Plant Spacing Implications for Grafted Grapevine I. Soil Characteristics, Root Growth, Dry Matter Partitioning, Dry Matter Composition and Soil Utilisation

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Six plant spacings (3 x 3 m, 3 x 1,5 m, 2 x 2 m, 2 x 1 m, 1 x 1 m, 1 x 0,5 m) were evaluated for their effect on aboveground and subterranean growth, dry matter partitioning and dry matter composition of different plant parts of vertically trellised *Vitis vinifera* L. cv. Pinot noir vines grafted onto rootstock 99 Richter. The vines were pruned to six buds/m^2 soil surface area and supplementary irrigated just after pea berry size and véraison stages. Root distribution was studied by using the profile wall method and by excavating the whole plant. Apparently higher bulk densities occurred in the top soil layers of closer spacings. In the case of fine (< 0,5 mm), extension (0,5 - 2 mm) and permanent (2 - 5 mm) roots, closer spaced vines significantly compensated in terms of root number per profile wall area. Higher root densities occurred with closer spacing. Aboveground and subterranean growth of the closer-spaced vines were reduced; a distinction between in-row spacings of 1,5 m and wider and those 1 m and narrower occurred. Aboveground and subterranean growth were positively related. The angle of root penetration and size of the root system increased with wider spacing. The spread of the root system was apparently not affected by either inter-row or in-row spacing. The majority of roots were located within the allocated in-row distance. Cane and root mass and total vine dry mass per m^2 soil surface indicated optimum utilisation of soil volume for medium-spaced vines (2 x 2 m, 2 x 1 m). Evidently higher starch concentrations occurred in the cordons, trunks and roots of wider-spaced vines. Roots contained the highest starch concentrations, followed by the trunk, cordon, canes and rootstock trunk. Starch contents of aboveground and subterranean plant parts were similar. The ratio of aboveground:subterranean starch content was, however, lower for closely spaced vines.

Although the selection of a particular plant spacing on a given locality is one of the most important long-term decisions in the cultivation of grapevines and is critical for sustained productivity, this aspect of grapevine cultivation has been extensively studied during recent years by only a few investigators (Shaulis, 1980; Archer & Strauss, 1990; Bandinelli, Cesari & Di Collalto, 1993; Reynolds, Wardle & Naylor, 1995; Valenti, Tonni & Cisani, 1996). Furthermore, in spite of the pronounced effect of the root system on plant performance (Van Zyl, 1988; Hunter & Le Roux, 1992; Hunter *et al.,* 1995), knowledge of the effect of plant spacing on root development and distribution is limited. Except for earlier classical studies and others quoted by Champagnol (1984), later comprehensive studies dealt with three-year-old (Archer & Strauss, 1985), six-year-old (Bandinelli *et al.,* 1993; Kliewer, Benz & Morano, 1996) and nine-year-old (Morlat, Remoné & Pinet, 1984) vines. Long-term effects, dry matter partitioning, reserve nutrient status of the different plant parts, and the very important concept of land utilisation, have all been neglected to a great extent in previous investigations on plant spacing of grapevines.

Prior to planting, vine spacing is dictated by the soil's physical and chemical properties, which determine water-holding capacity as well as efficient root development and distribution for the supply of water, minerals and growth regulators to aboveground parts (Richards, 1983 and references therein). The yielding capacity of the soil can be greatly increased by e.g. soil management practices such as ridging, liming and irrigation (Raath & Saayman, 1995) as well as judicious nitrogen fertilisation, which all impact directly on growth and fruit composition (Conradie, 1991; Christensen *et al.,* 1994). However, the physical confinement of the root system and the change in soil yielding capacity created by different spacing of vines will undoubtedly affect distribution as well as the morphological and biochemical composition of the root system, eventually affecting the performance of the whole vine. It is quite conceivable that the constraint induced

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by this would affect the accumulation of storage tissue reserve compounds, notably starch, which has been identified as the main reserve compound (Winkler & Williams, 1945).

In this study, soil characteristics, aboveground and subterranean growth, as well as dry matter partitioning and composition, were quantified in order to determine the response of a mature, supplementary irrigated *Vitis vinifera* L. cv. Pinot noir/99 Richter vineyard to different plant spacings on a medium-potential soil.

MATERIALS AND METHODS

Vineyard and treatments: A 14-year-old *Vitis vinifera* L. cv. Pinot noir (clone BKV)/99 Richter (clone RY 1/30/1) vineyard planted to six different spacings was investigated. The soil was classified as a medium-potential Glenrosa (Soil Classification Working Group, 1991) developed from Malmesbury Shale. Vines were spaced (inter-row/in-row) 3,0 x 3,0 m, 3,0 x 1,5 m, 2,0 x 2,0 m, 2,0 x 1,0 m, 1,0 x 1,0 m, and 1,0 x 0,5 m, representing 1 111, 2 222, 2 500, 5 000, 10 000, and 20 000 vines/ha, respectively. They were trained to a five-strand hedge and spur pruned to six buds/m^2 soil surface area. Canopy management practices, namely suckering (removal of all shoots not located on spurs at 30 cm shoot length) and shoot positioning (twice during the season) were applied, whereas all shoots growing in excess of 30 cm above the top wire were topped just after pea size stage. Over the last five years of the experiment, supplementary irrigation of 50 mm was applied just after pea size and véraison stages, respectively. Vines were previously grown under dryland conditions (Archer & Strauss, 1985).

Soil conditions: Before planting, the soil was deep delved in two directions to a depth of 1 m using a wing plough. In autumn a cover crop (rye) was sowed between the rows and killed with a herbicide before bud break. The soil's physical characteristics were determined according to standard ARC-Nietvoorbij methods in three layers, i.e. 0 - 30 cm, 30 - 60 cm, and 60 - 90 cm. Bulk density was determined in 0 - 30 cm and 30 - 60 cm soil layers. Soil-borne pests (phylloxera, margarodes, nematodes) were quantified according to methods described by De Klerk (1970, 1978) and Loubser (1985).

Aboveground and subterranean growth, dry matter partitioning: Measurements included cane mass, cordon mass, trunk mass and circumference, rootstock trunk mass and circumference, root mass and root distribution. The latter was determined by using two methods: the profile wall method of Böhm (1979) as modified by Hunter & Le Roux (1992), and whole root system excavation.

The ***profile wall method*** consisted of the digging of a trench of approximately 1,4 m deep parallel to the vine row and 30 cm from the vine trunk. After exposure of the roots, a 20 x 20 cm grid system was set up against the profile wall. The width of the grid system extended to the centre between two adjacent vines. Roots were plotted in six soil layers (0 - 20 cm, 20 - 40 cm, 40 - 60 cm, 60 - 80 cm, 80 - 100 cm, 100 - 120 cm depth) and in five root thickness classes (< 0,5 mm, 0,5 - 2 mm, 2 - 5 mm, 5 - 10 mm, > 10 mm). They were categorised according to Richards (1983) as fine (< 0,5 mm), extension (0,5 - 2 mm), permanent (2 - 5 mm) and framework (5 - 10 mm and > 10 mm) roots. Cane, cordon, trunk, rootstock trunk, and root samples were taken from these vines for chemical analyses (vid. "dry matter composition").

For the ***excavation of the whole root system***, trenches were dug outside the surface area allocated per vine, whereafter the roots were carefully exposed up to a depth of 1,2 m by using pegs and water jets. The intact plant was then photographed. After removal of the whole vine, the original spatial distribution of the intact root system was recreated and the plants again photographed (with wide-angle lens from a fixed position) to determine the size of the plants as well as horizontal and vertical distribution of the roots. The excavated plants were also used to determine total dry mass of canes, cordon, trunk, rootstock trunk and roots (dry matter partitioning) as well as trunk and rootstock trunk circumference. Circumference of the rootstock trunk was measured in one position, whereas that of the trunk was measured in three positions (top, middle, bottom); means are presented.

Dry matter composition: Starch, glucose and fructose were extracted from freeze-dried cane, cordon, trunk, rootstock trunk and root samples as described by Hunter *et al.* (1995). Starch was determined enzymatically (Hunter *et al.*, 1995), whereas glucose and fructose were analysed by HPLC, using the equipment and conditions described by Hunter, Visser & De Villiers (1991).

Experimental design and statistical analyses: The full experimental layout consisted of completely randomised treatments and replicates (five) allowing a minimum of 33 and a maximum of 48 vines per replicate. To eliminate side-effects, border rows were included. The root study was done during the winter of 1995 on three of the above replicates per treatment. One vine per replicate was used for each of the profile wall and whole root system excavation studies. Student's t-LSD was used to test for significant differences.

RESULTS AND DISCUSSION

Soil conditions: The numbers of soil-borne pests were insignificant and did not affect grapevine health (data not shown). A general increase in clay and silt and a decrease in sand content with an increase in depth were found (Table 1). The soil compaction index (measured as bulk density) exceeded the critical value of 1,5 g/cm^3, beyond which root penetration is believed to decline (Richards, 1983) (Fig. 1). Apparently higher bulk densities in the top soil layers (0 - 30 cm, 30 - 60 cm) of closer spacings indicate higher soil compaction between the rows, probably because movement was confined to a small surface area between the rows. As these zones are normally highly colonised by roots (Fig. 2) (cf. also Hunter *et al.*, 1995 and references therein), root development and distribution of closer spacings may have been impeded. Root penetration is, however, also affected by water potential of the soil as well as size and rigidity of soil pores (soil porosity) (Richards, 1983). As shown before, soil water potential may have pronounced effects on the performance of grapevines planted to different spacings (Archer & Strauss, 1985, 1989, 1990).

TABLE 1

Physical characteristics of a medium-potential Glenrosa soil.

Depth (mm)	Clay (< 0,002 mm) (%)	Silt (%)		Sand (%)			
		Fine (0,002 - 0,02 mm)	Coarse (0,02 - 0,05 mm)	Very fine (0,05 - 0,1 mm)	Fine (0,1 - 0,25 mm)	Medium (0,25 - 0,5 mm)	Coarse (0,5 - 2,0 mm)
0 - 300	16,9	11,8	11,0	17,5	22,6	12,3	9,1
300 - 600	18,4	12,7	11,8	17,0	21,0	10,6	8,2
600 - 900	21,2	18,3	11,2	15,2	18,2	9,4	6,2

Values represent the means of five replications.

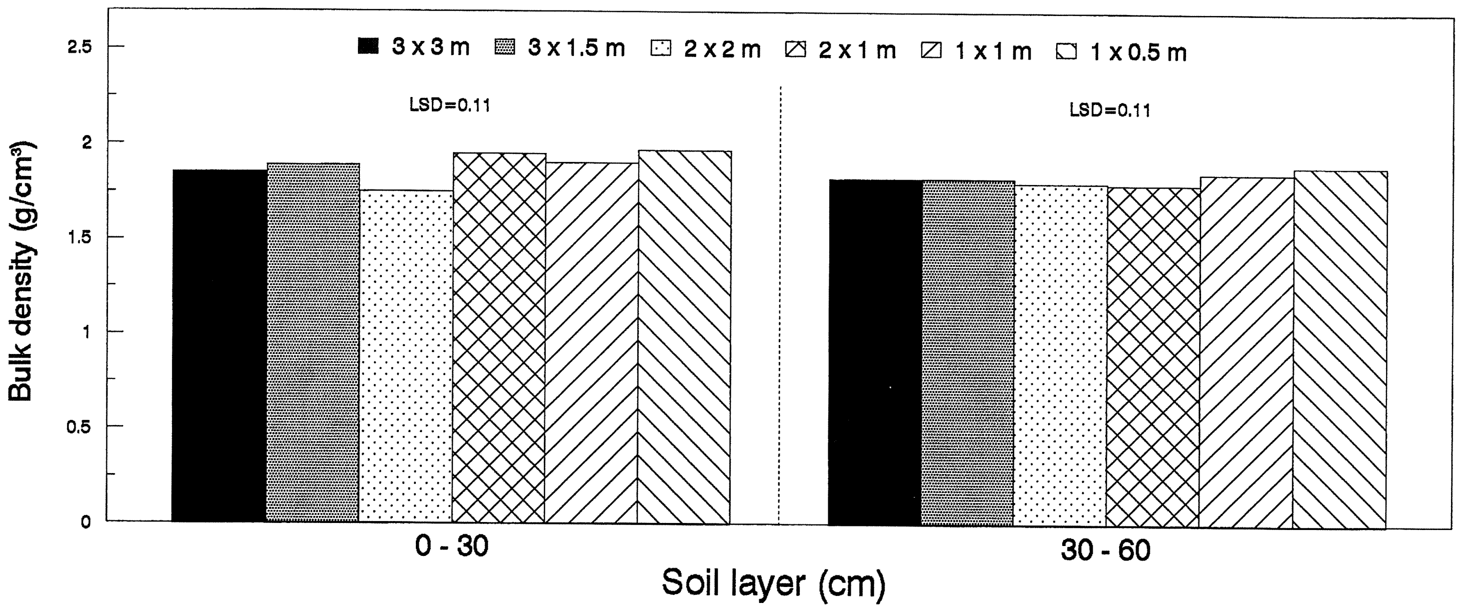

FIGURE 1
Vine-spacing effect on bulk density in different soil layers.

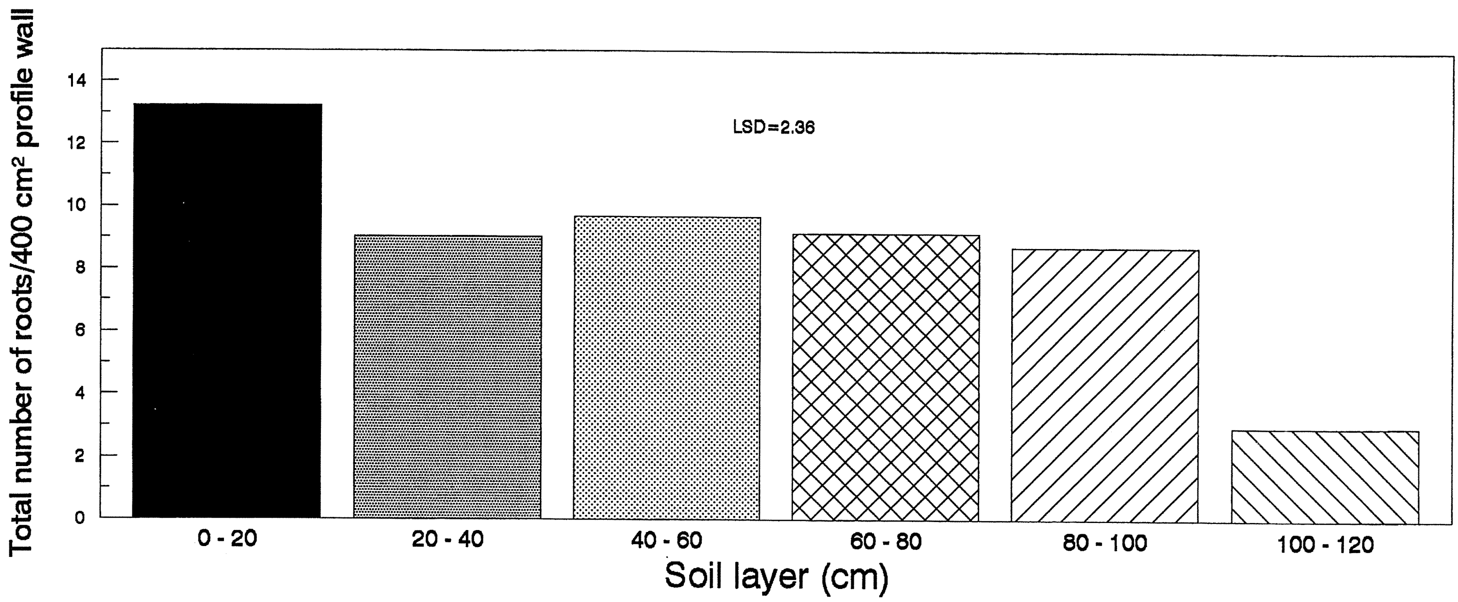

FIGURE 2
Number of roots in different soil layers, irrespective of treatment.

Aboveground and subterranean growth, dry matter partitioning: Given the in-row distance, it is evident that closer-spaced vines in the case of fine, extension and permanent roots significantly compensated in terms of root number per profile wall area, resulting in higher root densities (Table 2). Although close relationships between cane mass and root density were previously found for various rootstocks under different cultivation practices (Swanepoel & Southey, 1989; Hunter *et al.*, 1995 and references therein), cane mass (Table 3) was negatively related to root density/m^2 profile wall (Table 2) in this study. Therefore, although root density is recognised as an important indicator of grapevine performance (Freeman, 1983; Richards, 1983), this parameter cannot solely be used to predict aboveground growth under the restrictive soil volumes of different planting densities. Nevertheless, despite the lower total number of roots per profile wall (Table 2), occurrence of higher densities of particularly fine (< 0,5 mm) and extension ((0,5 - 2 mm) roots in the soil volumes of closer-spaced vines (Table 2) (cf. also Archer & Strauss, 1985; Bandinelli *et al.*, 1993) could have contributed to sustained and even increased performance of these vines on a m^2 soil surface basis, as is evident from Table 3 and Fig. 3. The presence of rapidly growing fine and extension roots would not only increase the absorptive capacity and activity of the root system and allow more efficient utilisation of water and nutrients from the soil, but also enhance the production of growth regulators (particularly cytokinin) involved in the regulation of shoot and fruit development (Freeman, 1983; Richards, 1983).

Considering dry mass of all aboveground and subterranean vegetative parts of the vine, the closer-spaced vines consistently displayed lower values (Table 3). Values obtained for in-row spacings of 1,5 m and wider and for those of 1 m and narrower

TABLE 2

Vine-spacing effect on root number and root density.

Spacing (m)	Total number of roots/profile wall	Root density/m^2 profile wall/root size (mm)					Total root density/m^2 profile wall
		< 0,5	0,5 - 2	2 - 5	5 - 10	>10	
3 x 3	506,0 a	120,1 c	12,2 c	5,6 c	1,3 a	1,4 a	140,6 b
3 x 1,5	307,3 bc	133,0 bc	15,6 c	7,1 c	2,6 a	1,7 a	160,1 b
2 x 2	382,7 b	124,5 c	23,8 bc	8,5 c	1,7 a	1,1 a	159,4 b
2 x 1	337,3 bc	230,3 a	33,3 ab	14,2 ab	1,7 a	1,7 a	281,1 a
1 x 1	301,7 bc	208,9 ab	30,6 b	9,4 bc	1,1 a	1,4 a	251,4 a
1 x 0,5	236,3 c	265,7 a	44,9 a	15,7 a	1,4 a	0,5 a	328,2 a

Values in columns followed by the same letter do not differ significantly ($p \leq 0.05$).

TABLE 3

Vine-spacing effect on morphological dimensions and dry matter partitioning.

Spacing (m)	Canes/vine			Cordon/vine			Trunk/vine		Rootstock trunk/vine		Total root dry	Total root dry mass
	Length (m)	Mass (kg)	Mass (kg)/m^2 soil surface	Length (cm)	Circumference (cm)	Mass (kg)	Circumference (cm)	Mass (kg)	Circumference (cm)	Mass (kg)	mass/vine (kg)	(kg)/m^2 soil surface
3 x 3	27,3 a	0,45 a	0,05	245,3 a	9,5 a	2,37 a	14,4 a	0,88 a	24,5 a	1,48 a	2,08 a	0,23
3 x 1,5	24,1 a	0,41 a	0,09	147,3 c	9,0 a	1,36 b	13,9 a	0,73 a	20,0 ab	1,37 a	1,51 b	0,34
2 x 2	27,4 a	0,52 a	0,13	180,7 b	9,2 a	1,57 b	14,1 a	0,79 a	20,7 a	1,38 a	1,61 b	0,40
2 x 1	11,3 b	0,19 b	0,10	90,0 d	9,3 a	0,78 c	10,2 b	0,48 b	14,6 bc	0,76 b	0,88 c	0,44
1 x 1	8,8 bc	0,16 bc	0,16	83,0 d	8,7 ab	0,59 cd	9,6 b	0,35 bc	11,9 cd	0,50 bc	0,68 cd	0,68
1 x 0,5	4,0 c	0,05 c	0,31	41,0 e	7,3 b	0,23 d	7,4 c	0,23 c	9,0 d	0,32 c	0,40 d	0,80

Values in columns followed by the same letter do not differ significantly ($p \leq 0,05$).

were distinctly different, indicating a dominating effect of in-row spacing on growth. Positive relationships between aboveground and subterranean growth were found and were apparently not changed by plant spacing. Although maximum and minimum values were found for closely *versus* widely spaced vines, cane and root mass (Table 3) and total vine dry mass (Fig. 3) on a m^2 soil surface basis showed that optimum utilisation of available soil volume occurred for medium-spaced vines (2 x 2 m, 2 x 1 m), i.e. a stabilisation in performance was observed at medium spacing.

Regardless of plant spacing, roots were predominantly located in the 0 - 80/100 cm soil zone (data not shown). This is in agreement with previous findings under different conditions of cultivation (Van Zyl, 1988; Swanepoel & Southey, 1989; Hunter & Le Roux, 1992; Hunter *et al.,* 1995). The formation and vertical penetration of roots in different soil layers are probably affected by genetic factors, depth of soil preparation, irrigation practices and soil structure.

The angle of root penetration as well as size of the root system progressively increased the wider the plant spacing (Figs. 4a & 4b). This was also found by Archer & Strauss (1985) and is evidence of the physical constraint caused by the root systems of adjacent vines, particularly under conditions of narrow spacing. It is, however, noticable that neither inter-row nor in-row spacing had any obvious directional bearing on the horizontal distribution of roots, i.e. roots were approximately equally distributed in all directions. In the case of narrow- and medium-spaced vines, roots penetrated slightly beyond the in-row distance per vine. However, roots of 3 x 3 m and 3 x 1,5 m spaced vines penetrated well short of and well beyond the allocated in-row space, respectively. In spite of this, the great majority of the roots were still located within the available in-row space, which is further evidence of the restrictive effect of in-row spacing on growth.

Dry matter composition: Wider-spaced vines apparently contained higher starch concentrations in the cordons, trunks (Table 4) and roots (Table 5), which may indicate that these vines were subjected to a lower degree of plant stress during the growth season. It has been found that stored starch can be mobilised from perennial parts of the plant under stress conditions (Candolfi-Vasconcelos, Candolfi & Koblet, 1994). Irrespective of size, roots contained the highest starch concentrations, followed in general by the trunk, cordon, canes and rootstock trunk, the latter two having almost identical concentrations. Furthermore, considering total starch content of each aboveground part *versus* that of the total root system, it is evident that the root system is the main starch storer. In line with previous findings (Hunter *et al.,* 1995), extension (0,5 - 2 mm) and permanent roots (2 - 5 mm) contained the highest starch concentrations. It is interesting to note that the starch content of the vines was approximately equally distributed between aboveground (Table 4) and subterranean growth (Table 5). However, the ratio of aboveground:subterranean starch content was lower than one for closely spaced vines (1 x 1 m, 1 x 0,5 m) (Table 5), indicating a preference of closely spaced vines for aboveground sucrose export instead of transitory starch formation, i.e. the carbohydrate demand of aboveground growth was seemingly higher. This is also indicated by the apparently higher hexose (glucose, fructose) contents in aboveground growth of closer-spaced treatments.

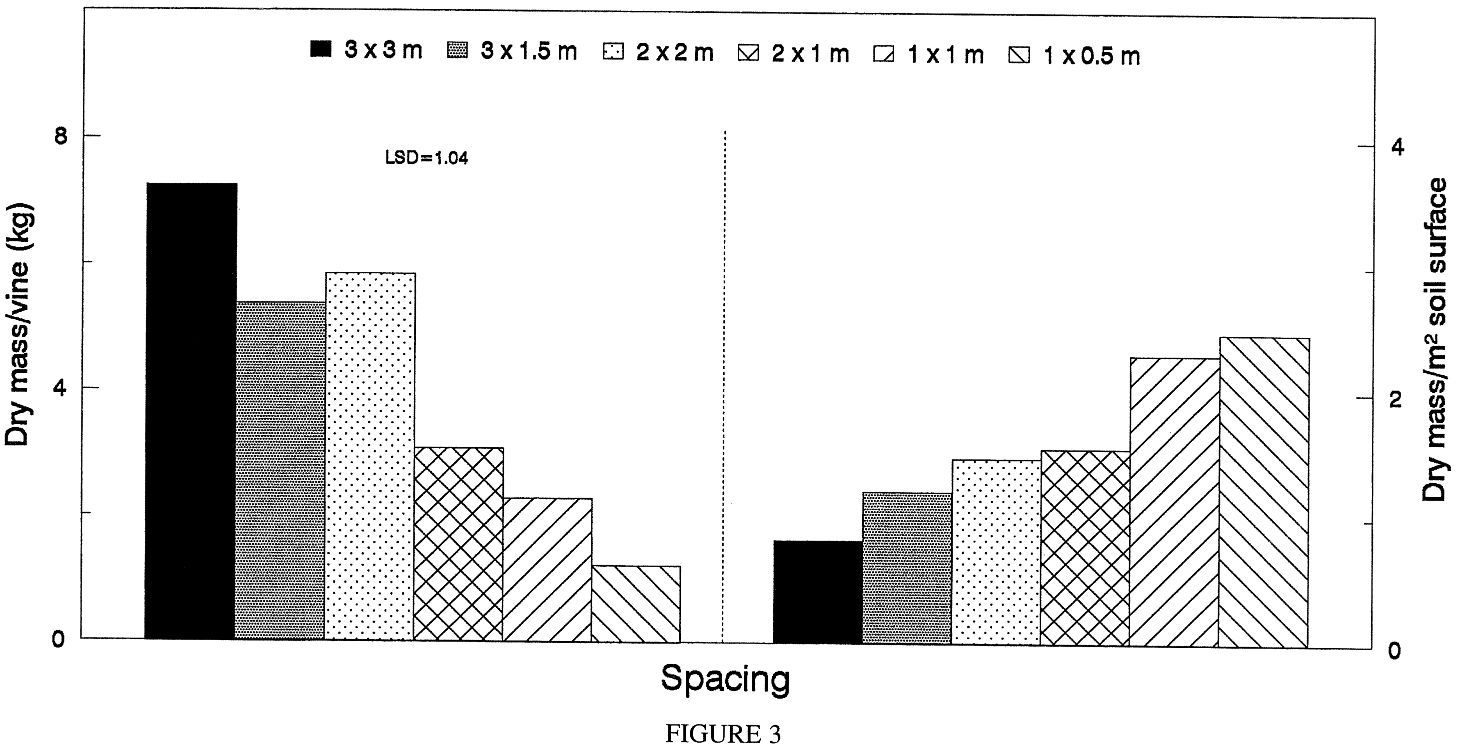

FIGURE 3
Vine-spacing effect on dry mass per vine and dry mass per m^2 soil surface.

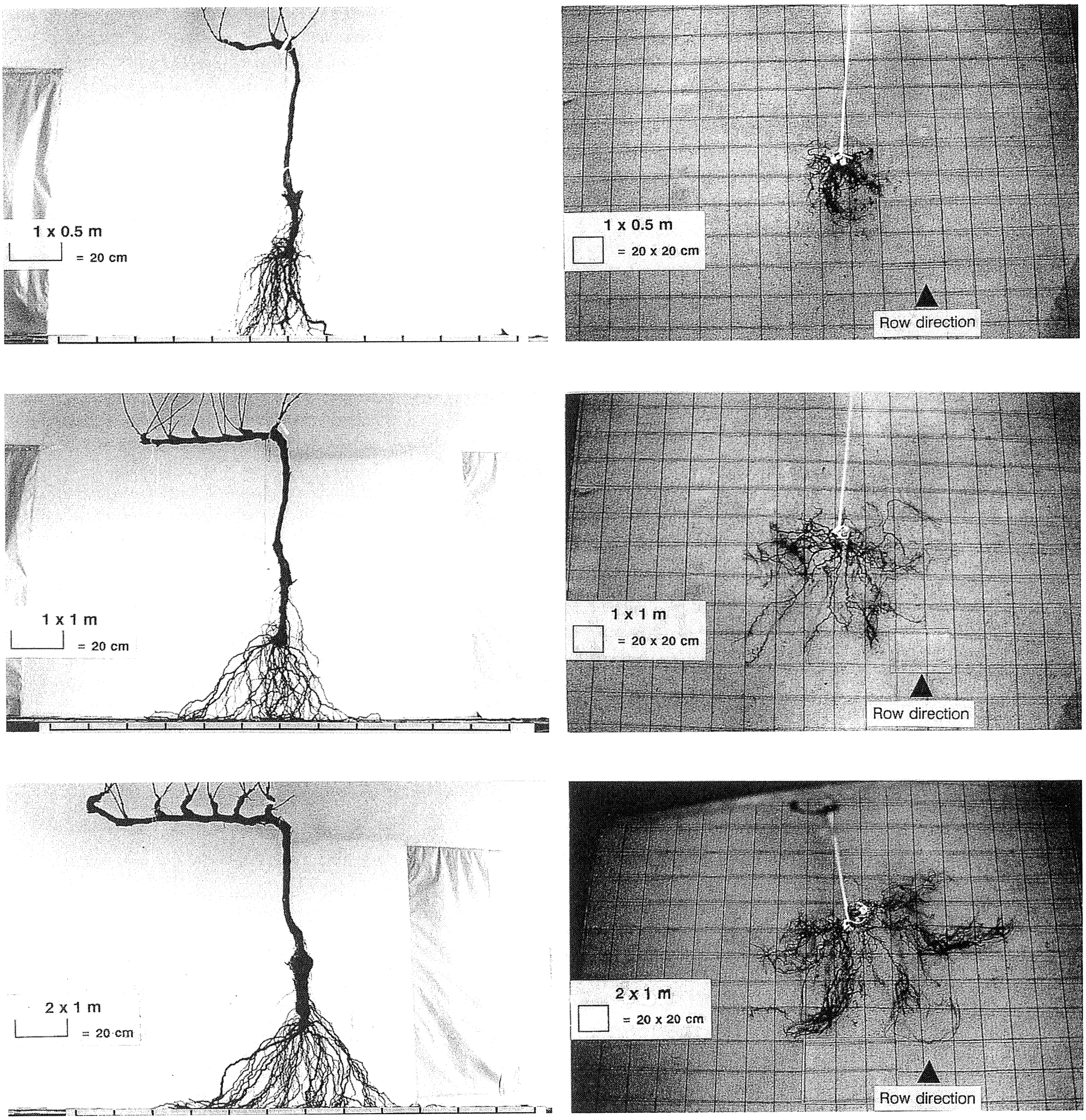

FIGURE 4a
Vine-spacing effect on the angle of root penetration and the size of the root system. Representative examples are shown.

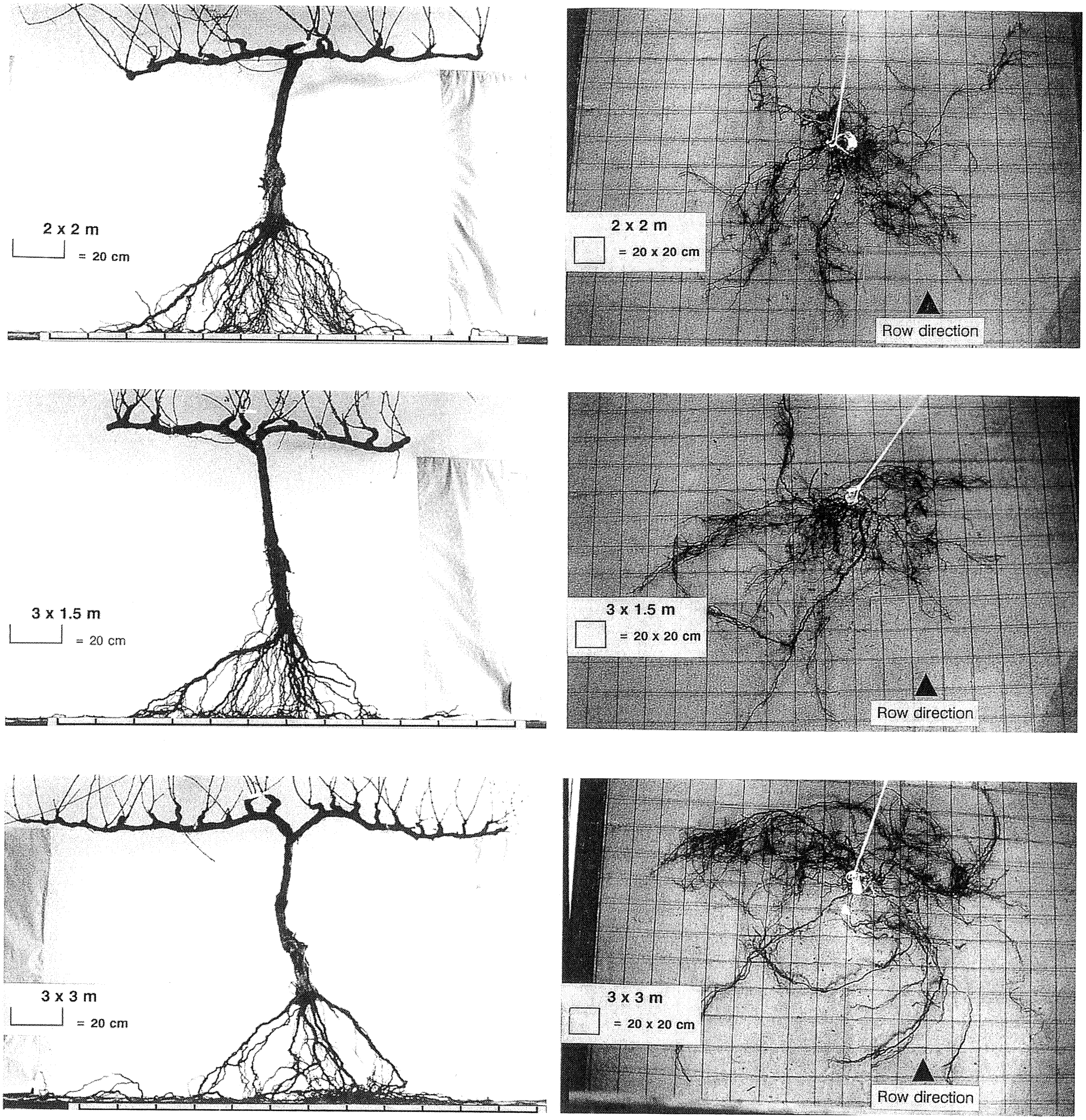

FIGURE 4b
Vine-spacing effect on the angle of root penetration and the size of the root system. Representative examples are shown.

TABLE 4

Vine-spacing effect on starch and hexose content of aboveground dry matter.

Plant part	Carbohydrate		Spacing (m)					
			3 x 3	3 x 1,5	2 x 2	2 x 1	1 x 1	1 x 0,5
Canes	Starch	: mg/g	51,82 b	58,33 ab	52,69 b	74,77 a	59,28 ab	61,53 ab
		g/vine	23,58 ab	24,40 a	27,16 a	13,62 bc	9,83 c	3,22 c
	Glucose	: mg/g	1,59 ab	1,06 b	3,29 a	3,31 a	2,74 ab	1,89 ab
		g/vine	0,83 b	0,40 b	1,70 a	0,66 b	0,45 b	0,09 b
	Fructose	: mg/g	3,86 ab	2,96 b	4,83 a	4,19 ab	4,27 ab	4,29 ab
		g/vine	1,78 ab	1,23 bc	2,50 a	0,81 bc	0,68 c	0,23 c
Cordon	Starch	: mg/g	74,89 a	78,51 a	63, 85 a	59,24 a	59,30 a	60,01 a
		g/vine	178,86 a	106,11 b	100,27 b	47,11 c	34,64 c	13,98 c
	Glucose	: mg/g	4,21 a	1,97 b	4,78 a	5,42 a	3,34 ab	4,05 ab
		g/vine	9,78 a	2,73 bc	7,41 a	4,26 b	2,08 bc	0,92 c
	Fructose	: mg/g	2,79 b	2,87 b	5,82 a	6,21 a	4,87 a	4,38 ab
		g/vine	6,45 b	3,95 bc	9,04 a	4,88 bc	2,93 cd	0,98 d
Trunk	Starch	: mg/g	86,63 a	78,23 ab	84,80 a	76,33 ab	73,60 ab	65,55 b
		g/vine	77,74 a	56,48 ab	65,65 a	36,68 bc	25,58 c	15,80 c
	Glucose	: mg/g	4,07 a	5,01 a	4,22 a	5,98 a	5,06 a	3,78 a
		g/vine	3,77 a	3,66 a	3,42 a	2,87 ab	1,77 ab	0,83 b
	Fructose	: mg/g	5,50 ab	6,25 ab	4,81 ab	7,11 a	6,10 ab	4,16 b
		g/vine	5,13 a	4,56 a	3,89 ab	3,43 ab	2,10 ab	0,99 b
Rootstock Trunk	Starch	: mg/g	51,47 a	55,76 a	67,40 a	54,62 a	57,06 a	62,63 a
		g/vine	76,14 ab	76,34 ab	97,54 a	42,17 bc	28,40 c	20,04 c
	Glucose	: mg/g	0,74 b	2,22 ab	1,71 ab	3,64 ab	4,62 a	3,09 ab
		g/vine	1,15 a	3,03 a	2,10 a	2,76 a	2,22 a	0,99 a
	Fructose	: mg/g	2,51 b	2,95 ab	2,90 ab	2,82 ab	6,62 a	4,18 ab
		g/vine	3,74 a	4,04 a	3,48 a	2,15 a	3,19 a	1,34 a

Values in rows followed by the same letter do not differ significantly ($p \leq 0,05$).

TABLE 5

Vine-spacing effect on starch and hexose content of subterranean dry matter.

Root size (mm)	Carbohydrate		Spacing (m)					
			3 x 3	3 x 1,5	2 x 2	2 x 1	1 x 1	1 x 0,5
< 0,5	Starch	: mg/g	146,08 a	151,18 a	170,37 a	165,22 a	147,18 a	134,45 a
		g/vine	6,59 a	3,37 b	7,30 a	3,03 bc	2,59 bc	0,40 c
	Glucose	: mg/g	5,23 a	5,55 a	0,98 c	2,99 abc	2,64 bc	2,41 c
		g/vine	0,23 a	0,13 b	0,03 c	0,05 c	0,04 c	0,01 c
	Fructose	: mg/g	6,66 ab	7,64 a	4,32 b	4,02 b	4,67 b	4,34 b
		g/vine	0,29 a	0,17 b	0,18 b	0,07 c	0,07 c	0,02 c
0,5 - 2	Starch	: mg/g	192,73 a	210,00 a	194,72 a	172,80 a	152,82 a	168,73 a
		g/vine	43,69 ab	60,00 a	68,24 a	37,02 ab	21,26 b	18,05 b
	Glucose	: mg/g	2,18 ab	4,43 a	1,30 b	2,04 ab	2,10 ab	2,69 ab
		g/vine	0,48 b	1,31 a	0,43 b	0,45 b	0,33 b	0,29 b
	Fructose	: mg/g	5,47 a	6,23 a	4,46 a	3,26 a	3,80 a	4,41 a
		g/vine	1,24 a	1,76 a	1,75 a	0,72 a	0,56 a	0,48 a
2 - 5	Starch	: mg/g	186,55 a	202,02 a	177,76 a	174,85 a	172,26 a	172,26 a
		g/vine	135,80 a	65,11 bc	79,53 b	67,84 bc	44,93 bc	30,69 c
	Glucose	: mg/g	2,57 a	4,77 a	4,46 a	3,81 a	3,04 a	3,88 a
		g/vine	1,89 a	1,72 a	2,01 a	1,51 a	0,81 a	0,99 a
	Fructose	: mg/g	3,69 a	6,24 a	5,48 a	4,60 a	5,28 a	3,95 a
		g/vine	2,73 a	2,15 a	2,42 a	1,79 a	1,39 a	0,72 a
5 - 10	Starch	: mg/g	158,66 a	180,76 a	154,74 a	128,67 a	143,12 a	131,22 a
		g/vine	97,33 a	94,03 a	63,83 ab	22,50 bc	35,90 bc	6,88 c
	Glucose	: mg/g	2,17 b	5,39 a	3,91 ab	3,41 ab	3,54 ab	3,88 ab
		g/vine	2,20 ab	2,78 a	1,70 ab	0,61 cd	0,88 bcd	0,21 d
	Fructose	: mg/g	3,31 a	7,76 a	4,85 a	4,57 a	5,69 a	5,36 a
		g/vine	2,24 ab	3,99 a	2,15 ab	0,81 b	1,36 b	0,29 b
> 10	Starch	: mg/g	121,66 a	109,58 a	94,50 a	100,65 a	110,16 a	112,11 a
		g/vine	62,43 a	35,23 ab	33,68 ab	9,31 b	3,21 b	8,78 b
	Glucose	: mg/g	4,32 a	4,78 a	4,18 a	3,78 a	3,13 a	4,64 a
		g/vine	2,11 a	1,52 ab	1,46 ab	0,36 b	0,09 b	0,47 ab
	Fructose	: mg/g	5,60 a	6,03 a	5,14 a	5,53 a	5,01 a	5,11 a
		g/vine	3,01 a	2,09 a	1,87 a	0,59 a	0,15 a	0,49 a
Mean starch concentration (mg/g)			161,1	170,7	158,4	148,4	145,1	143,8
Total subterranean starch (g/vine)			345,8 a	257,7 a	252,6 a	136,6 b	106,8 b	61,9 b
Ratio aboveground:subterranean starch			1,03	1,02	1,15	1,02	0,92	0,86

Values in rows followed by the same letter do not differ significantly ($p \leq 0,05$).

CONCLUSIONS

The study showed that both aboveground and subterranean growth are greatly affected by physical confinement of grapevines by means of plant spacing. Higher densities of particularly fine and extension roots in soil volumes of closer-spaced vines probably played a large role in the sustained performance of these vines on an area basis. Although dry matter partitioning between aboveground and subterranean growth was not affected, distinct differences between in-row spacings of 1,5 m and wider and those of 1 m and narrower show that growth is largely dominated by in-row spacing. Although it is recognised that the distribution of roots may vary under different cultivation conditions, this aspect has serious implications for optimal land utilisation and should be borne in mind whenever recommendations regarding the spacing of vines are made. Under the conditions of this investigation aboveground and subterranean growth as well as land utilisation showed that medium-spaced vines (2 x 2 m, 2 x 1 m) consistently performed optimally. This can therefore be used as guideline for producers. Although all root types are likely to contribute to some extent to the total uptake of required substances, it would appear that the composition of the root system has a critical role in its efficient functioning, supply to aboveground parts of the vine, and eventual realisation of the full potential of the vine in terms of productivity and longevity, particularly under conditions where the perception prevails that vines are too closely spaced. As the composition of the root system relates to root activity, the data can be interpreted as supporting suggestions that shoot and root output (size x activity) are in equilibrium and homeostatically interrelated. However, the question arises as to the way in which a root system with primarily bigger-sized roots *versus* one with primarily smaller-sized roots will affect grape composition and eventually wine quality. The differential contribution of these two components should be determined.

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