 2% and Foliar spray with $CaCl_2$ @ 0.5% at 70 and 90 DAS	4.64	8.59	0.89	1.35	12.24
T_6	Seed treatment with CCC @ 100 ppm and Foliar spray with CCC @ 20 ppm at 70 and 90 DAS	4.42	8.19	0.87	1.34	12.01
T_7	Seed treatment with KNO_3 @ 0.5% and Foliar spray with KNO_3 @ 0.5% at 70 and 90 DAS	4.20	7.77	0.87	1.31	11.91
T_8	Seed treatment with $ZnSO_4$ @ 0.5% and Foliar spray with $ZnSO_4$ @ 0.5% at 70 and 90 DAS	4.55	8.43	0.88	1.34	12.18
T_9	Foliar spray with $CaCl_2$ @ 0.5% at 70 and 90 DAS	3.90	7.22	0.86	1.30	11.88
T_{10}	Foliar spray with CCC @ 20 ppm at 70 and 90 DAS	3.79	7.01	0.84	1.29	11.86
T_{11}	Foliar spray with KNO_3 @ 0.5% at 70 and 90 DAS	3.73	6.92	0.82	1.29	11.82
T_{12}	Foliar spray with $ZnSO_4$ @ 0.5% at 70 and 90 DAS	3.85	7.12	0.84	1.30	11.88
T_{13}	Water soaking	3.30	6.11	0.82	1.28	11.43
T_{14}	Control	2.87	5.32	0.78	1.23	11.09
	Mean	3.89	7.20	0.85	1.31	11.78
	SEm+	0.15	0.27	0.03	0.05	0.44
	CD @ 5%	0.42	0.78	0.09	0.14	1.28

DAS-Days after sowing

The influence of seed hardening treatments and foliar spray of chemicals significantly increased the cotton yield (Table 3). The increased cotton yield was attributed to higher dry matter production and its accumulation in reproductive parts. The data on present study revealed that the increase in Bt cotton yield was significantly more in seed hardening with $CaCl_2$ at 2% and foliar spray at 0.5% (2276 kg ha^{-1}) followed by seed treatment with $ZnSO_4$ at 0.5% and foliar spray at 0.5% (2179 kg ha^{-1}). Calcium serves as an important membrane stabilizer and specific activator for certain enzyme synthesis (Subbaraman and Selvaraj, 1989). It increases chlorophyll content which leads to better photosynthesis (Muhammad Iqbal *et al.* 2006). The seed hardening treatments enabled maximum water holding capacity of seeds, more intense photosynthetic activity and more tissue hydration, thereby enabling the plant to resist soil moisture

Table 3. Influence of seed hardening and foliar nutrition on yield and yield traits in Bt-cotton (*RCH-2*)

Treatments		Yield (kg ha^{-1})	Boll weight (g boll^{-1})	No. of bolls plant^{-1}
T_1	Seed treatment with $CaCl_2$ @ 2%	1968	4.02	22.00
T_2	Seed treatment with CCC @ 100 ppm	1903	3.79	21.00
T_3	Seed treatment with KNO_3 @ 0.5%	1877	3.52	21.00
T_4	Seed treatment with $ZnSO_4$ @ 0.5%	1939	3.93	22.00
T_5	Seed treatment with $CaCl_2$ @ 2% and Foliar spray with $CaCl_2$ @ 0.5% at 70 and 90 DAS	2276	5.12	28.00
T_6	Seed treatment with CCC @ 100 ppm and Foliar spray with CCC @ 20 ppm at 70 and 90 DAS	2102	4.32	24.00
T_7	Seed treatment with KNO_3 @ 0.5% and Foliar spray with KNO_3 @ 0.5% at 70 and 90 DAS	2013	4.07	23.00
T_8	Seed treatment with $ZnSO_4$ @ 0.5% and Foliar spray with $ZnSO_4$ @ 0.5% at 70 and 90 DAS	2179	4.78	26.00
T_9	Foliar spray with $CaCl_2$ @ 0.5% at 70 and 90 DAS	1958	4.04	21.00
T_{10}	Foliar spray with CCC @ 20 ppm at 70 and 90 DAS	1892	3.61	20.00
T_{11}	Foliar spray with KNO_3 @ 0.5% at 70 and 90 DAS	1846	3.40	20.00
T_{12}	Foliar spray with $ZnSO_4$ @ 0.5% at 70 and 90 DAS	1927	3.91	20.00
T_{13}	Water soaking	1803	3.21	18.00
T_{14}	Control	1780	3.01	16.00
	Mean	1962	3.91	21.57
	SEm+	33.69	0.19	0.81
	CD @ 5%	98	0.56	2.35

DAS-Days after sowing

stress more efficiently (Henckel, 1964). These results are in conformity with the findings of earlier researches who found that seed hardening with $CaCl_2$ @1% recorded significantly higher number of pods per plant and pod yield in groundnut (Arjunan and Srinivasan, 1989). Narayanaswamy and Shambalingappa (1998) reported on the increase in seed yield and yield attributes due to pre-sowing invigouration. Narayanareddy and Biradarpatil (2012) reported that hydration of sunflower seeds with 2% $CaCl_2$ for 12 h resulted in higher seed yield.

Conclusion

The present study reiterated the importance of seed hardening and foliar nutrition on growth and yield of Bt-Cotton. The morphological and growth parameters, yield and yield attributing characters significantly increased with the seed hardening and foliar spray with $CaCl_2$ @ 2 and 0.5% respectively over untreated control. Seed hardening enabled maximum water holding capacity of seeds, more intense photosynthetic activity and more tissue hydration, thereby enabling the plant to resist soil moisture stress more efficiently Hence, these treatments could be used for enhancing the yield of Bt-Cotton under rainfed condition.

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