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Effect of water deficit on relationship between yield and physiological attributes of banana cultivars and hybrids

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This study examined the relationship between the yield reduction by chlorophyll stability index (CSI), membrane stability index (MSI) and relative water content (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 attributes mechanism of banana cultivars and hybrids. Water stress was imposed at different critical growth stages viz., 3rd, 5th, 7th and 9th month after planting. The stress was given by scheduling irrigation at the 50% available soil moisture (ASM) 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 about -6 bars. In stressed plots, the irrigation was given at 50% ASM with the soil water potential of -14 bars. In stressed plots, 50% ASM was reached around 30 days. The present study was 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 x Pisang Jajee, Saba and Sannachenkathali recorded significantly higher yield (67.3, 52.4, 55.8 and 41.3 t ha^{-1}) and the magnitude of yield was decreased by 12% than the cultivars and hybrids of Matti, Pisang Jajee x Matti, Matti x Anaikomban and Anaikomban x Pisang Jajee (14.9, 11.1, 10.3 and 10.6 t/ha). Similarly, Karpuravalli, Karpuravalli x Pisang Jajee, Saba and Sannachenkathali recorded significantly high relative water content, chlorophyll stability index and membrane stability index with lesser reduction percent were shown than the cultivars and hybrids of Matti, Pisang Jajee x Matti, Matti x Anaikomban and Anaikomban x Pisang Jajee.

Key words: Water deficit, relative water content (RWC), chlorophyll stability index (CSI), membrane stability index (MSI), yield, banana.

INTRODUCTION

Water stress is a major problem in banana growth and development. It is the leading tropical fruit in the world market with a highly organized and developed industry. 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 (Bray et al., 2000). On a global basis, it is a

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major cause limiting the productivity of agricultural systems and food production (Bray et al., 2000). Banana productivity is greatly affected by environmental stresses such as drought, water and cold. Plants respond and adapt 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 plant's photosynthesis. Turner and Thomas (1998) reported that, the banana is sensitive to soil water deficits, expanding tissues in emerging leaves and growing fruits are among the first to be affected. As soil begins to dry, closer of stomata leaves become highly hydrated, probably through high negative root pressure. Productivity is affected because of the early closure of stomata. Turner and Thomas (1998) who showed measurements of leaf water potential of exuding xylem or relative leaf water content could not be reliably linked to stomatal movement, net photosynthesis and leaf folding. However, water potential can be measured by the exuding latex that appeared to be the viable for determining leaf water status, even though only a small change in plants were experienced under soil water deficit supported by the hydrated status of banana leaves under dry condition. Understanding banana plant response to soil moisture deficit and expression of physiological, biochemical traits are of basic scientific interest and have potential application in bananas (*Musa* spp.) for higher productivity. With a view to elucidate information on these aspects, field and laboratory investigations were undertaken.

MATERIALS AND METHODS

The experiment was carried out at National Research Centre for Banana, Thiruchirapalli, Tamil Nadu, India during 2011-2012. The experiments consists of two treatments considered as main plot and twelve cultivars and hybrids taken as sub plots laid out in split plot design with three replications. The main plots were, 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 (Figure 1) .The sub plots are, S_1: Karpuravalli (ABB), S_2: Karpuravalli x 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 x Cultivar Rose, S_9: Matti (AA), S_{10}: Pisang Jajee x Matti, S_{11}: Matti x Anaikomban and S_{12}: Anaikomban x 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 Arnon (1949) for chlorophyll (Chl) content. 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 and 9th month after planting and at harvest stages of the crop. The yield and yield components were assessed at the time of harvesting.

Relative water content (RWC)

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:

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

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

Chlorophyll stability index (CSI)

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). Chl content was determined by using the method of Arnon (1949) and Sairam et al. (1997) and calculated as follows:

$$CSI = (\text{total Chl under stress/total Chl under control}) \times 100$$

Membrane stability index (MSI)

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

EXPERIMENTAL RESULTS

Relative water content (RWC)

The data on RWC revealed that a progressive increase was noticed from 3rd to 7Th MAP and it decline thereafter. The main and sub-plots treatments differed significantly at all the growth stages (Table 1). The treatment M_1 performed better with higher RWC value of 78.2% at 7th MAP stage, whereas M_2 recorded significantly lesser RWC value of 68.7%. Among the sub-plot treatment (varieties), S_1 was found to be effective in maintaining higher RWC value (83.8%), which was followed by S_2 (83.1%) and S_3 (80.2%) and least was recorded by S_{12} (63.7%). All the interaction treatments registered significant differences at all the stages, therefore, M at S and S at M attained differences significantly. Treatment M_1S_1 registered higher RWC of 86.1% followed by M_1S_2 (85.4%), M_1S_3 (82.5%) and M_1S_4 (82.0%). 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 maintained its superiority (81.5, 80.8, 77.9 and 77.4%) with about 5 to 8% reduction, whereas, all the

Pressure plate with sample ring

Saturated soil sample filled inside the ring

Completely filled saturated soil sample

Setting the pressure

Running the instrument

Ring removed from the plate

Collection of the soil sample from the plate

Soil sample in the hot air oven for drying

Figure 1. Soil moisture measurement by using pressure plate membrane apparatus.

other treatments showed about 12 to 20% reduction than M_1 and subplot treatments.

Chlorophyll stability index (CSI)

The result of 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 treatments at main plot level revealed that, M_1 recorded higher CSI of 84.2% than M_2 (74.7%) at 7th MAP. At harvest, the decline in the value of CSI was lesser in M_1 (72.2%) than M_2 (62.6%). The sub-plot treatments also differed significantly at all stages. Among the sub plot treatments, S_1 registered significantly higher CSI percentage of 84.6%, followed by S_2 (82.4%) and S_3 (83.3%). The lowest CSI was recorded by S_{12} to be 74.2%. The interaction effects of M at S and S at M revealed significant differences at all the stages of growth. Treatment M_1S_1 recorded higher CSI of 85.1%. This was closely followed by M_1S_2 (84.8%). However, the interaction between M_2 and subplot treatments exhibited considerable reduction over the interaction between M_1 and subplot treatments, among them, M_2S_1, M_2S_2, M_2S_3 and M_2S_4 recorded lower reduction percent of about 2 to 5 followed by M_2S_5, M_2S_6, M_2S_7 to M_2S_8 showing 11 to 12% reduction, whereas, M_2S_9, M_2S_{10}, M_2S_{11} and M_2S_{12} registered

Table 1. Effect of water stress on relative water content (RWC: %) at different growth stages of banana cultivars.

Treatment	**3rd MAP**	**5th MAP**	**7th MAP**	**9th 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	**3rd MAP**	**5th MAP**	**7th MAP**	**9th MAP**	**Harvest**	**Mean**
M_1S_1	83.3	85.0	86.1	81.0	80.8	83.24
M_1S_2	82.6	84.3	85.4	80.3	80.1	82.54
M_1S_3	79.7	81.4	82.5	77.4	77.2	79.64
M_1S_4	79.2	80.9	82.0	76.9	76.7	79.14
M_1S_5	78.9	80.6	81.7	76.6	76.4	78.84
M_1S_6	78.2	79.9	81.0	75.9	75.7	78.14
M_1S_7	74.5	76.2	77.3	72.2	72.0	74.44
M_1S_8	72.8	74.5	75.6	70.5	70.3	72.74
M_1S_9	70.7	72.4	73.5	68.4	68.2	70.64
M_1S_{10}	68.6	70.3	71.4	66.3	66.1	68.54
M_1S_{11}	68.3	70.0	71.1	66.0	65.8	68.24
M_1S_{12}	68.1	69.8	70.9	65.8	65.6	68.04
M_2S_1	78.7	80.4	81.5	76.4	76.2	78.60
M_2S_2	78.0	79.7	80.8	75.7	75.5	77.90
M_2S_3	75.1	76.8	77.9	72.8	72.6	75.00
M_2S_4	74.6	76.3	77.4	72.3	72.1	74.50
M_2S_5	69.3	71.0	72.1	67.0	66.8	69.20
M_2S_6	68.6	70.3	71.4	66.3	66.1	68.50
M_2S_7	64.9	66.6	67.7	62.6	62.4	64.80
M_2S_8	63.2	64.9	66.0	60.9	60.7	63.10
M_2S_9	56.4	58.1	59.2	54.1	53.9	56.29
M_2S_{10}	54.3	56.0	57.1	52.0	51.8	54.19
M_2S_{11}	54.0	55.7	56.8	51.7	51.5	53.89
M_2S_{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

Table 1. Contd.

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.

Treatment	**3rd MAP**	**5th MAP**	**7th MAP**	**9th 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	**3rd MAP**	**5th MAP**	**7th MAP**	**9th MAP**	**Harvest**	Mean
M_1S_1	83.6	84.3	85.1	80.2	77.8	82.20
M_1S_2	80.0	80.2	84.8	74.7	71.1	78.16
M_1S_3	82.2	80.5	83.7	75.1	70.3	78.34
M_1S_4	74.2	83.4	78.6	77.2	74.2	77.51
M_1S_5	79.0	82.2	83.6	77.1	72.1	78.79
M_1S_6	81.9	80.1	83.7	77.0	72.2	78.98
M_1S_7	75.6	82.8	81.5	77.2	73.2	78.05
M_1S_8	72.3	79.2	82.7	73.5	70.5	75.63
M_1S_9	81.6	83.0	83.0	74.2	71.0	78.56
M_1S_{10}	71.7	82.4	81.2	71.3	70.6	75.44
M_1S_{11}	80.9	78.6	83.5	80.2	72.5	79.14
M_1S_{12}	74.5	75.4	81.4	75.5	71.4	75.65
M_2S_1	79.0	79.7	84.2	75.5	73.2	78.30
M_2S_2	75.4	75.6	80.2	70.0	66.5	73.52
M_2S_3	77.6	75.9	83.0	70.4	65.6	74.49

Table 2. Contd.

M_2S_4	69.5	78.8	74.0	72.5	69.6	72.87
M_2S_5	69.3	72.6	74.0	67.5	62.5	69.15
M_2S_6	72.2	70.5	74.1	67.4	62.5	69.34
M_2S_7	66.0	73.2	71.9	67.6	63.5	68.41
M_2S_8	62.7	69.6	73.1	63.8	60.9	65.99
M_2S_9	67.3	68.7	68.7	59.8	56.7	64.21
M_2S_{10}	57.4	68.1	66.9	57.0	56.2	61.09
M_2S_{11}	66.6	64.3	69.2	65.8	58.2	64.79
M_2S_{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	

significantly higher reduction percent of about 15 to 19 than M_1 and subplot treatments.

Membrane stability index (MSI)

The values of 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 M_1 had higher MSI value of 80.9% than M_2 (71.3%) at 7th MAP stage (Table 3). Analyzing the effect of sub-plot treatments, it was revealed that S_1 recorded higher MSI value of 86.4% which was higher than the S_{12} by 66.4%. The former treatment was followed by S_2 (85.7%), S_3 (82.8%) and S_4 (82.3%) over S_{12} (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 M_2 and subplot treatments. Among the interaction treatments M_2S_1, M_2S_2, M_2S_3 and M_2S_4 recorded lower MSI of 84.2, 83.5, 80.6 and 80.1%. M_2S_5, M_2S_6, M_2S_7 and M_2S_8 showed the values ranging from 72 to 74%, whereas, M_2S_9, $M_2S_{10,}$ M_2S_{11} and M_2S_{12} recorded values ranging from 67 to 69%.

Yield

The data on yield (t ha^{-1}) was significantly differed. Among the main plot treatments, M_1 registered highest yield ha^{-1} of 32.8 over M_2 (27.5). All the subplot treatments were significantly different (Figure 2). Among them, S_1 ranked first (60.5 t ha^{-1}), which was followed by S_3 (50.2 t ha^{-1}), S_5 (47.1 t ha^{-1}) and S_4 (37.1 t ha^{-1}). The lowest yield of 9.3 was registered by S_{12}. The interaction effects of M at S and S at M were also significantly differed. Among the interaction treatment effects, M_1S_1 performed better than other treatments showing significantly higher yield of 63.3 t ha^{-1} followed by M_1S_3 (53.6) and M_1S_5 (50.9). However, the interaction between M_2 and subplot treatments exhibited considerable reduction over the interaction between M_1 and subplot treatments. $M_2S_{1,}$ $M_2S_{2,}$ M_2S_3 and M_2S_4 registered about 8.7 to 13.8% reduction. M_2S_5 $M_2S_{6,}$ M_2S_7 and M_2S_8 recorded about 14.8 to 22.7% reduction, whereas M_2S_9, $M_2S_{10,}$ M_2S_{11} and M_2S_{12} showed 24.6 to 38.8% yield reduction (t ha^{-1}) over the interaction between M_1 and sub plot treatments.

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. 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

Table 3. Effect of water stress on membrane stability index (MSI: %) at different growth stages of banana cultivars.

Treatment	3rd MAP	5th MAP	7th MAP	9th 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	**3rd MAP**	**5th MAP**	**7th MAP**	**9th MAP**	**Harvest**	**Mean**
M_1S_1	86.1	87.8	88.8	83.8	83.5	86.00
M_1S_2	85.4	87.1	88.1	83.1	82.8	85.30
M_1S_3	82.5	84.2	85.2	80.2	79.9	82.40
M_1S_4	82.0	83.7	84.7	79.7	79.4	81.90
M_1S_5	81.7	83.4	84.4	79.4	79.1	81.60
M_1S_6	81.0	82.7	83.7	78.7	78.4	80.90
M_1S_7	77.3	79.0	80.0	75.0	74.7	77.20
M_1S_8	75.6	77.3	78.3	73.3	73.0	75.50
M_1S_9	73.5	75.2	76.2	71.2	70.9	73.40
M_1S_{10}	71.4	73.1	74.1	69.1	68.8	71.30
M_1S_{11}	71.1	72.8	73.8	68.8	68.5	71.00
M_1S_{12}	70.9	72.6	73.6	68.6	68.3	70.80
M_2S_1	81.5	83.2	84.2	79.2	78.9	81.36
M_2S_2	80.8	82.5	83.5	78.5	78.2	80.66
M_2S_3	77.9	79.6	80.6	75.6	75.3	77.76
M_2S_4	77.4	79.1	80.1	75.1	74.8	77.26
M_2S_5	72.1	73.8	74.8	69.8	69.5	71.96
M_2S_6	71.4	73.1	74.1	69.1	68.8	71.26
M_2S_7	67.7	69.4	70.4	65.4	65.1	67.56
M_2S_8	66.0	67.7	68.7	63.7	63.4	65.86
M_2S_9	59.2	60.9	61.9	56.9	56.6	59.05
M_2S_{10}	57.1	58.8	59.8	54.8	54.5	56.95
M_2S_{11}	56.8	58.5	59.5	54.5	54.2	56.65
M_2S_{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

Table 3. Contd.

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

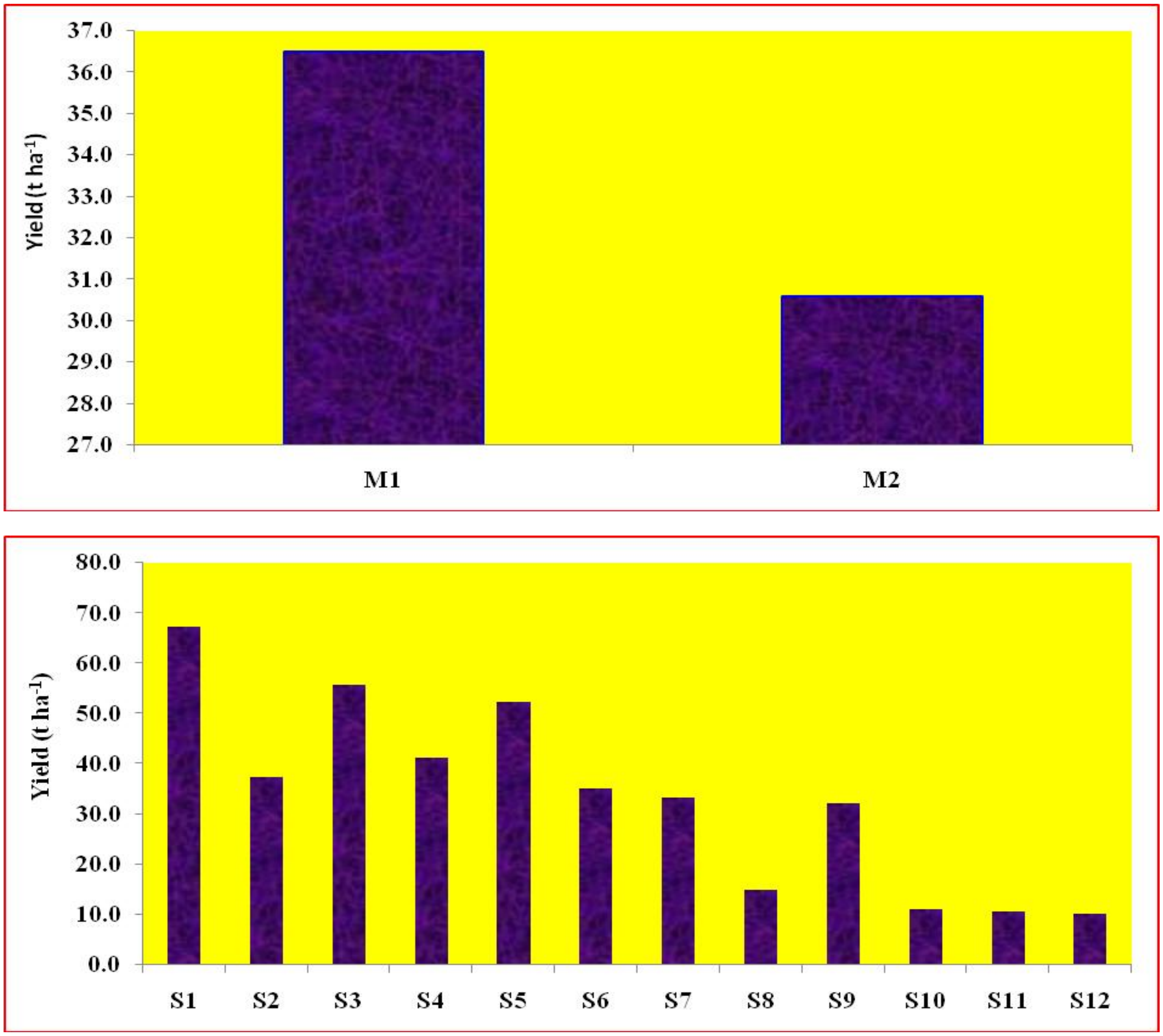

Figure 2. Effect of water stress on yield (t ha^{-1}) of banana cultivars and hybrids.

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 x Pisang jajee, Saba and Sannachenkathali were able to maintain higher relative water content under water deficit condition with 6% 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 x Anaikomban, Matti x cultivar rose and Pisang jajee x 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% due to water deficit than 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 as 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 became 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 as compared to the control. Leakage control was also observed by Deshmuukh 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% than the control (Figure 2). 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.

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