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INFLUENCES OF WATER STRESS ON PLANT PHOTOSYNTHETIC, GROWTH AND LEAF YIELD OF DIFFERENT MAULBERRY VARIETIES

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ABSTRACT

Photosynthesis plays a prime role in carbohydrate metabolism and influenced by environmental stress conditions. Water stress is one of the environmental stress factors, which alters several regulatory mechanisms and consequently leads to yield loss in crop plants. With the above background information, selected six mulberry (*Morus sp.)* genotypes namely V1, M5, G4, G2, RC1 and RC2 and conducted experiments under natural photoperiod conditions in potted plants under normal and water stress conditions. During the experimentation physiological parameters such as photosynthetic rate, stomatal conductance, transpiration rates and relative water content and plant growth and yield parameters under control and stressed plants was recorded. Results indicated that water stress conditions have significantly influenced the altering of all photosynthetic and plant growth and yield parameters in water stressed conditions compared to watered conditions (normal). Photosynthetic rate was significantly reduced in all the varieties in the order *viz.* V1 (17.6 µ mol $CO_2/m^{-2}s^{-1}$), M5 (9.84), G4 (7.77), G2 (8.79), RC1 (7.40) and RC2 (12.9) as compared to Controls of V1 (22.2), M5 (11.4), G4 (10.4), G2 (13.4), RC1 (9.79) and RC2 (14.81µ mol $CO_2/m^{-2}s^{-1}$), respectively. Similar trend was noticed in case of stomatal conductance, transpiration rate, chlorophyll content, relative water content and other mulberry plant growth and yield parameters of all the varieties. However it was reverse in case of Transpiration rate. It was recorded increased levels in stress conditions compared to normal watering in all the varieties in the order V1 (5.54-5.27µ mol $CO_2/m^{-2}s^{-1}$) followed by M5 (5.32-5.33), RC2 (4.12-4.84), G4 (3.12-3.15), G2 (2.37-5.57) and RC1 with 2.24 to 2.48µ mol $CO_2/m^{-2}s^{-1}$, respectively. Water stress conditions also affected the mulberry plant growth and yield parameters in all the varieties in the order as mentioned above. From the study it can be inferred that water stress conditions not only hamper the physiological parameters but also severely affects the plant growth and yield parameters and inferring that this information can be used in screening the mulberry genotypes for water stress tolerance.

KEYWORDS: Water stress, mulberry genotypes, photosynthesis, leaf yield.

INTRODUCTION

Irrigation is the artificial application of water which aims to maintain the soil moisture required for an optimum in plant growth. Water demand has significantly increased over the last decades while available water resources are becoming increasingly scarce. This is mainly due to the combined effect of climate change, persistent drought and the increase of water demands related to increase in irrigated surfaces. In this context, improvement of water management in agriculture, which is the biggest water consumer, is necessary to enhance agricultural productivity in order to meet food demands of the growing population but also it is an imperative to evolve drought resistant varieties to cultivate even under low water regimes (Kharrou *et al.,* 2011). Mulberry (*Morus spp*.) is a potential perennial tree crop for agro forestry yielding fodder, fruit, fuel, wood and medicine also cultivated as a seasonal crop for its foliage to feed silkworm and to generate raw silk. It has been exploited commercially for the silk industry to rear silkworms (*Bombyx mori* L). The crop has a transcontinental distribution and is cultivated in more than 50 countries both in temperate and tropical climates (Biasiolo *et al.,* 2004). In India, the total area under mulberry cultivation is around 171.95 ha (Lakshmanan, 2007).

Plant nutrients are taken up by plants in solution form for which soil moisture without nutrients is of no use to the plants. The sustainability of any production system requires optimum utilization of resources be it water, fertilizer or soil. Similarly mulberry leaf production and productivity is related to soil moisture and nutrients available therein and both these factors are interrelated and are complimentary to each other. Water availability is one of the most important determinants of leaf yield in mulberry (Chaitanya *et al.*, 2002). It is observed that irrigation increased leaf yield of mulberry by about 68% (Sudhakar *et al*., 2018). Hence, increase in leaf production and productivity of mulberry is possible by improved methods of irrigation. Leaf quality and leaf area with desired levels of nutrient status such as proteins, sugars, fibre and rich in chlorophylls is the major economic unit of mulberry to determine the quality raw silk production. All the above nutrient status are directly or indirectly dependant on the availability of water resource. Several reports revealed that stomatal conductance, transpiration rate, low photosynthesis rate effected by water stress conditions. There is very less information available about how decreasing and increasing photosynthesis rates, stomatal and transpiration rates varies under water stress conditions among the mulberry genotypes are not discussed ornately. Limited literature is available on varied mulberry cultivars in regard to their physiological alterations during water stress conditions (Dandin *et al*., 2003; Chaitanya *et al*., 2003; Ramanjulu *et al*., 1998; Thimmanaik *et al*., 2002). Moreover, data on the physiological growth responses and leaf yield contributing traits of mulberry under water stress conditions are scanty. The ability to maintain key physiological processes, such as photosynthesis during water stress, is indicative of sustainable productivity under water shortage. To understand various factors controlling and determining the growth and leaf yield of mulberry under water stress, it is imperative to identify certain morpho-physiological traits which are directly associated with drought stress tolerance. Hence, the study was undertaken to find out the happenings in leaf physiology and morphology, plant growth and yield alterations under stress conditions in the tropical region of Andhra Pradesh.

MATERIALS AND METHODS

The experiment was conducted at Department of Botany, Sri Krishna Devaraya University Anantapuramu, Andhra Pradesh during 2017-18. Mulberry cultivars recommended in the field among farmers like (V1, M5, G4 & G2) and other resource constraint varieties (RC1 & RC2) were selected for the study. From the 6 months old matured shoots of the above varieties cuttings were prepared in 12-15 cm long & 8-10 mm diameter with 3 to 4 active buds were planted in earthen pots containing 5 kg of air dried red loamy soil along with farmyard manure (FYM) in 3:1 proportion. Before filling the soil the initial soil reaction (pH & EC) and soil organic carbon was determined as pH-7.45, EC-0.058 dS/m & OC 0.280%. The experimental design was a randomized block design (RBD) with plot arrangement of treatments (Chaturvedi and Sarkar, 2000). The earthen potted plants of different varieties as detailed above were maintained following the standard procedures (Dandin *et al*., 2003) for one year under natural photoperiod exposure in the botanical garden of the university.

Treatment application: Before initiation of treatments the potted plants were pruned to a height of 10-12cms height applied 750g of FYM (i.e. 1.50kg in two splits/ yr) and after 15-20 days of sprouting of the plants chemical fertilizers *viz.* 28:14:4 g/plant/crop of Ammonium Sulphate (AS), Single Super Phosphate (SSP) and Muriate of Potash (MOP) were applied in each pot followed by the irrigation. Among the entire treatmental pots five crops schedule was maintained throughout the year with a gap of 70-80 days/ pruning schedule (Dandin *et al*., 2003). The treatments were imparted in two levels i.e. irrigation regimes with well-watered as **Control** and water-limited with stress condition as **treatment** during all the seasons but irrigation in the form of control and treated was imparted meticulously under the prevailing drought stricken conditions during the years 2017 & 2018. Two watering treatments of the plants *viz.* drought stress i.e. **water stress** (50% water of the FC) and **non-stress** i.e. control (80% water of FC) were applied at 14 days after emergence (DAE) and maintained throughout the growing season. Tested genotype V1 was selected as a check plant among all the varieties as because it has been recommended to the Southern part of India as a high yielding and most suitable variety cultivated under irrigated conditions (Dandin *et al.*, 2003; Kotresha *et al*., 2007). The photosynthetic measurements were recorded using IRGA Analysis instrument (IRGA-LICOR 6400-20, UK) make. The physiological parameters such as Photosynthetic rate, Stomatal conductance, Transpiration rate, Chlorophyll content and Relative Leaf Water Content (RLWC) were recorded using Soil Plant Analysis Development (SPAD) instrument during photosynthetically active radiation (PAR) at peak photosynthetic time (08:00–09.00 hours) ranged from 1400 to 50 µ mol $m^{-2}s^{-1}$ after 45 day of pruning in 5^{th} & 6^{th} leaves from the apical buds considered as most active and suitable leaves to record (Rao *et al.*, 1991). The plant growth and leaf yield parameters such as plant height, no. of branches, no. leaves, leaf area and leaf yield were recorded after 70 days of pruning (Satpathy *et al*., 1992; Sudhakar *et al.*, 2018). Control pots were irrigated twice per week (with a frequency of 20-24 times irrigations) in each growing season depending upon the edaphic and climatic conditions, whereas the pots given with stressed watering were irrigated once in fortnight in a growing season. The mean values of the replicated data was subjected for ANOVA and presented in **Table 1 & 2**.

RESULTS AND DISCUSSION

The perusal of the results shows that in all the mulberry varieties considered for the study such as V1, M5, G4, G2, RC1 and RC2 have shown significant variations against the normal (watered) and stress (limited watered) conditions physiologically and morphologically. The photosynthetic rate was recorded reduced levels in all the varieties under stress conditions as compared to the normal watering conditions (control). It was recorded that in. V1 (17.6 µ mol CO_2/ $m^{-2}s^{-1}$), M5 (9.84), G4 (7.77), G2 (8.79), RC1 (7.40) and RC2 (12.9) as compared to controls of V1 (22.2), M5 (11.4), G4 (10.4), G2 (13.4), RC1 (9.79) and RC2 (14.81 µ mol $CO_2/m^{-2}s^{-1}$), respectively. Similar trend was noticed in case of all the other physiological parameters such as stomatal conductance, Chlorophyll content and relative water content in all the varieties except in case of Transpiration rate where it was recorded increased levels of transpiration rate under stress conditions compared to normal watering (**Table 1 & Fig. 1 & 2**). Among the varieties it is observed that increased levels of photosynthetic rate was recorded in V1 variety under normal watering (Control-22.2 µ mol $CO_2/m^{-2}s^{-1}$) and stressed conditions (17.6 µ mol $CO_2/m^{-2}s^{-1}$) followed by RC2 (14.8 to 12.9), G2 (13.4 to 8.79), M5 (11.4 to 9.84), G4 (10.4 to 7.77) and RC1 (9.79 to 7.40), respectively. In case of stomatal conductance (SC) increased levels SC was recorded in RC1 variety (0.047-0.036 µ mol $H_2O/m^{-2}s^{-1}$) followed by G4 (0.039-0.004), M5 (0.036-0.016), RC2 (0.035-0.027), G2 (0.020-0.017) and least was in V1 variety with 0.018 to 0.017 µ mol $H_2O/m^{-2}s^{-1}$. In case of transpiration rate (TR) it was recorded in the order maximum in V1 (5.54-5.27 µ mol $CO_2/m^{-2}s^{-1}$) followed by M5 (5.32-5.33 7), RC2 (4.12-4.84), G4 (3.12-3.15), G2 (2.37-5.57) and RC1 with 2.24 to 2.48 µ mol $CO_2/m^{-2}s^{-1}$, respectively (Table 1 & Fig. 1). Whereas the chlorophyll content was recorded maximum in RC2 (28.87-25.00 µ mol/m^{-2}) followed by G2 (28.03-23.03), G4 (24.80-14.80), RC1 (24.67-22.44), M5 (23.93-17.33) and was least in V1 with 22.73 to 21.67 µ mol/m^{-2}, respectively. Moisture content of the leaf (RWC) was recorded maximum in V1 (95.3-73.8%) followed by G4 (93.6-80.5), M5 (84.6-69.5), RC1 (84.5-67.3), RC2 (82.6-69.8) and the least was recorded in G2 variety with 81.4 to 67.3% (**Fig. 2**).

Table 1: Influence of stress conditions on the plant physiological activities of different mulberry varieties.

Mulberry variety	Photosynthetic Rate (µ mol CO2/m-2s-1)		Stomatal Conductance (µ mol H2O/m-2s-1)		Transpiration Rate (µ mol CO2/m-2s-1)		Chlorophyll content (µ mol/m-2)		Relative leaf water content (RWC%)	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress
V1 var	22.2	17.6	0.018	0.017	5.54	5.27	22.73	21.67	95.3	73.8
M5 var	11.4	9.84	0.036	0.016	5.32	5.33	23.93	17.33	84.6	69.5
G4 var	10.4	7.77	0.039	0.004	3.12	3.15	24.80	14.80	93.6	80.5
G2 var	13.4	8.79	0.020	0.017	2.37	5.57	28.03	23.03	81.4	67.3
RC1 var	9.79	7.40	0.047	0.036	2.24	2.48	24.67	22.44	84.5	67.3
RC2 var	14.8	12.9	0.035	0.027	4.12	4.84	28.87	25.00	82.6	69.8

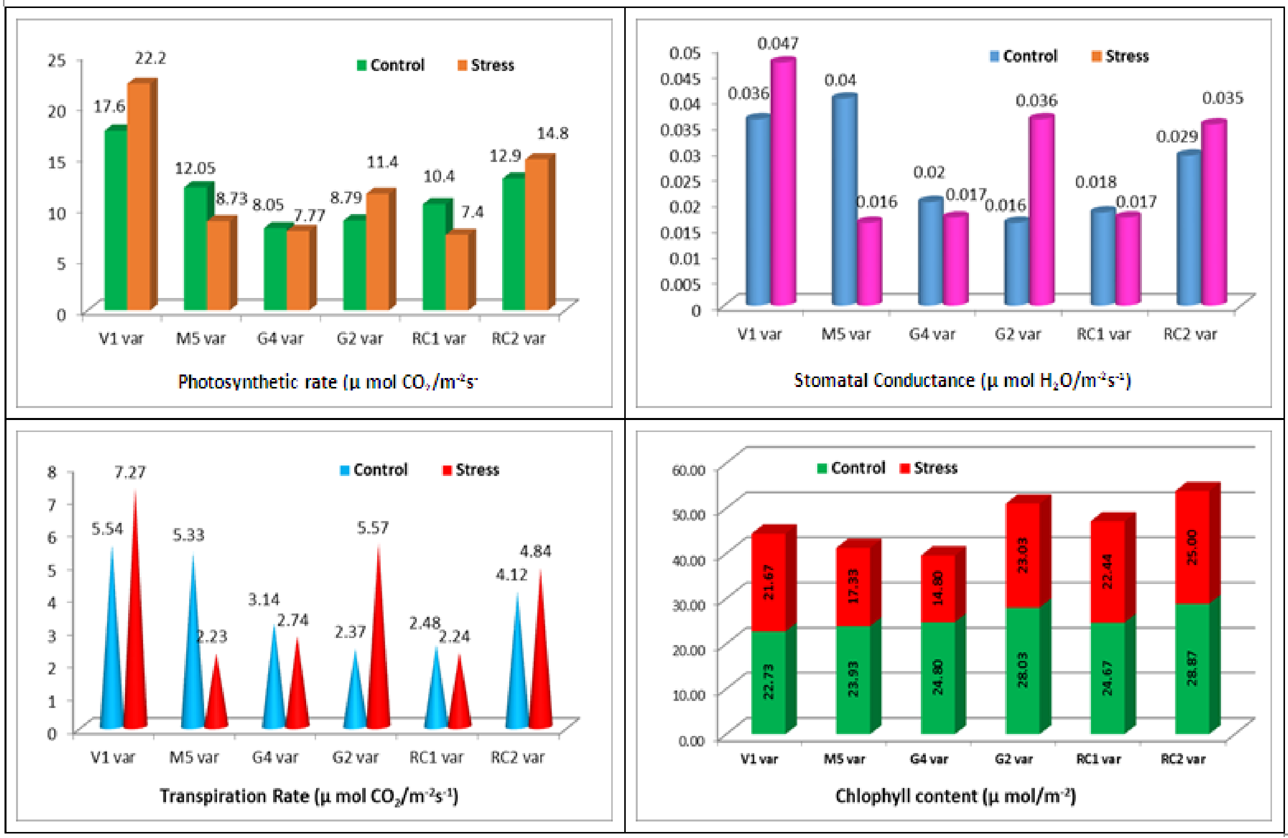

Fig. 1: Influence of stress conditions on the plant physiological parameters of different mulberry vaieties.

Kawamitsu *et al.* (2000) reported that drought stress decreased the rate of photosynthesis in an intertidal algae and a land plant. Purwanto (2003) also reported that photosynthetic rate decreased as water stress was increased. Photosynthetic reduction due to drought was caused by a decrease in leaf expansion, impaired photosynthetic machinery, pre-mature leaf senescence and associated reduction in food production (Wahid and Rasul, 2005). The decreased photosynthesis under stress might be attributed partly due to reduced stomatal conductance (Nagy and Galiba, 1995) and lowered transpiration of photosynthate. Drought stress may reduce plant photosynthesis by reducing leaf area, closing of stomata, and reducing the activity of dehydrated protoplasmic machinery.

Stomatal conductance is considered as a very important physiological parameter indicates the degree of exchange of CO_2 and water vapour between ambient and inner leaf. Stomatal conductance decreased very quickly as soil dried (Atteya, 2003). Water stress condition significantly decreased the stomatal conductance of leaves in all the genotypes studied (**Table 1 & Fig. 1**). Stomatal conductance was decreased under water stress, and plants grown under drought condition had lower stomatal conductance in order to conserve water (Purwanto, 2003). The effect of drought stress on transpiration rate was similar to that on photosynthesis. Transpiration rate in all the 6 mulberry genotypes decreased with water stress. The water stress conditions also affected the mulberry plant growth and yield parameters in all the varieties in the order as mentioned above. From the study it can be inferred that water stress conditions not only hamper the physiological parameters but also severely affects the plant growth and yield parameters and inferring that this information can be used in screening the mulberry genotypes for water stress tolerance. The stress conditions created by way of reduced irrigation level in limited frequency of irrigation has further affected the reduced levels of plant growth and yield parameters in all the high yielding mulberry varieties.

Increased levels of leaf yield was noticed in G4 variety (0.780 g/plant) with decreased yield due to stress condition (0.685 g/plant) followed by V1 (0.768-0.695), M5 (0.698-0.559), G2 (0.683-0.610), RC2 (0.655-0.600) where as RC1 recorded lower yield (0.605g to 0.505 g/plant) compared to all the mulberry varieties. Similar trend was noticed in case of all the other plant growth and yield parameters such as plant height, no. of branches/ plant, no. of leaves/ plant and leaf area (**Table 2 & Fig. 3**). Several workers reported the alterations due to drought stress conditions like causing changes in photosynthetic pigments and components (Anjum *et al.*, 2003), damaged photosynthetic apparatus (Fu and Huang, 2001) and diminished activities of Calvin cycle enzymes, which are important factors for reducing crop yield (Monakhova and Chernyadev, 2002). The less reduction of photosynthesis under stress condition was obviously helpful for maintaining better growth hence V1 variety has become farmer's choice of cultivation for enhanced quality leaf and increased silkworm cocoon production among the farming community in Southern part of India.

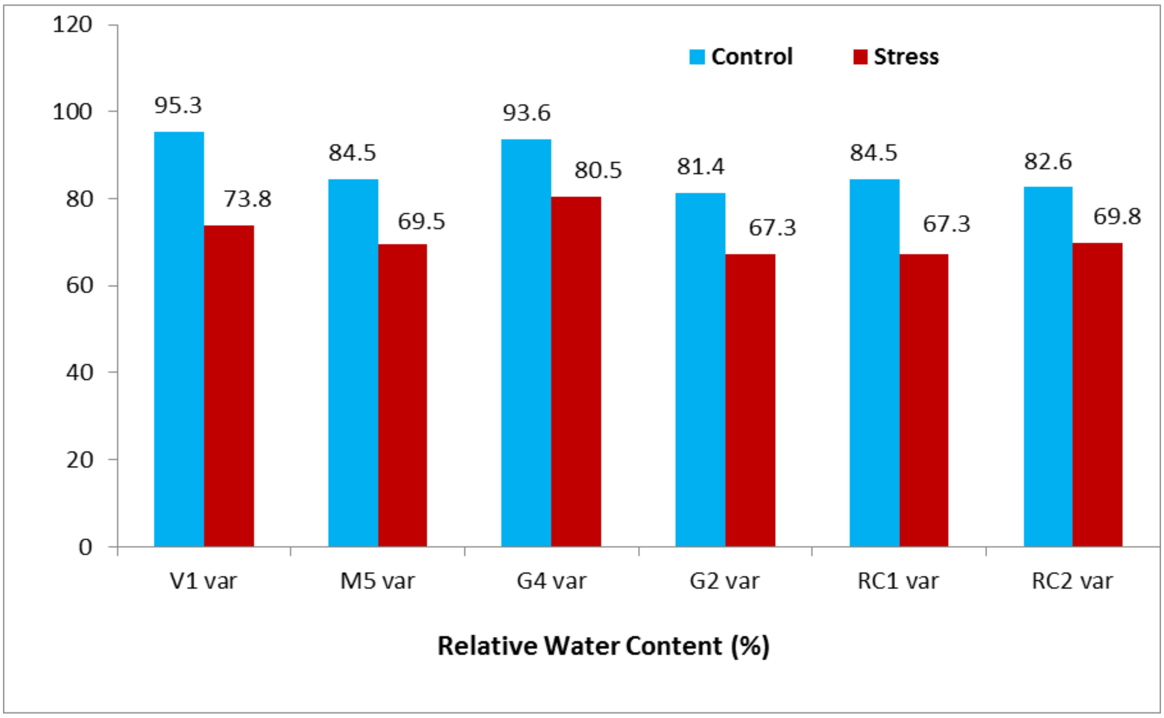

Fig. 2: Leaf moisture content in different mulberry cultivars under varied watering conditions.

Table 2: Influence of stress conditions on the plant growth and yield parameters of different mulberry varieties.

Mulberry variety	Plant height (cm)		No. of branched/ plant		No. of leaves/ plant		Leaf area (cm^2)		Leaf yield/ plant (gm)	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress
V1 var	158.3	148.0	8.3	7.85	270.8	255.5	191.8	185.5	0.768	0.695
M5 var	152.8	134.8	8.2	743	255.2	210.3	164.2	144.5	0.698	0.559
G4 var	160.2	138.5	8.9	8.02	261.4	245.4	195.2	175.5	0.780	0.685
G2 var	138.0	124.2	7.3	7.15	235.4	225.5	165.2	155.2	0.683	0.610
RC1 var	141.6	135.3	6.9	5.65	215.5	204.5	150.9	142.5	0.605	0.505
RC2 var	132.1	124.5	6.4	6.02	223.9	210.5	158.5	150.5	0.655	0.600

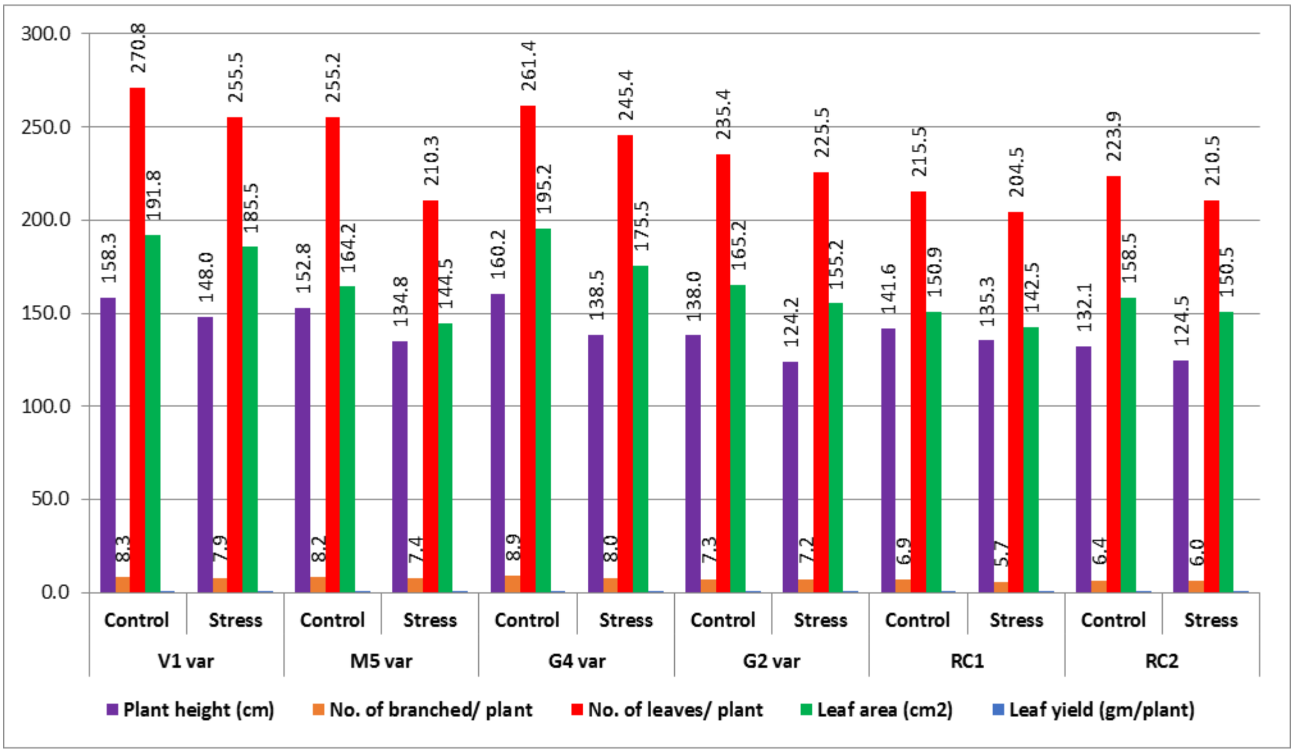

Fig. 3: Influence of stress conditions on the mulberry plant growth and leaf yield parameters.

CONCLUSSION

From the above study it can be inferred that water is important for plant growth and without water any biological activity will come down and under extremely drought stricken conditions wilting of the plant is a symptom of nearing to the death of a plant. Mulberry leaves with more than 90% moisture in chawki leaves are fed to chawki worms upto 3rd moult and later the leaves with more than 70% leaf moisture possessing were continued to feed the silkworms until its closure of life cycle by farming the cocoons. Any changes in moisture content and inferior nutritional aspects of the leaves cannot be compromised by the silkworms. Therefore, breeders always concentrate while selecting the mulberry varieties for recommendation unless they are resistant to drought tolerance by maintaining all the required quality parameters even under limited water recourses only screened for the benefit of silkworm rearing. Hence, the mulberry varieties like V1, M5, G4 and G2 were recommended for irrigated regions and the RC1 and RC2 were recommended for the low water with limited nutritional status and rainfed regions naming them as resource constraint varieties for the benefit of sericulturists.

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