HAITI AGROFORESTRY RESEARCH PROJECT

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Seedling Growth and Development in Different Container Types and Potting Mixes

by R. Kent Reid
Nursery Specialist

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Summary

This investigation tested the various containers and potting mixes used in the AOP. Effects were measured on nursery development of five non-nitrogen-fixing species (chene, kapab, cassia, neem, and ced). Four container types (Winstrips, standard Rootrainer 5s, Rootrainer Deep 5s, and Sacks) and three potting mixes (Gromix, Haiti mix, and Neg mix) were tested. Seedlings were grown in a randomized complete block design at the Operation Double Harvest nursery near Port-au-Prince.

Seedlings were harvested and measured when they were four months old. Resulting data were tested for treatment effects. Mix affected certain growth measurements for all species. Cassia was largest in Gromix and smallest in Neg mix, kapab and sed were larger in Haiti mix, while chene and neem were not affected strongly by mix. Neg mix tended to produce large root:shoot ratios but smaller seedlings, and would benefit from amendment with an acidifying phosphate fertilizer. Haiti mix is an acceptable locally-produced substitute for Gromix.

Interactions between container and mix were minor. Seedlings in sacks were always largest, followed by those in Deep 5s, Winstrips, and Rootrainers. However, for certain measurements, neem and chene were smaller in Winstrips than in Rootrainers, and ced and cassia were larger in Winstrips than in Deep 5s. Container affected root:shoot ratio only for ced, which had the largest root: shoot ratio in Rootrainers and the smallest in Sacks. Generally, the three rigid containers produced high quality seedlings with only minor morphological differences.

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Rezime Kreyol

Esperyans sa-a te eseye divès veso epi divès miks ki moun sevi nan AOP. Te gen kat kalite veso (Winstrip, Woutrene pa fon, Woutrene fon, ak Sache plastik) ak twa kalite miks (Gromiks, Ayiti miks, ak Neg miks) nan esperyans sa-a. Nou te mezire efè tretman pepinyè-yo te gen sou devlopman pepinyè pou senk espès ki pa fè azot nan rasin yo (chèn, kapab, kasya, nim, ak sèd). Ti pyebwa-yo te grandi nan pepinyè ODH nan Cazeau.

Apre kat mwa, nou te rasche e mesire ti pyebwa-yo. Nou te eseye tout mezi ki soti pou chèche si gen diferans ant veso yo epi miks yo. Miks yo te bay diferan mezi pou tout espès. Kasya te pi gwo nan Gromiks e pi piti nan Neg miks. Kapab ak sèd te pi gwo nan Ayiti miks, pandan chèn ak nim pa gen gwo diferans. Neg miks te fè gwo pwopòsyon rasin ak kòs, men pi piti ti pyebwa, e li ta bon pou melanje yon angre avèk fosfo e acid nan li. Ayiti miks se yon bon miks local pou ramplase Gromiks.

Avèk Sache, ti pyebwa te pi gwo pase sa yo ki nan Woutrene fon, nan Winstrip, ak nan Woutrene pa fon. Men, pou kek mezi, nim ak chèn pi piti nan Winstrip pase nan Woutrene, e sèd ak kasya pi gwo nan Winstrip pase nan Woutrene fon. Veso te fè yon diferans nan pwopòsyon rasin ak kòs pou sèd selman. Sèd te gen pwopòsyon rasin ak kòs pi gwo nan Woutrene pa fon e pi piti nan Sache plastik.

Gen kèk rekomandasyon pou pepinyeris ayisyen. Pou fè grenn yo jèmen pi byen, semen grenn chèn tankou yon tapi andan yon veso. Nim grandi pi byen nan Woutrene fon avèk Ayiti mix. Sèd pa grandi byen an Winstrip avèk Neg miks. An jeneral, yon pepinyeris kapab sevi ak de kalite Woutrene, e l'ap jwenn preska menm rezilta. Winstrip yo bon, tout, men yo bezwen ampil dlo. Yon pepinyeris kapab sevi ak Sache plastik si li gen ampil miks, si li gen anpil plas nan pepinyè-a, e si li gen ampil moun pou travay nan pepinyè-a.

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CARE and Peter Welle provided Neg mix, seed, and plastic bags;

PADF and Scott Josiah provided seed, Gromix, and both Rootrainer types.

ODH and Steve Gronski provided Haiti mix, Winstrips, and greenhouse and nursery space. ODH was a paid participant, but their dedication to the success of this study exceeded the requirements of their contract.

SECID/ Auburn team members critiqued a draft of this text, and Duverger Vernis helped with the seedling measurements and with the Creole summary.

Contents

Introduction

Various container types and potting mixes have been used to produce tree seedlings for the AOP in Haiti. Winstrips, several types of Rootrainers and black plastic Sacks currently are among the containers used. Imported peat-vermiculite (Gromix) has been used extensively in the program, but recent price increases make other locally-produced mixes attractive. Haiti mix, composed of newly composted bagasse, soil, rice hulls, and imported peat moss, is produced by ODH and widely used by PADF. Neg mix is a modified Haiti mix produced by CARE. Bagasse for Neg mix comes from old bagasse piles, rice hulls are replaced by a candlewood tree residue, and no peat moss is added. A comprehensive comparison of these containers and mixes has been needed for some time.

The objective of this study was to evaluate the influences of container type and potting mix on nursery growth and development of seedlings for several non-leguminous species commonly planted in the AOP.

Throughout this report, "cell" refers to the container division holding one plant. Thus a Winstrip case comprises 146 cells; a Deep 5, five; and a Sack, only one. The two types of Spencer-LeMaire bookplanters are referred to as Rootrainers (100 mm deep) and Deep 5s (125mm deep). Distinguishing characteristics of the different mixes and containers are presented in Appendix A.

Methods

This study was carried out at the Operation Double Harvest nursery in the Cazeau section of Port-au-Prince. Table 1 lists the evaluated treatments and species.

Containers were filled immediately before planting and placed on raised, open benches in a greenhouse. Winstrip cases supported themselves on the benches. Sacs were supported in basket-weave plastic tomato flats, and Rootrainer 5s and Deep 5s held in wood-and-wire racks provided by PADF for that purpose.

Preparing seed for sowing began 4 January with a warm-water soak of kapab seed. (Seed information is listed in Appendix B). Seed were treated as recommended in Josiah (1989). With the exception of ced and the second planting of chene, seed were germinated between moist brown paper in basket-weave flats. Germinated seed were sown into containers, one seed per cell, in the order kapab, cassia, chene, and neem, between 14 and 18 January. Non-germinated chene were replanted directly into containers 24 January. Some kapab were replanted on 25 January. Non-germinated ced were planted directly into containers on 27 and 28 January. Containers were kept under a shadehouse covered with translucent plastic until after seedlings had emerged.

Water and fertilizer additions were begun according to the standard ODH practices of irrigation from an overhead sprinkler system when needed, and 20-20-20 soluble fertilizer as a drench once or twice weekly. However, since ODH practices were established for Winstrips filled with Haiti mix, those practices had to be modified for the other combinations. Notably, hand-watering was necessary to prevent waterlogging in Neg mix and in containers other than Winstrips. More fertilizer was applied to Gromix than to the other mixes, and a very low rate of triple superphosphate was added as a top dressing to cassia and chene growing in Neg mix on 11 April.

Transfer from shade to full sun was made according to standard practice for each species (Josiah 1989). All seedlings of a species were transferred on the same day. Neem and cassia were transferred on 6 Feb; kapab, 6 March; ced, 15 March; and chene, 30 March. Thinning and transplanting resulting in one tree per cell were carried out in shade when possible. Emergence was counted before thinning (except for chene and ced) or transplanting. These data were not tested for differences.

Randomization of containers occurred when they were moved into full sunlight. Treatment combinations (container X mix for each species) were arranged into four blocks for cassia, kapab, and chene, and three for neem and ced. Individual seedlings produced per treatment combination were 96 to 146 for combinations planted in Winstrips and 50 to 58 for combinations planted in one of the other containers.

Seedlings were harvested by block during the period 16-24 May 1989. At harvest, ten seedlings from each treatment combination were selected for measurement. Border trees were not selected. Variables measured were shoot length, root collar diameter, and root and shoot dry weights. Variables calculated from these measurements were root:shoot (dry wt.:dry wt., abbreviated R:S) and root-collar-diameter:root (mm:g dry wt., abbreviated C:R) ratios. Treatment differences were detected within each species by analysis of variance of a randomized complete block design. When treatment differences were detected, main effect means were separated by contrast statements. Differences among species were not tested statistically. Protection against type I errors was set at five percent, or $\alpha=0.05$. Physical and chemical properties of each soil mix were determined by the Auburn University Agricultural Experiment Station Soil Testing Laboratory.

Results

Emergence is presented by container and mix in Table 2. Seed germination was not counted, but seedling emergence was. Percentage of seedlings emerging from the cell was greatest for neem and ced, less for cassia, much less for kapab, and least for chene. Kapab, cassia, and chene needed transplanting; ced needed thinning.

Table 3 shows results from measurements taken on chene. Interactions were seen with height and root collar diameter. The interaction for height is not surprising given that mix and container effects are both strong. An interaction under these circumstances implies a minor variation in one effect is controlled by large changes in the other effect (Snedecor and

Cochran 1967). In this case, a minor variation in the mix effect probably is controlled by the container, possibly container volume. The interaction for root collar diameter is not as simple, and appears to be a true interaction, where different combinations produce different results. Certain observations are higher or lower than normal, but they are not different enough to be outliers and deleted, and they are retained in this analysis and for the graph in Appendix C.

Neg mix caused short chene heights, primarily because of its effect in Sacks. Other measurements were not different for the three mixes. Sacks produced the largest measurements for all variables except C:R ratio, which were the smallest in Sacks. Winstrips produced shorter chene, but R:S and C:R ratios were not different from those found with the bookplanters.

Table 4 shows results with cassia. Interactions were seen with height and weight variables, and are due to strong mix and container effects. The interactions are significant but not strong (Appendix D), and the main effects are sufficient to explain the results (Snedecor and Cochran 1967).

Height, root collar diameter, and shoot weight decreased with increased soil in the mix. Root weight was greatest and C:R ratio least with Haiti mix, and R:S ratio increased with increased soil in the mix. The root:shoot ratio for Neg mix was the highest seen in the entire study. Sacks produced the largest seedlings, with Winstrips second and Rootrainers and Deep 5s smallest. Cassia R:S ratio did not differ by container, although unlike with chene, it tended to be smaller in Sacks. The C:R ratio significantly decreased as container volume increased.

Kapab results are given in Table 5. Haiti mix produced the largest kapab seedlings, principally due to its outstanding performance in Deep 5s and Sacks (Appendix C). Kapab in Haiti mix also produced the smallest root:shoot ratio of any species and mix combination in this study. Sacks again produced the largest seedlings, and seedling size tended to increase with increasing mix volume among the other containers, but differences were detectable only for Sacks. Root:shoot ratio was not different among any of the containers. The C:R ratio changed only slightly, decreasing as mix volume increased. No interactions were found.

Table 6 shows results with neem. Interactions were seen with height and root and shoot weights. These interactions are the most interesting found in this study. The interaction for height reflects a trivial difference in size, but similar tendencies are seen with the weight measurements, and those differences are not trivial (Appendix C). These interactions are due to neem growing well in Deep 5s only when they are filled with Haiti mix, and neem growing best in Sacks filled with Gromix. From examining raw data and observations made at harvest, the reaction in Deep 5s is not related to their overfiling. Root:shoot ratio suffered slightly, but still was acceptable. The large neem in Gromix in Sacks were characterized by big tap roots bearing few lateral roots.

Neem seedling size decreased with increased soil in the mix, although differences usually were not detectable (Table 6). Root:shoot ratios for mixes were not different, but were relatively high compared to other species. The C:R ratios were not affected by mix, but both C:R and R:S ratios tended to decrease with increasing container volume. Other morphological measurements were significantly smaller in Winstrips and larger in sacks.

Ced showed interactions with height, root collar diameter, root weight, and C:R ratio (Table 7). Height, root weight, and C:R ratio had strong main effects and a small interaction effect. Diameter, on the other hand, had strong main effects, but an interaction effect that was stronger than the mix effect, indicating an interaction worth close attention. Examination of the raw data (not shown) shows that seedlings in one block of Haiti mix in Rootrainers were larger than in the other two blocks, and that seedlings in Gromix in Sacks varied with individual and included a few large ones, and suggests these apparent interactions may not be real. On the other hand, true interactions were observed, for seedlings grown in Neg mix in Winstrips were always small with very little individual variation, and seedlings in Gromix in either bookplanter also were small.

Mix produced differences in ced seedling size, but differences were not ordered similarly for the different measurements. For example, seedlings were tallest in Neg mix and shortest in Gromix, but had thickest root collars with Haiti mix and thinnest ones with Neg mix. Sacks produced the largest and Winstrips the next-largest seedlings, with Rootrainers and Deep 5s not different. Root:shoot and C:R ratios were significantly lower for Sacks, however, and greatest for Rootrainers.

Discussion

Certain variables associated with this investigation were not measured, but general observations were made of them. One such variable was ease of container filling. Winstrips were easiest to fill because workers could quickly spread mix over the case and pack it into cells. Rootrainers were next easiest, but were more difficult than Winstrips primarily because when assembled in racks the surface formed by them is not smooth and tends to catch mix and fingers, and the thin edges irritate skin. Deep 5s were almost equal to Rootrainers in ease of filling, but were prone to overfilling. Sacks were by far the most difficult to fill; holding the sack open while simultaneously trying to put mix in it was not easy. The large volume also meant more time was needed to fill each cell.

Overfilling of bookplanters occurs throughout Haiti. This problem arises because a rack flexible enough to accept the container also expands when being filled with mix, and too much mix ends up in the container. Deep 5s aggravate this tendency because they are taller than their supports in the racks, thus giving leverage which allows them to open more easily. Most nurseries avoid this problem by packing bookplanters tightly in the racks for filling, and removing every third bookplanter after the new seedling is established.

At least part of the overfilling problem in this study comes from filling them at ODH. Not all bookplanters were packed tightly in the racks, allowing them to expand and be overfilled. Furthermore, ODH personnel are accustomed to tamping Haiti mix into Winstrips so it will cohere and not fall out the bottom. Cohesion is not as important in bookplanters, but just as ODH workers started by irrigating all containers and mixes the same way, they filled all containers the same way. Thus, they tamped mix into Rootrainers and Deep 5s, spreading their tops and overfilling them.

A side benefit of this tamping down is the resulting similarity in mix bulk density. Bulk density could affect growth, and might be part of the differences observed among the three mixes. Bulk density of the same mix would vary among container types when containers were properly filled, since a Winstrip would need packing, a Sack would not, and bookplanters would be intermediate between the two. This study did not measure bulk density, but bulk density of any one mix probably was consistent among containers. Bulk density could be a critical property of potting mixes, and deserves investigation at some time in the future.

Water-holding capacity of containers and mixes was also observed. Sacks, as expected, held the most water. Deep 5s held less than sacks but more than Rootrainers, again as expected. Winstrips held the least water, and their tendency to drain and dry quickly led to the overwatering problems in the other containers early in the study. As for mixes, water-holding capacity was directly related to amount of soil present in the mix. Thus, Gromix held the least water, Neg mix the most, and Haiti mix was intermediate.

Chene germinated better if sown to form a mat in a cell. These hairy seeds would adhere to each other and form a mat that was lifted as the hypocotyls elongated. Hypocotyls tended to etiolate like this, but this undesirable trait was more than offset by almost total germination in each cell.

Kapab in Gromix exhibited symptoms of a micronutrient deficiency. By mid-March, kapab growing in Gromix in all the containers had a virus-like leaf crinkle and a mild marginal necrosis, suggesting Cu deficiency (Salisbury and Ross 1978). Since Cu^{2+} is strongly bound to organic matter and sometimes is called reclamation disease because it is common on newly reclaimed peat lands (Mengel and Kirkby 1979), its deficiency in a peat-vermiculite mix is not surprising. Symptoms were not seen on seedlings growing in the other mixes. On 30 March, a 1% $CuSO_4$ solution was applied to one-half of the Winstrip cases containing kapab in Gromix. Within a week, two of the cases responded positively, and foliage of all kapab in Gromix was treated with the $CuSO_4$ solution on 20 April.

Gromix, at least for this study, grew cassia better. This difference was noted by Steve Gronski befcre the seedlings were 3 weeks old. As time passed, Haiti mix outperformed the Neg mix, also. Seedlings were largest and greenest in Gromix, and smallest, reddest, and most prone to leafspot in Neg mix, with Haiti mix intermediate between the two. Triple-super phosphate was added to Neg mix to help this condition. In mid-March, ODH personnel realized mono-ammonium phosphate had been left out of this batch of Haiti mix, probably explaining the problems with growing cassia.

Few insect and disease problems were seen, and these were not serious. Cassia had its typical leafspot which was controlled by Benlate. Chene had aphids in mid-March and cheni in mid-April, both controlled with Sevin.

Other observations were made during harvest. These were made incidental to harvest, and are neither comprehensive nor tested for significance. Chene and ced seedlings tended to be too small and/or not hardened off, especially when grown in Winstrips filled with Neg or Haiti mix. Sacks produced dense, matted root systems at their bottom, but often lateral root production was satisfactory and well-distributed in Sacks. Neem's strong tap root almost always doubled back on itself several times at the bottom of the sack, and lateral root production on neem in Sacks was generally poor.

Roots often crossed into the adjacent cell in overfilled Deep 5s, and chene in Sacks occasionally cross-rooted from one sack to another. Winstrips produced what appear to be the best root systems, because lateral roots tended to be air-pruned rather than turn downward when they met the cell wall in the bookplanters. Roots at the bottom drain hole of bookplanters tended to converge and form a plug, something which was not seen in the open bottom of the Winstrip. The effect of these container-induced root orientations can only be determined by field testing.

One of the primary reasons for undertaking this study was to compare nursery development of seedlings grown in standard Rootrainers to those grown in Deep 5s. Field workers have noticed increased outplanting survival when seedlings were produced in Deep 5s. On the other hand, nursery workers prefer standard Rootrainers because they require less mix and a shorter season to produce a plantable seedling. At the point where seedlings are removed from the nursery, few differences between standard Rootrainers and Deep 5s are apparent (Tables 3 through 7 and Appendix D), and those differences do not seem biologically important. Treatment combinations selected from this study have been outplanted to test container effects on field survival and growth, and short-term survival was not different between Rootrainers and Deep 5s (data not shown). A report of that study is in preparation.

One conclusion from this study is that container volume and seedling size are directly related. This fact is widely recognized (Tinus and McDonald 1979) and would have been cause for concern had it not occurred. Some species-specific effects did occur, however, with regard to Winstrips and Deep 5s. These two containers are close to the same volume when properly filled, but overfilling definitely made the Deep 5's volume greater. For ced, seedling size was greater in Winstrips than in Deep 5s. Surprisingly, neem was slightly smaller in Winstrips than in Deep 5s or even Rootrainers.

While a large seedling typically survives better when outplanted onto a severe site (Tinus and McDonald 1979), large size is not necessarily a desirable seedling characteristic. A R:S ratio of one or slightly more is a desirable characteristic, but the R:S ratio on a larger seedling might be small. The clearest example of such an inverse relationship can be seen in the cassia results (Table 3). Growth was greatest in Gromix and least in Neg mix, but R:S ratio was significantly smaller in Gromix than in Neg mix. Many times, R:S ratio is affected by fertility, and decreases as fertility increases. Many tree species adapted to infertile sites also follow the survival strategy of putting much of their biomass into the root system, and have higher-than-average R:S ratios even when adequately fertilized. Black-jack oak (<u>Quercus marilandica</u>) in North America does this, and neem apparently does this in Haiti. Thus, while larger seedlings may be better, recommendations for proper seedling size and R:S ratio vary by species.

This study calculated and tested for differences among values of the morphological variable C:R ratio. Use of this variable was suggested by one of the cooperators, but after working with it, it is not recommended as an indicator of seedling quality for three reasons. First, as can be seen from the bar graphs in Appendix C, recommending a target C:R ratio to a nurseryman is not easy because its range is too great among plantable seedlings within a species. Next, this value is strongly dependent on form inherent in the species. Thus, C:R ratios for species with thick seedling root collars such as Gliricidia, Sesbania, or the Cedrela in this study will be several times larger than species without the same basal thickening. Finally, these two values are auto-correlated; big (and heavy) root systems are connected to thick root collars.

With additional investigations in Haiti and a more extensive review of the seedling quality literature, C:R ratio may come into use as an indicator of seedling quality. Similar use may one day be made of other easy-to-measure ratios, such as root-collar-diameter:height ratio. For the time being, however, root:shoot ratio and root collar diameter probably are the best indicators to use to predict seedling quality.

Unfortunately, recommendations of proper seedling morphology cannot be developed based on this study alone. Seedlings of known morphology need to be outplanted and followed to determine nursery and morphology effects on survival and growth. Toward that end, seedlings from selected treatment combinations studied here have been outplanted onto two different sites in Haiti. Survival and growth are being monitored in these seedlings to see if nursery practices influence them, and to begin to develop morphological guidelines for seedling production.

One conclusion to be drawn from this study is the need to amend Neg mix with an acidifying, phosphate fertilizer. Related to this is the conclusion that pH needs to be kept low to grow cassia. Cassia performance was related to amount of soil in the potting mix, which was confounded here with pH and phosphate availability. Adding soil increased pH, and phosphate availability decreases as pH increases. The omission of mono-ammonium phosphate from this batch of Haiti mix strengthens the case for sufficient phosphate and/or acidity to grow cassia. Some nurseries have trouble growing cassia in Gromix, however. The woman in charge of the nursery at Passe Catabois, for instance, refuses to use Gromix, relying instead on a combination of Neg mix and Gromix which has been recycled from cells that did not produce seedlings the previous season. Growing good cassia consistently depends on factors not yet determined, but the present general recomendations of low pH and higher phosphate will always be a part of the correct strategy.

Recommendations

1. Chene should be planted in the container as a mat of seed on top of the mix.

2. Copper sulfate may be applied to kapab growing in Gromix to prevent or cure Cu deficiency symptoms. This largely cosmetic problem will almost always disappear with outplanting, however.

3. The pH of the mix and/or the irrigation water should be

decreased for best cassia growth.

4. Based on nursery observations, both standard Rootrainers and Rootrainer Deep 5s can be used to produce well-formed seedlings. The minor differences observed suggest they probably can be used interchangeably.

5. Winstrips have several advantages over the currently-used bookplanters, and should be considered for use in nurseries that have an adequate supply of clean irrigation water.

6. Sacks can be used to produce healthy seedlings in areas where the extra mix, labor, and land they need are available.

7. Haiti mix should be substituted for Gromix when possible.

8. Neg mix should be amended with an acidifying, phosphate fertilizer. Reduction of the proportion of soil in the mix should also be considered.

9. Neem grows best in Deep 5s filled with Haiti mix, and that combination should be used when possible.

10. Ced does not grow well in Winstrips filled with Neg mix, and that combination should be avoided.

Table 1. Mixes, containers, and species evaluated in trials in the ODH nursery near Port-au-Prince.

Treatment	Component
Potting Mix	Gromix Haiti Neg
Container	Rootrainer Winstrip Deep 5 Sack
Species	neem (Azadirachta indica A.Juss) cassia (Cassia siamea Lam.) chene (Catalpa longissima (Jacq.) Sims) ced (Cedrela odorata L.) kapab (Colubrina arborescens (Mill.) Sarg.)

Table 2. Percentage seedling emergence in the nursery by species, mix, and container. Means were not tested for differences.

Species	Mix	Container: Rootrnr	Winstrp	Deep 5	Sacks
Cassia	Gro	87.5	91.9	94.0	85.8
	Haiti	80.5	81.6	93.0	87.1
	Neg	77.5	87.0	89.0	89.2
Kapab	Gro	75.0	82.0	63.5	86.2
	Haiti	60.5	54.4	37.5	63.3
	Neg	82.0	77.6	66.0	78.9
Chene	Gro	83.5	97.9	95.0	93.6
	Haiti	84.5	84.6	93.0	83.2
	Neg	91.0	68.7	86.5	83.2
Neem	Gro	90.0	91.7	94.0	93.1
	Haiti	94.0	78.2	89.0	76.2
	Neg	87.5	83.3	95.5	85.7
Ced	Gro	96.0	96.1	93.0	93.9
	Haiti	100.0	97.1	100.0	94.0
	Neg	93.0	99.0	95.0	87.6

Table 3. Chene (*Catalpa longissima*) seedling measurements taken[*] four months after sowing in a Port-au-Prince nursery. Values are means of 160 individuals for mixes and 120 individuals for containers.

	Height	Root Collar Diameter	Root Weight	Shoot Weight	R:S	C:R
	-cm-	-mm-	- g -	- g -		
Mix - Gro	15.5a	2.5a	0.52a	0.61a	1.04a	6.71a
Haiti	17.8a	2.6a	0.61a	0.62a	1.09a	6.24a
Neg	13.6b	2.1a	0.46a	0.48a	1.09a	6.04a
Interaction	+	+	0	0	0	0
Container - Rootrainer	12.2bc	2.2b	0.28b	0.31b	1.02a	8.24a
Winstrip	11.5c	2.1b	0.34b	0.34b	1.16a	7.51ab
Deep 5	14.1b	1.9b	0.35b	0.47b	0.81a	6.49b
Sack	24.3a	3.4a	1.10a	1.12a	1.31a	3.54c

* - values followed by the same letter are not different ($\alpha=0.05$)

Table 4. Cassia (Cassia siamea) seedling measurements taken four months after sowing in a Port-au-Prince nursery. Values are means of 160 individuals for mixes and 120 individualsfor containers.

	Height	Root Collar Diameter	Root Weight	Shoot Weight	R:S	C:R
	-cm-	-mm-	- g -	- g -		
Mix - Gro	16.2a	3.3a	0.87b	1.33a	0.94b	4.60a
Haiti	12.6b	3.4a	1.10a	1.06b	1.30ab	4.01b
Neg	10.8c	2.8b	0.63c	0.55c	1.47a	5.07a
Interaction	+	0	+	+	0	0
Container - Rootrainer	9.8c	2.4c	0.51c	0.51b	1.21a	5.27a
Winstrip	12.5b	3.2b	0.65bc	0.69b	1.26a	5.27a
Deep 5	10.4c	2.6c	0.69b	0.54b	1.48a	4.37b
Sack	20.1a	4.4a	1.65a	2.14a	1.05a	3.27c

- values followed by the same letter are not different (α=0.05)

Table 5. Kapab (Colubrina arborescens) seedling measurements taken four months after sowing in a Port-au-Prince nursery. Values* are means of 160 individuals for mixes and 120 individuals for containers.

	Height	Root Collar Diameter	Root Weight	Shoot Weight	R:S	C:R
	-cm-	-mm-	- g -	- g -		
Mix - Gro	12.9b	3.2a	0.71a	0.81b	0.99a	5.25a
Haiti	15.3a	3.3a	0.88a	1.19a	0.85a	4.71a
Neg	12.4b	2.7b	0.71a	0.76b	1.02a	4.90a
Interaction	0	0	0	0	0	0
Container - Rootrainer	11.4b	2.6b	0.54b	0.66b	0.85a	5.57a
Winstrip	11.1b	2.7b	0.61b	0.73b	0.99a	5.20ab
Deep 5	11.5b	2.9b	0.67b	0.84b	0.96a	4.99ab
Sack	19.8a	4.2a	1.23a	1.45a	1.07a	4.11b

* - values followed by the same letter are not different ($\alpha=0.05$)

Table 6. Neem (<u>Azidirachta indica</u>) seedling measurements taken* four months after sowing in a Port-au-Prince nursery. Values are means of 120 individuals for mixes and 90 individuals for containers.

	Height	Root Collar Diameter	Root Weight	Shoot Weight	R:S	C:R
	-cm-	-mm-	- g -	- g -		
Mix - Gro	11.0a	4.2a	1.06a	0.87a	1.25a	4.37a
Haiti	11.5a	4.0a	1.03a	0.95a	1.18a	4.81a
Neg	10.4a	3.5b	0.98a	0.76a	1.43a	4.12a
Interaction	+	0	+	+	0	0
Container - Rootrainer	10.0c	4.1a	0.74c	0.61c	1.30a	5.10ab
Winstrip	8.2d	2.8b	0.56c	0.51c	1.15a	5.67a
Deep 5	11.3b	4.0a	1.00b	0.84b	1.40a	4.31b
Sack	14.3a	4.5a	1.86a	1.55a	1.24a	2.69c

* - values followed by the same letter are not different ($\alpha=0.05$)

Table 7. Ced (<u>Cedrela</u> <u>odorata</u>) seedling measurements taken four months after sowing in a Port-au-Prince nursery. Values* are means of 84 individuals for mixes and 63 individuals for containers.

	Height	Root Collar Diameter	Root Weight	Shoot Weight	R:S	C:R
	-cm-	-mm-	- g -	- g -		
Mix - Gro	10.6b	4.3ab	0.70a	0.80a	0.90a	7.59b
Haiti	11.6a	4.5a	0.59ab	0.74a	1.01a	11.19a
Neg	12.2a	4.0b	0.43b	0.67a	0.76a	13.45a
Interaction	+	+	+	0	0	+
Container - Rootrainer	8.2c	4.2b	0.34c	0.30c	1.16a	14.44a
Winstrip	11.1b	3.7c	0.53b	0.67b	0.76bc	8.87b
Deep 5	9.1c	4.3b	0.43bc	0.51bc	1.00ab	13.07a
Sack	17.4a	4.9a	1.04a	1.50a	0.69c	6.08c

* - values followed by the same letter are not different ($\alpha=0.05$)

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APPENDICES

APPENDIX A

MIX AND CONTAINER DESCRIPTIONS

Mixes -

Gromix - 1 : 1 peat moss : vermiculite
(Fafard II)
commercially available, imported
sold by Conrad Fafard, Inc.,
Springfield, MA 01101, USA

Haiti mix - 7 : 1.5 : 1.5 : 2.5
newly composted sugarcane bagasse :
unground rice hulls : soil : peat moss
locally-produced by ODH at Cazeau

Neg mix - 7 : 1.5 : 1.5
old sugarcane bagasse :
candlewood tree residue : soil
formerly called CARE mix
locally produced by CARE at Gonaives

Containers -

Rootrainers - 100 mm deep, 60 ml/cell, 5 cells/bookplanter
not self-supporting, imported
manufactured by Spencer-Lemaire Industries, Ltd.,
Edmonton, Alta., Canada

Winstrips - 110 mm deep, 75 ml/cell, 146 cells/case
self-supporting, imported
manfactured by Operation Double Harvest,
Fletcher, NC, USA

Deep 5s - 125 mm deep, 85 ml/cell, 5 cells/bookplanter
not self-supporting, imported
manufactured by Spencer-Lemaire Industries, Ltd.,
Edmonton, Alta., Canada

Black Plastic Sacks - 130 mm deep, 265 ml/cell
not self-supporting, available locally
manufactured by various companies

Chemical Analysis of Mixes

	Gromix	Haiti mix	Neg mix
pH	6.6	6.6	7.4
specific conductance (mmhos/cm)	0.88	2.80	5.20
soluble salts (ppm)	616	1960	3460
phosphorus (P, ppm)	12.4	83.2	6.1
potassium (K, ppm)	16.1	167.1	212.7
magnesium (Mg, ppm)	62.8	61.8	115.6
calcium (Ca, ppm)	70.2	177.2	273.4
nitrate-nitrogen (NO_3-N, ppm)	46.9	108.4	125.5

APPENDIX B

SEED DESCRIPTION

cassia
(Cassia siamea)

source - Ruanda, Africa
date collected - unknown
lot no. - PADF 554
tested germination - 75%
pre-sowing treatment -
warm water scarification,
48 hr soak

chene
(Catalpa longissima)

source - Dept. du Nord
date collected - September 1988
lot no. - PADF 549
tested germination - not tested
pre-sowing treatment - none

kapab
(Colubrina arborescens)

source - Ennery
date collected - May 1988
lot no.- PADF 461
tested germination - 20%
pre-sowing treatment -
warm water scarification,
48 hr soak

neem
(Azidirachta indica)

source - Matelas
date collected - January 1989
lot no. - none
tested germination -not tested
pre-sowing treatment -
24 hr soak in cold water

ced
(Cedrela odorata)

source - Fonds-Verrettes
date collected - January 1989
lot no. - PADF 637
tested germination - not tested
pre-sowing treatment - none

APPENDIX C

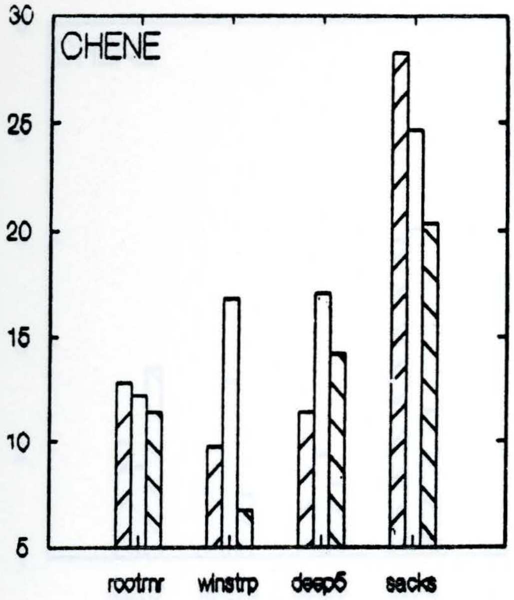
BAR GRAPHS BY MEASUREMENT

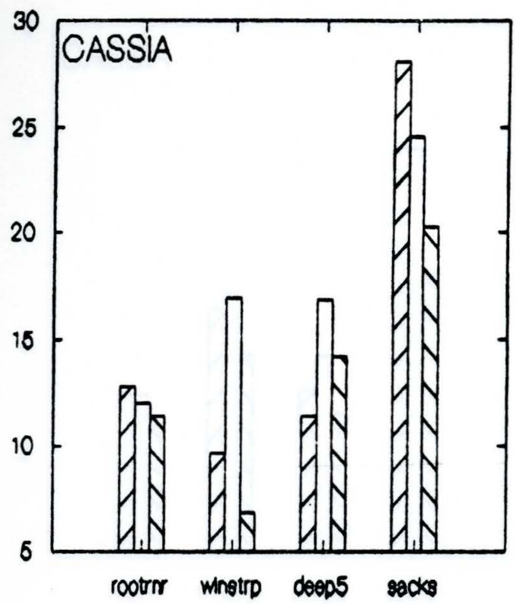
Container and Mix Effects on HEIGHT (cm)

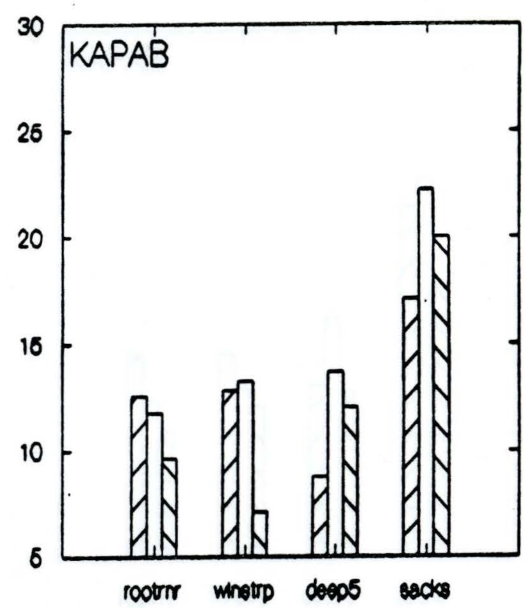
Gromix

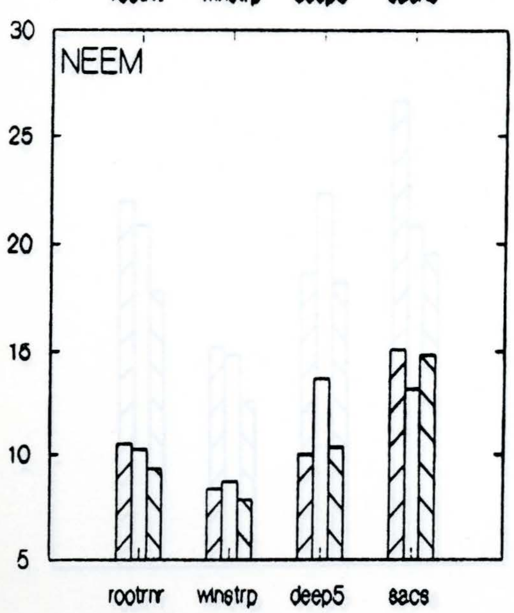
Haiti mix

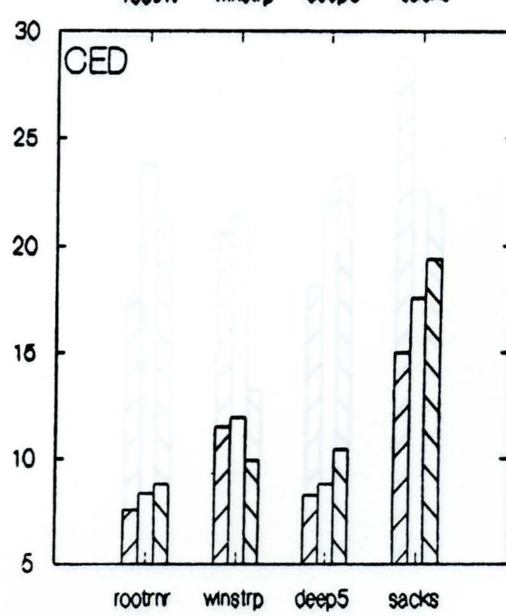
Neg mix











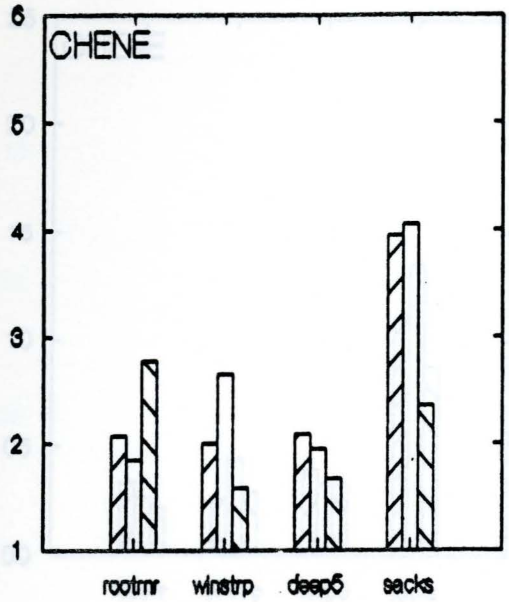
Container and Mix Effects on

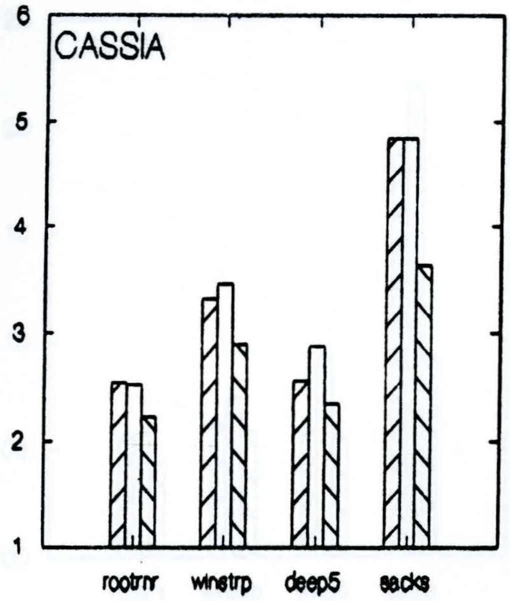
ROOT COLLAR DIAMETER (mm)

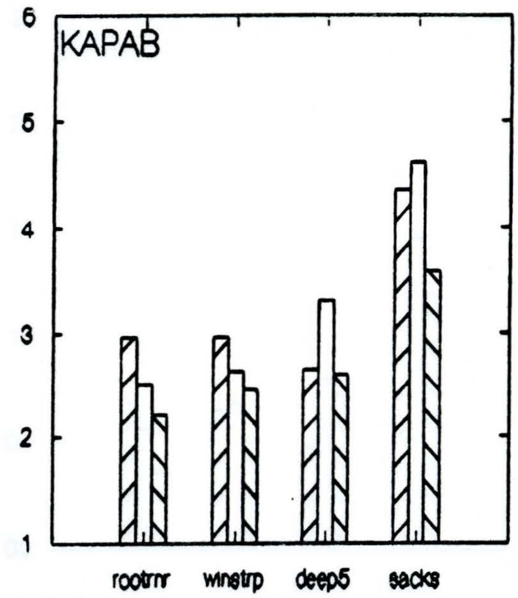
Gromix

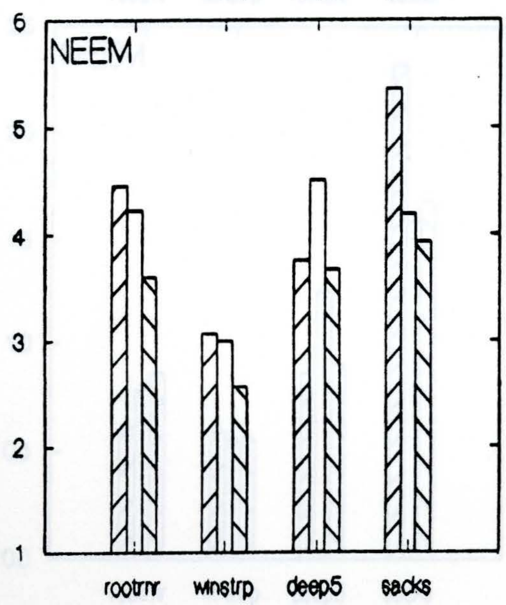
Haiti mix

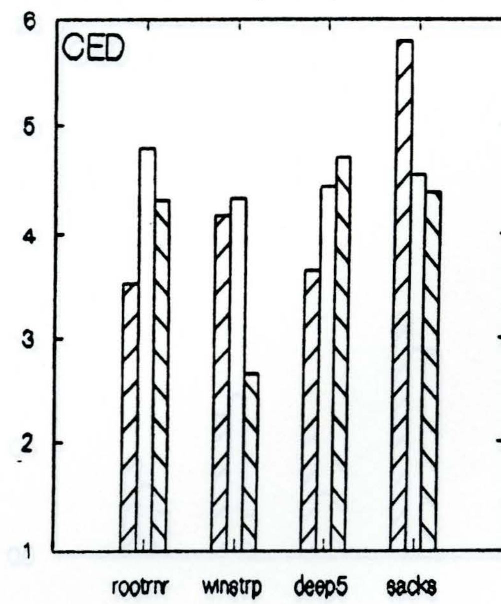
Neg mix





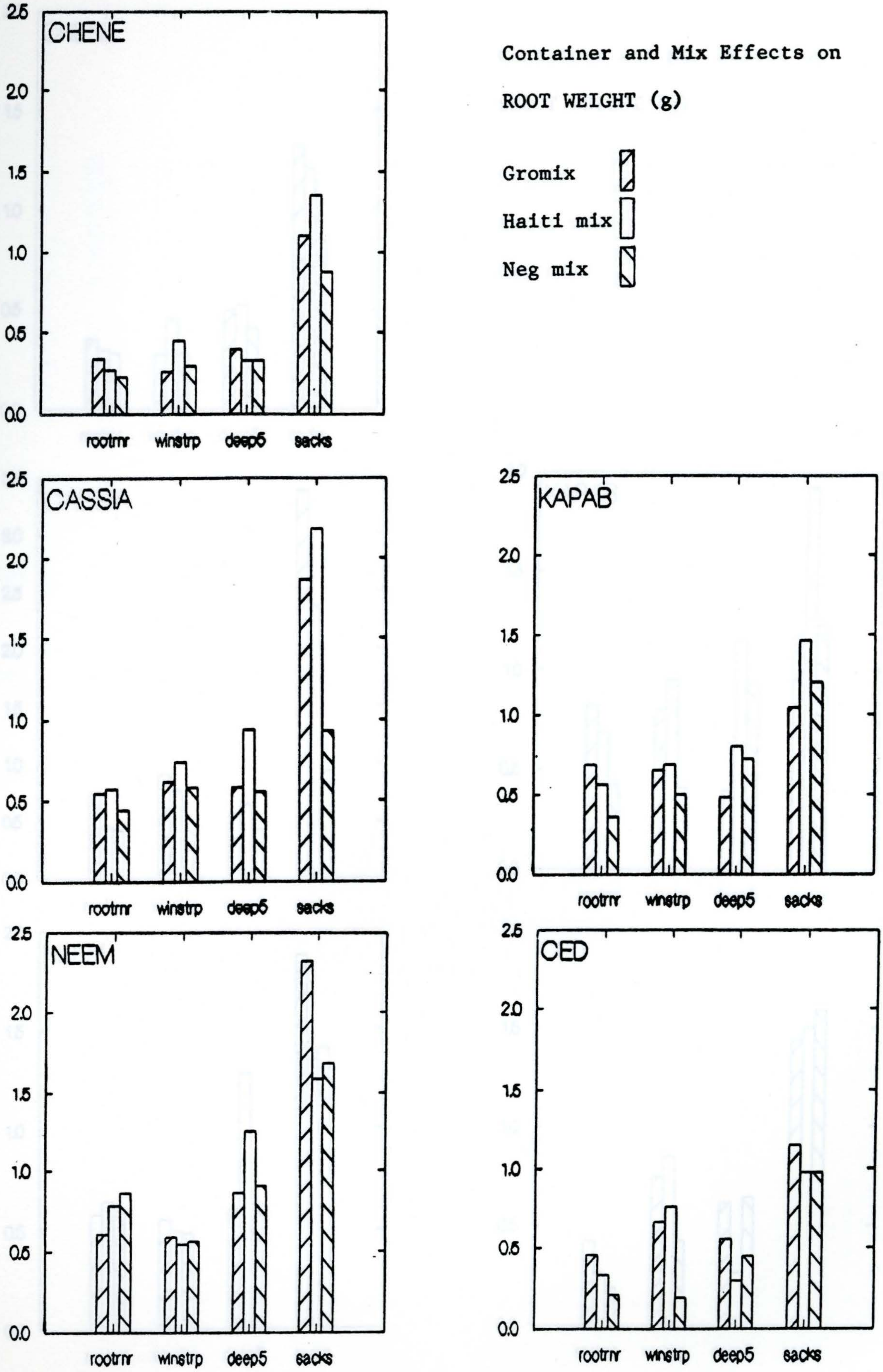


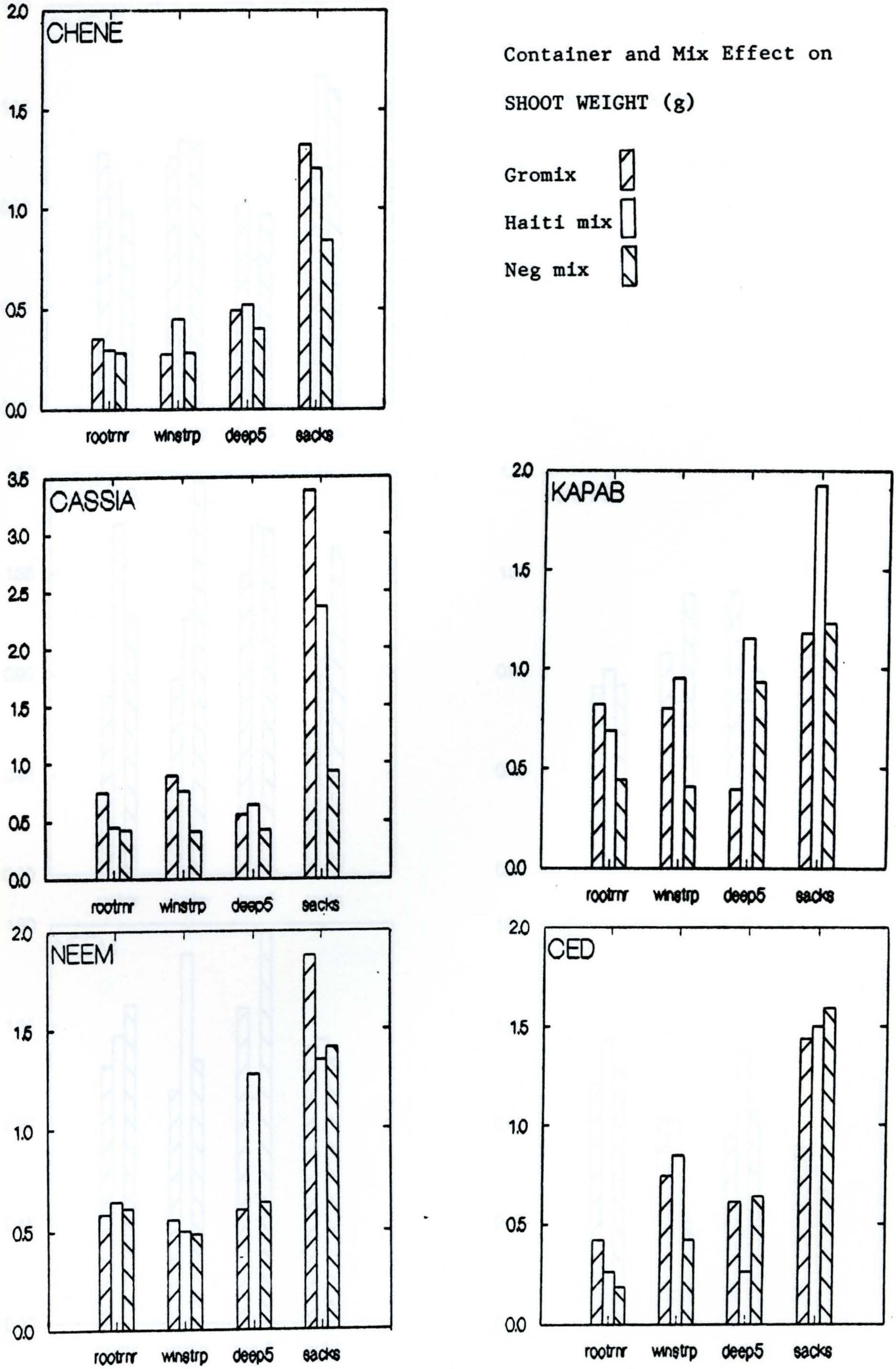




Container and Mix Effects on

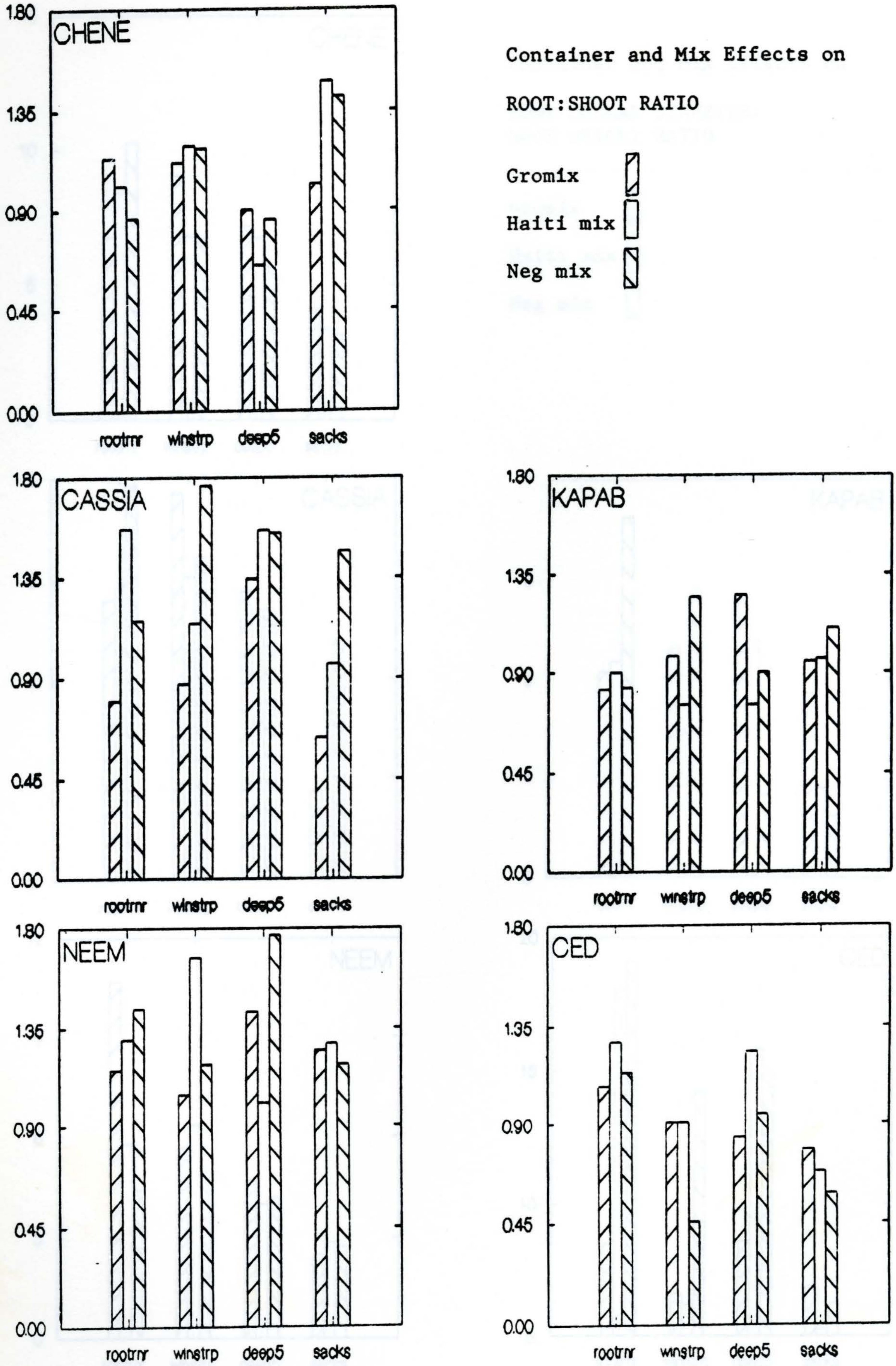
ROOT WEIGHT (g)

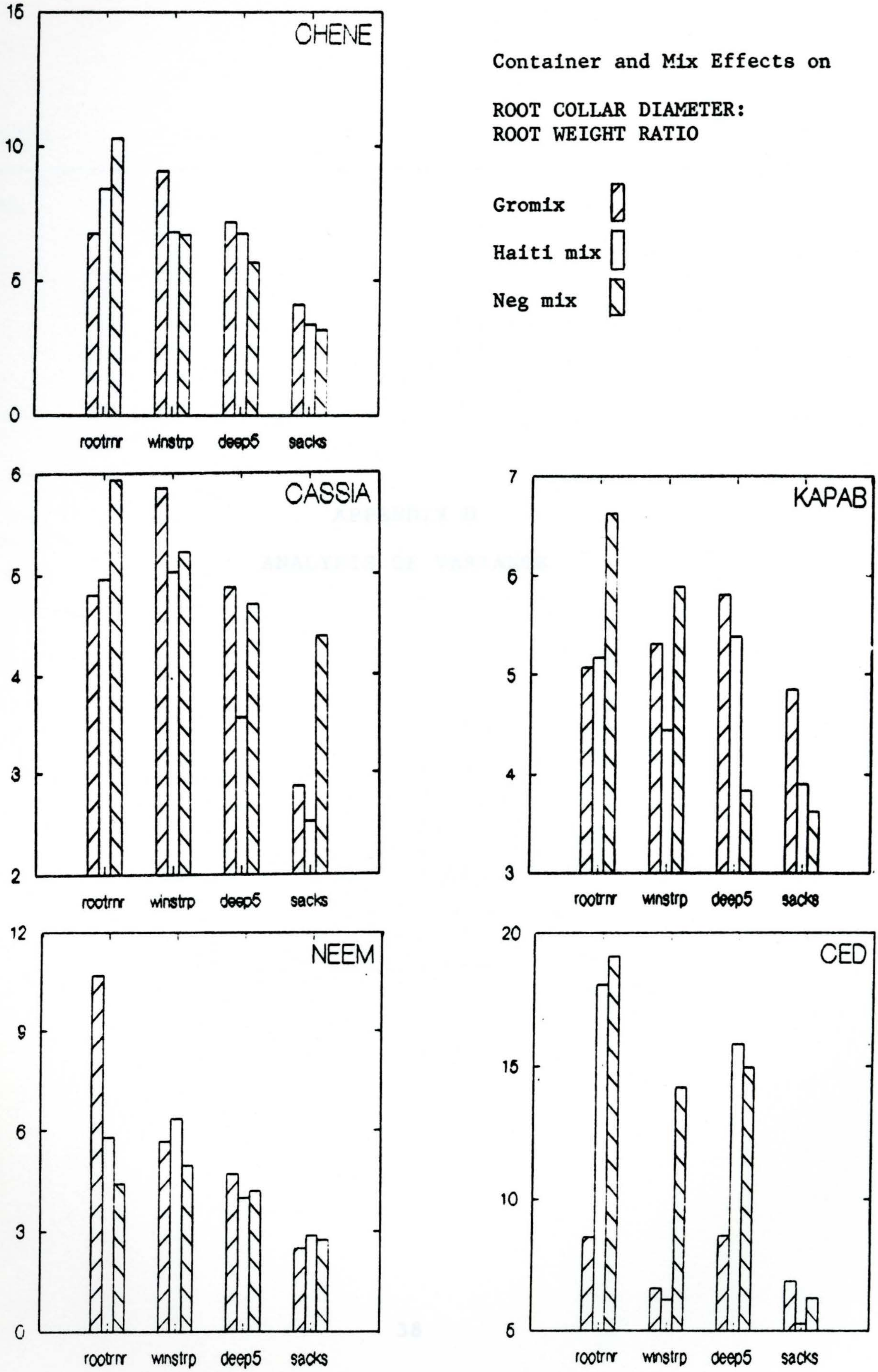




Container and Mix Effect on

SHOOT WEIGHT (g)


Container and Mix Effects on
ROOT:SHOOT RATIO
Gromix
Haiti mix
Neg mix
CHENE
CASSIA
KAPAB
NEEM
CED
1.80
1.35
0.90
0.45
0.00
rootrnr
winstrp
deep5
sacks



Container and Mix Effects on

ROOT COLLAR DIAMETER:
ROOT WEIGHT RATIO

APPENDIX D

ANALYSIS OF VARIANCE

Chene ANOVA

Variable	Source	df	MS	F	prob>F
height	block	3	9.847	0.951	0.428
	mix	2	75.619	7.304	0.002
	Haiti-Gro	1	34.310	3.314	0.078
	Gro-Neg	1	43.137	4.167	0.050
	container	3	439.867	42.487	0.000
	Sac-Dp5	1	627.304	60.592	0.000
	Dp5-Rtr	1	25.348	2.448	0.127
	Rtr-Wst	1	6.360	0.614	0.439
	Dp5-Wst	1	54.917	5.304	0.028
	mix X cont	6	40.839	3.945	0.005
	error	32	10.353	-	
root collar diameter	block	3	0.615	1.569	0.216
	mix	2	1.136	2.899	0.070
	container	3	5.722	14.723	0.000
	Sac-Rtr	1	9.095	23.198	0.000
	Rtr-Dp5	1	0.551	1.405	0.245
	mix X cont	6	1.473	3.758	0.006
	error	32	0.392	-	
root dry weight	block	3	0.056	1.305	0.290
	mix	2	0.103	2.395	0.108
	container	3	1.825	42.257	0.000
	Sac-Dp5	1	3.410	78.981	0.000
	Dp5-Rtr	1	0.036	0.840	0.367
	mix X cont	6	0.057	1.313	0.281
	error	31	0.043	-	
shoot dry weight	block	3	0.350	4.357	0.011
	mix	2	0.199	2.483	0.100
	container	3	1.776	22.140	0.000
	Sac-Dp5	1	2.485	30.976	0.000
	Dp5-Rtr	1	0.217	2.700	0.110
	mix X cont	6	0.042	0.528	0.782
	error	31	0.080	-	

Chene ANOVA (continued)

Variable	Source	df	MS	F	prob>F
R:S ratio	block	3	1.166	5.963	0.002
	mix	2	0.066	0.340	0.715
	container	3	0.565	2.889	0.051
	mix X cont	6	0.121	0.619	0.713
	error	31	0.196	-	
C:R ratio	block	3	16.307	2.890	0.051
	mix	2	0.972	0.172	0.843
	container	3	56.431	10.002	0.000
	Rtr-Wst	1	6.324	1.121	0.298
	Wst-Dp5	1	6.687	1.185	0.285
	Rtr-Dp5	1	26.616	4.717	0.038
	Dp5-Sac	1	53.423	9.469	0.004
	mix X cont	6	8.173	1.449	0.228
	error	31	5.642	-	

Cassia ANOVA

Variable	Source	df	MS	F	prob>F
height	block	3	12.043	5.175	0.005
	mix	2	122.035	52.437	0.000
	Gro-Haiti	1	102.352	43.980	0.000
	Haiti-Neg	1	27.575	11.849	0.002
	container	3	269.034	115.601	0.000
	Sac-Wst	1	344.776	148.147	0.000
	Wst-Dp5	1	26.818	11.524	0.002
	Dp5-Rtr	1	2.007	0.862	0.360
	mix X cont	6	11.060	4.752	0.001
	error	33	2.327	-	
root collar diameter	block	3	0.173	1.540	0.223
	mix	2	2.124	18.879	0.000
	Haiti-Gro	1	0.144	1.284	0.265
	Gro-Neg	1	2.448	21.751	0.000
	container	3	9.836	87.408	0.000
	Sac-Wst	1	8.237	73.198	0.000
	Wst-Dp5	1	2.568	22.817	0.000
	Dp5-Rtr	1	0.177	1.571	0.219
	mix X cont	6	0.265	2.357	0.053
	error	33	0.113	-	
root dry weight	block	3	0.017	0.651	0.588
	mix	2	0.936	36.070	0.000
	Haiti-Gro	1	0.315	12.129	0.002
	Gro-Neg	1	0.548	21.098	0.000
	container	3	2.993	115.303	0.000
	Sac-Dp5	1	5.254	202.423	0.000
	Dp5-Rtr	1	0.177	6.830	0.014
	Dp5-Wst	1	0.011	0.427	0.518
	Wst-Rtr	1	0.102	3.915	0.057
	mix X cont	6	0.325	12.515	0.000
	error	31	0.026	-	
shoot dry weight	block	3	0.798	5.767	0.003
	mix	2	2.508	18.135	0.000
	Gro-Haiti	1	0.647	4.680	0.038
	Haiti-Neg	1	2.114	15.284	0.000
	container	3	7.273	52.576	0.000
	Sac-Wst	1	13.015	94.092	0.000
	Wst-Rtr	1	0.171	1.239	0.274
	mix X cont	6	1.035	7.482	0.000
	error	32	0.138	-	

Cassia ANOVA (continued)

Variable	Source	df	MS	F	prob>F
R:S ratio	block	3	2.970	18.120	0.000
	mix	2	0.898	5.479	0.009
	Neg-Haiti	1	0.390	2.379	0.133
	Haiti-Gro	1	0.554	3.382	0.075
	container	3	0.316	1.929	0.145
	mix X cont	6	0.336	2.052	0.088
	error	31	0.164	-	
C:R ratio	block	3	1.757	3.331	0.032
	mix	2	4.625	8.766	0.001
	Neg-Gro	1	1.629	3.088	0.089
	Gro-Haiti	1	2.616	4.959	0.033
	container	3	9.681	18.350	0.000
	Wst-Dp5	1	4.638	8.791	0.006
	Dp5-Sac	1	6.572	12.457	0.001
	mix X cont	6	0.885	1.677	0.160
	error	31	0.528	-	

Kapab ANOVA

Variable	Source	df	MS	F	prob>F
height	block	3	10.878	1.161	0.339
	mix	2	41.061	4.384	0.020
	Haiti-Gro	1	46.433	4.957	0.033
	Gro-Neg	1	3.121	0.333	0.568
	container	3	220.089	23.497	0.000
	Sac-Dp5	1	420.333	44.875	0.000
	Dp5-Wst	1	0.997	0.106	0.746
	mix X cont	6	21.846	3.945	0.005
	error	33	9.367	-	
root collar diameter	block	3	0.319	1.758	0.174
	mix	2	1.534	8.453	0.001
	Haiti-Gro	1	0.003	0.017	0.898
	Gro-Neg	1	2.216	12.210	0.001
	container	3	6.775	37.338	0.000
	Sac-Dp5	1	10.671	58.809	0.000
	Dp5-Rtr	1	0.494	2.721	0.109
	mix X cont	6	0.365	2.010	0.092
	error	33	0.181	-	
root dry weight	block	3	0.074	1.363	0.271
	mix	2	0.165	3.029	0.062
	container	3	1.246	22.916	0.000
	Sac-Dp5	1	1.936	35.600	0.000
	Dp5-Rtr	1	0.120	2.211	0.146
	mix X cont	6	0.094	1.728	0.145
	error	33	0.054	-	
shoot dry weight	block	3	0.270	1.326	0.282
	mix	2	0.863	4.233	0.023
	Haiti-Gro	1	1.119	5.489	0.025
	Gro-Neg	1	0.021	0.104	0.749
	container	3	1.620	7.948	0.000
	Sac-Dp5	1	2.350	11.528	0.002
	Dp5-Rtr	1	0.194	0.949	0.337
	mix X cont	6	0.298	1.460	0.222
	error	32	0.204	-	

Kapab ANOVA (continued)

Variable	Source	df	MS	F	prob>F
R:S ratio	block	3	0.278	4.523	0.009
	mix	2	0.145	2.362	0.110
	container	3	0.046	0.757	0.526
	mix X cont	6	0.129	2.101	0.080
	error	33	0.061	-	
C:R ratio	block	3	2.718	1.424	0.253
	mix	2	0.927	0.486	0.619
	container	3	5.748	3.012	0.044
	Rtr-Dp5	1	3.212	1.683	0.204
	Wst-Sac	1	7.317	3.834	0.059
	mix X cont	6	4.166	2.183	0.070
	error	33	1.908	-	

Neem ANOVA

Variable	Source	df	MS	F	prob>F
height	block	2	2.002	1.146	0.337
	mix	2	2.276	1.303	0.293
	container	3	54.673	31.303	0.000
	Sac-Dp5	1	39.368	22.540	0.000
	Dp5-Rtr	1	7.894	4.519	0.046
	Rtr-Wst	1	12.535	7.177	0.014
	mix X cont	6	5.111	2.926	0.031
	error	21	1.747	-	
root collar diameter	block	2	1.537	4.159	0.030
	mix	2	1.548	4.187	0.029
	Gro-Haiti	1	0.128	0.345	0.563
	Haiti-Neg	1	1.782	4.821	0.039
	container	3	4.039	10.928	0.000
	Sac-Dp5	1	1.217	3.292	0.084
	Dp5-Wst	1	5.300	14.339	0.001
	mix X cont	6	0.507	1.370	0.272
	error	21	0.370	-	
root dry weight	block	2	0.029	0.499	0.614
	mix	2	0.025	0.444	0.647
	container	3	2.850	49.788	0.000
	Sac-Dp5	1	3.308	57.804	0.000
	Dp5-Rtr	1	0.303	5.288	0.032
	Rtr-Wst	1	0.129	2.256	0.148
	mix X cont	6	0.213	3.721	0.011
	error	21	0.057	-	
shoot dry weight	block	2	0.009	0.206	0.816
	mix	2	0.082	1.907	0.173
	container	3	1.882	44.021	0.000
	Sac-Dp5	1	2.257	52.785	0.000
	Dp5-Rtr	1	0.232	5.428	0.030
	Rtr-Wst	1	0.035	0.808	0.379
	mix X cont	6	0.204	4.773	0.003
	error	21	0.043	-	

Neem ANOVA (continued)

Variable	Source	df	MS	F	prob>F
R:S ratio	block	2	0.076	0.624	0.546
	mix	2	0.149	1.234	0.311
	container	3	0.109	0.904	0.456
	mix X cont	6	0.119	0.980	0.463
	error	21	0.121	-	
C:R ratio	block	2	1.759	2.140	0.144
	mix	2	1.424	1.733	0.202
	container	3	13.890	16.903	0.000
	Wst-Rtr	1	0.739	0.900	0.354
	Rtr-Dp5	1	3.052	3.714	0.068
	Wst-Dp5	1	6.998	8.516	0.009
	Dp5-Sac	1	11.568	14.078	0.001
	mix X cont	6	0.680	0.827	0.563
	error	20	0.822	-	

Ced ANOVA

Variable	Source	df	MS	F	prob>F
height	block	2	0.561	0.458	0.638
	mix	2	8.884	7.254	0.004
	Neg-Haiti	1	2.028	1.656	0.212
	Haiti-Gro	1	7.419	6.058	0.022
	container	3	153.834	125.615	0.000
	Sac-Wst	1	179.551	146.614	0.000
	Wst-Dp5	1	16.620	13.571	0.001
	Dp5-Rtr	1	4.084	3.335	0.081
	mix X cont	6	5.753	4.698	0.003
	error	22	1.225	-	
root collar diameter	block	2	0.868	8.277	0.002
	mix	2	0.806	7.692	0.003
	Haiti-Gro	1	0.370	3.528	0.074
	Gro-Neg	1	0.437	4.173	0.053
	container	3	2.139	20.402	0.000
	Sac-Dp5	1	1.850	17.652	0.000
	Dp5-Rtr	1	0.010	0.098	0.758
	Rtr-Wst	1	1.125	10.733	0.003
	mix X cont	6	1.915	18.268	0.000
	error	22	0.105	-	
root dry weight	block	2	0.188	9.500	0.001
	mix	2	0.116	5.862	0.010
	Gro-Haiti	1	0.073	3.714	0.068
	Haiti-Neg	1	0.051	2.576	0.124
	container	3	0.770	38.976	0.000
	Sac-Wst	1	1.104	55.889	0.000
	Wst-Dp5	1	0.047	2.370	0.139
	Dp5-Rtr	1	0.024	1.191	0.288
	Wst-Rtr	1	0.130	6.577	0.018
	mix X cont	6	0.075	3.787	0.011
	error	20	0.020	-	

Ced ANOVA (continued)

Variable	Source	df	MS	F	prob>F
shoot dry weight	block	2	0.294	3.674	0.044
	mix	2	0.022	0.277	0.761
	container	3	2.281	28.536	0.000
	Sac-Wst	1	3.112	38.924	0.000
	Wst-Dp5	1	0.125	1.564	0.226
	Dp5-Rtr	1	0.145	1.812	0.193
	Wst-Rtr	1	0.517	6.467	0.019
	mix X cont	6	0.108	1.353	0.281
	error	20	0.080	-	
R:S ratio	block	2	0.103	1.524	0.242
	mix	2	0.201	2.966	0.074
	container	3	0.491	7.257	0.002
	Rtr-Dp5	1	0.251	3.708	0.068
	Dp5-Wst	1	0.254	3.757	0.067
	Rtr-Wst	1	0.968	14.294	0.001
	Wst-Sac	1	0.016	0.229	0.637
	Dp5-Sac	1	0.369	5.446	0.030
	mix X cont	6	0.079	3.945	0.005
	error	20	0.068	-	
C:R ratio	block	2	49.381	6.065	0.009
	mix	2	80.091	9.837	0.001
	Neg-Haiti	1	15.311	1.881	0.185
	Haiti-Gro	1	77.854	9.563	0.006
	container	3	132.206	16.239	0.000
	Rtr-Dp5	1	10.243	1.258	0.275
	Dp5-Wst	1	79.095	9.715	0.005
	Wst-Sac	1	42.861	5.265	0.033
	mix X cont	6	34.274	4.210	0.007
	error	20	8.141	-	