THE PROPAGATION AND PRODUCTION OF WESTERN SOAPBERRY

by

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B.S. UNIVERSITY OF KHARTOUM, 1976

A MASTER'S REPORT

submitted in partial fulfillment of

the requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

Kansas State University

Manhattan, Kansas

1985

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ACKNOWLEDGMENTS

I wish to express my deep appreciation to my major advisor, Dr. Houchang Khatamian for his guidance and continuous effort and encouragement throughout the course of this investigation. I also wish to extend my thanks to the members of my committee, Dr. David Hensley and Dr. Wayne Geyer for their suggestions and invaluable advice. I also appreciate the effort of Dr. J. Higgins in helping with the statistical analysis of the data. This undertaking would not have been possible without the moral support of my husband, Hussein, and my daughter, Israa, to whom I am ever grateful. I finally thank the government of Sudan for supporting me financially during my studies.

CHAPTER 1

LITERATURE REVIEW

Pregermination Treatment

Seed germination consists of the resumption of active growth by the embryo and emergence of the radicle (85). Even when the external conditions of temperature, water potential, and oxygen tension are optimum, some viable seeds may fail to germinate. This failure is usually the result of one or more kinds of dormancy imposed on the seed (14,49,63).

Physical dormancy due to a hard seed coat which prevents water and/or oxygen uptake is well documented and the removal or damage of these hard seed coats in some way usually induces germination (3,88,79). A common method of breaking hard seed coats is the use of concentrated acids which has been employed successfully on the seeds of many woody plants (27,69,70). Concentrated sulfuric acid has proven to be very effective in softening hard seed coat in some legume species such as Kentucky coffee tree (Gymnocladus dioicus L. (Koch), honey locust (Gleditsia triacanthos L.), red bud (Cercis canadensis L.), and yellowwood (Cladrastis lutea (Micx. F.) C. Koch) (30,53). Hard seed coat of Golden raintree (Koelreuteria paniculata laxm.) was removed by soaking the seeds for one hour in sulfuric acid (32). In another study (15), the treatment of the seeds with concentrated sulfuric acid also increased the percent germination in American elder (Sambucus canadensis L).

The other type of dormancy is the physiological dormancy which is the most common type of dormancy occurring in nature, and in which the

seed is unable to germinate because it contains an embryo that is not properly developed. Sometimes the embryo may be extremely small containing undifferentiated tissue as in English holly (*Ilex aquifolium* L.) and *Magnolia spp*. The embryo also may be properly differentiated but is small in size and requires warm or cold treatment to enlarge as in European ash (*Fraxinus excelisor* L.) (36).

Depending on its level, physiological dormancy has been further classified as shallow dormancy as in conifers, intermediate dormancy as in sycamore and maple and deep dormancy observed in many members of the rose family. Therefore, physiological dormancy can be overcome by cold stratification or by the use of growth promoters (36,49).

The changes occurring during stratification of seeds include an increase in pH, in water holding capacity, in reducing sugar, in respiratory rate and in the vigor of the embryo. There is also an increase in the level of endogenous hormones such as gibberellins and auxins which are important for the activation of hydrolytic enzymes such as amylase and protease (87,88). The embryo grows and increases its dry weight during the stratification period at 2° C, but not above 15° C. The breakdown of proteins in the endosperm and the transfer of soluble nitrogen and sugars to the embryo is more efficient at 2° C.

Similarly, ABA level seems to fall with the stratification period. Three weeks after stratification no ABA, as measured by wheat (*Triticum aestivum* L.) coleoptile straight growth test, could be detected. A similar observation was made in peach seeds (*prunus persica* L). In *Fraxinus americana* L. (green ash) the highest concentration of ABA was

found to be in the pericarp and dormant seeds. During chilling treatment the level of ABA decreased up to about 68% (52,64).

On the other hand, in hazel nut (Corylus avellana L.) and beech (Fagus sylvatica L.) seeds which require 2-12 weeks of stratification for germination, there was no significant change in the inhibitor level as a result of chilling. There was rather an increase in the activity of GA-like substance that counteracted the effect of the inhibitor when the seeds were chilled for 6-17 weeks (29).

Stratification period usually varies from one kind of plant seed to another, but for some it may become a rather long process and the period required may be as long as 26 weeks as has been shown (36) for European beech (Fagus sylvatica L.). Chemicals such as GA_3, ethrel, KNO_3, and thiourea proved to be effective in substituting the stratification period (49).

Potassium Nitrate

Potassium nitrate was investigated by Sinha (72) who reported that it had no effect on the germination of rice (Oryza sativa L.) seeds. Inorganic nitrogenous compounds such as KNO_2 and KNO_3 were shown to be effective promoters of photoblastic seeds of tobacco (Nicotiana tabacum L.) and the dark germination of positively photoblastic seeds of tobacco was increased by the use of KNO_3 (40). Similarly in tobacco seeds, it was found that KNO_3, KNO_2, and ammonium nitrate increased the percentage of light-induced germination (56). Using KNO_3, seed germination of tumbleweed (Amaranthus albus L.), garden

lettuce (Lactuca sativa L.), and watercress (Barbarea vulgaris L.) was stimulated, even under low oxygen tension (39). Bermuda grass (Cynodon dactylon L.) seeds soaked in 1.0% of KNO_3 had a germination percentage significantly higher than that of seeds soaked in water. This particular concentration of KNO_3 was found to be optimum and it was further concluded that KNO_3 substituted for light requirement by the seeds (93).

Thiourea

Thiourea increased the percent germination and growth of the embryonic axis of chick pea (Cicer arietinum L.) seeds. It also induced the uptake of K^+ ions and glucose (1,8). Application of thiourea significantly reduced the number of days required for the germination of peach (Prunus persica L.) seeds and induced the early initiation of seed germination by accelerating RNA synthesis in the embryo in a manner similar to that of GA_3 (43). Germination of cocklebur (Xanthium pennsylvanicum L.) seeds was increased by thiourea which stimulated the production of endogenous CO_2 (21).

When ethylene, thiourea and CO_2 were applied to the seeds of medic (Medicago trunculata L.) and clover (Trifolium subterraneum L.), it was found that thiourea was the most effective of the three compounds in inducing the germination of fresh as well as dry seed (20,35). Thiourea also ranked second to GA_3 in inducing the germination of Rosen T. labore grape (Vitis vinifera L.) cultivar seed (71). Similarly, thiourea improved the germination of stratified Romi Red grape cultivar seeds, especially at a concentration of 2.5-3% in contrast to

ethrel which had little effect (68). The requirement for thiourea in the germination of lettuce seeds increased more in the dormant and deteriorating stages than in the non-dormant stage, especially at a high temperature of about 30° C (77).

Ethrel

Ethrel was used to stimulate the germination of witchweed seeds (Striga lutea Low) and produced 89-98% germination (17). Strawberry (Fragaria X ananasa) seeds treated with ethrel reached 90-100% germination within a period of four weeks compared with GA_3 and thiourea which gave only 45% and 55% germination respectively (24). Ethrel was also found to be associated with germination process of non-dormant seeds and to participate in breaking seed dormancy in some peanut varieties (48). The application of ethrel to aged seeds of rape (Brassica napus L.) enhanced both germination and the evolution of ethylene (78). It was also found that ethrel had a significant effect in inducing the germination of dormant and immature seeds of medic and clover (35).

Unlike the growth promoters, ethrel was found to be the most effective material in promoting the germination of cocklebur seeds (21). Although it failed to stimulate germination of immature and fresh lettuce seeds as well as Romi Red grape seeds (68,77), ethrel effectively increased the germination of red root pigweed seeds and was most effective in the early phases of the germination process (17,55). Generally the early initiation of germination under ethrel and thiourea reduced the period of stratification (43).

Cutting Propagation

Western soapberry is usually propagated by seeds, and propagation by cuttings is rarely used in nursery practice due to poor rooting (62). Attempts were made to develop a simple, fast method of propagating difficult-to-root plants by cuttings using some growth regulators. IBA, NAA, and their derivatives have been used for rooting cuttings (89,90). Auxins were found to be beneficial for numerous plant species, but their effects on root initiation have sometimes been conflicting, and for some difficult-to-root species were sometimes found to be detrimental (12,80).

There is evidence that increasing age or loss of juvenility is one of the most important factors limiting the rooting ability of many species that are difficult to root from cuttings (9,37). It has been advised that high concentrations of growth regulators be used to promote rooting in these species (9). In fact, certain hard-to-root species have been successfully rooted after treatment with high concentrations of growth regulators, for example English oak (Quercus robur L. 'Fastigiata') cutting rooted after treatment with 20,000 ppm IBA (13). Flemer (25) and Saunders (65) obtained higher rooting values for catawba rhododendron (Rododendron catawbiense L. 'English Roseum') cuttings treated with 20,000 ppm IBA and 30,000 ppm IBA than those treated with 10,000 ppm IBA or 45,000 ppm IBA. Concentrations of 10,000 ppm and 20,000 ppm IBA increased rooting percentages and improved the number and length of root per cutting of saucer magnolia (Magnolia soulangiana L.) and Kobus magnolia (Magnolia kobus L.) (7). Brown and Dirr (9) reported successful

rooting of softwood cuttings from a mature crabapple tree due to high IBA concentrations. Significant stimulation in rooting of cuttings from mature Tilia (linden) with 20,000 ppm IBA was observed (76). However, IBA concentrations of 10,000 to 30,000 ppm did not promote rooting of mature English oak (Quercus robur L.) or black walnut (Juglans nigra L.) cuttings, although juvenile black walnut cuttings could be promoted to root when dipped for 5 seconds in 5,000 and 8,000 ppm IBA solution (73). Oka (57) determined the effect of different concentrations of IBA and NAA, separately and in combinations on the rooting of a number of Dracaena species and cultivars. He found that IBA at 2,000 and 5,000 ppm were more effective in promoting rooting for the majority of the species tested when dipped for 5 seconds, and that there was a remarkable increase in root quality with high IBA concentrations. NAA, on the other hand, improved rooting at concentration of 5,000 ppm or higher but at lower concentration of 2,000 ppm it had a better rooting effect only in combination with IBA.

Flint and Jesinger (26) found that April and August cuttings of Canada hemlock (Tsuga canadensis (L.) Carr) had a higher percentage of rooting than the July cuttings, and that cuttings which were treated with 0.5% IBA and 0.5% NAA in combination did much better than those treated with 0.5% IBA alone.

Pair and Khatamian (59) reported a successful rooting of Chinese pistache (Pistacia chinensis Bunge) cuttings treated with IBA, as 92% rooting occured at 5,000 ppm IBA, and although there was no improvement in rooting percentages above 5,000 ppm, root development appeared better

at a higher IBA level of 10,000 ppm. In another study, Bauer (4) found that flowering dogwood (Cornus florida L.) responded to higher dosages of IBA and the best results, in terms of root number and percentage of rooted cuttings were obtained with a 2% IBA quick dip. Similarly, Fordham (28) obtained a 100% rooting of mountain laurel (Kalmia latifolia L. 'Fuscata') when the cuttings were dipped for 5 seconds in 2,500 ppm IBA or NAA. Fankhauser (22) obtained the following results for softwood cuttings of golden elm (Ulmus procera 'Van Houttei': 60% rooting with .37% NAA, 75% rooting with 0.6% IBA, 75% rooting with 1:1 mixture of .37% NAA and .6% IBA. For osage orange (Maclura pomifera (Raf.) schneid), Pair and Keen (60) obtained a highest rooting percentage at 5,000 ppm IBA than at 10,000 or 20,000 ppm IBA. Ellyard (18) found that both species Persoonia chemaepitys L. and P. pinifolio L.) rooted better when the base of the cuttings were treated with a combination of 6,000 ppm IBA/6,000 ppm NAA than with either of the two hormones alone.

Container Size Effect

It has been established that container-grown seedlings are more successful than bare-root stocks, and many plant species do better in containers than in nursery beds (75). Moreover, planting seasons could be extended, the survival of container-grown seedling is improved and growth is better when the plant goes into the field.

In the last decades there was a considerable interest in various container systems other than the typical round pot, especially in sizes suitable for seedlings (67,83). Various container shapes and configurations had been used, but the bottomless containers present a great

potential in the nursery trade. According to one study (34), strong fibrous root system was obtained due to the branching of the air-pruned roots. Container size played an important role in determining plant growth, and seedling size was found to be a product of container diameter and volume (45). The survival in the field of greenhouse-grown stocks was greatly influenced by the soil volume in the container and a 20% overall gain in survival through the use of container-grown stocks was reported (2,42,82).

The establishment and survival of many plant species was influenced by container size, and for pine trees a low level of fertilizer in smaller containers was desirable (34). Seedling height of nursery-grown mountain ash (Eucalyptus regnans L.) was found to be directly related to container volume and although height growth in the field of plants raised is smaller containers was relatively less, it was considered to be satisfactory for that particular trial site. It was suggested that root volume at the time of planting was a significant factor in determining subsequent early growth (47). The seedling height growth of Douglas fir (Pseudotsuga menziesii L.) and white pine (Pinus strobus L.) were found to be directly proportional to container volume (11,44,46). Height and stem calipers of many tree seedlings increased as container size increased leading to the conclusion that container-grown seedlings would serve some purposes better than those of bare-root stocks (54,75).

Container size and shape and potting medium interacted to influence the growth of black walnut (Juglans nigra L.) seeds; tall, narrow, vent pipe containers had no effect on total dry weight while large containers

tended to produce large trees (31). Increasing container volume greatly increased root dry weight of lodgepole pine (Pinus taeda L.), white spruce (Picea glauca), (Moench Voss.) and Jackpine (Pinus banksiana Lamb.) (19,66). Similarly, it was concluded that pot surface area was strongly correlated with increase in the dry weight of ponderosa pine (Pinus ponderosa L.) (58). The development of root and top in Chinese pistache (Pistacia chinesis L.), Western soapberry (Sapindus drummondii Hook Arn), and Japanese black pine (Pinus thunbergiana L.) was found to be proportional to the surface area of the square container (16). It was also shown that not only pore space size, but also the size and depth of the container determined aeration, drainage and distribution within the containers of roots of Tam juniper (Juniperus sabina L. 'Tamarisifolia' and English Holly (Ilex aquifollium L.); root growth and branching was greatly influenced by the depth and width of the container (44). In another study it was found that the performance of the bottomless containers was poorer than that of bottomed containers, and was suggested that the absence of bottom might have allowed for the drying and subsequent injury to the root tips in the bottom of the containers (5). Root weight and root grade of juniper and holly cuttings increased as container size increased. Intermediate depth (6-7 cm) was the best for both species in terms of root and shoot weights, but smaller containers with smaller diameters tended to restrict lateral root development (81).

CHAPTER 2

PROPAGATION OF WESTERN SOAPBERRY BY SEEDS AFTER PREGERMINATION TREATMENTS

Introduction

In recent years some improved selections and hybrids of Midwestern native plants have appeared in the nursery trade and an increasing number of species is being utilized in the landscape. These, however, are only a small fraction of the enormous number of native species with ornamental values. An example of such native species is Western soapberry (*Sapindus drummondii* Hook and Arn). In spite of its desirable characteristics both as a good city tree and for landscape and wildlife environments, it has not been grown for nursery production.

One of the growth problems of Western soapberry is associated with seed germination. Seed germination is inhibited by seed coat impermeability and embryo dormancy (62). There is uncertainty as to which of these two factors is the more important in the field (61). In the greenhouse, embryo dormancy poses more of a problem than the hard seed coat which can be removed mechanically or by acid scarification (53,70). To overcome embryo dormancy some physical means, such as temperature treatment, or chemical treatment are required. Seed germination responds to internal metabolic regulators as well as to externally applied compounds (36). Chemicals such as ethrel, thiourea, and potassium nitrate have been used to substitute partially or completely for the conditions needed to improve seed germination of rape (*Brassica napus* L.

variety chisayanalane), chick pea (Cicer arietinum L.) and tumbleweed (Amaranthus albus L.) (1,55,78). The objective of this study is to enhance seed germination and to reduce the stratification period required by the seeds of Western soapberry by using ethrel, thiourea and potassium nitrate.

Materials and Methods

Western soapberry seeds were collected in the fall of 1982 from a mature tree on Kansas State University campus and the germination tests were performed immediately after harvest.

Germination Procedure

Untreated seeds were sown directly on flats filled with a medium consisting of one part peat moss, one part perlite, and one part soil (v/v), and labelled as control. The remainder of the seeds were soaked in concentrated sulfuric acid for two hours, then were washed thoroughly with water for 20-30 minutes and dried. Some of these seeds were sown in the same medium mentioned, while the rest were subjected to chemical treatments.

Chemical Treatments

The chemicals used to treat the seeds were potassium nitrate at a concentration of 1%, thiourea at a concentration of 3%, and ethrel at 5mM concentration. Stock solutions of these chemicals were prepared at the beginning of the experiment and kept in a refrigerator; when needed, the solutions were diluted and used for seed treatment. The seeds were

treated by soaking them in at least twice their volume of the pertinent chemical in 250 ml beakers for 24 hours. The beakers were covered with clean, sterile watch glasses and the soaked seeds were then sown as described.

Stratification

Well-washed, sterile sand was used as the stratification medium. The seeds to be stratified were soaked 12 hours in water, drained and stratified in 2 inches thick alternating layers of the sand placed in 5 gallon wooden boxes. The sand boxes were kept in the refrigerator at 2-5° C for a period of one, two, or three months. After each period the seeds were divided into four equal patches: one patch was used as a control and sown directly; each of the remaining three patches was soaked for 24 hours in KNO_3, thiourea or ethrel and sown as previously described. Each treatment was replicated four times with each replicate consisting of 25 seeds planted in a flat. The flats were maintained in the greenhouse with a daily temperature of 18-28° C. The flats were watered as required, and emerging seedlings were counted daily until no further emergence was observed. The percent germination was calculated, and data was analyzed using LSD for the mean comparison.

Embryo Measurement

After each stratification period, the embryos from about 20 seeds randomly selected were carefully excised using a sharp razor blade. Each embryo was examined microscopically and the length was determined to the nearest one-tenth of a millimeter using a calibrating lens.

Results and Discussion

The application of ethrel, thiourea and KNO_3 to Western soapberry seeds considerably enhanced their germination (Table 1). Overall the stratification periods, treatment with ethrel and thiourea resulted in the highest percentage of germination, while KNO_3 was significantly less effective when compared to ethrel and thiourea. However, seed treated with KNO_3 germinated significantly better than the control (Table 1). With no stratification the three chemicals produced significantly greater percent germination than the control (Fig. 1). Ethrel and thiourea gave significantly better percent germination than the KNO_3. When the seeds were stratified for one or two months and then chemical treatment was applied ethrel produced the highest germination percent compared to the control. However, ethrel effect was not significantly different from thiourea or KNO_3. After three months stratification none of the three chemicals proved statistically superior to the control (Fig. 1).

Table 2 shows that stratification increased percent germination when averaged over all chemical treatments. All three stratification periods were significantly better than the control in increasing germination percent. Although a period of two months stratification was significantly better than a period of three months, both periods overlap with the period of one month in the average percent germination value. Therefore, two or three months stratification were not significantly better than one month period.

The results clearly show that all three chemicals induced dormant Western soapberry seeds to germinate. The effect of ethrel treatment was in agreement with results obtained for strawberry (24), medic, and clover (35) where ethrel had a significant effect in breaking dormancy and increasing the percent germination. Thiourea improved the germination of Rosen T. labore grape cultivar and substituted for the stratification period required by peach seeds (8,71). Western soapberry seeds appeared to respond similarly to treatment with thiourea. KNO_3 failed to increase the germination percent of rice seed and cocklebur seed (21,72) for Western soapberry, although KNO_3 improved the percent germination of the seed compared with the control, yet its effect was significantly higher when it was coupled to stratification.

The embryo length of nontreated Western soapberry seeds was measured at the beginning of the experiment and at the completion of each stratification period. The embryo increased from an initial length of 1.8 mm to 2.5 mm at one and two months of stratification and finally to 3.7 mm after three months. A strong correlation ($r = .998$) between the embryo size and the stratification period was found. The increases in percent germination corresponding to these increases in embryo size were 0% at the start of the experiment, 59% after one month stratification, and 63% two and three months later. The fact that the size of the embryo increased during stratification may be due to cold temperature and a favorable moisture regime. A period of cold temperature treatment has been shown to bring about essential changes in the metabolic activities of the embryo (87,88). These changes included an increase in water absorbing power, enzyme activity, the breakdown of stored proteins, and

the transport of soluble nitrogen and sugars to the embryo. All of these changes contribute to enhancing the growth of the embryo as a result of stratification. This condition is similar to environmental conditions surrounding the newly mature seeds in winter season. It is likely that in temperate regions the embryo may need to go through the winter season to bring about an increase in size similar to that obtained by stratification.

Delay in germination in many plant species was found to be due to the presence of some growth inhibitor(s) (29,52). For instance, dormant seeds of peach and hazel have been found to contain high level of ABA concentrated mainly in the seed coat of the freshly harvested seed. This amount of ABA decreased considerably when the seeds were stratified. It was also found that dormant seeds of European beech, hazel and peach contained low levels of gibberellin which increased during chilling to a level that enabled the seeds to germinate (29,36). Similar situations may exist for Western soapberry seeds. However, these factors are known to be affected by chemical treatment as well as stratification (87).

The growth regulating properties of ethrel are known to be due to its ability to produce ethylene in plant tissue which acts as a germination promoter (24). However, the nature of the inhibition removed by ethylene is still not clear. Varner and Chen (87) showed that in barely ethylene enhanced gibberellin-induced -amylase. Ethylene was also shown to induce changes in the levels of endogenous cytokinin and a gibberellin-like substance. The amount of endogenous ethylene was found to be not enough to trigger the germination of freshly harvested seeds in many species (17,78). The seeds used in this experiment were treated

with ethrel immediately after collection. It is probably that these seeds had a low amount of ethylene and treatment with the ethylene-generating ethrel increased this amount. This resulted in releasing the seed from dormancy and a high percent germination was obtained.

The effect of thiourea in breaking dormancy was found to be mainly due to its ability to counteract the effect of inhibitor(s) within the embryo (1,43). Sondheimer et al (74) suggested that stratification released Fraxinus spp seeds from dormancy by reducing the level of ABA within them. Thiourea was also found to have a similar effect as gibberellin in accelerating RNA synthesis in the embryo (43) and in stimulating the evolution of endogenous CO_2 (21). These diverse effects of thiourea directly participate in the growth of the embryo and early initiation of germination. When fresh Western soapberry seeds were treated with thiourea the percent germination (92%) was significantly better even than that obtained after three months stratification (63%). Thiourea thus had a more positive effect than stratification in releasing Western soapberry seeds from dormancy.

The role of KNO_3 in breaking dormancy is not clearly understood. It was related to the enhancement of light-induced germination (56,93) and to an increase in the respiration rate of the embryo (39). It was also suggested that KNO_3 did not overcome dormancy per se but it acted in conjunction with a dormancy-breaking factor such as light or temperature to increase the proportion of seeds capable of prompt germination (93). Whatever the effect of KNO_3, results with Western soapberry indicate that stratification greatly enhanced the effect of KNO_3 on seed germination.

The embryo of Western soapberry seeds has certain requirements before germination occurs. Although these requirements may not be totally clear, treatment with ethrel, thiourea, KNO_3 or stratification met these requirements to varying degrees, and hence imporved seed germination. Ethrel and thiourea were clearly superior to KNO_3 when these chemicals were applied to freshly collected Western soapberry seeds. However, all the three chemicals performed the same when the soapberry seeds were stratified.

Table 1: Mean percent germination of Western soapberry seeds following treatment with KNO_3, ethrel and thiourea overall the stratification periods

Treatment	Mean % Germination[Z]
Ethrel	95.40a[Y]
Thiourea	89.75a
KNO_3	78.00b
Control	46.40c

Z: Mean being the average of 16 values.

Y: Values in column not followed by the same letter are significantly different at 5% level by LSD mean separation.

Table 2: Mean percent germination of Western soapberry seeds at different periods of stratification averaged overall the chemical treatments.

Stratification Period (month)	Mean % Germination
0	58.75c[Y]
1	82.50ab
2	86.00a
3	80.25b

Z: Mean being the average of 16 values.

Y: Values in column not followed by the same letter are not significantly different at 5% level by LSD mean separation.

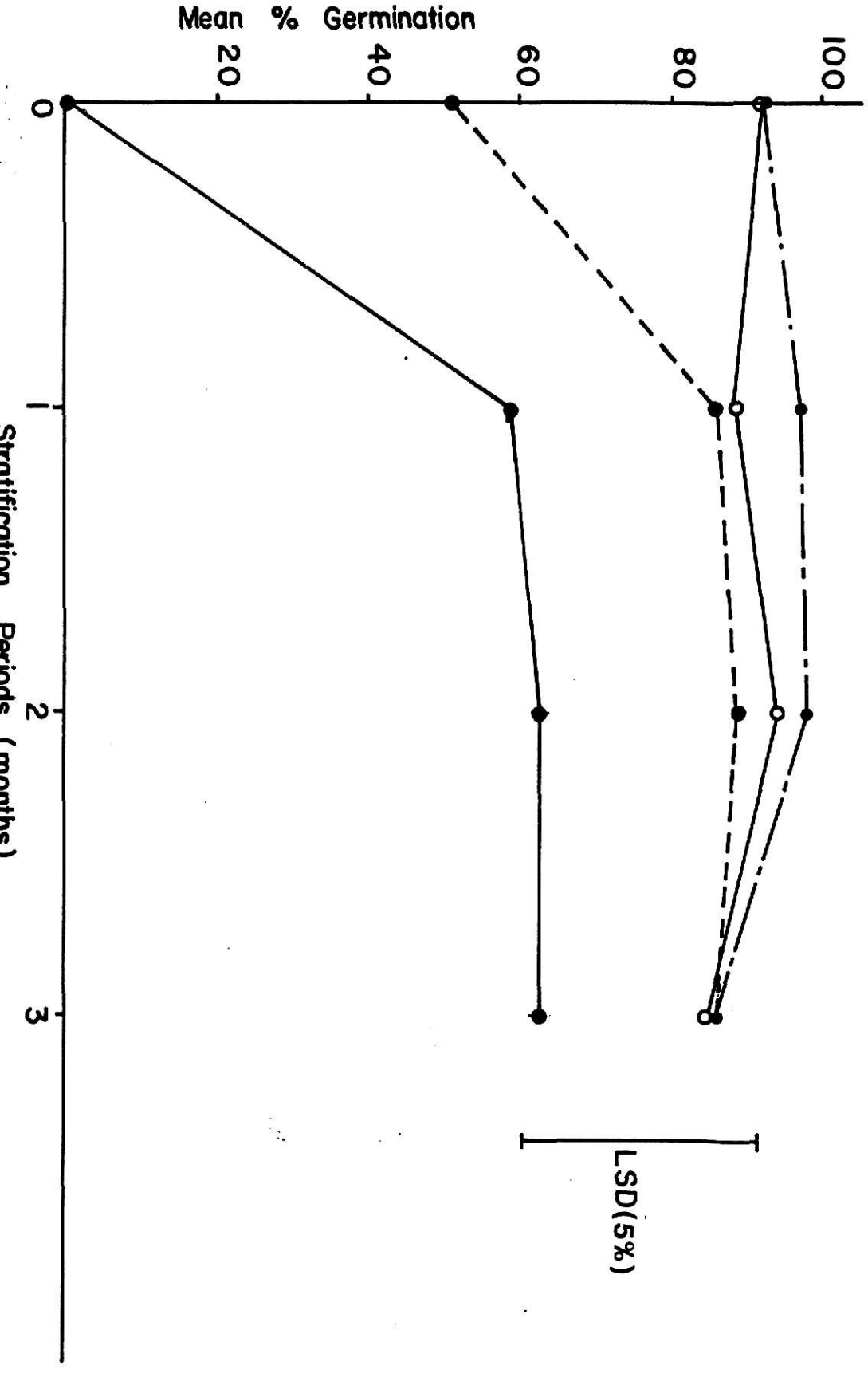


Figure 1: Effect of Chemical Treatment on percent Germination of Stratified and Non - Stratified Seeds of Western Soapberry

Chapter 3

PROPAGATION OF WESTERN SOAPBERRY BY SOFTWOOD CUTTINGS USING GROWTH HORMONES

Introduction

The propagation and growing of Western soapberry is not a common practice in Midwestern nurseries. Propagation by seeds had been reported to be successful after a pregermination treatment, but cutting propagation is not widely used (62).

One of the problems associated with soapberry propagation through rooting of the green cuttings involves the considerable period of time required for rooting to occur. In general, cutting propagation, however, is considered as easier, more rapid and more economical type of plant propagation especially for easy-to-root plant species (37). For hard-to-root plants such as Western soapberry, rooting hormones are commonly used to improve rooting of cuttings. The response to these hormones usually varies greatly depending upon the species or cultivar (37), and the time of the year the cuttings are taken (50).

Plant regulators like IBA, NAA or the combination of the two were found to vary greatly in their effect depending upon the species and the concentration used (37). Sometimes, these regulators at high concentrations may entirely inhibit rooting, or when less severe, few roots develop. This study was thus undertaken to determine the influence of IBA and NAA alone or in combination, on rooting of softwood cuttings of Western soapberry.

Materials and Methods

Stem cuttings were collected June 10, 1984 from the terminal branches of the current season's growth of mature tree of Western soapberry, 15-20 M. tall located at Kansas State University campus. The stem cuttings were of uniform thickness and of similar length of approximately 18 cm. Basal portions of all cuttings were stripped of folioage and the number of the remaining leaflets were cut in half to reduce the surface area.

The basal tips of the cuttings were dipped for 5 seconds in the solutions of 5,000, 10,000, 20,000 or 30,000 ppm IBA, NAA or IBA + NAA dissolved in 50% ethanol. The 50% ethanol was used as the control treatment.

After dipping, the cuttings were immediately stuck into a medium of 3 parts peatmoss: 7 parts perlite (V/V), in a greenhouse propagating bench measuring 350 cm. in length, 90 cm in width and 15 cm in depth. Intermittent mist was applied for 6 seconds every three minutes for a duration of 12 hours.

The experimental design used was a randomized complete block with three replications and 13 treatments of 5 cuttings per each replication. Six weeks later, the cuttings were removed, and evaluated for rooting percent, total root length, number of roots and total root fresh weight.

Percent rooting was a measurement of the percent of cuttings that initiated roots. Total root length was obtained using only the primary roots. The number of roots were determined by counting the number of primary roots for each cutting.

Results and Discussion

The percentage of Western soapberry softwood cuttings that developed roots was slightly better when the cuttings were treated with IBA or IBA+NAA, but there was no significant difference between these treatments and the control (table 3). NAA, on the other hand, tended to decrease the percent of rooted cuttings. At 30,000 ppm NAA the number of cuttings that developed roots (6.67%) was significantly less than the control and all other treatments (Table 3). There was no increase in the number of roots per cutting as a result of chemical treatments except in the case of IBA at 10,000 ppm, which produced significantly greater number of roots per cutting than the control, all NAA treatments, all IBA+NAA treatments below 30,000 ppm as well as IBA at 5,000 ppm (Table 4). However, no significant difference existed among the number of roots per cutting at IBA concentrations of 10,000 ppm and higher. IBA improved root fresh weight at all concentrations above 5,000 ppm. Neither of the other two treatments (IBA+NAA and NAA) resulted in any significant gain in root fresh weight compared to control except IBA+NAA at 5,000 ppm (Table 5). In terms of the average root length of cuttings IBA+NAA at 5,000, 20,000 and 30,000 ppm resulted in significantly longer roots than the control (Table 6).

These results indicate that there was some favorable response of Western soapberry cuttings to IBA and IBA+NAA above 5,000 ppm. However, a strong case for these two treatments could be made only in a few instances. The cuttings did not respond well to NAA particularly at 30,000 ppm NAA, percent rooting was sharply reduced (Table 3).

The rooting data also shows a great deal of variation among the various treatments. Although the differences were sometimes greater than 10-fold between some treatments, the statistical analysis would still place these values in the same category. The statistical analysis revealed, as was evident from the raw data, a strong repliaction effect (Appendices 2,3,4,5). The number of roots and root weight for the third replicate were significantly higher than those for the remaining two replicates. Moreover, both the second and third replicates had significantly higher values than the first replicates in terms of the percent of rooted cuttings and the root length. In pointing out these differences between replicates we are not certain what caused them. It is possible that the mist system did not provide even distribution of moisture through the propagating bench or some other environmental factor intervened.

Rooting of cuttings is a complex phenomenon influenced by factors such as physiological condition, genetic origin of the donor plant, climatic conditions, treatments with growth regulators, and the season on which the cuttings were taken (37). Softwood cuttings of many difficult to root species have been induced to root using high level of IBA. A larger number of roots, higher percent rooting and longer roots were obtained when softwood cuttings of Cotoneaster acutifolius L., Taxus cuspidata L. and Malus 'Hopa' were treated with IBA in the range of 20,000-40,000 concentrations (10,13). Flemer (25) obtained 50% rooting when he treated softwood cuttings of Quercus alba with 20,000 ppm IBA. However, a higher rooting percent was obtained for soapberry cuttings when treated with similar IBA concentrations (Table 3).

Generally the rooting data of soapberry cuttings showed higher values when the cuttings were treated with IBA concentrations in the 10,000-30,000 ppm range. The number of roots per cutting was significantly higher at 10,000 ppm IBA (Table 4). This was similar to results obtained for six crabapple cultivars. However, in the case of crabapples, unlike Western soapberry, IBA concentrations of 20,000 and 30,000 ppm resulted in phytoloxicity (9).

The lack of rooting ability in some species might be due to the absence of necessary active enzymes or substrates that induce the meristematic state, and thus the initiation of root primorida. Therefore, root primordia must be biochemically induced for rooting to occur, and this could be achieved by the use of growth stimulants (51). Evidence further suggested that each step of the rooting process is controlled by a delicate balance of plant hormones in conjunction with other rooting cofactors and complex enzymes (84,86). According to Hartman and Kester (37), some difficult-to-root plants may not possess the necessary amount of auxins required to induce rooting, or the amount of auxin may be reduced due to factors such as age or time of the year. Such reduced amount of auxin may cause a delay of rooting. It seems logical, therefore, that application of external auxin would help to enhance rooting of these plants. Results with Western soapberry softwood cuttings confirm this to some extent. Figures 2 and 4 show the positive effect of auxin treatment on the rooting of Western soapberry cuttings. Better root growth was obtained by IBA and IBA+NAA treatment compared to the control. In addition, IBA at 10,000 ppm resulted in a significantly greater number of roots per cutting (Table 4). Similarly,

treatment with IBA in the range of 10,000-30,000 ppm and IBA+NAA at 5,000 ppm resulted in a greater root fresh weight than the control (Table 5).

Brown and Dirr (9) indicated that high concentration of IBA of 20,000-30,000 ppm often resulted in defoliation, significant injury, or death in crabapple and many other species. Based on the root fresh weight data (Table 5) the results showed that IBA concentrations in the range used resulted in higher rooting response, particularly 20,000-30,000 ppm IBA and 5,000 IBA in combination with NAA. NAA alone resulted in reduced rooting, and the addition of IBA to NAA slightly enhanced its stimulatory effect in this study, especially at 5,000 ppm concentration.

Although statistical analysis did not show a clear positive effect of chemical treatment in many instances, some improvement was observed in both root quality and quantity with IBA and IBA+NAA application (Fig. 2 and 4). These figures show a progressive increase in root mass as auxin concentration was increased. Cuttings treated with 20,000-30,000 ppm IBA and IBA in combination with NAA show considerably bigger root mass than the control. NAA treatment tended to have a negative effect on rooting as the concentration increased. Cuttings treated with NAA were never significantly better than the control, and as the concentration of NAA inceased a significant reduction in rooting was observed (Fig. 3). The cutting treated with 20,000 ppm developed few roots which were short, bent and thick. At 30,000 ppm total inhibition of rooting occurred, the basal portion of the stem was necrotic. This was accompanied by the yellowing and dropping of the leaves and blackening of the stem. These symptoms are probably the result of NAA toxicity. Blazich

(6) and Hitchcock and Zimmerman (41) found NAA to be toxic over a wide range of concentrations, while addition of IBA slightly reduced its harmful effect in this study.

Treatment of softwood cuttings of Western soapberry with IBA or IBA+NAA had a positive effect on rooting while NAA treatment affected rooting negatively in the 5,000-30,000 ppm concentration range. IBA treatment in the 10,000-30,000 ppm range produced more than double the number of roots per cutting, and resulted in root fresh weight more than four times higher than the control (Tables 4,5). In spite of the statistics, which were affected by large differences among the replicates, there were clear increases in root mass and quality over the control when the cuttings were treated with IBA or IBA in combination with NAA.

Table 3: Effect of different concentrations of IBA, IBA+NAA and NAA on the percent of rooted cuttings of Western soapberry.

Hormone	Concentration (ppm)	Mean percent of rooted cutting[Z]
Control	0	60.00 abc[Y]
IBA	5000	73.33 ab
IBA	10000	86.67 a
IBA	20000	86.67 a
IBA	30000	73.33 ab
IBA+NAA	5000	86.67 a
IBA+NAA	10000	80.00 ab
IBA+NAA	20000	73.33 ab
IBA+NAA	30000	80.00 ab
NAA	5000	60.00 abc
NAA	10000	53.00 bc
NAA	20000	40.00 c
NAA	30000	6.67 d

Z: Means being the average of 15 values.

Y: Values in columns followed by the same letter are not significantly different at 5% level by LSD mean separation.

Table 4: Effect of different concentrations of IBA, IBA+NAA and NAA on number of roots per cutting of Western soapberry.

Hormone	Concentration (ppm)	Average number of root[Z] per cutting
Control	0	1.80 bcde[Y]
IBA	5000	1.87 bcde
IBA	10000	5.13 a
IBA	20000	4.13 ab
IBA	30000	4.07 abcd
IBA+NAA	5000	2.27 bcde
IBA+NAA	10000	1.93 bcde
IBA+NAA	20000	2.47 bcde
IBA+NAA	30000	3.40 abcd
NAA	5000	1.27 de
NAA	10000	1.47 cde
NAA	20000	0.60 e
NAA	30000	0.13 e

Z: Means being the average of 15 values.

Y: Values in columns followed by the same letter are not significantly different at 5% level by LSD mean separation.

Table 5: Effect of different concentrations of IBA, IBA+NAA and NAA on the root fresh weight of Western soapberry cuttings.

Hormone	Concentration (ppm)	Average root fresh weight[Z] (g)
Control	0	0.24 cd[Y]
IBA	5000	0.47 bcd
IBA	10000	1.10 ab
IBA	20000	1.23 a
IBA	30000	1.17a
IBA+NAA	5000	0.93 ab
IBA+NAA	10000	0.64 abde
IBA+NAA	20000	0.72 abcd
IBA+NAA	30000	0.85 abc
NAA	5000	0.48 bcd
NAA	10000	0.51 bcd
NAA	20000	0.16 d
NAA	30000	0.097 d

Z: Means being the average of 15 values.

Y: Values in columns followed by the same letter are not significantly different at 5% level by LSD mean separation.

Table 6: Effect of different concentrations of IBA, IBA+NAA and NAA on the average root length of Western soapberry cuttings.

Hormone	Concentration (ppm)	Average root length[Z] (cm)
Control	0	7.58 cde[Y]
IBA	5000	10.18 bcd
IBA	10000	15.82 abc
IBA	20000	14.65 abc
IBA	30000	14.02 abc
IBA+NAA	5000	16.08 ab
IBA+NAA	10000	15.08 abc
IBA+NAA	20000	16.26 ab
IBA+NAA	30000	18.64 a
NAA	5000	10.91 abcd
NAA	10000	8.58 bcd
NAA	20000	4.46 de
NAA	30000	0.10 e

Z: Means being the average of 15 values.

Y: Values in columns followed by the same letter are not significantly different at 5% level by LSD mean separation.

Figure 2: Effect of IBA concentrations on rooting of stem cutting of Western soapberry.

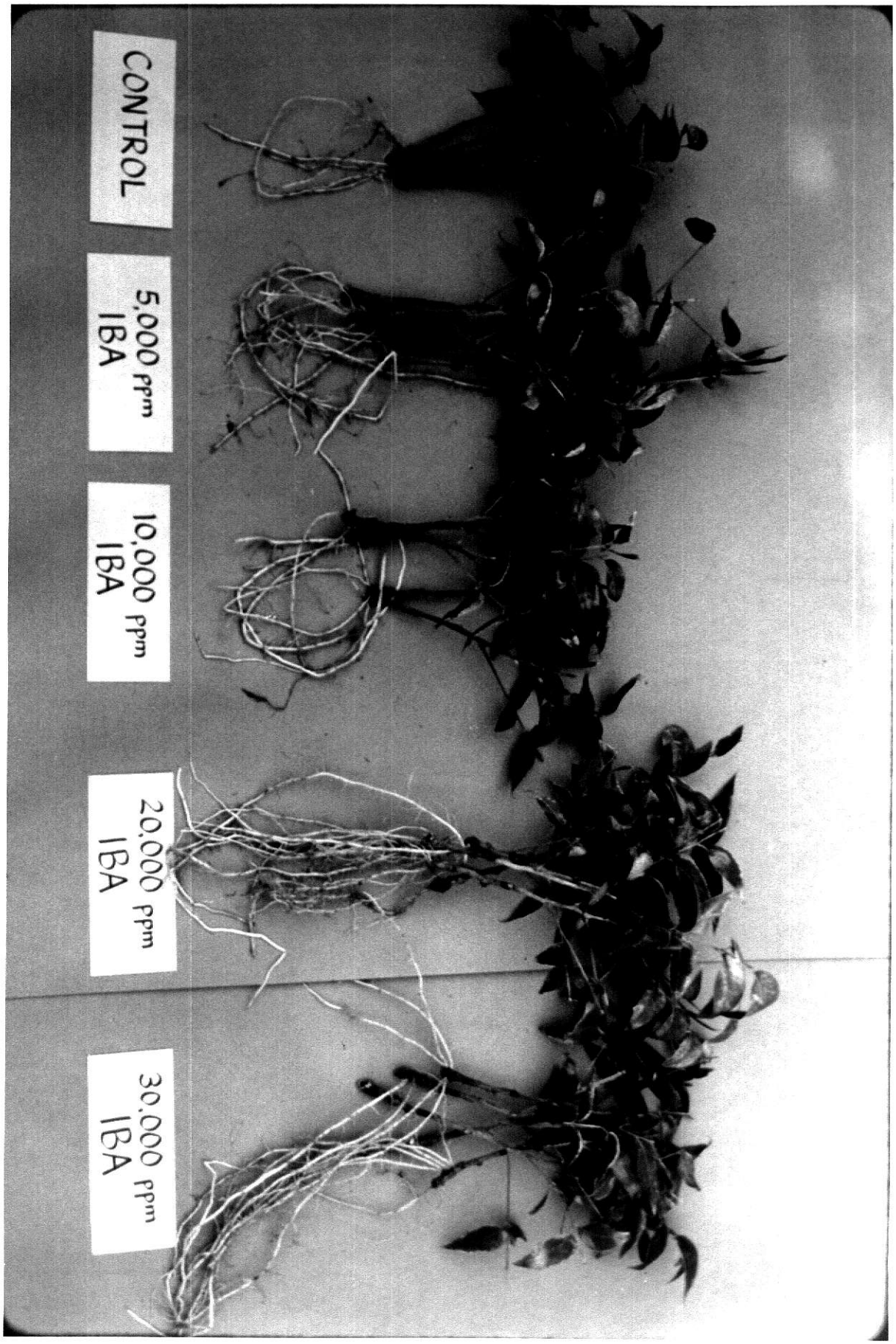

CONTROL
5,000 ppm IBA
10,000 ppm IBA
20,000 ppm IBA
30,000 ppm IBA

Figure 3: Effect of NAA concentrations on rooting of stem cutting of Western soapberry.

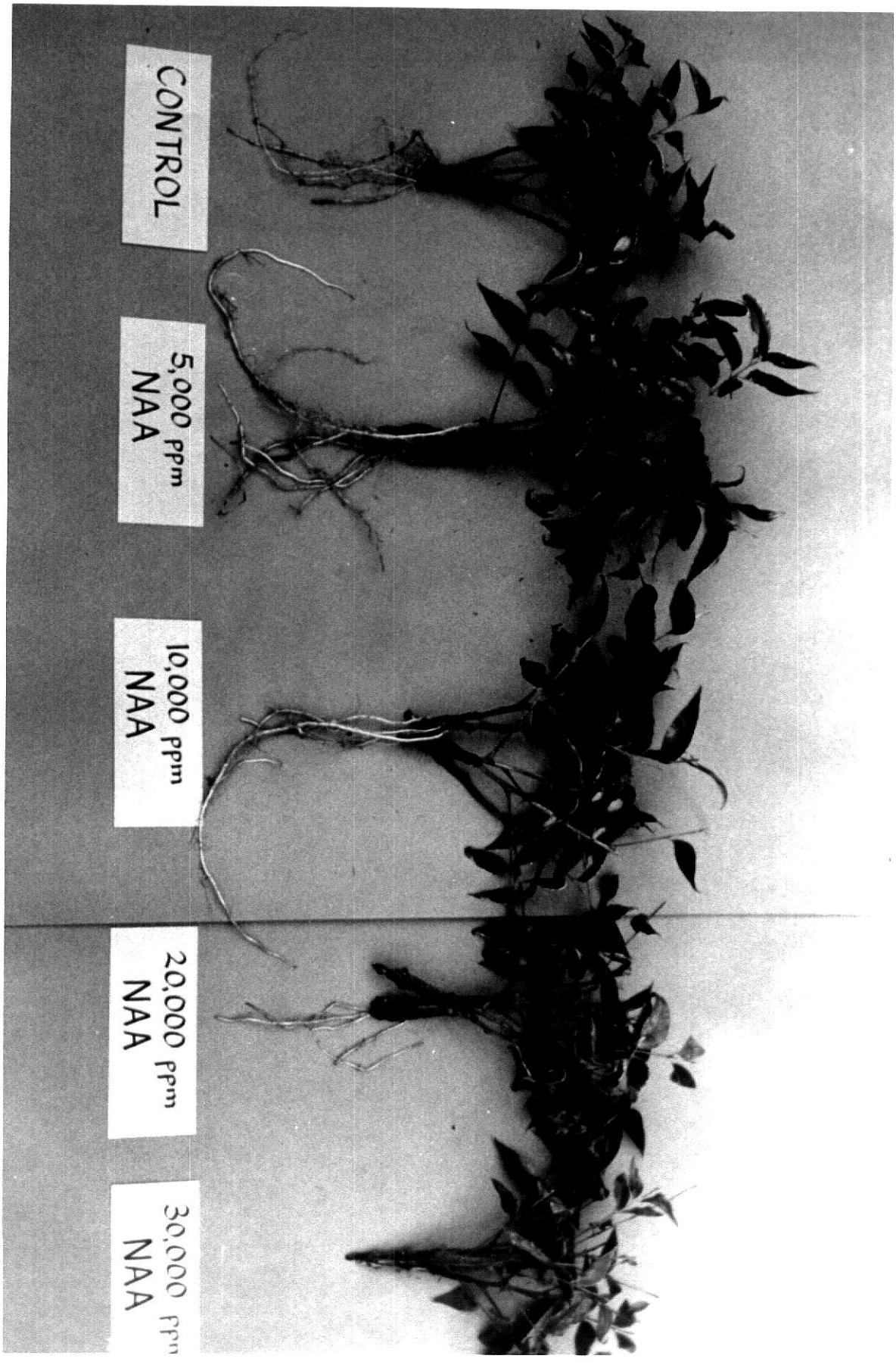
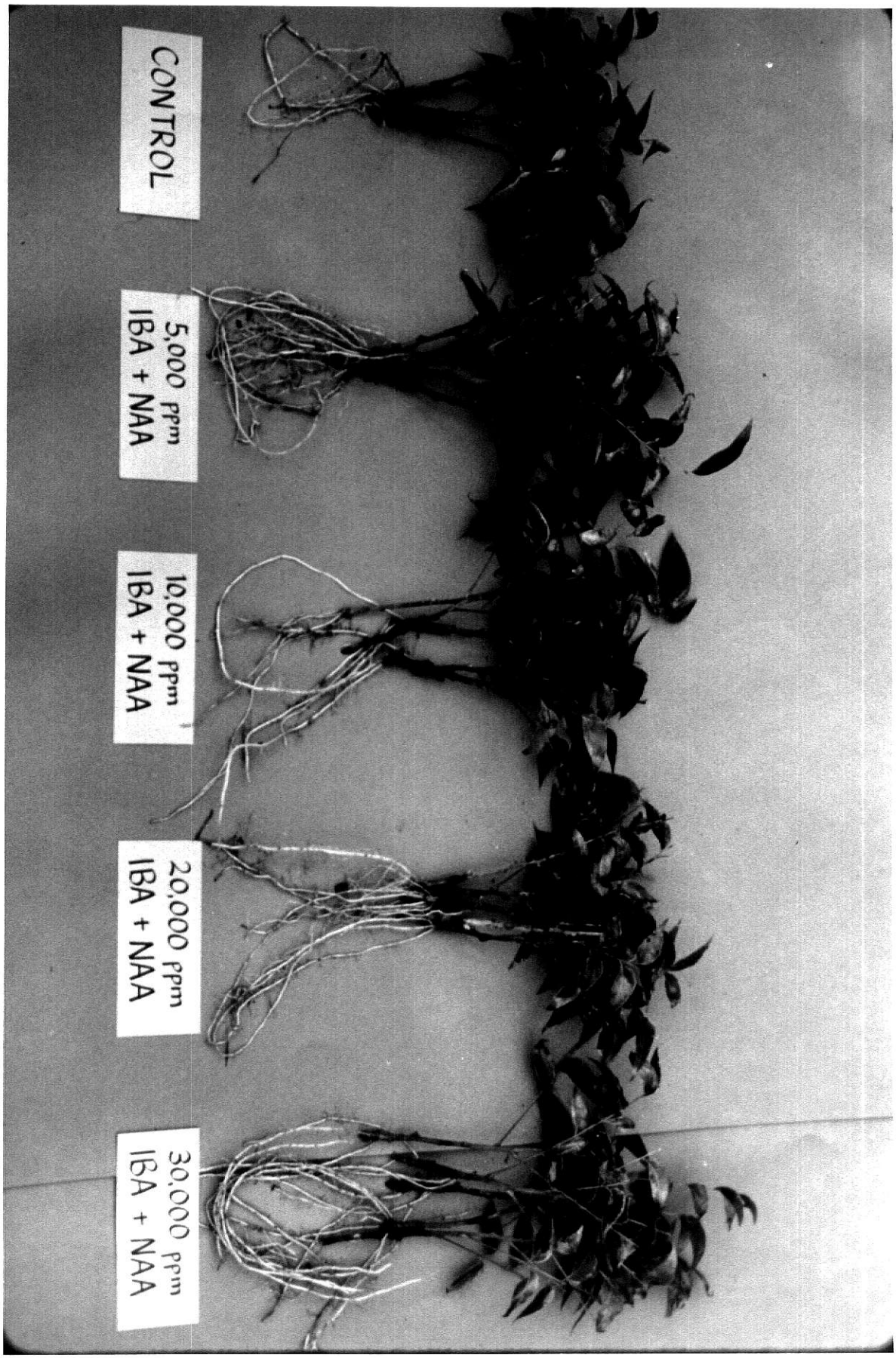

CONTROL
5,000 PPm NAA
10,000 PPm NAA
20,000 PPm NAA
30,000 PP
NAA

Figure 4: Effects of IBA & NAA concentrations on rooting of stem cutting of Western soapberry.


CONTROL
5,000 ppm IBA + NAA
10,000 ppm IBA + NAA
20,000 ppm IBA + NAA
30,000 ppm IBA + NAA

Chapter 4

INFLUENCE OF CONTAINER SIZE ON SEEDLING GROWTH AND DEVELOPMENT OF WESTERN SOAPBERRY SEEDLING

Introduction

Planting of container grown tree seedlings is proceeding at a rapid pace in many areas of the United States, but little information is available on the influence of container size on plant growth. Propagation containers usually come in many shapes and sizes, which leaves nurserymen with a wide selection to choose from. The container size is one of the most important considerations, since the development of strong fibrous root system that would ensure successful transplanting when the plant is transfered to the field is recommended. This can be achieved by determining an optimum size of the container in which the plant is to be maintained both indoors and outdoors.

The production of shade and ornamental trees in containers can be very beneficial if survival following transplanting increased, growth of top and root increased, thus decreasing production time, and root quality increased, aiding survival and/or performance in the landscape. Therefore, the purpose of this study was to evaluate the influence of container size on growth and production of good tree liners of Western soapberry.

Materials and Methods

The containers used in this experiment were originally constructed from cylindrical polyvinyl chloride pipes of 1-2 mm thickness and 5-10 cm diameter. These cylindrical pipes had been cut into 15 different sizes resulting in 15 classes of bottomless containers having the following dimensions:

Container size (diameter, cm x depth, cm)	Container volume (cm^3)
5 x 5	98.17
5 x 10	196.35
5 x 15	294.52
5 x 20	392.70
5 x 25	490.87
7.5 x 5	220.89
7.5 x 10	441.79
7.5 x 15	662.68
7.5 x 20	883.57
7.5 x 25	1104.47
10 x 5	392.70
10 x 10	785.40
10 x 15	1178.10
10 x 20	1570.80
10 x 25	1963.50

The containers were placed on wire benches to provide air pruning (11,16). The growing medium consisted of equal parts (v/v) of perlite, peat moss and soil. Plants were grown in the greenhouse under an extended 18-h photoperiod (one 60 watt incandescent bulb per 0.47 m^2). The prevailing greenhouse temperature is maintained at a daily temperature of 18-30° C and 40-50% relative humidity.

After six weeks all the plants were fertilized using liquid fertilizer (20 N-8.6P-16.6K) at a concentration of 200 ppm twice a week. After 8 weeks the fertilizer concentration was raised to 300 ppm. Watering was performed according to the plant need and container size using tap water. The containers were spaced sufficiently apart to avoid crowding and shading of shorter containers by taller ones.

Treatments were replicated five times in a randomized complete block design. After 18 weeks the roots were cleaned and washed. Shoots and roots were dried for 4-5 days in an oven at 48-50° C and were then weighed. Stem length, root dry weight, shoot dry weight, and shoot/root ratio were determined.

Results and Discussion

Container size had a significant effect on the growth of Western soapberry seedlings (Appendices 6,7,8,9). Root dry weight, shoot dry weight and the stem length of seedlings increased as the container size increased. In contrast shoot/root ratio decreased with an increase in container size.

Figure 5 shows the effect of container size on root dry weight. In the group of containers with a 5 cm diameter (1-5), containers with 15-25 cm depth (3-5) supported better root growth than 5 cm depth. Although the seedlings in 10 cm deep containers had better root growth than in 5 cm deep ones, the difference was not significant. The least amount of root growth in the 7.5 cm diameter group (6-10) occurred in 5 cm deep containers. The seedlings from the 15-25 cm deep containers (8-10) had a greater root weight than the 10 cm deep ones. The same was true with the 10 cm diameter group of containers (11-15) except that there was no difference between the 5 cm and 10 cm depth containers. In all three diameter categories, the highest increase in root growth occurred between the 5 cm and 15 cm depths. Although the 20 cm and 25 cm depths generally produced the largest amount of root growth, the transition from 15 cm to 25 cm was not as sharp.

In terms of shoot dry weight (Fig. 6), the shallowest containers (5 cm deep) had the worst values and there were little differences among the rest of 5 cm diameter group (1-5). At 7.5 cm diameter (6-10), shoot dry weight was least in 5 cm deep containers, followed by the 10 cm deep containers, and the best shoot growth occurred at depths of 15-25 cm containers (8-10). Among the 10 cm diameter group (11-15), plants

in 5 cm depth produced the least shoot growth. The shoot growth of plants in 10-25 cm deep containers (12-15) was highest and there was no difference in shoot growth among these containers. Generally, the sharpest increase in shoot dry weight among all containers occurred between the containers of 5 cm and 10 cm depths.

In contrast to root and shoot dry weights the stem length of Western soapberry seedlings was little affected by the majority of container sizes (Fig. 7). Only five container sizes (7.5 x 15, 7.5 x 25, 10 x 10, 10 x 15, 10 x 20 cm) were significantly better than the two smallest sizes of 5 x 5 and 5 x 10 cm. Plants grown in 10 x 10 and 10 x 20 cm also had longer stems than those grown in 5 x 20 cm containers.

The shoot/root ratio (Fig. 8) was not significantly affected by depth when the container diameter was 5 cm (1-5), although the ratio tended to decrease as the container got deeper. At 7.5 cm diameter (6-10), the shoot/root ratio was highest for the shallowest containers of 5 cm depth, but there were no great differences among the rest of the depths. Among the 10 cm diameter containers (11-15), only 10 cm deep containers had a significantly higher shoot/root ratio than the rest of the depths except for 5 cm deep containers. The shoot/root ratio in 5 cm deep containers was significantly higher than 25 cm deep containers.

Container volume affected growth in a manner similar to that of container size. Root dry weight was highest in 7.5 and 10 cm wide containers with depths between 15-25 cm (Fig. 5). These containers varied in volume from 662.68-1963.5 cm^3. The 10 x 10 cm container

(785.4 cm^3) which falls within this volume range produced significantly lower root dry weight. It was also not significantly different from the 5 x 10 (196.35 cm^3) container although it had four times the volume. It is apparent that an increase in volume results in higher root dry weight only when accompanied by a depth/diameter ratio higher than one. Although the 10 x 5 cm and 5 x 20 cm containers had identical volume (392.7 cm^3) the root dry weight in the latter was significantly higher. The 5 x 20 cm container had a depth/diameter ratio of 4 compared to that of 1/2 for the 10 x 5 cm container (Fig. 5).

Similarly, shoot dry weight was highest in containers with larger volumes (662.68-1963.5 cm^3). Unlike root dry weight container 10 x 10 (785.4 cm^3) produced high shoot dry weight as well (Fig. 6). As with root dry weight, the 5 x 20 cm container was significantly better than 10 x 5 cm container in terms of shoot dry weight although the volume was the same (392.7 cm^3). The stem length was significantly longer for the plants grown in container volumes of 662.68 cm^3, 1104.47 cm^3, 785.40 cm^3, 1178.10 cm^3 and 1570.80 cm^3 than those in smallest volume containers (98.17 cm^3 and 196.35 cm^3) (Fig. 6). The shoot/root ratio generally decreased as container volume increased. The lowest shoot/root ratio was found in the 10 x 25 cm (1963.5 cm^3) container and the highest is 7.5 x 5 (220.89 cm^3) container. In containers with volumes in the 662.68-1963.5 cm^3 range had lower shoot/root ratio with the exception of the 10 x 10 cm (785.4 cm^3) container which had a depth/diameter ratio of one. All other containers in this group had a depth/diameter ratio greater than one. A higher shoot/root ratio was obtained for plants grown in containers with

98.17-490.87 cm^3 volume. Within this volume range 5 x 5, 7.5 x 5 and 10 x 5 cm containers had the highest shoot/root ratio (Fig. 7).

When the container size was broken down into width and depth components, both of them had a significant effect on root and shoot growth (Appendices 10,11). However, only the container diameter had a significant effect or stem length (Appendix 12). Shoot/root ratio, on the other hand, was only significantly affected by depth (Appendix 13). When the root dry weight and stem length were averaged over all depths, containers of 7.5 and 10 cm diameter had greater values of root dry weight and stem length than 5 cm wide containers (Table 7). Shoot dry weight was greatest in wider containers of 10 cm diameter and there was no difference in shoot growth between the other two diameters (7.5 x 5 cm). The width of the container had no effect on the shoot/root ratio (Table 7).

Root dry weight was generally greater in deeper containers. The highest amount of root growth occurred in 25 cm deep containers followed by containers of 15 cm and 20 cm depth and then by 10 cm deep containers. The plants grown in 5 cm deep containers produced the lowest amount of root growth. Similarly the shoot growth, as measured by the shoot dry weight, was least in 5 cm deep containers. The maximum stem length occurred in 25 cm deep containers and the least stem length was found in the container with 5 cm depth. The stem length in intermediate containers (10, 15 and 20 cm) was not significantly different from stem length in 25 cm or 5 cm deep containers. The shoot/root ratio was highest in shallow containers of 5 and 10 cm depth. There was no difference

among the 15, 20 and 25 cm deep containers (Table 8). The factorial analysis did not show any significant interaction between diameter and depth of the container.

Although container size affected both top and root growth, the component that had the most effect was the depth rather than the diameter or the volume of the container. Plants grown in containers that were 5 cm deep had the worst shoot and root growth regardless of the container diameter (Fig. 5,6). As the container diameter increased from 5 cm to 7.5 cm and 10 cm the container volume increased by two and four fold respectively. Yet this increase in container volume did not result in any increase in the root or the shoot growth (Figures 5 and 6). This effect of depth can further be illustrated if we compare root and shoot growth in 5 x 20 cm and 10 x 5 cm containers which were identical in volume (392.70 cm^3). Figures 7 and 8 show that the 5 x 20 cm container had significantly better root and shoot dry weight than the 10 x 5 cm container. Plants grown in 7.5 x 15 cm containers (662.8 cm^3) had significantly higher root dry weight than those 10 x 10 cm containers (785.4 cm^3) because they had a more favorable depth/diameter ratio (2:1) (Fig. 5). Carlson and Endean (11) suggested that in the growth of white spruce (Picea glauca (Moench) voss), container diameter rather than height had a more positive effect. Threadgill and Whitcomb (81) obtained similar results with San Jose juniper (Juniperus chinesis L.) 'San Jose'), and dwarf Yaupon holly (Ilex vomitoria L. 'Nana'). Similar positive effect of container diameter was obtained for Western soapberry seedling growth, but the depth effect appeared to be greater than that of the diameter. While container diameter has no effect on drainage,

deeper containers provide good drainage and aeration which are very important consideration in the container system. According to Whitcomb (91), the media in deep containers would be well-drained and the plants would be expected to make good use of water and nutrients for a relatively longer period of time. The improved growth of river birch (Betula nigra L.) was found to be due to an increase in container depth resulting in a large total root surface area (5). In Western soapberry containers 15-25 cm deep generally supported better shoot and root growth compared with the shallower containers.

Funk working with black walnut (31) reported that the shoot/root ratio increased with the plant weight. Contrary to the Funk's findings, the present work with Western soapberry show that the shoot/root ratio appeared to decrease as plant weight increased (Figures 5, 6 and 8). These results are in agreement with eastern cottonwood (Populus deltoides L.) grown in loam at two soil moisture regimes (23). When eastern cottonwood plants were grown under favorable soil moisture conditions, the relationship between shoot/root ratio and plant weight was found to be negative, but it was positive under moisture stress. Factors contributing to the high shoot/root ratio in shallower containers (5 and 10 cm depth) include frequent watering and frequent fertilization, especially during the early phase of the growth period due to rapid drying of the media in the containers. Moreover, the shallowness of the containers resulted in early pruning of the tap root. This caused a distortion of the tap root and stimulated the development of thin loose fibrous root branches with light weight.

The use of bottomless containers resulted in a compact fibrous root mass due to air pruning of the roots at the bottom of the container. These fibrous lateral roots can reach every part of the growth medium and thus increase access to moisture and nutrients. Having fibrous root system is beneficial in increasing transplanting success both in summer and fall (91,92). Containers with depth in the 15-25 cm range provided better plant growth and the effect of container depth was noticeable in root growth. Plants with better growth generally had a lower shoot/root ratio. This would probably work to their advantage in the event of transplanting to the landscape.

Table 7: Effect of container diameter as a main effect on growth of Western soapberry seedlings

Container Diameter (cm)	Growth Parameters[Z]			
	Root Dry Wt. (g)	Shoot Dry. Wt. (g)	Stem Length (cm)	Shoot/Root Ratio
10	2.77a	2.29a	13.74a	1.11a[Y]
7.5	2.48a	1.99b	12.66a	1.14a
5	1.63b	1.76b	11.16b	1.33a

Z: Mean being the average of 25 values from 5 different depths.

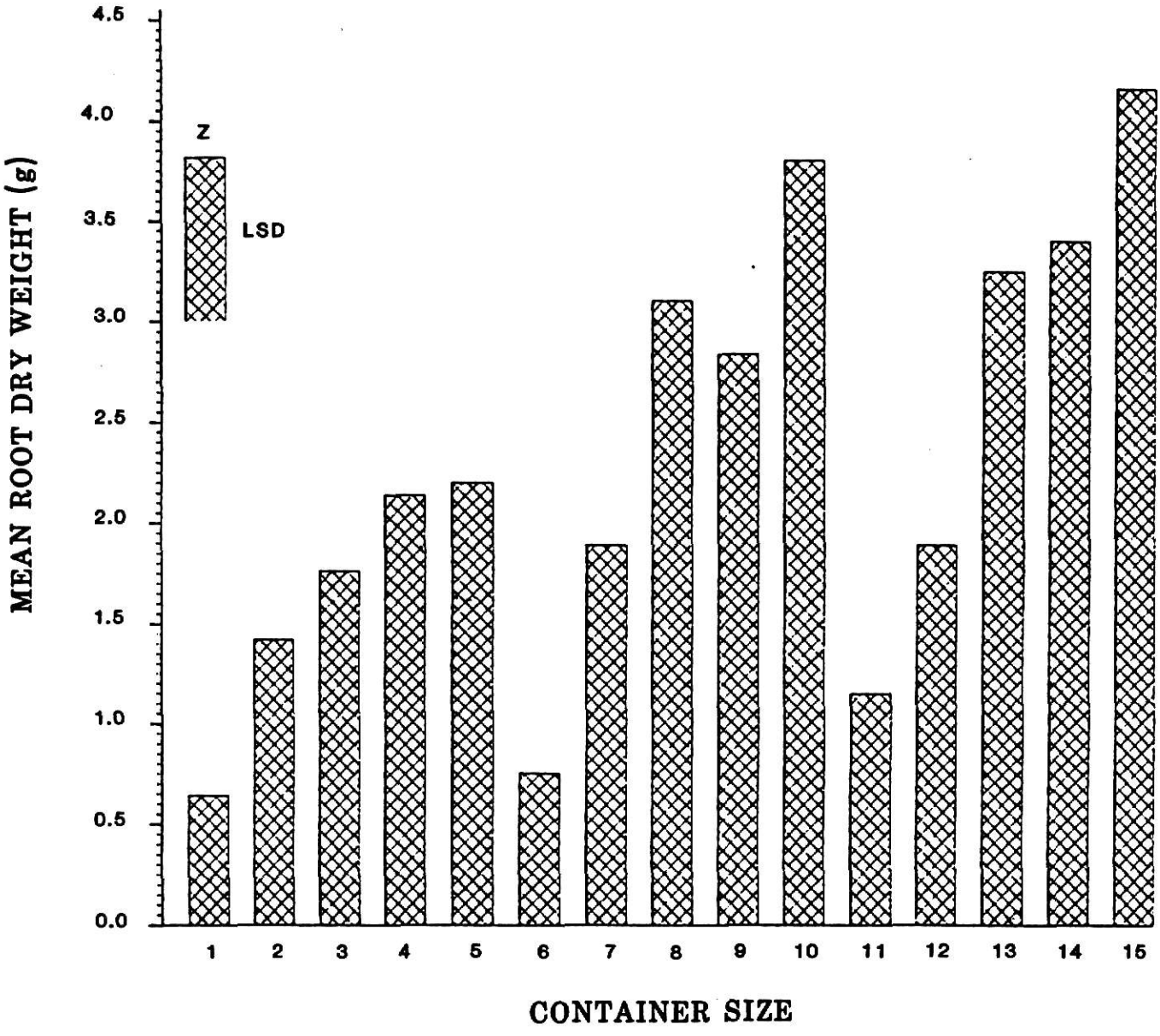
Y: Values in columns with the same letters are not significantly different at 5% level by LSD mean separation.

Table 8: Effect of container depth as a main effect on growth of Western soapberry seedlings

Container Depth (cm)	Growth Parameters[Z]			
	Root Dry Wt. (g)	Shoot Dry. Wt. (g)	Stem Length (cm)	Shoot/Root Ratio
25	3.39a	2.31a	13.21a	0.84b[Y]
20	2.79b	2.29a	12.94ab	0.92b
15	2.70b	2.23a	12.52ab	1.03b
10	1.73c	2.11a	12.23ab	1.50a
5	0.85d	1.12b	11.70b	1.68a

Z: Mean being the average of 15 values from 3 different diameters.

Y: Values in columns with the same letters are not significantly different at 5% level by LSD mean separation.

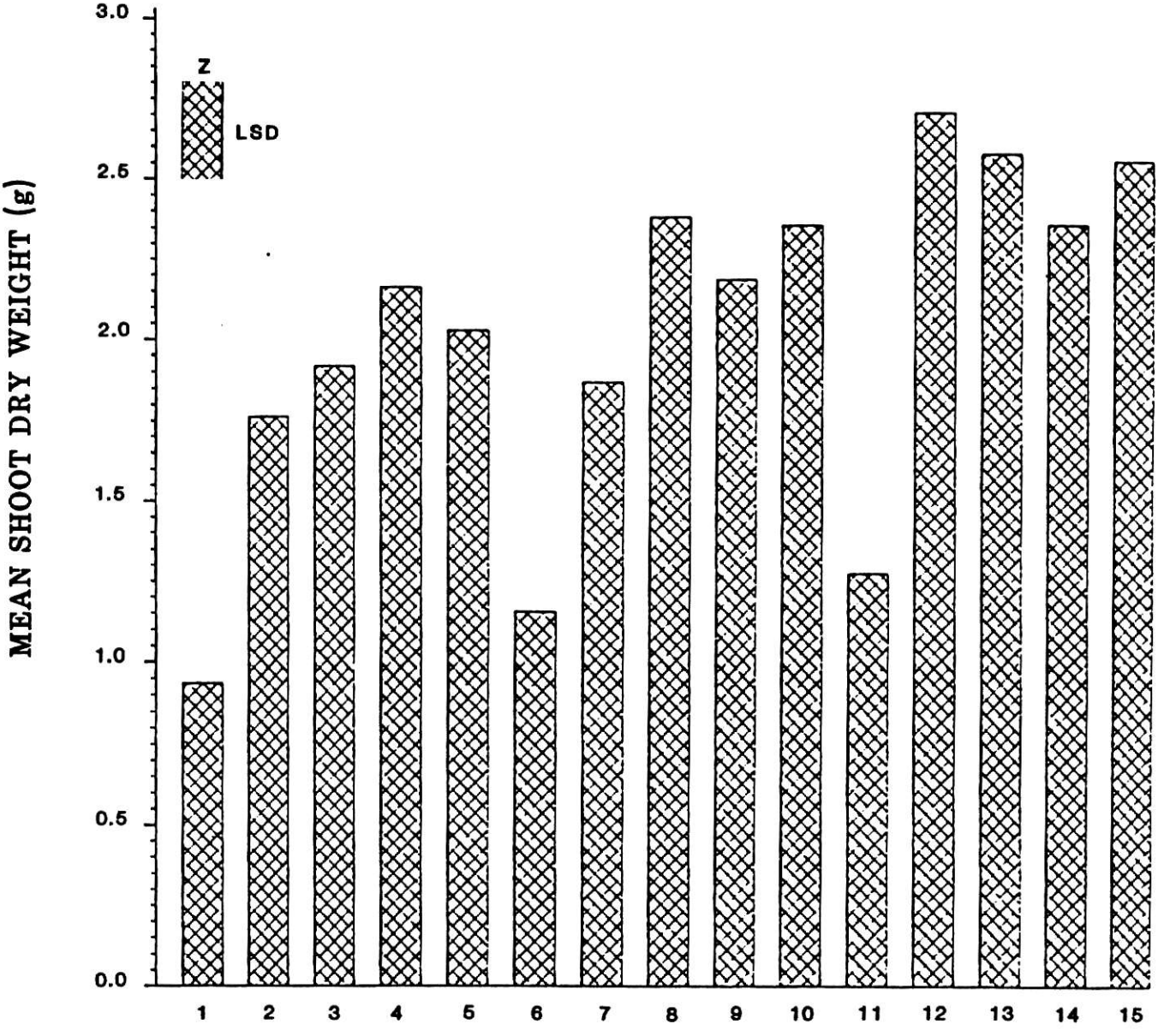


CONTAINER SIZES (AND VOLUMES cm^3)

1=5*5	(98.17)	2=5*10	(196.35)	3=5*15	(294.52)
4=5*20	(392.70)	5=5*25	(490.87)	6=7.5*5	(220.89)
7=7.5*10	(441.79)	8=7.5*15	(662.68)	9=7.5*20	(883.57)
10=7.5*25	(1104.47)	11=10*5	(392.70)	12=10*10	(785.40)
13=10*15	(1178.10)	14=10*20	(1570.80)	15=10*25	(1963.50)

Figure 6. EFFECT OF CONTAINER SIZE ON ROOT DRY WEIGHT OF WESTERN SOAPBERRY SEEDLING

Z = differences between bars less than the LSD bar are not significant at the 5% level by LSD mean separation.

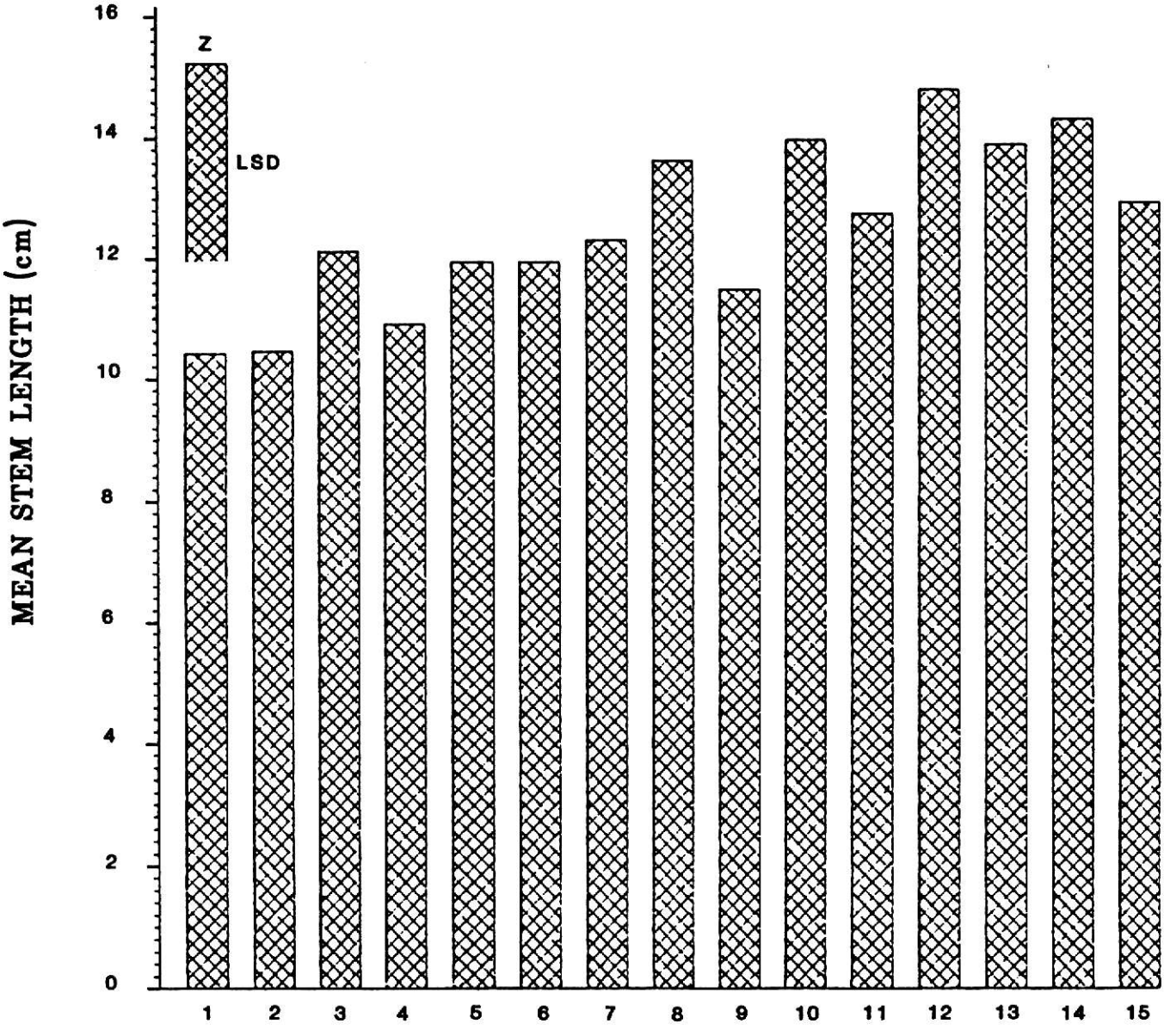


CONTAINER SIZES (AND VOLUMES cm^3)

1=5*5	(98.17)	2=5*10	(196.35)	3=5*15	(294.52)
4=5*20	(392.70)	5=5*25	(490.87)	6=7.5*5	(220.89)
7=7.5*10	(441.79)	8=7.5*15	(662.68)	9=7.5*20	(883.57)
10=7.5*25	(1104.47)	11=10*5	(392.70)	12=10*10	(785.40)
13=10*15	(1178.10)	14=10*20	(1570.80)	15=10*25	(1963.50)

Figure 6. EFFECT OF CONTAINER SIZE ON SHOOT DRY WEIGHT OF WESTERN SOAPBERRY SEEDLING

Z = differences between bars less than the LSD bar are not significant at the 5% level by LSD mean separation.

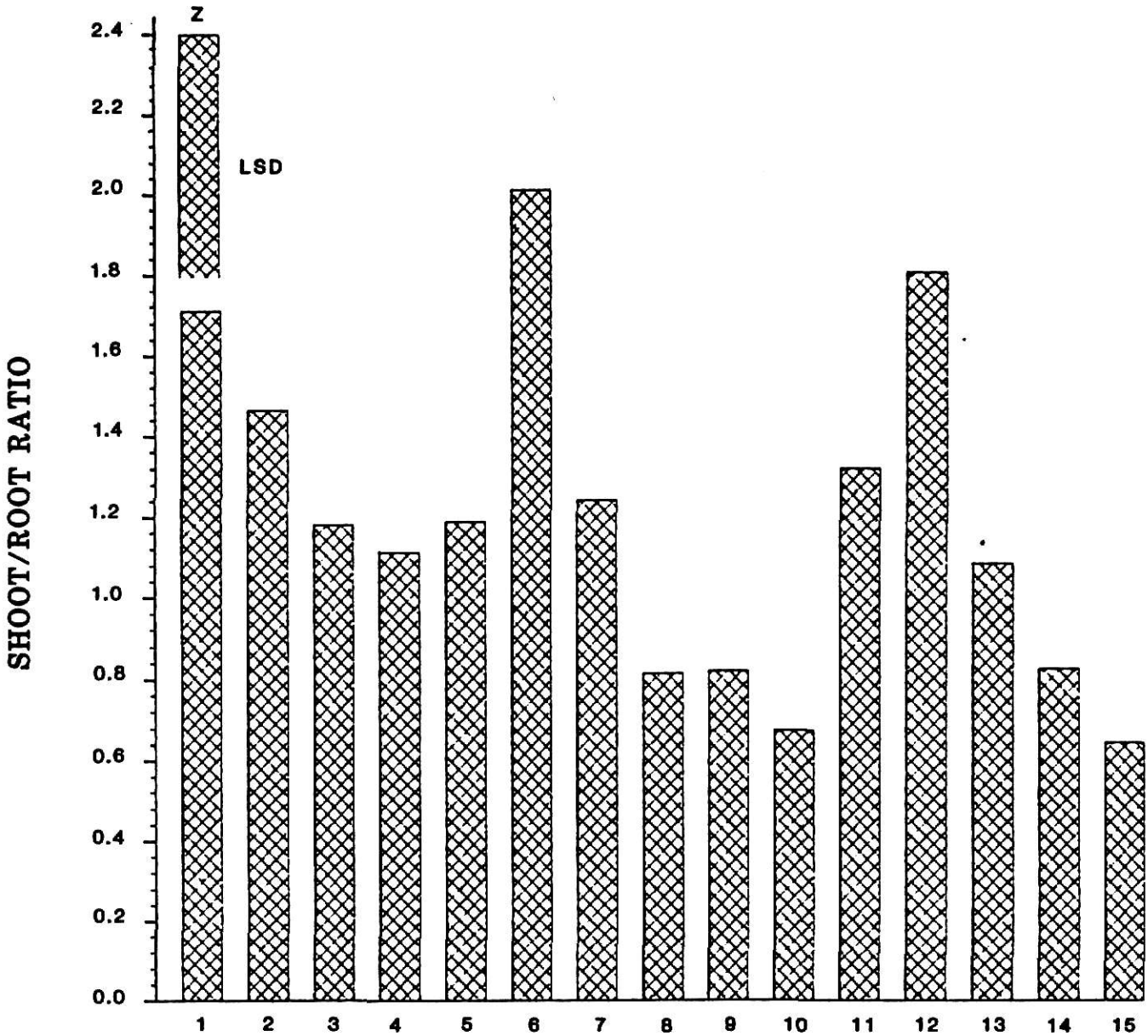


CONTAINER SIZES (AND VOLUMES cm^3)

1=5*5	(98.17)	2=5*10	(196.35)	3=5*15	(294.52)
4=5*20	(392.70)	5=5*25	(490.87)	6=7.5*5	(220.89)
7=7.5*10	(441.79)	8=7.5*15	(662.68)	9=7.5*20	(883.57)
10=7.5*25	(1104.47)	11=10*5	(392.70)	12=10*10	(785.40)
13=10*15	(1178.10)	14=10*20	(1570.80)	15=10*25	(1963.50)

Figure 7. EFFECT OF CONTAINER SIZE ON STEM LENGTH OF WESTERN SOAPBERRY SEEDLING

Z = differences between bars less than the LSD bar are not significant at the 5% level by LSD mean separation.



CONTAINER SIZES (AND VOLUMES cm^3)

1=5*5	(98.17)	2=5*10	(196.35)	3=5*15	(294.52)
4=5*20	(392.70)	5=5*25	(490.87)	6=7.5*5	(220.89)
7=7.5*10	(441.79)	8=7.5*15	(662.68)	9=7.5*20	(883.57)
10=7.5*25	(1104.47)	11=10*5	(392.70)	12=10*10	(785.40)
13=10*15	(1178.10)	14=10*20	(1570.80)	15=10*25	(1963.50)

Figure 8. EFFECT OF CONTAINER SIZE ON SHOOT/ROOT RATIO OF WESTERN SOAPBERRY SEEDLING

Z = differences between bars less than the *LSD bar are not* significant at the 5% level by LSD mean separation.

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APPENDIX 1

Analysis of variance of percent germination of Western soapberry seeds after chemical treatment at different periods of stratification

Source	df	SS	MS	F	P
Treatment	3	1.504	0.500	8.00	0.002
Time	3	0.682	0.227	3.64	0.019
Treatment and Time	9	1.871	0.208	3.33	0.003
Error	48	3.002	0.063		
Total	63	7.056			

APPENDIX 2

Analysis of variance of the effect of different hormonal concentrations on the percent of rooted cuttings of Western soapberry

Source	df	SS	MS	F	P
Total	38	39323.08			
Treatment	12	18789.74	1565.81	4.86	0.0005
Replicate	2	12800.00	6400.00	19.86	0.0001
Error	24	7733.33	322.22		

APPENDIX 3

Analysis of variance of the effect of different hormonal concentrations on the number of roots per cutting of Western soapberry

Source	df	SS	MS	F	P
Total	38	186.14			
Treatment	12	76.91	6.41	2.69	0.0019
Replicate	2	51.95	25.98	10.89	0.0004
Error	24	57.27	2.39		

APPENDIX 4

Analysis of variance of the effect of different hormonal concentrations on the fresh root weight of Western soapberry cuttings

Source	df	SS	MS	F	P
Total	38	13.05			
Treatment	12	5.19	0.43	2.92	0.0124
Replicate	2	4.30	2.15	14.49	0.0001
Error	24	3.56	0.15		

APPENDIX 5

Analysis of variance of the effect of different hormonal concentrations on the average root length of Western soapberry cuttings

Source	df	SS	MS	F	P
Total	38	2180.90			
Treatment	12	1041.66	86.81	3.62	0.0035
Replicate	2	564.49	282.25	11.79	0.0003
Error	24	574.74	23.95		

APPENDIX 6

Analysis of variance of the effect of container size on root dry weight of Western soapberry seedling

Source	df	SS	F	P
Block	4	15.14	5.63	0.0008
Container	14	249.63	23.71	0.0001
Block * Container	56	60.20	1.43	0.0464
Subsample	2	0.37	0.25	0.7811
Error	148	111.29	0.75	
Total	224	436.63		

APPENDIX 7

Analysis of variance of the effect of container size on shoot dry weight of Western soapberry seedling

Source	df	SS	F	P
Block	4	17.33	11.60	0.0001
Container	14	60.70	11.61	0.0001
Block * Container	56	40.22	1.92	0.0010
Subsample	2	1.26	1.69	0.1884
Error	148	55.26	0.37	
Total	224	174.76		

APPENDIX 8

Analysis of variance of the effect of container size on stem length of Western soapberry seedling

Source	df	SS	F
Block	4	42.06	0.08
Container	14	407.67	0.0001
Block * Container	56	703.48	0.0001
Subsample	2	5.78	0.5537
Error	148	720.03	
Total	224	1879.01	

APPENDIX 9

Analysis of variance of the effect of container size on shoot/root ratio of Western soapberry seedling

Source	df	SS	P
Block	4	1.11	0.7127
Container	14	36.09	0.0001
Block * Container	56	34.61	0.2171
Subsample	2	1.23	0.3123
Error	148	77.59	
Total	224	150.63	

APPENDIX 10

Analysis of variance table of the effect of container diameter and depth on root dry weight of Western soapberry seedlings

Source	df	SS	MS	F	P
Diameter	2	17.417	8.709	24.33	0.0001
Depth	4	60.204	15.051	42.00	0.0001
Dia. * Depth	8	5.589	0.699	1.95	0.0703
Replicate	4	5.045	1.261	3.52	0.0124
Error	56	20.068	0.358		
Total	74	108.324			

APPENDIX 11

Analysis of variance table of the effect of container diameter and depth on shoot dry weight of Western soapberry seedlings

Source	df	SS	MS	F	P
Diameter	2	3.563	1.782	7.44	0.0014
Depth	4	15.307	3.827	15.98	0.0001
Dia. * Depth	8	1.362	0.170	0.71	0.6806
Replicate	4	5.775	1.444	6.04	0.0004
Error	56	13.407	0.239		
Total	74	39.414			

APPENDIX 12

Analysis of variance table of the effect of container diameter and depth on stem length of Western soapberry seedlings

Source	df	SS	MS	F	P
Diameter	2	83.478	41.739	9.97	0.0002
Depth	4	21.334	5.334	1.27	0.2912
Dia. * Depth	8	31.077	3.885	0.93	0.5011
Replicate	4	14.018	3.505	0.84	0.5075
Error	56	234.493	4.187		
Total	74	384.400			

APPENDIX 13

Analysis of variance table of the effect of container diameter and depth on shoot/root ratio of Western soapberry seedlings

Source	df	SS	MS	F	P
Diameter	2	0.725	0.363	1.76	0.1815
Depth	4	8.446	2.112	10.25	0.0001
Dia. * Depth	8	2.858	0.357	1.73	0.1105
Replicate	4	0.372	0.093	0.45	0.7712
Error	56	11.537	0.206		
Total	74	384.400			

THE PROPAGATION AND PRODUCTION OF WESTERN SOAPBERRY

by

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B.S. UNIVERSITY OF KHARTOUM, 1976

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of

the requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

Kansas State University

Manhattan, Kansas

1985

ABSTRACT

Western soapberry (Sapindus drummondii Arn & Hook) seeds were treated with ethrel, thiourea and potassium nitrate, with or without stratification. All three chemicals increased percent germination and reduced the stratification period. Ethrel and thiourea treatments resulted in the highest germination percent.

Western soapberry softwood cuttings were dipped for 5 seconds in solution of 5,000, 10,000, 20,000 and 30,000 ppm of IBA, NAA and IBA + NAA and placed in a propagating medium consisting of 3 parts peat and 7 parts perlite. IBA at 10,000, 20,000, and 30,000 ppm resulted in a significantly higher root fresh weight. At 10,000 ppm IBA a greater number of roots per cutting was obtained compared to the control. While there was no significant difference between IBA & IBA + NAA in this respect, NAA was the least effective, especially at higher concentrations.

One-month-old Western soapberry seedlings were transplanted in cylindrical, bottomless polyvinyl chloride containers of 15 different sizes. Root dry, shoot dry weight and stem length were greatest in larger containers (10 x 25 cm) and least in smallest containers (5 x 5 cm). Medium size containers (7.5 x 15 cm) produced intermediate size plants. The shoot/root ratio decreased as the container size increased. Generally containers of 15-25 cm depth resulted in better plant growth.

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