HAITI AGROFORESTRY RESEARCH PROJECT

SOUTH-EAST CONSORTIUM FOR INTERNATIONAL DEVELOPMENT/
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Development of Stock Quality Criteria

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EXECUTIVE SUMMARY

This study examined survival and growth of seedlings of several species produced in standard and Deep 5 Rootrainers. The objectives were to test for differences between the two containers, and to determine the minimum size needed for outplanting.

Instead of a random, representative sample, nursery seedlings having the smallest and largest root collar diameter were selected for outplanting. Root systems received a numerical root quality ranking as they were planted. Container effects were compared by analysis of variance (for morphologial measurements) and by straight-line models (for patterns of growth).

Occasional differences were discovered, but meaningful differences between standard and Deep 5 Rootrainers do not exist. Kasya demonstrated no container differences, but the five-cm initial height difference between neem trees growing in the two containers had not changed at nine months. Initial condition of the root system and root plug had little or no effect on subsequent field performance. Calculation of straight-line models showed only a very weak relationship between initial morphological measurements and field performance. However, grouping seedlings based on initial root collar diameter showed that those smaller than a species-dependant minimum performed poorly when outplanted. This critical minimum is not smaller than 2mm, and may be larger. Seedlings smaller than this should not be allowed to leave the nursery, and nursery practices which increase seedling root collar diameter must be encouraged.

RÉZIMÉ

Etid si-la examinin jan ti pyebwa differen espes chape le yo soti Woutrene fon ak pa fon. Objectif la sé pou testé pou diférens ki genyen ent dé (2) veso sa-yo. Objectif la sé tou détéminé gwosé ki pipiti ké nou bezwen pou planté en déyo de pépinyé-yo.

Ti pyebwa nan pépinyé ki gen pi piti ak pi gwo diamet nan pié ti pyebwa-yo té choizi pou al planté an déyo pépinyé-yo. Pandan nou tap planté ti pyebwa-yo, nou te mete yon nimewo sou chak pyebwa, bou identifye kondisyon rasinn-yo. Efé veso-yo genyen sou ti pyebwa té komparé nan yon analiz de varians (pou mézi morfolojik) ak nan plizié modél ligne dwat (pou jan y-ap grandi).

Nou té jwenn kék diférans pa si pa la. Diférans nou t'ap chéché-yo pa éksisté. Kasya pa bay ankenn diférans nan veso-yo, men ti diféranse nan oté de 5 cm ki genyen ent pié neem-yo k'ap grandi nan dé (2) veso-yo pa chanjé nan yon périod de 9 moi. Kondisyon première de sistém rasinn gen yon ti ou bien pa gen éfé sou péfomans nan jadin-yo. Kalkil sou modél ligne dwat démontré yon ti relasion ent mézi morfolojik ak péfomans nan jadin. Sepandan, ti pyebwa ki an group bazé sou gwosé diamét nan pié-yo démontré ti pyebwa ki pipiti pasé yon minimum de éspés pa bien remét lé yo planté nan jadin. Minimum kritik si-la pa pipiti ke 2.5 mm, et li ka pi laj. Ti pyebwa ki pipiti pasé si-la pat dwé kité pépinyé-yo. Fó yo sévi ak téknik ki agrandi diamét plis, nan pyebwa-yo.

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SECID/Auburn team members critiqued a draft of this report. Duverger Jn. Vernus helped with the measurements and site management.

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INTRODUCTION

Reforestation workers all over the world desire a way to use seedling morphological measurements made at the time seedlings are removed from the nursery to predict their growth and development after outplanting. Plantation failures sometimes occur, and a measure that reliably predicts how seedlings will perform would be priceless. Such a measure would be especially valuable in Haiti, where an entire community's faith in a program can be destroyed because of planting failures.

For a number of reasons, growth prediction is difficult, and the sought-after index of seedling quality has not yet been found. At least in the southern United States, seedling grading has been abandoned; however, culling, or rejection of seedlings which fall short of a standard, continues to be practiced. Agroforestry II nursery programs now are well enough established that culling can begin in Haiti. The primary objective of this study was to determine the minimum size a seedling should be before it is outplanted, and thus allow seedlings smaller than that minimum to be culled and left at the nursery.

A recently-released report (Reid 1991a), which described a study initiated in Spring 1989 (Reid 1989), concluded that no biological differences existed between Deep 5 and standard 5 Rootrainers. Since those results have such profound implications for AFII, an additional goal of the present study was to continue to compare standard Rootrainers with Rootrainer Deep 5s. Since sample size was adequate in the 1989 study, a different kind of comparison, a comparison of two regression analyses, is made here.

The data collected in this study will be applied toward testing a formula which will enable us to predict how well a seedling will perform based on morphological measurements at planting. Final results of that portion of the study will be reserved for the final report, but preliminary findings will be touched upon here. Those findings cover: analysis of variance of Rootrainer, nursery, and site effects; effect of initial root ball condition and initial diameter; and influence of initial measurements on subsequent performance.

MATERIALS AND METHODS

Seedlings used in this study were grown in standard Rootrainers and Rootrainer Deep 5s. Four species were selected for testing. Each species came from two nurseries (except sed, which came from only one nursery) and originated in both Rootrainers in each nursery. The Ecole Baha'i nursery at Lilavois supplied *Colubrina arborescens* (Mill.) Sarg. and *Azadirachta indica* A. Juss., the Eglise Wesleyenne Methodiste nursery at Thomonde supplied *C. arborescens*, *A. indica*, and *Cassia siamea* Lam., and from the Cap Haitien area, the Hopital Bon Samaritain nursery at Limbe and Centre Agricola nursery at Quartier Morin supplied *C. siamea* and *Cedrela odorata* L., respectively.

Seedlings coming out of the nursery were selected based on root collar diameter. Seventy-two individuals were selected from each container in each nursery. A random, representative sample was not selected. Instead, the 27 smallest and 27 largest individuals of a species in a nursery were selected for outplanting. The remaining 18 individuals were selected from average-sized seedlings from each nursery-species combination. Lilavois seedlings were selected on 16 May 1990 and Thomonde seedlings on 18 May. Cap Haitien seedlings were selected on 28 May and flown to Port-au-Prince on the following day.

Root systems received a numerical root quality ranking as they were planted. This ranking ranged from 1 (best) to 7 (poorest) and was based on visual characteristics such as number and coverage of roots on the surface of the plug and plug integrity (Table 1). Treatment combinations were planted in a completely random design.

Seedlings were planted between 24 May and 1 June 1990, in roughly the order they were selected from their respective nurseries. Seedlings were planted onto three different parcels in Port-au-Prince, two of them inside the industrial park on highway National 1 (Reid 1991b) and the third one in Cazeau. All four species were planted on what was judged to be the better site inside the industrial park, while kasya, kapab and nim were planted on the poorer site, and sed was planted at Cazeau. Each Rootrainer x nursery combination was planted on each site.

Initial shoot height and root collar diameter were measured immediately after the seedlings were planted. Survival was checked on 25 and 29 June, and survival was checked and trees measured on 21 and 24 August, 3 and 4 December 1990, and 25 February 1991. Treatment differences were determined by analysis of variance of a completely random design containing two container x two nursery x two site treatments. Protection against Type I errors was set at 5%, or α=0.05.

A separate analysis of variance was run using grouped initial diameter as a treatment. Eight groups of more-or-less equal numbers of individuals were made by grouping according to initial diameter. These groups were then tested as an effect in analysis of variance of a completely random design. Container, nursery, or site effects were included in this analysis of variance when those effects had been significant in the earlier analysis. When initial diameter group had an effect on a measurement, means were separated using contrast statements (Snedecor and Cochran 1967).

RESULTS

Only one sed was still alive after three months, and it remained alive at nine months. Survival was also very poor among the kapab. Results for both these species are presented in Table 2, and are dropped from further discussion.

For the remaining nim and kasya, four groups of results are discussed: analysis of variance with container, nursery, and site; effect of initial root plug condition; relationship of initial measurements and performance, and comparisons of these relationships between standard and Deep 5 Rootrainers; and the effect of initial diameter.

ANOVA of container, nursery, and site

Means of three-, six- and nine-month measurements are presented for nim and kasya in Table 3. Some significant differences were found, but they generally were not large. Rootrainer type affected nim more than kasya. Nursery had no main effect after the initial measurements, but often interacted with site. Site strongly affected both species. When site affected survival, survival was less on the grass-covered site (house site) than on the brushy site (wall site). When site affected diameter or height, the trees on the house site were larger than trees on the wall site.

Some nim specifics are worth mentioning. Initial observations generally are not shown, but follow: Rootrainer type affected the sturdiness index and height; nursery affected condition of the root plug (see below), the sturdiness index, and diameter, and site affected the sturdiness index, diameter, and height. Initial diameter and height and one-month survival showed container x nursery and nursery x site interactions (analysis not shown). Outplanted Deep 5 nim seedlings were statistically taller and thicker than those from standard Rootrainers every time they were measured (Table 3). Site affected three-, six-, and nine-month survival counts, and six- and nine-month diameter and height. The nursery x site interaction remained significant for three- and six-month height and diameter, and for nine-month height.

The same general results are true for kasya. For initial observations, generally not shown: Rootrainer type affected root plug condition, the sturdiness index, diameter, and height; nursery affected the sturdiness index, diameter, and height; and site had no effect. No interaction effects were seen with initial observations. In the field, Rootrainer affected only three-month height, while site affected six- and nine-month height and diameter. One-month survival showed site main effects and nursery x site and container x nursery x site interactions. After the first month in the field, nursery x site was the only interaction observed, and was seen with one-month survival, three-month survival and height, and six- and nine-month survival, diameter, and height.

Effect of initial root plug condition

Initial measurement means based on grouping according to the initial root plug condition are listed in Table 4. Trends are not readily apparent, and these values were not tested for differences. When mean separation tests were run, ranges were broad, and unequal sample size influenced the tests. As a result, when two means on Table 5 or 6 are said to be different, that statement is conservative and that difference is real.

Field measurements on nim are listed in Table 5, and on kasya in Table 6. For nim, initial condition of the root plug had little effect on subsequent performance, outside of the general observations that those ranked 1 performed better than those ranked 7, and overgrowing the plug (rank 2) seemed detrimental.

These same general observations hold for kasya. Indeed, initial condition affected only survival for the kasya. The lack of survival for those kasya ranked as 3 is not cause for alarm, since only three seedlings were given that rank. However, the high survival for those ranked as 6 was not expected, especially considering only four seedlings were given that ranking.

Performance prediction based on initial measurements

Values for straight-line equations describing selected relationships between initial and subsequent variables for nim are found in Tables 7 - 8 and for kasya in Tables 9 - 10. As was the case with the root plug, initial measurements had little effect on subsequent performance (Tables 7 - 10). These selected relationships are like the others not shown here in that they are not strong. This observation was true especially for kasya, which never had an r^2 value greater than 0.20. For nim, the relationships among initial and subsequent measurements were stronger, but could not be called useful since those relationships do not account for enough variation. The strongest was for nim growing on the wall site, where initial diameter predicted six-month diameter with an r^2 of 0.532.

These relationships also are representative in that differences between lines used to describe data from the two types of containers are almost never different. Tables 7 - 10 show that a model which uses data from both standard and Deep 5 Rootrainers but keeps their coefficients separate (not shown, but equal to the two Rootrainer models added) is not different from a model that does not distinguish Rootrainer type. The lines describing these relationships were different only for nim on the wall site, and then only for the relationship between initial height and six-month root collar diameter. For that model, the two slopes were different, but the intercepts were not significantly different.

Effect of initial diameter

Means resulting from grouping these data according to initial diameter are presented in Tables 11 - 13. These diameter classes have different numbers of observations because they were grouped according to where raw data broke naturally (Table 11). Sturdiness of the seedling was not affected by grouping. The ranking of initial condition, however, tended to decrease with increased diameter, the expected and desired effect.

Initial diameter had a profound effect on subsequent performance, especially when considering the smallest diameters and especially with nim (Table 12). With kasya (Table 13), this effect was visible early, but had largely disappeared by six months. For both nim and kasya, some container, nursery, and site differences apparent in the original analysis disappeared when initial diameter class was added to the analysis of variance. For both species, seedlings did not perform well when initial diameter was 2.5 mm or less. Performance also increased with increasing diameter until diameter reached the largest class, where performance decreased.

DISCUSSION

My public statements about this study have been that it confirms the conclusions of earlier studies (Reid 1989, 1991a), and no differences exist between the two containers. I have been forced to soften that statement, and now say that the differences are minor when they are found. This study, particularly the diameter comparison, helps in understanding why these differences sometimes arise.

ANOVA of container, nursery, and site

Nursery effects were not found after the initial measurements, an observation that was expected. However, differences due to Rootrainer type were found using analysis of variance. They were found for most of the nim values, but were all but absent from the kasya data. Stronger than this Rootrainer effect, however, was the site effect. This site effect was strong enough to be observed with the kasya. As in an earlier study with sacks (Reid 1991b), the grass cover on the house site reduced survival (Table 3), but in contrast to the sack study, those seedlings which survived grew better on the house site.

Other than saying the seedlings from the different nurseries performed differently on the two sites, which is one definition of an interaction, the nursery x site interactions common in the study are not characterized. Consistently, however, both nim and kasya from Thomonde survived much more poorly and grew much better on the house site than on the wall site. Nim from Lilavois and kasya from Limbe followed this same pattern, but the site effect did not seem as strong as it was with kasya from Thomonde. These differences seem to be the reason the interaction is significant, but an explanation of how they arose is not attempted here.

Effect of initial root plug condition

Finding no effect due to initial root plug condition was disappointing. Before this study, the possibility existed that initial plug condition could have led to a legitimate, useful predictor of seedling performance. The results show no useful pattern of differences, however, and without differences prediction is not possible.

One new useful observation did come out of this exercise, however. Seedlings should not be allowed to overgrow the potting mix in their containers during their time in the nursery. Neem roots in particular should be kept within this root plug.

Performance prediction based on initial measurements

Describing the straight-line relationship between initial and subsequent measurements enabled testing the two Rootrainer types in a way that had not been tested. The possibility existed that even though a relationship was weak overall, it may have been weaker in one Rootrainer than the other, or may have had a different slope or intercept, and different equations would need to be used to describe the two relationships. For these data, the two Rootrainers showed different relationships between initial and subsequent measurements only once, for a rather odd pair of variables (initial height and 6-month diameter, Table 8). These findings are further evidence that standard Five and Deep 5 Rootrainers do not produce seedlings that perform differently.

More important than the lack of difference between the two container types, however, is the weak relationships between initial and subsequent measurements (the r^2 values, Tables 7 - 10), especially with kasya. With nim, the strength of the relationship diminishes with time since planting, as would be expected. These weak relationships were expected (Krueger and Trappe 1967, Wakeley 1971, Chung and Barnes 1980), and demonstrate that Haiti is like the rest of the world when it comes to lack of a seedling morphological measurement that predicts field performance.

Effect of initial diameter

The strong effect of initial diameter on performance was a surprise, especially considering the apparent weak relationship among initial and subsequent measurements discussed in the preceeding section. How can the relationship between initial diameter and subsequent measurements be so weak when tested as a straight line model, but have a strong effect when tested as an eight-category analysis of variance? Part of the answer lies in the nature of the two analyses and the resulting test statistics. The straight-line models test the strength of the relationship between two variables, and the analysis of variance tests manipulated diameter as a treatment and that treatment effect on subsequent performance.

Another part of the answer has to do with the degrees-of-freedom associated with each analysis. The analysis-of-variance of the straight-line relationship has two treatment (regression) degrees-of-freedom; that of the diameter classes, seven. Increasing the number of degrees-of-freedom associated with a treatment, within limits, increases the likelihood that a treatment is statistically significant. This statistical property may have influenced these two sets of conclusions. This property also implies that the effect of grouping by initial diameter could possibly be made stronger, or could be shown to be significant with variables with which it is not now significant, if the categories were further sub-divided. Note, however, that while this would make the effect of grouping stronger, the likelihood that any two groups are different would decrease, since that difference is directly related to the number of observations in each group.

Some final remarks on the results seen in Tables 11 - 13 are in order. The two species were not formally compared, but examination of the way they were grouped shows more nim than kasya were in the small diameter classes at planting (Table 11). This is surprising, especially considering how sturdy a typical nim seedling is. Nim also stood out because of the strength of its diameter class differences. Note also that the two diameter classes with the widest ranges were the smallest kasya group and largest nim group (Table 11), even though the tendency of seedlings to get too large was strongest with kasya (Table 13).

Implications for nursery management

The portion of this report comparing straight-line models rejected a relationship between initial measurements and outplanting performance, while the section on diameter classes showed a strong effect due to initial diameter. The statistical factors discussed above account for these seemingly divergent results. These data lead to the conclusion that initial diameter can affect performance. Larger diameter generally is desirable in a seedling, but an unidentified upper limit seems to exist. Thus, seedlings less than a certain minimum size, which will vary by species, should be left behind in the nursery when deliveries are made. Large trees should be rejected if they have a small, poor root:shoot or are not extremely sturdy.

The reason the standard vs. Deep 5 Rootrainer debate exists is because the effects of initial diameter and of container type are being confounded. In practice, so that their root systems have time to fully exploit potting mix volume, Deep 5 seedlings are held longer in the nursery than are those from standard Rootrainers. Thus the Deep 5 typically produces a seedling with a larger diameter, and this initial difference leads to better performance in the field. This increased performance is not a property of Rootrainer depth, and would be negated by holding standard and Deep 5 seedlings for the same length of time in the nursery. Past experiences which showed equal performance by standard and Deep 5 seedlings probably showed no differences in initial seedling diameter, and vice-versa.

Nursery managers do not have a morphological predictor of seedling performance, but they can increase the field performance of the seedlings they produce if they are willing to do just a little more work. The first step to increased field performance is preventing seedlings that are too small from leaving the nursery. A root collar diameter of at least 2 mm would be a very conservative minimum for all species. This study found minimum diameters of 2.5 mm for nim and for kasya would be appropriate.

The second step to increased field performance would be to actively seek to increase root collar diameter of nursery seedlings. One way of doing this would be to hold seedlings longer, which would be more effective with standard Rootrainers than with Deep 5s. The most effective method would be to decrease seedling density in the nursery, and the most effective time for that would be at the start of the hardening-off period. About 75% of current density, or a Rootrainer every other space, should be about right. Implementing this recommendation means more labor for the nursery, but it comes at a time when labor needs are minimal. Implementation also means more racks and rack supports will be needed at each nursery, but does not call for more shadehouse area. Since these recommendations do entail an additional cost for the nursery, the grantees will need to insist upon these changes if they want them implemented. At any rate, overcrowding and the resulting tall, skinny seedlings are to be avoided from now on.

CONCLUSIONS AND RECOMMENDATIONS

1. No meaningful differences exist between standard and Deep 5 Rootrainers. Occasional differences may be found, but regular, predictable differences are found neither in morphologial measurements compared by analysis of variance nor in patterns of growth compared by testing straight-line growth models. Past observations which suggested Deep 5s outperform standard 5s may have resulted from initial diameter differences, and not from an inherent property of either container.

2. Initial condition of the root system and root plug is not a good indicator of future performance. However, poorly-formed systems which have allowed the plug to lose soil should not be allowed to leave the nursery.

3. Initial morphological measurements show little promise as indicators of future field performance.

4. Seedlings which are small in diameter or are excessively large should not be shipped.

5. The minimum critical root collar diameter will vary with species. Based on the results presented here, the minimum diameter at outplanting is 2.5 mm for nim and for kasya.

6. A root collar diameter of at least 2 mm would be a conservative minimum for all species, but acceptance of this

standard would lead to planting of many seedlings which were not large enough. For most species, the critical minimum would approach 2.5 mm, and that standard probably would not be large enough for thick-stemmed species such as gliricidya and pwa valyè.

7. Nursery practices which increase root collar diameter at planting must be encouraged. Such practices are anything that increases sunlight interception by the individual seedling: holding longer in the nursery, increasing spacing within the rack, shading as little as possible during the season, etc.

Table 1. Rankings given to describe condition of root plugs at planting.

Ranking	Initial condition of root plug
1	firm, well-bound, losing no soil, no visible problems
2	firm, but roots have over-grown the plug and many growing tips are outside it
3	soft, resulting from too little soil in the Rootrainer; soil-free gaps may be seen
4	firm, but soil has broken away during handling, causing a soil-free gap with sharp edges
5	plug has been broken, or is no longer in one piece, but no soil is lost
6	any combination of ranking 4 with ranking 2, 3, and/or 5
7	any combination not containing ranking 1 (never in a combination) or ranking 4

Table 2. Rootrainer comparison for the four species used in this study. Within a species, observation means followed by the same letter are not different (α=0.05).

Species Rootrainer	Initial roots	Initial diam	Initial height	One-month survival	Three-month surv	Three-month diam	Three-month height	Six-month surv	Six-month diam	Six-month height
	score	-mm-	-cm-	-%-	-%-	-mm-	-cm-	-%-	-mm-	-cm-
kapab -										
Standard	2.2a	3.3b	20.2b	56a	9a	3.9a	27.6a	7a	7.1a	54.9b
Deep 5	2.6a	4.0a	31.6a	59a	7a	4.3a	35.9a	4a	8.7a	70.7a
sed -										
Standard	1.7a	6.0a	17.7b	27a	0a	.	.	0	.	.
Deep 5	1.6a	6.0a	21.4a	22a	1a	5.0	19.6	1	.	.
nim -										
Standard	2.5a	3.3a	11.9b	86a	80a	4.0b	19.5b	77a	10.0b	69.3b
Deep 5	2.5a	3.3a	16.0a	84a	76a	4.3a	25.0a	73a	10.8a	75.5a
kasya -										
Standard	1.6b	3.0b	22.5b	64a	34a	4.1a	27.3b	32a	13.5a	76.5a
Deep 5	2.8a	3.5a	32.7a	60a	41a	4.4a	36.8a	34a	13.0a	76.3a

Table 3. Nim and kasya means, separated by container and by container, nursery, and site. Not all differences discussed in the text can be shown in this table. Within a species, observation means followed by the same letter are not different (α=0.05).

Species Rootrainer Nursery-Site	Three-month			Six-month			Nine-month		
	surv	diam	height	surv	diam	height	surv	diam	height
	-%-	-mm-	-cm-	-%-	-mm-	-cm-	-%-	-mm-	-cm-
nim -									
Standard	80a	4.0b	19.5b	77a	10.0b	69.3b	78a	12.6b	74.8b
Lilavois-house	76e	3.8d	16.6d	76e	9.5d	61.5d	74e	13.5d	73.8d
-wall	92d	4.2d	21.7d	84d	9.8e	68.8e	84d	11.0e	70.8e
Thomonde-house	76e	4.3d	21.4d	73e	12.6d	90.3d	73e	15.9d	96.3d
-wall	77d	3.4d	17.6d	77d	7.5e	52.5e	77d	9.4e	53.4e
Deep 5	76a	4.3a	25.0a	73a	10.8a	75.5a	74a	14.2a	80.7a
Lilavois-house	59e	4.2d	21.7d	53e	11.6d	76.7d	56e	16.0d	87.7d
-wall	89d	4.1d	24.1d	86d	9.2e	67.8e	86d	10.5e	72.3e
Thomonde-house	71e	4.5d	26.5d	71e	14.4d	102.4d	71e	18.4d	102.0d
-wall	83d	4.3d	26.8d	81d	9.4e	64.3e	81d	13.6e	70.4e
kasya -									
Standard	34a	4.1a	27.3b	32a	13.5a	76.5a	31a	17.0a	85.9a
Thomonde-house	53d	4.4d	28.3d	48d	16.6d	96.9d	47d	19.8d	111.9d
-wall	17d	3.9d	26.3d	16d	8.8e	52.2e	17d	12.1e	51.5e
Limbe									
-house	27d	3.9d	23.5d	24d	15.0d	78.9d	22d	18.3d	94.2d
-wall	39d	3.9d	29.3d	39d	10.9e	62.2e	39d	15.0e	66.1e
Deep 5	41a	4.4a	36.8a	34a	13.0a	76.3a	34a	16.6a	83.9a
Thomonde-house	51d	5.0d	37.3d	46d	17.9d	104.2d	46d	21.7d	111.3d
-wall	49d	3.9d	30.4d	40d	8.2e	50.7e	40d	11.9d	54.4e
Limbe									
-house	29d	4.3d	36.4d	17d	13.6d	68.3d	17d	15.9d	72.8d
-wall	36d	4.4d	44.6d	33d	10.9e	68.5e	33d	14.8e	73.6e

Table 4. Initial measurements of nim and kasya grouped on root plug condition ranking. Means were not tested for differences.

Variable	Root plug ranking						
	1	2	3	4	5	6	7
Nim -							
N	150	41	33	13	10	7	34
diameter(mm)	3.46	2.56	4.68	3.25	2.76	3.71	2.36
height(cm)	14.64	12.15	16.38	12.33	15.70	14.14	10.53
sturdy(ht/dia)	4.31	4.73	3.55	4.06	5.64	3.89	4.69
diameter class	5.01	3.29	6.94	4.39	3.70	5.71	2.74
Kasya -							
N	185	13	3	54	17	4	12
diameter(mm)	3.26	4.69	2.67	3.25	2.64	4.03	2.66
height(cm)	25.39	41.81	22.00	32.26	25.85	40.87	25.71
sturdy(ht/dia)	7.73	8.78	7.58	9.46	9.54	9.57	9.37
diameter class	4.40	7.23	2.67	4.28	2.47	5.25	2.83

Table 5. Nim means when observations are grouped on root plug ranking. Numbers within a row followed by the same letter are not different (α=0.05).

Variable	Root plug ranking 1	2	3	4	5	6	7
one-month - survival(%)	91.3a	63.4bd	100.0a	100.0ab	80.0ab	85.7ab	64.7b
three-month - survival(%)	84.7ab	56.1c	97.0a	100.0a	70.0bc	85.7ab	50.0c
diameter(mm)	4.2ab	3.4c	5.1a	3.6bc	4.1abc	4.6a	3.0c
height(cm)	23.5a	17.9bc	25.7a	17.6bc	21.2abc	24.9ab	14.5c
six-month - survival(%)	84.1a	56.1b	93.9a	92.3a	70.0ab	71.4ab	50.0b
diameter(mm)	11.1a	9.2ab	11.5a	11.5a	10.0ab	12.3a	6.8b
height(cm)	75.2a	64.6a	75.3a	80.2a	57.1ab	85.6a	40.6b
nine-month - survival(%)	83.1ab	53.7c	93.9a	92.3ab	70.0bc	71.4bc	50.0c
diameter(mm)	13.7a	11.5ab	14.9a	15.1a	12.4ab	16.1a	8.1b
height(cm)	80.3ab	64.8b	80.5ab	93.4a	70.7ab	90.8ab	42.4c

Table 6. Kasya means when observations are grouped on root plug ranking. Numbers within a row followed by the same letter are not different (α=0.05).

Variable	Root plug ranking 1	2	3	4	5	6	7
one-month - survival(%)	62.7a	84.6a	0a	63.0a	47.1a	75.0a	58.3a
three-month - survival(%)	42.2a	38.5a	0a	25.9a	35.3a	75.0a	16.7a
diameter(mm)	4.3a	4.8a	.	4.4a	3.6a	5.0a	3.9a
height(cm)	30.9a	38.0a	.	37.9a	31.7a	38.5a	42.5a
six-month - survival(%)	37.8ab	23.1ab	0b	22.2b	35.3ab	75.0a	8.3b
diameter(mm)	13.4a	9.7a	.	13.9a	13.0a	11.2a	13.5a
height(cm)	76.0a	47.7a	.	83.3a	84.0a	60.0a	84.0a
nine-month - survival(%)	37.3ab	23.1ab	0b	22.2b	35.3ab	75.0a	8.3b
diameter(mm)	16.7a	14.3a	.	17.5a	18.1a	15.6a	16.5a
height(cm)	85.4a	54.3a	.	90.3a	93.7a	62.0a	84.0a

Table 7. Straight-line model values (a=intercept, b=slope) for nim growing on the house site.

Response Variable	single line a	single line b	single line r^2	standard a	standard b	Deep 5 a	Deep 5 b	F-stat for=lines	P
initial height as predictor -									
6-month height	20.11	4.78	0.43	13.94	5.42	20.24	4.66	0.3156	>0.05
6-month diameter	3.33	0.67	0.43	2.43	0.77	2.93	0.66	0.6560	>0.05
9-month height	43.16	3.58	0.21	27.27	5.09	47.69	3.13	0.9053	>0.05
9-month diameter	5.41	0.80	0.31	4.95	0.87	4.87	0.81	0.1683	>0.05
initial diameter as predictor -									
6-month height	21.71	17.34	0.23	30.80	13.22	10.91	22.37	2.7605	>0.05
6-month diameter	2.34	2.76	0.29	3.40	2.30	1.04	3.34	1.7884	>0.05
9-month height	42.24	13.55	0.12	45.52	11.72	39.16	15.58	0.5812	>0.05
9-month diameter	3.69	3.47	0.22	5.84	2.63	0.86	4.55	1.9758	>0.05

Table 8. Straight-line model values (a=intercept, b=slope) for nim growing on the wall site.

Response Variable	single line			standard		Deep 5		F-stat for=lines	P
	a	b	r^2	a	b	a	b		
initial height as predictor -									
6-month height	26.74	2.30	0.25	13.14	3.40	30.36	2.01	1.7591	>0.05
6-month diameter	4.05	0.30	0.33	1.46	0.53	4.27	0.26	8.3314	<0.01
9-month height	28.34	2.35	0.21	10.31	3.70	38.37	1.76	2.2201	>0.05
9-month diameter	6.22	0.30	0.07	2.70	0.53	9.21	0.15	1.5366	>0.05
initial diameter as predictor -									
6-month height	20.48	12.09	0.31	19.06	11.41	18.71	13.46	1.5054	>0.05
6-month diameter	2.46	1.78	0.53	2.41	1.75	2.35	1.85	0.5955	>0.05
9-month height	23.41	11.85	0.28	19.68	11.63	25.64	12.31	1.5168	>0.05
9-month diameter	5.06	1.65	0.12	4.21	1.16	5.59	1.75	1.2993	>0.05

Table 9. Straight-line model values (a=intercept, b=slope) for kasya growing on the house site.

Response Variable	single line			standard		Deep 5		F-stat	
	a	b	r^2	a	b	a	b	for=lines	P
initial height as predictor -									
6-month height	83.16	0.39	0.01	82.10	0.44	85.93	0.31	0.0047	>0.05
6-month diameter	15.16	0.05	0.01	15.28	0.04	15.37	0.05	0.0079	>0.05
9-month height	104.59	0.06	0.00	103.90	0.11	104.68	0.05	0.0020	>0.05
9-month diameter	20.85	0.04	0.00	21.96	0.14	21.66	0.05	0.2231	>0.05
initial diameter as predictor -									
6-month height	54.38	11.72	0.04	67.45	7.71	36.97	16.25	0.1169	>0.05
6-month diameter	8.99	2.28	0.05	11.29	3.17	5.49	3.17	0.1756	>0.05
9-month height	60.75	13.80	0.05	69.75	12.13	33.92	20.16	0.2944	>0.05
9-month diameter	11.87	2.41	0.04	15.82	1.18	7.16	3.65	0.1922	>0.05

Table 10. Straight-line model values (a=intercept, b=slope) for kasya growing on the wall site.

Response Variable	single line			standard		Deep 5		F-stat	
	a	b	r^2	a	b	a	b	for=lines	P
initial height as predictor -									
6-month height	44.69	0.46	0.09	52.02	0.29	36.46	0.64	0.7265	>0.05
6-month diameter	7.17	0.09	0.13	8.15	0.08	5.35	0.12	2.0607	>0.05
9-month height	51.20	0.38	0.05	52.92	0.35	48.93	0.43	0.0471	>0.05
9-month diameter	10.45	0.11	0.11	12.29	0.07	7.99	0.16	1.6675	>0.05
initial diameter as predictor -									
6-month height	40.78	4.94	0.05	25.53	10.25	39.60	4.80	0.4252	>0.05
6-month diameter	4.45	1.51	0.20	2.26	2.44	3.23	1.65	2.2462	>0.05
9-month height	37.17	7.14	0.09	16.40	7.87	40.73	5.97	0.6069	>0.05
9-month diameter	6.73	1.94	0.18	4.86	2.83	5.12	2.15	1.6418	>0.05

Table 11. Initial measurements for nim and kasya when initial diameters were divided into 8 categories. Means were not tested for statistical differences.

Variable	Diameter category 1	2	3	4	5	6	7	8
Nim - diameter range	1.0-1.9	2.0-2.3	2.4-2.5	2.6-2.9	3.0-3.4	3.5-4.0	4.1-4.7	4.8-7.5
N	37	36	27	29	35	51	38	35
diameter(mm)	1.68	2.12	2.43	2.74	3.19	3.75	4.47	5.67
height(cm)	8.27	9.07	11.20	12.66	13.96	15.65	20.17	18.63
sturdy(ht/dia)	5.04	4.29	4.62	4.63	4.40	4.17	4.49	3.31
condition	3.84	2.75	2.37	2.59	2.26	1.88	1.95	2.40
Kasya - diameter range	1.2-2.5	2.6-2.7	2.8-2.9	3.0-3.2	3.3-3.4	3.5-3.6	3.7-3.9	4.0-6.5
N	55	34	37	31	33	18	28	52
diameter(mm)	2.19	2.64	2.85	3.09	3.35	3.56	3.80	4.77
height(cm)	15.84	22.06	24.00	28.53	25.73	27.94	33.57	43.75
sturdy(ht/dia)	7.11	8.35	8.41	9.24	7.68	7.85	8.84	9.16
condition	3.11	2.26	1.86	1.93	1.55	1.39	2.21	2.19

Table 12. Measurements of nim when initial diameter was divided into 8 categories. Numbers within a row followed by the same letter are not different (α=0.05).

Variable	Initial diameter (mm) 1.0-1.9	2.0-2.3	2.4-2.5	2.6-2.9	3.0-3.4	3.5-4.0	4.1-4.7	4.8-7.5
one-month - survival(%)	51.4d	66.7cd	77.8bc	86.2ab	91.4ab	100.0a	100.0a	100.0a
three-month - survival(%)	35.1c	47.2c	66.7b	86.2ab	85.7ab	98.0a	100.0a	97.1a
diameter(mm)	2.3g	2.7fg	2.9f	3.4e	3.9d	4.3c	5.1b	5.5a
height(cm)	10.7e	12.6de	14.8de	16.8cd	20.7bc	23.6b	30.6a	29.6a
six-month - survival(%)	32.4d	44.4d	63.0c	82.8bc	82.9bc	96.1ab	100.0a	91.4ab
diameter(mm)	4.5e	7.1e	7.1de	8.5cd	10.4bc	10.9b	12.9a	13.8a
height(cm)	31.1d	46.1d	53.5cd	58.0bc	76.1b	74.4b	91.4a	92.2a
nine-month - survival(%)	29.7e	44.4d	63.0c	86.2ab	82.9bc	96.1ab	100.0a	91.4ab
diameter(mm)	6.3c	8.9c	8.8c	10.1c	15.7ab	14.0b	15.9ab	16.8a
height(cm)	35.2d	53.2d	62.3cd	61.1cd	88.2ab	80.5bc	91.5ab	95.2a

Table 13. Measurements of kasya when initial diameter was divided into 8 categories. Numbers within a row followed by the same letter are not different (α=0.05).

	Initial diameter (mm)							
Variable	1.2-2.5	2.6-2.7	2.8-2.9	3.0-3.2	3.3-3.4	3.5-3.6	3.7-3.9	4.0-6.5
one-month - survival(%)	43.6c	55.9bc	62.2bc	58.1bc	63.6abc	88.9a	71.4ab	73.1ab
three-month - survival(%)	21.8a	29.4a	43.2a	32.3a	42.4a	61.1a	46.4a	42.3a
diameter(mm)	3.2d	3.3d	4.2bc	3.8cd	4.4abc	4.3abc	4.9ab	5.0a
height(cm)	24.3bc	25.7bc	30.5bc	27.8bc	31.3abc	32.0abc	34.7ab	43.9a
six-month - survival(%)	21.8a	23.5a	32.4a	29.0a	39.4a	55.6a	39.3a	38.5a
diameter(mm)	10.9bc	8.6c	16.8ab	10.8c	14.3ab	11.6bc	17.5a	13.3ab
height(cm)	64.8ab	52.8b	99.3a	63.0ab	76.9ab	70.5ab	95.0a	76.1ab
nine-month - survival(%)	21.8a	20.6a	32.4a	29.0a	39.4a	55.6a	39.3a	38.5a
diameter(mm)	14.6a	11.3a	19.9a	14.3a	17.4a	15.9a	19.6a	17.8a
height(cm)	69.1a	60.3a	104.4a	71.7a	87.2a	84.2a	102.9a	85.8a

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