THE UNIVERSITY OF ZAMBIA

The Effects of Potting Sizes on the Growth of Rough Lemon (*Citrus jambiri* Lush) Rootstocks

Dissertation submitted in partial fulfillment of requirements for the award of the BACHELOR'S OF SCIENCE DEGREE OF AGRICULTURAL SCIENCES.

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APPROVAL

The undersigned herewith certify that this dissertation entitled 'The Effects of Potting Sizes on the Growth of Rough Lemon (*Citrus jambiri* Lush) Rootstocks' was not previously presented for the award of a degree, and the work contained herein were carried out by BAIMOLO GOMA under my supervision. The dissertation hereby submitted to the School of Agricultural Sciences in partial fulfillment of requirements for the award of the Bachelor's degree of Agricultural Sciences in Crop Science is accepted.

Approved by

M. Mataa (PhD)

ABSTRACT

The effects of root restriction on rough lemon (*Citrus jambhiri* .Lush.) seedlings induced by root restriction bags of different volume was evaluated. The seedlings were transplanted into 1.1L, 1.9L, 3.9L and 6.2L polyethylene sleeves (UV-untreated), a direct soil planted, non-restricted root treatment was included as a control. Reduction in growth occurred with reduction in pot size,.the smallest pots (1.1L) had the shortest plants followed by the medium. There was no difference between the three larger pot sizes. Plants in the control treatment were able to attain the minimum stem diameter of 24 mm at a height of 25 cm at an age of 101 days after field planting, than the rest of the treatments that were only able to attain it by 202 days after field planting. Leaf area tended to increase with increased pot size (or less root restriction),. The same trend was observed in dry matter content. Dry matter ratios for 1.9L and the direct soil planted treatments were not different from each other. Severe root restriction (1.1L) caused higher reductions in canopy size relative to the roots. The smallest pot size had a root: shoot ratio of 0.82 compared to an average of 0.73 for the larger pots.

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DEDICATION

This dissertation is dedicated to my late paternal grandparents Samuel and Kristina Nachela Goma, my father, my wife Alice, daughter Clare and son Lameck.

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Chapter one

1.0 INTRODUCTION

Origin and Botany

Citrus are believed to be native to a very large Asiatic area extending from Himalayan foothills of North-Eastern India to North China and the Phillipines in the East, Burma, Thailand, Indonesia and New Caledonian in the South east, except for grape fruit which originated in the West Indies (Chapot, 1975 and Bhullar, 1986). The genus citrus belongs to the division – Embryophyta Subdivision Angiospermae; class Dicotyledoneae; Order Geraniales; Suborder Geraniineae; Family Rutaceae; Subfamily Aurantioideae; Tribe citreae and subtribe citrinae. The subtribal consist of: Group A – the primitive citrus fruit tress (genera-Severinia, Pleiospermium, Burkillanthus, Limmocitrus and Hespecrethusa; Group B – the Near-citrus fruit trees (genera-citropsis and Atalantia; Group C – the true citrus fruit trees (genera – Poncirus, Fortunella and Citrus).

Ecology and Physiology

Citrus are grown in the tropical and sub-tropical climates, between 40°Noth and 40° South, throughout the world. In citriculture, temperature is an important climatic factor. The minimum and maximum temperatures for citrus are -2.2°C and 51°C respectively with duration determining the extent of injury. Different types of citrus have different frost tolerance. (David, 1975; Bullar, 1984). Batchelor and Webber (1948) produced the following list of commercial citrus species arranged in order of increasing frost tolerance, the citron being generally recognized as the most tender: citron, limes, lemon, grapefruit and shaddock, sweet orange, sour orange, mandarin, kumquat, trifoliate Orange. As a general principle citrus should only be planted (in open field), on sites known to be reasonably frost free seedlings are generally more susceptible to cold than older trees. The extent of injury caused by low temperature depends upon the conditions of the trees, species varieties and the duration. High temperatures of 38°C or above cause scalding of trees, dropping of young fruits and scorching of foliage. (Bhullar, 1986). The average temperature for proper growth is about 16°C to 2°C although shoot growth takes place between 10.6°C and 24.2°C. Gill et al 1990

Sites with strong wind are not good for citrus growing. Breaking off and/or scarring of fruits may result where trees are exposed to strong winds.

Citrus trees grow on a wide range of soils varying from sands to those high in clay. Deep, well-drained, medium to light loamy soils and free from injurious salts with a slight acidic reaction are considered the best. pH values of 5.5 to 8.0 are optimum (Bernstein, 1969; Kirk-Patrick and Bitters, 1969; Bhullar. 1984). Most citrus rootstocks are adversely affected by salinity levels at which conductivity of the saturated soil extract (EC) is about 250 – 300m Sm^{-1} (Bernstein, 1975; Peynado and Roger 1962;) The soil fertility status is important as it impacts on the productivity of the land and its costs. A generally flat land is ideal as it affects the standpoint of air drainage, frost protection, orchard layout, irrigation system, erosion and food control measures. (Bhullar, 1986).

Provision of adequate water supply and an irrigation system capable of applying sufficient water during the time of peak water demand are pre-requisites in citriculture. (Bernstein, 1969). Moisture content should be maintained at not less than 55% to 65% of field capacity for a Wet regime between bloom and will until the young fruit has grown larger than 25mm in diameter and a drier regime for the remainder of the year (Koo, 1969).

Fumigation or sterilization of seedbed or the potting media is desirable to avoid the infestation of nematodes injurious to the seedlings. Brown ants *(formicide)*, Black Citrus aphid (*Toxoptera aurantii)*, *Thrips (Thripidae)* etc should be avoided if control measures prove uneconomical. The same applies to the citrus diseases that are transmitted by budding, grafting and by insect vectors. The use of tolerant or resistant varieties will aid to ameliorate the negative effects of pest and disease attacks on citrus coupled with economical and judicial control measures. (Knor and Schwarz, 1972; Fabregat, 1975).

A plant is made up of 2 parts; the canopy and the root system. The shoot system consists basically of a stem with leaves, the flattened organs of photosynthesis, attached in a more or less regular arrangement for most plants, the shoot system bears, harvestable products. (Jain, 2000). The root system may consist of taproot system with many smaller lateral roots coming out of it as is the case in citrus and other dicots and gymnosperms or fibrous root system were several to many –same sized roots develop from the end of the stem as exhibited by monocots (Solomon and Berg, 1995). In cultivated citrus the taproot system is disturbed so the plant has only fibrous root system.

Roots supply Cytokinins and gibberellins to the upper part of the plant and may exert hormonal control over certain metabolic functions of the shoot. (Kende and Sitton, 1967). Roots also fulfill the common function of water and solutes absorption, anchorage of the plant to the substratum. They may also act as organs for the storage of food materials and as perennating structures. (Cutter, 1971; Solomon and Berg, 1995). The root system was the basis of this study in citrus.

ECONOMIC IMPORTANCE

Citrus fruits are rich in vitamin C, which is essential for the normal formation of teeth and bones, and prevent scurvy. Vitamin C also helps in the utilization of proteins, provision of calcium, Iron Vitamin A and thiamine (Bhullar, 1986). In production systems where citrus fruit processing is advanced a number of products, specialty and by products have been produced not only for breakfast or cocktail drink but also in cosmetics, perfumes, dyestuffs among others. Some products produced include frozen concentrated orange juices, single strength juices (chilled pasteurized and canned) and dehydrated juices. According to Kerterson and Braddock, (1975) specialty and by products of processed citrus fruit include, essential oils, citrus molasses, citrus wine, marmalade, juice sacs, citrus pulp, amino acids from seeds and bioflavonoids.

Nursery Management and Propagation

The foundations of a successful citrus orchard are laid in the nursery (Bhullar, 1984). Zambia, the rough lemon (*citrus jambhiri* Lush) is the most commonly used rootstock. The rough Lemon has many advantages including a high percentage of true-to-type seedlings, is adapted to a wide range of soil types, produces quick growing tree and has a marked resistence to Tristeza virus though its fruit quality is generally inferior to that produced on trees growing on other rootstocks such as sour orange *(Citrus aurantium L)* (Bhullar, 1986).

Raising rootstock seedlings extracted from fresh seed of fully ripe fruit gives the best germination. The best time to sow the seed in Zambia is during August or September when the cold weather is virtually over. The seeds should first be immersed in hot water at 52° C for about 10 minutes or thin powdery coat of fungicide powder maybe applied to check phytophthora infection. (Gill et al., 1990). Using the container method, citrus seeds can be sown in moist clean sand or light textured soil in a perforated container. After 2 – 3 weeks the seed will start to germinate and can be planted out in black polyethylene sleeves with manured light textures soil. Alternatively the seeds many be sown directly in the polyethylene sleeves. Rough lemon seedlings, being fast growers, are usually ready for transplanting 6 – 7 months after sowing (March – April) by which time they will generally have reached a height of 25 – 30cm. Budding or grafting is done 4 – 5 months after transplanting (August – September). A single headed stem should be maintained up to this time (Bhullar, 1984, 1986).

In the conventional direct planting method, seedbeds should be sited on virgin soil (or at least on soil not previously used for citrus) and preferably of a light texture with good drainage. The selected area should be thoroughly cultivated to a depth of not than 30cm and then fumigated against possible presence of the citrus nematode, *Pratylenchus semi-penetrans.* The forming of seedbeds should not take place sooner than 3 – 4 weeks after fumigation. (Bhullar, 1984). Raised, level beds about 8cm wide and 38cm to 50cm in length or longer, depending on the layout available may be constructed. An application of 28g – 57g of superphosphate and the same quantity of calcium ammonium nitrate per square metre should be worked into the soil. If well-rotted weed-tree manure or compost is available this can be applied at the rate of 5 – 8kg per square metre. (Gill et al., 1990). The nursery rows are usually 90 – 120cm apart. Alternatively, the beds should be 2 – 3m long, 60cm wide and 15 to 20cm high from the ground level. There should be sub-channels on both sides of the beds for irrigation. The seed is sown in rows 10cm apart and in these furrows the seeds are placed 2cm apart and 1cm deep. After the seeds are sown, they are covered with a layer of sand and farmyard manure mixture about 0.5cm thick. The seeds are irrigated immediately after sowing by sprinkling with hand hoes and the next few irrigations are applied in a way the beds are moistened through seepage. (Gill et al., 1990).

Due to increasing land values and taxes, a decreasing availability of desirable citrus land, an increasing cost of machinery and materials, and other production costs, growers are seeking more efficient means of fruit production and harvesting (Gardner and Horanic, 1961).

According to 2001 FAO estimates Zambia only managed to produce a paltry 4000 metric tones of citrus fruits (oranges) last year, twenty times less than Zimbabwe during the same period. This disparity lends itself to investigation.

Tropical and sub-tropical evergreen trees exhibit alternate cycles of vigorous vegetative and reproductive growth. Controlling the vigour of shoots is of great importance to maintaining high and consistent yields. Hsu et al, 1996; Mandre et al., 1995). The use of rootstocks to restrict vegetative growth of the scion has been a horticultural practice for centuries (Tukey, 1964). Manipulating vegetative growth by withholding water and nutrients (Proebsting et al., 1989), training, prunining and girding (Ferhandez-Escorbar et al., 1987) or by growth regular applications (Wood, 1984) are used in controlling shoot growth. Root systems have been manipulated by root pruning, (Zyl and Hyssteen, 1987) and root restriction (Mataa and Tominaga, 1998) to control the shoot growth by limiting the soil volume and indefinitely dwarfing plants and controlling vegetative vigour. (Geisler and Ferree, 1984). Therefore, in closely spaced (high-density) orchards root restrictions is more useful. It also induces, in trees, moderate growth restriction, better flower and fruit production balance (Mataa and Tominaga, 1998).

Citrus, like in many other fruit trees exhibit alternate root and shoot growth. (Bevington and Castle, 1985; Williamson and Coston, 1989). Sometimes this may overlap. (Maust and Williamson, 1994). Roots respire rapidly per unit mass than shoots, thus using a higher proportion of total plant carbohydrates at the expense of the aerial development. (Sauerback and Johnen, 1976).

In a study by Schuch and Pittenger (1995) it was found that root containers of the same volume, tall found that for containers of the same volume, tall ones with height: width ratio of 3.8 produced plants with more roots than regular –shaped containers (3.7. litres) with a height: width ratio of 1:1, presumably because tall containers have a larger volume of well-drained soil. In related studies, increased root shoot ratios in tall similarly root and shoot growth were stimulated when a high height: width ratio. (Biran and Eliassaf, 1980; Whitcomb(1988) Similarly attributed more root growth in tall containers to better aeration of the medium.

Black polyethylene sleeves bags are commonly used as nursery plant containers than the clear ones. Accordingly to Garner and Chaudhri (1995), the main difference is that clear polyethylene sleeves permit the growth of algae. Soil in black containers with sides exposed to the sun may overheat and this may seriously affect root development in the container. It is therefore recommended to shade the nursery plants or preferable to bury the containers in the soil leaving the shoots exposed

According to Tukey (1964) and Philips (1969), yields during early years are directly proportional to the number of trees per hectare. By planting more trees per hectare, it is possible to realize earlier economic returns from initial investments. By increasing production the cost per unit is reduced. Controlling tree size with root restriction is one way of reducing-tree size to keep population per hectare high.

In this light, new methods of citrus nursery propagation are being developed. The use of containers or pots has been on an increase particularly the use of polyethylene sleeves because of imminent advantages such as easy to transport, less damage to roots at selling, little or no tillage operations and reduced land use, over the conventional direct method. However, the Zambian citrus nursery propagation industry has no standard sizes of polyethylene sleeves to use. (Tafi, personal communication 2002). This has resulted in a free-for-all affair in the seedling with roadside vendors literally using any empty containers of various sizes, some of which include, milk packs and tins, local brew packs and bottles without regard on their effects on the seedlings. According to Fred, a seedling marketeer, (personal communication), marketeers having been basing their pot sizes on the plant size. The bigger the plant the bigger the pot and vice versa. However, it is not known if the initial size reduction also reported by Mataa and Tominaga (1998) is permanent or is lost after the potted plants are planted in the field after some years

Information on the effects of root volume restriction on root stock growth and development is very limited. Root restriction research in fruiting plants has largely involved short-term responses of Peach (Mandre et al., 1995; Rieger and Marra, 1994) (Mataa and Tominaga, 1998). The objectives of the study were:

- To determine the optimum pot volume that is able to produce plants that reach desired sizes in the least time period.
- Monitor changes that occur during development in the different pot sizes.
- To determine long term effects of roots restriction during propagation on field tree development and productivity.

Chapter two

MATERIALS AND METHODS

Experimental Site

The experiment was set up on 21st January 2002 and conducted at the University of Zambia Field Station. Data was collected up to October 2002. The site was located in the agro-ecological zone II, and at the latitudes 15° 23' South and 28° 20' East and is about 1140m above sea leave. The soil type is mixed fine loam Isohyperthemic oxic Pleustaif. The previous crop grown during the 1999/2000 growing season was cabbage *(Brassica oleracea var.* Capitata*)* which were only basal dressing. The site was fallow up to the time of the experiment.

A randomised complete block design with 5 replications was used. Each treatment was assigned to 4 tree plots. There were five treatments; Direct planting, small Polyethylene sleeve (1.1L), Medium (1.9L), Large (3.9L) and the Extra Large pot (6.2L). A total of 100 plants were used. At the last sampling date one - subplot from each treatment was destructively analysed for dry matter proportion in the root, shoot and leaves. A spacing of 45cm between plants and plots within replication whereas 1m spacing separated the replications.

2.2 Plant Materials

Propagation

Rough lemons *(Citrus jambhiri* Lush*)* seeds were sown from freshly harvested fruits obtained from the Tree Crop Research Section, Mt. Makulu Research Station. The seeds were germinated in sterile sand for 4 weeks and individually transplanted into black polyethylene sleeves in the greenhouse. The sleeves were produced by Polythene Products (Z) Ltd and were not UV treated the experiment had the following sizes: 6.2L, 3.9L, 1.9L and 1.1L. The potting mixture consisted of garden soil: compost and sand in the ratio 2:1:1 by volume respectively. At about

105 days old, the potted seedlings were buried in the field just below the soil level of about 30cm and the control. The unrestricted plants were planted directly into the ground.

First grafting was done on the 19th of August 2002. The cleft method was used using Washington navel sweet orange (Citrus sinesis) as the scion. Days to the first bud emergence from the scion were noted.

Management

The seedlings were regularly inspected for weeds, insects and pests throughout the period. A routine spray programme at intervals of 10 –14 days, with alteration of chemicals at each interval to control among others, white fly *(Dialeurodes citri)*, Black Citrus aphid *(Toxoptera aurantii)*, California red scale *(Aonidiella auranii)* and the Cottony Cushion scale (Icerya purchasi) was carried out with Rogor 40 percent EC (Dimethoate) at 7.5ml/101 water or Cyrux ® (Cypermethrin) 6ml/101 water or Avigard ® at 5ml/010 water. It was also done against such diseases as Anthracnose lesion caused *by Colletotrichum geloosporiodes* and *Gloesporium Spp.* And *Alternaria Citri* using Fundasor ® or Dithane M45 both at 2g/11 water. The chemicals were alternated to prevent resistance build up.

Irrigation was delivered with non-pressurised drip system supplied by International Development Enterprises (IDE) drip emitter to each plant to field capacity. Weeds were controlled by cultivation and hand weeding. Prunning of lateral branches was done routinely to maintain a single stem for each seedling. Border seedling of rough lemon were planted around the experimental field to act as barriers.

Data Collection and Analysis

Plant Height, Stem Circumference and Leaf Area.

The data was collected at 3 months intervals starting 21st January 2002. Except for leaf area data that was not recorded at the start of the experiment. Plant height was measured using a foot ruler above the soil surface for each individual plant. Stem circumference was measured at 25cm above ground level. The length and width of 10 leaves per plant were obtained and the average was multiplied by 0.45 to estimate the leaf area.

Dry Matter Analysis

At the last sampling date, some seedlings from each treatment were dug out and washed. These were weighed for fresh weights before drying them at 80 °C for 48 hours to analyse for dry matter content. Dry weights of whole plant, root, canopy and root to whole plant dry ratio, shoot to whole plant ratio were obtained.

Agro-meteorological data on rainfall, temperature and relative humidity for the 2001/2002 growing season was obtained from the Lusaka City Airport (Appendix1).

All the data collected was subjected to an analysis of variance and mean separation was done according to Duncan's multiple range test (Little and Hills, 1978). Data was analysed by the Computer Software, Superanova (Abacus Concepts). Differences were considered significant at $p \leq 0.05$.

Chapter three

RESULTS

Effects of Root Restriction on Plant Height

Plant height was influenced by pot size (Table 1). The Small pots (1.1L) had the shortest plants followed by the medium; Large and extra large (there was no difference between these 3 pot sizes), the direct planted were the largest. This trend was consistent over the 202 days study period.

Stem Circumference

Stem circumference was also influenced by pot size (Table 2). The least stem circumference was obtained with plants treated to pot size 1.1L (smallest pot size) and the largest was obtained in the control, the direct planted treatment plants obtained from treatments – pot size 1.9L size, 3.9L and 6.2L, were not significantly different at the thirty-first and one hundred and ten days after start of experiment. Pot sizes 1.1L, 1.9L and 3.9L were not different at the 202 days sampling time. Despite being the smallest relative to the other treatments at thirty-one days after field planting, the smallest pot size had by 110 days after field planting become similar with the rest of the potted treatments. The direct soil planted treatment was able to attain the standard grafting stem circumference of 24mm earlier than the rest of the treatments. All treatments had attained the standard 24cm stem circumference by 202 days after field planting.

Table 1. The effects of container size on plant height of rough lemon (*Citrus jambiri* Lush.) rootstock seedling

Container size	Plant height (mm)		
	Days after start of experiment		
	31	110	202
Small (1.1 L)	122.8a	244.5a	435.0a
Medium (1.9L)	207.4b	343.0b	562.5b
Large (3.9L)	187.2b	378.0b	600.0b
Extra large (6.2L)	189.5b	390.0b	590.9b
Direct planting	262.2c	492.0c	841.1c

Mean separation was done by Duncan's multiple range test. Means followed by the Same letter in the same column were not significantly different at $p \leq 0.05$.

Table 2. The effects of container size on stem circumference of rough lemon (*Citrus jambiri* Lush.) rootstock seedling. Circumference was determined at 25 cm above the stem/ root junction.

Container size	Stem circumference (mm)		
	Days after start of experiment		
	31	110	202
Small (1.1 L)	2.8a	14.1a	24.5a
Medium (1.9L)	4.1b	15.1a	26.1a
Large (3.9L)	3.8b	15.4a	27.6a
Extra large (6.2L)	3.8b	17.3a	35.5b
Direct planting	4.7c	29.9b	39.9c

Mean separation was done by Duncan's multiple range test. Means followed by the Same letter in the same column were not significantly different at $p \leq 0.05$

Leaf Area

Root restriction had an influence on leaf area (Table 3). Though a clear pattern could not be obtained, the pot size 1.1L had the least leaf area ($12.4cm^2$) and the direct soil planted treatment had the largest leaf area by 202days after field planting. Reductions in leaf area were observed for pot volumes 1.9L and 3.9L at 202 days of the experiment, no differences were obtained for all potted treatments, with a general trend of increasing leaf area with reducing root restriction.

Dry Matter Content

Pot sizes had an effect on the dry matter partitiong. (Table 4). The largest mean dry matter content was obtained from the direct treatment and the least was from the 1.1L Pot volume for all sampled plant parts. For the whole plant, the dry matter content was not different among pot sizes -1.9L, 3.9L and 6.2L and 6.2L.The shoot dry matter content was not different for treatment pot volumes 1.9L, 3.9L, 6.2L and the direct soil planted treatment. No differences were obtained from treatments - 1.1L, 1.9L, 3.9L and 6.2L for the leaves pot volumes 1.1L, 1.9L and 3.9L gave significant differences for root dry matter content. There were no differences between 6.2L and the direct soil planted treatment with greater than in the other treatments A consistent carbon partitioning pattern, Shoot > Root> Leaves was observed over pot volumes-1.1L, 1.9L ,3.9L and the direct soil planted treatment , Though the trend was reversed at pot volume for 6.2L for shoot and root.

Dry Matter partitioning

For all pot sizes, there were no differences on root/whole plant and shoot/whole plant dry matter ratios (Table 5). Inconsistent differences were recorded for root/shoot at all treatment levels, with the 6.2L pot size having

Table 3. Changes in leaf area of rough lemon (*Citrus jambiri* Lush.) rootstock seedlings grown in polyethylene sleeves of different volumes.

Container volume	Leaf area (cm^2)	
	Days after start of experiment	
	110	202
Small (1.1 L)	12.4ab	12.5a
Medium (1.9L)	14.2bc	14.0a
Large (3.9L)	14.8c	14.4a
Extra large (6.2L)	14.4bc	14.6a
Direct planting	12.0a	18.7b

Mean separation was done by Duncan's multiple range test. Means followed by the same letter in the same column were not significantly different at $p \leq 0.05$.

Table 4. Dry matter contents of plant components of (*Citrus jambiri* Lush.) rootstock seedlings grown in polyethylene sleeves of different volumes. The analysis was done eight months after transplanting.

Container volume	Component dry matter content (g)			
	Whole plant	Shoot	Leaves	Roots
Small (1.1 L)	15.9a	8.7a	4.6a	7.1a
Medium (1.9L)	27.4b	18.3b	7.9a	9.1a
Large (3.9L)	24.3b	14.1b	6.4a	10.2a
Extra large (6.2L)	35.2b	17.3b	7.1a	17.9b
Direct planting	50.7c	12.9b	12.9b	16.6b

Mean separation was done by Duncan's multiple range test. Means followed by the Same letter in the same column were not significantly different at $p \leq 0.05$.

Table 5. Ratios of dry matter contents of plant components of (*Citrus jambiri* Lush.) rootstock seedlings grown in polyethylene sleeves of different volumes. The analysis was done eight months after transplanting.

Container volume	Ratios of component dry matter contents		
	Root: whole plant	Shoot: whole plant	Roots: shoot
Small (1.1 L)	0.45a	0.55a	0.82b
Medium (1.9L)	0.33a	0.67a	0.50a
Large (3.9L)	0.41a	0.58a	0.72b
Extra large (6.2L)	0.51a	0.49a	1.03c
Direct planting	0.33a	0.67a	0.49a

Mean separation was done by Duncan's multiple range test. Means followed by the Same letter in the same column were not significantly different at $p \leq 0.05$.

the greatest ration followed by the smallest, 1.1L and 3.9L pot volumes respectively. Pot volumes 1.9L and the direct soil planted treatment had no differences though least relative to the other treatments. The greatest root: shoot ratio of 1:1 was obtained in the pot volume 6.2L and the least (1:3) was in the smallest pot size (1.1L). Therefore, there was a steady increase in root size and length as the pot size increased Chapter four.

Chapter Four

DISCUSSION

Eight months following field planting, there were significant differences in the seedling heights with the direct soil planted treatment attaining the greatest height and the least been the 1.1L pot volume (the smallest pot volume). Root restriction regardless of the treatment used, reduced the vegetative growth of Rough lemon seedlings. According to Wareing (1970), Plants generally maintain a fixed shoot to root ratio. Therefore, when root growth is reduced, the shoot is similarly affected. Sauerback and Johnen (1976), had suggested that roots respire more rapidly per unit mass than shoots, thus using a higher proportion of total plant carbohydrates at the expense of aerial development. Thus, where root growth is restricted, the amount of carbohydrates spent on respiration is equally reduced. The 'excess' carbohydrate may then be used for the canopy development. Hameed et.,al had also suggested that confining root growth to the small containers substantially reduces shoot and root growth and increases the proportion of total dry matter present in the stems. Unfortunately measurement on the water relations were not taken thus, whether moisture conditions had an effect and by how much could not be determined. However in my study, it was observed that the smallest pot volume had the densest root system. The direct soil planted treatment had a relatively less dense root system but thicker and longer than the rest of the treatments due to reduced root impedence, though the nutrient aspect cannot be overlooked. No difference observed among potted treatments for stem circumference at the time of grafting, because the stem circumference growth rate is lower than that of plant height therefore differences are not very pronounced and the pot size effects were therefore not uniform.

The increased growth trend, in height, after May can be attributed to rising optimum temperature duration during summer. This implies increased photoassimilate production and use. The same trend was observed, with stem circumference. Isolated cases of stunted growth with a rosette effect and plants failing to reach the standard grafting height of 25cm, were observed in all potted treatments with severe cases in 6.2L and 3.9L pot volumes. The casual factor can only be related rather than attributed to nutrient deficiency. Presumably one such factor could be zinc deficiency as exhibited by short internodes with small terminal leaves (Chapot, 1975). The may explain the inconsistency of patterns observed for plant heights and stem circumferences, another factor could be Magnesium deficiency or inadequacy as evidenced by mature leaf drop offs with yellow leaf blotches for all treatments.

Another probable explanation for the observed effects on plant height and stem circumference could be a compounding effect triggered by a genetic response. Plants have a natural pattern of growth and will respond, if disturbed, with a tendency to reverting to the original pattern of growth. By reducing the pot size, the growth of roots is also restricted (Proebsting et., al, 1989).The plant will respond by producing more roots, as a survival mechanism ,towards unrestricted or less restricted areas. However,the amount of moisture is equally limited. The proliferation of new roots, only works to quickly deplete the available moisture. With the plant sensing the inadequate moisture, growth restricting hormones such as abscisic acid may increase culminating in into stomata closure. Thus reduces the amount of carbon dioxide, entailing reduced photoassimilate production. Consequently,a direct reduction in root growth and indirectly in reducing the production of cytokinin (growth promoting hormone) in the root. With little cyctokinin produced, the aerial growth is retarded (Jain, 2000)..This retardation effect was much more pronounced in the smallest pot volume 1.1L.

Inconsistency in dry matter content patterns can be attributed to factors already alluded to since dry matter content is a resulting parameter. Vyvyan (1957) showed that there is a constant ratio between the stem/shoot and roots increments and an allometric relation between shoot dry weight nd root dry weight for certain species, so that a straight line is obtained when the logarithms of shoot weight is plotted against the logarithm of root weight. Where this allometric relation holds, it implies that there is a constant ratio between the relative growth rates of shoot and root. This relation could not be established in the study because dry matter weights were only obtained for one sampling date.

Chapter five

Conclusion

There were indications that pot volume affects shoot growth and development. Excessively small pot sizes such as the 1.1L may reduce plant growth and development to an extent where the time to budding and grafting is delayed. Root restriction impacted negatively on the major commercial parameters - stem circumference and plant height that influence the time of grafting.

The pot volume 1.1L may delay growth and pot volume 1.9L seems to offer a much more economical benefit in terms of production costs per plant and probable space utilization in the nursery over the conventional direct soil planting method.

This paper has focused on the morphological effects on the seedlings with the pot size been the only variable. However, the depth and shape of transplant containers may influence tree development. It is therefore, desirable that future studies focus on; The effects of pot size, depth and shape separately The economical benefit arising from efficient use of nursery space against the potential income loss due to lower or delayed yields.

Chapter six

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Appendix 1

Climatic data for 2001/02 growing season, Lusaka

MONTH	TOTAL RAINFALL (mm)	MEAN TEMPERATURE °C		RELATIVE HUMUDITY %
		Maximum	Minimum	
November, 2001	132.8	30.4	18.6	74.9
December, 2001	-	-	-	-
January, 2002	120.5	-	16.1	-
February, 2002	90.1	28.9	17.7	89.5
March, 2002	26.8	29.8	16.4	86.3
April, 2002	83.2	28.0	14.5	84.0
May, 2002	-			
June, 2002	-			
July, 2002	-			
August, 2002	-			
TOTAL	453.4			

Source: Meteorological Dept. GRZ (2002)