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Response of Cotton Genotypes to Drought Mitigation Practices

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Abstract: A field experiment was conducted during kharif season 2004 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad to study the effect of drought management practices on yield and physio-biochemical traits in cotton genotypes. The experiment was laid out in split plot design, with four genotypes *viz.,* Jayadhar, Rahs-14, Abadhita and LRA-5166 and five drought management treatments: glycine betaine foliar spray @ 0.3%, proline seed treatment @ 0.1%, $CaCl_2$ seed treatment @ 2%, integrated drought management (IDM) practice and control. The IDM treatment consisted of FYM application 2 t/ha, seed hardening treatment with $CaCl_2$ @ 2%, wide row spacing (90-20), mulching, 0.3%, KCl foliar spray and kaoline foliar spray @ 1.25%. The results revealed that the genotype Jayadhar recorded significantly higher yield (721.2 kg/ha) and the magnitude of yield increase was 45 per cent higher than the lowest yielding genotype Abadhita (390.0 kg/ha). Similarly, Jayadhar recorded significantly higher specific leaf weight (771.9 mg/dm^2), relative water content (67.78%), leaf water potential (-17.5 bar), chlorophyll fluorescence (0.221 P/O), total chlorophyll content (1.65 mg/g), chlorophyll stability index (65.36%) and proline content (0.091 mg/g). Among the treatments, integrated drought management recorded significantly higher yield (639.89 kg/ha) and it was 27.5 per cent higher over control. IDM recorded higher values of specific leaf weight (747.3 mg/dm^2), relative water content (66.86%), leaf water potential (-19.83 bar), chlorophyll fluorescence (0.202 P/O), total chlorophyll content (1.55 mg/g), chlorophyll stability index (71.12%) and proline content (0.082 mg/g).

Key words: Cotton · Drought management · Relative water content · Glycine betaine · Proline

INTRODUCTION

Cotton, the king of fibre crops is also known as white gold and is the main raw material for textile industry. It is the most important global cash crop and controls economy of many nations. Cotton provides gainful employment to several million people in cultivation, trade, processing, manufacturing and marketing, sustaining directly or indirectly about 10 per cent of the population of India. Like most major agricultural crops, cotton production and productivity is negatively influenced by moisture stress. Nearly, 60 per cent cotton growing area falls under rainfed conditions and is characterized by scarcity of soil moisture. Depending upon the extent of residual soil profile moisture and the scarce winter rains, cotton suffers to varying degree due to mounting moisture stress and consequently the productivity declines. To combat such adverse soil moisture scarcity conditions, matching integrated drought management practices need to be evolved for various agro-ecological regions. Several such practices *viz*., pre-sowing seed treatments to induce seed hardening [1], foliar spray of osmolytes [2, 3, 4], fertilizer solutions [5] and mulching [6] have been reported to increase productivity of cotton.

The research work with respect to the possibilities of overcoming stresses, imposed by environmental factor is limited. It is important to understand how best the stress effect can be minimized by adopting different strategies and to elucidate the impact of such strategies in enhancing productivity potential of cotton under water limited conditions. For this, a better understanding of yield, physiological and biochemical parameters that influence crop yields would provide valuable information for exploiting genetic variability. In this direction, investigation was carried out to know the effect of drought management practices on yield and physio-biochemical parameters in cotton genotypes.

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MATERIALS AND METHODS

A field experiment was conducted during kharif season of 2004 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad on medium deep black soil. The experiment was laid out in split-plot design with three replications. Main plots were allotted with genotypes viz., Jayadhar, Rahs-14, LRA-5166 and Abadhita. Sub-plots were allotted with drought management treatments viz., glycine betaine foliar spray @ 0.3%, proline seed treatment @ 0.1%, $CaCl_2$ seed hardening @ 2%, integrated drought management (IDM) and control. The integrated drought management (IDM) treatment comprised of FYM application @ 2 t per ha, seed hardening by $CaCl_2$ @ 2%, wide row planting (90 × 20 cm), mulching, KCl foliar spray @ 0.3% and kaoline foliar spray @ 1.25%. The crop was sown in the month of July with a spacing of 60 × 30 cm. Fertilizers were applied as per the recommendation (40:20:20 N, P_2O_5, K_2O kg/ha), 50% N, 100% P and K fertilizers were applied as basal and remaining 50% N was applied at 30 DAS. The total rainfall during cropping period was 315.3 mm, received in 33 rainy days. The leaf water potential was measured by Dew Point Microvoltmeter, chlorophyll fluorescence was measured by Teaching-PAM chlorophyll fluorometer, relative water content was estimated as per the method of Barrs and Weatherly [7]. The proline content was estimated as per the method of Bates *et al*. [8] and chlorophyll content was estimated as per the method of Hiscox and Israelstam [9].

RESULTS AND DISCUSSION

Genotypes differ in their yield potential depending on many factors and are the resultant of a complex process occurring in various parts of plant involving many yield and morphological changes which are controlled by both genetic make up and environment. Yield potential of a genotype lies in its ability to produce more number of sympodial branches, squares and bolls per plant. Among the genotypes studied, Jayadhar (721.2 kg/ha), Rahs-14 (604.5 kg/ha) and LRA-5166 (455.6 kg/ha) recorded significantly higher yield and the magnitudes of yield increase was 45, 35 and 14.4 per cent higher than Abadhita (390.0 kg/ha), respectively (Table 1).

The yield levels of all cotton genotypes are less mainly because of insufficient rainfall to meet crop requirement. During the cropping period (July-February) 315.3 mm total rainfall was received in 33 rainy days. Cotton crop experienced moisture stress in the months of November, December, January and February and total rainfall of 3.2 mm was received which it was coincided with critical water requirement of cotton. The drought management practices studied in this investigation have

Table 1: Effect of drought management practices on yield and physio-biochemical parameters in cotton genotypes under rainfed condition

	Seed cotton yield (g/plant)	Seed cotton yield (kg/ha)	Specific leaf weight (mg/dm^2)	Relative water content RWC (%)	Leaf water potential (bars)
Genotypes (G)					
G_1 - Abadhita	7.06	390.0	627.86	48.34	-30.70
G_2 - LRA-5166	8.26	455.6	630.30	59.87	-25.34
G_3 - Rahs-14	10.91	604.5	724.80	63.25	-21.38
G_4 - Jayadhar	12.98	721.2	771.90	67.78	-17.50
S. Em±	0.22	11.06	10.27	0.80	0.46
CD at 5%	0.77	38.27	35.54	2.76	1.60
Treatments (T)					
T_1 - Glycine betaine @ 0.3% foliar spray	9.80	543.13	702.60	60.62	-23.28
T_2 - Proline @ 0.1% seed treatment	9.08	504.16	663.20	57.34	-24.93
T_3 - $CaCl_2$ @ 2% seed treatment,	10.16	563.89	730.17	62.85	-23.00
T_4 - IDM (FYM 2 t/ha, $CaCl_2$ 2% seed treatment, Wide row, Mulch, KCl 0.3%, Kaoline 1.25%)	11.56	639.89	747.30	66.86	-19.83
T_5 - Control	8.43	463.86	600.20	51.37	-27.60
S. Em±	0.22	11.18	9.60	0.96	0.52
CD at 5%	0.64	32.21	27.67	2.75	1.49
G × T at same treatment					
S. Em±	0.45	22.36	19.21	1.909	1.03
CD at 5%	NS	NS	NS	NS	NS
G × T at same/different treatment					
S. Em±	0.46	22.85	20.02	1.88	1.03
CD at 5%	NS	NS	NS	NS	NS

IDM = Integrated drought management NS = Non-significant significantly increased the cotton yield compared to control. Cotton yield ha^{-1} due to drought management practices viz., glycine betaine foliar spray (543.13 kg/ha), proline seed treatment (504.16 kg/ha), $CaCl_2$ seed treatment (563.89 kg/ha) and integrated drought management (639.89 kg/ha) recorded significantly higher yield and the extent of increase was 12.4, 8.7, 15.62 and 27.5 per cent higher than the control(463.86 kg/ha), respectively.

A better understanding of different physio-biochemical processes is essential to know the mechanism of drought tolerance in crop plants. Specific leaf weight (SLW) is the integral structure of the leaf and is known to have correlation with photosynthetic rate [10]. The results with respect to SLW differed significantly among the genotypes, Jayadhar (771.9 mg/dm^2) and Rahs-14 (724.8 mg/dm^2) recorded significantly higher SLW (Table 1). Among different drought management treatments, integrated drought management recorded significantly higher SLW (747.3 mg/dm^2), followed by $CaCl_2$ seed treatment (730.17 mg/dm^2), glycine betaine foliar spray (702.6 mg/dm^2) and proline seed treatment (663.2 mg/dm^2). Higher SLW noticed at early stage in the present study might have helped in enhancing the photosynthetic rate resulting in better growth.

Two physiological parameters that describe the water status of plants are relative water content (RWC) and leaf water potential. The RWC is a measure of the amount of water present in the leaf tissue and the treatment having higher RWC under stress conditions would be preferable to maintain water balance. In the present study, Jayadhar (67.7%) maintained higher RWC followed by Rahs-14 (63.25%) and Abadhita (59.87%). Jayadhar is known for its relatively better drought tolerance. Among the treatments, integrated drought management treatment recorded significantly higher RWC (66.86%) followed by $CaCl_2$ seed treatment (62.85%), foliar spray of glycine betaine (60.62%) and the proline (62.85%).

Water potential of a plant equals the sum of various component potentials. Solute potential is (Ψ_s) dictated by number of particles dissolved in water. Water potential was decreased as solute concentration increased. Pressure potential (Ψ_p) reflects physical forces exerted on water by its environment. Significant differences were observed for leaf water potential at all growth stages. Results of the present study indicated that leaf water potential was decreased with increasing crop growth and decreased soil moisture content. Similar results were obtained by Singh *et al.* [11]. The genotypes, Jaydhar (-17.50 bars) and Rahs-14 (-21.38 bars) recorded significantly higher leaf water potential under moisture stress. This is due to the fact that drought tolerant plants can regulate their solute potential to compensate for transient or extended periods of water stress, by the process called osmotic adjustment, which results from a net increase in the number of solute particles present in the plant cell. Through decreasing the plant solute potential, osmotic adjustment can drive root water potential to values lower than soil water potential, thus allowing water to move from soil to plant down a potential gradient. Osmotic adjustment is believed to play a critical role in helping plants acclimatize to drought conditions. Among the drought management treatments, integrated drought management treatment (-19.83 bar), $CaCl_2$ seed treatment (-23.00 bar) and glycine betaine foliar spray (-23.28 bar) recorded significantly higher leaf water potential. This increase in water potential under moisture stress condition is due to accumulation of osmolytes, which plays an important role in osmoregulation.

Chlorophyll fluorescence is directly correlated to the leaf water potential and as the leaf water potential decreases chlorophyll fluorescence also decreases and vice versa. Significant differences were observed for chlorophyll fluorescence among the genotypes and drought management treatments. Results in the present study indicated that the chlorophyll fluorescence decreased along with decrease in leaf water potential. Similarly, Govindjee *et al.* [12] reported that chlorophyll 'a' fluorescence decreased along with decrease in leaf water potential. In the present study, Jaydhar (0.221 p/o) and Rahs-14 (0.166 p/o) recorded significantly higher chlorophyll florescence. Among the treatments, it has been observed that chlorophyll fluorescence was highest in integrated drought management (0.202 p/o), $CaCl_2$ seed treatment (0.158 p/o) and glycine betaine foliar spray (0.151 p/o).

Significant increase in chlorophyll 'a', 'b' and total chlorophyll contents was observed due to integrated drought management treatment, osmolyte spray and seed hardening at all the stages. Among the genotypes, Jayadhar recorded significantly higher chlorophyll content compared to other genotypes. Among the treatments, the maximum chlorophyll 'a', 'b' and total chlorophyll contents were observed in integrated drought management.

The chlorophyll stability index (CSI) was higher in drought tolerant genotypes Jayadhar (65.36 %) and Rahs-14 (62.36 %) compared to other genotypes (Table 2). There was reduction in total chlorophyll content due to higher temperature stress among drought susceptible genotypes. The decrease in chlorophyll content due to high temperature stress and water stress was due to loss

Table 2: Effect of drought management practices on physio-biochemical parameters in cotton genotypes under rainfed condition

	Chlorophyll fluorescence (p/o)	Chlorophyll 'a' content (mg/g f. w)	Chlorophyll 'b' content (mg/g f. w)	Total chlorophyll (mg/g f. w)	Chlorophyll stability index (CSI) %)	Proline content (mg/g fresh weight)
Genotypes (G)						
G_1 - Abadhita	0.097	0.81	0.28	1.08	54.43	0.064
G_2 - LRA-5166	0.116	0.95	0.37	1.32	58.82	0.069
G_3 - Rahs-14	0.166	1.02	0.45	1.46	62.36	0.078
G_4 - Jayadhar	0.221	1.07	0.58	1.65	65.36	0.091
S. Em±	0.005	0.01	0.01	0.06	0.94	0.001
CD at 5%	0.018	0.05	0.04	0.20	3.27	0.004
Treatments (T)						
T_1 - Glycine betaine @ 0.3% foliar spray	0.151	0.98	0.42	1.40	66.12	0.076
T_2 - Proline @ 0.1% seed treatment	0.132	0.92	0.38	1.37	63.20	0.072
T_3 - $CaCl_2$ @ 2% seed treatment,	0.158	0.99	0.45	1.45	68.23	0.078
T_4 - IDM (FYM 2 t/ha, $CaCl_2$ 2% seed treatment, Wide row, Mulch, KCl 0.3%, Kaoline 1.25%)	0.202	1.10	0.49	1.55	71.12	0.082
T_5 - Control	0.108	0.83	0.34	1.18	58.12	0.068
S.Em±	0.060	0.01	0.01	0.65	0.91	0.001
CD at 5%	0.017	0.04	0.04	0.19	2.63	0.004
G × T at same treatment						
S. Em±	0.012	0.27	0.03	0.13	1.83	0.003
CD at 5%	NS	NS	NS	NS	NS	NS
G × T at same/different treatment						
S. Em±	0.012	0.03	0.03	0.11	1.89	0.003
CD at 5%	NS	NS	NS	NS	NS	NS

IDM = Integrated drought management NS = Non-significant

of chloroplast membrane integrity under water deficit situation. Among the drought mitigation treatments, integrated drought management practices (71.12 %), $CaCl_2$ seed treatment (68.23 %) and glycine betaine foliar spray (66.12 %) recorded significantly higher chlorophyll stability index compared to control (58.12%).

Free proline content has been shown to accumulate upon desiccation in leaves of many plant species. It has been suggested by Jones *et al.* [13] that accumulation of proline could make useful contribution to the osmotic adjustment. Proline plays an important role as storage compound for carbon and nitrogen, detoxification of NH_3, preserving the hydration of proteins in dehydrated tissues thereby contributing to the survival of cellular functions. In the present study, Jayadhar (0.091 mg/g) and Rahs-14 (0.078 mg/g) recorded significantly higher proline content followed by LRA-5166 (0.069 mg/g) and lowest proline content was recorded in Abadhita (0.064 mg/g). Among the treatments, it is noticed that integrated drought management treatment recorded significantly higher proline content (0.082 mg/g) followed by seed treatment with $CaCl_2$ (0.078 mg/g) and glycine betaine foliar spray (0.076 mg/g).

Under rainfed conditions plant suffers from terminal drought stress. This drought affects plant by reduction in soil moisture, excess transpiration from plant, stomatal activity, more germination time, loss in turgor pressure, shrinkage of cytoplasm and loss of plant cell water. IDM treatment takes care of all these factors *i.e.*, the mulching increases the soil moisture content, infiltration rate and conservation of soil moisture by suppressing excess evaporation and FYM application increases the water holding capacity of the soil, infiltration rate and total porosity [14]. Application of antitranspirant kaoline reduces excess transpiration, increases leaf water potential and relative water content [15]. Seed hardening has been reported to induce drought resistance in the plants. The hardened seeds have usually greater capacity to withstand dehydration and over heating. The other beneficial effects of hardening are inducing better root growth, higher rate of photosynthesis and more dry matter accumulation [16]. The KCl spray plays important role in osmoregulation and helps in maintaining turgor pressure, thereby IDM enables the plant to acclimatize to the soil moisture stress.

CONCLUSION

Among the genotypes, Jayadhar gave significantly higher yield compared to the other genotypes under rainfed conditions. Among the treatments, integrated drought management practices, gave significantly higher yield compared to the other drought management treatments. Therefore, it could be concluded that the drought resistance genotype Jayadhar along with IDM is better for enhancing productivity under rainfed conditions.

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