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Influence of Different Shade Levels on the Growth and Quality of *Codiaeum variegatum* var. 'Bush on fire' in the Batticaloa District

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Abstract

Codiaeum variegatum var. "Bush on fire" is an ornamental foliage shrub with beautifully variegated glossy leaves. The vivid shiny leaves add value for its quality in the export market. Shade level greatly influences the amount of variegation in these plants. An experiment was conducted to investigate the effect of different shade levels on the growth and quality of *C. variegatum* var. "Bush on fire", in the Batticaloa district at the crop farm, Eastern University, Vanthrumoolai, Sri Lanka . Graded level of shades were defined as treatments *viz.* open field (T1), 50% (T2), 60% (T3), 70% (T4), and 80% (T5) of shade levels. The experiment was arranged in a completely randomized design with twenty replicates. Measurements were taken at monthly interval and Analysis of Variance was performed to determine significant difference among treatments ($p< 0.05$). The results revealed that plants grown at 50% shade level showed significantly ($p<0.05$) better performance in measured growth parameters *viz.* plant height, plant biomass and biomass partitioning, while the lowest performance was observed in plants grown at 80% (T5) shade level. In quality evaluation, plants grown at open

field (T1) received significantly highest score. Further plants grown at open field showed compactness, appropriate leaf size and increased leaf thickness. From this study it could be concluded that, plants grown at 50% shade level would have received optimum light level as the growth of the plants was higher. However, open field condition is suitable for export oriented cultivation of *C.variegatum* var. "Bush on fire" in the Batticaloa district as the quality of the plants was high. Therefore these findings are helpful for the commercial level cultivation of *Codiaeum variegatum* var. "Bush on fire"in the Batticaloa district.

Key words: Biomass partitioning;Leaf area;Plant height;Shade level; Biomass; Leaf thickness

I. Introduction

Codiaeum variegatum (L.) A. Juss with its stunning colors and leathery leaves is regarded as a beautiful foliage plant [1]. *C. variegatum* the magnificent, multi coloured foliage plant is long since known in horticulture. *C. variegatum* plant is said to be the world's most colourful and variable shrub [2]. *C. variegatum* are beautifully variegated leafy perennial ornamental plant [3].

C. variegatum consists with many varieties and "Bush on fire" is a popular foliage variety in the world floriculture industry. *C. variegatum* are popularly used for inner decoration in homes and buildings [4]. *C. variegatum* are used as potted decorative plants and sold as gifts for any occasion and as souvenir for special occasions [5]. A wide range of dissimilarities in leaf shape and coloration has fascinated breeders, landscapers, horticulturists and gardeners, and a huge number of cultivars have been fixed for commercial production in *C. variegatum*[6]. *C. variegatum* have now become one of the most popular ornamental tropical shrubs in Europe and U.S[7]. *C. variegatum* is an important crop in Sri Lanka. It is mainly exported to Europe as cut stems or rooted stems[8]. In Sri Lanka, large scale croton plantations are available. However, the nursery growers encounters the problems of low productivity due to reduced growth rate of plants, low quality planting

materials and lack of land area for cultivation. The agro climatic diversity in Sri Lanka is very much advantageous for growing wide range of foliage ornamentals and cut flowers. However, commercial nurseries are mainly found in the Western, North Western and Central Provinces [9].

Sri Lanka includes dry zone which covers 1/3 of the country's land area. It has numerous potential for future agricultural development [10].Climatic conditions prevailing in the dry zone are suitable for growing foliage ornamentals under appropriate growing conditions. However, field trials on in different floricultural crops in the dry zone have not been investigated in detailed manner.

Batticaloa is a prominent agricultural district in the central part of the Eastern Province of Sri Lanka. Around 75% of the land is flat terrain. The annual mean rainfall is less than 1500 mm. The annual rainfall varies from 864 mm to 3,081 mm distribution which has slight variation throughout the district. Most of the rain is received during the month of October to January in both inter-monsoon and North East monsoon types. The temperature of this District varies from 25 oC to 35.4 oC. The west of the Batticaloa district contain reddish brown earth, non-calcic brown soils and low humic clay soils and the east coast contain sandy regosol soil [11]. Commencement of foliage crops in the Batticaloa district as a commercial venture would grant several benefits to the society. It could be act as a livelihood activity for many women headed households[12]. Climatic requirement of crotons is compatible to the current climatic conditions in the Batticaloa district. Therefore this crop could be act as a foreign income earner to this area.

The leaf of crotons is probably green in its original natural state, but in cultivated forms, it has striking variegations and also streaked, blotched or banded with different colors when grown in appropriate light conditions [13]. This makes *C. variegatum* one of the most interesting ornamentals. However, it has a flexible response to various light conditions. When grown at different light intensities and growing conditions, it

shows different leaf colors. The shaded leaves are more greenish than those exposed to full sun. The mosaic pattern on the leaves may also be influenced by light intensity [14]. Light level influences the chloroplast development in leaves during the growth thereby influence leaf colour and variegation[15].

Shade net has been found to improve vegetative growth, yield, vase life and quality of cut foliage[16]. Shade nets are often deployed over crops to reduce heat stress [17]. Each plant has its individual requirement for sunlight and shade under which it flourishes at its best. To create optimum climatic conditions, selection of the correct percentage of shade level is a key factor to enhance plant's productivity to its highest value [18].

Therefore provision of shade is recommended for the cultivation of foliage plants in Sri Lanka. Inappropriate shade levels cause reduction of the export quality of the plants. As Sri Lanka has wide range of climatic diversity, regional specific researches are needed to discover optimum shade level for the cultivation of *C. variegatum* var.'bush on fire' for given location. A study on possible influence of different shade levels on the growth, development and quality of *C. variegatum* var.'bush on fire' could lead to development of recommendation for the agronomic management in the Batticaloa district of Sri Lanka. Therefore this study was carried out to identify optimum shade level for the cultivation of *C. variegatum* var.'bush on fire'in the Batticaloa district of Sri Lanka.

II. Materials and method

Experimental duration and site description

The experiment was done from July 2017 to November 2017 at the Crop Farm, Eastern University, Vantharumoolai, (7.7976° N, 81.5820° E), Batticaloa located in low country dry zone of Sri Lanka. The agro ecological region of this site is denoted as DL2. Average elevation of the experimental site is 100m above sea level. The major soil group of the site is sandy regosol. The mean annual temperature of the district varies

from 28°C to 32 °C. The mean annual rainfall of the district varies from 1800 mm to 2100 mm. Average temperature and relative humidity during the experimental period was 34 ± 2 °C and 64 ± 4%, respectively[19].

Experimental design

Experiment was arranged in a completely randomized design (CRD). Graded shade level were defined as treatments

T1 - 0% of shade (Open field, Control)

T2 - 50% of shade,

T3 - 60% of shade

T4 - 70% of shade

T5 - 80% of shade

Each treatment contained 20 replications. An experimental unit consisted of one plant. Plants were arranged at a spacing of 20 plants per m^2.

Description of shade houses

Four shade houses were covered with shade nets of 50, 60, 70 and 80% separately for that commercial black polypropylene shade nets were used. The shade house was designed into arch shape. The length and width of the shade house were 5m and 3 m, respectively. The height of the shade house at gutter level and middle were 2m and 2.5 m respectively. The roof and side were covered with shade nets of particular shade levels.

Preparation of polyethylene bags and potting media

Polyethylene bags were used to establish plants. Black polyethylene sheet having the thickness of 500 gauge was used to prepare the bags. The diameter and height of the bags were 13cm and 17.5 cm, respectively. Six holes were punched at the bottom and sides of the bag for drainage of excess irrigation water. The potting mixture was prepared as top soil and compost in a ratio of 1: 1 (volume basis). Top soil and compost were used after sieved through 0.5 mm sieve to remove coarse particles. The potting mixture was treated with

fungicide (Captan®) and kept for three days for sterilization. The polythene bags were filled with potting mixture to three fourth of its volume.

Planting materials and agronomy practices

Uniform, rooted and one month old cuttings of *C. variegatum* var."Bush on fire"were obtained from commercial nursery. Before planting the cuttings were treated with fungicide (Captan®) to avoid disease infections. The cuttings were planted into the filled polybags.Basal fertilizer application was practiced as mixed with the rooting media according to the recommendation before planting. A controlled released fertilizer (Osmocote ®, which contain 14% N, 14% P2O5 and 14% K2O) was applied as topdressing fertilizer and 5 grams of granules applied per plant after one month of planting . A liquid foliar fertilizer (Nitrophoska®) application was practiced once in two week as 45ml/16L (water) to all treatments equally.

Measurements

Measurements were taken at monthly interval from one month after planting. Sampling interval was one month. Destructive sampling method was practiced.

Quality evaluation of experimental plants

Three month after planting quality evaluation was arranged at the Department of crop science, Faculty of agriculture to evaluate the quality of plants subjected to different treatments. Representative samples (cuttings) were obtained from each treatment and transported to Department of Crop Science under optimum condition. Cuttings were harvested early morning and wet packing was done to avoid desiccation.

Statistical analysis

Samples were randomly collected and were tabulated. One way Analysis of Variance (ANOVA) test was used to determine the significance level of the treatments. Data were checked for normality and homogeneity. Statistical analysis was carried out using Statistical Analysis System (SAS) for Windows. Treatment means

were compared using Tukey test at the 0.05 probability level. Scores obtained from the quality evaluation of plants were analyzed through Mood's Median test at the 0.05 probability level.

III. Results and Discussions

1. Plant height (cm)

Different shade levels influenced the plant height of crotons (*Codiaeum variegatum* var. "Bush on fire") significantly ($p<0.05$) (Figure 1). Plant height was significantly ($p<0.05$) higher in treatment 2 (T2) compared with other treatments at 1, 2 and 3 months after transplanting (MAT).

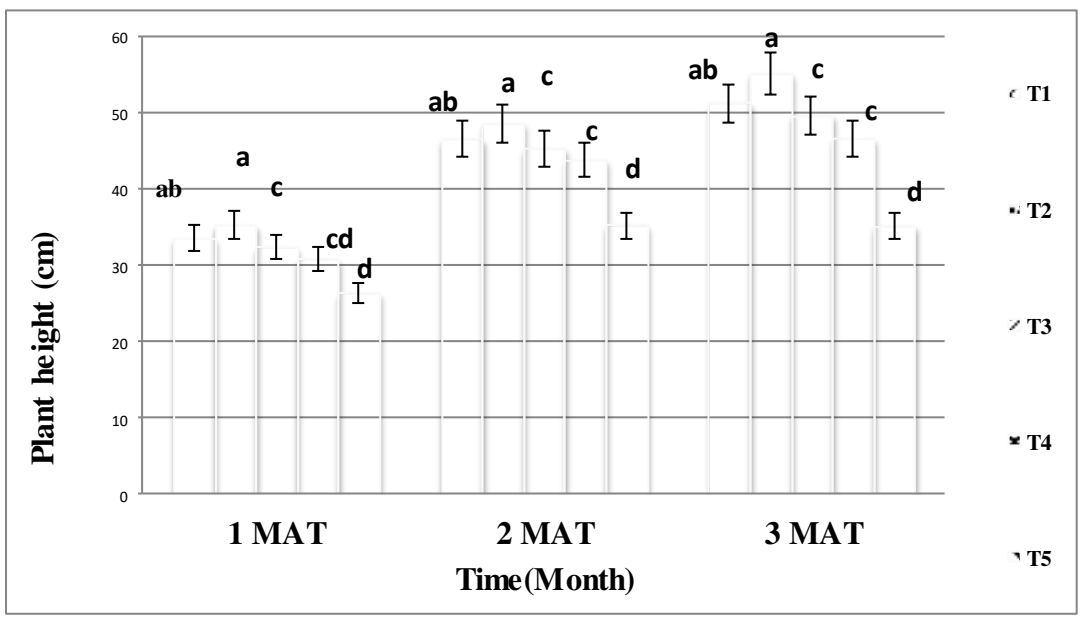

Figure 1. Plant height of the *Codiaeum variegatum* var. "Bush on fire" under different shade levels at 1, 2 and 3 months after transplanting (MAT). Means followed by same letter within a month are not significantly different with the Tukey test at 5% level of probability. (n=3)

Different shade levels influenced the plant height *C. variegatum* var. "Bush on fire" significantly ($p<0.05$) (Fig.1). Plant height was significantly ($p<0.05$) higher in treatment 2 (T2) compared with other treatments at

1, 2 and 3 months after transplanting (MAT).Plants grown at 80% shade level (T5) had the lowest plant height (35.11 cm) while the highest plant height (55.23 cm) was recorded on plants provided with 50% shade level (T2). *C. variegatum* var. "Bush on fire" plants showed highest plant height in shade level of 50% (T2) followed by in 60% (T3), 70% (T4), 80% (T5) at 1, 2, 3 MAT. It was observed that, plant height decreased with increasing shade levels. The results showed that plants grown in open field conditions (T1) produced significantly ($p<0.05$) second highest plant height. It was also observed that, there were no significant ($p<0.05$) differences in the plant height of open field condition (T1) and 50% shade level (T2).

In higher shade levels, the light level received by the plants might be lower than their requirement. Optimum light level is important for maximum photosynthesis. At higher shade levels, radiation received by the plants might be lower than their requirement. Higher shade levels could reduce the photosynthesis and subsequently plant growth. Under 80% shade treatment carbon assimilation was limited and plant growth was decreased in Oriental Lily (*Lilium auratum* L.) [20].

The plants grown under 50% shade would have received optimum light for better growth. Optimum light level is important for maximum photosynthesis. Therefore the plant height was increased. The photosynthetic activity and growth rate were significantly higher in Cordyline (*Cordyline terminalis*) under 50% shade level [18]**.**It was also observed that, there were no significant ($p<0.05$) differences in the plant height of open field condition (T1) and 50% shade level (T2). However plants grown in open field would have received increased level of light. Therefore height of plants belong to open field (T1) was lower than 50 % shade level (T2). Stomatal conductance and photosynthetic rate were found significantly lowered by growing soybean plant under continuous light [21].

2. Leaf area per plant (cm^2)

It was observed that there were significant ($p<0.05$) differences among the treatments in leaf area per plant (Figure 2). Leaf area was significantly ($p<0.05$) higher in treatment 4 (T4) compared with other treatments at 1, 2 and 3 months after transplanting (MAT).

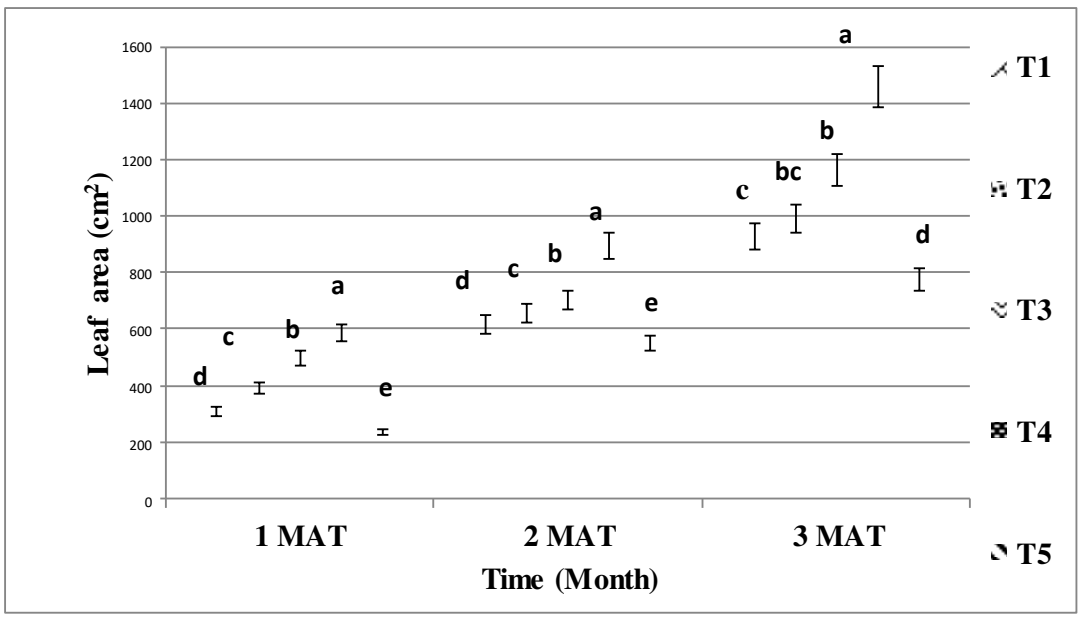

Figure 2. Leaf area of the croton (*Codiaeum variegatum* var.“Bush on fire”) under different shade levels at 1, 2 and 3 months after transplanting (MAT). Means followed by same letter within a month are not significantly different with the Tukey test at 5% level of probability. (n=3).

It was observed that there were significant ($p<0.05$) differences among the treatments in leaf area per plant (Fig.2). *C. variegatum* var. “Bush on fire”Plants grown at 80% shade level (T5) had lowest leaf area (774.196 cm^2) among all the treatments, while the highest leaf area (1456.79 cm^2) was recorded in plants provided with 70% shade level (T4) at 3 MAT. Plants grown in open field conditions (T1) also produced lower leaf area. It was observed, leaf area of croton increased with increasing shade level except plants grown under 80% shade

level In 80% shade level, development of leaf area was significantly reduced in croton *C. variegatum* var. "Bush on fire" plants as radiation received by the plants was lower than their requirement. It caused reduction in photosynthesis and subsequent growth. Eventually growth and leaf size of the plants were suppressed in 80% shade.

Plants grown in open field conditions (T1) also produced lower leaf area. It was necessary for leaves in areas of high light intensity to had small leaves to reduce the amount of transpiration and desiccation. Chlorophyll is a substance found in chloroplasts those chloroplasts found in the cells of leaves. They are used to produce glucose which is used as plant food and growing materials. A leaf which was exposed to plenty of light had sufficient amounts of food and it does not need an excessive amount of chlorophyll. This enabled the leaf to have a small surface area.

C. variegatum var."Bush on fire" plants showed highest leaf area in shade level of 70% followed by in 60%, 50%, 80% at 1, 2, 3 MAT . With increased shade level except 80% plants produce a large leaf to absorb as much light as possible for photosynthesis in order to increase their dry matter production. These might be the reasons for leaf area of croton increased with increasing shade level. Generally, an increase in leaf area with decreasing light intensity might compensate for the reduced photosynthesis per unit leaf area and cause overall photosynthesis per plant to be equal [22]. Under different light levels the highest leaf area was under 70% shade level in *Centella asiatica* [23].

3. Total biomass (g)

The plant biomass was significantly ($p<0.05$) influenced by different shade levels (Figure 3) and it was significantly ($p<0.05$) higher in treatment 2 (50 % shade level) compared with other treatments at 1, 2 and 3 months after transplanting (MAT).

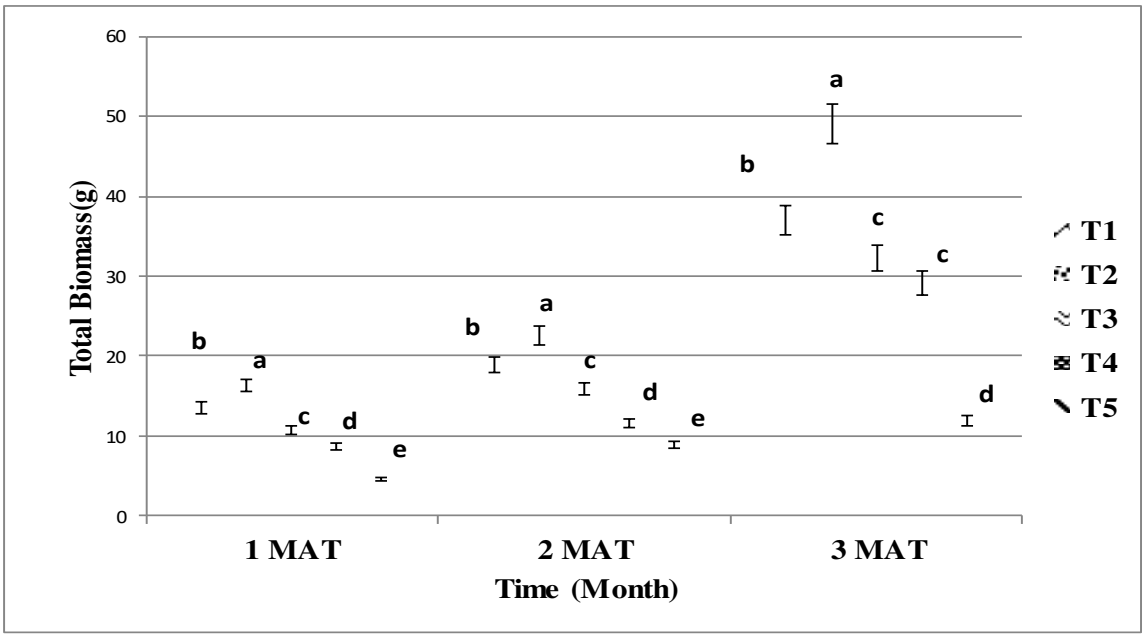

Figure 3. Total Biomass of the croton (*Codiaeum variegatum* var. "Bush on fire") under different shade levels at 1, 2 and 3 months after transplanting (MAT). Means followed by same letter within a month are not significantly different with the Tukey test at 5% level of probability. (n=3)

The plant biomass was significantly ($p<0.05$) influenced by different shade levels (Fig.3). *C. variegatum* var. "Bush on fire" plants grown at 80% shade level (T5) produced significantly ($p<0.05$) lowest biomass. The highest total biomass was obtained in 50% shade level (T2). The results showed that plants grown under open field conditions (T1) produced significantly second highest plant biomass. Dry matter accumulation was significantly reduced by the higher levels of shading. Plant growth and development tend to reduce under deficient light intensities. This was due to low amount of light intensity restricted the rate of carbon accumulation and photosynthesis. Below a least possible light intensity, the plant falls below the

compensation point. Compensation point is the metabolic point at which the rates of photosynthesis and respiration are the same [24]. While respiration continues photosynthesis was slow down significantly. Dracaena plants grown under 80% of shade level produced significantly lowest plant biomass [25].

The plants grown under 50% shade would have received ideal light for better growth. Therefore, their growth rate and carbon assimilation were at highest level. Different plants have different optimum requirements and both deficient and excessive light intensities are injurious [26]. Plants grown at open field conditions would have received light slightly higher than their requirement. Higher light levels in plants can decrease photosynthesis causing in a decrease in the biomass [27]. Crotons might not be sensitive to higher light levels. However, they may prefer low light level for their maximum growth.

4. Biomass partitioning

There was a significant ($p<0.05$) difference in biomass partitioning between different treatments (Figure 4).Different shade levels significantly ($p<0.05$) influenced the biomass partitioning of croton (*Codiaeum variegatum* var.“Bush on fire”) plants.

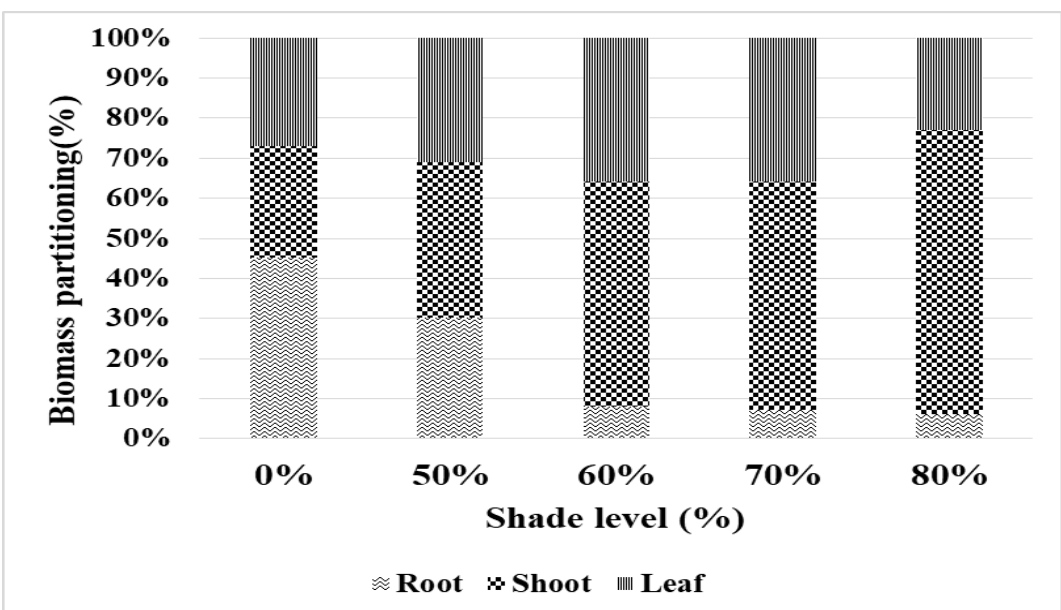

Figure 4. Effect of graded shade levels on the percentage distribution Biomass partitioning

There was a significant ($p<0.05$) difference in biomass partitioning between different treatments (Table 1).Different shade levels significantly ($p<0.05$) influenced the biomass partitioning of *C. variegatum* var."Bush on fire" plants. Biomass allocation for root was highest in open field (T1) as 45% of total biomass of plant. Followed by 50%, 60%, 70%, 80% of shade levels as 30%, 9%, 7%, and 6% of biomass allocation for root at 3 MAT. Allocation of biomass for shoot was highest (71%) in 80% of shade level while lowest (28%) in open field Allocation of biomass for leaves was highest (36%) in 70% of shade level while lowest in control. From these findings, it could be stated that the biomass allocation for plants grown at 50% shade level higher and approximately equal for roots (30%) shoots (39%) and leaves (31%) (Fig.4). It indicates that, 50% shade level was optimum for the growth of *C. variegatum* var."Bush on fire" plants.

In open field condition there was a limitation of water in root zone because of higher solar irradiation and evaporation. Thus the plants try to get used to the condition and allocate more resources to root for water absorption. *Camellia williamsii, Photinia fraseri,* and *Viburnum tinus* shows higher root dry weight in full sun than in mild and heavy shade [28]. Allocation of biomass for shoot was highest (71%) in 80% of shade level while lowest (28%) in open field. Under high shade level, light was a limiting factor. It limited the photosynthetic resources of plant to produce vegetative growth. Thus the plants try to pay compensation to this condition. According to the optimum partitioning theory (OPT), allocation of biomass for shoot was higher at 80% shade level to obtained maximum light in order to develop their vegetative growth of plant.

The top shoot growth of buffalo grass (*Stenotaphrum secundatum*), mat grass (*Axonopus compressus*) and kikuyu grass (*Pennisetum clandestinum*) were higher under shade than in full sun and shade level increased shoot: root ratio in all species[29] .In response to shading, allocation of biomass to leaves increased. It is well established that in lowlight level, light is considered as a scarcest resource. Therefore in order to enhance light capture, more biomass is allocated proportionally to leaves .

5. Quality

The Quality of plants was significantly (Mood's Median test, p= 0.00) influenced by different shade levels (Table 1) and it was significantly (p = 0.00) higher in treatment 1 (open field) compared with other treatments at 3 months after transplanting (MAT).

Table 1 Quality analysis of crotons (*Codiaeum variegatum* var."Bush on fire") at 3 months after transplanting

Shade level (%)	Median
Open field	88.5
50%	80.3
60%	73.5
70%	58.5
80%	47.0
P value	**0.00**

(n=10)

The Quality of plants was significantly (Mood's Median test, p= 0.00) influenced by different shade levels and it was significantly (p = 0.00) higher in treatment 1 (open field) compared with other treatments at 3 months after transplanting (MAT).Followed by 50%,60%,70%,80% of shade levels as 80.3 ,73.5,58.5 , 47.0 respectively.

In quality evaluation *C. variegatum* var."Bush on fire" plants grown at open field condition (T1) obtained significantly highest median (88.5) while significantly lowest median (47.0) was received by 80% (T5) plant. Further plants grown at open field showed variegation, compactness, better leaf size and increased leaf

thickness. Plants react to changing light conditions in terms of quantity and composition of pigments in the chloroplasts. Plants grown at open field would have had higher amount of carotenoids than other treatments. A number of plant carotenoids have an added industrial value to the foliages based on their colorant. Carotenoids are the reason for the mosaic pattern and fabulous variegation present in *C. variegatum* var."Bush on fire". Variations in variegation by light intensity have been often explored because of the importance of the aesthetic value of variegation in foliage plants. Leaves of full sun grown *Ginkgo biloba* had higher carotenoid content than total chlorophyll, and carotenoid contents under full sun grown plant leaves were double than those found in shade grown leaves properties[30] .

Compactness and leaf thickness are the main exported quality parameters of foliage plants [31]. Compactness of plants is directly correlated with lateral branches formation. Different light level finely modulated the branch formation. Low intensity light caused decreased branching, while high-intensity light stimulated branching in several shrubs and trees such as *Vaccinium bracteatum* [32]. Therefore high light intensity increased compactness of plants**.**

Chlorophyll level increased and carotenoids level decrease in leaves as light levels decreased [33]. Polka dot (*Hypoestes phyllostachya*) plant showed significant reduction in variegation in leaves under low light along with reduction in anthocyanin contents [34.]

IV. Conclusion

*C. variegatum v*ar. "Bush on fire" plants grown at 50% shade level showed better performance in growth parameters such as plant height, plant biomass and biomass partitioning. Plants grown at open field condition attained better score in quality assessment . Further plants grown at open field showed compactness, better leaf size and increased leaf thickness. Plants grown at higher shade levels showed reduced growth rate and low score in quality assessment.

From this study it could be concluded that, plants grown at 50% shade level would have received optimum light as the growth of the plants was higher. However, open field condition is suitable for export oriented cultivation of *Cvariegatum* var. “Bush on fire” in the Batticaloa district as the quality of the plants was higher. A commercial scale evaluation is needed to recommend these findings to floricultural industries.

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