Non-destructive leaf area estimation of Fig (Ficus carica L.) cv. Iraqi grown in different root zone spatial limitation and controlled porosity level under greenhouse condition

M M Isa1,2, K F Kasim1,4, M F A Muttalib1,2 and M N Jaafar1,2

1 Faculty of Chemical Engineering Technology, Universiti Malaysia Perlis, 02600, Arau, Perlis, Malaysia
2 Institute of Sustainable Agrotechnology (INSAT), Sungai Chuchuh, Universiti Malaysia Perlis, 02100, Padang Besar, Perlis, Malaysia
3 School of Agriculture Science and Biotechnology, Faculty Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Tembila Campus, 22200, Besut, Terengganu, Malaysia
4 Centre of Excellence for Biomass Utilization, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia

E-mail: musianie@yahoo.com.my

Abstract. Leaf area (LA) is associated with many agronomic and physiological processes including growth, photosynthesis, transpiration, photon interception, energy balance and yield potential of the plant. Accurate, rapid and non-destructive leaf area estimation is a useful subject of study for the fields of applied plant science especially with potted plants. However, till date there is lack of information available on Fig (Ficus carica L.) cv. Iraqi grown in containers under different root zone spatial limitation and controlled porosity level. Thus, this study aims to determine the effect of both factors on leaf area of the crop. Determining the individual LA of F. carica cv. Iraqi involves measurements of leaf parameters such as length (L) and width (W), or some combinations of these parameters. The widest part of the foliage was taken as leaf width (W) and leaf length (L) was defined as the distance between the two furthest points (from lamina tip to the point of petiole intersection along the midrib) of the foliage. The length (L) and width (W) of each leaf will be measured by using a leaf area meter having a sensor and read-out unit which calibrated to 0.01 cm². There is significant interaction was observed for each treatment. It can be concluded that application of the right root zone and porosity level gave positive effect on leaf area of F. carica cv. Iraqi grown under greenhouse condition.

1. Introduction

Ficus (Moraceae) consists one of the largest genera of angiosperms with more than 800 species of trees, hemiepiphytes, shrubs, creepers and climbers in the subtropics and tropics worldwide. Many Ficus species consist of a lot of varieties with significant genetic diversity and outstanding pharmacological activities that are of remarkable commercial importance. F. carica L. is an important member of the genus Ficus and it is ordinarily deciduous and commonly referred to as “fig” [1, 2]. Figs have recently attracted a great deal of attention and are widespread throughout the world. According to Aljen and
Nahdi [3] 82% of figs are produced in Mediterranean countries and the world produces over one million tons of figs annually.

Figs leaves are largely green with curly margins and have a hairy surface. The leaves are alternate and borne on 5–12 cm long, grooved petioles. Lamina is variable in shape and size, broadly ovate to nearly orbicular. Leaves part contains milky white latex that consist of ficin a protein-degrading enzyme [4]. According to Cemek et al. [5] leaf area is one of the key determinants for crop growth and productivity. Thus, the leaf area which is used as an indicative of growth and productivity can be useful as an important feature in physiological and agronomic studies. The application of tools for measuring and estimating crop leaf area has attracted interest from many researchers. There is a considerable number of approaches for leaf area determination which include direct and direct methods [6]. The direct method comprises of removing and measuring all leaves in the plant which are destructive and requires adequate, potentially expensive equipment. This method may cause problems to other measurements or research due to damage of plant canopy. For instance of direct methods include planimetric or gravimetric analyses of leaves which may require the leaves to be harvested directly or indirectly [7] [8]. Portable scanning planimeters such as LI-3000 are usually used as a reference method to attain the leaf area [6]. Indirect methods are useful due to non-destructive method, less expensive (can be used when the equipment is not available), user friendly, and can providing accurate and rapid leaf area estimates. This method can be used in field conditions or in pots that have low plant density of controlled experiments. Besides, the advantages for measurements of this method are sampling of the same plant can be repeated over time and also biological variation can be cleared [9-11].

In previous study several factors have been found to be related to study in leaf area. As an example, a research conducted by Emmanuel [12] on watering regimes and water quantity on the total leaf area of Picralima nitida found that highest mean leaf area value of 423.3 cm² was obtained from seedlings watered at full capacity for every 5 days. This results was followed by seedlings which had 20 ml of water daily with a mean value of 410.6 cm². Meanwhile, seedlings grown under flooding conditions obtained lowest mean value which was 125.06 cm². Hernandez-Santana [13] studied the photosynthetic limitations by water deficit on final leaf area. The researchers found that regulated deficit irrigation may gave negative impact on the leaf area of olive grown in orchard. The plant water stress stimulates by regulated deficit irrigation reduces stomatal conductance and photosynthesis rate which results on the decreasing of leaf area but not on the reducing of single fruit growth or the total fruit yield normalized by leaf area. While leaf area is determined by photosynthesis, fruit yield is related to leaf area. Thus, the most important variables that need to be controlled to limit tree growth without curtailing the yield are photosynthesis and leaf area.

Soil is a highly complex environment encompassing physical and chemical heterogeneity across a wide range of spatial and temporal scales [14]. Plants can respond to soil condition in many ways. Porosity of the soil is one of the physical feature of soil that affects the plants growth without affecting the availability of water and nutrients through which roots are growing [15]. Sandy soils occur extensively in various environments and possibility or probability to use them for agriculture purposes differ accordingly [16]. Sandy soils have low nutrient and water retention capacity because of the lack of small pores, low cation exchange capacity due to sand particles and also can be water repellent [17].Thus, proper soil management practices can prevail to an increase in the fine texture fraction which assist in improving the soil characteristics and crop productivity [16].

Addition of clay soil to sandy soil can enhanced maximum water holding capacity about two to six-fold with a greater increase at 20% than at 10% [18]. Clay and organic matter addition to sandy soil would change soil physical properties as an example soil water content, soil aggregation and soil porosity through cohesion, cementation and replacement of soil particles. In addition, clay has the possibility and potential to stabilise soil organic matter by providing a protective coating on soil particles that inhibits or retards microbial decomposition. Higher root distribution and penetration may enhance greater water and nutrient uptake and increasing plant growth can be obtained due to improve soil physical properties [19].
A study conducted by Ismail and Ozawa [20] on maize and cucumber grown in sandy soil treated with clay on the enhancement of water productivity and crop yield showed that the leaf area in cucumber and number of leaves in maize were increased in the treatments treated with clay. In addition, roots grew intensively in the layers treated with clay. Another study conducted by Stirzeker et al. [21] on barley plants grown in cylindrical pots in which coarse sand, fine sand, silt, and clay were packed at different bulk density from moderate to high bulk density. The authors examined the effects of different soil bulk densities by comparing growth of plant in uniformly hard soil with plant growth in hard soil containing biopores. The results showed that the leaf area greatly affected by the roots which having access to large pore in the hard soil about 30% smaller with 3.2 mm holes than with no holes in the hard soil. This results also indicated that barley plants must be grown in proper soil condition because the root growth would be restricted in very hard soil or the roots of the plants would explored the entire pot in very soft soil.

Growing plants in a root restriction or limited rooting volume is an impressive technique to enhance the utilization efficiency of agricultural resources for instances water, space and nutrition due to root restriction impedes the root system to a limited space resulting in a denser root mass and decrease root growth. Besides limiting the volume of the soil accessible to the root system for water and nutrient uptake, it also affects shoot growth via many plant physiological and biochemical processes [22, 23]. Ismail and Davies [24] stated that root restriction may become significant for growers who are concerned with the establishment and maintenance of urban trees or with high density planting and those producing plants in containers also for researchers that involved in growing plants in confined spaces such as controlled environments and phytotrons. Therefore, root growth restriction would become a concern in many experimental studies because any treatment that restricts root growth might affect shoot development via a disturbance of plant water relations.

Ismail and Noor [23] reported the effects of restriction on root growth obtained through the reduction of soil volume grown Starfruit (Averrhoa curambola L., Clone B17). The plants were cultivated in two levels of root zone volume which were 3.36 m³ or 0.68 m³ and two levels of water availability namely well watered or 30% of field capacity. The results revealed that the growth of starfruit was inhibited by root restriction as shown by the decreasing in leaf and root growth. However, the researchers has not investigated the effects on root restriction on leaf area in the plants. Another study by Yeh and Chiang [25] explored the growth and flowering of Hydrangea macrophylla as affected by container volume and leaf removal. The plants were grown in round, plastic pots of four different capacities which were 140, 150, 260 and 320cm³. The results showed that no significant differences in node number and leaf area were obtained between container volume treatments.

Shi et al. [17] also observed that root restriction in both soil culture and soilless culture cause detrimental effects such as reduction of plant height, leaf area, biomass production as well as root death to the plants. The root system is densely matter when roots grow in a confined rooting volume which leads to O₂ diffusion and supply being inevitable altered. An experiments conducted by using pots on plants grown in them create rooting environments that are affected by limited soil volume which can affect various physiological processes along with transpiration and plant growth [26]. There is lack of information on the effect of root zone spatial limitation and porosity level on total leaf area of F. carica. Based on the above considerations, the aim of the study was to determine the effect of root zone spatial limitation and controlled porosity level on the leaf area of F. carica grown under greenhouse condition.

2. Materials and methods

2.1. Plant material

F. carica plant was propagated through air layering method. This method was used because propagation through seedlings are not preferred due to characteristic differences diverting from mother plants. This study was carried out on 48 uniform, 3 months old of F. carica var. Iraqi. This plant was obtained from
the nearest nursery of research station. All the cultural practices including hand weeding were carried out regularly. The irrigation was given immediately after transplantation of the plants.

2.2 Experimental design

The experiment was conducted in the greenhouse of Universiti Malaysia Perlis (UniMAP) Agrotechnology Research Station, Sg. Chucuh, Perlis and set up as randomized complete block design (RCBD). An arrangement of 1.4 m between rows and 0.5 m between plants, which corresponds to a planting density of 0.7 plants m\(^2\) was used. The experiment included two factors which are container sizes and soil composition. Three cylindrical container sizes will be used in this experiment (Table 1). Two different soils were used namely Beach Ridges Interspersed with Swales (BRIS) and clay soil. These soils were mixed in different proportions (Table 2).

| Treatment | Soil composition (%) |
|-----------|----------------------|
| BRIS      | Clay                 |
| Mix 1     | 0                    | 100               |
| Mix 2     | 25                   | 75                |
| Mix 3     | 50                   | 50                |
| Mix 4     | 75                   | 25                |

Table 2. Root zone volume applied during experiment

| Treatments | Root zone volume (L) |
|------------|----------------------|
| Low        | 15                   |
| Medium     | 30                   |
| High       | 45                   |

2.3. Measurement of leaf area

Leaves were sampled during the full-foliage period. Each leaf was spread over millimetre graph paper, and the outline of leaf was drawn. The length (L) and width (W) of each leaf will be measured by using a leaf area meter (LI-3100C Area Meter, LI-COR BIOSCIENCE) which having a sensor and read-out unit. The widest part of the foliage was taken as leaf width (W) and leaf length (L) was defined as the distance between the two furthest points (from lamina tip to the point of petiole intersection along the midrib) of the foliage. Figure 1 showed the leaf width and leaf length of *F. carica* [27].
2.4. Statistical analysis
In this experiment, an analysis of variance of the data was performed by using JMP Pro 13 statistical software. In cases where significant treatment effects were found, a means comparison test was performed using Tukey’s HSD least significant difference comparisons among treatments with a significance level of $\alpha=0.05$.

3. Results and discussion

3.1. Effect of different root zone spatial limitation and controlled porosity level on leaf area of F.carica
Plant withstand numerous physiological and morphological changes in response to reduced rooting volume, which can affect crop performance and quality. Root restriction that related to container size did affected biomass accumulation and partitioning, root and shoot growth, leaf chlorophyll content, photosynthesis, nutrient uptake, plant water relations, respiration and yield [28]. Regulation of root-soil interaction might optimize resource capture, while providing leverage to minimize soil and water degradation [14].

Figure 1. Length and width of F. carica leaf
Table 3. ANOVA for leaf area of *F. carica* as influenced by different root zone spatial limitation, controlled porosity level and the interaction of both factors.

| Source of variations     | DF | Total leaf area (cm²) |
|--------------------------|----|-----------------------|
| Root zone                | 2  | <0.0001               |
| Mixture                  | 3  | <0.0001               |
| Root zone*Mixture        | 6  | 0.0014*               |

The Analysis of Variance (ANOVA) relating leaf area in *F. carica* were presented in Table 3. The leaf area was significantly affected by the different root zone spatial limitation as well as media mixture (different porosity level) and their interaction (P<0.0014). The significant effects between treatments for leaf area parameter was proved by using Tukey HSD test. The results were shown in the next section.

3.2. Effect of different root zone spatial limitation and controlled porosity level interaction on leaf area of *F. carica*

Root zone spatial which is influenced by container sizes have significant contribution on the above ground and below ground crop performances and productivity of *F. carica*. Furthermore, porosity of soils also affects many physical, chemical and biological properties. Greater pore structure may lead to better root structure which will benefit plant nutrient uptake and will help attain more leaf area to the plants [29]. Poor pore structure of soil is believed to be a major threat to soil physical quality and crop sustainable production [30].

![Figure 2. Total leaf area as affected by different root zone and media mixture](image-url)
The result on interaction effects of different root zone spatial limitation and media mixture (different porosity level) on leaf area of *F. carica* was shown on Figure 2. According to the analysis result it was revealed that *F. carica* plant grown in high volume root zone container with Mix 3 (50% BRIS soil + 50% Clay) gave the highest value of total leaf area which was 225.11 cm² compared to other plants which grown in the same volume root zone container. Similar results was obtained on *F. carica* plant grown in medium and small volume of root zone container with Mix 3 (50% BRIS + 50% Clay). For plants grown under medium volume root zone container the value of total leaf area was 139.70 cm². Meanwhile, the value for leaf area plant in low root zone volume container was 43.68 cm². All treatments showed significantly different with each other. These results could be due to the fact that the clay existence would aid retaining water for a certain period of time and also prevent leaching from actively occurred [31]. Addition of clay could also protect the incoming organic material such as plant residues and manures from decomposition by binding to clay particle and ultimately would increase the fertility of the soil [32]. Furthermore, the proportion of clay particles in a soil also decides available moisture and thus its contribution to the soil strength. Tahir and Marschner [18] stated that addition of clay to sandy soil increased soil organic carbon retention compared to sandy soil alone because this soil mixture can increase crop production on sandy soils. These results were in agreement with those observed by Mann et al. [33] on radish experiment grown in sandy soil and was ameliorate with clay soil. The authors reported that leaf area was significantly higher for the very good (479 cm² pot⁻¹) than for the very poor productivity zone (312 cm² pot⁻¹). Phosphatic clay (434 cm² pot⁻¹) were equally effective in increasing the leaf area significantly over the control (265 cm² pot⁻¹). Bouzo and Favaro [34] compared the effect of container size (20, 40, 70 and 350 mL) on leaf area of tomato (*Solanum lycopersicum* L.) found that leaf area was higher for the higher sized containers. The higher leaf area in treatment V₃₅₀ was due not only to the higher number of leaves but also that those leaves were bigger sized (more than 20 cm²) in comparison to the other treatments that never exceeded 7 cm² per leave.

Another result that can be obtained from the Figure 2 was *F. carica* planted in low volume root zone with Mix 1 (100% clay) container gave the lowest value of total leaf area compared to other treatments which was 43.68 cm². In addition, similar results also attained from *F. carica* grown in medium and high root zone container with Mix 1. The results showed that the value of total leaf area in both treatments were 96.29 cm² and 155.40 cm² respectively. NeSmith and Duval [28] mentioned that rooting volume were proportionately related to leaf area production because less leaf area was produces as rooting volume decreased. The result revealed that reduction in leaf area was due to both fewer and smaller leaves per plant. An experiment was conducted by Hsu, Tseng and Lin [35] to examine one year old root bearing wax-apple trees grown in different-sized containers filled with potting mixture on the restriction of shoot and/or root growth. The result reported that increasing container volume at the end of the first year and second year growth of wax apple trees would linearly increase the leaf area of the plant. It showed that leaf area was positively correlated with container volume. Additionally, *F. carica* plant grown in Mix 1 contains 100% clay which have high bulk density in conjunction with high soil strength. This situation would reduce root elongation rates and root penetration which keeping roots lacking of available water and nutrients stored beyond these high strength layers [36].

Even though leaf area increased with the addition of BRIS soil, a negative effect of increasing BRIS soil to total leaf area still can be seen in the Mix 4 which contained 75% of sandy soil. According to Adzemi et al. [37] BRIS soil was poorly structured because its consists of high percentage of sand and having low water retention capacity which limiting ability to support growth of plant due to excessive accumulation of sediments and sand from undulating sea during the monsoon seasons that carries along coarse sand particles. Furthermore, constant leaching process which reduces the moisture content of the soil also become one of the factor that contribute to this result. This was supported by a research conducted by Toriman et al. [31] who found that low moisture content and high composition of sand in BRIS soil would not allowed the soil to retained water. Thus, the application of appropriate clay soil can considerably improve the productivity of the plant. Also, in general as root zone spatial increases plant leaf area also would increase. However, root restriction can imitated the effect of soil moisture stress even when there is ample soil moisture for normal plant growth [38].
4. Conclusion
The suitability of using several root zone was investigated in this study. Also, possibility of using two different type of soil (BRIS and clay) as media composition for enhancing crop performances (total leaf area) were tested. Taking into account these results, we concluded that high volume root zone container (45 L) with Mix 3 (50% BRIS soil + 50% Clay) was the suitable treatment to be used to grow *F. carica* plant under greenhouse condition especially in container. Total leaf area of *F. carica* can be influenced by increased root zone spatial and porosity level of the growing mixture. Thus, treating BRIS soil with clay can be one of the good options to increase total leaf area as well as crop performances.

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