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Impact of water deficit on growth attributes and yields of banana cultivars and hybrids

K. Krishna Surendar[1]*, V. Rajendran[1], D. Durga Devi[2], P. Jeyakumar[2], I. Ravi[3] and K. Velayudham[4]

[1]Vanavarayar Institute of Agriculture, Pollachi, India.
[2]Department of Crop PhysiologyTamil Nadu Agricultural University Coimbatore, India.
[3]National Research Centre for Banana (ICAR), Thiruchirapalli, India.
[4]Director of CSCMS, TNAU, Coimbatore-641 003, India.

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Water deficit is one of the most important factors to limit banana productivity in the world, especially in dry and semidry areas where large fluctuation in the amount and distribution of the rain these areas faces. Some cultivars and hybrids have a set of physiological adaptations that allow them to tolerate water deficit and the degree of morphological and physiological adaptations may vary considerably among species. This study examined the relationship between the yield reduction by leaf area (LA), leaf area index (LAI) and specific leaf weight (SLW). Our results showed significant reduction in all growth attributes at all the stages due to water deficit. Association between all these growth attributes character and yield components was observed particularly at 5th and 7th MAP stage. It is clear that all these parameters could explain some of the mechanisms which indicate tolerance to drought and help in understanding the physiological responses that enable plants to adapt to water deficit and maintain growth and productivity during stress period and indicate important of these traits in future breeding programs for screening and selection of tolerant cultivars and hybrids of banana.

Key words: Banana, water deficit, leaf area, leaf area index, specific leaf weight and yield.

INTRODUCTION

Soil water deficit limits plant growth and field crops production more than any other environmental stresses (Zhu, 2002; Almeselmani et al., 2011). Its remains an ever-growing problem that severely limits banana production worldwide and causes important horticultural and agricultural losses particularly in arid and semiarid areas (Kallarackal et al., 1990). It induces many morphological and physiological responses on plants; so that banana plants are able to develop tolerance mechanisms which will provide to be adapted to limited environmental conditions (Turner, 1998). Banana 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 leads to reduction in photosynthetic pigments (Kallarackal et al., 1990) with increased leaf senescence (Turner, 1998). Leaf area is an important component that is closely related to the physiological processes controlling dry matter production and yield. Leaf area has

*Corresponding author. E-mail: surendartnau@gmail.com.

been shown to influence the radiant energy interception, an important photosynthetic parameter in crop plants, showing positive relationship with net photosynthetic activity. Plants may respond to water deficit in different ways such as reducing leaf area, hence the transpiring surface (Meyer and Boyer, 1972). Leaf Area as one of the growth parameters also indicates the size of photosynthesizing apparatus. Leaf Area is a fundamental determinant of the total photosynthesis by the plant. Leaf Area showed a positive relationship with net photosynthetic activity. In banana, higher amount of LA on a shoot coincide with the emergence of the bunches (inflorescence) from the top of the pseudostem. After this, no new leaves are produced on that shoot because the bunch is terminal as the older leaves senescence (Turner, 1998). Turner (1998) found that water stress resulted in reduced LA leading to decreasing Leaf Area Index in banana. SLW is useful in understanding the means of the assimilates in leaf expansion. The SLA is a measure of LA per unit dry weight and it varies with cultivar, leaf position, growth stage and the environmental condition by Veerawirdh (1974). The SLW refers to photosynthetic efficiency and in turn higher total dry matter accumulation. It is the leaf dry weight per unit leaf area produced. Kramer (1983) found that water stress not only reduced LA but often increased leaf thickness, thereby increasing the weight per unit area, that is, in increased SLW. Thicker leaves aids in leaf water conservation because of the lower surface or lower volume ratio (Lopez, 1997). Drought has rarely been addressed in the past, but is gaining importance in the face of depleting natural resources (Iyyakkutty Ravi et al., 2013). The results of successful cultivation, especially of the water loving Cavendish clones, in drought prone areas with protected irrigation have provided the required momentum to perform research on drought in bananas (Iyyakutty Ravi et al., 2013). In subtropical and semi- arid banana cultivation zones have very limited rainy days and also had uneven distribution of rainfall, new crop management practices in terms of varieties selected, soil improvement (in terms of physical properties and nutrient enrichment), water management, etc. are being adopted (Iyyakutty Ravi et al., 2013). With this above background, the experiment aimed at evaluating the effects of the progressive water deficit, as well as to investigating the growth attributes behavior in twelve banana cultivars and hybrids submitted to water restriction during the different growth stages.

MATERIALS AND METHODS

The experiment was carried out at National Research Centre for banana, Thiruchirapalli, during 2011 to 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, 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 (Table 1 and 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 growth attributes of Leaf area, leaf area index and specific leaf weight were measured during 3rd, 5th, 7th, 9th month after planting and at harvest stages of the crop. The procedure for measuring leaf area, leaf area index and specific leaf weight are given as follows.

Leaf area (LA)

The leaf area was calculated by multiplying leaf length and breadth with the Constant factor 0.83 and number of green leaves and expressed in m^2 (Hewitt, 1955).

Leaf area = l x b x n x 'K'

Where, l = length of the leaf; b = breadth of the leaf; n = number of leaves, and 'K' = constant factor (0.83).

Leaf area index (LAI)

The leaf area index (LAI) of functional leaves was calculated by employing the formula of Williams (1946):

$$LAI = \frac{\text{Leaf area per plant}}{\text{Ground area occupied by the plant}}$$

Specific leaf weight (SLW)

The specific leaf weight (SLW) was calculated by using the formula of Pearce et al. (1968) and expressed as mg cm^{-2}:

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

RESULTS

Leaf area (LA)

The leaf area was affected by water deficit in all the cultivars and hybrids as well as the interaction of M at S and S at M were significant (Table 2). Among the twelve cultivars and hybrids, Karpuravalli, Karpuravalli x Pisang Jajee, Saba, and Sannachenkathali had significant differences in leaf area under the irrigation at 50% available soil moisture level. The highest leaf area was observed in Karpuravalli with very lesser reduction was noticed under the water deficit (Figures 2 and 3). The lowest leaf area was observed in Matti, Pisang Jajee x Matti, Matti x Anaikomban and Anaikomban x Pisang Jajee cultivars and hybrids under the water deficit, respectively. There was a high and positive correlation

Table 1. General observations on germplasm performance under water deficit conditions (Anon, 2006, 2007; Iyyakutty Ravi et al., 2013, Uma and Sathiamoorthy, 2002; Uma et al., 2002).

Genomic group	Sub group / status	Genotypes (verities / types)	Reaction to water deficit
AA	Wild	*M. acuminata* ssp Burmannica	Highly susceptible
		M. acuminata ssp burmannicoides	Highly susceptible
		M. acuminata ssp malaccensis	Highly susceptible
		M. acuminata ssp zebrina	Highly susceptible
BB	Wild	Athiakol,	Susceptible
		Elavazhai, Attikol	Less tolerant
		Bhimkol,	Moderately tolerant
		M.balbisiana type Andaman	Tolerant
AAA	Ney Poovan	Ney Poovan and Nattu Poovan	Tolerant
	Unique	Thellachakkarakeli	Moderately tolerant
	Cavendish	Grand Naine, Robusta, Dwarf Cavendish, Williams	Susceptible
AAB	Mysore	Poovan	Moderately tolerant
ABB	Pisang Awak	Karpuravalli and Udhayam	Tolerant
	Monthan	Pidi Monthan and Ash Monthan	Moderately Tolerant

between leaf area and yield water deficit conditions.

Leaf area index (LAI)

The result on LAI had similar effect were showed in all the growth stages and also all the cultivars and hybrids by water deficit. The interaction effects of M at S and S at M were significant differed at all the cultivars and hybrids (Table 3). Water deficit decreased LAI in banana cultivars and hybrids. Among the twelve cultivars and hybrids, Karpuravalli, Karpuravalli x Pisang Jajee, Saba, and Sannachenkathali had significant differences in LAI under the main plot treatments. The highest LAI were observed in Karpuravalli due to the water deficit. The lowest LAI was observed in Matti, Pisang Jajee x Matti, Matti x Anaikomban and Anaikomban x Pisang Jajee cultivars and hybrids under the water deficit, respectively.

Specific leaf weight (SLW)

The data on SLW was affected under water deficit as well as the interaction of M at S and S at M were significant at all stages of growth (Table 4). Water deficit reduced SLW in all the twelve banana cultivars and hybrids. Among the twelve cultivars and hybrids, Karpuravalli, Karpuravalli x Pisang Jajee, Saba, and Sannachenkathali had significant differences in SLW under the main plot treatments. The highest SLW was observed in Karpuravalli under the water deficit than the other cultivars and hybrids. The lowest SLW content was observed in Matti, Pisang Jajee x Matti, Matti x Anaikomban and Anaikomban x Pisang Jajee cultivars and hybrids under the water deficit, respectively. There was a high and positive correlation between SLW and yield water deficit conditions (Figure 4).

DISCUSSION

Leaf area is a fundamental determinant of the total photosynthesis of a plant. Leaf area always shows a positive relationship with net photosynthetic activity, because leaf enlargement is attributed to increase in number and width of grana and also high degree of stacking of grana (Flore et al., 1985). Leaf area development is based on the length and width of leaf, in general, was very sensitive to water deficit in banana as reported by Turner (1981). The leaf length of banana reduced during water stress situation, which is associated with reduced organ development. Gardner et al. (1981) opined that water stress decreases the leaf area due to reduced cell division and cell enlargement which could be caused by accumulation of unexpanded cells during the cycle. According to the results obtained in the present study, the cultivars of Karpuravalli, Karpuravalli x Pisang jajee, Saba and Sannachenkathali showed a lesser reduction in leaf area in the range of 8 to 12% due to water deficit over control. A 20 to 26% reduction in leaf area was registered by the cultivars of Poovan, Ney Poovan, Anaikomban and Anaikomban x Pisang jajee, whereas cultivars of Matti, Matti x Anaikomban, Matti x cultivar rose and Pisang jajee x Matti had higher

Table 2. Calculated pressure from stress treatment and soil moisture content from regression equation.

Soil moisture content (%)	Pressure (bar)	ASM (%)
33.46	-0.69	100.00
31.32	-2.46	93.60
30.19	-3.39	90.23
29.18	-4.22	87.21
28.14	-5.08	84.10
27.09	-5.94	80.96
26.12	-6.74	78.06
25.29	-7.43	75.58
24.91	-7.74	74.45
24.32	-8.22	72.68
23.78	-8.67	71.07
23.40	-8.98	69.93
23.11	-9.22	69.07
22.86	-9.43	68.32
21.28	-10.73	63.60
20.83	-11.10	62.25
19.51	-12.19	58.31
19.30	-12.36	57.68
18.63	-12.91	55.68
18.11	-13.34	54.12
17.81	-13.59	53.23
17.52	-13.83	52.36
17.10	-14.01	50.11
16.72	-14.47	49.01
16.00	-15.08	47.82

reduction in leaf area of about 38 to 48% over control. These results were confirmed by the findings of Levy et al. (1978) observing that leaf area increases with an increase in water supply because plants are able to photosynthesize more efficiently. This is because that an increased accumulation of photosynthates accelerates the pace of growth which in turn is reflected by vigorous plant growth. In banana, soil water regimes had a direct relationship on leaf width. There was an increase in leaf width with an increase in soil water regimes. This is because water is important for biochemical and physiological processes that lead to organ growth and development (Turner, 1972). A reduction in leaf area leading to reduced biomass accumulation and decreased growth and also leaf elongation of Kiwi fruit induced by water stress was a result of preferential partitioning of photosynthate to the roots and also shoots and thus affected leaf area development.

Leaf area index (LAI) is one of the principle factors influencing canopy net photosynthesis of the crop plants (Hansen, 1982). The capacity of a canopy of leaves in a plantation to intercept light and fix carbon is measured by the LAI. Turner et al. (2007) reported that the optimum LAI for banana is 2 to 5. In banana plantation with LAI of 4.5 about 90% of the ground will be shaded at noon on a sunny day. This implies that about 90% of incoming radiation is being intercepted by the leaf canopy. Thus increasing LAI beyond this value is of little benefit to the plantation because most of the incoming solar radiation is already being intercepted (Turner et al., 2007). Drought stress induced changes in LAI, which duly reflected in biomass production (Kerby et al., 1990). Turner (1998) found that water stress resulted in reduced LA leading to decreased LAI in banana (Table 5). The lack of cell expansion due to water shortage would be determined by decreased LA rather than the number of leaves (Hsiao, 1973). In the present study also the effect of water deficit on LAI could be revealed. The cultivars like, Karpuravalli, Karpuravalli x Pisang jajee, Saba and Sannachenkathali showed a reduction of 8 to 12% in LAI, whereas the cultivars like Poovan, Ney Poovan, Anaikomban and Anaikomban x Pisang jajee recorded 8 to 12 and 19 to 25% reduction in LAI at 7th MAP over control. However, the other cultivars of Matti, Matti x Anaikomban, Matti x cultivar rose and Pisang jajee x Matti registered a higher reduction percent of about 38 to 43 over control. As per the report of De Silva et al. (1979), reduction in LAI was observed due to acceleration of senescence under drought. According to Hoffman and Turner (1993), leaf growth rate was more sensitive to water stress.

Specific leaf weight (SLW), a measure of thickness of leaf, has been reported to have a strong positive correlation with leaf photosynthesis in several crops as reported by Bowes et al. (1972). In many crop species, thicker leaves would have more number of mesophyll cells with high density of chlorophyll and, therefore, have a greater photosynthetic capacity than thinner leaves (Craufurd et al., 1999). Specific Leaf Weight is highly correlated with the development of reproductive organ namely flower and ultimately yield. As observed in the present study, Karpuravalli, Karpuravalli x Pisang jajee, Saba and Sannachenkathali recorded higher SLW with lesser reduction per cent of about 8 to 9 due to water deficit over control. The mechanism of maintaining higher SLW could be related to its thick leaves with more photosynthetic proteins per unit area of the leaf (Wells and Nugent, 1980). The higher reduction in SLW (24 to 26%) under stressed conditions in the cultivars of Matti, Matti x Anaikomban, Matti x cultivar rose and Pisang jajee x Matti could also be related to lesser number of mesophyll cells leads to lower photosynthetic efficiency (Gardner et al., 1985).

Conclusion

Plants respond to drought stress through alteration in physiological and biochemical processes. Our results showed that the growth attributes of leaf area, leaf area index and specific leaf weight decreased under the water deficit condition. The banana cultivars and hybrids of

Table 3. Effect of water stress on leaf area (m^2 $plant^{-1}$) at different growth stages of banana cultivars and hybrids.

Treatment	3rd MAP	5th MAP	7th MAP	9th MAP	Harvest	Mean
Main plot						
M_1	2.7	4.5	6.3	5.7	5.1	4.87
M_2	2.1	3.9	5.1	4.5	3.9	3.89
Mean	2.41	4.20	5.66	5.14	4.48	4.38
SEd	0.023	0.037	0.054	0.053	0.039	
CD (P= 0.05)	0.101	0.159	0.234	0.229	0.168	
Sub plot						
S_1	5.1	8.8	13.7	12.0	9.3	9.77
S_2	4.3	7.2	11.5	8.7	8.6	8.09
S_3	3.8	7.1	7.9	7.9	7.1	6.76
S_4	2.4	4.2	6.1	6.1	5.0	4.77
S_5	2.6	4.6	6.5	5.8	5.2	4.92
S_6	2.4	3.4	4.4	4.3	3.9	3.69
S_7	2.0	3.1	3.9	3.7	3.4	3.22
S_8	1.5	3.0	3.8	3.7	3.3	3.08
S_9	1.5	2.8	2.8	2.7	1.9	2.34
S_{10}	1.3	2.6	2.8	2.7	2.4	2.34
S_{11}	1.1	2.2	2.3	2.0	1.9	1.88
S_{12}	0.9	1.4	2.2	2.1	1.9	1.69
Mean	2.41	4.20	5.66	5.14	4.48	4.38
SEd	0.056	0.088	0.126	0.120	0.097	
CD (P= 0.05)	0.114	0.179	0.254	0.243	0.197	
Interaction effect						
M_1S_1	5.7	9.4	14.3	12.6	9.9	10.35
M_1S_2	4.9	7.8	12.1	9.3	9.2	8.67
M_1S_3	4.4	7.7	8.5	8.4	7.7	7.34
M_1S_4	3.0	4.8	6.5	6.5	5.4	5.23
M_1S_5	2.8	4.8	7.2	6.5	5.8	5.43
M_1S_6	2.7	3.7	5.1	5.0	4.5	4.20
M_1S_7	2.2	3.4	4.6	4.3	4.1	3.73
M_1S_8	1.8	3.2	4.5	4.4	4.0	3.59
M_1S_9	1.7	3.0	3.4	3.3	2.5	2.75
M_1S_{10}	1.5	2.8	3.3	3.3	3.0	2.75
M_1S_{11}	1.3	2.3	2.8	2.6	2.4	2.29
M_1S_{12}	1.0	1.6	2.7	2.7	2.5	2.10
M_2S_1	4.5	8.2	13.2	11.4	8.7	9.19
M_2S_2	3.8	6.7	10.9	8.1	8.0	7.50
M_2S_3	3.2	6.6	7.4	7.3	6.5	6.17
M_2S_4	1.8	3.7	5.7	5.7	4.6	4.30
M_2S_5	2.3	4.3	5.8	5.1	4.5	4.41
M_2S_6	2.1	3.2	3.8	3.7	3.2	3.18
M_2S_7	1.7	2.8	3.2	3.0	2.8	2.71
M_2S_8	1.2	2.7	3.2	3.1	2.6	2.57
M_2S_9	1.4	2.6	2.2	2.1	1.4	1.93
M_2S_{10}	1.1	2.4	2.2	2.1	1.8	1.93
M_2S_{11}	0.9	2.0	1.7	1.5	1.3	1.47
M_2S_{12}	0.7	1.3	1.6	1.5	1.3	1.28
Mean	2.41	4.20	5.66	5.14	4.48	4.38
SEd						
M at S	0.080	0.126	0.179	0.171	0.138	

Table 3. Contd.

S at M	0.080	0.125	0.178	0.170	0.138
CD (P= 0.05)					
M at S	0.177	0.278	0.399	0.384	0.303
S at M	0.161	0.253	0.359	0.344	0.278

Table 4. Effect of water stress on leaf area index (LAI) at different growth stages of banana cultivars and hybrids.

Treatment	3rd MAP	5th MAP	7th MAP	9th MAP	Harvest	Mean
Main plot						
M_1	0.69	1.13	1.57	1.43	1.27	1.22
M_2	0.52	0.97	1.27	1.14	0.97	0.97
Mean	0.60	1.05	1.42	1.28	1.12	1.09
SEd	0.006	0.009	0.013	0.013	0.010	
CD (P= 0.05)	0.027	0.042	0.057	0.056	0.046	
Sub plot						
S_1	1.28	2.20	3.44	2.99	2.32	2.44
S_2	1.08	1.81	2.88	2.18	2.15	2.02
S_3	0.94	1.78	1.99	1.96	1.77	1.69
S_4	0.60	1.06	1.53	1.52	1.25	1.19
S_5	0.64	1.14	1.63	1.45	1.29	1.23
S_6	0.60	0.86	1.11	1.08	0.97	0.92
S_7	0.49	0.78	0.97	0.92	0.86	0.80
S_8	0.38	0.74	0.96	0.93	0.83	0.77
S_9	0.38	0.70	0.70	0.67	0.49	0.59
S_{10}	0.33	0.65	0.69	0.67	0.60	0.59
S_{11}	0.28	0.54	0.57	0.51	0.46	0.47
S_{12}	0.22	0.35	0.54	0.53	0.47	0.42
Mean	0.60	1.05	1.42	1.28	1.12	1.09
SEd	0.014	0.022	0.031	0.029	0.024	
CD (P= 0.05)	0.028	0.045	0.064	0.060	0.049	
Interaction effect						
M_1S_1	1.42	2.34	3.58	3.14	2.46	2.59
M_1S_2	1.23	1.95	3.03	2.33	2.30	2.17
M_1S_3	1.09	1.93	2.13	2.11	1.92	1.83
M_1S_4	0.75	1.21	1.63	1.62	1.35	1.31
M_1S_5	0.71	1.21	1.80	1.62	1.46	1.36
M_1S_6	0.66	0.93	1.28	1.25	1.14	1.05
M_1S_7	0.56	0.84	1.14	1.09	1.03	0.93
M_1S_8	0.45	0.81	1.13	1.10	1.00	0.90
M_1S_9	0.42	0.74	0.84	0.81	0.63	0.69
M_1S_{10}	0.37	0.69	0.83	0.81	0.74	0.69
M_1S_{11}	0.32	0.58	0.71	0.66	0.61	0.57
M_1S_{12}	0.26	0.39	0.69	0.68	0.61	0.53
M_2S_1	1.13	2.05	3.29	2.84	2.17	2.30
M_2S_2	0.94	1.67	2.73	2.04	2.01	1.88
M_2S_3	0.80	1.64	1.84	1.82	1.62	1.54
M_2S_4	0.46	0.92	1.43	1.42	1.15	1.08
M_2S_5	0.58	1.08	1.46	1.28	1.12	1.10
M_2S_6	0.53	0.79	0.94	0.92	0.80	0.80
M_2S_7	0.43	0.71	0.81	0.75	0.69	0.68

Table 4. Contd.

M_2S_8	0.31	0.68	0.79	0.77	0.66	0.64
M_2S_9	0.34	0.66	0.55	0.52	0.34	0.48
M_2S_{10}	0.29	0.61	0.54	0.52	0.45	0.48
M_2S_{11}	0.24	0.50	0.42	0.37	0.32	0.37
M_2S_{12}	0.18	0.31	0.40	0.39	0.32	0.32
Mean	0.60	1.05	1.42	1.28	1.12	1.09
SEd						
M at S	0.020	0.031	0.045	0.042	0.035	
S at M	0.020	0.031	0.045	0.042	0.034	
CD (P= 0.05)						
M at S	0.045	0.071	0.100	0.094	0.078	
S at M	0.040	0.064	0.091	0.084	0.070	

Table 5. Effect of water stress on Specific Leaf Weight (SLW: mg / cm^2) at different growth stages of banana cultivars and hybrids.

Treatment	3rd MAP	5th MAP	7th MAP	9th MAP	Harvest	Mean
			Main plot			
M_1	0.65	0.69	0.77	0.76	0.73	0.72
M_2	0.53	0.57	0.65	0.64	0.61	0.60
Mean	0.59	0.63	0.71	0.70	0.67	0.66
SEd	0.008	0.005	0.007	0.007	0.007	
CD (P= 0.05)	0.034	0.023	0.031	0.031	0.030	
Sub plot						
S_1	0.68	0.72	0.80	0.79	0.76	0.75
S_2	0.67	0.71	0.79	0.78	0.75	0.74
S_3	0.66	0.70	0.78	0.77	0.74	0.73
S_4	0.65	0.69	0.77	0.76	0.73	0.72
S_5	0.62	0.66	0.74	0.73	0.70	0.69
S_6	0.60	0.64	0.72	0.71	0.68	0.67
S_7	0.59	0.63	0.71	0.70	0.67	0.66
S_8	0.56	0.60	0.68	0.67	0.64	0.63
S_9	0.52	0.56	0.64	0.63	0.60	0.59
S_{10}	0.51	0.55	0.63	0.62	0.59	0.58
S_{11}	0.51	0.55	0.63	0.62	0.59	0.58
S_{12}	0.50	0.54	0.62	0.61	0.58	0.57
Mean	0.59	0.63	0.71	0.70	0.67	0.66
SEd	0.007	0.008	0.009	0.009	0.008	
CD (P= 0.05)	0.015	0.016	0.018	0.018	0.018	
			Interaction effect			
M_1S_1	0.71	0.75	0.83	0.82	0.79	0.78
M_1S_2	0.70	0.74	0.82	0.81	0.78	0.77
M_1S_3	0.69	0.73	0.81	0.80	0.77	0.76
M_1S_4	0.68	0.72	0.80	0.79	0.76	0.75
M_1S_5	0.68	0.72	0.80	0.79	0.76	0.75
M_1S_6	0.66	0.70	0.78	0.77	0.74	0.73
M_1S_7	0.65	0.69	0.77	0.76	0.73	0.72
M_1S_8	0.62	0.66	0.74	0.73	0.70	0.69
M_1S_9	0.60	0.64	0.72	0.71	0.68	0.67
M_1S_{10}	0.59	0.63	0.71	0.70	0.67	0.66

Table 5. Contd.

M_1S_{11}	0.59	0.63	0.71	0.70	0.67	0.66
M_1S_{12}	0.58	0.62	0.70	0.69	0.66	0.65
M_2S_1	0.64	0.68	0.76	0.75	0.72	0.71
M_2S_2	0.63	0.67	0.75	0.74	0.71	0.70
M_2S_3	0.62	0.66	0.74	0.73	0.70	0.69
M_2S_4	0.61	0.65	0.73	0.72	0.69	0.68
M_2S_5	0.56	0.60	0.68	0.67	0.64	0.63
M_2S_6	0.54	0.58	0.66	0.65	0.62	0.61
M_2S_7	0.53	0.57	0.65	0.64	0.61	0.60
M_2S_8	0.50	0.54	0.62	0.61	0.58	0.57
M_2S_9	0.44	0.48	0.56	0.55	0.52	0.51
M_2S_{10}	0.43	0.47	0.55	0.54	0.51	0.50
M_2S_{11}	0.43	0.47	0.55	0.54	0.51	0.50
M_2S_{12}	0.42	0.46	0.54	0.53	0.50	0.49
Mean	0.59	0.63	0.71	0.70	0.67	0.66
SEd						
M at S	0.013	0.012	0.014	0.014	0.014	
S at M	0.011	0.011	0.012	0.013	0.012	
CD (P= 0.05)						
M at S	0.038	0.030	0.037	0.038	0.039	
S at M	0.022	0.023	0.026	0.026	0.025	

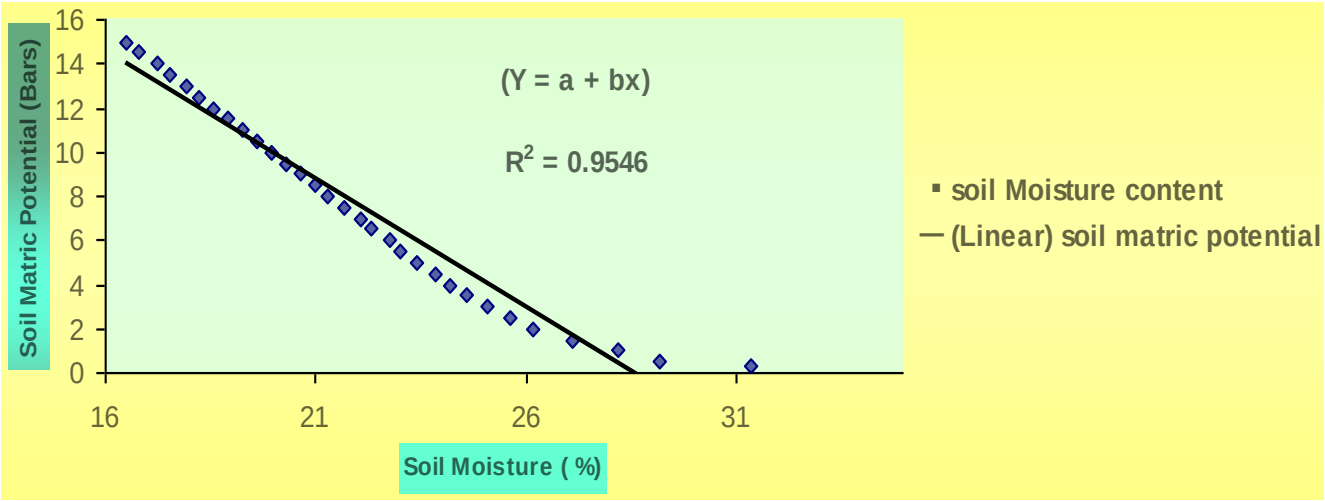

Figure 1. Pressure plate apparatus soil moisture release curve. Regression equation to find out pressure from soil moisture: [Y = a + bx]; where Y = Pressure (bar); X = soil moisture content (%); 'a' = 28.26158 and 'b' = - 0.8239.

Karpuravalli, Karpuravalli x Pisang jajee, Saba and Sannachenkathali with lesser reduction in leaf area, leaf area index and specific leaf weight and also smaller bunch yield reduction when the plants endured water deficit. The findings of this research also showed that the leaf area, leaf area index and specific leaf weight can be used as a drought tolerance index to selection tolerant genotypes under water deficit conditions in banana cultivars and hybrids.

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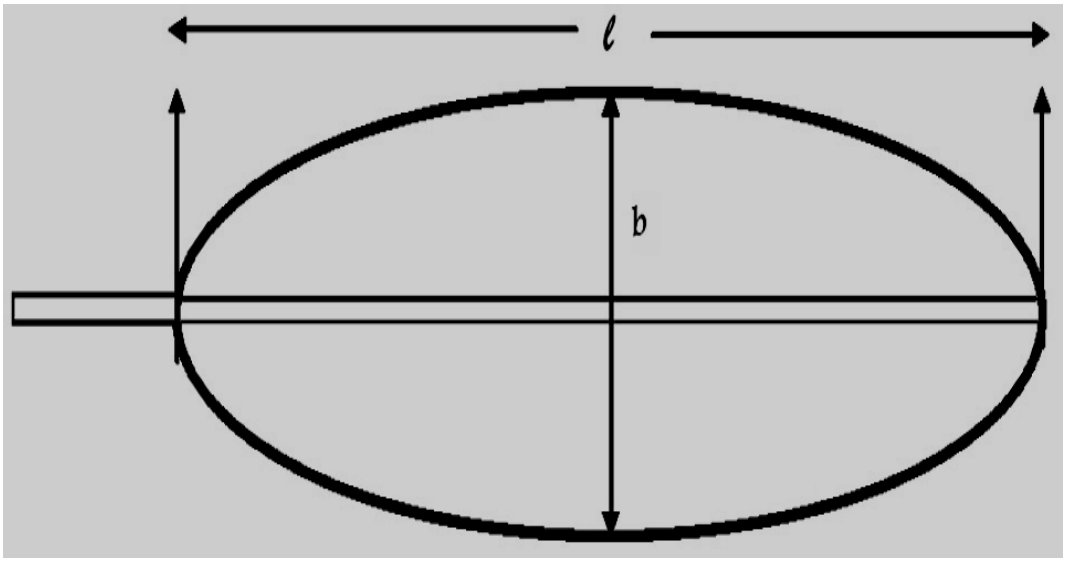

Figure 2. Diagram representing the banana leaf for measuring lamina length (*l*) and width (*b*). Source: Iyyakutty Ravi et al. (2013).

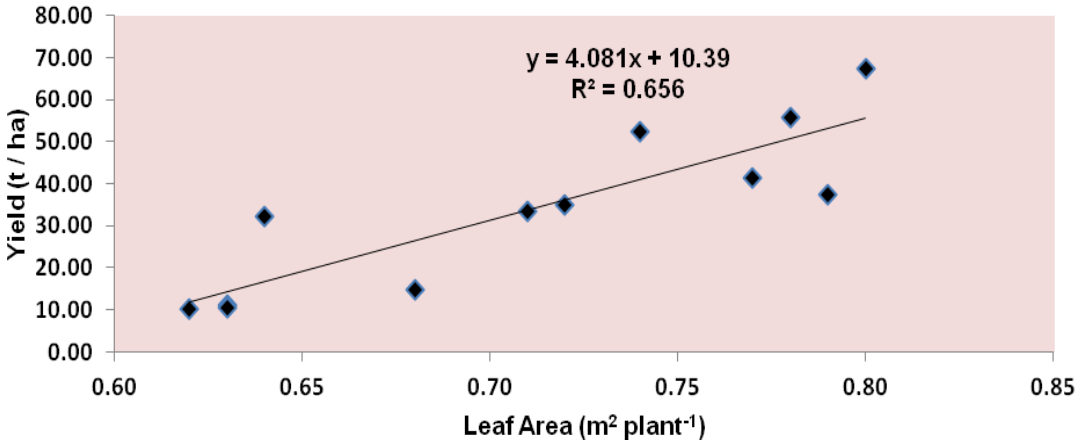

Figure 3. Correlation of leaf area (m^2 $plant^{-1}$) (LA) with yield.

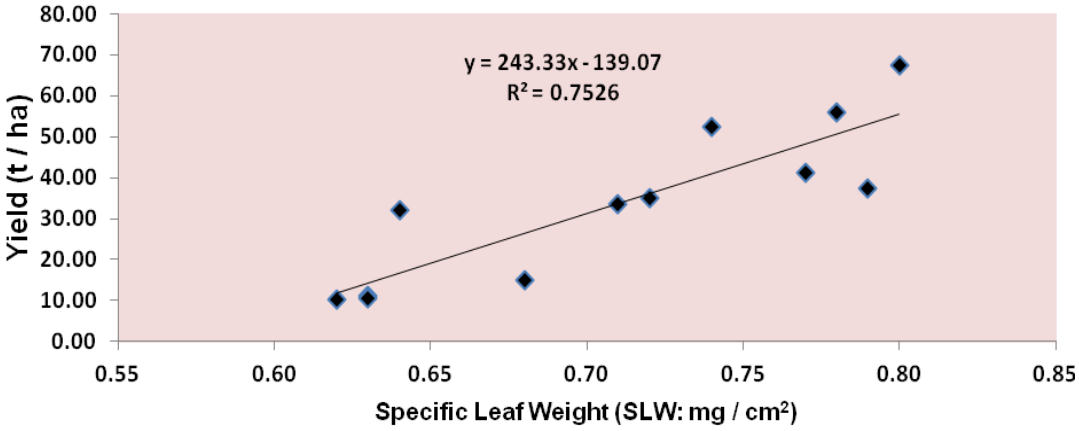

Figure 4. Correlation of specificleaf weight (mg/cm^2) (SLW) with yield.

Abbreviations: LA, Leaf area; **LAI,** leaf area index; **SLW,** specific leaf weight; ****,** highly significant; ***,** significant.

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