LATERAL ROOT GROWTH OF PINUS RADIATA ADJACENT TO DEVELOPED PASTURES

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FOREST & FARM PLANTATION MANAGEMENT COOPERATIVE

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EXECUTIVE SUMMARY

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ABSTRACT

Many district plans call for 'step-back' provisions where plantations are established against a boundary. These commonly state that planting must not be closer than a certain distance (usually set at between 5-20m) from the boundary. Pastoral landowners see boundary plantings as a potential form of trespass, as shade, root competition, and litter are perceived as having detrimental effects on pasture production and quality. Forest owners see the larger set backs (i.e. 20m) as being unnecessarily restrictive, particularly as in the past shelterbelts have commonly been planted along boundaries without causing comment.

Research into the effects of *Pinus radiata* shelterbelts on adjacent pasture growth and composition, and on soil moisture and nutrient status over the past seven years has shown that most effects occur within the 0-10 metre distance from the trees.

A recent study examined the lateral extent to which tree roots grow into the adjacent pasture-rooting zone. The physical presence of tree roots, their yield and diameter class contribution, at a range of distances from the trees were measured at nine *Pinus Radiata* shelterbelts covering a range of soil types and with tree ages from 12 to 19 years in selected sites within the North Island. The standard method of measurement was for 5 replicate pits, 500mm by 250mm by 300mm deep, and at about 10m spacing, to be excavated at distances of 5m and 7.5m from the shelterbelt, and for the soil to be sorted to extract tree root material. The root material was sorted into diameter size ranges and weighed. At distances greater than 7.5m a trench was dug leading away from the shelterbelt and the point of furthermost tree root presence noted.

A more detailed measurement was subsequently made from one shelterbelt with 10 replicate transect pits excavated 10m apart at distances of 5, 6.25, 7.5, 8.75 and 10m distance from the trees.

Lateral tree branch extension was measured on four shelterbelts and litter fall was measured on a seasonal basis from both aspects of one shelterbelt (at Central Plateau) to 40-metre distance.

Results indicated that tree roots in the pasture rooting zone of 0-300mm depth rarely extended beyond 10m. There was a significant reduction in tree root biomass as distance from the tree increased from 5-10 m in any one transect. However, there was a wide variation in root biomass and root size distribution between pits, which was independent of aspect, tree age and tree spacing. There was also a wide variation of root diameter distribution between soil types although on friable sandy silt, the roots extended slightly further and were of a smaller diameter class than on other soils.

Pine needle (litter) accumulation on pasture decreased markedly with increase in distance from the shelterbelt. These measurements were made on one shelterbelt only and therefore can provide indicative information only. Pine needles contributed up to 11.5 kg N, 1.7 kg P and 4.6kg K annually at the 10m distance on the NE aspect, and the contribution declined to 0.6, 0.1 and 0.2 kg/ha respectively at the 40m distance. The needle nutrient contribution was less on the SW aspect. In this location the contribution of pine needle nutrients to pasture uptake would provide only a minor proportion of total annual nutrient requirements. At distances closer than 5m from the trees any benefit of extra nutrients from pine needles to pasture could be offset by shading, the smothering effect of the litter and low soil moisture levels in this zone.

It is concluded that for shelterbelts up to age 19 years, the competitive effects of tree and pasture roots (and therefore any associated effects on pasture productivity) were limited to within 10m distance of the shelterbelts on all soil types. Shading effects were not part of this investigation.

CONTENTS

1.0 INTRODUCTION

Many trees have been planted into farmland. Some of these are as shelterbelts on paddock boundaries, some as spaced plants to provide shade and shelter, or for erosion control. In addition large areas of pastoral farmland have been purchased by forest companies and planted in *Pinus radiata* for forestry purposes. In all situations, and especially where property boundaries are involved, there is interest in the extent of the effect of trees on the adjacent land, both in causing shading and needle fall, but also in relation to the extent of tree roots. This is an issue of particular interest to some district councils, forest owners and pastoral landowners.

Pilot studies adjacent to an 18m high multirow *P. radiata* shelterbelt and a 22 year old *P. radiata* stand margin showed that tree roots did not extend beyond 10m distance from the planted location (i.e. the tree centres) in the top 200mm of soil (Hawke, unpubl). Watson and O'Loughlin (1990) in a study at Mangatu forest, showed that roots from 25-year-old *P. radiata* did not extend beyond 10m and the maximum depth was about 3m. The results of these early studies indicate that the zone of major influence of trees on the adjacent soil and pasture is not as great as some District Councils and Authorities have been suggesting. There have however been no detailed studies of the extent of tree root growth in soils developed under pasture.

The combined AgResearch/*Forest Research* programme to date on shelterbelts has concentrated on measuring the relationship between the sheltering effects of trees (from wind) on associated pasture growth at increasing distances from the trees. Results have shown that most of the effects on grass growth, livestock induced changes in soil fertility, soil moisture, and needle fall occur within 10 metres of the trees. Part of this effect may be due to shelter from rainfall and part may be due to competing effects of tree roots for available moisture.

This study examined the extent to which the physical presence of trees extended into neighbouring grassland by measuring tree roots, branch extension and needle fall over a range of tree heights, ages and on contrasting soil types. Shading effects were not studied.

1.1 Objectives

- To measure the distance that lateral and plate tree roots and branches extend from *Pinus radiata* shelterbelts or plantation margins into adjacent pastoral land.
- To measure the extent of significant dry matter and nutrient contributions by *Pinus radiata* needles to adjacent pastures.

1.2 Site Details

Table 1: Details of shelterbelts and sites used to examine tree root extension into adjacent pastures

Site/Location	Aspect	Shelterbelt Design	Tree Height (m)	Tree age (years)	Soil Type
1. Central Plateau	NE	Six row	20-23	15-17	Y.B.Pumice
2. Central Plateau	SW	Six row	20-23	15-17	Y.B.Pumice
3. Manawatu	W	Four row	15	12	Sandy silt
4. Wairarapa	SE	Two row	15	11	Stony silt loam
5. Whangarei	SE	Forest edge	26	19	Heavy clay
6. Rotorua	NE	Two row	18	14	Sandy silt

1.3 Methods

Over a two year study period, pits (500mm x 250mm x 300mm deep) were dug at 5m and 7.5m distances from the shelterbelt at each location. Five replicates at about 10m intervals were measured at each distance parallel to each shelterbelt. All tree roots were collected. The tree roots were dried for 10-12 days and separated into diameter classes of <2mm, 2-5mm, 5-20mm, 20-50mm and >50mm. The roots were weighed and biomass calculated. Beyond 7.5m distance, for each replicate, 300mm deep trenches at 90° to the tree rows were dug and the furthest root extension measured.

Lateral branch length was measured at the Central Plateau site only. Within the lowest 3m of tree crown the longest branch from the middle of the tree trunk was measured. Five replicates of twenty measurements of branch length were taken, 2m apart and spanning the root measurement study area

Pine needles were collected on both aspects of one shelterbelt at the Central Plateau site. Five needle traps at 5m intervals were secured under cages at 0, 5, 10, 20 and 40 m distances from the shelterbelt. Needles were collected seasonally for one year and the dry matter calculated. Samples from the total annual collection were analysed for major nutrients by ***Forest Research*** staff.

In year three, detailed sampling was conducted on the SW aspect of the Central Plateau site in order to determine if a more intensive sampling routine reduced the estimate of root variability. Ten replicates at 10m intervals were dug at 5, 6.25, 7.5, 8.75 and 10m distances from the shelterbelt.

2.0 RESULTS

Tree Root Biomass

A wide range of total root biomass was recorded between pits at any one distance and from any one shelterbelt (Table 2). However, biomass yields were more consistent between replicates on the friable soils e.g. at Rotorua and Manawatu. The percentage of root diameter class was also variable.

Total root biomass was always greater at 5.0m distance than at 7.5m distance (P=0.01). At the Central Plateau site, the NE aspect (1) had significantly (P=0.05) greater biomass than the SW aspect. However, on the same farm but on two different shelterbelts with similar aspects, the SW (2) aspect had a much greater biomass (Table 2).

Table 2: Total biomass (kg/ha) and contribution per root diameter class (%)

Location / Aspect	Distance From belt (m)	Total Root Dry matter		Root Diameter Class (%)				
		Kg/ha	CV%	<2mm	2-5mm	5-20mm	20-50mm	> 50mm
C.Plateau (1)/NE	5.0	20320	51.6	10	14	50	26	0
	7.5	2448	61.6	29	38	33	0	0
C.Plateau (1)/SW	5.0	9384	71.9	19	30	46	5	0
	7.5	1072	59.7	41	49	10	0	0
Manawatu/W	5.0	4088	45.8	44	38	18	0	0
	7.5	896	117.0	48	46	6	0	0
Wairarapa/SE	5.0	4976	55.2	11	19	70	0	0
	7.5	448	96.1	18	43	39	0	0
C.Plateau (2)/NE	5.0	12696	56.2	10	17	52	21	0
	7.5	1144	154.5	27	42	31	0	0
C.Plateau (2)/SW	5.0	26208	52.6	4	9	37	41	9
	7.5	1640	98.1	7	28	65	0	0
Rotorua/NE	5.0	1296	30.3	22	46	32	0	0
	7.5	920	66.4	21	53	26	0	0
Whangarei/SE	5.0	4944	107.9	3	9	63	25	0
	7.5	1162	130.3	4	11	85	0	0

Root and branch length

Only traces of roots were found beyond the 10m distance with the longest roots occurring in the more friable soils. Average maximum branch length at the one site measured (Central Plateau) was approximately 50% of the maximum root length (Table 3).

Table 3: Length of furthest root and average longest branch in the lower 3m of canopy

Location/Aspect	Max root length (m)	Max branch length (m)
C. Plateau (1)/N.E.	9.0	4.8
C. Plateau (1) /S.W	8.8	4.4
Manawatu /W.	9.1	*
Wairarapa /S.E	8.4	*
C. Plateau (2)/N.E.	8.2	4.6
C. Plateau (2)/ S.W.	8.9	4.3
Rotorua /N.E.	9.2	*
Whangerei /S.E.	8.5	+

* not measured, due to high pruning or side trimming.
+ not measured, due to uneven edge effect.

Pine needle fall

Needle accumulation on pasture decreased markedly on both aspects as distance from the shelterbelt increased (Table 4). Seasonal differences reflected changes in wind direction. During summer, autumn and spring the predominant wind was from the S.W, and during winter, was from the N.E. Needle litter accumulation was highest directly under the trees.

Table 4: Pine needle litter fall (kg/ha/day) at Central Plateau shelterbelt

Aspect	Distance from shelter (m)	Season				Total Year
		Summer	Autumn	Winter	Spring	
South West	5	4.6	3.2	3.3	1.8	3.2
	10	2.6	0.1	1.2	1.4	1.3
	20	0.6	0	0.4	0.9	0.5
	40	0	0	0	Trace	Trace
North East	5	6	13.5	1.8	12.2	8.4
	10	2.7	4.9	0.7	5.2	3.4
	20	0.6	3.3	0.1	1.6	1.4
	40	0.1	0.5	Trace	0.1	0.2
Under Trees	0	22.4	26	15	27.3	22.7

Pine Needle Nutrient Contribution

For chemical analysis purposes, the needles from under the trees and from the 5m distance on both aspects were amalgamated into one sample and those from 10, 20 and 40m on both aspects were also amalgamated. All nutrient levels were in the normal range (Skinner *pers. comm.*). The N, P and K %'s were slightly higher in the amalgamated sample from the 10/20/40m distances (Table 5).

Table 5. Nutrient content of *Pinus radiata* needles from contrasting distances from a shelterbelt

Sample Test	Analysis - March 1999 0/5m		10/20/40m	
	%	ppm	%	ppm
Nitrogen	0.85		0.94	
Phosphorus	0.117		0.138	
Potassium	0.323		0.374	
Magnesium	0.072		0.069	
Calcium	0.373		0.340	
Boron		10		9
Manganese		287		350
Zinc		50		43
Copper		4		5
K Mg Ratio	4.5		5.4	

The nutrient contributions of N, P and K to the pasture decreased as distance from the shelterbelt increased (Table 6).

Table 6: Estimated annual pine needle nutrient contribution to pasture

Aspect	Distance (m)	Nutrient N (kg DM/ha/annum)	P	K
SW	5	10.0	1.4	3.8
	10	4.5	0.7	1.8
	20	1.6	0.2	0.6
	40	Trace	Trace	Trace
NE	5	26.0	3.6	9.9
	10	11.5	1.7	4.6
	20	4.7	0.7	1.9
	40	0.6	0.1	0.2
Under Trees	0	70.5	9.7	26.8

In year three (1998-99), the biomass results showed large variations between transects at any given distance (Appendix1). There were more of the larger diameter root classes close to the shelterbelt and a greater relative contribution in the smaller diameter classes further out (Fig. 1).

Figure 1: Root biomass (kg/m ^{3}) on a log scale for cumulative root diameter ranges and distance from a 6 row shelterbelt (Central Plateau)

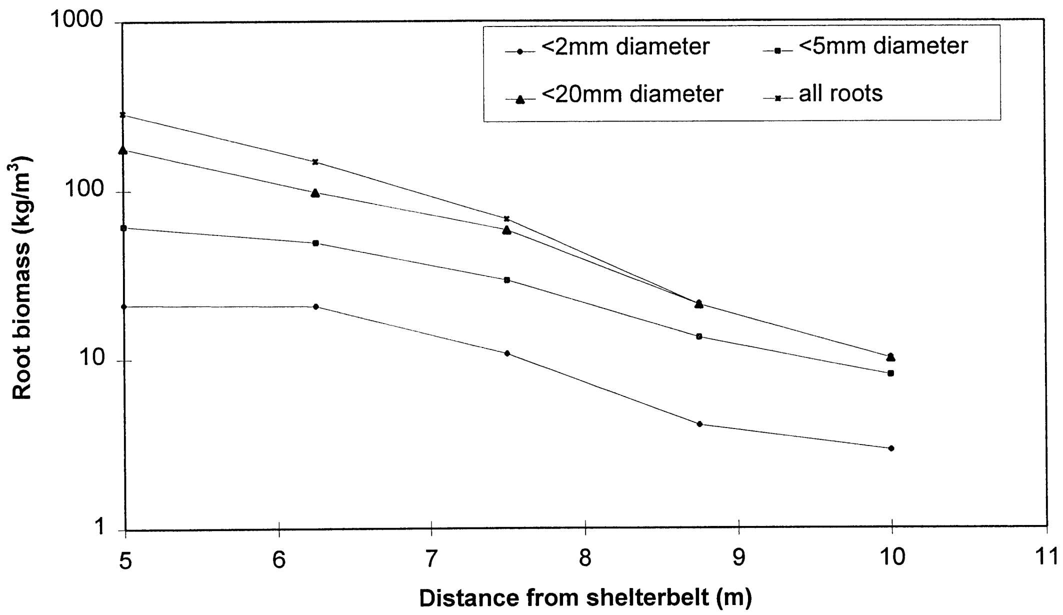


Figure 2 represents the confidence intervals: the outer dotted line represents the 95% confidence interval for any point adjacent to the shelterbelt at the range of distances measured and the inner line represents variation at any point on the same transect.

Figure 2: Total root biomass (log scale) and confidence intervals between and within transects

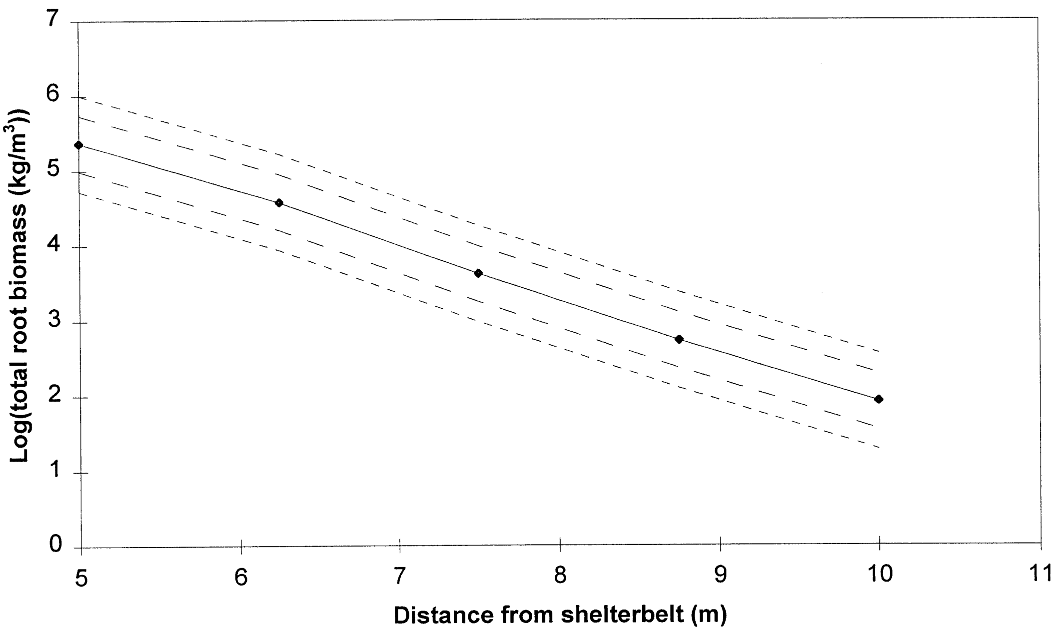
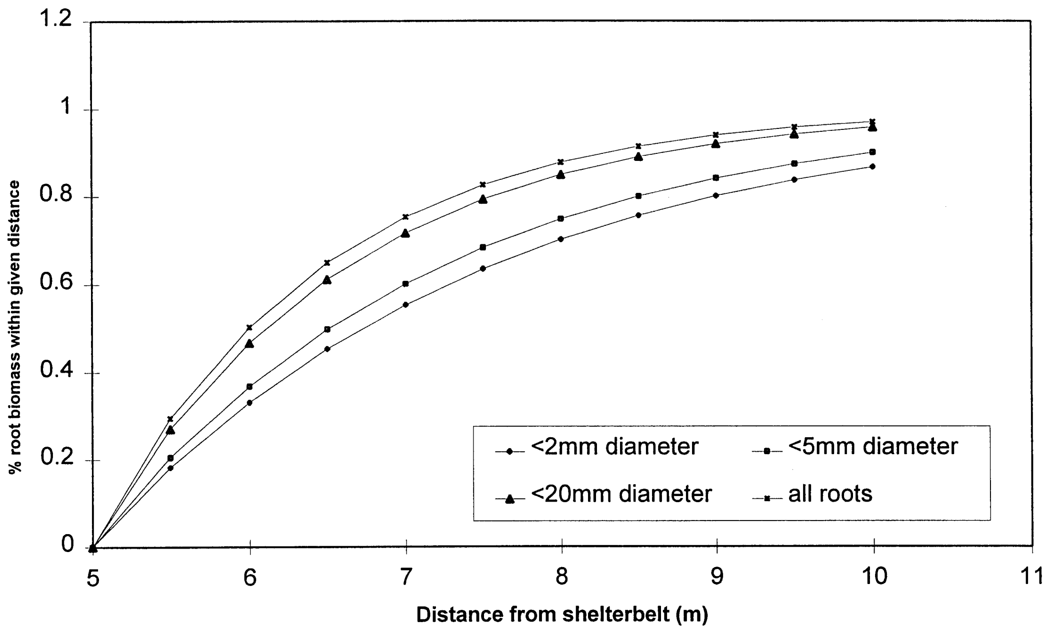


Figure 3 shows that 50% of all roots were accounted for at the 6m distance and 97% of all roots at the 10m distance from the shelterbelt (note that measurements started at 5m distance).

Figure 3: The % contribution of cumulative root biomass diameter classes at sampled distances from the shelterbelt



DISCUSSION

There has been extensive research on structural tree root morphology over many years (Phillips and Watson, 1994) in New Zealand and overseas (Sinclair, 1996). These studies have concentrated on root structure, strength, decay rates, biomass, contribution to stability and research techniques.

This particular study was initially proposed as one component of the shelterbelt research programme to enhance our understanding of the many factors involved in the effects of shelterbelts on pastoral production. Its scope widened as the issue of boundary effects of tree planting on neighbouring properties came under scrutiny.

The methodology used was based on the premise that competition between tree and pasture roots occurred primarily in the top 300mm of soil. Shelterbelt age, height and soil types were also considered as important factors in comparing lateral root growth. The detailed measurements in the most recent study were adjacent to a 6-row shelterbelt, which is similar to a forest edge. Root size diameter classes were grouped according to the study by Watson (1990) and recommended as the standard for root studies.

The technique of digging pits, separating and collecting the roots was a relatively easy (but time consuming) procedure as tree roots were horizontal and of a different colour and form compared with pasture roots which tended to be vertical in the excavated pits. Tree roots were also located predominantly below the main pasture-rooting zone of 0-100mm. However, the technique used of digging a trench beyond the 7.5m pit to locate the root extremity had limitations in terms of accurately describing the variation in the extension of tree root growth into pasture.

The detailed measurements on the Central Plateau site gave a much better indication of root extension and the results supported the findings of the trench method.

The variation in the total root biomass between pits at any one distance did not appear to be related to the diameter or position of the closest tree. For example, where a tree was missing or the transect happened to fall between trees, roots had still occupied that space in a relatively uniform manner.

The aspect comparison at the two Central Plateau sites gave contrasting results, which suggested that root growth was independent of aspect, and prevailing winds.

The results also suggested that there was a similar pattern of root distribution adjacent to the trees, irrespective of soil type. The distance the lateral roots extended, within a 300mm depth was relatively consistent and the slightly longer root length at Rotorua and Manawatu probably reflected the relatively more friable sandy soils at those locations. This finding is supported by a study on the assessment of roots in toppling trials (Turner and Tombleson, 1998) where the friable silt soils had trees with superior lateral root distributions.

Taller (and older) shelterbelts had higher root biomass and a greater contribution of the larger root diameter classes. The similarity of results from both the pumice and heavy clay sites, two very different soil types, suggested that tree age was more important than soil type in affecting root size distribution.

It was observed that at the Wairarapa and Manawatu shelterbelts, root growth was more concentrated in the lower profile of 200-300mm depth, which may be related to the dry surface soil conditions in summer at these two sites.

Branch length was measured only on the Central Plateau site, as other shelterbelts had been high pruned or side trimmed. Consequently, this was a limited data base on which to make firm conclusions.

Pine needle litter measurements showed the influence of wind direction very effectively. In the 12-month period of needle collection (February 1998 - January 1999), a mild winter was associated with a high percentage of NE winds which was reflected in the higher needle fall on the SW aspect. In a normal winter, the opposite effect would be anticipated with winds predominantly from the SW aspect. Needle fall was greatest on the NE aspect as a result of predominantly W and SW winds in spring and summer. Needle fall in periods of most active pasture growth was considered unlikely to have much effect on smothering pasture. Needle fall under trees was similar to that measured at Tikitere under a full tree canopy (Hawke, unpubl.).

The chemical analysis which showed slightly higher N, P and K levels in needles from the 10/20/40m distance reflected the higher nutrient status of needles originating from the top of the tree canopy which would tend to be the source of needles travelling these distances. Needle decomposition rates are greater under the trees than in more open situations, which may also account for the lower N, P and K values (Skinner, *pers. comm.*) in needles collected from that zone. The contributions of nutrients to the pasture from pine needles are low, relative to the annual amounts generally required for optimum pasture growth.

In this study the shelterbelts measured were in the height range 15-26m, which accounts for the medium distribution of height of shelterbelts in New Zealand. Younger (and shorter) shelterbelts are likely to have lower biomass root growth, and, as a consequence less effect on adjacent pasture growth and boundary issues. Conversely, the root systems of older (more mature) and taller trees may extend further into the adjacent land.

While the predominant tree planted in plantations and shelterbelts is *P. radiata*, there are many different tree species used for farm plantings which may have different rooting patterns. They have not been measured in this study.

This study has examined the direct effects of needle-fall and roots, but other factors could influence "set-back" distances from boundaries. These include shading, shelter, aesthetics, rain shadow effects, the risk of falling trees or fire and, the ingress of weeds where land is left unplanted.

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APPENDIX 1: Central Plateau Shelterbelt ; Distribution class and total biomass for each transect and distance (g/sample)

Transect	Distance(m)	<2mm	2-5mm	5-20mm	20-50mm	>50mm	Total
1	5.00	16.26	36.58	181.13	83.76	0.00	317.73
1	6.25	16.50	24.92	53.17	16.57	0.00	111.16
1	7.50	12.31	19.72	15.94	0.00	0.00	47.97
1	8.75	3.51	10.13	0.00	0.00	0.00	13.64
1	10.00	2.48	5.72	0.00	0.00	0.00	8.20
2	5.00	25.08	34.96	91.75	54.83	0.00	206.62
2	6.25	14.91	24.59	26.97	0.00	0.00	66.47
2	7.50	4.54	13.64	6.79	0.00	0.00	24.97
2	8.75	0.79	5.54	0.00	0.00	0.00	6.33
2	10.00	0.04	0.13	0.00	0.00	0.00	0.17
3	5.00	19.98	35.66	140.27	183.26	0.00	379.17
3	6.25	17.81	40.14	160.05	241.72	0.00	459.72
3	7.50	14.81	27.43	62.87	0.00	0.00	105.11
3	8.75	12.69	22.75	33.30	0.00	0.00	68.74
3	10.00	6.91	5.90	5.90	0.00	0.00	18.71
4	5.00	6.89	14.13	30.38	0.00	0.00	51.40
4	6.25	10.79	17.39	3.47	0.00	0.00	31.65
4	7.50	4.48	15.63	0.00	0.00	0.00	20.11
4	8.75	1.09	6.05	7.01	0.00	0.00	14.15
4	10.00	1.46	1.72	0.00	0.00	0.00	3.18
5	5.00	21.28	46.50	86.92	45.83	0.00	200.53
5	6.25	10.58	25.14	35.54	0.00	0.00	71.26
5	7.50	4.10	16.91	6.73	0.00	0.00	27.74
5	8.75	3.11	13.15	6.04	0.00	0.00	22.30
5	10.00	3.70	6.92	0.93	0.00	0.00	11.55

6	5.00	5.00	30.03	57.81	0.00	0.00	92.84
6	6.25	17.64	21.65	10.15	0.00	0.00	49.44
6	7.50	3.83	7.89	0.00	0.00	0.00	11.72
6	8.75	4.21	4.92	6.33	0.00	0.00	15.46
6	10.00	1.84	6.19	0.00	0.00	0.00	8.03
7	5.00	33.87	48.74	294.14	94.78	188.36	659.89
7	6.25	9.09	36.55	52.52	0.00	0.00	98.16
7	7.50	8.83	11.11	0.00	0.00	0.00	19.94
7	8.75	0.84	5.98	1.90	0.00	0.00	8.72
7	10.00	2.21	4.90	0.00	0.00	0.00	7.11
8	5.00	48.46	85.44	175.79	359.92	0.00	669.61
8	6.25	25.63	36.81	103.62	219.86	0.00	385.92
8	7.50	13.92	40.91	179.38	93.20	0.00	327.41
8	8.75	8.22	13.45	12.50	0.00	0.00	34.17
8	10.00	1.89	3.97	0.00	0.00	0.00	5.86
9	5.00	15.99	20.56	38.80	0.00	0.00	75.35
9	6.25	3.93	11.89	7.46	0.00	0.00	23.28
9	7.50	2.47	5.75	0.00	0.00	0.00	8.22
9	8.75	0.34	0.63	0.00	0.00	0.00	0.97
9	10	0.00	0.00	0.00	0.00	0.00	0.00
10	5.00	16.11	49.85	75.63	83.46	0.00	225.05
10	6.25	78.39	43.79	39.56	29.86	0.00	191.60
10	7.50	37.59	24.96	15.78	0.00	0.00	78.33
10	8.75	5.80	10.15	8.35	0.00	0.00	24.30
10	10	8.35	15.62	13.54	0	0	37.51