FOREST & FARM PLANTATION MANAGEMENT COOPERATIVE

WAIHI TOPPLING TRIAL — ASSESSMENT OF ROOTS FOLLOWING SEVERE TOPPLING

J. D. Tombleson & J. A. Turner

Report No. 52 November 1998

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EXECUTIVE SUMMARY

WAIHI TOPPLING TRIAL — ASSESSMENT OF ROOTS FOLLOWING SEVERE TOPPLING

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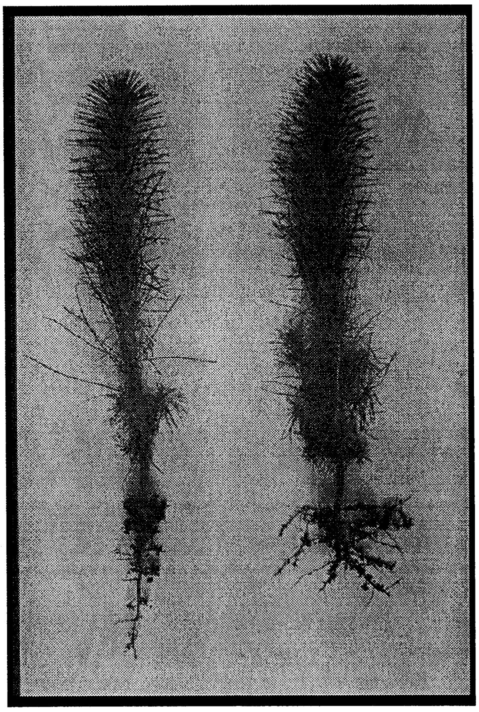
A toppling trial was established on a very exposed fertile farm site near Waihi in September 1996. The trial compares conventional nursery conditioned seedlings with severe lateral root trimmed seedlings which had well defined taproots that could not easily be distorted at planting. The trees were carefully planted to avoid root distortion. In August 1997 when the trees were 11 months of age the trial was subjected to a severe wind storm with westerly winds averaging up to 100 km/ hr. More than 50% of the trees toppled with an average lean of 17°. 40% of the trees contained in the trial had severely 'socketed'. The incidence of toppling and degree of lean was similar for both nursery treatments. In April 1998 (trees aged 19 months) the trial was re-assessed to quantify stem recovery from the earlier topple at 11 months. At the same time a sample of 16 trees (8 severe lateral root trim and 8 conventionally root conditioned trees) were excavated and the roots assessed for any effects from toppling. Only three of the sixteen trees contained laterals in all four quadrants. Vertical root distributions were also distorted. 22% of the roots were assessed at an angle above the horizontal. It is concluded that despite careful planting, the seedlings contained uneven and 'distorted' root systems. The assessment to quantify recovery from severe topple showed that almost all trees contained within the trial had fully recovered to the upright position eight months following the storm event.

Trial Objective

The objective of the Waihi trial was to evaluate the stability of seedlings specifically grown in the nursery to produce well defined tap roots as shown in Figure 1. Following lifting, the lateral roots were severely trimmed using hand shears. The premise is that such root systems will readily regenerate from the tap root creating strong, dominant and well developed tap roots resulting in greater tree stability. Another premise is that the severely trimmed laterals will also ensure that the root system can not be distorted at planting, possibly contributing to improved stability. These treated seedlings are compared with conventionally produced seedlings which do not contain a well defined tap root as shown below.

Figure 1: Seedling on left received a deep undercut to produce a well defined tap root in comparison to conventional nursery root conditioned seedling shown on right.



Site Description

The Waihi toppling trial was established in September 1996 on a fertile farm site located near Waihi. The trial is located on a very exposed ridge top with a west and east aspect and is extremely exposed to winds from all directions. The soil is described as being Waitekauri sandy loam, hill soil (55H) from Waihi Ash overlying rhyolite and andesite. The annual rain fall is approximately 2,500 mm.

Establishment

Considerable care was taken when planting the seedlings to avoid compromising future tree stability and hence confounding the trial. A 'best practices' planting technique was applied which involved soil cultivation to a depth of approximately 26 cm, equal to the depth of the spade blade. In the centre of each cultivated spot a hole was created with a minimum depth of 15cm and width of approximately 60 mm to ensure that the seedling root system could be inserted without incurring any distortion. Following insertion of the roots into the planting hole the soil was firmed. All trees were planted to a depth whereby the base of the stem needles were just covered with soil. Verification of planting quality was carried out by an independent forestry consultant Mr Robin Trewin who confirmed that the planting technique used met all the required standards.

The trees were released using Velpar herbicide applied at 3 g/ tree using a 'Weed-A-Meter' applicator with a wide skirt. Because of the warm site along with germination and vigorous growth of summer grasses, such as paspalum, a further applications of Velpar were applied in December and the following autumn.

Plant Material and Nursery Treatments

Plant material used was GF19 seedlings which were raised in the ***Forest Research*** Nursery, Rotorua. The following nursery regimes were applied:

Treatment:

- a late and deep undercut to promote the formation of a long single tap root carried out when the seedlings were just over 30 cm tall;
- seedlings lifted on 1 September;
- seedlings were trimmed individually to a maximum total width of 4 cm using hand shears on 2 September;
- seedlings were cool stored at the ***Forest Research*** Nursery until dispatched in planting boxes and planted on 6 September 1996.

The Control seedlings received the following conventional nursery root conditioning regime:

Control:

- undercut when the seedlings were 20 cm tall to leave a 6 to 8 cm tap root;
- 5 weeks later seedlings were lateral pruned;

- every 2 to 4 weeks after lateral pruning, wrenching was carried out depending on the weather. During dry periods wrenching was delayed.

Trial design

Each severe lateral root trimming trial comprised the following:

- 98 paired plots (each plot being two trees), laid out in a block comprising 14 x 14 trees (as shown in Figure 2);
- each plot comprises a conventionally root conditioned seedling (Control) and a severe lateral root trimmed seedling (Treatment);
- an initial spacing of 4.0 x 4.0m = 625 stems/ ha;
- two surround rows planted at the same spacing as the trial.

Figure 2: Layout for severe lateral root trimming trial.

X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	X	X
X	X	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	X	X
X	X	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	X	X
X	X	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	X	X
X	X	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	X	X
X	X	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	X	X
X	X	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	X	X
X	X	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	X	X
X	X	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	X	X
X	X	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	X	X
X	X	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	X	X
X	X	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	X	X
X	X	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	X	X
X	X	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

KEY

C = Control seedling (conventionally root conditioned)

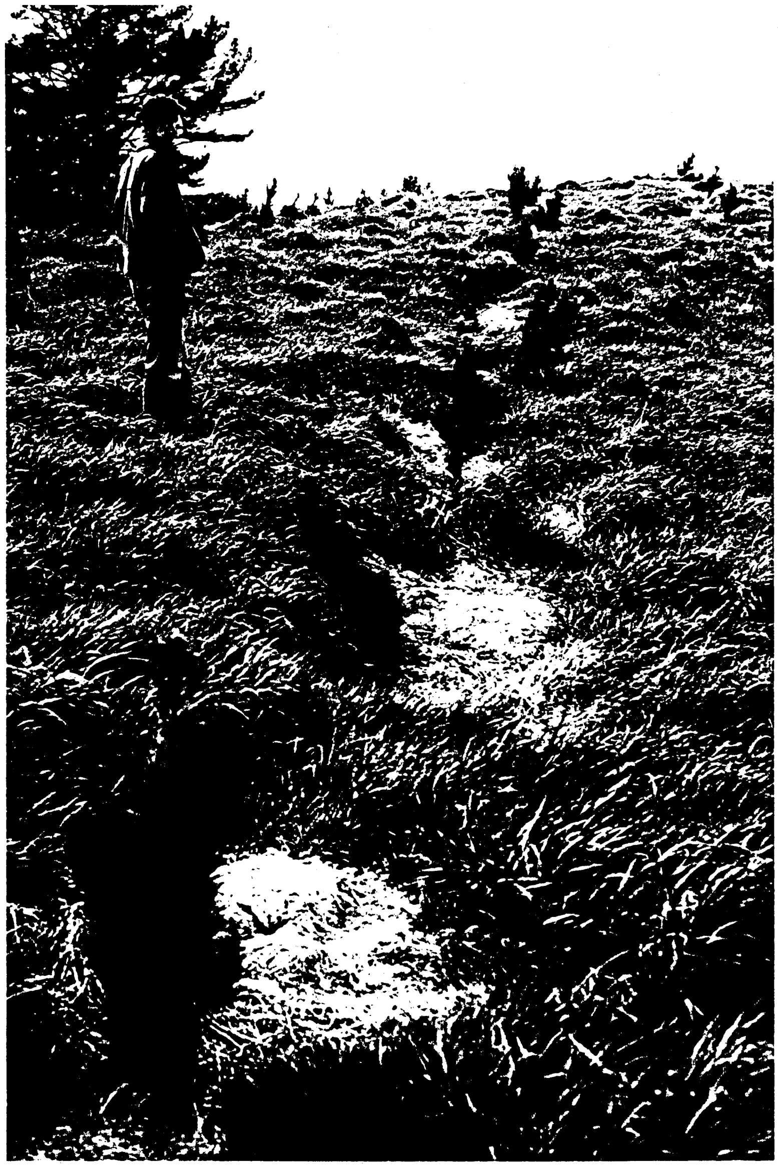
T = Treatment seedling (severe lateral root trimmed)

X = Surround seedling

Storm Event

On 14th August 1997 a severe storm resulted in a high incidence of topple (Figure 3). Wind and rainfall data, was obtained from the nearest meteorological station located 34 km away at Whangamata. This provided details of westerly winds averaging up to 100 km/ hr, along with 35 mm of rain fall over the previous four days.

Figure 3: Severe toppling at age 11 months. Note the good weed control.



Assessments

The trial was assessed for height, angle of lean, direction of lean, and incidence of socketing on the following occasions:

9 April 1997	Age 7 mths	Assessed for height and survival
14 August 1997	Age 11 mths	Assessed for height and lean following the storm event
6 April 1998	Age 19 mths	Assessed for height, diameter, degree of lean and roots were excavated

Root Excavation and assessment

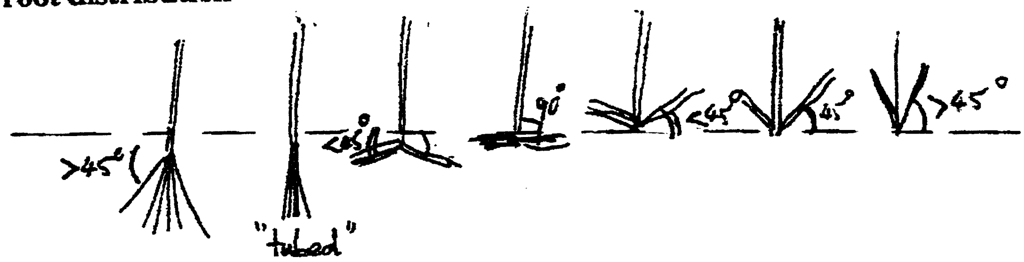
The assessment, carried out in April 1998, aged 19 months, involved the excavation of a sample of 16 root systems using a spade. Eight trees were chosen from the Treatment and eight trees from the Control. Trees were selected across the range of topple severity.

Root systems were assessed using the Menzies' Taproot Score (see Figure 5) and Lateral Root Score as shown in Figure 6. Root systems were also assessed for vertical root distribution using the Modified Menzies' Taproot Score as shown in Figure 4.

Depth of planting was measured on all sample trees excavated. This involved measuring the distance from ground level to the top of the root plate.

Figure 4 Modified Menzies' Taproot Score

(a) Vertical root distribution



Score 0 1 2 5 7 10 12

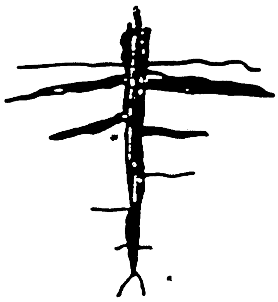
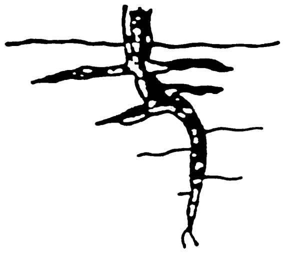
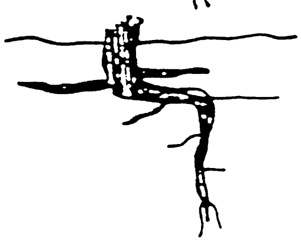
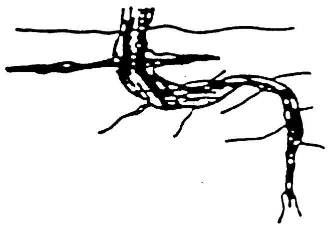
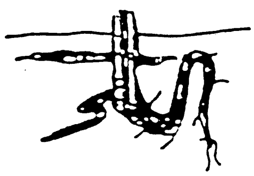
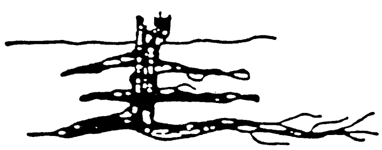
Photographs of Root Systems

The lateral and tap root systems of all 16 trees were photographed and are contained in Appendix 1. Photos showing the lateral roots were taken with the north side (which was marked in the field at the time of excavation) of the stem facing upwards on the page.

RESULTS

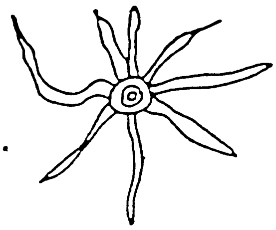
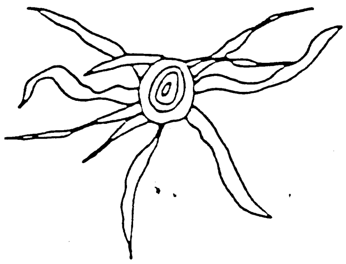
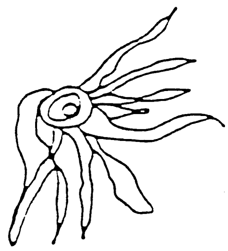
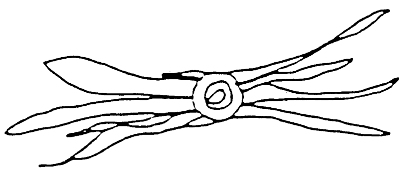
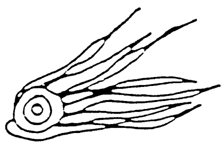
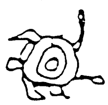
An assessment carried out at 11 months showed that more than 50% of the trees contained in the trial had toppled, with an average lean of 17° as shown in Figure 7. There was no difference between the Treatment and Control for incidence of topple.

Figure 5: Menzies' Taproot Score

SCORE	DIAGRAM	DESCRIPTION
0		Strong, dominant, well developed taproot
2		Stunted, slightly malformed, but still a definite taproot
4		Taproot distinctly hooked
6		Taproot quite badly hooked, but downward development still present
8		Taproot severely deformed into two or more fracture zones, but growth still downward
10		Taproot does not come below a horizontal plane, or no taproot at all. Subtract one point for each strong sinker present.

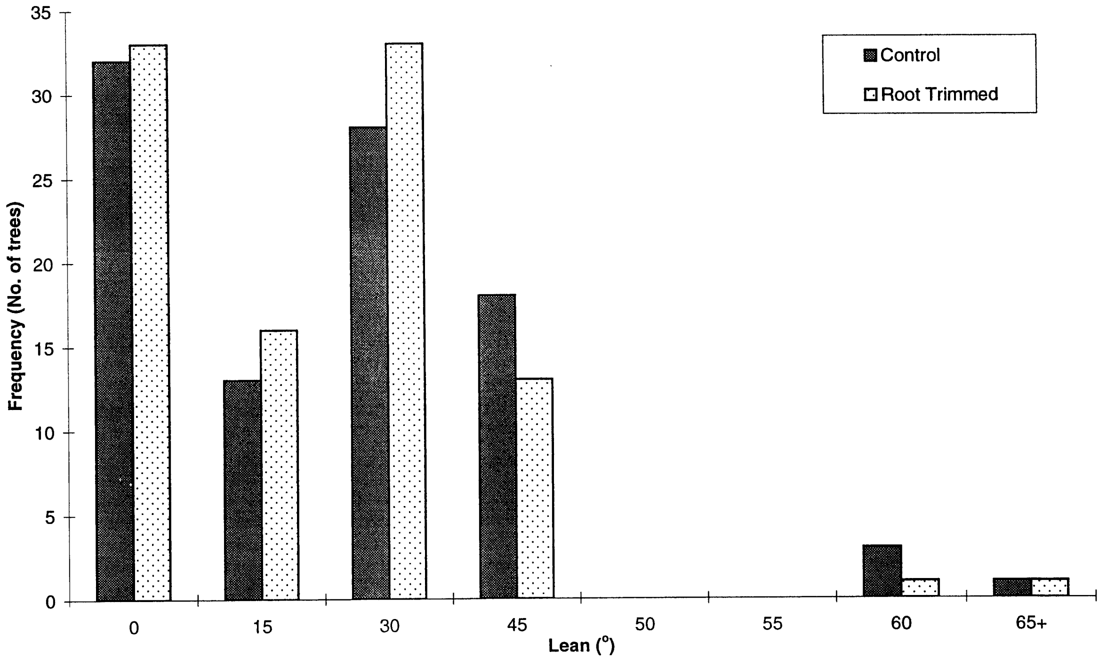
Menzies' Taproot Score. The score ranges from 0 for a good taproot system, to 10 for a poor one.

Figure 6: Menzies' Lateral Root Score

SCORE	DIAGRAM	DESCRIPTION
0		Laterals on all four sides
2		Laterals in three quadrants
4		Laterals in two adjacent quadrants
6		Laterals in two opposite quadrants
8		Laterals in one quadrant
10		No significant laterals in any quadrant

Menzies' Lateral Root Score. The score ranges from 0 for a good lateral root system, to 10 for a poor one.

Figure 7: Frequency and angle of lean resulting from toppling.



Lean direction and angle

All 16 trees excavated were assessed for direction and angle of lean as shown in Table 1. There were no differences in lean between the Treatment and the Control trees assessed at 11 months. Fifteen trees from the 16 trees excavated leaned towards the north or east quadrants at both the 11 and 19 month assessments (see Table 1). This direction of lean was as a result of the (prevailing) wind storm which was recorded to come from a westerly direction. At the time of the 11 month assessment 40% of the trees contained in the trial had severely 'socketed'. Socketing was also observed to occur in the opposite quadrant to that recorded above, created as a result of a wind storm from the opposing north easterly direction (see Figure 8).

Effect of Treatment on Lean Recovery

There is a moderately strong linear relationship ($R^2 = 0.76$) between tree lean measured at age 11 months (August 1997) and the change in lean measured at 19 months (April 1998). Trees which had a greater lean at 11 months have shown greater recovery (Figure 7a). There is no significant effect of treatment ($p > 0.05$) on this relationship. The effect of any topple which may have occurred between 11 and 19 months was incorporated into the analysis of variance using a variable representing the difference in direction of topple. There was no significant effect ($p > 0.05$), suggesting results were not confounded by any topple subsequent to age 11 months.

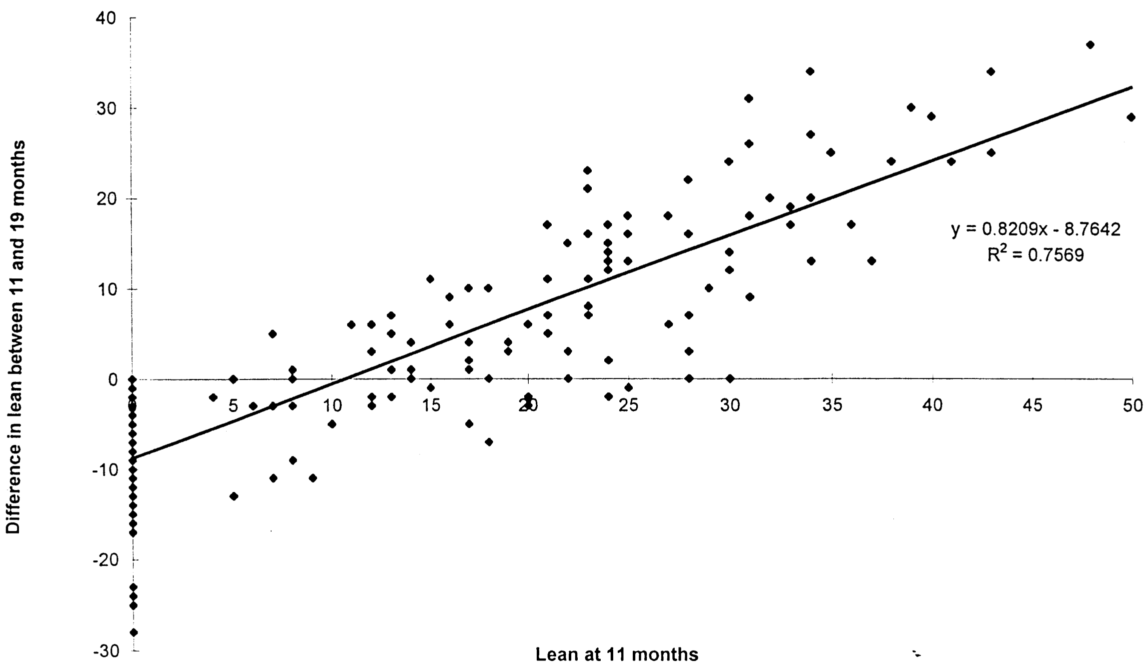


Figure 7a: Relationship between lean (°) measured at 11 months and recovery measured at 19 months of age.

TABLE 1: Summary of tree growth, lean and root assessment data

TREE NO	HEIGHT		DIAMETER	LEAN (degrees)			LEAN DIRECTION		ROOT ASSESSMENT			% ROOTS				
	11 -mths (m)	19-mths (m)	19-mths @ 30cm (mm)	11 -mths Root collar	19-mths Root collar	19-mths @ 30cm	11-mths	19-mths	Tap Root	Lateral 19-mths	Planting Depth	0	2	5	7	12
Root trim																
17	0.87	2.00	50	36	19	7	East	East	2	0	22	20	30	20	30	0
55	0.76	1.80	30	0	0	0	North	East	0	2	14	30	30	30	10	0
79	0.58	1.82	47	0	4	4	North	East	2	2	14	30	20	25	25	0
111	0.92	2.05	45	0	1	1	North	East	0	6	15	35	10	35	20	0
129	0.95	2.05	56	13	15	8	North/E	East	0	0	15	15	25	20	40	0
135	0.52	1.35	31	0	6	6	North	East	0	2	15	40	20	25	15	0
177	0.95	1.90	50	0	25	12	North	East	0	2	9	20	20	40	15	5
195	0.82	1.92	48	12	9	4	East	West	4	2	13	40	15	20	25	0
Mean	**0.80**	**1.86**	**45**	**8**	**10**	**5**			**1**	**2**	**15**	**29**	**21**	**27**	**23**	**1**
Control																
36	0.78	1.70	46	9	20	7	East	East	4	0	11	10	35	55	0	0
50	0.80	1.65	46	34	21	0	South/E	East	2	4	14	10	20	25	25	20
62	1.18	1.97	68	17	15	15	East	East	0	2	10	30	20	15	20	15
68	0.65	2.49	47	0	0	0	North	East	2	4	13	0	55	15	0	30
90	0.95	1.80	52	18	18	4	East	East	2	2	0	50	25	25	0	0
100	0.80	1.90	53	28	28	6	East	East	4	4	10	55	35	5	0	5
118	0.83	1.75	55	0	2	2	North	East	0	6	10	30	30	20	20	0
156	0.65	1.95	38	28	25	4	East	East	4	2	10	50	15	20	15	0
Mean	**0.83**	**1.90**	**51**	**18**	**16**	**5**			**2**	**3**	**10**	**29**	**29**	**23**	**10**	**9**

Figure 8 Socketing occurred on 40% of the trees at 11 months of age. Socketing also occurred in the opposing quadrant

Root Assessment

Menzies Taproot Score

All 16 trees have been assessed using the Menzies' Taproot Score as shown in Table 1. All 16 trees have a score of 0 to 4 (see Table 1). Seven of the 16 trees excavated have 'strong, dominant, well developed taproots' (score 0). Five trees have 'stunted, slightly malformed, but still a definite taproot' (score 2). The remaining four out of 16 trees have 'distinctly hooked taproots' (score 4) (see Table 2).

The Treatment trees have a higher proportion of strong, dominant, well developed taproots compared to the Control (see Table 2).

The relationship between Menzies' taproot score and the incidence of topple is significant ($p>0.05$).

Table 2: Menzies' Taproot Score, assessed at age 19 months

Score	Description	Root Trim No of trees	Control No of trees
4	Taproot distinctly hooked	1	3
2	Stunted, slightly malformed, but still a definite taproot	2	3
0	Strong, dominant, well developed taproot	5	2
	TOTAL No of trees	**8**	**8**
	Weighted Average	**1.0**	**2.3**

Menzies' Lateral Root Score

Each of the 16 trees has been assessed for the Menzies' Lateral Root Score as shown in Table 1. Only three of the 16 trees excavated contained laterals on all four quadrants. Eight trees contained laterals in three quadrants and five of the 16 trees contained laterals in only two quadrants (see Table 3). The Treatment trees had slightly better lateral root distributions than the Control (see Table 3)

Table 3: Menzies' Lateral Root Distribution Score, assessed at age 19 months

Score	Description	Root Trim No of trees	Control No of trees
8	Laterals in one quadrant	0	0
6	Laterals in two opposite quadrants	1	1
4	Laterals in two adjacent quadrants	0	3
2	Laterals in three quadrants	5	3
0	Laterals on all four quadrants	2	1
	TOTAL No of trees	**8**	**8**
	Weighted Average	**2.0**	**3.0**

Depth of Planting

Depth of planting was measured for each of the 16 trees excavated and is shown in Table 1. On average the planting depth was 12 cm which is a common depth to provide initial stability.

Menzies' Vertical Root Distribution Score

Each of the 16 trees has been assessed for % of roots contained in the seven Vertical Root Distribution Scores (see Table 1). 54% of the roots (averaged across the treatment and Control) are at an angle less than the horizontal ie a vertical root distribution score of 2 or 0. 25% of the roots were horizontal and 22% of the roots were distorted upwards at an angle above the horizontal. ie., a Vertical Root Distribution Score of 7 and 12 (see Tables 1 & 4).The weighted average Menzies' Vertical Root Distribution score is 3.4 and 3.5 for the severe root trim and Control respectively.

Table 4: Menzies' Vertical Root Distribution Score

Score	Description	Root Trim	Control
		% Roots	
12	Roots at an angle greater than **45° above** the horizontal	1	9
7	Roots at an angle less than **45° above** the horizontal	23	10
5	Horizontal roots	27	23
2	Roots at an angle less than **45° below** the horizontal	21	29
0	Roots at an angle greater than **45° below** the horizontal	29	29

19 Month Assessment

In April 1998 the trial was assessed for recovery from toppling which occurred at the earlier age of 11 months. Almost all trees had recovered to an upright position as shown in Figure 9.

Figure 9: Waihi toppling trial following the storm event at age 11 months

Figure 10: Waihi toppling trial eight months later at age 19 months

DISCUSSION

To the authors' best knowledge this study is the first occasion whereby trees have been excavated from a replicated trial on a fertile farm site that has also suffered a high incidence of toppling. The considerable incidence of root distortion encountered gives rise to the following discussion:

Root distortion

The absence of lateral roots being initiated in one or more quadrants may partially be related to toppling severity and socketing. Tree Nos. 50 and 100 severely toppled and also have very distorted lateral root systems (see photographs in Appendix 1) possibly caused through the compression and shear action associated with socketing. However, in contrast, tree Nos. 111 (Treatment) and 118 (Control) (see photographs in Appendix 1) had the two most distorted lateral root distributions (score 6), but neither of these trees had previously toppled (see Table 1). Root distortion as a result of incorrect planting technique is potentially a cause but is very unlikely on the basis that considerable care was taken to ensure that this trial was planted using correct planting techniques. Further more any root distortion as a result of incorrect planting is eliminated on the basis that tree No. 111 (Treatment) which had the most distorted lateral root system had its laterals trimmed in the nursery to a maximum length of 2 cm.

The high incidence of lateral roots being distorted at an angle above the horizontal (see Table 4) is a common feature of the 16 trees excavated. Root distortion as a result of incorrect planting technique is eliminated for the reason stated above and also for the reason that the severe lateral root trimmed trees displayed this characteristic. The most likely explanation for this distortion of the laterals is that the roots have come to the surface to feed on the nutrients and that the high annual rainfall of 2,500 mm means that soil moisture is not limiting and thus the root systems are not forced to grow downwards as they may be forced to do in a drier climate. The weed free environment around each tree may have also contributed to ensuring the soil moisture was not reduced.

Nine of the 16 trees had distorted taproots. An explanation for this may be the presence of a shallow B horizon which was presumably had a lower nutrient status and coupled with its compactness resulted in the taproots being malformed.

Weed growth and incidence of topple

During the assessment at age 11 months some of the trees had paspalum grass growth at their base as shown in Figure 11. It was interesting to note that none of these trees had toppled nor had they socketed. This stability could be a result of the grass binding the soil surface and preventing socketing and subsequent socketing. It would be interesting to know if the high incidence of toppling could have been reduced, had the weed control via herbicide application been less thus ensuring there was some grass cover to bind the soil surface.

Figure 11: Trees which had grass growing at their base were not socketed or toppled

Tree recovery

The most interesting result for this trial is that despite the very high incidence of severe topple assessed at aged 11 months, almost every tree recovered.

CONCLUSION

Historically root distortion associated with toppled trees has been considered to be a result of poor quality planting. The trees planted in this trial have unquestionably been correctly planted therefore the presence of root distortion can not be automatically linked with poor quality planting.

APPENDIX I

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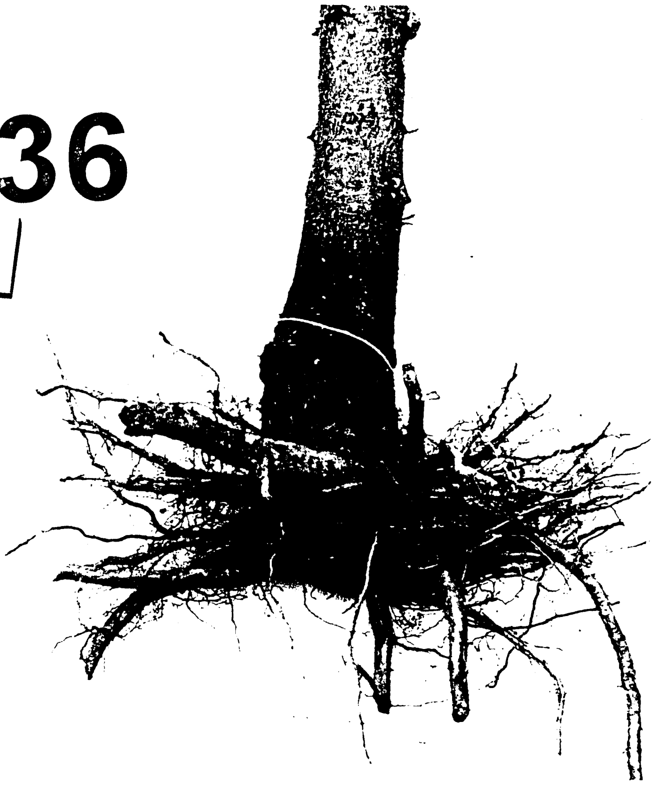

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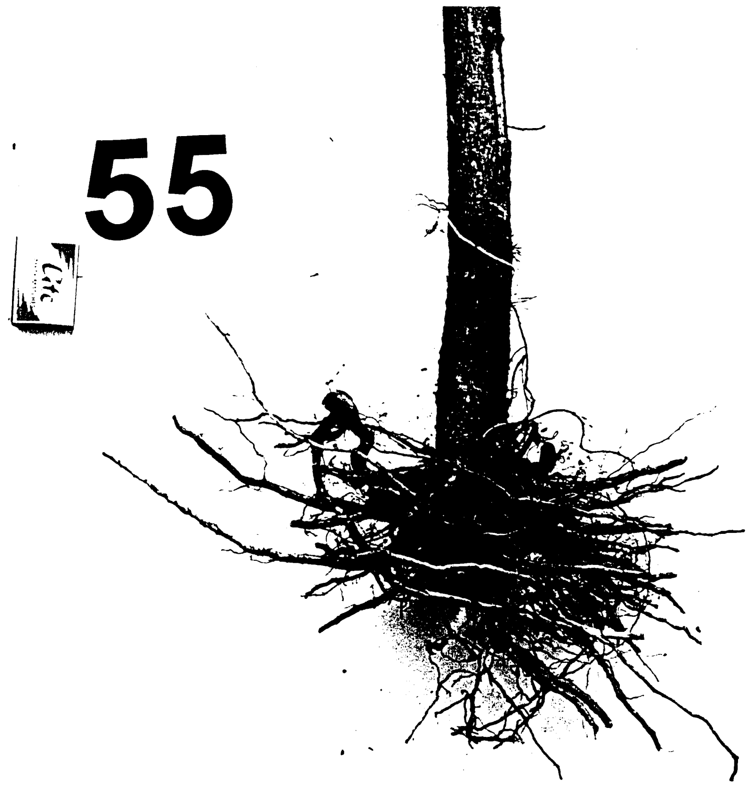
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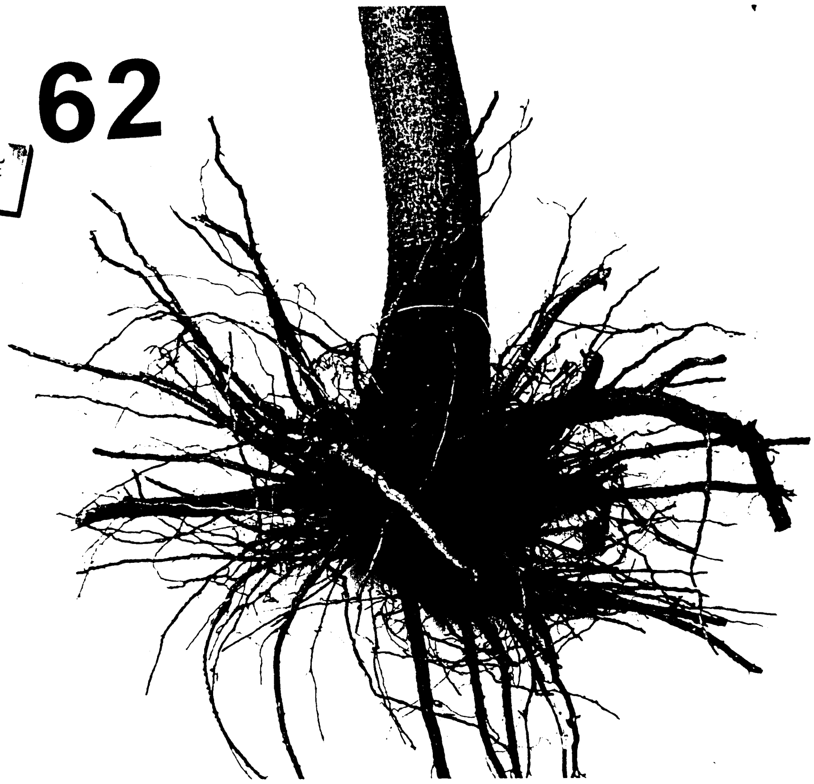

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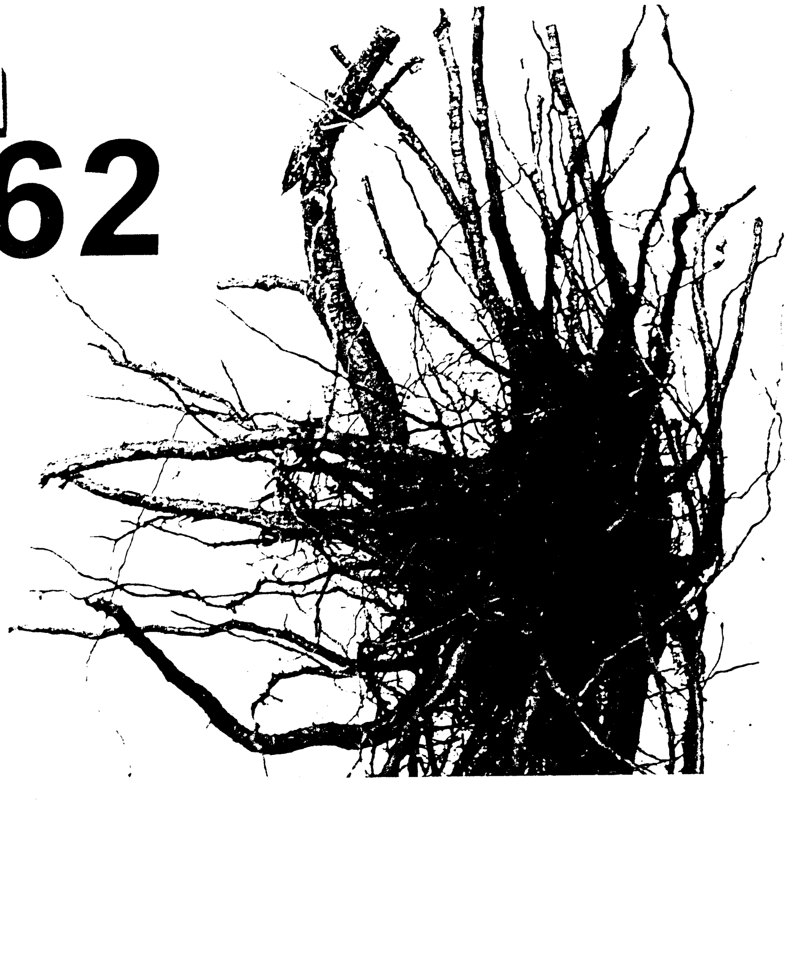

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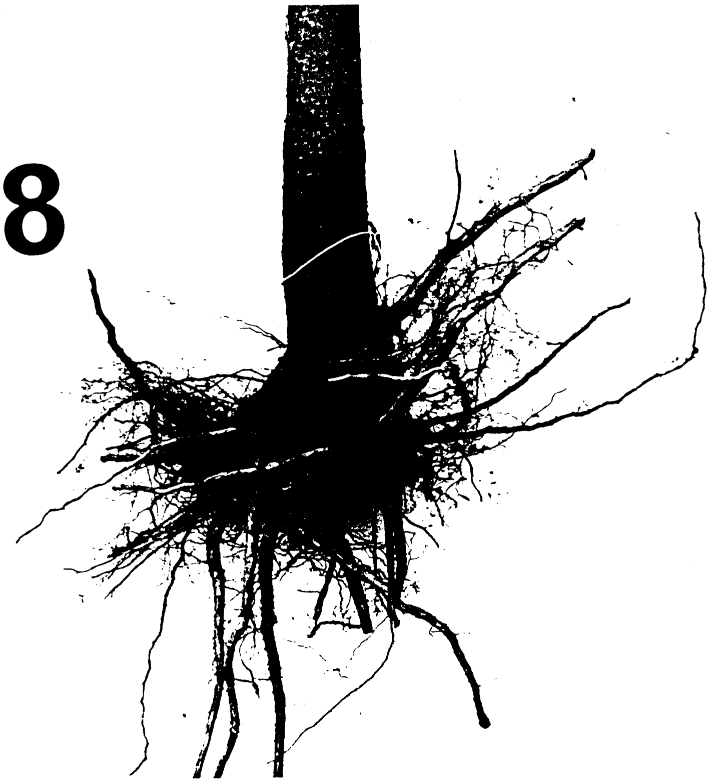

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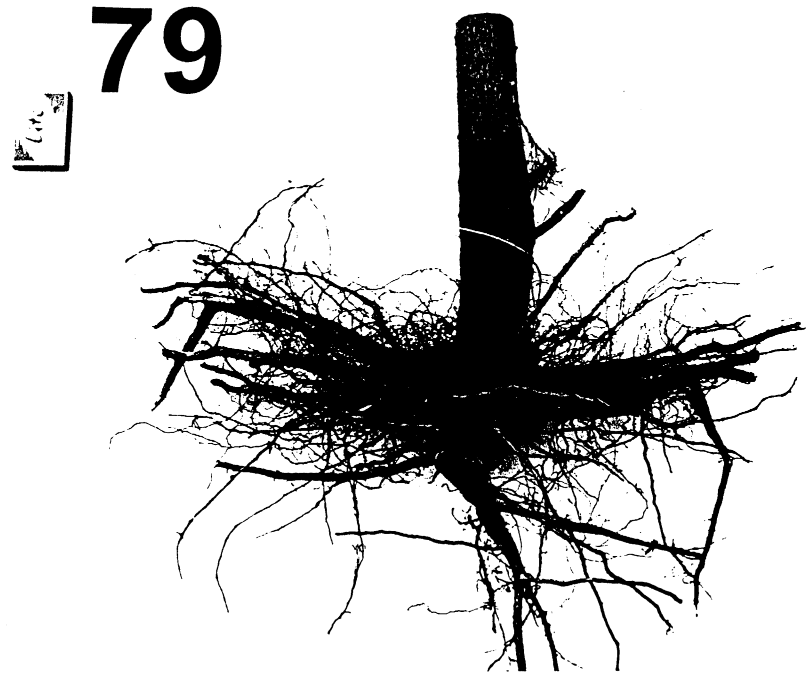
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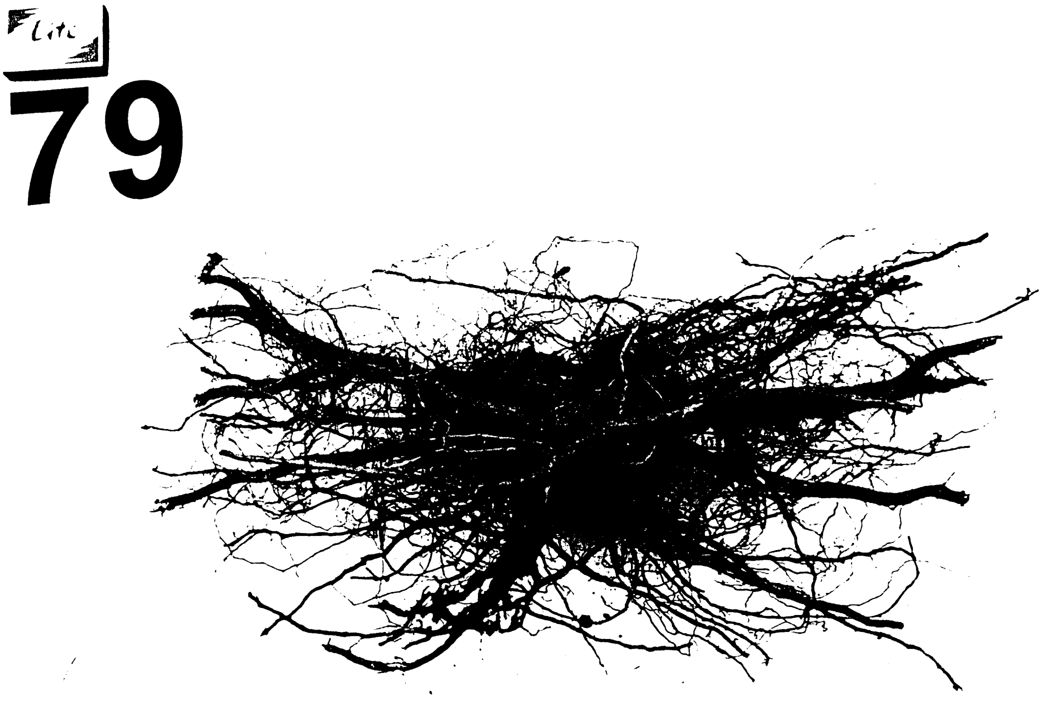
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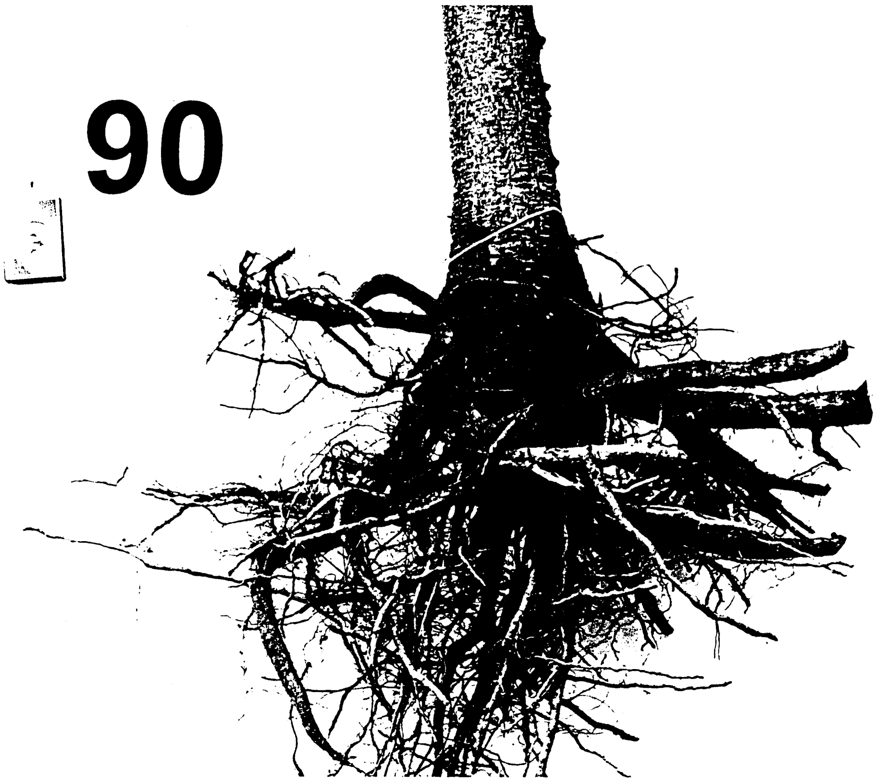
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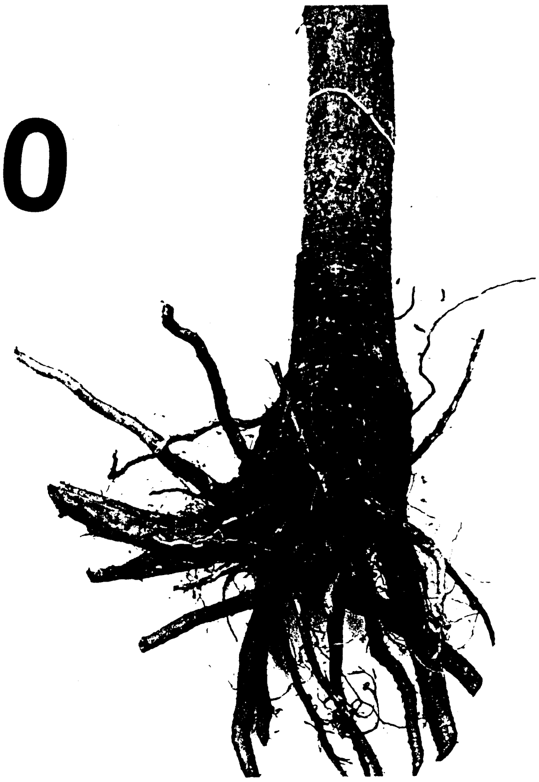

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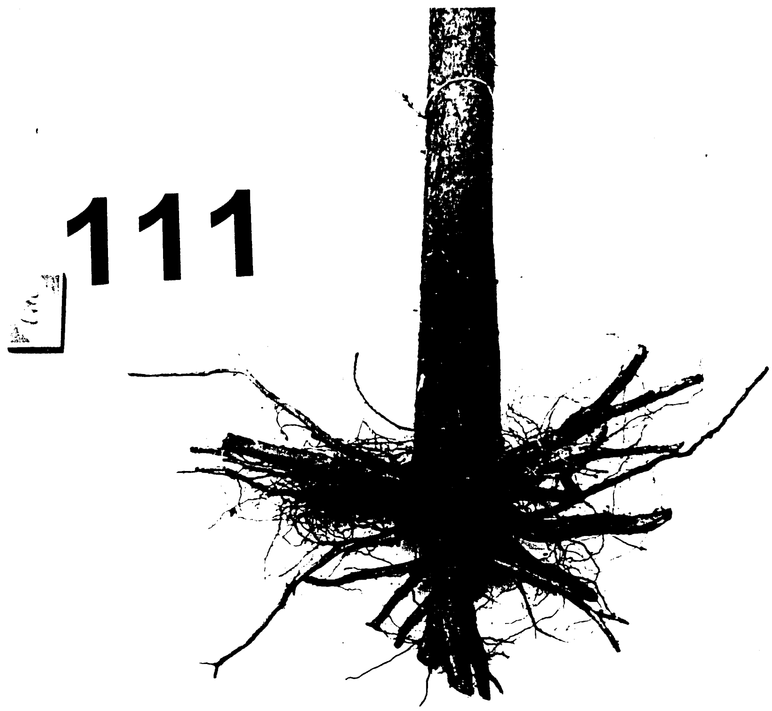
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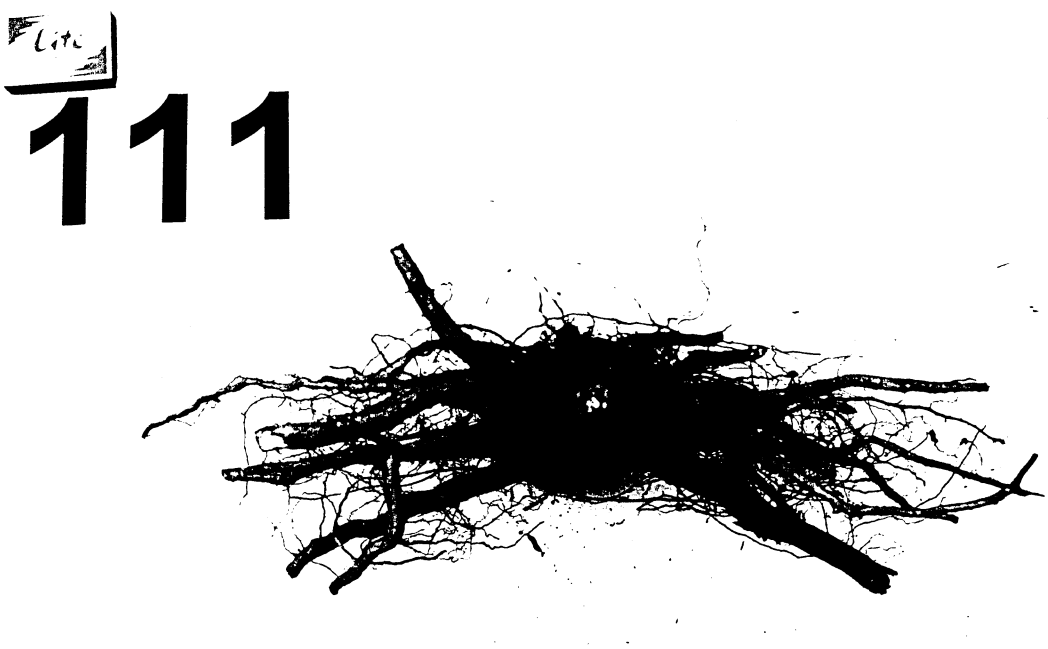
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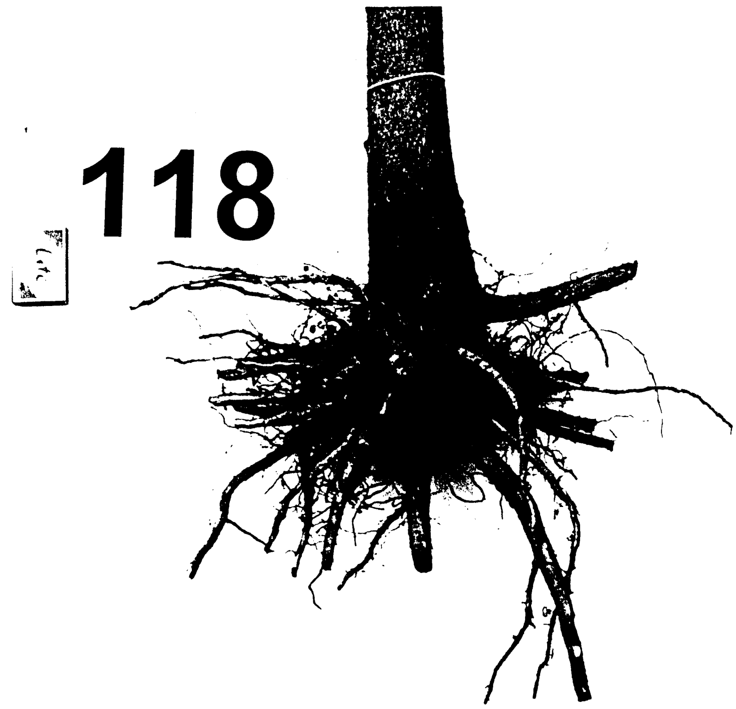
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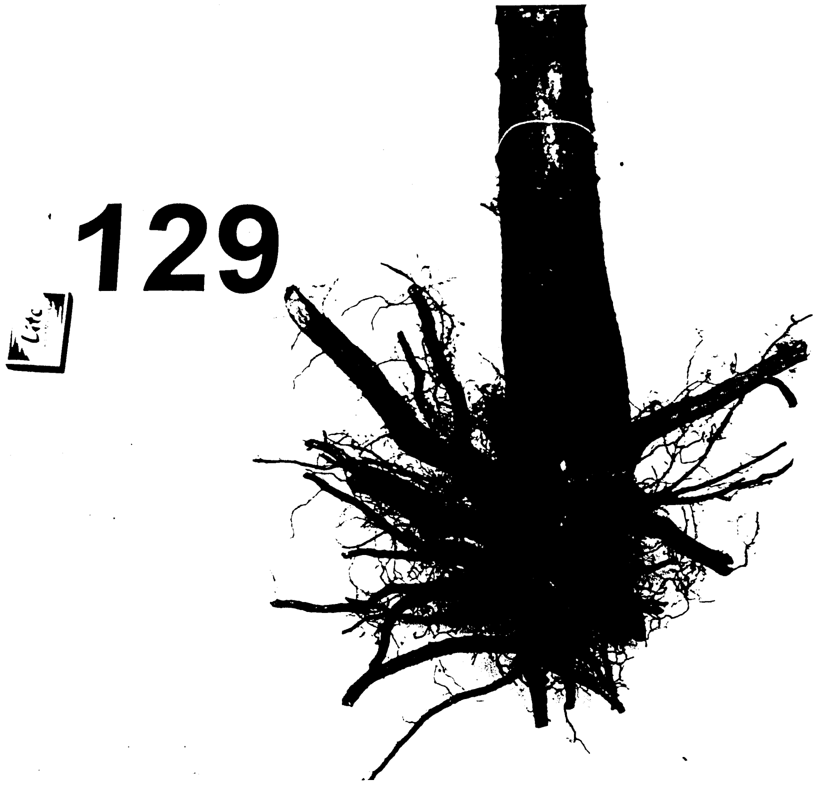

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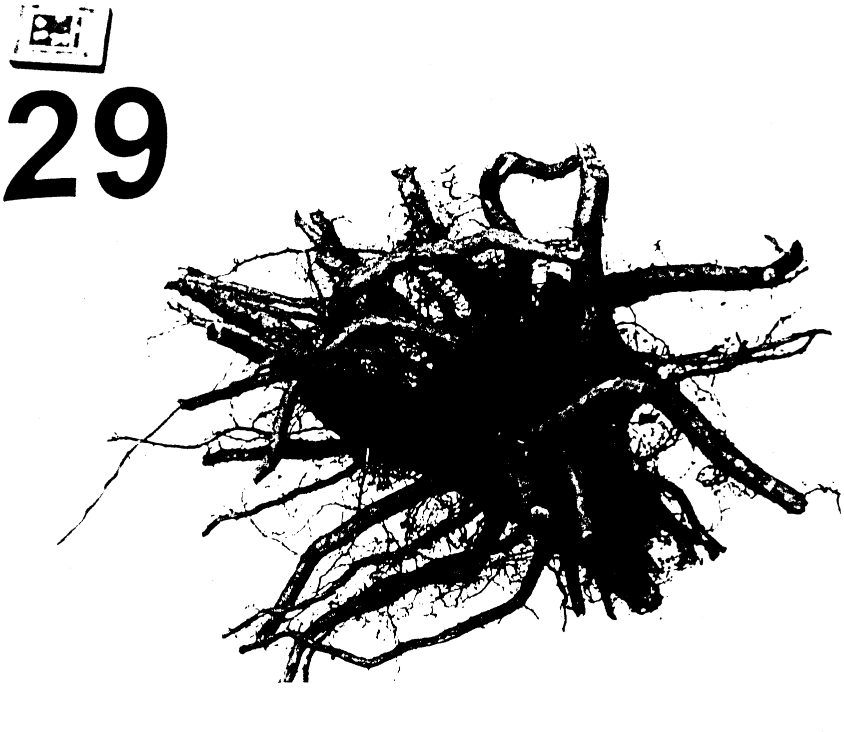

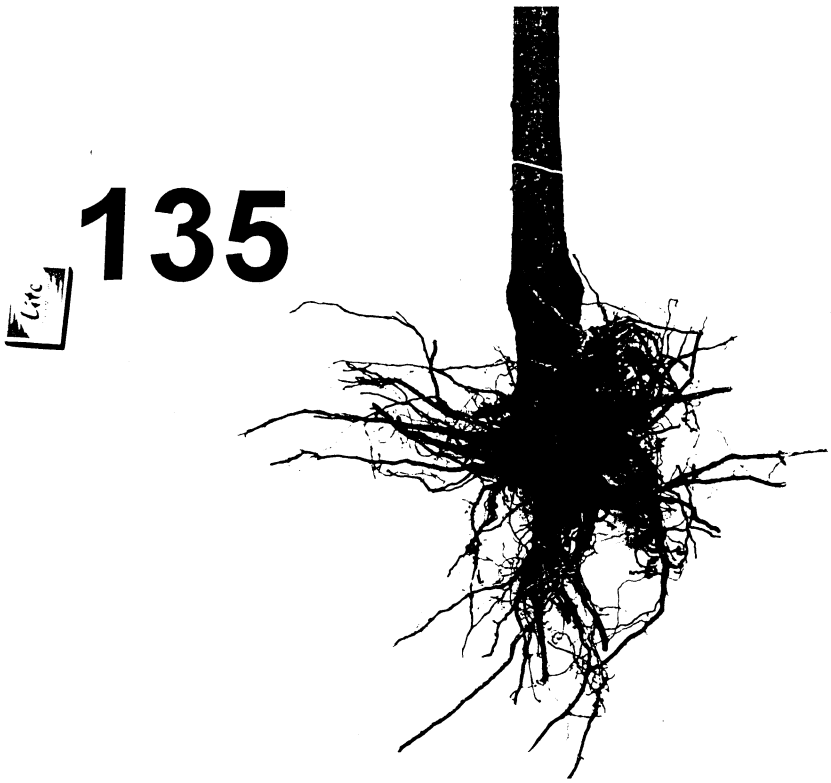
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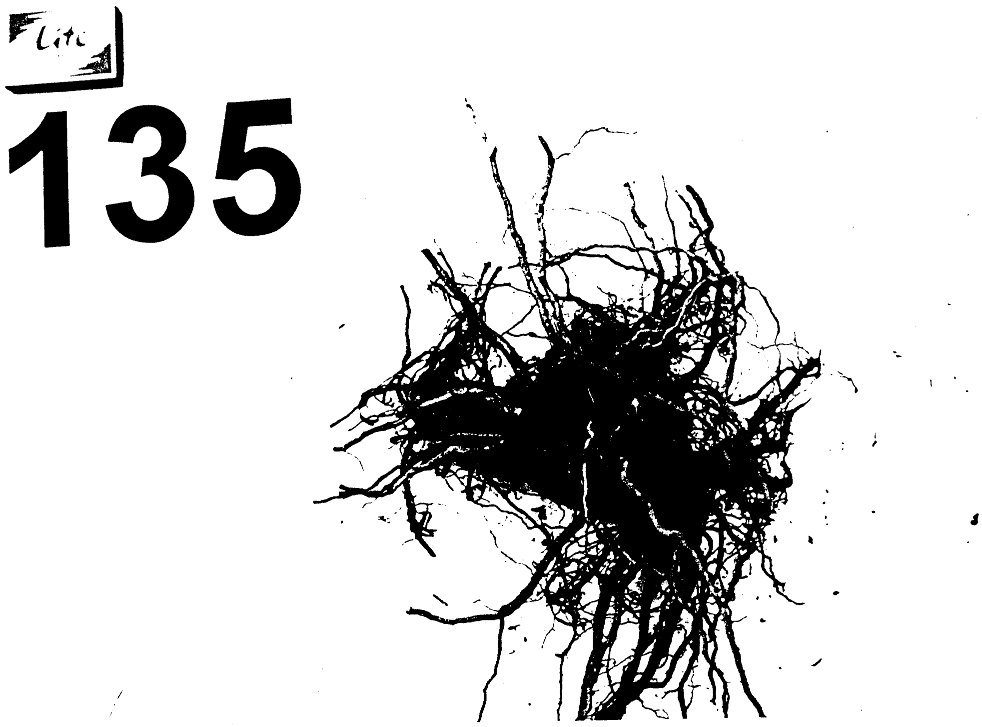
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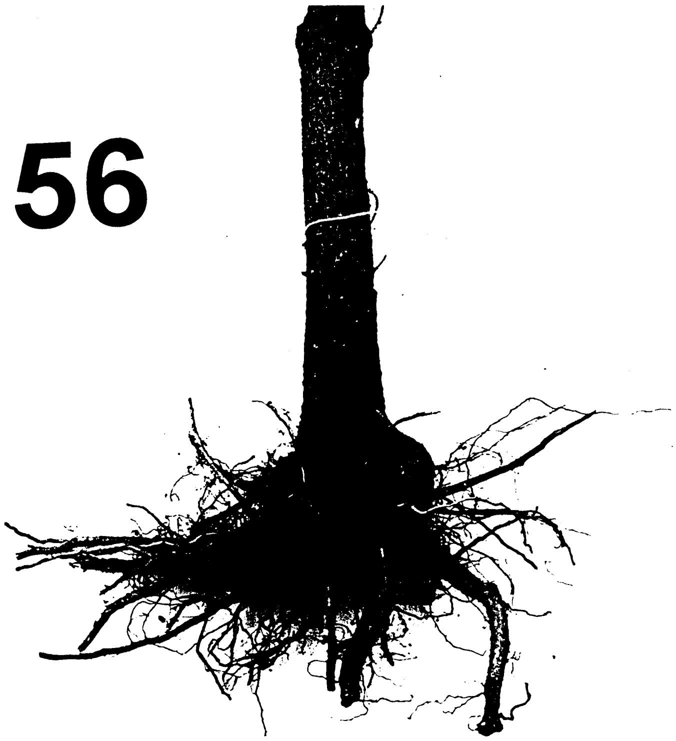

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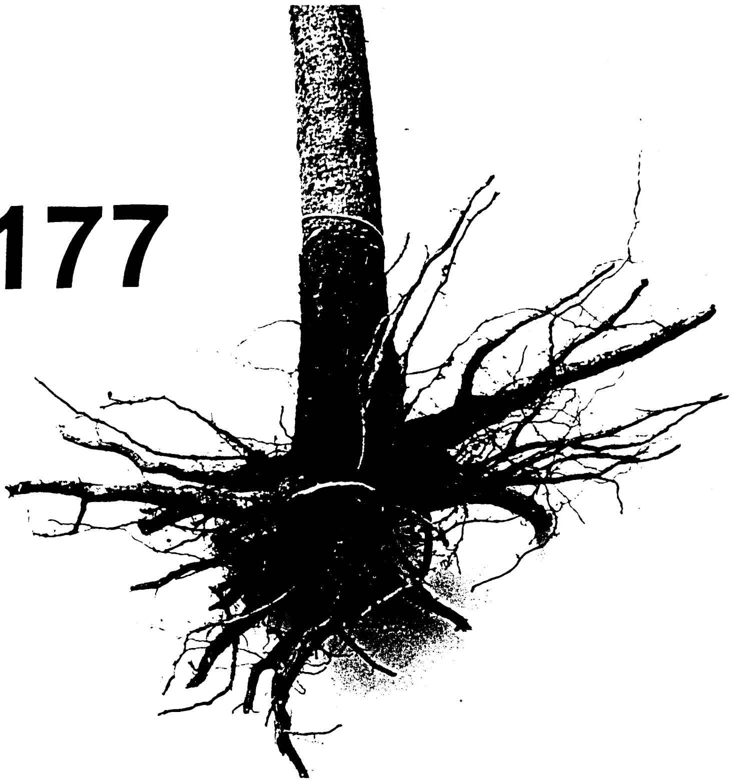

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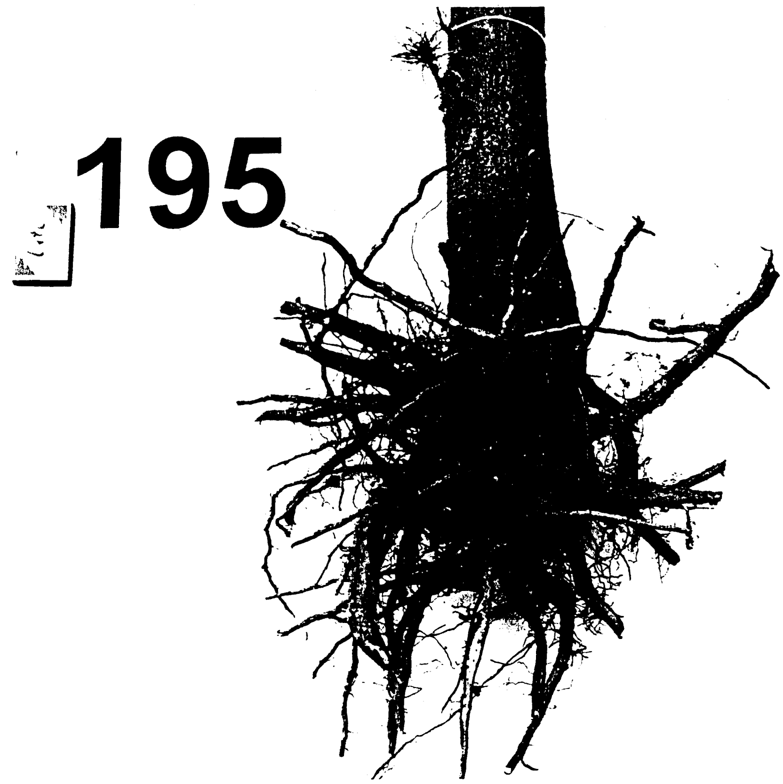
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