The Influence of Rootstock on the Rooting Pattern of the Grapevine

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Date submitted: February 1989
Date accepted: May 1989
Keywords: grapevine, root density, root distribution, rootstocks

The rooting pattern of rootstocks grafted with Chenin blanc, on an Oakleaf soil with minimum restrictions to root penetration, was investigated. Both root density and distribution were affected by rootstock. Under conditions of intensive irrigation and high potential soil, the best colonisation and utilisation of the available soil volume was obtained with Berlandieri 13/5, 101-14 Mgt and 1103 Paulsen while 140 Ruggeri and US 12-6-8 performed poorly as regards their subterranean growth. This was also reflected in the above ground performance.

Growth, development and distribution of grapevine roots have been the subject of many studies. Chemical (Conradie 1983) and physical soil conditions (Saayman & Van Huyssteen, 1980; Saayman, 1982; Van Zyl, 1984), cultivation practices (Van der Westhuizen, 1980; Van Huyssteen & Weber, 1980; Saayman & Van Huyssteen 1983; Archer & Strauss, 1985; Archer, Swanepoel & Strauss, 1988) genetic characteristics (Champagnol, 1984; Southey & Archer 1988) and phytosanitary status of the soil (De Klerk & Loubser, 1988) were shown to exert an influence on the subterranean performance of the grapevine. The available soil volume is, however, probably the most important factor dictating the size and distribution of the root system (Saayman & Van Huyssteen, 1980; Saayman, 1982) and if the former factors are optimal, vine roots can attain exceptional depths (Seguin, 1972; Richards, 1983; Champagnol, 1984).

Although vine roots can penetrate deep soil layers, more than half of the root mass is found in a preferential zone (Champagnol, 1984). The depth and size of this zone can be affected by natural soil properties such as texture, structure and fertility (Champagnol, 1984) and/or cultivation practices such as black plastic mulch (Van der Westhuizen, 1980), soil cultivation methods (Saayman & Van Huyssteen, 1980; Saayman, 1982), plant spacing (Hidalgo & Candela, 1969; Branas, 1974; Archer & Strauss, 1985) and trellising (Van Zyl & Van Huyssteen, 1980; Archer *et al.*, 1988). Stoev & Rangelov (1969) and Nagarajah (1987) also reported a deeper preferential zone for grafted than ungrafted vines.

According to Daulta & Chauhan (1980) not only the rootstock, but also the scion cultivar affected the zone of maximum root concentration and the size of the total root system. On a species level it appeared as if *Vitis champini* Planch. had the largest root volume (Perry, Bowen & Lyda, 1979). According to Harmon & Snyder (1934), however, Ramsey *(V. champini)* was relatively shallow rooted, while Dog Ridge *(V. champini)* had deep roots. Southey & Archer (1988), in an investigation on different soil types under different climatic conditions, found that the spatial root distribution was predominantly a function of the soil environment, whilst root density appeared to be a function of the rootstock. Furthermore, a definite balance between top and root growth exists (Saayman & Van Huyssteen, 1980; Van Zyl & Van Huyssteen, 1980; Saayman, 1982; Richards, 1983; Archer *et al.*, 1988) and any limitations to the root growth usually reduced the above ground performance. The aim of this study was, therefore, to establish to what extent genetic properties determine the rooting pattern on a soil with minimum restrictions to root penetration.

MATERIALS AND METHODS

A five-year-old Chenin blanc (Clone 9/481) vineyard grafted on different rootstocks (Table 1) and situated in the Upper Breede River Valley, was used in this study. The soil was a dark silty loam with a high organic material content and was classified as an Oakleaf form: Jozini series according to Mac Vicar *et al.* (1977). The soil had a water table at a mean depth of 1,5 m in winter, which dropped to below 2,0 m during summer.

TABLE 1: Genetic origin and clone numbers of the rootstock cultivars investigated.

Rootstock Cultivar	Clone	Genetic origin
Berlandieri 13/5	66/03/08	*Vitis Berlandieri* Planch.
101-14 Millardet et de Grasset	2/3/25	*V. riparia* Mich. x *V. rupestris* Sch.
775 Paulsen	66-01-13	*V. Berlandieri* x *V. rupestris*
1103 Paulsen	64-01-20	*V. Berlandieri* x *V. rupestris*
99 Richter	1/1/13	*V. Berlandieri* x *V. rupestris*
110 Richter	1/28/2	*V. Berlandieri* x *V. rupestris*
140 Ruggeri	64-01-20	*V. Berlandieri* x *V. rupestris*
US 12-6-8	-	Jacquez (*V. aestivalis* Mich. x *V. cinerea* Engel. x *V. vinifera* L.) x 99 R (*V. Berlandieri* x *V. rupestris)*
US 16-13-26	-	1202 Couderc (*V. vinifera* x *V. rupestris)* x 99 R (*V. Berlandieri* x *V. rupestris)*

The physical and chemical characteristics of the soil were determined on completion of the investigation in September using standard VORI methods. The occurrence of the most important soil – borne fungi and pests in South Africa *viz,* phytophthora, nematodes, phylloxera and margarodes was determined according to the methods proposed by Marais (1983), Loubser (1985) and De Klerk (1970; 1978) respectively.

The soil was double delved in two directions before planting, incorporating 63 ton/ha agricultural lime to a depth of 0,9 m. The vines were planted 2,7 m x 1,2 m and trained on a 1,5 m slanting trellis as described by Zeeman (1981). Minimum tillage was practised and the vineyard was sprinkle irrigated (approximately 25 mm) before bloom and veraison respectively.

Plots consisted of 5 vines per rootstock and, based on

The assistance of the Wine Grapes, Soil Science and Plant Protection sections and in particular the technical contribution of H. C. Strauss and G. W. Fouché is acknowledged.

shoot mass and trunk circumferances, 1 representative vine per plot was selected for root studies. Border vines as well as vines with visual disease symptoms were excluded. Roots from 2 replicates per rootstock were plotted using the profile wall method proposed by Böhm (1979). A trench of at least 1,3 m deep was dug parallel to the vine row and 500 mm from the vines. After the roots were exposed a 200 mm x 200 mm grid system, 1,2 m high and 1,2 m wide, was placed against the profile wall for the mapping of the roots using 5 root diameter classes *viz,* ≤ 0,5 mm; 0,5-2 mm; 2-5 mm; 5-10 mm and ≥ 10 mm (Southey & Archer, 1988).

RESULTS AND DISCUSSION

Soil characteristics

Soil physical and chemical data are shown in Table 2. Contrary to average South African vineyard soils the carbon content of this soil was exceptionally high and tended to increase with depth. The pH was below 5,5 and might have exerted an effect on root development, especially for rootstocks with a low tolerance to acid soils, e.g. 101-14 Mgt (Conradie, 1983). It is, however, also possible that the high organic matter content could have helped to evade the negative effect of aluminium.

Root density

All the rootstocks colonised the available horizontal soil volume completely and therefore only vertical distribution is discussed.

High root densities (number of roots per m^2) were observed for Berlandieri 13/5 and 1103 Paulsen (1103P), while that of 140 Ruggeri (140 Ru) and US 12-6-8 were very low (Table 3). Contrary to this, Southey & Archer (1988) found that under dryland conditions and on a different soil type, the drought tolerant 140 Ru had the highest root density (1 852 roots/m^2) and the moderately tolerant 1103 P the lowest root density (669 roots/m^2). It is doubtful whether the low root densities found for 140 Ru can be ascribed to the low pH since Conradie (1983) found this rootstock to be well adapted to acid soils. Neither could the susceptibility of 140 Ru and US 12-6-8 to *Meloidogyne incognita* (Loubser & Meyer, 1987) have affected their performance, since this nematode was not found in these rootstocks.

Using the widely planted 99 Richter (99 R) as reference, Berlandieri 13/5, 101-14 Mgt, 1103 P and 110 Richter (110 R) had higher root densities (Table 3). Moreover, these rootstocks induced higher shoot masses as well as yields per vine. With the exception of 775 Paulsen (775 P), which had a low root density but a good above ground performance, the correlation between subterranean and aerial growth is evident. A stepwise linear regression analysis indicated that root density, rooting index and number of fine roots (< 2,00 mm diameter) contributed significantly (p ≤ 0,05) to yield (r^2=0,91).

TABLE 2: Analytical data of the Oakleaf soil, Upper Breede River Valley.

Depth (mm)	pH (KCL)	Al (me %)	R (Ohm)	P (mg/kg)	Exchangeable cation (me %)				Org. C. (%)	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Bulk density (g/cm^3)
					K	Na	Ca	Mg							
0–200	4,6	0,188	2725	119	0,58	0,78	1,53	0,86	11,9	7,2	11,3	10,9	49,6	21,0	1,36
200 – 400	3,9	0,228	2780	74	0,20	0,70	1,42	0,84	13,3	2,9	9,6	10,4	55,6	21,5	1,61
400 – 800	4,0	0,658	1890	71	0,27	0,68	1,80	1,23	16,1	5,0	7,5	10,3	49,9	27,3	1,72
800 – 1200	4,1	0,827	1060	90	0,26	2,00	2,48	2,34	13,4	5,1	11,4	12,3	46,9	24,3	1,68

TABLE 3. Root distribution and grapevine performance for different rootstocks on an Oakleaf soil.

Rootstock	Number of roots per m^2	% of 99R	*Rooting Index	Number of roots per Diameter (mm) Class					Grapevine performance for 1987 (kg/vine)	
				<0,5	0,5 -2	2 – 5	5 – 10	> 10	Shoot mass	Yield
Berlandieri 13/5	2 069	181,8	39,6	1792	226	38	10	3	3,6	18,2
101-14 Mgt	1 604	140,9	27,1	1210	337	43	11	3	2,6	13,8
775P	1 006	88,4	44,7	839	145	16	4	2	2,3	17,0
1103 P	2 660	233,7	41,9	2199	399	53	6	3	2,1	21,1
99 R	1 138	100	28,9	833	267	30	8	0	1,6	13,1
110 R	1 468	129,0	29,9	1103	319	37	9	0	2,7	14,9
140 Ru	635	55,8	20,2	483	122	21	6	3	0,7	10,0
US 12-6-8	813	71,4	38,7	695	98	16	4	0	0,4	4,4
US 16-13-26	1 062	93,3	18,3	760	247	42	10	3	1,4	14,4

$$^{*}\ \frac{\text{number of roots} < 2\ \text{mm}}{\text{number of roots} \geq 2\ \text{mm}}$$

Low numbers of nematodes known to attack grapevines (40 per 250 ml soil) were present in all plots and it is, therefore, unlikely that nematodes had any pronounced effect on root distribution (J. T. Loubser-personal communication, 1988). Phytophthora, phylloxera and margarodes were absent.

Although root densities differed from those obtained under dryland conditions (Southey & Archer, 1988), the percentage roots per diameter class for specific rootstocks was comparable.

Root distribution

The rootstocks Berlandieri 13/5, 101-14 Mgt, 1103 P, 110 R and US 16-13-26 colonised the available soil volume more evenly to a depth of 1200 mm than 140 Ru and US 12-6-8 of which relatively few roots were present in the deeper soil layers . Examples of root distribution for Berlandieri 13/5 and 140 Ru are shown in Fig. 1. The virtually complete colonisation of the available soil volume by a rootstock such as US 16-13-26 (Fig. 2), however, did not necessarily imply a better utilisation of the available soil volume by this rootstock. Good utilisation of soil is implied by a high number of fine roots as for Berlandieri 13/5 and 1103 P (Table 3) which contributed more than 15% of the total number of fine roots (Fig. 3a). Since the fine roots are mainly responsible for the uptake of mineral nutrients, it can be argued that these rootstocks have a higher nutrient absorption capacity. This aspect is currently being investigated.

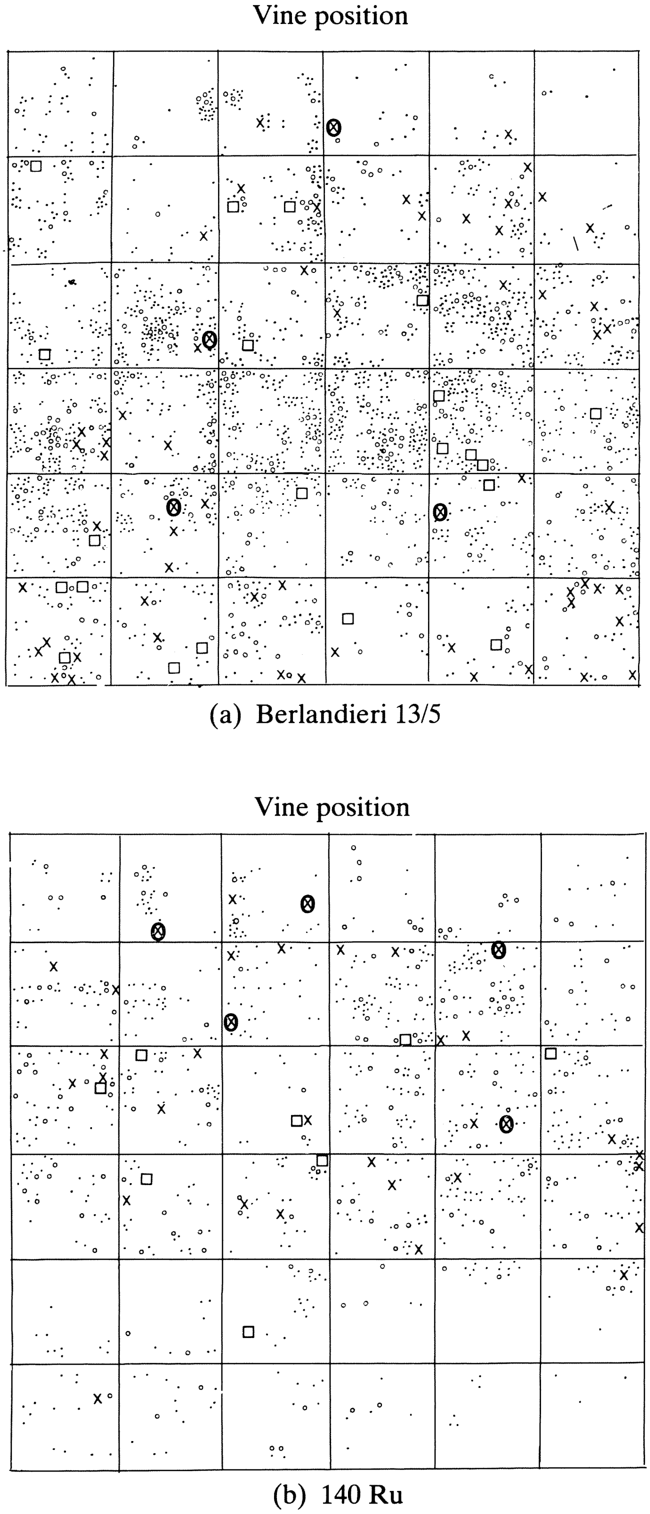

FIG. 1

Colonisation of an Oakleaf soil by the roots of (a) Berlandieri 13/5 and (b) 140 Ruggeri. Grid system: 200mm x 200mm. · ÷ $<$0,05mm; 0=0,5-2mm; x = 2-5mm; □ = 5-10mm;⊗$>$ 10mm.

The effectiveness of the root system can be indicated by a rooting index (RI) eg. the RI $\frac{\text{number of roots} <2 \text{ mm}}{\text{number of roots} \geqslant 2 \text{ mm}}$ as suggested by Van Zyl (1984). A high RI reflects favourable soil conditions and a better utilisation of the available soil. Since the soil studied favours root penetration, the calculated RI may be a function of the rootstock. It could, therefore, be argued that the root systems of Berlandieri 13/5, 775 P, 1103 P and US 12-6-8 (RI $>$ 38%) were more effective than those of 99 R, 140 Ru and US 16-13-26 (RI $<$ 10%) (Table 3). However, this was not in all cases reflected in the above-ground performance of the vine since 775 P performed well and US 12-6-8 poorly in this respect. RI values alone can, therefore, not be used for comparing rootstocks.

Thick roots have a better regenerative ability than thin roots (Van Zyl & Van Huyssteen, 1986). The high number of roots thicker than 2 mm diameter ($>$ 12,5% of the total number of thick roots) of Berlandieri 13/5, 101-14 Mgt, 1103 P and US 16-13-26 (Fig. 3b) could, therefore, lead to better performance of these cultivars after root pruning in vineyards where root growth is restricted by soil compaction.

The number of roots for all rootstocks was lowest in the upper (0-200 mm) and deeper (1000-1200 mm) soil layers (Fig. 2). Although 101-14 Mgt had a relatively even distribution of roots between the 200 and 1 000 mm soil layers, the highest number of roots for each soil layer was obtained between 200 and 800 mm. Thus, differences between rootstocks regarding their preferential zone, are very small on deep soils with sufficiently large moisture reservoir. This corresponds with the findings of Van Zyl (1984) and Loubser & Meyer (1986) who reported the largest number of roots in these zones.

Only 14,5% of the roots of 140 Ru were deeper than 800 mm, while 28,5% of the roots of 101-14 Mgt were present in this zone. Although acid soil impeded root development (Conradie, 1983), the few 140 Ru roots in the deeper soil layers could not be ascribed to a low pH since this rootstock is regarded by Conradie (1983) as being adapted to acid soils. Since Kriel (1985) classified 101-14 Mgt as having a higher tolerance to waterlogging than 140 Ru, a higher soil moisture content in the 800 to 1200 mm soil layer for 140 Ru (92% versus 65% – data not shown) could explain the poor root distribution of this rootstock in the deeper soil layers. Under dryland conditions and restricted soil depth, exactly the opposite emerged in that the drought resistant 140 Ru had 50,1% of its roots deeper than 800 mm, while for

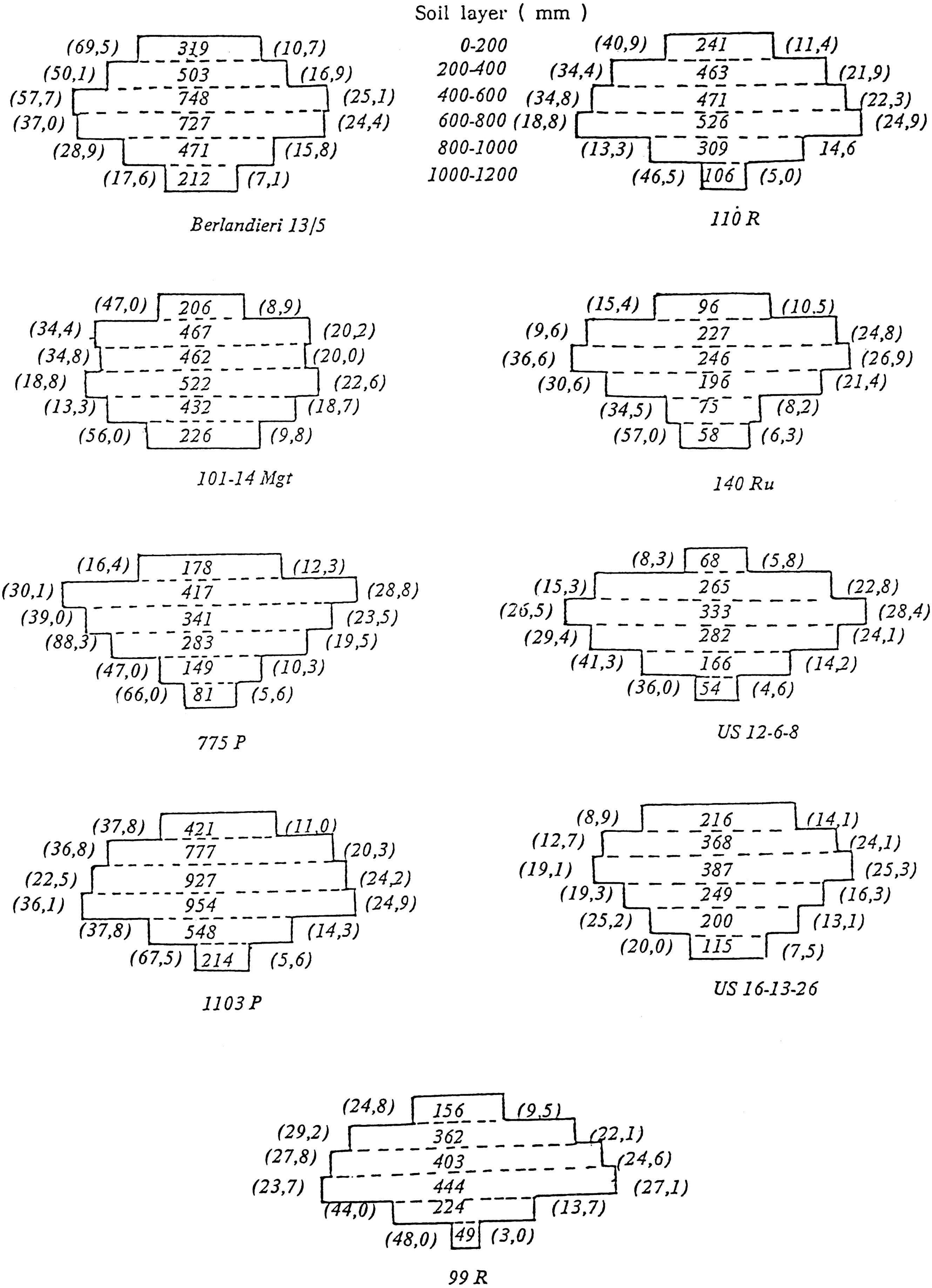

FIG. 2

Effect of rootstocks on the number of roots present in different layers of an Oakleaf soil [Values in brackets are the RI for each layer (left) and % of total number of roots for each rootstock (right).]

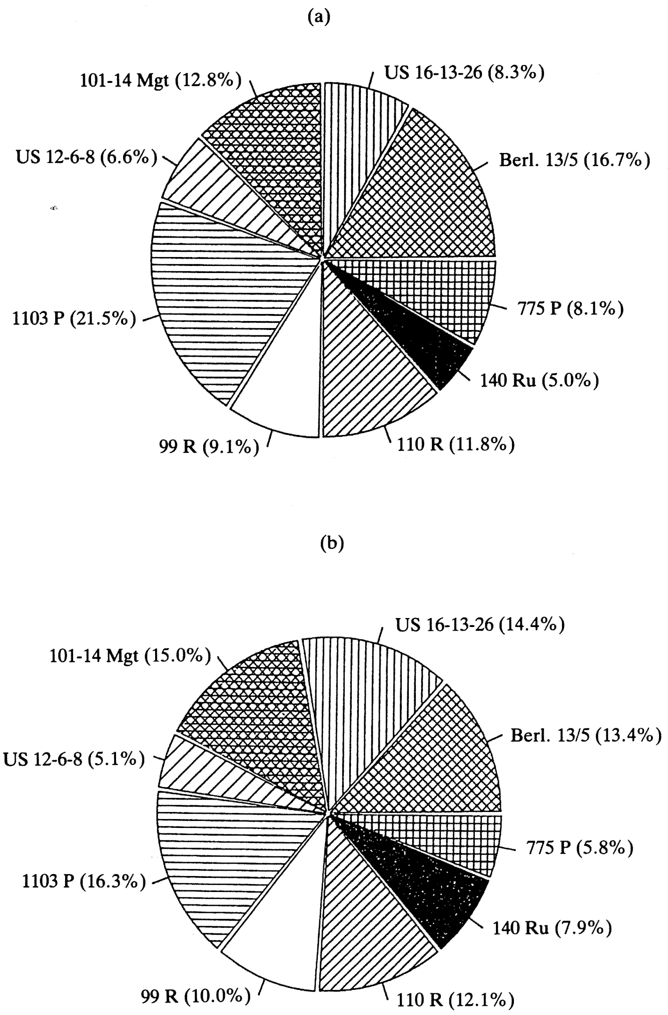

FIG. 3

The relative contribution of each rootstock to the total number of (a) fine (<2mm) and (b) thick (>2mm) roots present in an Oakleaf soil to a depth of 1200mm.

101-14 Mgt 26,5% of its roots were present in this zone (Southey & Archer, 1988).

A very high soil moisture content (107% and 97% respectively – data not shown) in the deeper soil layers of 110 R and 1103 P, two rootstocks moderately tolerant to wet conditions (Kriel, 1985) did, however, not impede root growth in these zones. For 775 P (96% soil moisture), however, a rootstock also regarded as being moderately tolerant, fewer roots were present in this zone. High soil moisture content could, therefore, not be the only factor impeding root growth of certain rootstocks.

CONCLUSIONS

Above ground growth of the grapevine is largely correlated to density, spatial distribution and effectivity of roots. Therefore, the natural rooting pattern of a rootstock is an important factor determining the above-ground performance of the vine. Root density and distribution are influenced by a large number of factors, but in a soil with minimum restrictions to root penetration, genetic characteristics exert an important influence on both these parameters.

Large differences in number of roots per m^2, varying between 813 (140 Ru) and 2 660 (1103 P), indicated the variation in the subterranean performance of the grapevine. Although cuttings of Berlandieri 13/5 root poorly under field conditions, this rootstock formed numerous roots under good soil conditions indicating a strong subterranean growth within the first five years after planting.

If utilisation of the available soil volume is expressed by the number of fine roots per m^2 then Berlandieri 13/5, 101-14 Mgt and 1103 P performed best, while poor utilisation was obtained with 140 Ru, US 16-13-26 and US 12-6-8. A good root distribution did not necessarily imply a good utilisation of the available soil volume since US 16-13-26 colonised the soil volume to its maximum depth, but had a low percentage of fine roots.

In this study, low pH-values did not exert an influence on root growth. Since the presence of exchangeable aluminium in acid soils is mostly responsible for poor root growth (Conradie, 1983), the high organic matter content of the soil could buffer this effect. Lower root numbers in the deeper soil layers of 140 Ru, which is susceptible to waterlogging could, however, be explained by the high soil moisture contents in these zones.

The differences obtained in the subterranean growth were reflected in shoot growth and ultimately in yield. Berlandieri 13/5, 101-14 Mgt and 1103 P rootstocks, which colonised and utilised the available soil volume to a maximum, had a better above-ground performance than 140 Ru, US 12-6-8 and US 16-13-26.

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