Effect of Plant Density on Root Distribution of Three-Year-Old Grafted 99 Richter Grapevines

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Date submitted: April 1985
Date accepted: July 1985
Keywords: Plant density, Root distribution, Root density, Vine spacing

The effect of plant density on root distribution of a three-year-old vineyard (Pinot noir/99 Richter) planted on a Glenrosa soil under dryland conditions, was investigated. Although narrower plantings induced smaller root systems per vine, root density was increased. Three years after planting the roots of more closely spaced vines utilised soil more intensively than those of more widely spaced vines. More closely spaced vines have an earlier vegetative period than more widely spaced vines. The ratio of primary, secondary and tertiary roots is not affected by plant density.

To understand the behaviour of vines under conditions where competition for moisture and nutrients plays an important role, it is necessary to study the behaviour of the roots. Literature on the effect of plant density on root systems is scarce as most reports deal only with the quality and quantity of the crop (Winkler, 1959 and 1969; Turkington, Peterson & Evans, 1980; Morris & Cawthon, 1981). Besides genetic characteristics (Branas, 1974; Champagnol, 1984) root distribution can be affected by soil physical properties (Seguin, 1970; Saayman & Van Huyssteen, 1980; Van Zyl & Weber, 1981; Saayman, 1982), soil chemical properties (Branas, 1974; Champagnol, 1979; Saayman & Van Huyssteen, 1981a; Conradie, 1983), soil moisture (Seguin, 1970; Van der Westhuizen, 1980; Van Huyssteen & Weber, 1980 a, b, c) and plant density (Branas, 1974; Champagnol, 1979).

Except for the work by Hidalgo & Candela reported in 1966 (Champagnol, 1979) and that of Branas (1974) no other experimental results on the effect of plant density on vine root distribution could be found. In these studies it was found that although total root mass per vine increased with lower plant density, root density decreased. This tendency held true for both shallow and deep roots while the highest density for all treatments was found within 600 mm soil depth. In irrigation studies Van Zyl & Weber (1981) also reported the highest root density within 600 mm soil depth.

Champagnol (1984) states that a low plant density on poor soils results in an irregular and insufficient exploitation of the soil by the roots while a high plant density under these conditions results in greater exploitation. The maximum expansion possibilities of a root system are limited by the characteristics of the soil and it can only be experimentally established for any given situation (Champagnol, 1984). Evidently little is known about root behaviour as affected by competition between vines and a study was therefore conducted to establish the effect of plant density on root distribution.

MATERIALS AND METHODS

Soil: The soil chosen was typical of those occurring in the Western Cape on which dry-land viticulture is usually practised and it is of the Glenrosa form derived from Malmesbury shale as described by MacVicar *et al.* (1977). To ensure the biggest possible soil moisture reservoir, the soil was prepared for planting by deep delving with a wing plough as described by Saayman & Van Huyssteen (1981b). During preparation, while the soil was criss-crossed with the plough to an effective depth of 1 000 mm, it was limed to approximately pH 5 (1N KCl). To maintain moisture as well as the best physical conditions in the soil, minimum tillage practices as described by Van Huyssteen & Weber (1980 a & b) were adopted for this experiment. No irrigation was applied.

Treatments: A *vitis vinifera* L. cv. Pinot noir (BK V) grafted onto 99 Richter (1/30/1) vineyard, planted to six different densities, was used. Plant densities were 20000 (1,0 × 0,5 m), 10000 (1,0 × 1,0 m), 5000 (2,0 × 1,0 m) 2500 (2,0 × 2,0 m), 2222 (3,0 × 1,5 m) and 1111 (3,0 × 3,0 m) vines per hectare, each replicated five times. The vines were trained on a 4-strand Hedge system and no crop was allowed in order to obtain a complete formation of vines on the trellising system. One vine per treatment was used for the root study and was selected to be representative of each treatment on the basis of trunk diameter, cordon diameter and cordon length.

Root studies: Root studies were done during the third winter after planting. In the case of wider spacings, trenches were dug in the work row on the perimeter of the theoretical soil surface available for each plant on both sides and the soil was systematically excavated towards the trunk to a depth of 600 mm. For the narrower spacings the digging of trenches was impossible and in these cases the root follow technique was used starting from the trunk to the perimeter of the theoretical available soil, also to a depth of 600 mm. Exposed roots were kept in position by means of sharpened, supporting dowels as well as fine strands attached to the trellis wires.

Two 200 mm × 200 mm grid systems, using fine white elastic strands, were constructed horizontally on the 600 mm depth plane and vertically beneath the trunk position in the same plane as the trellising strands. Measurements of root lengths were made using a fine strand to follow the growth pattern of each root while the angle of penetration on the 600 mm depth plane was measured as follows: A thin, flexible wire was bent into the interior angle (closest to the trunk) between the pene-

*Part of Ph.D. thesis to be presented to University of Stellenbosch. Promotor: Prof. C. J. Orffer trating root and the 600 mm depth plane and the angle of the wire measured using a protractor. This was done for each root which penetrated the soil at the 600 mm depth plane.

Colour slides were taken of both horizontal and vertical root distribution. These slides were projected on a pre-prepared standard grid system and by shifting the projector the grid system on the slides of each treatment could be superimposed on the standard grid system after which the roots were copied from the projected picture onto tracing paper. These drawings were mounted and photographed using a fixed camera at a fixed distance from the drawings.

In South Africa the root distribution patterns of vines are mostly determined by the physical conditions of the soil (Saayman, 1982; Van Zyl & Van Huyssteen, 1980). A custom built, automated, constant speed penetrometer (Van Huyssteen, 1983) was therefore used to measure soil strength at a moisture content of field capacity on a 200 mm square grid system at 50 mm depth intervals. At the same time soil samples for moisture content determinations were taken at 300 mm depth intervals at four randomly selected localities around each vine studied.

Budbreak determinations: Date of budbreak was taken when 50% of buds in each treatment reached the green leaf stage.

RESULTS AND DISCUSSION

The effect of plant density on horizontal and vertical root distribution is shown in Figs. 1 and 2. The magnitude of a root system is largely diminished by increased inter-plant competition at higher plant densities.

The size of the root system is an important factor in determining the growth of the top (Buttrose & Mullins, 1968; Kliewer & Fuller, 1973; Richards, 1983) and a certain balance between shoot and root growth is maintained for each given circumstance. In this trial more closely spaced vines produced smaller root systems and therefore it can be expected that this will produce plants with a lower potential yield capacity.

Vines planted in perfect squares (Fig. 1) tended to have more even root distributions around the trunks than those planted in rectangles (Fig. 2). This is in accordance with results mentioned by Champagnol (1984).

Table 1 shows the tendency of diminishing total root length with increasing plant density, verifying the visual impression. The ratio of primary, secondary and tertiary roots appears to be constant for all treatments. To what extent this property is genetically fixed or affected by varying physical soil properties is not known.

A marked increase in root density (root length per m^3) at higher plant densities was found (Table 1) verifying the results of various reports quoted by Richards (1983). Closer spacing results in a more effective utilisation of available soil and it may result in a more exhaustive exploitation of soil moisture and nutrients as was suggested by Branas (1974) and Champagnol (1979). Soil moisture has a decisive effect on root growth and distribution (Van der Westhuizen, 1980; Van Huyssteen & Weber, 1980c). Enhanced soil moisture depletion, in the case of closer plantings, may therefore induce deeper roots at high plant densities.

Although the steeper angle of penetration, in the case of more closely spaced vines (Table 1) may be an indication of deeper root penetration, this must be verified in future studies. Because of competition for available soil space, roots of more closely spaced vines exhibit a remarkably constant angle of penetration compared to more widely spaced vines as shown by the coefficient of variance (Table 1).

The reason for the drastic differences in the date of budbreak between different plant densities (Table 1) is not known and will be investigated during future studies.

Figs. 3A and B show that soil strength in the wider spacings could be ignored as a possible cause for different root distribution patterns. Although the same basic relationship between soil strength and depth was obtained from the closer spacings (1,0 × 1,0 m and 1,0 × 0,5 m), higher soil strength values were measured (Fig. 3C). The normal procedure to obtain field capacity is to allow three days after water application for soil moisture to reach equilibrium before penetrometer measurements are made. The obviously lower soil moisture content in the case of closer spacings was possibly caused by the higher root density and more rapid soil moisture utilisation causing higher soil strength in the deeper layers.

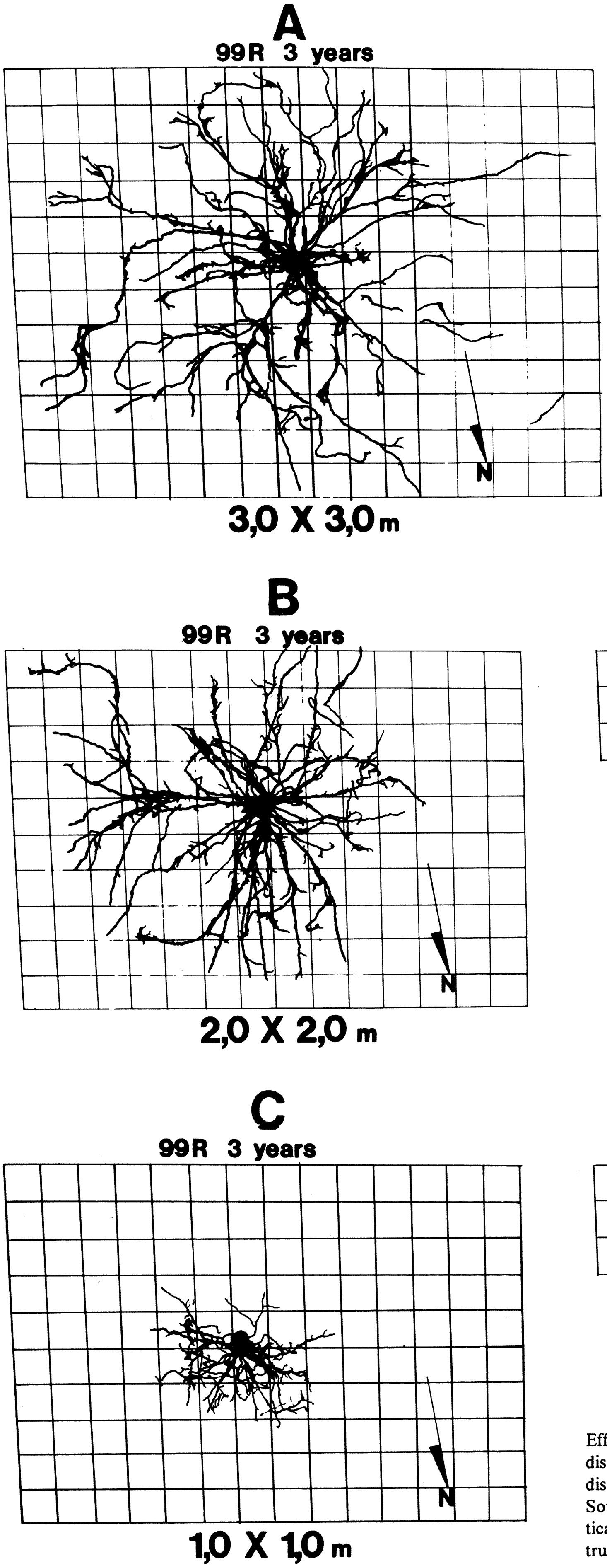
CONCLUSION

Although the size of a root system diminishes, a higher root density occurs with higher plant density. The ratio between primary, secondary and tertiary roots does not seem to be easily changed by different plant densities and is possibly genetically fixed. The roots of more closely spaced vines have a steeper angle of penetration which may be indicative of a deeper penetration three years after planting and this, together with a higher root density will probably exhaust soil moisture and nutrients at a faster rate than in the case of more widely spaced vines. Under conditions of restrictive soil depth combined with dry-

TABLE 1

The effect of plant density on root pattern and budbreak of Pinot noir/99R vines

Parameter measured	Plant spacings					
	3,0 × 3,0 m	3,0 × 1,5 m	2,0 × 2,0 m	2,0 × 1,0 m	1,0 × 1,0 m	1,0 × 0,5 m
Primary roots (m)	2,207 (37%)	1,760 (38%)	1,677 (35%)	1,625 (39%)	1,092 (37%)	0,890 (36%)
Secondary roots (m)	2,992 (50%)	2,306 (49%)	2,576 (53%)	1,945 (47%)	1,379 (47%)	1,117 (46%)
Tertiary roots (m)	0,766 (13%)	0,614 (13%)	0,587 (12%)	0,560 (14%)	0,461 (16%)	0,450 (18%)
Total root length (m)	5,965	4,680	4,840	4,130	2,932	2,457
Root density (mm^{-3})	1,105	1,733	2,017	3,442	4,887	8,213
Angle of penetration	15,3° (cv = 29,1%)	22,6° (cv = 20,2%)	30,9° (cv = 16,4%)	41,1° (cv = 10,5%)	58,6° (cv = 9,2%)	77,5° (cv = 5,8%)
Budbreak	17/9	13/9	13/9	7/9	30/8	15/8



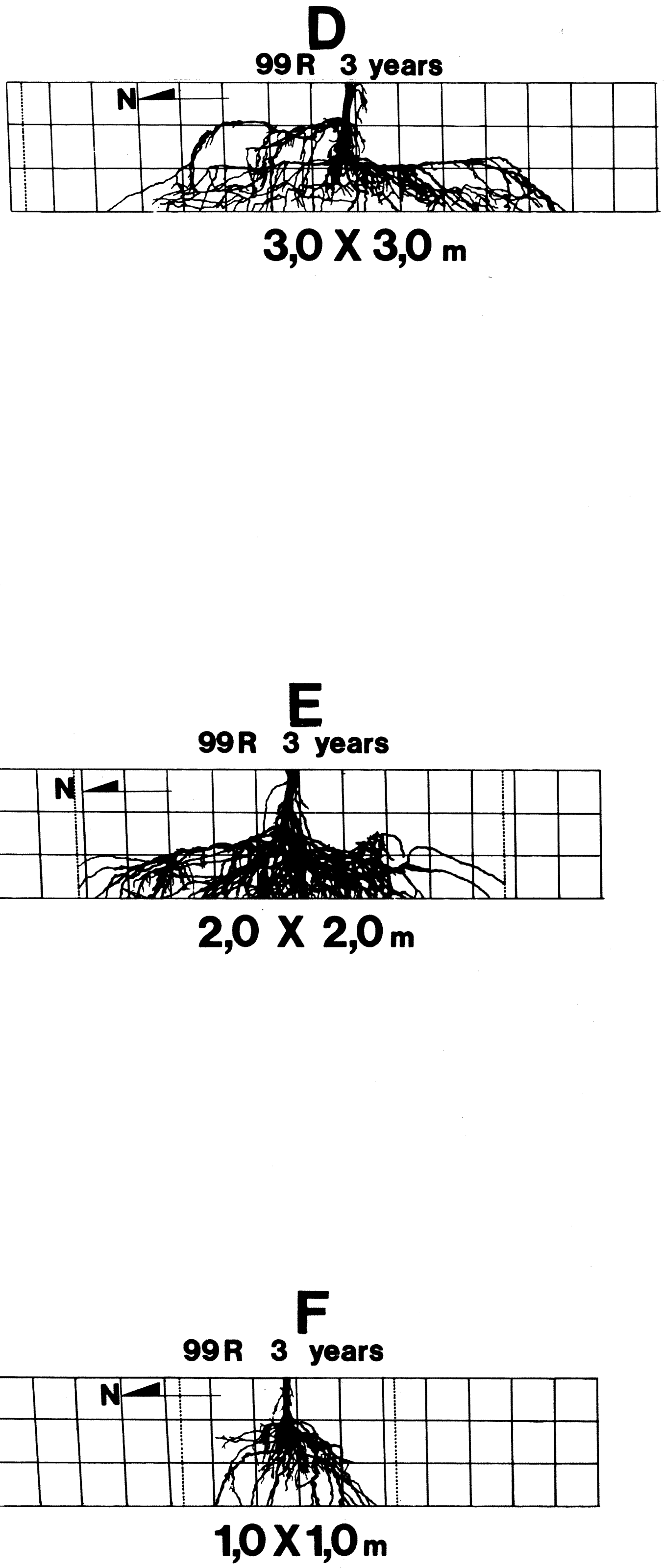
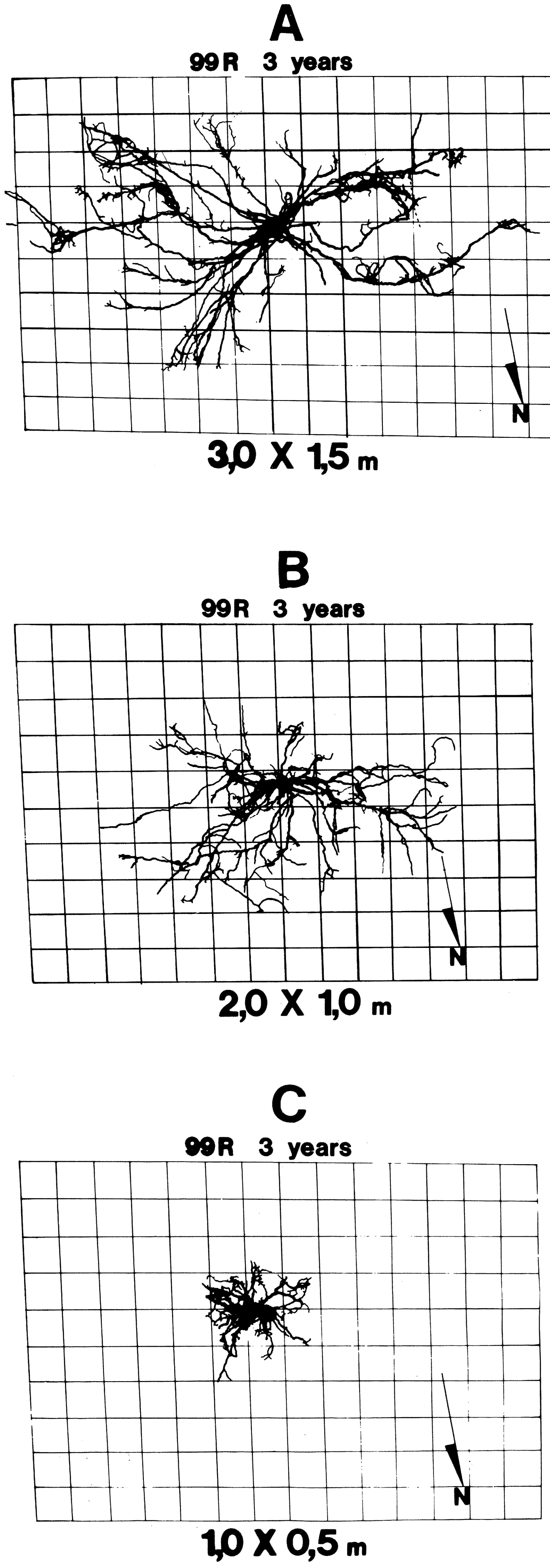


FIG. 1

Effect of plant density on vine root distribution. A, B and C: Horizontal distribution. D, E and F: Vertical distribution. Note relative even root distribution around the trunk. Row orientation: North, North-East to South, South-West. Broken lines on vertical distribution depict theoretical available soil. Grid system: 200 mm × 200 mm. ● = position of the trunk.



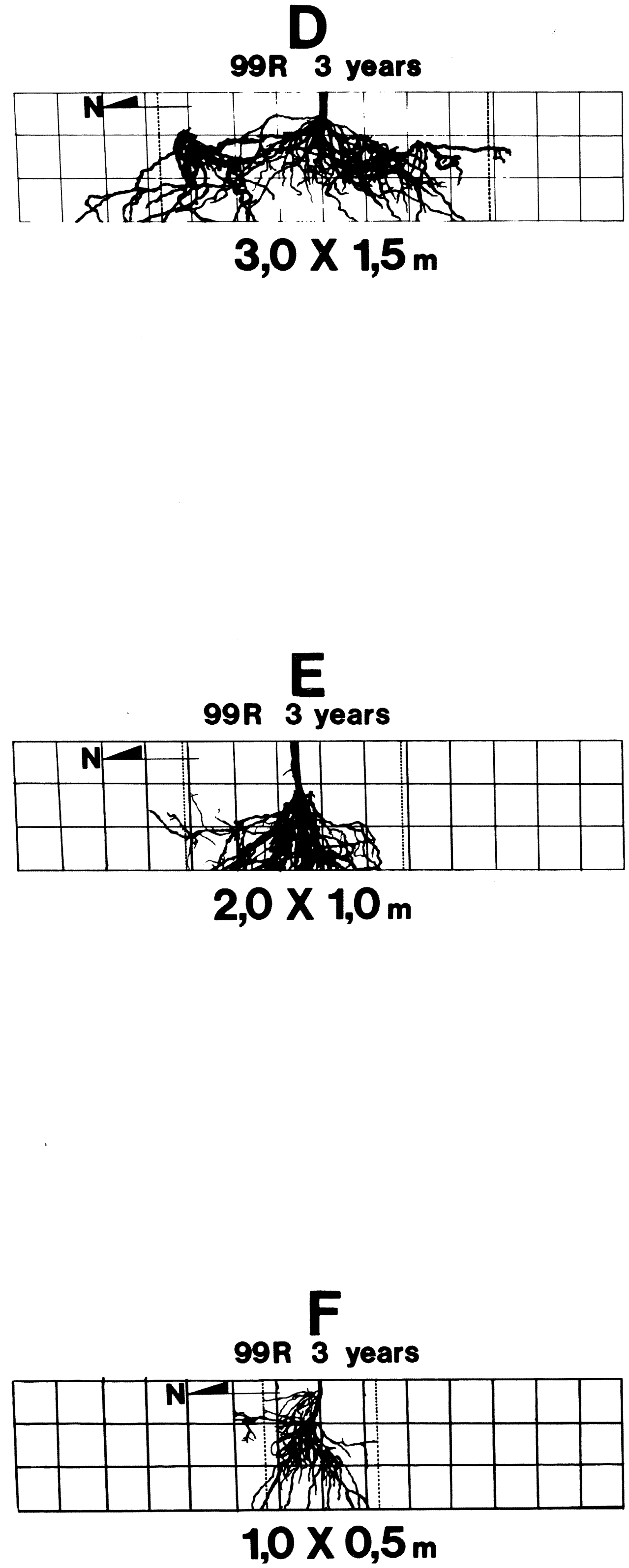


FIG. 2

Effect of plant density on vine root distribution. A, B and C: Horizontal distribution. D, E and F: Vertical distribution. Note better root growth into work row. Row orientation: North, North-East to South, South-West. Broken lines on vertical distribution depict theoretical available soil. Grid system: 200 mm × 200 mm. ● = position of the trunk.

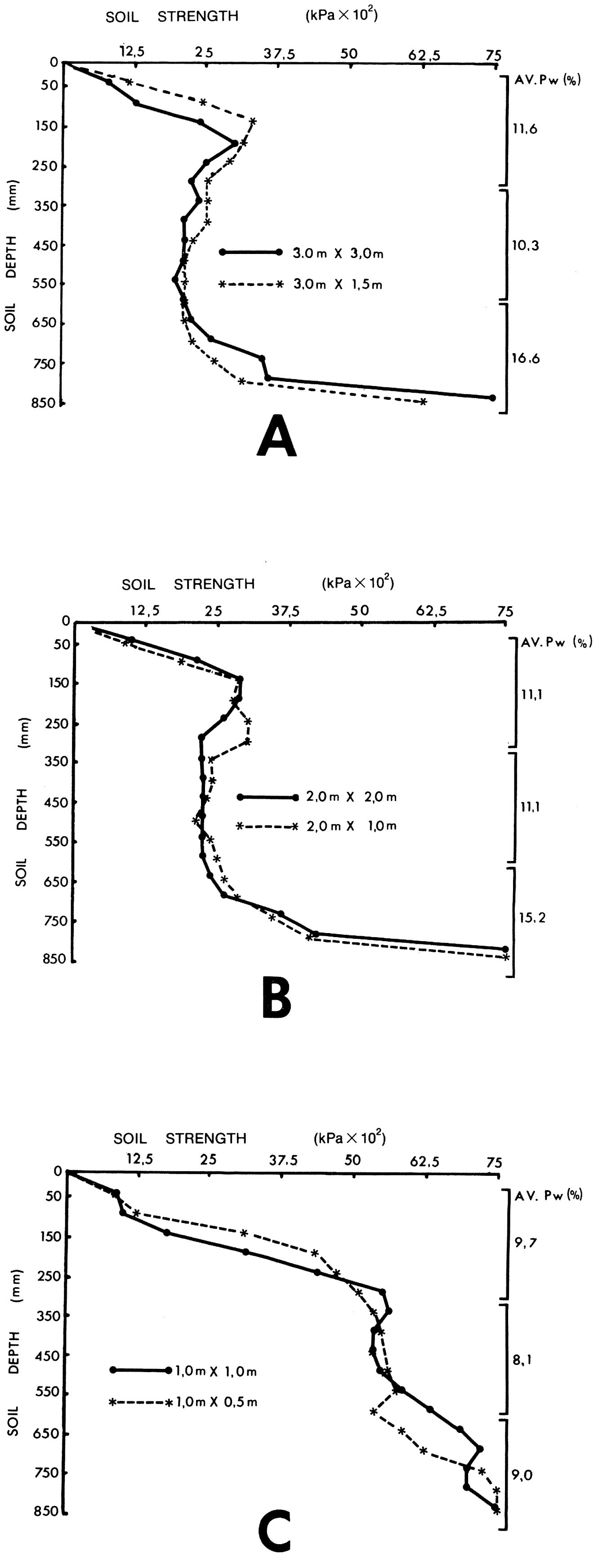


FIG. 3

Soil strength at different soil depths in a plant density trial. A: 1 111 and 2 222 vines per ha. B: 2 500 and 5 000 vines per ha. C: 10 000 and 20 000 vines per ha. AV. Pw (%) = Average moisture content (mass basis).

land cultivation, this may give rise to poor vine performance during certain growing seasons with little or no rain. Optimum plant density for conditions similar to those of this experiment can only be defined after several years of vine performance measurements.

To ascertain the effect of plant density on soil moisture content, in depth studies on the seasonal fluctuation of soil moisture must be undertaken especially since indications were found that high root densities in the case of close plantings may cause a rapid depletion of soil moisture under dry-land cultivation. This may be of significant importance since an earlier vegetative period is induced by high plant densities. This study only shows the effect of plant density on root distribution three years after planting and will be repeated in five years to define the effect on adult root systems.

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