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Effect of Water Deficit on Relationship between Yield and Physiological Attributes of Banana Cultivars and Hybrids

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International Journal of Horticulture, 2013, Vol.3, No.12 doi: 10.5376/ijh.2013.03.0012

Received: 22 Mar., 2012

Accepted: 27 Mar., 2013

Published: 30 Mar., 2013

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Preferred citation for this article:

Surendar et al., 2013, Effect of Water Deficit on Relationship between Yield and Physiological Attributes of Banana Cultivars and Hybrids, International Journal of Horticulture, 2013, Vol.3, No.12 61-69 (doi: 10.5376/ijh.2013.03.0012)

Abstract This study examined the relationship between the yield reduction by CSI, MSI and RWC. The field experiment was conducted at national research centre for banana to screen the banana cultivars and hybrids for water deficit tolerance and to elucidate information on growth attribute mechanism of banana cultivars and hybrids. Stress was imposed at different critical stages viz., 3rd, 5th, 7th and 9th month after planting. The stress was given by scheduling irrigation at the 50 per cent available soil moisture (ASM) characteristic during critical stages. The soil moisture content was analyzed by using pressure plate membrane apparatus. In control plots, the irrigation was given at the ASM of 80% with the soil water potential of around -6 bars and in the case of stressed plots; the irrigation was given when an ASM reached 50 per cent with the soil water potential of -14 bars. In stressed plots, 50 per cent ASM was reached around 30 days. In this present study conducted with twelve cultivars and hybrids with three replications. The data were analyzed by using split plot design. The results revealed that the cultivars of Karpuravalli, Karpuravalli×Pisang Jajee, Saba, and Sannachenkathali recorded significantly higher yield (67.3 t/ha, 52.4 t/ha, 55.8 t/ha and 41.3 t/ha) and the magnitude of yield decrease was 12% than the cultivars and hybrids of Matti, Pisang Jajee×Matti, Matti×Anaikomban and Anaikomban×Pisang Jajee (14.9 t/ha, 11.1 t/ha, 10.3 t/ha and 10.6 t/ha). Similarly, Karpuravalli, Karpuravalli×Pisang Jajee, Saba, and Sannachenkathali recorded significantly relative water content, chlorophyll stability index and membrane stability index with lesser reduction percent were showed than the cultivars and hybrids of Matti, Pisang Jajee×Matti, Matti×Anaikomban and Anaikomban×Pisang Jajee.

Keywords Water deficit; RWC; CSI; MSI; Yield; Banana

Background

Banana is the 'queen of tropical fruits' and is one of the oldest fruits known to mankind from pre-historic times. Today, it is the leading tropical fruit in the world market with a highly organized and developed industry. It is the fourth largest fruit crop in the world after grapes, citrus fruits and apples. Drought is an insidious hazard of nature. Although it has scores of definitions, it originates from a deficiency of precipitation over an extended period of time, usually a season or more. This deficiency results in a water shortage for some activity, group, or environmental sector. Water deficit occurs when water potentials in the rhizosphere are sufficiently negative to reduce water availability to sub-optimal levels for plant growth and development. On a global basis, it is a major cause limiting productivity of agricultural systems and food production (Bray et al., 2000). 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 stomatal conductance and leaf size (Kallarackal et al., 1990) increased leaf senescence (Turner, 1998). Bananas (*Musa* spp.) rarely attain their full genetic potential for yield due to limitations imposed by water ultimately limiting the plants photosynthesis. Turner and Thomas (1998) reported that, the banana is sensitive to soil water deficits, expanding tissues such as emerging leaves and growing fruit are among the first to be affected. As soil begins to dry, stomata close and leaves remain highly hydrated, probably through root pressure. Productivity is affected because of the early closure of stomata. Turner and Thomas (1998) who showed measurements of leaf water potential using either the exuding xylem or relative leaf water content could not be reliably linked to plant functions such as stomatal movement, net photosynthesis or leaf folding. Water potential measured by the exuding latex method appeared the best for determining leaf water status, but even this shows a small change in plants experiencing soil water deficit (Thomas and Turner, 1998) supporting

the hydrated status of banana leaves although the soil is dry. Understanding banana plant response to soil moisture deficit and expression of physiological, biochemical traits are of basic scientific interest and have potential application bananas (*Musa* spp.). With a view to elicit information on these aspects, field and laboratory investigations were undertaken.

1 Experimental Result

1.1 Relative water content

The data on RWC revealed a progressive increase from 3rd to 7th MAP with a decline thereafter. The main and sub-plots treatments differed significantly at all the growth stages (Table 1). The treatment M₁ outperformed with better RWC value of 78.2% at 7th MAP stage, whereas M₂ recorded significantly lesser RWC value of 68.7%. Among the sub-plot treatment varieties, S₁ was found to be effective in maintaining higher RWC value (83.8%) over S₁₂ (63.7%), which was followed by S₂ (83.1%) and S₃ (80.2%). All the interaction treatments registered significant differences at all the stages, therefore, M at S and S at M attained differences significantly. Treatment M₁S₁ registered higher RWC of 86.1 percentage followed by M₁S₂ (85.4%), M₁S₃ (82.5%) and M₁S₄ (82.0%). However, a considerable reduction could also be noticed in RWC due to interaction with M₂ and subplot treatments. M₂S₁, M₂S₂, M₂S₃ and M₂S₄ maintained its superiority (81.5%, 80.8%, 77.9% and 77.4%) with about 5 to 8 per cent reduction, whereas, all the other treatments showed about 12 to 20 per cent reduction than M₁ and subplot treatments.

1.2 Chlorophyll stability index

The result of Chlorophyll Stability Index (CSI) exhibited an increasing trend upto 7th MAP stage with a drastic reduction at 9th MAP to harvest stage (Table 2). Both the main plot treatments differed significantly at all the growth stages. Comparison of two treatment at main plot level revealed that, M₁ recorded higher CSI of 84.2 per cent than M₂ (74.7%) at 7th MAP. At harvest, the decline in the value of CSI was lesser in M₁ (72.2%) than M₂ (62.6%). The sub-plot treatments also differed significantly at all stages. Among the sub plot treatments, S₁ registered significantly higher CSI percentage of 84.6%, followed by S₂ (82.4%) and S₃ (83.3%). The lowest CSI was recorded by S₁₂ ranging of 74.2%. The interaction effects of M at S and S at M revealed

significant differences at all the stages of growth. Treatment M₁S₁ recorded higher CSI of 85.1%. This was closely followed by M₁S₂ (84.8). However, the interaction between M₂ and subplot treatments exhibited considerable reduction over the interaction between M₁ and subplot treatments, among them, M₂S₁, M₂S₂, M₂S₃ and M₂S₄ recorded lower reduction per cent of about 2 to 5 followed by M₂S₅ M₂S₆, M₂S₇ to M₂S₈ showed an 11% to 12% reduction, whereas, M₂S₉, M₂S₁₀, M₂S₁₁ and M₂S₁₂ registered significantly higher reduction per cent of about 15 to 19 than M₁ and subplot treatments.

1.3 Membrane stability index

The values of Membrane Stability Index (MSI) showed an increasing trend as the growth stages advanced upto 7th MAP and declined towards harvest. The main and subplot treatments differed significantly at all the growth stages. Treatment M₁ had higher MSI value of 80.9 per cent than M₂ (71.3%) at 7th MAP stage (Table 3). Analyzing the effect of sub-plot treatments, it is revealed that S₁ recorded higher MSI value of 86.4 per cent which was higher than the S₁₂ by 66.4%. The former treatment was followed by S₂ (85.7%), S₃ (82.8%), and S₄ (82.3%) over S₁₂ (66.4%). The interaction effects of M at S and S at M revealed significant differences at all the stages of growth. A considerable reduction in MSI could also be observed due to interaction with M₂ and subplot treatments. Among the interaction treatments M₂S₁, M₂S₂, M₂S₃ and M₂S₄ recorded lower MSI of 84.2, 83.5, 80.6 and 80.1 per cent. M₂S₅, M₂S₆, M₂S₇ and M₂S₈ showed the values ranging from 72 to 74 per cent, whereas, M₂S₉, M₂S₁₀, M₂S₁₁ and M₂S₁₂ recorded values ranging from 67 to 69 per cent.

1.4 Yield

The data on yield (t/ha) significantly differed. Among the main plot treatments, M₁ registered highest yield ha⁻¹ of 32.8 over M₂ (27.5). All the subplot treatments were significantly different (Figure 1). Among them, S₁ ranked first (60.5 t/ha), which was followed by S₃ (50.2 t/ha), S₅ (47.1 t/ha) and S₄ (37.1 t/ha). The lowest yield of 9.3 was registered by S₁₂. The interaction effects of M at S and S at M were also significantly differed. Among the interaction treatment effects, M₁S₁ performed better

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

Treatments	3 rd MAP	5 th MAP	7 th MAP	9 th MAP	Harvest	Mean
Main plot						
M ₁	75.4	77.1	78.2	73.1	72.9	75.35
M ₂	65.9	67.6	68.7	63.6	63.4	65.80
Mean	70.64	72.34	73.44	68.34	68.14	70.58
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	81.0	82.7	83.8	78.7	78.5	80.92
S ₂	80.3	82.0	83.1	78.0	77.8	80.22
S ₃	77.4	79.1	80.2	75.1	74.9	77.32
S ₄	76.9	78.6	79.7	74.6	74.4	76.82
S ₅	74.1	75.8	76.9	71.8	71.6	74.02
S ₆	73.4	75.1	76.2	71.1	70.9	73.32
S ₇	69.7	71.4	72.5	67.4	67.2	69.62
S ₈	68.0	69.7	70.8	65.7	65.5	67.92
S ₉	63.5	65.2	66.3	61.2	61.0	63.47
S ₁₀	61.4	63.1	64.2	59.1	58.9	61.37
S ₁₁	61.1	62.8	63.9	58.8	58.6	61.07
S ₁₂	60.9	62.6	63.7	58.6	58.4	60.87
Mean	70.64	72.34	73.44	68.34	68.14	70.58
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 ₁ S ₁	83.3	85.0	86.1	81.0	80.8	83.24
M ₁ S ₂	82.6	84.3	85.4	80.3	80.1	82.54
M ₁ S ₃	79.7	81.4	82.5	77.4	77.2	79.64
M ₁ S ₄	79.2	80.9	82.0	76.9	76.7	79.14
M ₁ S ₅	78.9	80.6	81.7	76.6	76.4	78.84
M ₁ S ₆	78.2	79.9	81.0	75.9	75.7	78.14
M ₁ S ₇	74.5	76.2	77.3	72.2	72.0	74.44
M ₁ S ₈	72.8	74.5	75.6	70.5	70.3	72.74
M ₁ S ₉	70.7	72.4	73.5	68.4	68.2	70.64
M ₁ S ₁₀	68.6	70.3	71.4	66.3	66.1	68.54
M ₁ S ₁₁	68.3	70.0	71.1	66.0	65.8	68.24
M ₁ S ₁₂	68.1	69.8	70.9	65.8	65.6	68.04
M ₂ S ₁	78.7	80.4	81.5	76.4	76.2	78.60
M ₂ S ₂	78.0	79.7	80.8	75.7	75.5	77.90
M ₂ S ₃	75.1	76.8	77.9	72.8	72.6	75.00
M ₂ S ₄	74.6	76.3	77.4	72.3	72.1	74.50
M ₂ S ₅	69.3	71.0	72.1	67.0	66.8	69.20
M ₂ S ₆	68.6	70.3	71.4	66.3	66.1	68.50
M ₂ S ₇	64.9	66.6	67.7	62.6	62.4	64.80
M ₂ S ₈	63.2	64.9	66.0	60.9	60.7	63.10
M ₂ S ₉	56.4	58.1	59.2	54.1	53.9	56.29
M ₂ S ₁₀	54.3	56.0	57.1	52.0	51.8	54.19
M ₂ S ₁₁	54.0	55.7	56.8	51.7	51.5	53.89
M ₂ S ₁₂	53.8	55.5	56.6	51.5	51.3	53.69
Mean	70.64	72.34	73.44	68.34	68.14	70.58
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 Chlorophyll Stability Index (CSI: %) at different growth stages of banana cultivars in main crop

Treatments	3 rd MAP	5 th MAP	7 th MAP	9 th MAP	Harvest	Mean
Main plot						
M ₁	78.1	81.0	82.7	76.1	72.2	78.04
M ₂	68.6	71.5	73.8	66.5	62.7	68.62
Mean	73.35	76.24	78.28	71.32	67.46	73.33
SEd	0.34	0.034	0.36	0.32	0.30	
CD (P=0.05)	1.49	1.48	1.56	1.39	1.31	
Sub plot						
S ₁	81.3	82.0	84.7	77.9	75.5	80.25
S ₂	77.7	77.9	82.5	72.4	68.8	75.84
S ₃	79.9	78.2	83.4	72.7	67.9	76.42
S ₄	71.8	81.1	76.3	74.9	71.9	75.19
S ₅	74.1	77.4	78.8	72.3	67.3	73.97
S ₆	77.1	75.3	78.9	72.2	67.4	74.16
S ₇	70.8	78.0	76.7	72.4	68.3	73.23
S ₈	67.5	74.4	77.9	68.6	65.7	70.81
S ₉	74.4	75.8	75.8	67.0	63.8	71.38
S ₁₀	64.5	75.2	74.0	64.2	63.4	68.27
S ₁₁	73.7	71.4	76.3	73.0	65.3	71.96
S ₁₂	67.3	68.2	74.2	68.3	64.3	68.47
Mean	73.35	76.24	78.28	71.32	67.46	73.33
SEd	0.92	0.94	0.97	0.88	0.84	
CD (P=0.05)	1.87	1.89	1.97	1.79	1.69	
Interaction effect						
M ₁ S ₁	83.6	84.3	85.1	80.2	77.8	82.20
M ₁ S ₂	80.0	80.2	84.8	74.7	71.1	78.16
M ₁ S ₃	82.2	80.5	83.7	75.1	70.3	78.34
M ₁ S ₄	74.2	83.4	78.6	77.2	74.2	77.51
M ₁ S ₅	79.0	82.2	83.6	77.1	72.1	78.79
M ₁ S ₆	81.9	80.1	83.7	77.0	72.2	78.98
M ₁ S ₇	75.6	82.8	81.5	77.2	73.2	78.05
M ₁ S ₈	72.3	79.2	82.7	73.5	70.5	75.63
M ₁ S ₉	81.6	83.0	83.0	74.2	71.0	78.56
M ₁ S ₁₀	71.7	82.4	81.2	71.3	70.6	75.44
M ₁ S ₁₁	80.9	78.6	83.5	80.2	72.5	79.14
M ₁ S ₁₂	74.5	75.4	81.4	75.5	71.4	75.65
M ₂ S ₁	79.0	79.7	84.2	75.5	73.2	78.30
M ₂ S ₂	75.4	75.6	80.2	70.0	66.5	73.52
M ₂ S ₃	77.6	75.9	83.0	70.4	65.6	74.49
M ₂ S ₄	69.5	78.8	74.0	72.5	69.6	72.87
M ₂ S ₅	69.3	72.6	74.0	67.5	62.5	69.15
M ₂ S ₆	72.2	70.5	74.1	67.4	62.5	69.34
M ₂ S ₇	66.0	73.2	71.9	67.6	63.5	68.41
M ₂ S ₈	62.7	69.6	73.1	63.8	60.9	65.99
M ₂ S ₉	67.3	68.7	68.7	59.8	56.7	64.21
M ₂ S ₁₀	57.4	68.1	66.9	57.0	56.2	61.09
M ₂ S ₁₁	66.6	64.3	69.2	65.8	58.2	64.79
M ₂ S ₁₂	60.2	61.1	67.1	61.2	57.1	61.30
Mean	73.35	76.24	78.28	71.32	67.46	73.33
SEd						
M at S	1.30	1.32	1.37	1.24	1.17	
S at M	1.31	1.33	1.38	1.25	1.18	
CD (P=0.05)						
M at S	2.84	2.86	2.99	2.70	2.55	
S at M	2.64	2.68	2.79	2.53	2.39	

Table 3 Effect of water stress on Membrane Stability Index (MSI: %) at different growth stages of banana cultivars in main crop

Treatments	3 rd MAP	5 th MAP	7 th MAP	9 th MAP	Harvest	Mean
Main plot						
M ₁	78.2	79.9	80.9	75.9	75.6	78.11
M ₂	68.7	70.4	71.4	66.4	66.1	68.56
Mean	73.44	75.14	76.14	71.14	70.84	73.34
SEd	0.44	0.45	0.49	0.42	0.42	
CD (P=0.05)	1.90	1.95	2.14	1.84	1.83	
Sub plot						
S ₁	83.8	85.5	86.5	81.5	81.2	83.68
S ₂	83.1	84.8	85.8	80.8	80.5	82.98
S ₃	80.2	81.9	82.9	77.9	77.6	80.08
S ₄	79.7	81.4	82.4	77.4	77.1	79.58
S ₅	76.9	78.6	79.6	74.6	74.3	76.78
S ₆	76.2	77.9	78.9	73.9	73.6	76.08
S ₇	72.5	74.2	75.2	70.2	69.9	72.38
S ₈	70.8	72.5	73.5	68.5	68.2	70.68
S ₉	66.3	68.0	69.0	64.0	63.7	66.23
S ₁₀	64.2	65.9	66.9	61.9	61.6	64.13
S ₁₁	63.9	65.6	66.6	61.6	61.3	63.83
S ₁₂	63.7	65.4	66.4	61.4	61.1	63.63
Mean	73.44	75.14	76.14	71.14	70.84	73.34
SEd	0.93	0.95	0.96	0.91	0.90	
CD (P=0.05)	1.88	1.92	1.94	1.83	1.83	
Interaction effect						
M ₁ S ₁	86.1	87.8	88.8	83.8	83.5	86.00
M ₁ S ₂	85.4	87.1	88.1	83.1	82.8	85.30
M ₁ S ₃	82.5	84.2	85.2	80.2	79.9	82.40
M ₁ S ₄	82.0	83.7	84.7	79.7	79.4	81.90
M ₁ S ₅	81.7	83.4	84.4	79.4	79.1	81.60
M ₁ S ₆	81.0	82.7	83.7	78.7	78.4	80.90
M ₁ S ₇	77.3	79.0	80.0	75.0	74.7	77.20
M ₁ S ₈	75.6	77.3	78.3	73.3	73.0	75.50
M ₁ S ₉	73.5	75.2	76.2	71.2	70.9	73.40
M ₁ S ₁₀	71.4	73.1	74.1	69.1	68.8	71.30
M ₁ S ₁₁	71.1	72.8	73.8	68.8	68.5	71.00
M ₁ S ₁₂	70.9	72.6	73.6	68.6	68.3	70.80
M ₂ S ₁	81.5	83.2	84.2	79.2	78.9	81.36
M ₂ S ₂	80.8	82.5	83.5	78.5	78.2	80.66
M ₂ S ₃	77.9	79.6	80.6	75.6	75.3	77.76
M ₂ S ₄	77.4	79.1	80.1	75.1	74.8	77.26
M ₂ S ₅	72.1	73.8	74.8	69.8	69.5	71.96
M ₂ S ₆	71.4	73.1	74.1	69.1	68.8	71.26
M ₂ S ₇	67.7	69.4	70.4	65.4	65.1	67.56
M ₂ S ₈	66.0	67.7	68.7	63.7	63.4	65.86
M ₂ S ₉	59.2	60.9	61.9	56.9	56.6	59.05
M ₂ S ₁₀	57.1	58.8	59.8	54.8	54.5	56.95
M ₂ S ₁₁	56.8	58.5	59.5	54.5	54.2	56.65
M ₂ S ₁₂	56.6	58.3	59.3	54.3	54.0	56.45
Mean	73.44	75.14	76.14	71.14	70.84	73.34
SEd						
M at S	1.34	1.37	1.40	1.30	1.30	
S at M	1.32	1.35	1.36	1.28	1.28	
CD (P=0.05)						
M at S	3.03	3.10	3.22	2.95	2.94	
S at M	2.66	2.72	2.75	2.59	2.58	

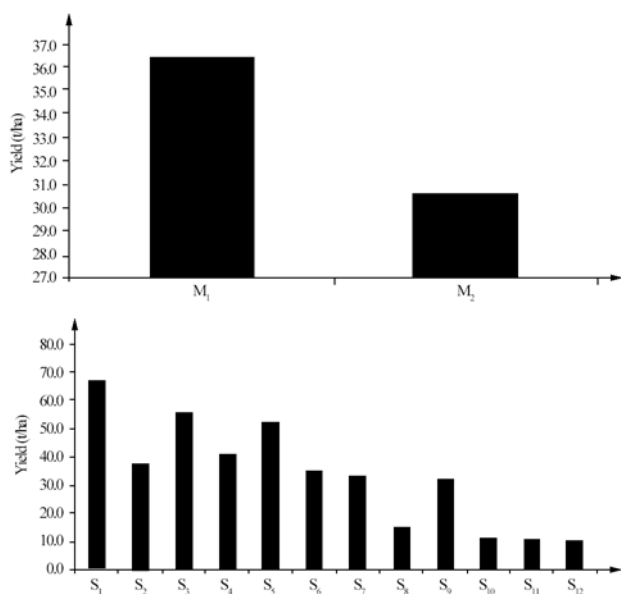


Figure 1 Effect of water stress on yield (t/ha) of banana cultivars and hybrids

than other treatments showing significantly higher yield of 63.3 t/ha followed by M₁S₃ (53.6) and M₁S₅ (50.9). However the interaction between M₂ and subplot treatments exhibited considerable reduction over the interaction between M₁ and subplot treatments. M₂S₁, M₂S₂, M₂S₃ and M₂S₄ registered about 8.7% to 13.8% reduction. M₂S₅, M₂S₆, M₂S₇ and M₂S₈ recorded about 14.8% to 22.7% reduction, whereas M₂S₉, M₂S₁₀, M₂S₁₁ and M₂S₁₂ showed 24.6% to 38.8% reduction yield (t/ha) over the interaction between M₁ and sub plot treatments.

2 Discussion

Relative water content is the ability of plant to maintain high water in the leaves under moisture stress conditions and has been used as an index to determine drought (Barrs and Weatherly, 1962) tolerance in crop plants. During plant development, drought stress significantly reduced relative water content values (Siddique and Islam, 2000). Relative water content may be attributed to differences in the ability of the varieties to absorb more water from the soil or the ability to control water loss through the stomata's. It may also be due to differences in the ability of the tested varieties to accumulate and adjust osmotically to maintain tissue turgor and hence physiological activities. Flore et al (1985) stated that relative water content was considered as an

alternative measure of plant water status, reflecting the metabolic activity in tissues. Blum et al (1989) reported that higher leaf relative water content allows the plant to maintain turgidity and this would exhibit relatively less reduction in biomass and yield. The estimation of RWC, instead of plant water potential could accurately indicate the balance between absorbed water by plant and lost through transpiration. 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 relative water content was estimated in order to find out the plant water status of banana cultivars under water stress situations. Leaf relative water content had a significant influence on photosynthesis, by reducing the net photosynthesis by more than 50% when relative water content was less than 80%. As observed by David (2002), a reduction by 5% in RWC led to reduction in photosynthesis by 40% to 50%. Among the twelve cultivars, Karpuravalli, Karpuravalli×Pisang jaje, 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 jaje×Matti, recorded lower RWC with higher reduction in the range of 22% to 24% 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.

A higher Chlorophyll Stability Index (CSI) helps the plants to withstand stress through better availability of

chlorophyll, leading to increased photosynthetic rate, more dry matter production and higher productivity. The decrease in chlorophyll under water stress was due to loss of chloroplast membrane integrity, which was associated with enhanced activity of phosphatase localized on the chlorophyll membrane (De Silva et al., 1979). CSI is an important parameter which indicates the tolerance capacity of the plants to water deficit and it is used to measure the integrity of membrane (Murthy and Majumdar, 1962). The chlorophyll stability index is an indicator of the stress tolerance capacity of plants (Koleyoreas, 1958). The present study revealed that tolerant and moderately tolerant cultivars and hybrids showed a lesser reduction in chlorophyll stability index (6% and 12%) in response to irrigation at 50% available soil moisture than control, while susceptible cultivars and hybrids had higher reduction in CSI of upto 19 per cent due to water deficit over control. Therefore, CSI of the leaf could be used as an indicator of water stress tolerance (Gomez et al., 1996). Singh et al (1985) stated that continuous moisture stress leads to a decline in leaf chlorophyll and chlorophyll stability index and relatively mild stress would inhibit chlorophyll synthesis in wheat. Higher CSI indicates the tolerance of plants under water stress condition.

Membrane stability is a widely used criterion to assess crop drought tolerance (Premachandra and Shimada, 1988). Water stress caused water loss from plant tissues which seriously impair both membrane structure and function. Cell membrane is one of the first targets of plant stresses (Levitt, 1972) and the ability of plants to maintain membrane integrity under drought is what determines tolerance towards drought. The results from electrolyte leakage measurements showed that membrane integrity was conserved for tolerant compared to susceptible varieties, this is in agreement with the conclusion of Martin et al (1987). Electrolyte leakage was correlated with drought tolerance. The leakage was due to damage to cell membranes which become more permeable under water deficit condition (Senaratna and Kersie, 1983). In banana, a major impact of plant environmental stress is cellular modification, which results in its perturbed function or total dysfunction. However, the cellular membrane dysfunction due to stress is well

expressed in increasing permeability and leakage of ions which can readily be measured by the efflux of electrolytes (Jagtap and Bhargava, 1998). In the present study, tolerant and moderately tolerant cultivars and hybrids had less electrolyte leakage due to water deficit. In susceptible cultivars, the water deficit treatment showed a higher leakage of electrolytes compared to control. Leakage control was also observed by Deshmukh et al (1991) who reported that the high electrolyte leakage of the water stressed plants was positively correlated with the high ROS activity in cigar leaves of banana. This might indicate membrane damage and thus a high risk of cell desiccation due to water deficit (Jones et al., 1985).

Water deficit impacted many physiological and developmental processes affecting fruit growth and production, including growth function of cell division and cell expansion and gas exchanging components (Jones et al., 1985). Similar results were observed by Manica et al (1975) indicating that, in banana the number of hands per bunch and number of finger per hands decreased linearly due to water deficit (75% available soil moisture). As observed in the present studies, tolerant and moderately tolerant cultivars and hybrids showed lesser reduction in yield components due to water deficit with the mean reduction of 12% and 34% due to water deficit over control. The susceptible cultivars showed yield reduction of 41% in than control (Figure 1). Similar to this study, a significant reduction in yield after water deficit treatment in banana was recorded by Turner and Thomas (1998). This reduction in yield was attributed to the marked decrease in all the yield components resulting from water stress in banana (Stover, 1972). The possible reason for the reduction in yield and yield components was explained by Turner and Thomas (1998) who stated that the finger length and finger circumference in banana was much affected where water stress was imposed during shooting stage. The fruit of water stressed plants were shorter in nature and also it reduces green life of fruit in banana (Daniells et al., 1984). These findings strongly support the results of the present study, that the tolerant and moderately tolerant cultivars and hybrids performed better in morphological, physiological, biochemical processes

besides yield and yield attributes in response to irrigated level of 50% available soil moisture.

3 Materials and Methods

The experiment was carried out at National Research Centre for banana, Thiruchirapalli, during 2011-2012. The experiment consists of two treatments as considered as main plot and twelve cultivars and hybrids as taken as sub plots were laid out in split plot design with three replications. The main plots are, M₁ (control) with the soil pressure maintained from -0.69 to -6.00 bar, M₂ (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 (Figure 2). The sub plots are, S₁: Karpuravalli (ABB), S₂: Karpuravalli ×

Pisang Jajee, S₃: Saba (ABB), S₄: Sanna Chenkathali (AA), S₅: Poovan (AAB), S₆: Ney poovan (AB), S₇: Anaikomban (AA), S₈: Matti × Cultivar Rose, S₉: Matti (AA), S₁₀: Pisang Jajee × Matti, S₁₁: Matti × Anaikomban and S₁₂: Anaikomban × Pisang Jajee. The relative water content were measured as per the procedure of Weatherly (1950) and expressed in percentage, chlorophyll stability index was estimated based on the procedure given by Chlorophyll (Chl) content was determined following the method of Arnon (1949). The chlorophyll stability index (CSI) was determined according to Sairam et al (1997) and expressed as percentage and above experiments were measured during 3rd, 5th, 7th, 9th month after planting and at harvest stages of the crop. The yield and yield components were assessed at the time of harvesting.



Figure 2 Soil moisture measurement by using Pressure Plate Membrane Apparatus

3.1 Relative water content

Relative water content (RWC) was estimated according to the method of Weatherly (1950) and calculated in the leaves for each drought period. Samples (0.5 g) were saturated in 100 mL distilled water for 24 h at 4°C in the dark and their turgid weights were recorded. Then they were oven-dried at 65°C for 48 h and their dry weights were recorded.

RWC was calculated as follows:

$$\text{RWC (\%)} = [(\text{FW} - \text{DW}) / (\text{TW} - \text{DW})] \times 100$$

where FW, DW, and TW are fresh weight, dry weight and turgid weight, respectively.

3.2 Chlorophyll stability index

Leaf samples were selected randomly from the plants and homogenized in a mortar in acetone. The extract was centrifuged at 5000 g for 5 min.

Absorbance of the supernatant was recorded at 663, 645 and 450 nm spectrophotometrically (Techcomp 8500 II, South Korea). Chlorophyll (Chl) content was determined following the method of Arnon (1949). The chlorophyll stability index (CSI) was determined according to Sairam et al (1997) and calculated as follows:

$$\text{CSI} = \left(\frac{\text{Total Chl under stress}}{\text{Total Chl under control}} \right) \times 100$$

3.3 Membrane stability index (MSI)

The Membrane Stability Index (MSI) of the leaf sample was estimated by the method proposed by Premachandra et al (1990) and expressed in percentage.

Acknowledgment

The research have been supported and facilitated by National Research Centre for Banana (ICAR), Trichy, Tamil Nadu, India. I extend my sincere thanks to Dr. M. M. Mustaffa (Director) NRC for banana, Dr. D. Durga Devi (Professor) TNAU and Dr. I. Ravi (Sr. Scientist) NRC for banana for given proper guidance during research.

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