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Mulch - Benefits Relating to Growth and Water Conservation in Ornamental Shrubs in a Tropical Environment

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Research Article

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ABSTRACT

Field experiments were conducted in sandy loam soil to evaluate the soil and plant water status in four shrubs under mulch and non-mulch conditions. Plants treated with mulch showed improved soil moisture status, treatments without mulch had significantly reduced growth performances in all four species tested. The plant water status, as evaluated by relative water content and leaf water potential were favourable under conditions with mulch suggesting the need for less water or reduced frequency of irrigation. Specific leaf weight and dry biomass were significantly greater when mulch was applied. Optimum soil and thermal environment with limited fluctuations were observed under conditions with mulch, even during dry periods. Therefore, it was concluded that mulching will be beneficial for the species evaluated here as it was able to maintain better soil and plant water status which led to enhanced growth.

INTRODUCTION

The benefits of mulching on conserving moisture and increasing growth and productivity in plants have been previously reported but mainly on crops [1-8]. Mulch has the potential to control weed growth, retain soil moisture and reduce the frequency of irrigation [9-12]. The conserved moisture has been shown to benefit plants during periods of drought [13].

The significance of this study stems from the poor understanding and inadequate quantification of growth attributes in relation to the application of mulch. Additionally, little is known about the effects of mulch on ornamental shrubs. *Bougainvillea glabra*, *Ixora coccinea*, *Hymenocallis speciosa* and *Costus woodsonii* Maas were tested in this study. These were shrubs that are widely grown in urban cities. They are used as ornamental shrubs for landscaping purposes and are favoured for their brightly coloured flowers. Given that these shrubs are grown for their aesthetics, the ability to keep them flowering is critical. Therefore, maintaining favourable soil moisture and temperature in the root zones will be ideal for sustained growth.

Among various measures, mulching may be one useful yet inexpensive option to maintain optimum moisture conditions in the soil. The intervention of mulching may also increase water use efficiency through reduced evaporation. This study was conducted in a sandy loam soil under tropical conditions to evaluate the soil and plant water status in four different shrubs under mulch and non-mulch conditions. The outcomes of this experiment will increase our understanding on the effects of mulch on shrub growth and mulching may be applied on other commonly grown shrubs to improve and sustain growth. Additionally, the retention of soil moisture will have other benefits relating to maintenance productivity, cost and water related savings.

MATERIALS AND METHODS

Experimental Plot and Meteorological Conditions

Field experiments were conducted during 2015–2017 over a 480-day period at a Research station in Singapore (1.3483˚N,

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103.6831˚E) with four ornamental shrubs, *Bougainvillea glabra*, *Ixora coccinea*, *Hymenocallis speciosa* and *Costus woodsonii* Maas. The climate was that of a tropical rainforest with no distinct seasons. The climate is characterised by uniform ambient temperature, high humidity and abundant rainfall **(Table 1)**. The soil is sandy loam with medium to angular blocky structure, and slightly acidic. The soil (0–30 cm) has a bulk density of 1.52 Mg m^{-3}; hydraulic conductivity of (saturated) 1.07 cm h^{-1}, saturated water content 0.51 $m^3 m^{-3}$; pH 6.5; organic C, 0.5 g kg^{-1}; total N, 0.047%; available P of 7.3 kg ha^{-1}; available K, 331 kg ha^{-1}; sand, silt and clay, 60.1, 22.8 and 17.1%, respectively. Available soil moisture ranged from 3–44% and 3–10% (wilting point) for the layers of soil at 0 to 0.9 m. Mean monthly air temperature, pan evaporation, relative humidity and total rainfall during the period of study is presented in **Table 1**.

Table 1. Climatic conditions during the period of study.

2015 - 2017	Temperature (°C)	(mm)	(mm day^{-1})	Humidity (%)
November	28.2	266	5.8	68
December	28.4	281	5.4	69
January	30.6	235	6.3	72
February	29.5	133	6.7	71
March	29.7	158	6.1	69
April	28.5	164	6.2	78
May	29.4	147	6.9	65
June	30.1	145	6.7	77
July	30.8	134	6.5	81
August	29.7	147	6.1	75
September	29.3	152	5.7	72
October	28.9	155	5.5	63
November	28.1	231	5.3	61
December	28.5	257	5.4	64
January	28.8	221	6	70
February	29.9	185	6.5	77

Experimental Design

The experiment was developed as a randomized block design with two treatments, namely, mulch and non-mulch conditions. Shrubs were approximately 1 to 1.3 m in height. Adequate irrigation to field capacity was applied daily, and each treatment was replicated thrice. The plot size was approximately 4 m by 3.0 m. The thickness of mulch was 1 ± 0.5 cm. The mulch used was comprised of organic compost derived from horticultural waste such as leaves, grasses, tree clippings and branches. The nutritional composition of the mulch was made up of N, P_2O_5, K_2O, $H_{14}MgO_{11}S$ in the proportions of 32:35.5:20:12.5 kg·ha^{-1}, respectively. Mulch was applied after the shrubs had emerged (10-15 Days after sowing (DAS)) and placed all around the base of each shrub. No fertilizer was applied throughout the course of this study. The plots were exposed to the natural elements except for rain.

Sampling and Measurements

Moisture (v/v) in the soil profile was monitored once a month at 15 cm increments (up to a maximum depth of 0.9 m) by measuring gravimetrically and then multiplying against bulk density. Soil water potential (SWP) was monitored at 0 cm to 15 cm and 15 to 30 cm depths using tensiometers (Spectrum Technologies, Inc. USA). Soil temperature was monitored at 7 cm, 14 cm, 21 cm and 28 cm depths using waterproof digital thermal probes (Dallas, Semiconductor – DS18B20) twice-a-day (1000 h and 1430 h).

The second fully expanded leaf from the top of each shrub was randomly collected every week between 1000 and 1200 h and transferred to the laboratory to determine the leaf water potential (LWP).

Relative water content (RWC) was identified according to the procedures in Barr and Weatherley [14].

The RWC was determined using this formula:

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

Where FW is the fresh weight, TW is the turgid weight, and DW, the dry weight.

LWP was measured using a pressure chamber and the details of the measurement are described in Balling and Zimmermann. This procedure was introduced by Scholander et al. [15,16].

Leaf area was measured using a Delta T area measurement system (Cambridge, UK). For growth data, the leaves were oven dried at 70°C and the Specific Leaf Weight (SLW) was expressed as leaf weight per unit of leaf area. The dry plant biomass was determined by drying the stem portion of the plant at 70°C and adding it to the respective leaf dry weight.

For Root Length Density (RLD), root samples were collected using a core auger. All above ground plant parts were removed and soil cores were excavated at every 15 cm depth down to 90 cm deep. The length of the cleaned, air-dried roots from each depth was measured using the WINRHIZO system (Regent Instruments Inc., Canada). RLD was determined for each soil depth by dividing the root length by the volume of the soil core. The data was statistically analysed using Statistical Analysis Software (SAS) package 9.4 [17]. Treatment means were compared using least significant difference (LSD, P=0.05).

RESULTS

Effect of Mulching on Soil Water Status

Soil moisture content was significantly higher (%, v/v) in the shallowest depth of 0 to 15 cm (approx. 38%) for conditions with mulch **(Figure 1)**. For non-mulch conditions, an average of 20% soil moisture was observed. Conversely, soil moisture content was lowest at the 75 to 90 cm depth **(Figure 1)**. Conditions with mulch at all soil depths were found to have higher soil moisture content. Differences in soil moisture between treatments ranged from 3 to 22.5% v/v **(Figure 1)**. The largest difference between mulch and non-mulch condition was observed at the shallowest depth (0-15 cm) and the smallest difference at 75-90 cm depth **(Figure 1)**.

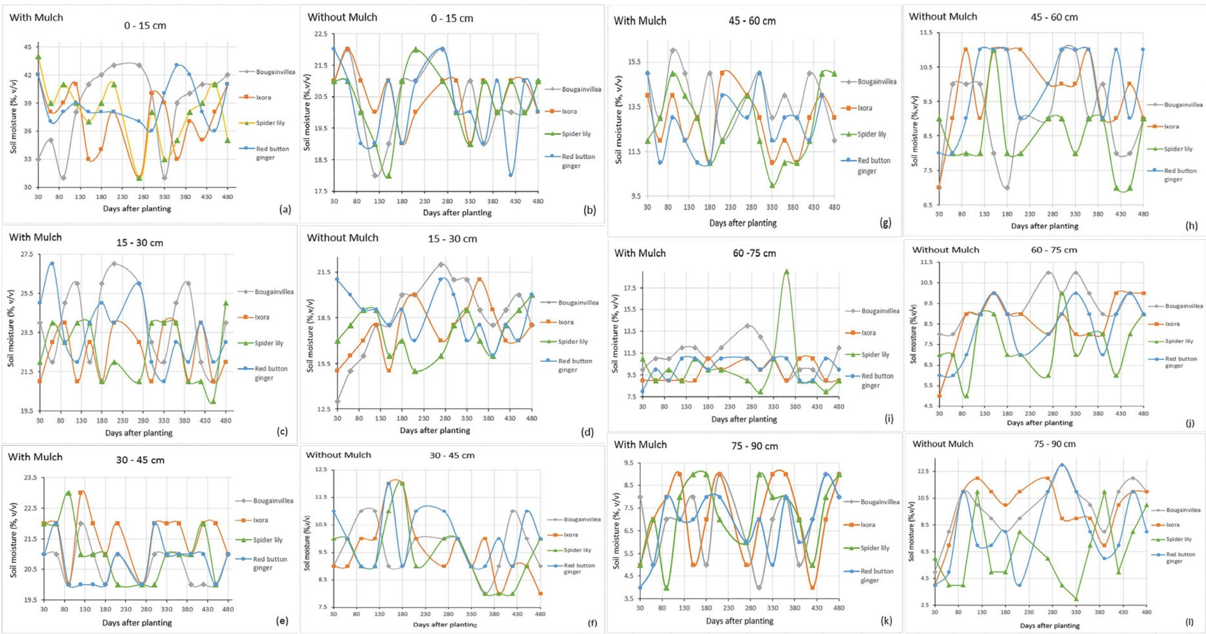

Figure 1. Profile soil moisture content with & without mulch at 0 – 15 cm, 15 – 30 cm, 30 – 45 cm, 45 – 60 cm, 60 – 75 cm, and 75 – 90 cm depths.

As the shrubs were irrigated daily the soil moisture was found to be consistent across species throughout the experimental period (**(Figure 1)**. Slight fluctuations in the data were a result of marginal changes in ambient temperature. This provided evidence to suggest the benefit of mulch on reduced evaporation.

Soil Moisture Potential

The moisture matric (tensiometric) potential over time was consistent when mulch was applied while rate of potential was more negative in plots without mulch **(Figure 2)**. Minimum fluctuations over time were observed for shrubs covered with mulch. Additionally, mulched shrubs also exhibited less negative potential values **(Figure 2)**.

Effect of Mulching on Soil Temperature

Average soil temperature was not significantly different at 1000 and 1430 h for all species and across all soil depths when mulch was present **(Table 2)**. Conversely, diurnal variation in soil temperature was observed when mulch was not applied. Soil temperature was significantly higher at 1430 h in non-mulch conditions and this was consistent at all depths in the soil **(Table 2)**.

Mulching on Plant Water Status

RWC of leaves was found to be between 75-95% across the experimental period when mulch was present **(Figure 3)**. A decrease was recorded following 300 days after planting (DAP) and was consistent for all species except for the red button ginger which exhibited a gradual decline. However, the shrubs were observed to have regained turgidity after 360 DAP. Conditions without mulch were observed to be associated with an inconsistent leaf water status throughout the experimental period affected by the ambient climatic conditions. Average RWC for mulch conditions was found to be between 83 - 86.6% while that of non-mulch plots were between 63.4 - 66%.

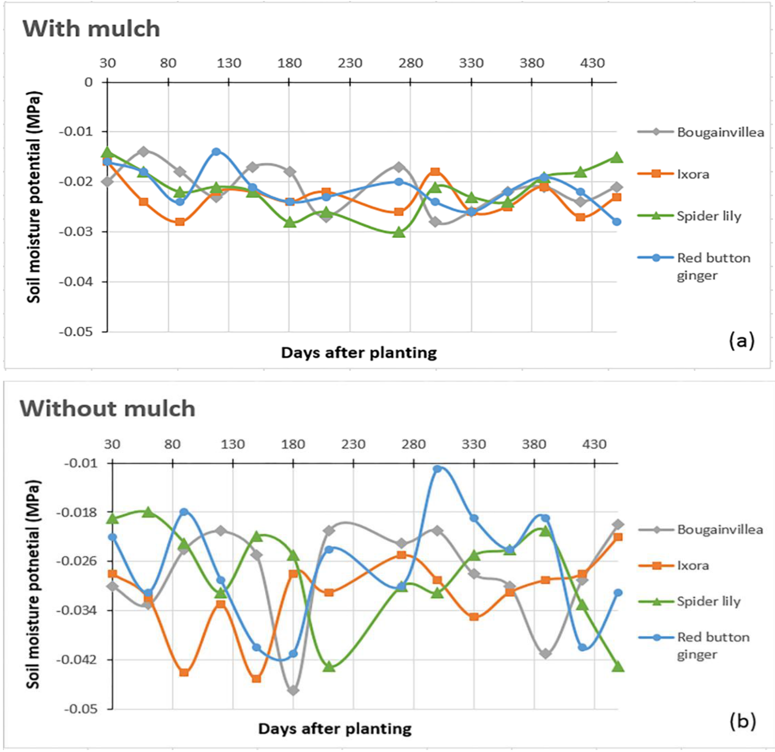

Figure 2. Soil moisture potential in shrubs under mulch and non-mulch conditions at 0 - 15 cm and 15 - 30 cm depths.

Table 2. Average soil temperature (°C) in shrubs for mulch and non-mulch conditions during 2015 – 2017.

With mulch	**Soil depth (cm)**							
	7		**14**		**21**		**28**	
	10 h	14:30 h	10 h	14:30 h	10 h	14:30 h	10 h	14:30 h
Bougainvillea	25.1[a]	27.3[a]	24.7[a]	26.7[a]	24.2[a]	26.2[a]	23.5[a]	25.3[a]
Ixora	25.6[a]	26.3[a]	25.2[a]	27.2[a]	24.7[a]	26.2[a]	24.2[a]	26.8[a]
Spider Lily	26.1[a]	27.5[a]	25.1[a]	27.5[a]	24.9[a]	26.4[a]	24.3[a]	26.1[a]
Red Button	25.5[a]	26.8[a]	24.7[a]	26.2[a]	24.1[a]	25.5[a]	23.6[a]	25.3[a]
Ginger								
Without mulch	**Soil depth (cm)**							
	7		**14**		**21**		**28**	
	10 h	14:30 h	10 h	14:30 h	10 h	14:30 h	10 h	14:30 h
Bougainvillea	27.5[a]	31.9[b]	27.2[a]	32.5[b]	26.5[a]	31.2[b]	26.1[a]	32.7[b]
Ixora	27.2[a]	32.5[b]	26.9[a]	32.6[b]	26.2[a]	32.3[b]	25.9[a]	32.9[b]
Spider Lily	28.1[a]	33.0[b]	27.3[a]	31.8[b]	26.9[a]	33.1[b]	26.5[a]	33.2[b]
Red Button	27.7[a]	32.8[b]	27.5[a]	33.2[b]	26.8[a]	32.7[b]	26.4[a]	33.5[b]
Ginger	-	-	-	-	-	-	-	-
Means within rows followed by different letters are significantly different at P=0.05.								

Leaf Water Potential

Similar to soil water potential, LWP had lesser fluctuations when mulch was applied while the opposite was seen with plots without mulch **(Figure 4)**. The average LWP for plots with mulch was found to be between -1.14 to -1.25 MPa while that of non-mulch plots were between -1.74 to -1.91 MPa **(Figure 4)**.

Growth - Specific Leaf Weight and Plant Dry Biomass

SLW was significantly lower under non-mulch condition. This was consistent across species and the differences were statisti

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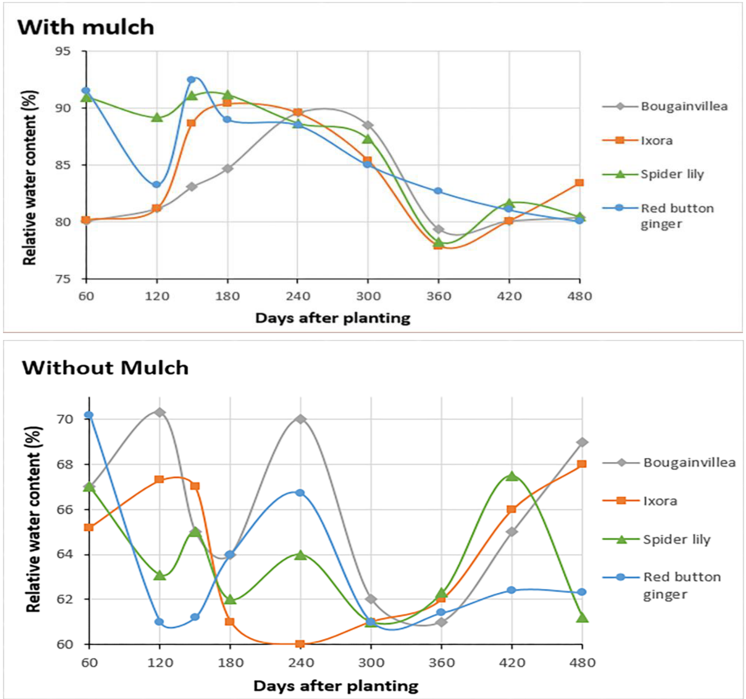

Figure 3. Relative water content in leaves of shrubs under mulch and non-mulch conditions.

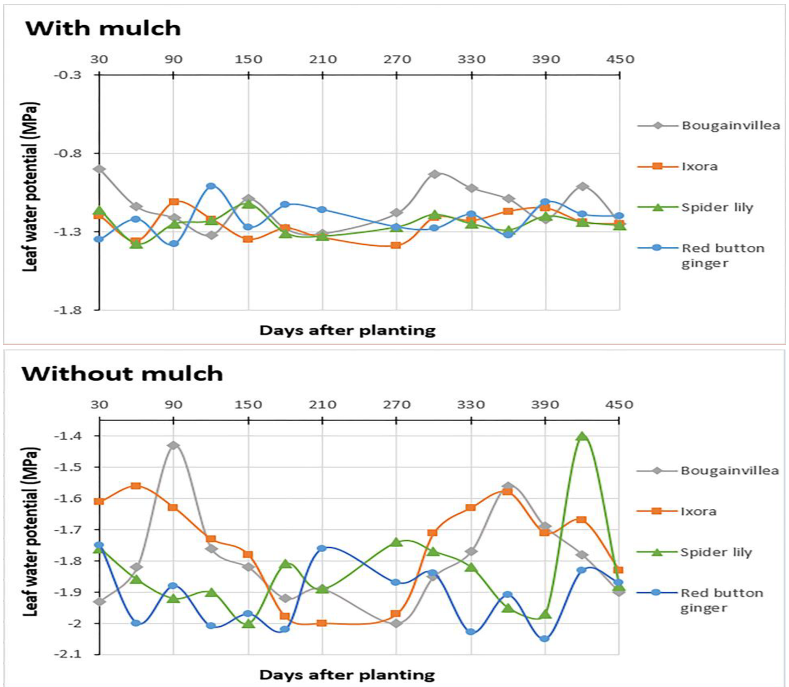

Figure 4. Leaf water potential in shrubs under mulch and non-mulch conditions.

cally significant **(Table 3)**. Similar to SLW, dry matter accumulation was significantly higher when mulch was present and the data recorded was consistent across species **(Table 3)**.

Root Length Density

Roots were mostly concentrated in the 0-15 cm layer and reduced as it went down the soil profile. RLD was significantly higher in plots where mulch was present **(Figure 5)**. The average RLD was between 1.21-1.47 cm cm^{-3} while that of the non-mulch plots were between 0.94 -1.10 cm cm^{-3}. RLD was significantly higher at the shallowest depth (0-15 cm) when mulch was present and declined with increasing depths **(Figure 5)**.

Table 3: Dry biomass of plants and specific leaf weight in shrubs for mulch and non-mulch conditions.

Variables	Dry biomass per plant (g) (above and below ground)		Specific leaf weight (mg cm^{-2})	
	With mulch	Without mulch	With mulch	Without mulch
Bougainvillea	69.8^{a}	56.7^{b}	6.3^{a}	4.9^{b}
Ixora	80.4^{a}	63.5^{b}	7.1 ^{a}	5.5 ^{b}
Spider Lily	72.3^{a}	60.8^{b}	11.7^{a}	8.3 ^{b}
Red Button	83.5^{a}	59.8^{b}	10.4 ^{a}	8.7 ^{b}
Ginger	-	-	-	-
Means within rows followed by different letters are significantly different at P=0.05.				

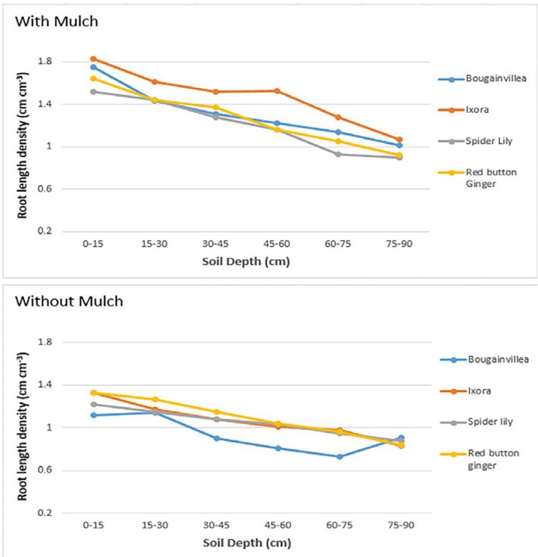

Figure 5. Root length density in shrubs at various depths in the soil profile under mulch and non-mulch conditions.

DISCUSSION

The higher soil moisture status indicated the role of mulch in conserving moisture in the soil. Soil drying was slower, extending the period of water availability which in turn, benefits shrub growth and development. Similar observations were reported in Ramakrishna et al. Mahajan et al. and Debashis et al. [18,20]. The ability to slow down soil drying will be particularly useful during periods of drought. Reduction of moisture from deeper layers under non-mulched plots may be explained through the upward flux of water to the upper, drier layers which were found to have dried out rapidly as a result of evapotranspiration [21,22].

The presence of mulch was also found to have led to less variation in moisture content where the soil water matric potential had lesser fluctuations, even during periods when rainfall was absent. Variation in soil moisture between mulch and non-mulch conditions was discernible up to 75 cm down the soil profile. Beyond that, there was very little fluctuation between treatments.

Much like earlier reports by Boatwright et al. and Chaudhary and Chopra, the presence of mulch led to lower soil temperatures potentially by reducing soil water loss and heat stress or damage caused to plant roots [23-26]. It was observed here that an increase in mean soil temperature (under non-mulch conditions) resulted in significantly lower SLW and dry biomass. This was consistent with reports by Lambers and Poorter, Dong et al. and Ramakrishna et al. [27,28].

Similar to soil water status, data for plant water status was also consistent across species. The data for RWC in leaves and LWP showed very little fluctuations when mulch was present. There was no strong correlation between LWP and soil moisture matric potential. When soil water and LWP data from both treatments were pooled, logarithmic relationships were found to have R^2 values between 0.0003 to 0.014 (data not shown).

With mulch present, all species showed significantly higher SLW which had translated into significantly higher above and below ground biomass. Similar findings were reported in De et al. Niu et al. Wang et al. and Dong et al. [29-33]. Improved dry matter despite no additional irrigation between treatments indicated that growth can be enhanced with limited water supply when mulch is used. This in turn, demonstrates the effectiveness of mulch in utilizing the conserved soil moisture to benefit growth.

RLD at all depths in the soil profile was found to be significantly higher when mulch was used. Alleviated mechanical resistance through conservation of moisture in plots with mulch may have confined the root growth primarily at shallower depths. This finding was similar to those reported in Sharma and Acharya, Lampurlanes and Cantero-Martinez and Rahman et al. [34,35]. Despite the shallow root development, benefit to root growth at any depth in the soil profile will assist with water and nutrient absorption [36-38].

Positive relationships were found between growth (SLW and plant dry biomass) and RLD (data not presented). R^2 values were found to be between the ranges of 0.321 to 0.517. Improved growth when mulch is used as opposed to non-mulch condition demonstrates the effectiveness of mulch in reducing soil evaporation and plant respiration [39-42].

CONCLUSION

The comparison made here has shown that the presence of mulch was found to provide a better soil physical environment in terms of soil moisture retention and reduced soil temperature. These favorable conditions led to higher plant water status, greater plant biomass and enhanced SLW. Taken together, the improved conditions led to enhanced shrub growth. RLD was also greater in conditions where mulch was present. These findings were suggestive that the shrubs were able to sustain growth with no additional water supplied. Future studies should focus on water use efficiency in plants with the presence of mulch.

In general, this study has shown that the use of mulch had a good potential for saving water. In essence, mulch is an inexpensive option to water saving in tropical, arid environments and ideal for changing climatic conditions. Additionally the input of mulch had no negative impact to the growth of plants.

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