AP432

High density production systems for apples

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NSW Agriculture

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FINAL REPORT

HIGH DENSITY PRODUCTION SYSTEMS FOR APPLES

AP 432

1 July 1994 to 30 June 1997

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NSW Agriculture

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SYNOPSIS

High density planting systems need to be developed for the higher light intensity situations found in Australian apple growing areas. Technology for the intensification of apple production is not available in Australia. Through exploiting European technology, this project will develop and evaluate high density planting systems that provide higher yields per hectare and a higher percentage of apples of good quality. High density planting systems using tree densities of between 2000 trees/ha and 5000 trees/ha have been shown overseas to have the potential to increase the efficiency of apple production. These systems, however, have required local modification of cultural practices such as pruning techniques, cultivars and machinery use. To achieve the increase of efficiency of higher density apple production, four high density bed systems were planted on dwarf rootstocks will be compared with commercial central leader systems. Fruit yield and quality will be assessed. The nutritional and irrigation requirements of different systems will be determined; pest and disease will be monitored to determine the efficiency of integrated pest management systems. Costs and timing of labour will be recorded for assessment of the economic efficiency of the different systems.

Industry Summary

Apple growing trends in Australia today are to produce small trees that begin to bear fruit in the second year. Varieties are now being grown on dwarf rootstocks, about 2m tall, planted closer together. In 1990 at Orange, Hi Early Delicious on M.9, M.26 and M.27 rootstocks were planted in one (1667 trees/ha), two (2286 trees/ha), three (3043 trees/ha) and four (2822 trees/ha) row bed systems. Rootstock influence on tree size in increasing order of size was M.27 (smallest), M.9, M.26 then MM.106 (largest). Yields by year five reached 50-70 tonnes/ha, and by year seven, 70->100 tonnes/ha. The design of the planting should have the rows orientated north/south so as to get the best light relations within the foliage canopy for good fruit development.

Fruit quality by size and colour was good, but fruit from M.27 can be smaller (more < 67mm) and may need more thinning. Shading within the beds has been no problem, but less highly coloured varieties (Fuji, Gala, Braeburn, Pink Lady) may have some problem of less colour in the middle rows in 3- or 4-row beds. Yields from 3- and 4-row beds by unit area were higher than single rows but less highly coloured varieties than Delicious may be more suited to 2 rows. Alleys were 4 m, but narrower alleys of 3 or 3.5 m, as long as narrow machinery is used, could be used efficiently with higher yields per hectare.

Dwarf rootstocks generally do not have good anchorage. It is necessary to stake trees individually or tie to a simple trellis to give support for the life of the planting. It is important to have the stakes or trellis at least 1.8m above the ground..

Weed control with herbicides in the single and double rows was no problem, but multiple rows (3- and 4- or more rows) can run into difficultieswithout adequate machinery developed for the purpose. The use of straw mulch can overcome this problem and also improve soil moisture. In areas where fire is more of a risk (eg. Bilpin) straw mulch might be too much of a risk and some other less flameable material be better suited. Irrigation with better water use under straw and nutrition was effectively developed and pest and disease controlled adequately with no additional difficulties.

Technical Summary

Apple growing on dwarf rootstocks produced small trees that began to bear fruit in the second year. In 1990 at Orange, Hi Early Delicious on M.9, M.26 and M.27 rootstocks were planted in one (1667 trees/ha), two (2286 trees/ha), three (3043 trees/ha) and four (2822 trees/ha) row bed systems. The experimental design was of 3 replicates of three rootstocks and four bed systems and one single row standard bed of MM.106. Rootstocks and bed systems were randomized within each replica.

The two row bed had the rows staggered and the middle row of the three row bed was diagonally between the other two rows. The four -row bed had a wider space between rows 2 and 3 to aid access for picking as well as light and spraying. The trees across the four rows are not at right angles to the row but angled at 0 to 0.5m across the rows.) to 1m would give a better access for spraying etc. The rows were orientated north/south for the trees to receive the best light penetration for fruit yield and quality. Trees grown on these dwarf rootstocks, were about 2 to 2½ m tall, planted closer together, though tree height needed to be limited especially on M.26.

The largest trees are the ones on MM.106 which are the standard., M.26 is the next followed by M.9 and then M.27 smallest. Yields by year five reached 50-70 tonnes/ha, and by year seven, 70->100 tonnes/ha. Fruit quality was good from red colour and size, but fruit from M.27 trees can be smaller. Shading within the beds has caused no problem on size or colour with Hi Early, but less highly coloured varieties (Fuji, Gala, Braeburn, Pink Lady) may produce less colour in the middle rows in 3 or 4 row beds.

Light measurements within the canopy of Gala trees, which were used as pollinators and buffers to the main variety Hi Early, did show reduction of colour due to less light in the middle of the 3- and 4-row beds. Light reduction within the 3- and 4-row beds has been insufficient to reduce colour, yield or size within Hi Early trees.

All dwarf trees were pruned as spindles. None of these dwarf rootstocks is suitable to be grown under these high density systems without some support such as a simple trellis or stake. It is important to have the stakes or trellis at least 1.8m above the ground to support the top of the tree especially those on M.27. Irrigation by means of drippers was monitored with a neutron probe. Nutrition was effectively developed and there was no difference in treatments between rootstock or bed. Pest and disease was controlled adequately with no additional difficulties. Even though there was a reduction in light within the multiple row beds and less wind movement inside the bed, there was no problem within the multi-row beds for pests or disease.

Acknowledgments

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Introduction

During the 1960s the average tree density in Australia, was 250-300 trees/ha. Trees were trained as vases, and first carried fruit by the fifth or sixth year with yields of 15-17 t/ha. Introduction of new growing methods such as medium density planting (8-900 trees/ha), semi-dwarfing rootstocks (MM.106 and Northern Spy), and central leader pruning significantly influenced the capacity of the apple industry to remain profitable under pressures from cost of production increases (Beattie *et al* 1979), with increased yields of 30 t/ha. A logical further stage in industry development was the intensification of production using higher density plantings with dwarfing rootstocks, which also allowed more labour saving at harvest by less ladder work and quicker picking, leading to reduced costs of production, and more cost effective hail damage protection. Prospective yields may increase to 50-100 t/ha. This in turn should produce a higher proportion of good quality apples with less wastage of small poor coloured fruit.

High density planting of apples on dwarf rootstocks (M.9 and M.26) in beds was developed in Holland (Wertheim and Lemmens 1976) in the 1970s. Trees on dwarf rootstocks grow to about 2m high and begin to carry a crop in the second year (Cummins 1994, Wertheim and Lemmens 1976). Overseas results have shown that tree densities of 2000 trees/ha up to 5000 trees/ha lead to higher yields per hectare and a higher percentage of fruit that is of good quality, large, well coloured and more uniform in size and maturity. These systems have been developed for use in other parts of the world, especially Europe (Palmer and Jackson 1977, Sansavini *et al* 1981, 1986, Wertheim *et al* 1986) and Canada (Oberhofer 1990, Proctor 1978). Adjustments to cultural systems have been necessary including new pruning techniques, cultivars and planting systems (Brooke Peterson 1989, Hutchinson 1977). The higher establishment costs of more trees/ha may be recovered in the first 5-6 years (Hutchinson 1977). New orchard machinery and management techniques have been developed to cope with the changes in orchard design (Brooke Peterson 1989, Hutchinson 1977). In Holland there are a large number of multiple row commercial orchards and there are many two or three row orchards in other countries in the world. Training systems were developed such as spindles to efficiently make use of these higher densities

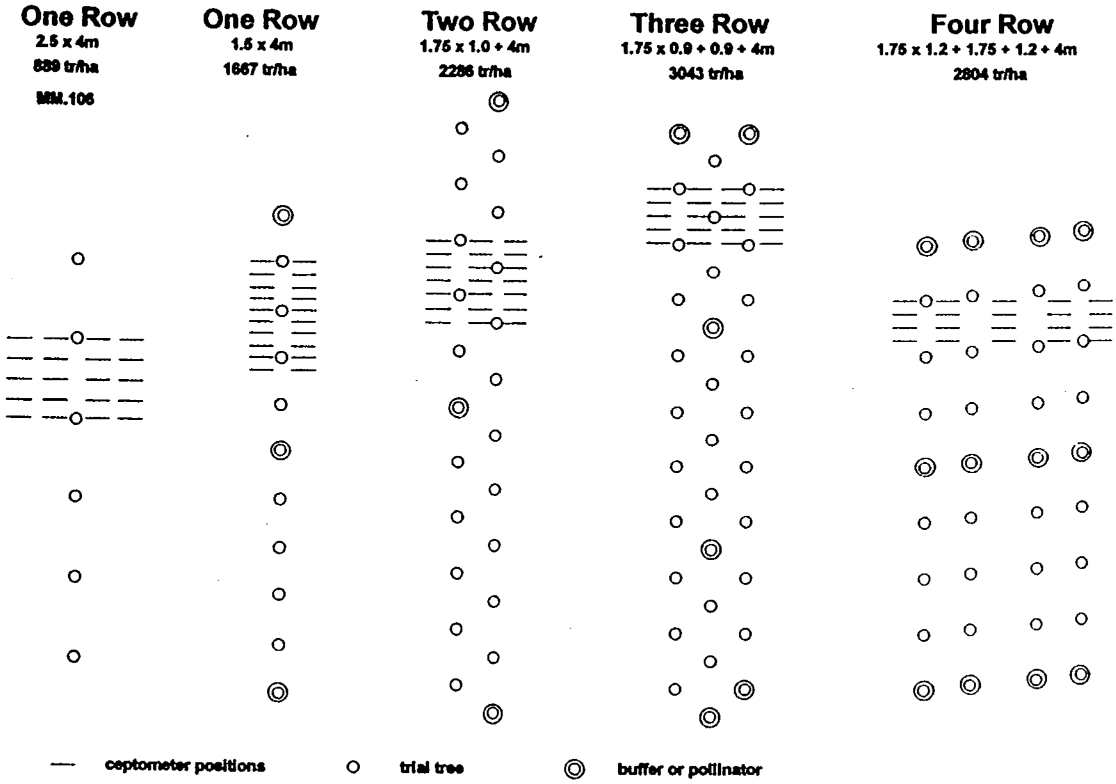
These systems have not been developed for the high light intensity situations found in Australian apple growing areas where 25% of total light is required for good colour and size compared with 50% for the 43° to 56° latitudes in the northern hemisphere. High light intensities of lower latitudes have been shown to produce higher yields than in higher latitudes (Landsberg 1979). Available suitable orchard land and conflicts with land usage are not yet as great as in Europe but efficiency of production is very high on the priority list.

The main aim of this trial was to see what system might be best under our high light intensity conditions in Australia.

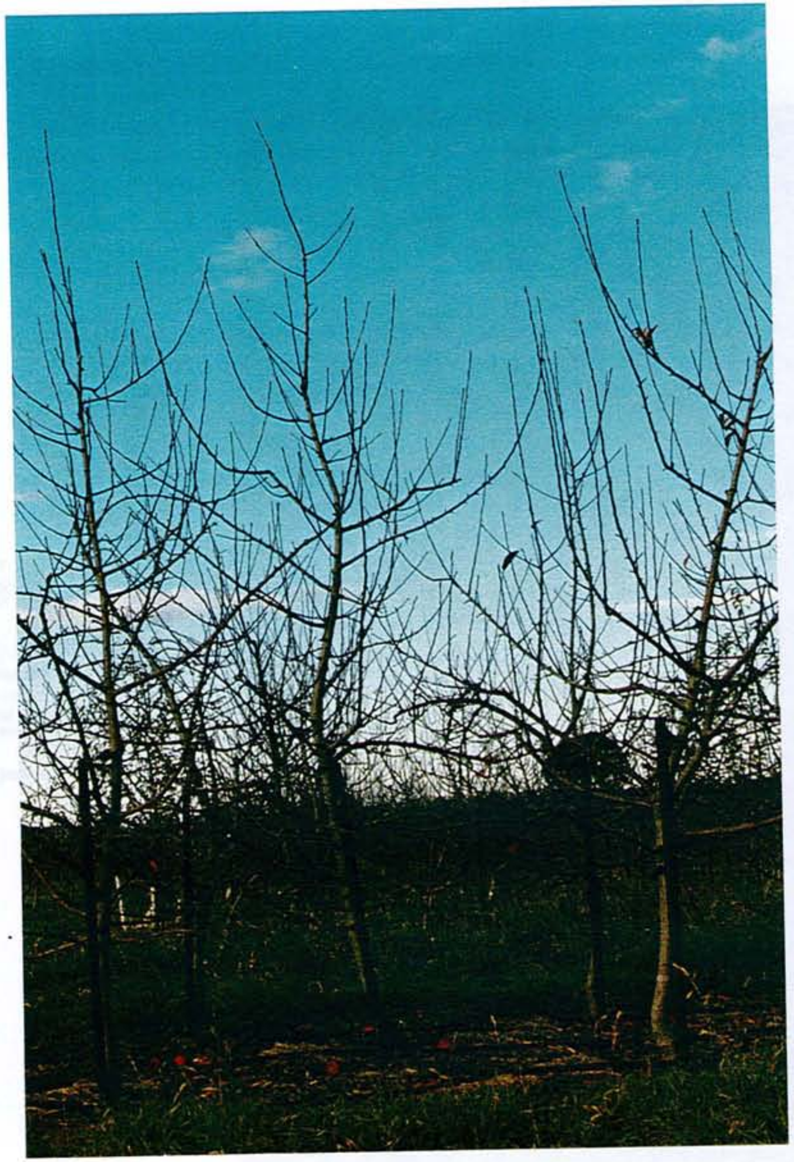
Materials and Methods

The Hi Early Delicious trees were planted in a deep well-drained red Krazonem basaltic loam soil in 1990 at Orange Agricultural Institute, Orange New South Wales (lat.33°10'S, long. 149°6'E, altitude 950, annual rainfall 900mm). The trees had been grown in the nursery for one season before planting as maiden whips. They were worked on the dwarf rootstocks, M.9, M.26 and with interstems of M.27 on MM.106, and planted in beds of 1, 2, 3 and 4 rows, at 1667, 2286, 3043 and 2822 trees/ha respectively (Plates 1 and 2). At the same time standard trees on MM.106 were planted in single rows for comparison at 880 trees/ha. All the rows were orientated north/south to make the best use of light. The trees on dwarf rootstocks were pruned as spindles, compared with current MM.106 trees as commercial central leaders. Each bed was approximately 75 sq.m depending on tree density including alleys of 4m wide. The planting systems and the spacing of trees are shown below in Figure 1.

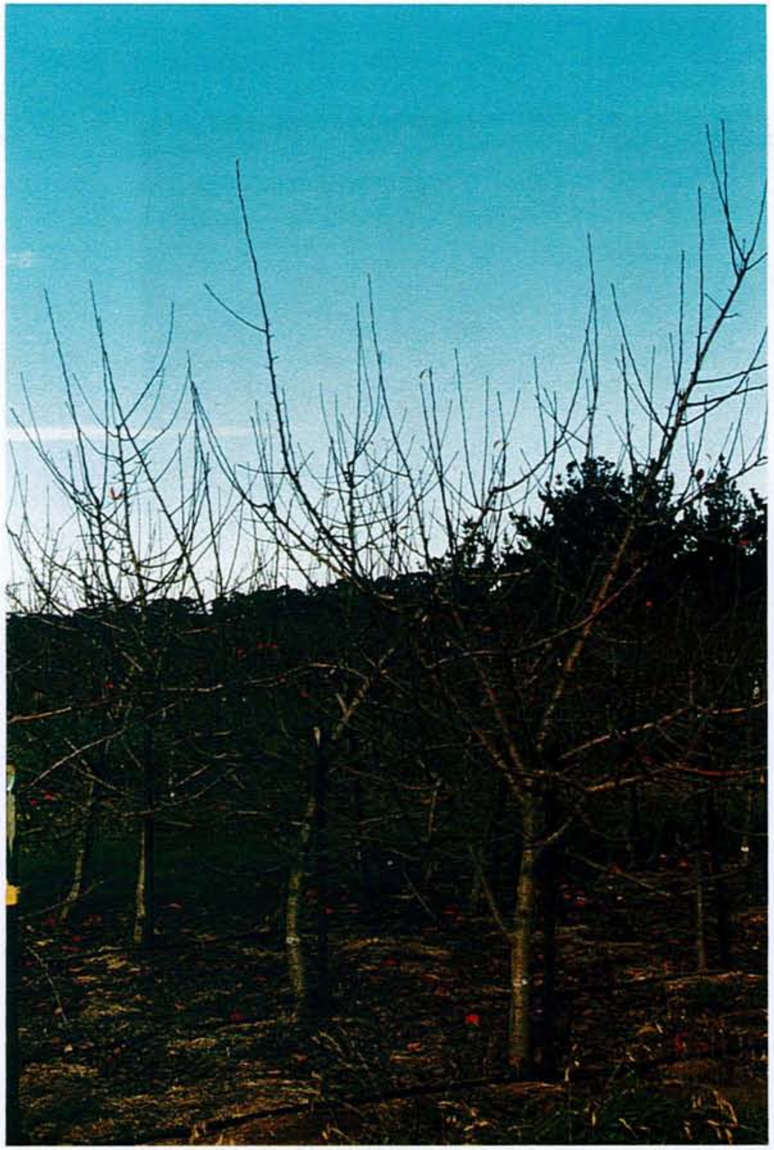
Figure 1. Planting design of the beds.



Trees were irrigated with drippers at one per tree and monitored with the neutron probe. Nutrition was monitored with leaf analysis. The timing and amount was applied in relation to scheduling. Chemical thinners were applied in spring in years 4, 5 and 7, but not 6 as blossom was too light. NAA (20ml/100l) was used in year 4 and 5 and carbaryl (180ml/100l) in year 7. In year 5, when chemical thinning was mostly effective, no extra hand thinning was done, and fruit on M.27 tended to be small compared to other rootstocks. In year 7, hand thinning was done to supplement the chemical thinning to M. 27. Pest and disease control was applied regularly or when required. As dwarf rootstocks are not well anchored, they were staked (2, 3 and 4-row beds) or put on to a simple 2 wire trellis (single-row bed). Trees on M.27, from previous experience, were found to be too weak in growth, so the rootstock was used as an interstem on



3-Row bed on M.9 rootstock in winter 1996



4-Row bed on M.9 rootstock in winter 1996

Plate 1.

2-Row bed on M.9 rootstock in summer 1995

4-Row bed on M.9 rootstock in summer 1995

Plate 2.

MM.106 in the hope that the trees would be able to stand on their own. This did not turn out to be the case, so they were staked or trellised too.

Tree growth was calculated each winter by measuring butt circumference at the same height from the ground (about 20 cm). The timing (mins) of pruning of each bed was recorded and the prunings were weighed (kg).

Fruit was picked from 1992 to 1997 and each bed's weight was recorded. They were then sized by grader to 3 sizes, small (< 67mm diameter), medium (67-73mm) and large (> 73mm). In 1994, and in the following years, the closeness of each canopy in the 3 and 4 row beds was thought to cause some shading that might affect fruit quality, size and colour. So the outside rows of these beds were picked separately to the inside rows to see if there was any effect on fruit number and quality within the multiple beds. The yields over the six years were combined to give the cumulative yields. Tree efficiency was calculated on the butt cross sectional area divided by the fruit weight.

It is difficult to distinguish redder than red with a highly coloured red variety such as Hi Early. So the effect of light on colour (within the beds) was measured on the Gala trees which had been planted as buffers at the beginning and ends of beds and as pollinators within the beds. Each tree was divided into 4 layers (60cm high) and the bottom 2 layers were divided further into a north and south half. With an Accupar ceptometer, light was measured in each section in the middle part of the day and calculated as a percentage of total light above the tree. At harvest, fruit was picked from each section, red colour assessed manually by eye as the percent of the surface coloured red (<40%, 40-60% and >60%)(Campbell 1987, Jackson 1968). Also red colour intensity on the reddest side of the fruit was assessed with a colour chart. The colour was related to the light measurement.

Results and Discussion

Tree Growth

Tree growth has been very satisfactory throughout the trial compared to previous trials at Orange on similar rootstocks. Tree size has remained in the order of smallest to largest, M.27, M.9, M.26 and MM.106 rootstocks with butt measurements steadily increasing (Figure 2, Table 1). The stakes used were 1.67 m long with about 1.25 m above the ground. After these trees were planted in winter 1990, I visited Europe (HRDC Project no AP02T) to look at high density bed systems in Italy, Holland and England, where the stakes used in these countries were approximately 1.82 m above the ground. The height of the stake above ground is not so critical for M.9 and M.26 trees but longer stakes would have supported the M.27 trees more effectively. Even so, longer stakes and trellices on single rows would have been more efficient to control the tree.

There was need to limit tree height on M.9 and M.26 to a side branch as well as MM.106. Where the growth of the terminal shoot had grown too vigorously, it was cut out to a weaker side branch.

Table 1. Tree size as Butt circumference (cm)

Rootstock	Row/Bed	Density/ha	1991	1992	1993	1994	1995	1996	1997
M.9	1	1667	2.9	6.6	10.6	14.1	17.1	25.1	29.7
	2	2286	2.3	5.4	9.5	13.7	16.8	24.9	29.8
	3	3043	2.1	4.4	7.7	10.9	13.1	18.8	21.7
	4	2822	1.4	3.9	7.5	10.8	13.7	19.4	22.7
M.26	1	1667	2.7	5.3	9.2	13.7	18.0	28.4	36.9
	2	2286	2.4	5.2	8.5	11.8	13.7	20.1	23.9
	3	3043	2.4	5.9	10.3	14.0	16.8	23.7	27.1
	4	2822	2.1	5.8	10.5	15.6	19.8	29.1	34.5
M.27	1	1667	1.8	3.8	6.3	8.7	10.3	13.7	16.0
	2	2286	1.5	4.5	7.4	9.6	11.1	15.0	17.9
	3	3043	2.2	5.7	7.9	10.1	11.5	15.0	17.7
	4	2822	1.8	4.9	7.0	9.4	10.8	15.2	18.1
MM.106	1	880	3.2	9.5	17.5	23.3	31.4	44.8	54.4
s.e.			1.36	2.67	4.30	5.82	7.15	9.76	11.31

Pruning Time and Weight

The time taken to prune the beds and the weight of prunings is shown in Figure 3. In 1991 the differences were very small and mostly not significant. All rootstocks took longer to prune in 1992 compared to MM.106 but not the weight of the prunings. There was an increase in time from 1 row to 4 row. Pruning time and weight did not differ much between MM.106 and M.27 in the following years, neither did those of M.9 and M.26 except for the 4 rows of M.26. The weight of the prunings and the time taken of trees on MM.106 in 1995 and 1996 was much less than of trees on M.9 and M.26. The explanation for this difference is probably due to the

MM.106 trees not yet having filled their allotted space so there was little need to prune because of crowding. M.9 and M.26 trees filled their allotted space by 1994, so some of the pruning was to cut back branches that spread into the neighbourig tree as well as normal pruning out of branches etc.

Fruit Production

Fruit was harvested from 1992 to 1997. This project became well established by the fourth season (Table 2), with all trees (particularly M.9 and M.26) producing excellent fruit quality and the yields still increasing. By 1997, there was no signs of overcrowding on fruit production with any density system. Trees on M.27 produced less fruit, as these trees are much smaller.

The yields per hectare (Table 2) in the high cropping years of 1995 and 1997 showed similar yields on M.9 and M.26. Within a rootstock, the one- and 2-row beds had similar yields wilst the 3- and 4-row beds had greater yields but both beds were similar. The yields on M.27 and MM.106 were much lower, but the more rows per bed increasing yields up to three-row beds with four-row being similar to three. Apart from MM.106, the yield differences within a rootstock were very much related to the number of trees per ha of the bed. Yields by year five have reached 50-70 tonnes/ha with high quality fruit, and 70-90 tonnes/ha in year seven. The crop in 1996 was "off" year. Fruit weight and number per bed steadily increased (Figure 5) and have not quite reached a plateau yet. The standard trees on MM.106 have a long way to go. In Figure 5, fruit weight and number in 1997 are similar to 1995 but fruit numbers from M.27 trees are higher in relation to weight.

Table 2. Yields in kg/ bed system on four rootstocks and 4 bed systems from 1992-1997, (tonnes/ha in brackets).

Rootstock	Bed System	Year 1992	1993	1994	1995	1996	1997
M.9	1 row	14.8(2.0)	103.7(14)	211(28)	434(58)	176(23)	504(67)
	2 row	9.7(1.3)	110.7(15)	213(28)	495(66)	109(15)	522(70)
	3 row	17.2(2.3)	121.7(16)	253(34)	575(77)	208(28)	692(92)
	4 row	4.7(0.6)	66.0(9)	225(30)	554(74)	299(40)	675(90)
M.26	1 row	19.5(2.6)	75.3(10)	211(28)	422(56)	208(28)	518(69)
	2 row	13.0(1.7)	105.0(14)	197(26)	451(60)	87(12)	428(57)
	3 row	7.8(1.0)	134.0(18)	263(35)	510(68)	197(26)	696(93)
	4 row	3.3(0.4)	114.0(15)	265(35)	716(95)	227(30)	812(108)
M.27	1 row	11.7(1.6)	57.3(8)	131(17)	143(19)	105(14)	241(32)
	2 row	6.7(0.9)	45.7(6)	147(20)	228(30)	64(9)	297(40)
	3 row	6.3(0.8)	108.0(14)	179(24)	389(52)	73(10)	371(49)
	4 row	7.7(1.0)	90.3(14)	155(21)	325(43)	64(9)	390(52)
MM.106	1 row	4.7(0.6)	39.3(5)	133(18)	180(24)	117(16)	356(47)
s.e.		16.1	75.4	89.3	244.6	115.2	142.8

Cumulative yields

Cumulative yields over the six years are shown in Table 3 and Figure 6. All the M.27 beds and MM.106 were similar but were significantly different to all M.9 and M.26 beds. The 3 and 4 row beds had more fruit but only the 3 row on M.9 and 3 and 4 row on M.26 were different.

Table 3. The cumulative yields of the different bed systems in tonnes/hectare from 1992-97.

Rootstock	1 Row 1667 tr/ha	2 Row 2286 tr/ha	3 Row 3043 tr/ha	4 Row 2822 tr/ha
M.9	195.2 bc	194.8 bc	345.9 d	249.7 c
M.26	193.4 bc	162.1 b	232.5 c	282.3 cd
M.27	93.4 a	113.0 a	149.8 a	142.1 a
MM.106	110.5 a 880 tr/ha	s.e. 62.4		

(Where a figure in the table is followed by the different letter it is significantly different)

Tree efficiency

Tree efficiency is shown in Table 4 and Figure 7. All the dwarf rootstocks beds had a better tree efficiency than MM.106. The 3 and 4 row beds were significantly different to 1 and 2 row on M.9 , and 2, 3 and 4 rows on M.26.

Table 4. Tree efficiency (1997)

Rootstock	1 Row 1667 tr/ha	2 Row 2286 tr/ha	3 Row 3043 tr/ha	4 Row 2822 tr/ha
M.9	50.6 bc	53.0 bc	86.1 d	82.3 d
M.26	39.4 b	55.7 c	64.2 c	61.8 c
M.27	44.2 bc	47.5 bc	64.0 c	58.7 c
MM.106	15.2 a 880 tr/ha	s.e. 15.5		

(Where a figure in the table is followed by the different letter it is significantly different)

Fruit Quality

The percent of large fruit was not significantly different between bed systems of M.9 or M.26 (Table 5). Size from both rootstocks was similar to MM.106. Neither were there more small fruit in these multiple bed nor MM.106. Trees on M.27 were the exception with more small fruit and less large fruit but bed systems on this rootstocks made no difference. These trees on M.27 appear to be too dwarfing for adequate production of quality fruit, also fruit size tends to be smaller than that growing on M.9 or M.26, aggravated by the too-short stakes or trellis wires.

Hi Early being a highly coloured striped red cultivar of Delicious has shown no sign of colour reduction in the higher density beds or elsewhere. Ordinary Gala did show sign of less red colour within the middle of the three and four row beds on the lower branches. In year 7, hand thinning was done to supplement the chemical thinning to M. 27, and this did improve fruit size similar to M.9 and M.26.

Table 5. The percent of small fruit and large fruit in each bed system in 1995 and (1997).

Rootstock	1 Row 1667 tr/ha		2 Row 2286 tr/ha		3 Row 3043 tr/ha		4 Row 2822 tr/ha	
	small	large	small	large	small	large	small	large
M.9	15.3ab	28.9bc (44.1)ab	16.4ab	31.0bc (55.8)ab	18.5ab	28.8bc (50.9)ab	10.8a	43.7c (57.3)ab
M.26	15.2ab	31.6bc (53.4)ab	19.6ab	20.1ab (41.7)a	22.9b	23.7b (42.4)a	13.5a	37.1c (47.7)ab
M.27	28.7b	10.2a (59.7)b	30.5b	9.3a (50.2)ab	28.8b	11.6a (58.6)b	30.3b	9.6a (66.2)b
MM106 880 tr/ha	13.6a	34.3bc (72.6)b	s.e. 8.99	11.93 (15.91)				

(Where a figure in the table is followed by the different letter it is significantly different)

Sunburn on apples can occur when temperatures exceed 30°C, but foliage can protect the fruit. Sunburn was particularly obvious on the trees on M.27, irrespective of bed system. The rootstock M.27 is also too weak in growth to fully occupy the space allowed with Hi Early Delicious and they did not have enough foliage in the top third of the tree to protect the fruit from sunburn.

Light relations and Fruit colour

The distribution of light within the canopy as a percent of total light above the tree is shown in Figure 8. The percent is reduced through the canopy with the lowest readings in the lower section and on the south side.

Figure 9 showed the effect of light (measured in the middle of the day) within the canopy on red colour of Gala. Red colour in the top layer and the bottom north layer were very uniform for colour regardless of the actual light measurement at that moment (lines nearly horizontal). This meant that the light changed quickly allowing for general good colour. Where the colour followed the light percent most closely was in the second and third layer both north and south. The second and third layers had much more red colour with high light and not much with poor light. The bottom layer south was less uniform. This pattern was very similar whether the tree was in a single or multiple bed at the ends or in the middle. The percent of the surface coloured red and red intensity were very similar (Figures 10 and 11), following a similar pattern to light

(Figure 8). The poorest colour and least red intensity was in the lowest half on the tree on the southern side in the middle tree of a multiple bed.

Orchard Management

Without having specialized equipment for the application of herbicide in the multiple row beds, there were problems with weed control in the two higher densities. The spreading of straw mulch (70-100mm deep) across the beds has helped control weeds much more efficiently. The mulch also improved soil structure, worm numbers, and helped maintain soil moisture levels.

Pest and disease control with spraying was no problem for tree cover. Spray coverage for pest and disease control was excellent for all bed systems. The actual incidence levels was so low that any records were insignificant for any bed system or rootstock.

Establishment Costs

The establishment costs of these various planting systems is shown in Table 6.

Table 6. Major establishment costs for high density plantation systems for apples.

	Trees per hectare				
	880	1667	2286	3043	2222
Lime 5t/ha @ $53/t	265.00	265.00	265.00	265.00	265.00
Single Super .375t/ha @ $2.33/t	87.33	87.33	87.33	87.33	87.33
Deep Ripping 1 ha/hr @ $100/hr	100.00	100.00	100.00	100.00	100.00
Tree Cost @ $6.50	5,720.00	10,835.00	14,859.00	19,779.00	14,443.00
Tree Planting @ $12.50/hr 2.5min/tree(No machine)	458.33	868.22	1,190.62	1,584.89	1,157.29
Support Stake (Star Post) @ $3.00	0.00	5,001.00	6,858.00	9,129.00	6,666.00
Irrigation (assume water at head of block)					
Sub, mains, laterals, drippers @ .96c/tree	844.80	1,600.00	2,194.56	2,921.28	2,133.12
TOTAL	$7,475.46	$18.756.55	$25,554.51	$33,866.50	$24,851.74

Soil Moisture Status

Neutron Probe access tubes were installed in the trial High Density Plantation in order to monitor general soil moisture status. The site is located on a Krasnozem soil and occupies the upper position of an undulating topography. The soil is well drained and deep with textures varying from silty/loam at the surface to light clay at depths below approximately 25cm. Isolated patches of cobbles and small boulders of the weathering parent material are present in the profile especially in the surface horizon. The profile as a whole has favourable aeration status and moisture availability for plant growth.

All plots in the trial area received the same quantity of water via drip irrigation ie. one dripper per tree, 4l/hr. Soil moisture was logged through December and January, 1996/97 on a regular basis. Soil moisture status is plotted in Figure 12 in sections a, b, c and d. Some general observations of the readings show that in higher density beds, soil moisture was drier i.e. sections a, b and c, due to greater canopy area. This may also be due to a greater density of roots in a confined area. i.e. the higher the density of planting, the higher the density of roots (wood) and so less soil available to hold water, therefore a lower percentage of volumetric soil water. No trees were removed to count or calculate root numbers and weight to support this. Section d shows the two, 2 bed systems, M26 and M9 overlayed indicating similar moisture status for the two dwarf rootstocks.

Recommendations

Recommendations for improvement of the planting to what was originally designed are as follows:

1) **Density and Rootstock** Under the high light intensities of Australia and the deep rich volcanic soils at Orange, tree density/bed should be lower in the multiple rows, especially with M.26. The distance between trees in the row would be better at 2m rather than 1.75 to let in more light and for ease of picking. Where soils are shallower and poorer, the distances of 1.75m should be adequate, but in some apple areas in Australia, even M.9 is too dwarf. In which case, M.26 or a slightly more vigorous stock like MM.106 should work just as well.

2) **Best bed system** The three-row bed gave the highest yields. Fruit size differences between bed systems was variable and more likely to be due to crop load on each tree rather than the bed. Where less highly coloured varieties are grown, 3-row may be less suitable than 2-row.

3) **Least effective bed system** The single row gave the lowest yields per hectare. For fruit colour, this could be useful but 2-row would be better.

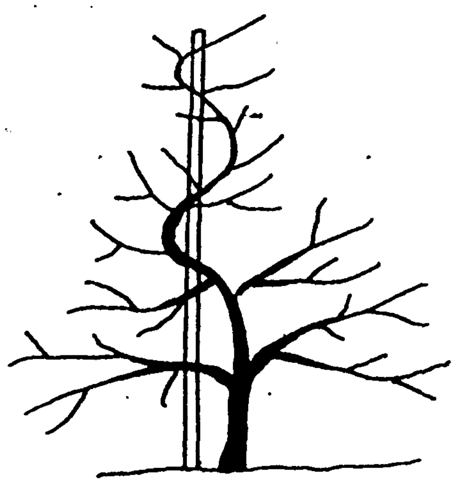
4) **Bed most suitable for colour** Where the variety to be grown is not as highly coloured as Hi Early, the wider spacing for light should also improve the red colour of the apples. Multiple rows (more than 2 rows) are not so suitable for less highly coloured varieties without at least wider spacing in the row (eg 2m).

1) **Alley width** The alley can be narrower in a commercial planting at 3.5 or even 3m wide, provided the tractor is small and has a narrow wheel base. Shading from one row to another with narrower alleys of north/south orientation will not be a problem.

6) **Support** Support of dwarf rootstocks is essential. The stakes or the trellis in single rows would have been more efficient at 1.87 m above the ground so that all fruit could be reached easily and the top supported. (The longer stakes have been used at Stanthorpe).

7) **Training of leader** Where the growth of the terminal shoot has grown too vigorously, it can be cut out to a weaker side branch. In years 3 and 4, the terminal shoot can be slowed down by bending it unpruned (see below) and this will also encourage flower bud formation along the shoot. This idea was shown in Bruce Barritt's book "Intensive Orchard Management". This was not done on these trees prior to 1993 when it should have been done, but looking back now on tree vigour of M.9 and M.26, it would be recommended.

Training the leader



8) **<u>Use of M.27</u>** M.27 rootstock may be still useful with a more vigorous triploid varieties such as Jonagold or Mutsu (which have more inherent vigour, growth and larger leaf and fruit size) on new apple soil. If longer stakes had been used with 1.8 metres above the ground combined with closer planting, the M. 27 trees could have been trained taller and have been more efficient. M.27 (which was too weak to hold up the leader),would appear to be more efficient with a longer stake and when growing triploid varieties such as Jonagold and Mutsu.

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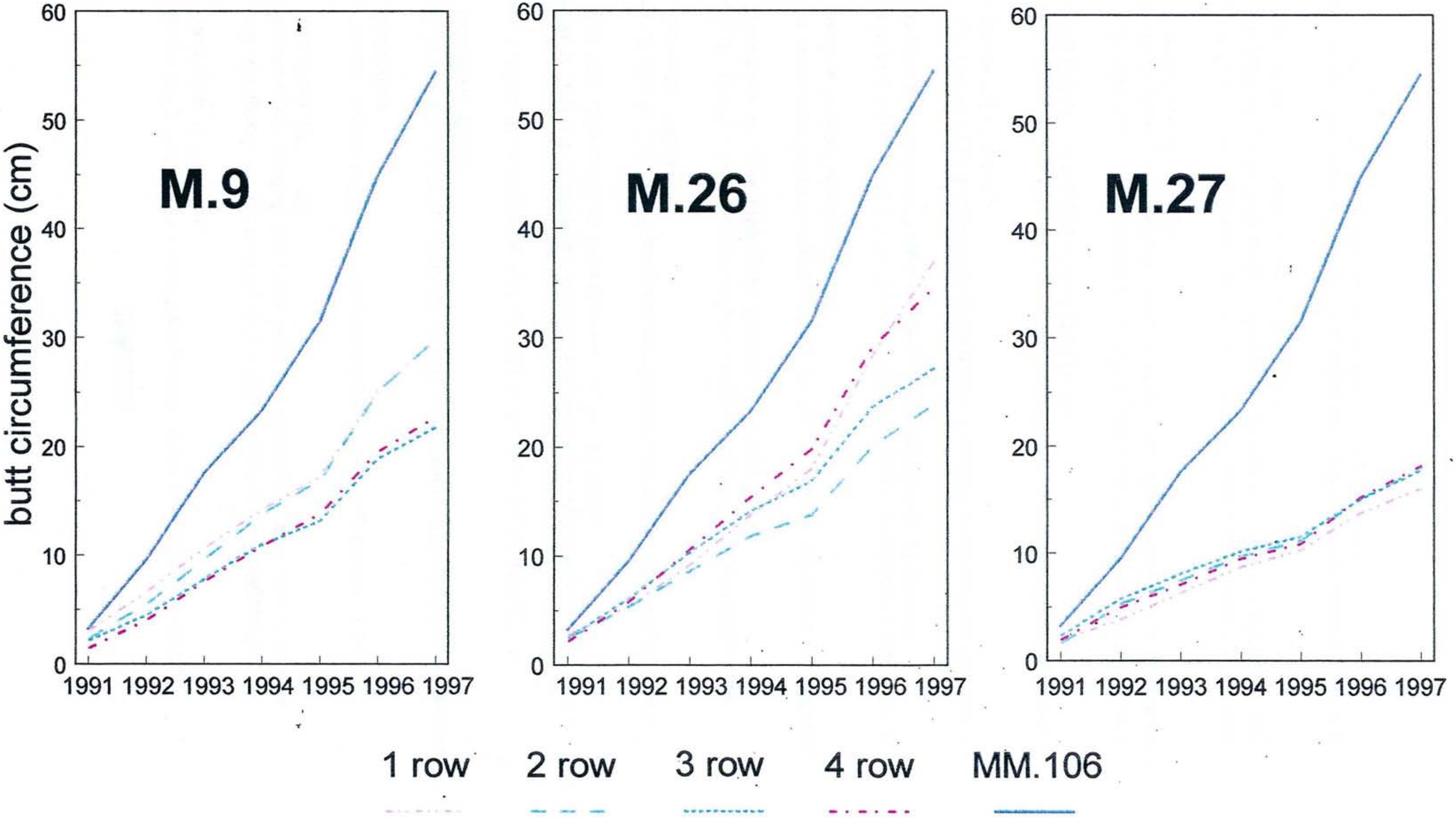
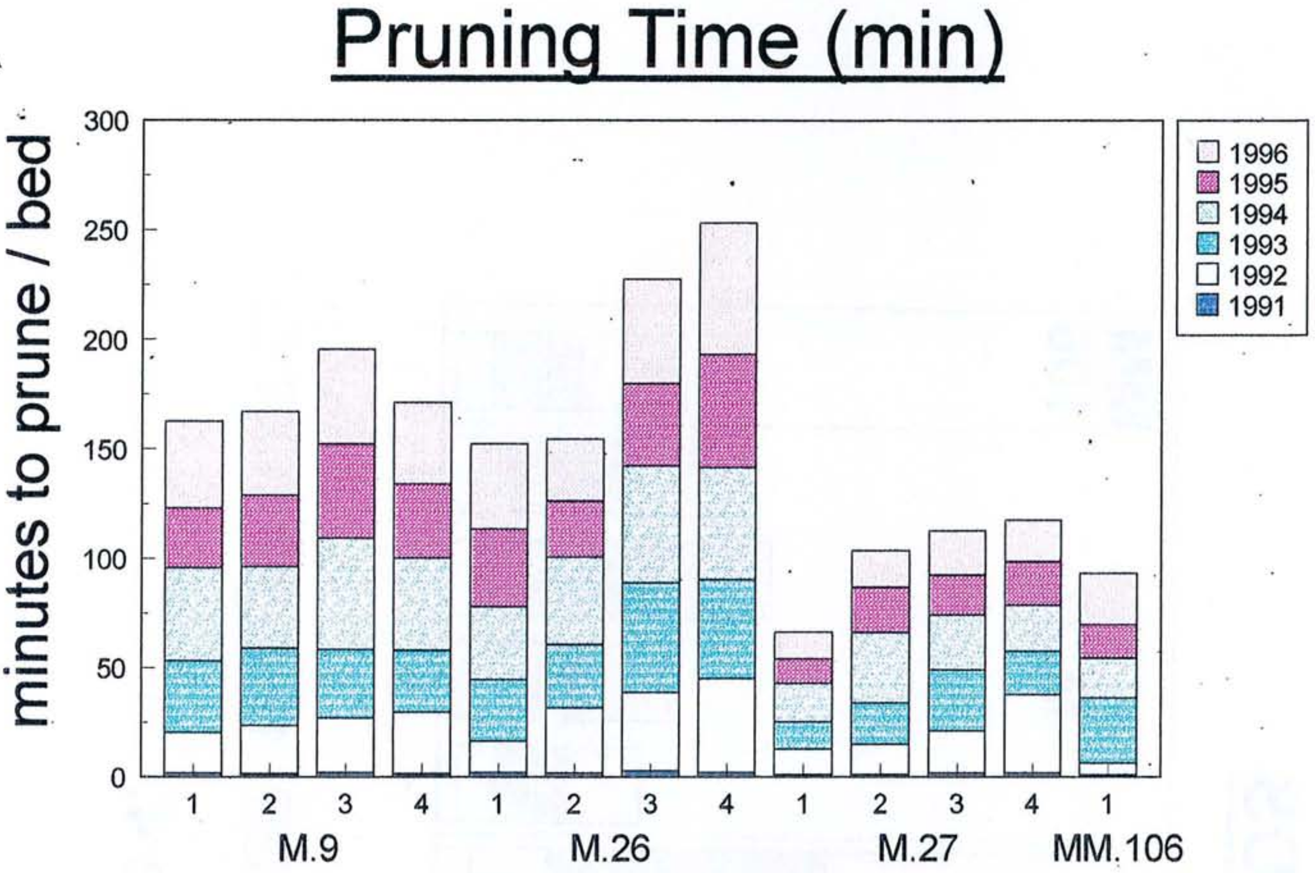
Figure 2.

BUTT CIRCUMFERENCE





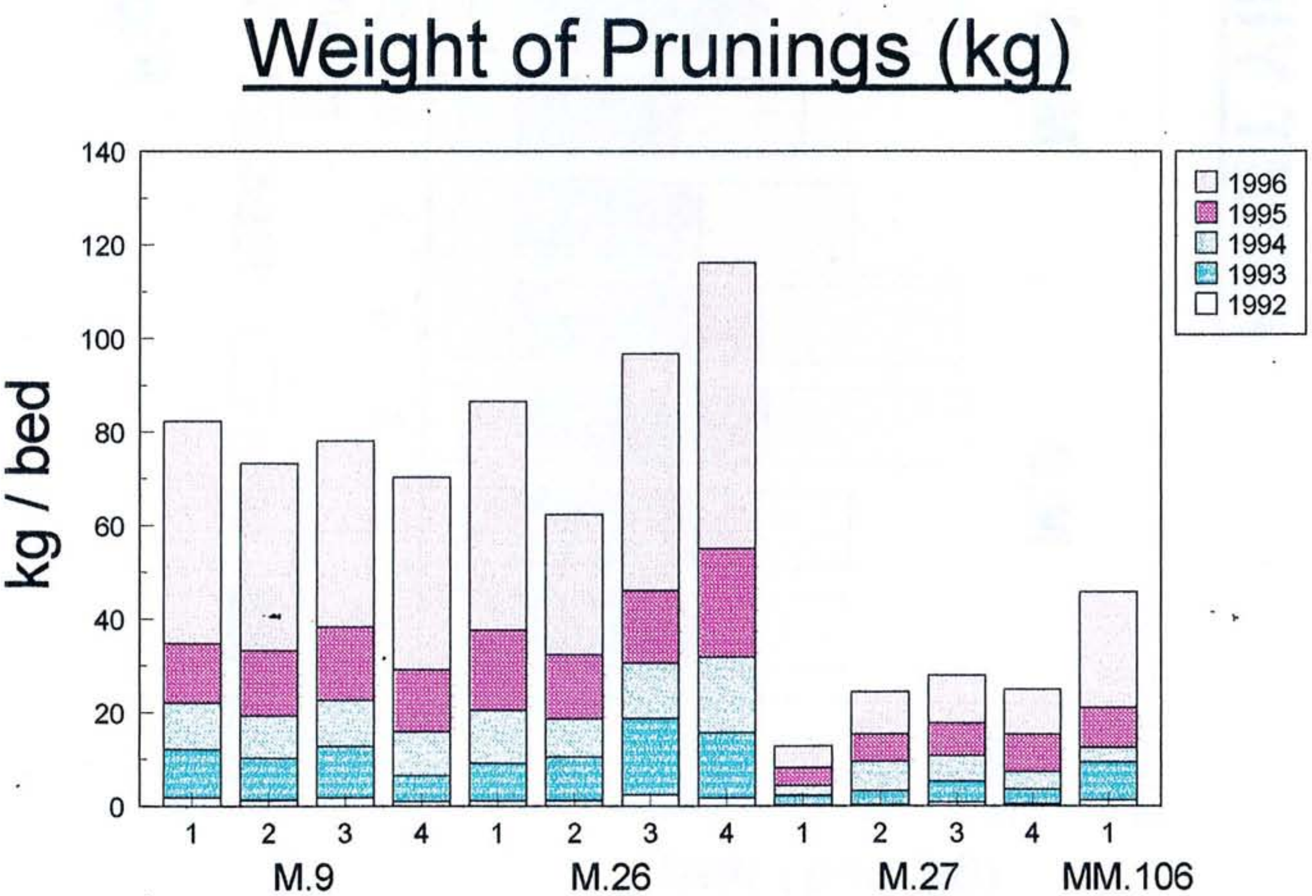


Figure 3. (no pruning weight 1991)

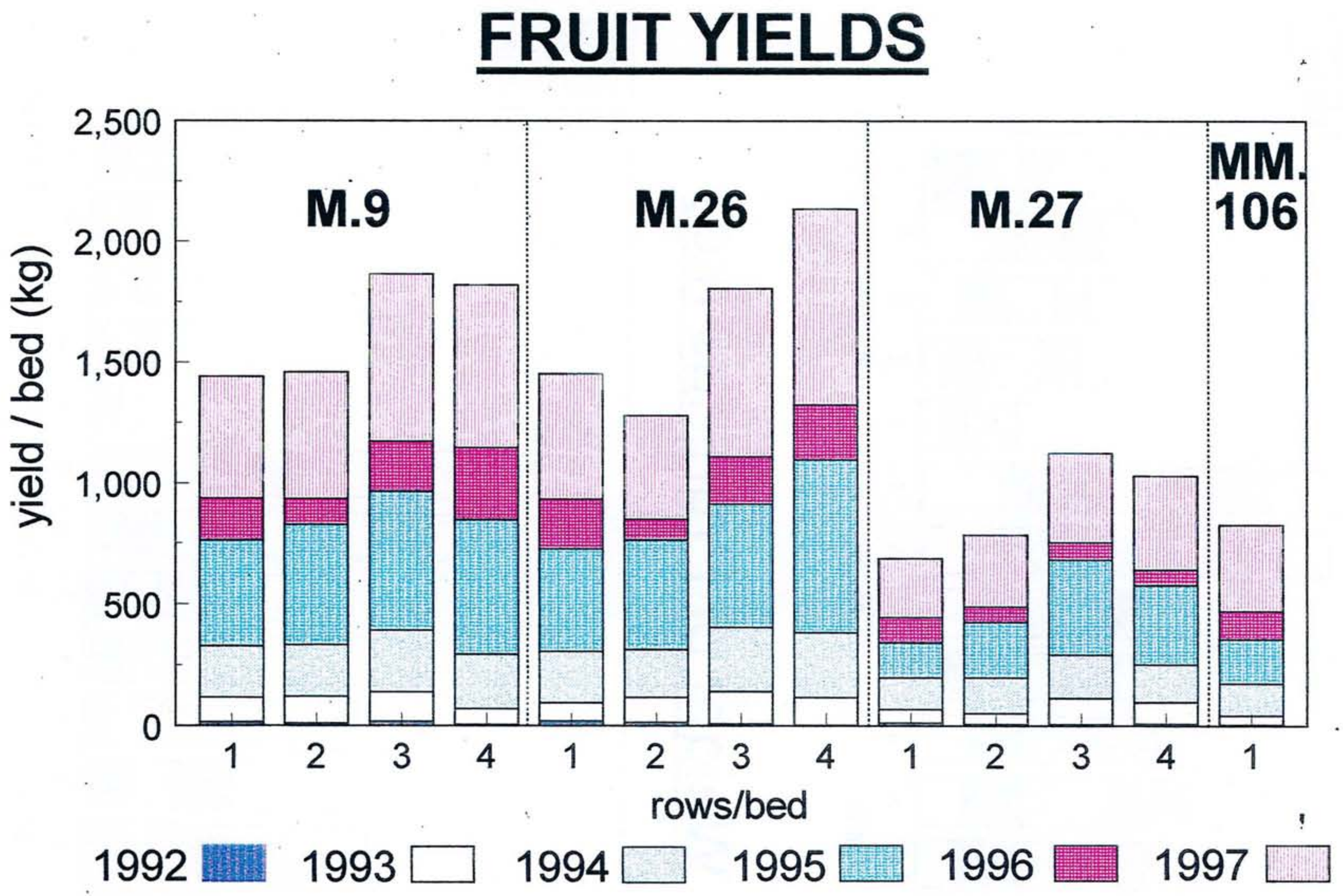
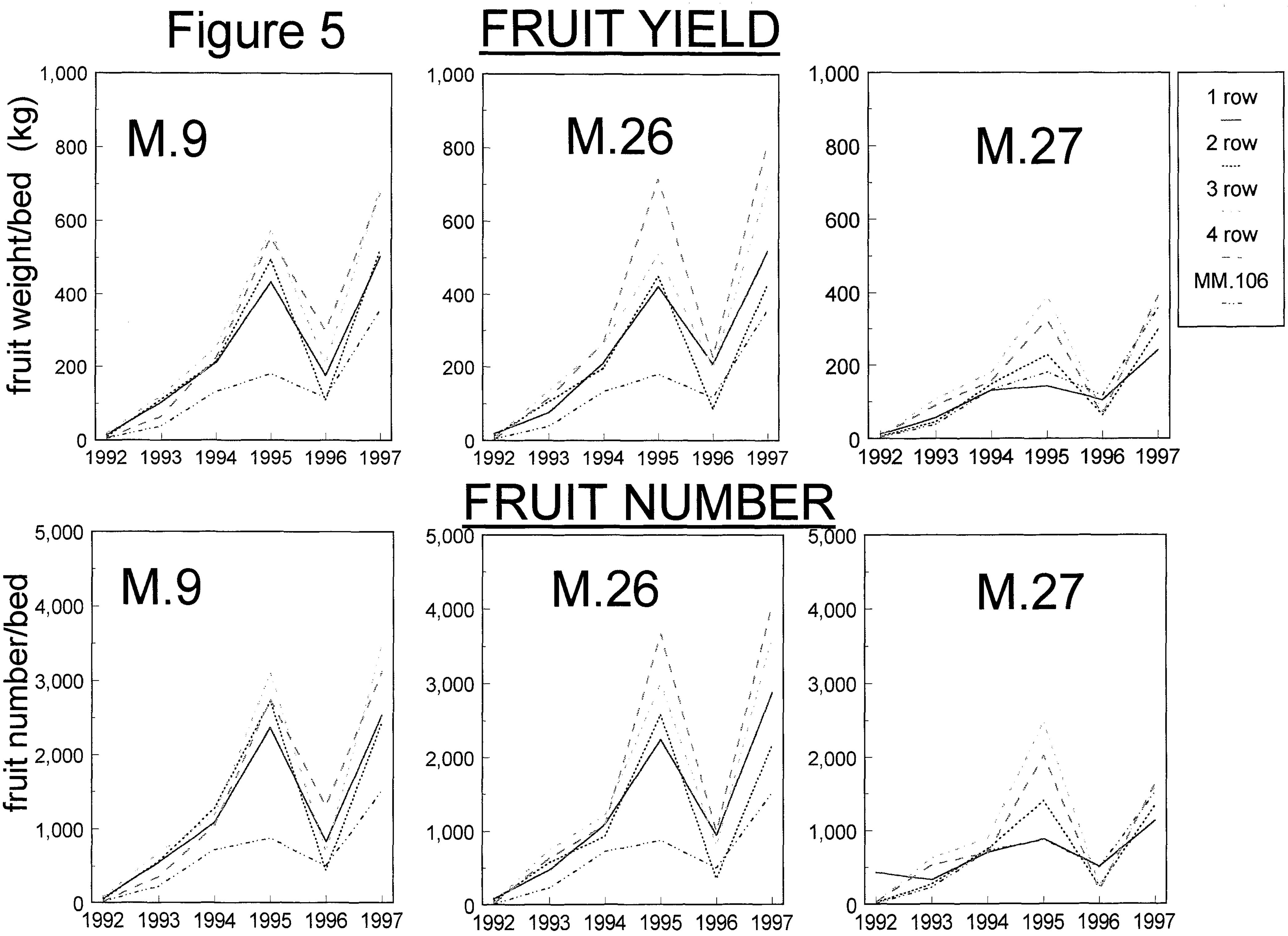

FRUIT YIELDS
2,500
2,000
1,500
1,000
500
0
yield / bed (kg)
M.9
M.26
M.27
MM.
106
1
2
3
4
1
2
3
4
1
2
3
4
1
rows/bed
1992
1993
1994
1995
1996
1997

Figure 4.

Figure 5


FRUIT YIELD
fruit weight/bed (kg)
M.9
M.26
M.27
1 row
2 row
3 row
4 row
MM.106
FRUIT NUMBER
fruit number/bed
M.9
M.26
M.27
1992 1993 1994 1995 1996 1997

Cumulative Yields (kg/bed)

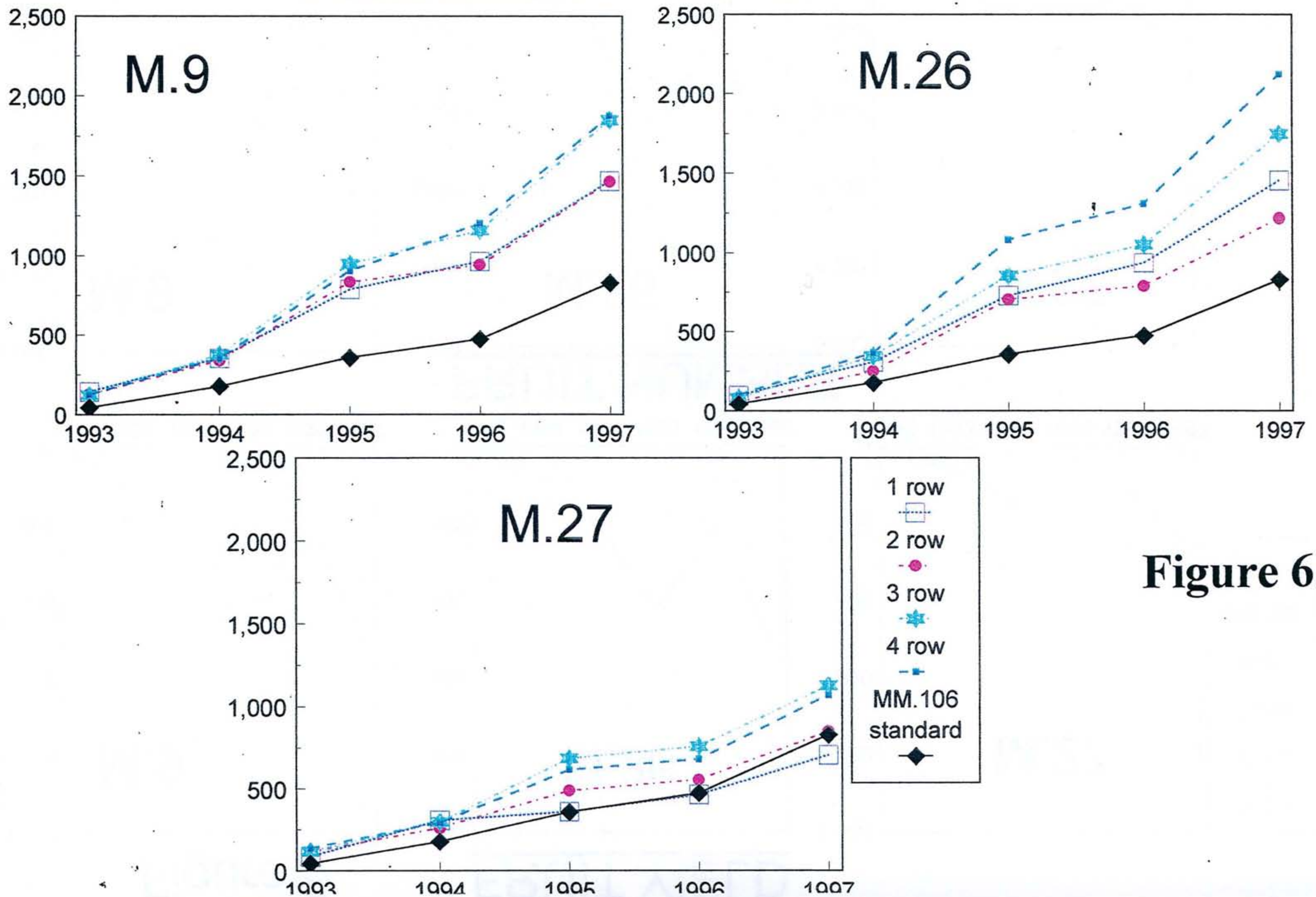


Figure 6.

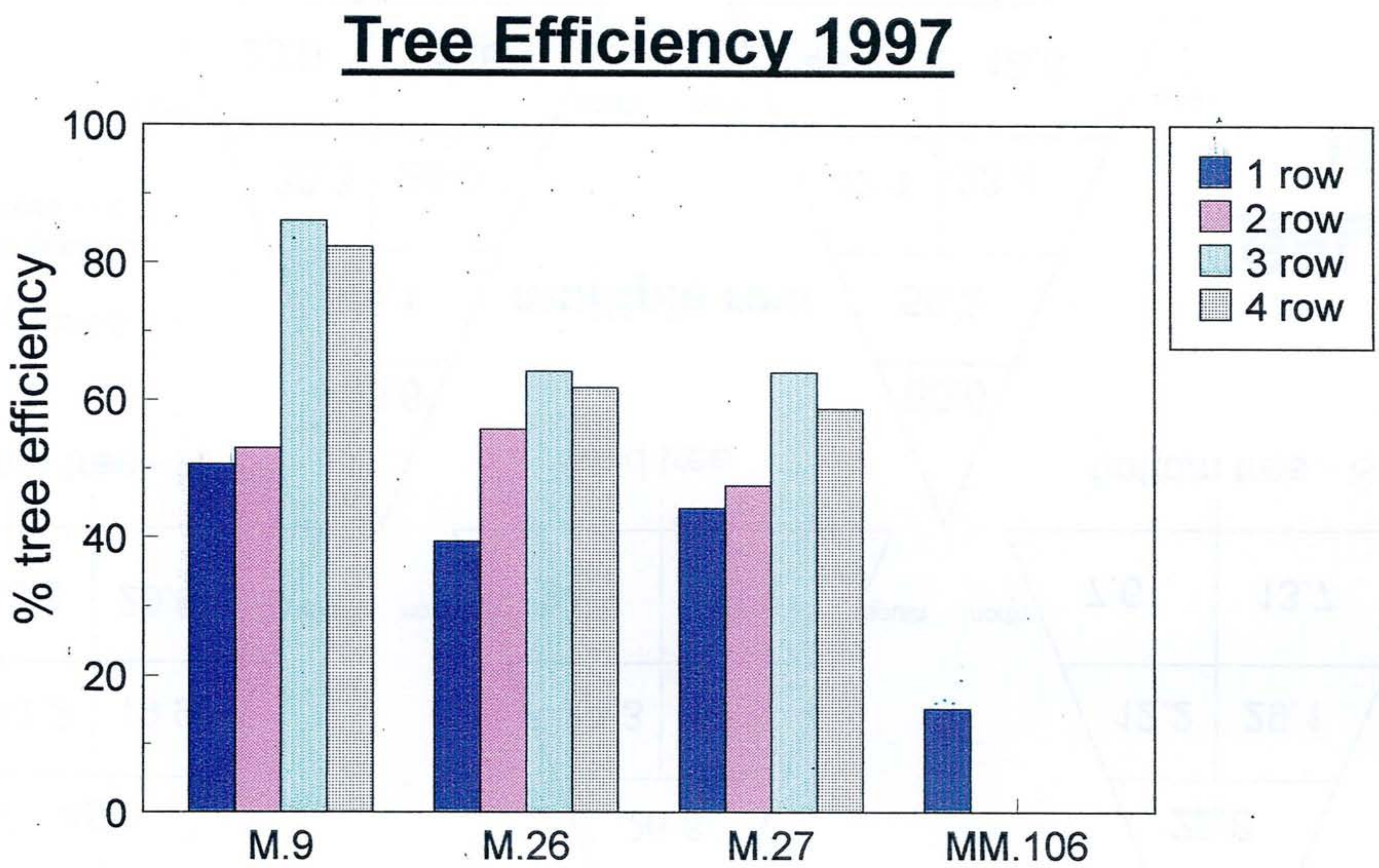

Tree Efficiency 1997
% tree efficiency
100
80
60
40
20
0
M.9
M.26
M.27
MM.106
1 row
2 row
3 row
4 row

Figure 7.

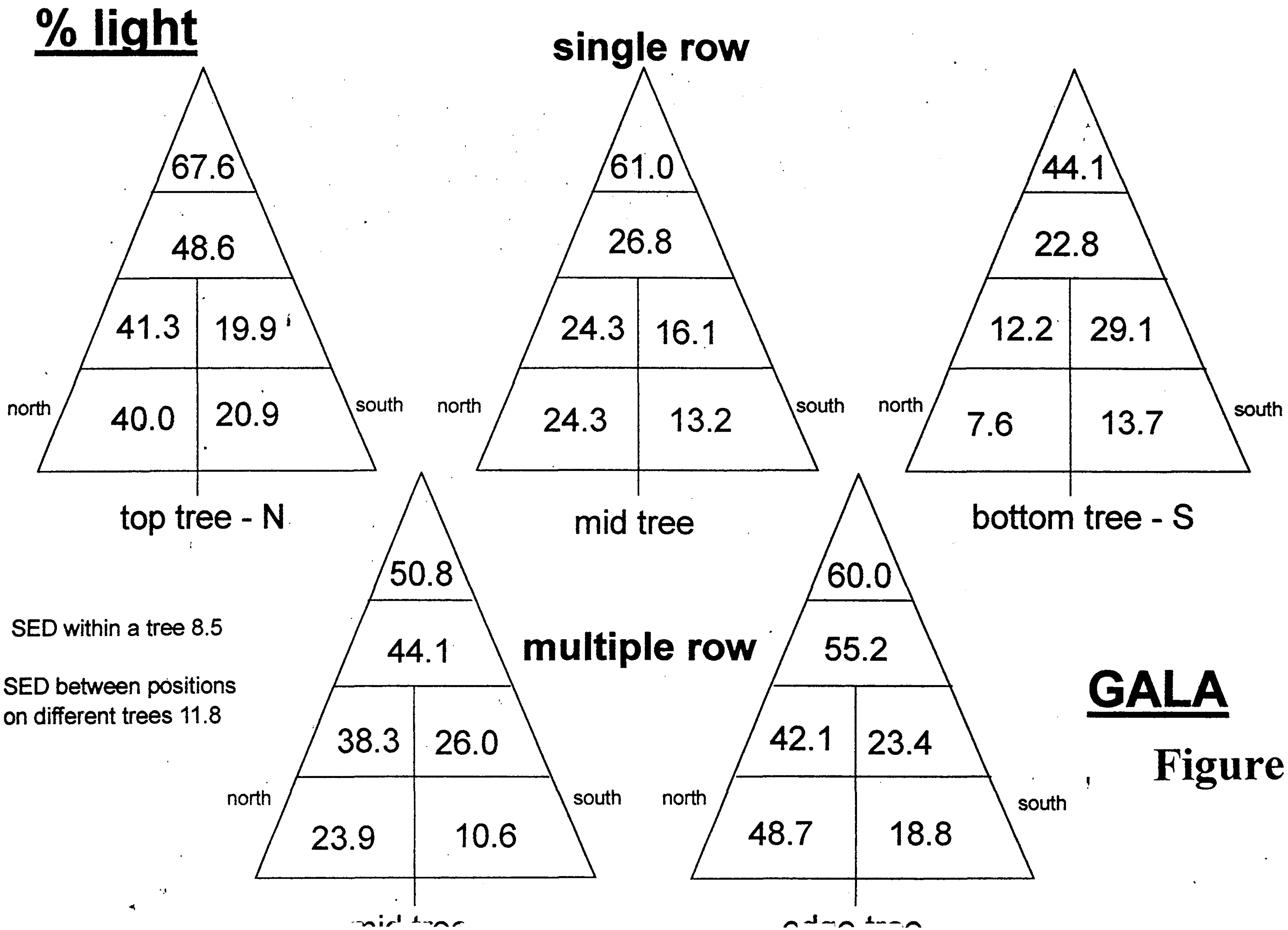

% light
single row
67.6
48.6
41.3
19.9
north
40.0
20.9
south
top tree - N
61.0
26.8
24.3
16.1
north
24.3
13.2
south
mid tree
44.1
22.8
12.2
29.1
north
7.6
13.7
south
bottom tree - S
multiple row
50.8
44.1
38.3
26.0
north
23.9
10.6
south
60.0
55.2
42.1
23.4
north
48.7
18.8
south
SED within a tree 8.5
SED between positions on different trees 11.8
GALA

Figure 8.

Effect of Light on Fruit Colour within Canopy

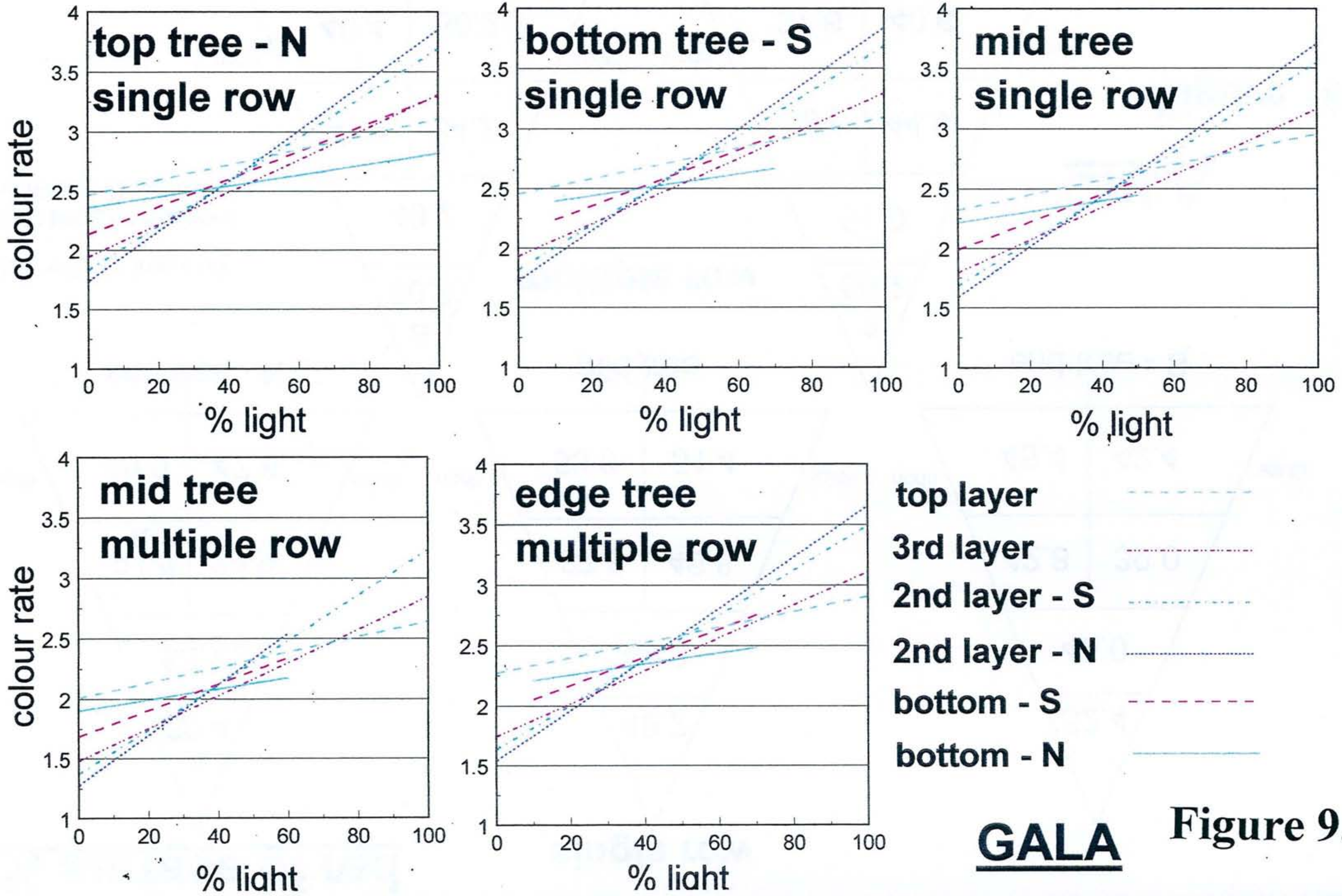


Figure 9.

% surface of red

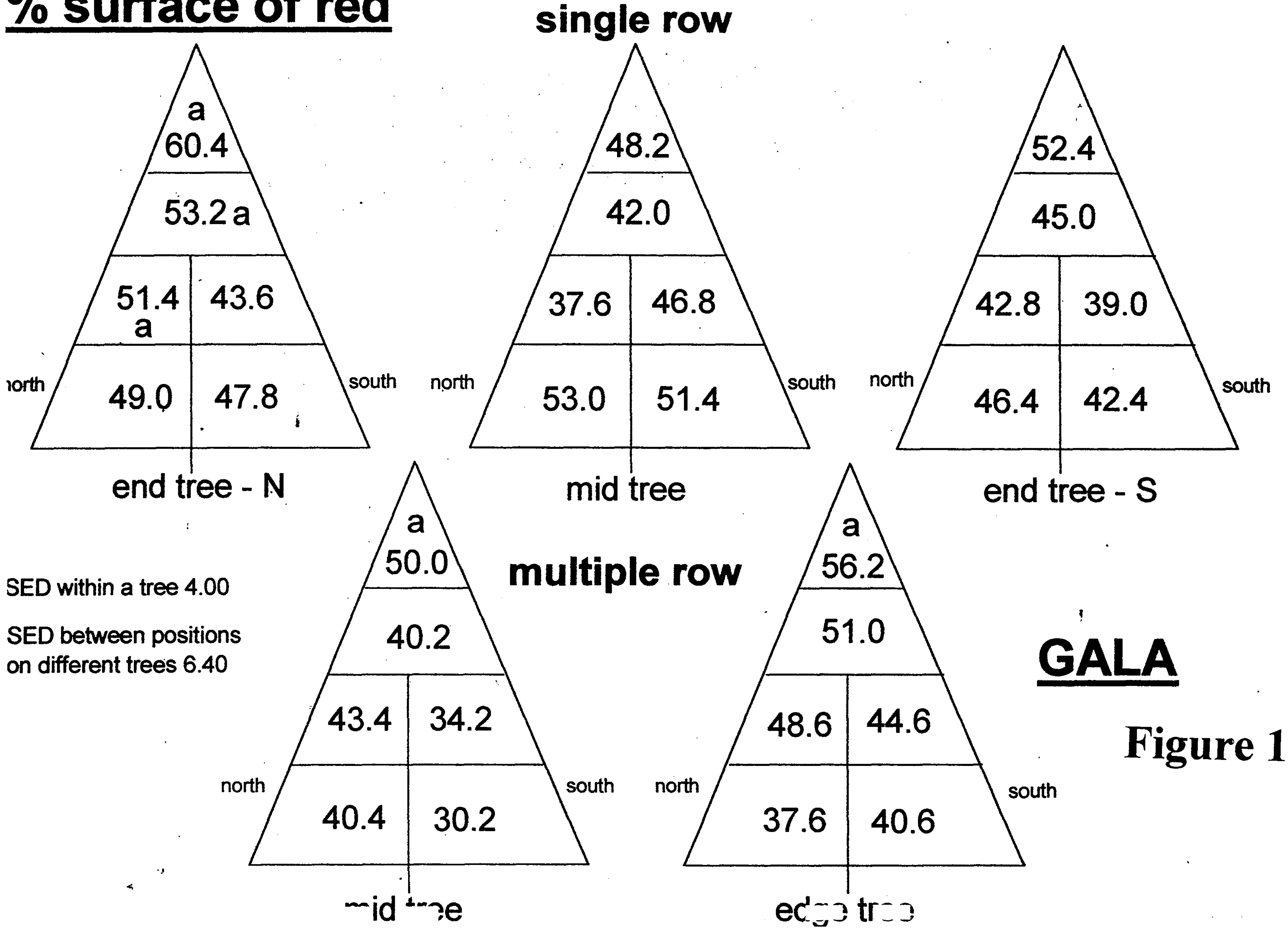


Figure 10.

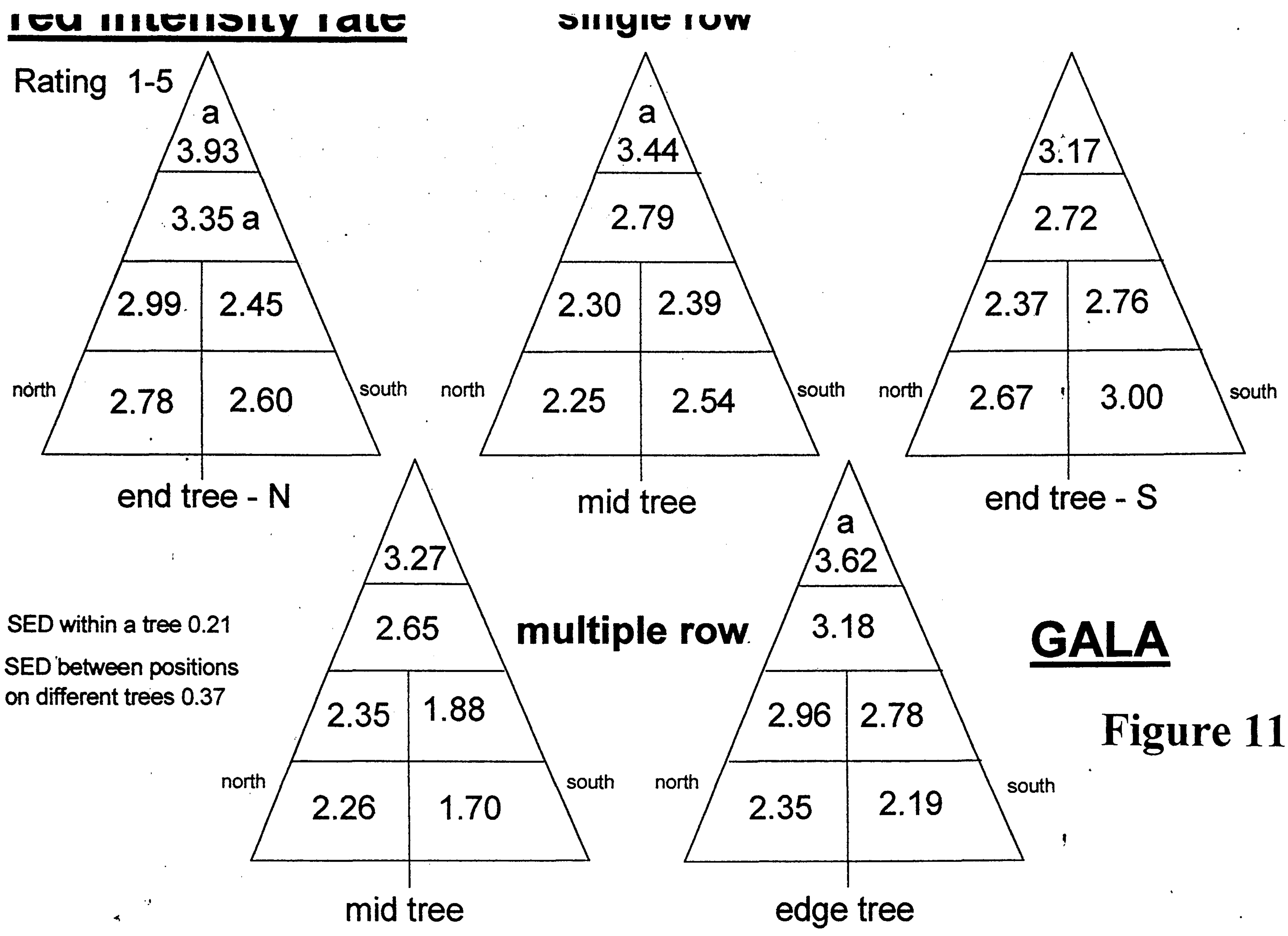

red intensity rate
single row
Rating 1-5
a
3.93
3.35 a
2.99
2.45
north
2.78
2.60
south
end tree - N
a
3.44
2.79
2.30
2.39
north
2.25
2.54
south
mid tree
3.17
2.72
2.37
2.76
north
2.67
3.00
south
end tree - S
3.27
2.65
2.35
1.88
north
2.26
1.70
south
mid tree
multiple row
a
3.62
3.18
2.96
2.78
north
2.35
2.19
south
edge tree
SED within a tree 0.21
SED between positions
on different trees 0.37
GALA

Figure 11.

NEUTRON PROBE READINGS 1996/97

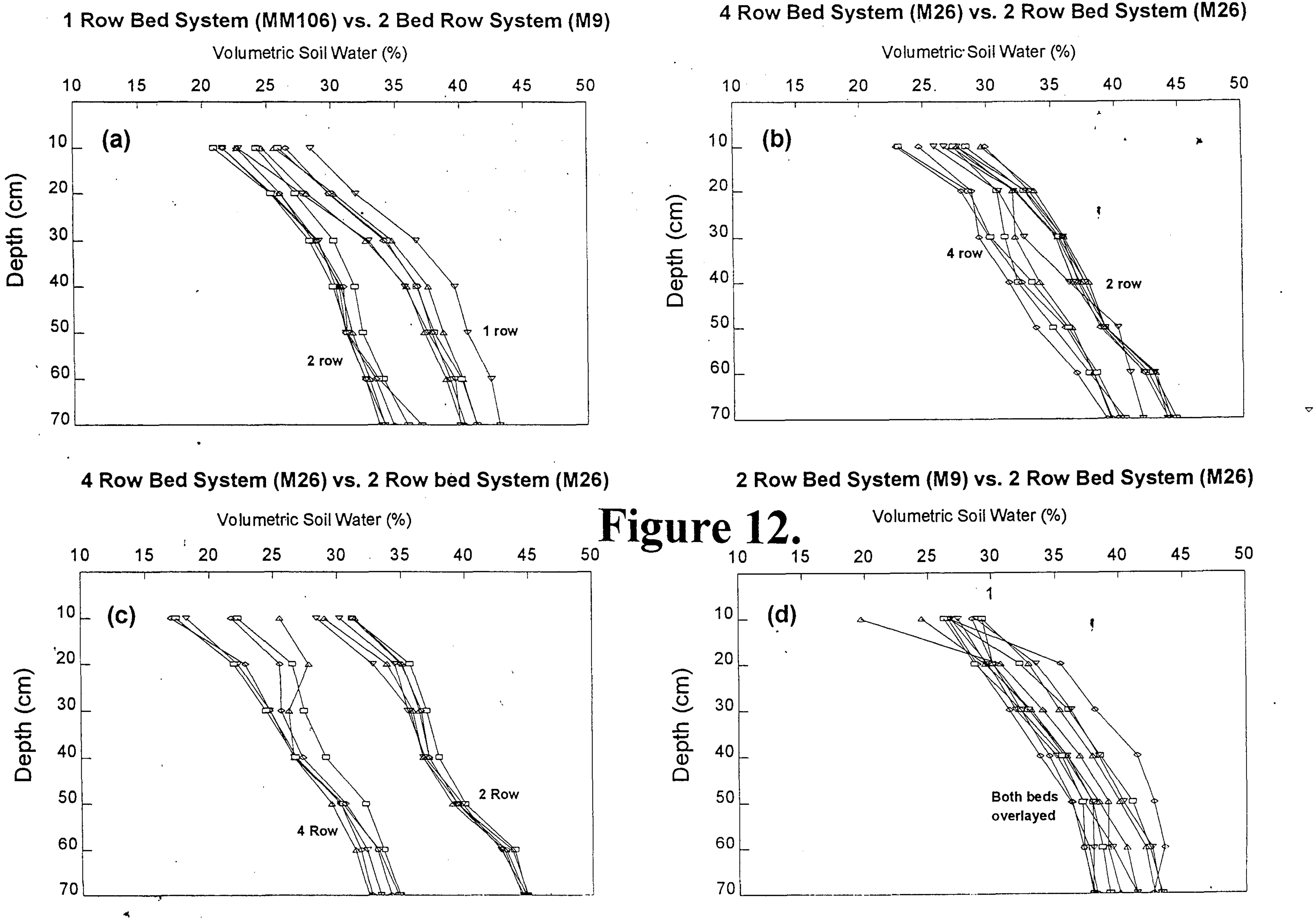


Figure 12.