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Water Stress Affects Plant Relative Water Content, Soluble Protein, Total Chlorophyll Content and Yield of Ratoon Banana

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Abstract Twelve cultivars of banana plants were grown in field conditions and were studied under two irrigation regimes under ratoon season in order to evaluate the relative water content, soluble protein content, total chlorophyll content and yield changes induced by water deficit. Irrigation was applied when soil water potential reached at 80 per cent ASM for the wet treatments and 50 per cent ASM for the stressed treatment plots. The ASM were calculated based on the soil moisture release curve. The soil moisture content was measured by using pressure plate membrane apparatus. The cultivars and hybrids of Karpuravalli, Karpuravalli x Pisang Jajee, Saba, and Sannachenkathali, the RWC was reduced in water-stressed leaves with 8 per cent over control, which could have accounted for the decreased soluble protein, total chlorophyll content and yield in the per cent reduction of 9 and 8 than the other cultivars and hybrids. The highest reduction of 24 per cent in RWC leads to 19 and 18 per cent reduction in soluble protein and chlorophyll content due to water deficit were registered by the cultivars and hybrid of Matti, Pisang Jajee x Matti, Matti x Anaikomban and Anaikomban x Pisang Jajee leads to reduce the yield.

Keywords Ratoon Banana; Water deficit; RWC; Soluble protein; Total chlorophyll and yield

Abbreviations: ASM: Available Soil Moisture; RWC: Relative Water Content; **: Highly significant; *: Significant)

Introduction

In the forthcoming days drought is a major factor to limit plant productivity in many regions of the world. Most of the research studies have shown that, the plant growth rates were directly proportional to the availability of water in the soil (Kamel and Loser, 1995). In drought, water deficit causes biochemical and physiological processes was changed ranging from photosynthesis

to protein synthesis and also solute accumulation (Hu and Schmidhalter, 1998). The limited water resources in the area and the cost of pumping irrigation water are the most important factors that force many farmers to reduce irrigation in many arid and semi-arid regions. Banana is an important tropical fruits. In production viz., Tamil Nadu rank first in banana. Among the all fruit crops banana is the fourth largest fruit crop in the world. It is one of the most important fruit crops that can tolerate short periods of water deficit (Turner, 1998). This deficiency results in a water shortage for some activity, group, or environmental sector. Banana plant productivity is greatly affected by environmental stresses such as drought, water and cold. Plants respond and adopt to these stresses to survive under stress condition at the molecular and cellular levels as well as at the physiological and biochemical levels. Physiological responses to soil water deficit are the feature that is most likely to determine the response of the crop to irrigation. The banana plants are sensitivity to soil moisture stress is reflected in changes in reduced growth through reduced relative water content, soluble protein content and leaf size leads to reduction in photosynthetic pigments (Kallarackal et al., 1990) with increased leaf senescence (Turner, 1998). The banana plants are able to maintain their internal water status during drought by reducing radiation load and closing stomata (Thomas and Turner, 1998).The RWC was estimated in order to find out the plant water status of banana cultivars under water stress situations. Leaf RWC had a significant influence on photosynthesis, by reducing the net photosynthesis by more than 50 per cent when RWC was less than 80 per cent. As observed by Slatyer (1955), a reduction by 5% in RWC led to reduction in photosynthesis by 40% to 50 %. The soluble protein content of the leaf, being a measure of RuBP carboxylase activity was considered as an index for photosynthetic efficiency. There were reports that

RuBP-case enzyme forms nearly 80 per cent of the soluble proteins in leaves of many plants (Joseph et al., 1981). Diethelm and Shibles (1989) opined that the RUBISCO content per unit leaf area was positively correlated with that of souble protein content of the leaf. Soluble protein content was estimated in order to find out the photosynthetic capacity of banana cultivars under water deficit situations. With this above background, the experiment aimed at evaluating the effects of the progressive water deficit, as well as to investigating the physiological and biochemical behavior in twelve banana cultivars and hybrids submitted to water restriction during the different growth stages.

1 Result

1.1 Relative Water Content

The time trend of RWC revealed a gradual increase upto 7Th MAP with a slight decline towards harvest. Analyzing the two main plot treatments, M_1 recorded a higher value of 75.5 per cent and M_2 with a value of 66.0 per cent with a 13 per cent reduction over M1 at 7th MAP (Table 1). Sub-plot treatment was also significantly differed among themselves. S_1 recorded the highest RWC of 81.1 per cent. This was followed by S_2 (80.4%) and S_3 (77.5%). The lowest RWC of 61.1 per cent was recorded by S_{12} followed by S_{11} (61.3%). The interaction effect of M at S and S at M also varied significantly. M1 subplot interactions registered comparatively higher values than M2 subplot interactions. However, a considerable reduction could also be noticed in RWC due to interaction with M_2 and subplot treatments. M_2S_1, M_2S_2, M_2S_3 and M_2S_4 recorded 5 to 6 per cent reduction, and M_2S_5, M_2S_6, M_2S_7 and M_2S_8 showed about 12 to 14 per cent reduction, whereas, M_2S_9, $M_2S_{10,}$ M_2S_{11} and M_2S_{12} exhibited in the range of 20 to 21 per cent over M_1 and subplot treatments. In this research study, the RWC was positively correlated with yield (Figure 1).

1.2 Soluble protein

The data on soluble protein content indicated a slight increase from 3rd to 7th MAP with a decline towards harvest (Table 2). The main plots M_1 and M_2 differed significantly at all the stages of growth. Among the main plots, M_1 recorded highest protein content of 10.1 mg/g at 7th MAP whereas, M_2 recorded 8.7 mg/g therefore a 14 per cent reduction was observed in M_2 over M_1. All the subplot treatments significantly differed, among them, S_1 registered the highest protein content of 11.6 mg g^{-1} and the lowest protein content was recorded in S_{12} (8.0 mg/g). Interaction effects of M at S and S at M also exhibited significant variations at all the stages of growth. All the M_1 subplot interactions registered comparatively higher values. The highest value of 12.2 mg/g was recorded by M_1S_1 followed by M_1S_2 (11.1 mg/g) M_1S_4 (10.4 mg/g) and M_1S_3 (10.3 mg/g). A remarkable reduction in protein content could also be observed as the result of the interaction of M_2 and subplots. M_2S_1, M_2S_2, M_2S_3 and M_2S_4 showed a reduction of about 9 to 12 per cent, and M_2S_5 $M_2S_{6,}$ M_2S_7 to M_2S_8 recorded about 13 to 14 per cent, whereas M_2S_9, $M_2S_{10,}$ M_2S_{11} and M_2S_{12} showed about 16 to 18 per cent reduction over the M_1 and sub plot treatments.

1.3 Total chlorophyll content

The result of total chlorophyll content showed a similar pattern of chlorophyll 'a', chlorophyll 'b' (Table 3). The two main plot treatments differed significantly at all growth stages. Between the main plot M_1 recorded higher total chlorophyll content of 1.10 mg/g than M_2 (0.98 mg/g) 7th MAP. M_2 registered 11 per cent reduction in total chlorophyll content over M1. All the sub-plot treatments differed significantly, among them, S_1 showed rank first 1.38 mg/g followed by S_2 (1.28 mg/g), S_3 (1.16 mg/g) and S_4 (1.12 mg/g). The lowest content was recorded by S_{12} (0.79 mg/g) at 7th MAP. The interaction effects of M at S and S at M were significantly differed at all growth stages. Here, M_1S_1 registered the highest total chlorophyll content of 1.42 mg/g followed by M_1S_2 (1.31 mg/g). However, the interaction between M_2 subplot treatments resulted a considerable reduction over the M_1 and subplots. $M_2S_{1,}$ $M_2S_{2,}$ $M_2S_{3,}$ and M_2S_4 resulted in a lower range of 5 to 8 per cent reduction. However, all the other treatments showed a greater reduction per cent of 12 to 15 over the interaction between M_1 and sub plot treatments.

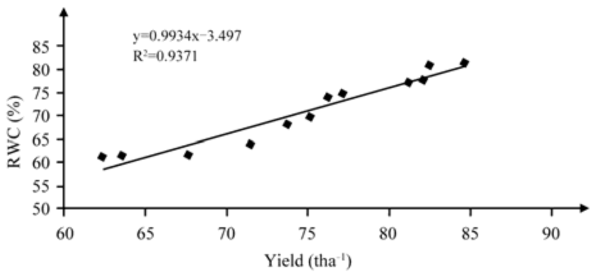

Figure 1 Correlation of RWC and yield in banana cultivars and hybrids

Table 1 Effect of water stress on Relative Water Content (RWC: %) at different growth stages of banana cultivars in ratoon crop

Treatments	3rd MAP	5th MAP	7th MAP	9th MAP	Harvest	Mean
Main plot						
M_1	72.7	74.4	75.5	70.4	70.2	72.67
M_2	63.2	64.9	66.0	60.9	60.7	63.13
Mean	67.96	69.66	70.76	65.66	65.46	67.90
SEd	0.42	0.43	0.48	0.41	0.41	
CD (P=0.05)	1.83	1.87	2.06	1.77	1.76	
Sub plot						
S_1	78.3	80.0	81.1	76.0	75.8	78.25
S_2	77.6	79.3	80.4	75.3	75.1	77.55
S_3	74.7	76.4	77.5	72.4	72.2	74.65
S_4	74.2	75.9	77.0	71.9	71.7	74.15
S_5	71.4	73.1	74.2	69.1	68.9	71.35
S_6	70.7	72.4	73.5	68.4	68.2	70.65
S_7	67.0	68.7	69.8	64.7	64.5	66.95
S_8	65.3	67.0	68.1	63.0	62.8	65.25
S_9	60.9	62.6	63.7	58.6	58.4	60.79
S_{10}	58.8	60.5	61.6	56.5	56.3	58.69
S_{11}	58.5	60.2	61.3	56.2	56.0	58.39
S_{12}	58.3	60.0	61.1	56.0	55.8	58.19
Mean	67.96	69.66	70.76	65.66	65.46	67.90
SEd	0.90	0.92	0.93	0.87	0.87	
CD (P=0.05)	1.82	1.86	1.88	1.77	1.76	
Interaction effect						
M_1S_1	80.6	82.3	83.4	78.3	78.1	80.57
M_1S_2	79.9	81.6	82.7	77.6	77.4	79.87
M_1S_3	77.0	78.7	79.8	74.7	74.5	76.97
M_1S_4	76.5	78.2	79.3	74.2	74.0	76.47
M_1S_5	76.2	77.9	79.0	73.9	73.7	76.17
M_1S_6	75.5	77.2	78.3	73.2	73.0	75.47
M_1S_7	71.8	73.5	74.6	69.5	69.3	71.77
M_1S_8	70.1	71.8	72.9	67.8	67.6	70.07
M_1S_9	68.0	69.7	70.8	65.7	65.5	67.97
M_1S_{10}	65.9	67.6	68.7	63.6	63.4	65.87
M_1S_{11}	65.6	67.3	68.4	63.3	63.1	65.57
M_1S_{12}	65.4	67.1	68.2	63.1	62.9	65.37
M_2S_1	76.0	77.7	78.8	73.7	73.5	75.92
M_2S_2	75.3	77.0	78.1	73.0	72.8	75.22
M_2S_3	72.4	74.1	75.2	70.1	69.9	72.32
M_2S_4	71.9	73.6	74.7	69.6	69.4	71.82
M_2S_5	66.6	68.3	69.4	64.3	64.1	66.52
M_2S_6	65.9	67.6	68.7	63.6	63.4	65.82
M_2S_7	62.2	63.9	65.0	59.9	59.7	62.12
M_2S_8	60.5	62.2	63.3	58.2	58.0	60.42
M_2S_9	53.7	55.4	56.5	51.4	51.2	53.62
M_2S_{10}	51.6	53.3	54.4	49.3	49.1	51.52
M_2S_{11}	51.3	53.0	54.1	49.0	48.8	51.22
M_2S_{12}	51.1	52.8	53.9	48.8	48.6	51.02
Mean	67.96	69.66	70.76	65.66	65.46	67.90
SEd						
M at S	1.29	1.32	1.35	1.25	1.25	
S at M	1.28	1.30	1.32	1.24	1.23	
CD (P=0.05)						
M at S	2.93	3.00	3.12	2.84	2.83	
S at M	2.57	2.63	2.66	2.50	2.49	

Table 2 Effect of water stress on foliage soluble protein (mg/g) at different growth stages of banana cultivars in ratoon crop

Treatments	3rd MAP	5th MAP	7th MAP	9th MAP	Harvest	Mean
Main plot						
M_1	9.5	9.7	10.1	8.5	4.4	8.44
M_2	7.5	7.7	8.7	7.1	3.4	6.89
Mean	8.54	8.67	9.41	7.80	3.92	7.67
SEd	0.049	0.049	0.053	0.048	0.024	
CD (P=0.05)	0.211	0.214	0.229	0.208	0.106	
Sub plot						
S_1	10.6	10.8	11.6	10.6	5.0	9.72
S_2	9.8	8.3	9.5	9.7	3.9	8.23
S_3	9.1	8.0	8.7	8.3	3.7	7.58
S_4	7.7	8.3	8.8	6.1	4.5	7.09
S_5	8.5	9.3	10.3	5.8	3.8	7.55
S_6	7.3	9.8	10.1	6.6	4.7	7.68
S_7	8.2	8.7	8.6	6.6	3.4	7.11
S_8	8.3	7.7	9.3	7.7	3.6	7.33
S_9	9.1	7.0	8.9	8.3	3.7	7.41
S_{10}	9.0	8.3	8.1	8.5	3.4	7.47
S_{11}	7.8	9.4	9.3	7.8	3.7	7.61
S_{12}	7.1	8.5	9.6	7.4	3.5	7.21
Mean	8.54	8.67	9.41	7.80	3.92	7.67
SEd	0.129	0.132	0.134	0.123	0.067	
Interaction effect						
CD (P=0.05)	0.261	0.267	0.270	0.249	0.136	
M_1S_1	11.2	11.4	12.2	11.2	5.3	10.27
M_1S_2	10.4	8.9	10.1	10.3	4.2	8.78
M_1S_3	9.7	8.6	9.3	8.9	4.1	8.12
M_1S_4	8.3	8.9	9.4	6.7	4.9	7.64
M_1S_5	9.7	10.5	11.0	6.5	4.3	8.38
M_1S_6	8.4	10.9	10.8	7.2	5.2	8.51
M_1S_7	9.4	9.8	9.3	7.3	3.9	7.94
M_1S_8	9.4	8.9	10.0	8.4	4.1	8.16
M_1S_9	10.3	8.3	9.7	9.2	4.3	8.36
M_1S_{10}	10.2	9.6	9.0	9.3	4.0	8.42
M_1S_{11}	9.1	10.7	10.1	8.6	4.3	8.56
M_1S_{12}	8.3	9.7	10.4	8.2	4.1	8.16
M_2S_1	10.0	10.2	11.0	10.0	4.6	9.17
M_2S_2	9.2	7.7	8.9	9.1	3.5	7.68
M_2S_3	8.5	7.4	8.1	7.7	3.4	7.03
M_2S_4	7.1	7.7	8.2	5.5	4.2	6.54
M_2S_5	7.4	8.2	9.7	5.1	3.3	6.73
M_2S_6	6.1	8.6	9.5	5.9	4.2	6.85
M_2S_7	7.1	7.5	8.0	6.0	2.9	6.29
M_2S_8	7.1	6.6	8.6	7.1	3.1	6.50
M_2S_9	7.8	5.8	8.1	7.5	3.1	6.46
M_2S_{10}	7.7	7.1	7.3	7.7	2.8	6.53
M_2S_{11}	6.6	8.1	8.5	7.0	3.1	6.66
M_2S_{12}	5.8	7.2	8.8	6.6	2.9	6.26
Mean	8.54	8.67	9.41	7.80	3.92	7.67
SEd						
M at S	0.183	0.186	0.188	0.174	0.094	
S at M	0.183	0.187	0.189	0.174	0.095	
CD (P=0.05)						
M at S	0.405	0.405	0.409	0.382	0.205	
S at M	0.369	0.378	0.382	0.352	0.192	

Table 3 Effect of water stress on total chlorophyll (mg/g) at different growth stages of banana cultivars in ratoon crop

Treatments	3rd MAP	5th MAP	7th MAP	9th MAP	Harvest	Mean
Main plot						
M_1	0.71	1.08	1.10	0.69	0.51	0.82
M_2	0.59	0.95	0.98	0.62	0.45	0.72
Mean	0.65	1.02	1.04	0.66	0.48	0.77
SEd	0.031	0.052	0.060	0.034	0.026	
CD (P=0.05)	0.134	0.226	0.260	0.146	0.113	
Sub plot						
S_1	0.79	1.36	1.36	0.82	0.65	1.00
S_2	0.76	1.26	1.25	0.79	0.65	0.94
S_3	0.77	1.16	1.16	0.78	0.60	0.89
S_4	0.75	1.12	1.12	0.75	0.57	0.86
S_5	0.68	1.01	1.05	0.69	0.53	0.80
S_6	0.67	0.98	1.02	0.68	0.53	0.78
S_7	0.64	0.95	0.98	0.64	0.47	0.74
S_8	0.63	0.93	0.97	0.61	0.46	0.72
S_9	0.58	0.93	0.96	0.59	0.42	0.70
S_{10}	0.55	0.89	0.92	0.55	0.33	0.65
S_{11}	0.50	0.81	0.84	0.48	0.29	0.59
S_{12}	0.48	0.79	0.79	0.44	0.25	0.55
Mean	0.65	1.02	1.04	0.66	0.48	0.77
SEd	0.078	0.133	0.134	0.086	0.066	
CD (P=0.05)	0.157	0.268	0.270	0.174	0.134	
Interaction effect						
M_1S_1	0.85	1.38	1.42	0.84	0.67	1.03
M_1S_2	0.82	1.28	1.31	0.81	0.67	0.98
M_1S_3	0.81	1.18	1.20	0.80	0.62	0.92
M_1S_4	0.78	1.14	1.15	0.77	0.59	0.89
M_1S_5	0.75	1.10	1.12	0.74	0.57	0.86
M_1S_6	0.74	1.07	1.09	0.73	0.57	0.84
M_1S_7	0.71	1.04	1.05	0.69	0.51	0.80
M_1S_8	0.70	1.02	1.04	0.66	0.50	0.79
M_1S_9	0.65	1.02	1.03	0.64	0.46	0.76
M_1S_{10}	0.62	0.98	0.99	0.60	0.37	0.71
M_1S_{11}	0.57	0.90	0.91	0.53	0.33	0.65
M_1S_{12}	0.55	0.84	0.86	0.49	0.29	0.61
M_2S_1	0.73	1.34	1.30	0.80	0.63	0.96
M_2S_2	0.70	1.24	1.19	0.77	0.63	0.91
M_2S_3	0.72	1.14	1.11	0.76	0.58	0.86
M_2S_4	0.72	1.10	1.09	0.73	0.55	0.84
M_2S_5	0.62	0.92	0.99	0.65	0.50	0.73
M_2S_6	0.61	0.88	0.96	0.64	0.50	0.72
M_2S_7	0.58	0.85	0.92	0.60	0.44	0.68
M_2S_8	0.57	0.84	0.91	0.57	0.43	0.66
M_2S_9	0.52	0.83	0.90	0.55	0.39	0.64
M_2S_{10}	0.49	0.80	0.86	0.51	0.30	0.59
M_2S_{11}	0.44	0.71	0.78	0.44	0.26	0.52
M_2S_{12}	0.42	0.75	0.73	0.40	0.22	0.50
Mean	0.65	1.02	1.04	0.66	0.48	0.77
SEd						
M at S	0.110	0.188	0.191	0.122	0.094	
S at M	0.110	0.187	0.189	0.121	0.094	
CD (P=0.05)						
M at S	0.242	0.412	0.429	0.267	0.207	
S at M	0.222	0.380	0.382	0.246	0.190	

2 Discussion

2.1 RWC under water deficit stress

Relative water czative water content had a significant influence on photosynthesis, by reducing the net photosynthesis by more than 50 per cent when relative water content was less than 80 per cent. As observed by Slatyer (1955), a reduction by 5% in RWC led to reduction in photosynthesis by 40 to 50%. Among the twelve cultivars, Karpuravalli, Karpuravalli×Pisang jajee, Saba and Sannachenkathali were able to maintain higher relative water content under water deficit condition with 6 per cent reduction over control. These findings were in agreement with the results of David (2002), in which a positive correlation between relative water content and gas exchange activities was observed and therefore, the reduction of relative water content was found to cause a strong reduction in photosynthesis, transpiration and stomatal conductance. Besset et al (2001) reported that drought resistant varieties showed consistently higher leaf water potential in their tissues than susceptible types under soil moisture deficit. In the present studies, cultivars like Matti, Matti×Anaikomban, Matti×cultivar rose and Pisang jajee×Matti, recorded lower RWC with higher reduction in the range of 22 to 24 per cent than control. Similarly in banana plants, a major decrease of soil moisture hardly reduced the leaf relative water content. The early reduction of stomatal conductance and the minor diminution of leaf relative water content could indicate that the banana plants showed a drought avoidance mechanism to maintain a favorable plant water status involving stomatal closure in response to water stress.

2.2 Soluble protein under water deficit stress

Protein synthesis represents a major sink for energy (Penning de Vries, 1975). Smith and Stitt (2007) stated that strengthened the idea that a tight link between carbon metabolism and protein synthesis is necessary to prevent acute carbon starvation, especially in growing tissues where most of the protein synthesis contributes to building new biomass (Piques et al., 2009). Soluble protein is the most abundant protein in green tissue, containing the enzyme RUBISCO, involved in CO_2 assimilation. As RuBisCO forms nearly 50% of the soluble protein in many plants, the enhancement in soluble protein content might have a direct impact on photosynthetic capacity of the crop plants (Joseph et al., 1981). RuBisCO activity is maintained even when leaf relative water content drops to 50% while stomata are already 75% closed (Smith and Stitt, 2007). A reduction in Rubisco activity during water deficit has also been reported by Castrillo et al (2001); Vu and Allen (2009). Plants leaf photosynthetic rate depends on photosynthetic components contents, such as RuBisCO, cytochromef, H^+-ATPase and reaction centers, but also on structural parameters, such as leaf thickness and area per leaf mass. The significant correlations of leaf water potential, leaf relative water content, and leaf osmotic potential with protein content and Rubisco at day 8 of rehydration, after severe stress, revealed a close relationship of these parameters on recovery (Mediavilla et al., 2001). Water deficit depressed the protein synthesis and accelerated their degradation and disturbed the soluble amino acid protein ratio in plants. The results of the present study revealed the effect of water deficit on soluble protein content. Tolerant and moderately tolerant cultivars behaved lesser reduction in soluble protein content with 9 and 14 per cent in response to irrigated level of 50% available soil moisture over control. The susceptible cultivars showed a higher reduction in soluble protein content of 18 per cent due to water deficit over control. According to Martignone et al (1987), soluble protein content was the first nitrogenous compound affected under stress conditions, which at severity got denatured and lost its activity and also decreased the photosynthetic efficiency. Tezara et al (1999) stated that water stress decreased CO_2 uptake more than O_2 evolution and also reduced the amounts of ATP, RUBP and RuBisCO activity (Castrillo and Calgno 1989). This decline is associated with a decrease in osmotic potential (Kaiser and Heber, 1986) and protein content (Castrillo and Trujillo 1994). Protein content and RuBisCO activity decreased when water potential decreased to −1.70 MPa in bean and maize leaf.

2.3 Total chlorophyll under water deficit stress

Chlorophyll is one of the major chloroplast components for photosynthesis, and relative chlorophyll content has a positive relationship with photosynthetic rate. Photosynthetic pigments are composed of chlorophylls a, b and total, and the main functions are reception and storage of light energy by inductive resonance through antenna complexes, and consequent electron transport carried out by the photosystem II (Taiz and Zeiger 2002). Both chlorophyll a and b are prone to soil dehydration (Farooq et al., 2009). Decreased or unchanged chlorophyll level during drought stress has been reported in many species, depending on the duration and severity of drought. According to Kaiser and Heber (1986) who found that water deficit induced reduction in chlorophyll content has been ascribed to loss of chloroplast membranes, excessive swelling and distortion of the lamellae vesiculation and the appearance of lipid droplets leads to minimize the photosynthetic pigment concentration, which can directly limit photosynthetic potential and hence primary production. As observed in the present study, the water deficit caused considerable reduction in chlorophyll content during shooting stage (7^{th} MAP) of about 16 to 18 per cent in Matti, Matti×Anaikomban, Matti×cultivar rose and Pisang jajee x Matti over control. The mechanism of reduction in chlorophyll content due to the consequence of reactive oxygen species leading to chlorophyll peroxidation and thereby its breakdown (Jabari et al., 2006). Jagtap et al (1998) noticed a reduction in chlorophyll content in drought stressed cotton. Robertson et al (1985) found that the total chlorophyll content decreased to a significant level at higher water deficits in sunflower plants. The reduction in chlorophyll content due to water deficit is loss of chlorophyll by the action of increased chlorophyllase enzyme activity and inactivation of photosynthesis in many crops (Mudrik et al., 2003). The photosynthesis performance and maintenance of chlorophyll concentrations under stress conditions can be considered among other physiological indices of drought tolerance. The present study revealed that tolerant and moderately tolerant cultivars showed lesser reduction in total chlorophyll content with 5 and 10 per cent in response to irrigated level of 50% available soil moisture over control. Similar effect was observed by Jagtap et al (1998), with a 20% to 30% chlorophyll loss due to water deficit in sorghum. Jabari et al (2006) also observed a remarkable reduction in total chlorophyll concentration under drought stress condition. Yellowing of leaves (leaf chlorosis) and senescence normally occur before leaves abscise in plants under water deficit, which is associated with chlorophyll degradation and translocation of nutrients to newer leaves in crop plants (Boyer, 1976). The total chlorophyll and carotenoid pigments in the leaf tissues of extreme water deficit were degraded by 60 and 72% respectively in sugarcane. Reduction in water use efficiency in this crop under water deficit level had a direct impact on photosynthetic pigment degradation, leading to reduce water oxidation in photosystem II (Shao et al., 2008). Total chlorophyll content decreased when plants are subjected to severe drought (50% of field capacity), these could be a result of a reaction centre or a photosystem II modification (Blum et al., 1989).

3 Conclusion

Plants respond to drought stress through alteration in physiological and biochemical processes. Our results showed that the RWC, soluble protein and total chlorophyll content were decreased under the water deficit condition. The banana cultivars and hybrids of Karpuravalli, Karpuravalli×Pisang jajee, Saba and Sannachenkathali with slight decreasing trend of RWC, soluble protein and total chlorophyll throughout the growth period of the crop and these four cultivars and hybrids was considered as tolerant to water deficit stress. The findings of this research also showed that the RWC, soluble protein and total chlorophyll can be used as a drought tolerance index to selection tolerant genotypes under water deficit conditions in banana cultivars and hybrids.

4 Materials and Methods

The experimental design was a split plot design with three replications. The main plots are, M_1 (control) with the soil pressure maintained from −0.69 to −6.00 bar, M_2 (water deficit) with the Soil pressure maintained from −0.69 to −14.00 bar. Soil pressure of −14.00 bar was reached at 30 days and measured by using soil moisture release curve and measured the soil moisture by using the pressure plate membrane apparatus. The sub plots considered as twelve banana cultivars and hybrids (S_1: Karpuravalli (ABB), S_2: Karpuravalli×Pisang Jajee, S_3: Saba (ABB), S_4: Sanna Chenkathali (AA), S_5: Poovan (AAB), S_6: Ney poovan (AB), S_7: Anaikomban (AA), S_8: Matti× Cultivar Rose, S_9: Matti (AA), S_{10}: Pisang Jajee×Matti, S_{11}: Matti× Anaikomban and S_{12}: Anaikomban×Pisang Jajee.) were randomly distributed within the sub-plots in each of the drought stress treatments (main plots). The RWC, soluble protein and total chlorophyll content were estimated during 3^{rd}, 5^{th}, 7^{th}, 9^{th} month after planting and at harvest stages of the crop and estimating procedure was given below.

4.1 Relative Water Content (RWC)

The Relative Water Content (RWC) of the leaf sample was estimated at all the stages of the crop by the method of Weatherly (1950) and expressed in percentage.

4.2 Soluble protein content

The content of soluble protein was estimated from the leaf samples following the method of Bradford (1974) and expressed as mg g^{-1} fresh weight.

Procedure: The leaf sample of 0.5g was macerated with 10 mL of phosphate buffer (0.1M, pH 7.0) using a pestle and mortar. The extract was centrifuged at 10000 rpm @ 4ºC for 20 minutes. 0.1 mL of supernatant was taken and 5 ml of dye mixture was added. The solution was mixed well and kept aside for 15 minutes. The colour intensity was recorded at 595 nm optical density.

Dye mixture preparation: 100 mg of Coomassie brilliant blue (G 250) was dissolved in 50 mL of 95% ethanol and 100 mL of ortho phosphoric acid was added and made upto 200 mL by using distilled water. 1 Ml of dye solution was taken and 4 ml of distilled water was added and it was used for sample analysis.

4.3 Total chlorophyll content

The total Chlorophyll content were estimated in physiologically active leaves as per the procedure of Hixcox and Israelstam (1979) and expressed as mg g^{-1} fresh weight.

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References

Flore J.A., A.N. Lakso, and J. W. Moon, 1985, The effect of water stress and vapor pressure gradient on stomatal conductance, water use efficiency, and photosynthesis of fruit crops, Acta Hort., 171:207-218

Hiscox J.D., and Israelstam G.F., 1979, A method for the extraction of chlorophyll from leaf tissue without maceration, Can. J. Bot., 57: 1332-1334 http://dx.doi.org/10.1139/b79-163

Hu Y., Schmidhalter U., 1998, Spatial distributions of inorganic ions and carbohydrates contributing to osmotic adjustment in the elongating wheat leaf under saline conditions. Aust. J. Plant Physiol., 25: 591-597 http://dx.doi.org/10.1071/PP97162

Jabari F., K. Postini, and A. Ahmadi, 2006, Effect of relation activity enzymes antioxidant on chlorophyll content and cell membrane stability of wheat cultivars, Iranian J. Agric. Sci., 37: 307-316

Jagtap V., S. Bhargava, P. Streb, and J. Feierabend, 1998, Comparative effect of water stress on photosynthetic reactions in sorghum, J. Exp. Bot., 49: 1715-1721 http://dx.doi.org/10.1093/jxb/49.327.1715 http://dx.doi.org/10.1093/jexbot/49.327.1715

Joseph M.C., D.D. Randall, and C.J. Nelson, 1981, Photosynthesis in polyploid tall fescue, II. Photosynthesis and RUBP case of polyploid tall fescue, Plant Physiol., 68: 894-898 http://dx.doi.org/10.1104/pp.68.4.894

Kaiser W.M., U. Heber, 1986, Photosynthesis under osmotic stress. Effect of high solute concentrations on the permeability properties of the chloroplast envelope and on activity of stroma enzymes, Planta, 153: 423-429 http://dx.doi.org/10.1007/BF00394980

Kallarackal J., Milburn J.A., and Baker D.A., 1990, Water relations of the banana. III effects of controlled water stress on water potential, transpiration, photosynthesis and leaf growth, Australian Journal of Plant Physiology, (17): 79-90 http://dx.doi.org/10.1071/PP9900079

Kamel A., and Loser D.M., 1995, Contribution of carbohydrates and other solutes to osmotic adjustment in wheat leaves under water stress. J. Plant Physiol., 145: 363-366 http://dx.doi.org/10.1016/S0176-1617(11)81903-6

Martignone R.A., J.J. Guiamot, and F. Nakayama, 1987, Nitrogen partitioning and leaf senescence in soybean as related to nitrogen supply, Field Crops Res., 17: 17-20 http://dx.doi.org/10.1016/0378-4290(87)90078-5

Mediavilla S., Escudero A., and Heilmeier H., 2001, internal leaf anatomy and photosynthetic resource use efficiency: interspecific and intraspecific comparisons, Tree Physiol., 21: 251-259 http://dx.doi.org/10.1093/treephys/21.4.251

Mudrik V.A., Romanova A.K., Ivanov B.N., Novichkova N.S., and Polyyakova V.A., 1997, Effect of increased CO2 concentration on growth, photosynthesis and composition of *Pisum sativam* plants, Fiziologya Rastenii, 44:141-146

Penning de Vries FWT, 1975, The cost of maintenance processes in plant cells, Annals of Botany, 39: 77-92

Piques M.C., Schulze W.X., Hoehne M., Usadel B., Gibon Y., Rohwer J., and Stitt M., 2009, Ribosome and transcript copy numbers, polysome occupancy and enzyme dynamics in Arabidopsis, Molecular Systems Biology, 5: 314 http://dx.doi.org/10.1038/msb.2009.68

Robertson J.M., Pharis R.P., Huang Y.Y., Reid D.M., and Yeung E.C., 1985, Drought induced increases in Abscisic acid levels in the root of apex sunflower, Plant Physiol, 74: 161-166

Shao H.B., L.Y. Chu, Z.H. Lu C.M., 2008, Kang, main antioxidants and redox signaling in higher plant cells, Int. J. Biol. Sci., 44: 12-18

Siddique M.R.B., and M.S., Islam, 2000, Drought stress effects on water relation of wheat, Bot. Bull. Acad. Sin., 41(1): 35-39

Slatyer R.O., 1955, Australian Journal of Agriculture Research, 61: 365-377 http://dx.doi.org/10.1071/AR9550365

Smith A.M, and Stitt M., 2007, Coordination of carbon supply and plant growth, Plant, Cell and Environment, 30: 1126–1149 http://dx.doi.org/10.1111/j.1365-3040.2007.01708.x

Taiz L., and Zeiger E., 2002, Plant physiology, third ed. Sinaur, sunderland

Tezara W., Mitchell V., Driscoll S.P and Lawlor D.W., 1999, Water deficits inhibits plant photosynthesis by decreasing coupling factor and ATP., Nature, 401: 914-917 http://dx.doi.org/10.1038/44842

Thomas D.S., and Turner D.W., 1998, Leaf gas exchange of droughted and irrigated banana cv. Williams (Musa spp.) growing in hot, arid conditions, Journal of Horticultural Science and Biotechnology, 73: 419-429

Turner D.W., 1998, The impact of environmental factors on the development and productivity of bananas and plantains. In Proceedings of the 13th ACORBAT meeting, Guayaquil, Ecuador, 635-663 (Ed. L. H. Arizaga). Ecuador, CONABAN

Weatherly P.E., 1950, Studies in the water relations of cotton 1, The field measurement of water deficits in leaves, New Phytol., 49: 81-97 http://dx.doi.org/10.1111/j.1469-8137.1950.tb05146.x