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Root dynamics and pattern of 'Riesling' on 5C rootstock using minirhizotrons

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Summary

Root length density (RLD) in the years from 1994-1997 was estimated using minirhizotrons. The field experiment was conducted on six 'Riesling' vines in Rheingau (Germany). The majority of root distribution was found in soil depths of 60-100 cm with considerable variations between the plants. Roots dynamics showed a periodicity with one or two maxima, depending on year and vine plant. The first peak of RLD was observed around veraison, the second peak appeared after harvest. The rate of root length death was estimated. In the deeper layer the turnover of roots was 60% of the total RLD every year.

K e y w o r d s : root length density, root dynamic, root depth, minirhizotron.

A b b r e v i a t i o n : root length density (RLD).

Introduction

Among the various possibilities of measuring root growth (e.g. root lenght, diameter, weight) root length density (RLD) calculated as root length per soil volume is one of the best parameters related to nutrition and water uptake (Böhm 1979). The quantification of RLD using the monolith method harvesting the entire roots system leads to exact data, but using this destructive method for studying the dynamics of root growth requires the subsequent use of different plants. To investigate dynamics in root growth, the observation of roots on transparent minirhizotron tubes is an alternative method which allows even *in situ* measurements of RLD (Smit *et al.* 2000). For vines, McLean *et al.* (1992) investigated the distribution of roots to a soil depth of 70 cm using minirhizotrons. Nevertheless, most studies about root dynamics were conducted with the monolith method. Mohr (1998) used this method to investigate the root tips dynamics of 'Müller-Thurgau' vines in Minheim/Mosel. In Geisenheim/Rheingau Reimers *et al.* (1994) investigated the development of 'Riesling' root tips in the vegetation period. Whereas they reported a single maximum of root growth, under South African conditions, two maxima can be found (Van Rooyen 1980, Loubser and Meyer 1986). On pottet 'Pinot Noir' vines, Koblet and Perret (1990) could not confirm this periodicity. They related non continuous root growth to the fact that different plants had to be harvested. The minirhizotron method is a reliable method to overcome this problem. To our knowledge, the single reported experiment with vine root observation using minirhizotrons is that of McLean *et al.* (1992). The present experiment was carried out from 1994 to 1997 using 18 minirhizotron tubes in a 'Riesling' vineyard. The objective of this work was to examine root distribution and dynamics in several soil depths over several years. The minirhizotron allowed to examine the roots of the same plants during the experiment and to study variability between vine plants.

Materials and Methods

F i e l d e x p e r i m e n t : The experiment was carried out from 1994 to1997 in Rheingau, Germany, (50°N, 8°E) in a vineyard of *Vitis vinifera* 'Riesling' grapevines on 5C rootstock planted in 1974. Standing space was of 2.5 m^2 with permanent green cover in every row. The soil was loamy sand with a pH of 7.4. Fertilization, pest control and other vineyard operations were consistent with commercially accepted practices. For weather data see Fig. 1.

R o o t o b s e r v a t i o n : The minirhizotron tubes were installed in the summer 1994. At six vine plants, three minirhizotrons at different angles to the soil surface (90°, 60°, 45°) were inserted at a distance of 10 cm, 50 cm or 56 cm, respectively. Tubes were 130 cm long with a diameter of 6 cm, the parts extending the soil surface were capped. The areas around minirhizotrons were kept weedfree. Roots were observed with a camera (Fa. Brox), which was mounted on a slight support. So replicate observations on each date could be made of the same place along each tube over multiple years. The visible window was 1.8 x 1.4 cm; every 1.35 cm along the tubes roots were counted. Furthermore, observations were made with the camera sight in front direction to the vine and laterally in 90° degrees to this direction; so on 2 x 76 locations per tube roots were recorded. Each root passing the whole window from one side to another was counted as 1, roots intersecting only one or no window side counted half. Following an idea of Upchurch and Ritchie (1983), the root number was converted to RLD assuming the roots would have grown through the volume of the tube. RLD was calculated with the equation $RLD = N\ (b\ U^{-1}\ \pi\ r\ L)^{-1}$ with N: root number, b: visible circle segment, U: perimeter of the tube, L: length of the visible window (Buckland *et al.* 1993). Data of RLD of the tubes and the sights were combined according to soil layers of 10 cm. The six individual vine plants were grouped according to RLD in High (H), Medium (M) and Low (L) with two vines each, so here presented RLD is the mean of 12 root observation. Root dynamics were monitored every two weeks for the duration of the four-year experiment. Root turnover were calculated by using the equation: Turnover = annual belowground production / maximum belowground

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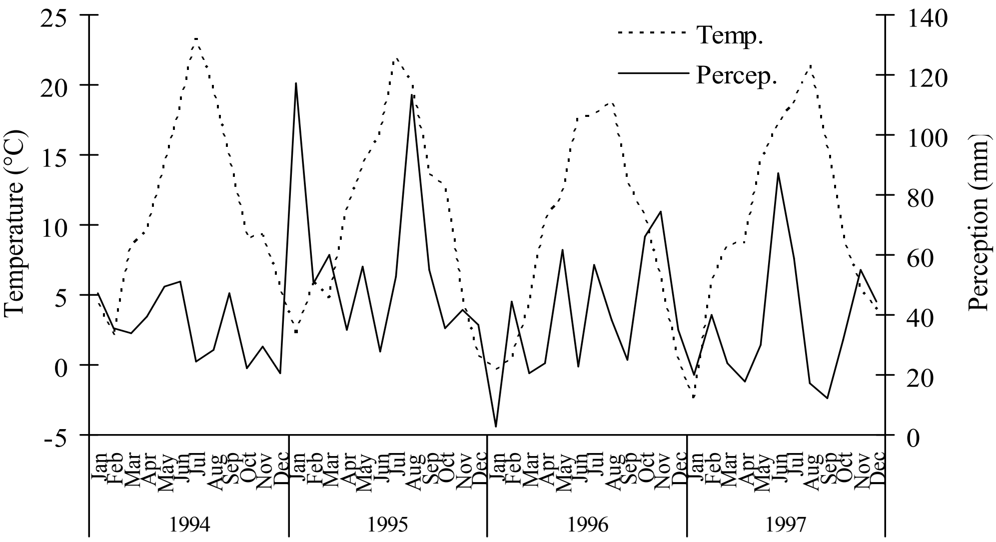

Fig. 1: Monthly mean temperature and sum of precipitation (data from the German Meteorological Service, Geisenheim) in the years 1994-1997.

standing crop and average belowground standing crop as base respectively (GILL and JACKSON 2000). The annual belowground production was calculated as sum of RLD reduction between two observation dates in a year.

Statistical analysis: The significance of means was calculated using one way ANOVA with the Turkey test at a significance level of 95 %. Mean values which are not significantly different are indicated by the same letters. The confidence interval for the autocorrelation was also calculated with a significance level of 95 %.

Results and Discussion

The distribution of RLD differed between the six examined vine plants (Fig. 2). They could be grouped into three types of distribution each containing two plants with small variations: In the first group ("High") two maxima of root distribution could be observed: at 40-60 cm and at 80-100 cm. In the second group ("Medium") the vine roots were mainly found in soil depths of 60-80 cm. Compared with these two groups, vines of the last group ("Low") had a three times lower RLD with a small maximum at 80-100 cm. The depth of root is not defined consistently. One definition is the appearance of the first roots (SMIT *et al.* 2000). Vine roots depth is normally reported at 6 m, but even in 32 m soil depth vine roots were found (POURTCHEV 2003). More usually root depth is defined as the soil depth, where most roots are found. The majority of roots were reported to be found to a depth of 60 cm with the maximum between 20 to 40 cm (LOUBSER and MEYER 1986, MCLEAN *et al.* 1992, SOUTHEY 1992, REIMERS *et al.* 1994). The green cover of vineyards has multiple benefits in viticultural practice (SCHMITT 2004). Under green cover, the maximum of root tips drops from 20-40 cm to 40-60 cm due to minor soil moisture (REIMERS *et al.* 1994). This is also the reason, why under dry condition under mulch more intense root growth can be found (VAN DER WESTHUIZEN 1980). In this experiment permanent green cover was established, but nevertheless, maximum RLD was found much deeper

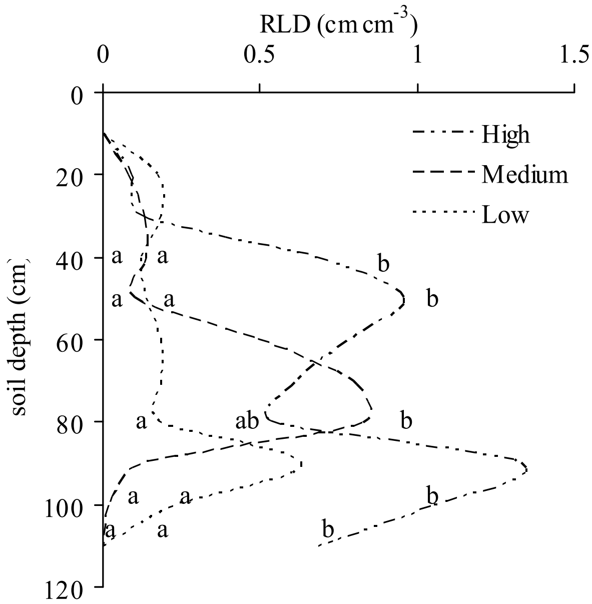

Fig. 2: Root length density (RLD) of three groups (High, Medium, Low) of two vines each and in sum 12 minirhizotron observations. Mean values which are not significantly dfferent at 95 % level are inicated by the same letters.

than usually reported. The lowered RLD in the upper soil layer and the maximum of RLD in soil depths at 80-100 cm can partly be explained with interaction between soil and minirhizotron. Inferior soil-to-tube contact, a thermal gradient and changed soil water conditions can prevent root intersections near the surface and enhance root growth in deeper layers (UPCHURCH and RITCHI 1983, MCMICHAEL and TAYLOR 1987, VOS and GROENWOLD 1987). However MCLEAN *et al.* (1992) also found the maximum of vine root number between 40-50 cm using minirhizotrons. Fig. 3 shows the root dynamics for the three root distribution types. In general RLD increased during the first year from summer 1994 to summer 1995. This is due to the roots being cut during the installation of the tubes. This reaction is known from root prunings (SAAYMAN and VAN HUYSSTEEN

1983, MOHR 1989). Apart from annual variation, RLD remained stable until the end of 1996. In 1997 a slight decrease of the RLD could be observed. This is likely to be due to the dry weather conditions in 1997 (Fig. 1). Seasonal variations in RLD differed between the years and the vines. Due to equilibration time, the vines with low RLD ("Low") showed a single maximum in 1996 and 1997. In 1995 a plateau of higher RLD with three small peaks could be found. Vines of group "Medium" with average values of RLD also had a single maximum in 1996, whereas in 1997 two RLD peaks could be observed and in 1995 there was a plateau in RLD after a maximum. In the last group with the highest RLD ("High"), in all three years two peaks of RLD were observed. The time when the maximum RLD occurred was around veraison. In 1995 RLD peak was about two weeks before veraison, in 1997 two weeks after veraison. And between the vines a difference about two weeks in RLD peak was observed too, so that for example the maximum of the vines of group B was at the same time when the other vines had their minimum. The periodicity of root growth is reported differently in literature. FREEMAN and SMART (1976) observed two peaks of root growth in Australia. The first one occurred when shoot growth had ceased. The second one, much smaller than the first one occured after harvest. In general this is in agreement with the results of VAN ROOYEN (1980) and LOUBSER and MEYER (1986) in South African vineyards. However under German conditions there is confusion about the periodicity of root growth. MOHR (1998) found one single maximum, STEINBERG (1968) described a non-significant second maximum and KOBLET and PERRET (1990) also could not confirm two maxima, although they measured two peaks in root growth because this "uncontinousity" (as they declare it) can be explained with the method of harvesting whole plants for each date. In a three-year experiment REIMERS *et al.* (1994) characterized the periodicity of root growth by one peak during bloom until veraison followed by continuous decline. Nevertheless they interpreted the investigations above cited in the following way: a periodicity with two maxima can be concluded for vine plants as it is also known for other woody plants like apple. It is notable that root development was similar between the different soil layers except in the year 1994 (Fig. 3). This is especially true for the vines with higher RLD (group "High" and "Medium") but also for the other vines in the later half of the experiment. Exceptions of this were observed in the upper soil layer like in may 1996 in group "Medium" or in may/july 1997 in group "High" and "Low". The latter even showed enormous peaks of opposite root development in the different layers at this date. Root development was observed on the same vines at the same place at different times. So, RLD data between two subsequent observations were strongly autocorrelated (Fig. 5). Even until an observation lag of 4 (1997) to 7 weeks (1995) RLD were correlated. For grapevine root death is a natural process like for all woody plants, and so roots may be a principal

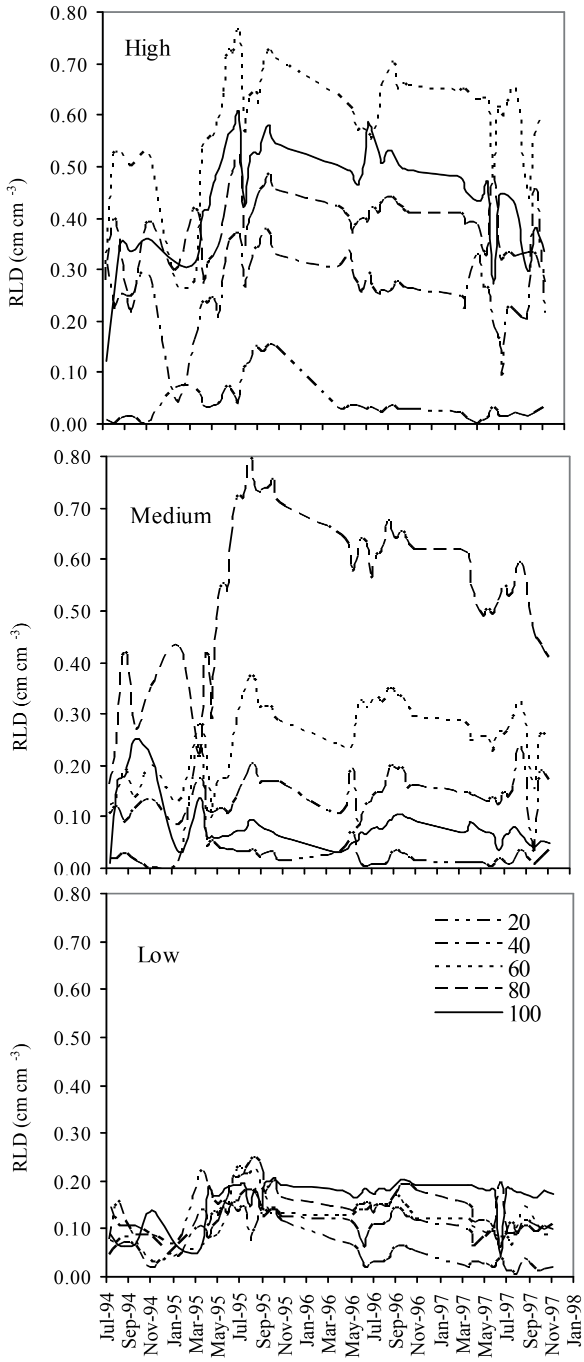

Fig. 4: Dynamic of root length density (RLD) in the soil depths from -20 cm to 80-100 cm for the vines f the groups High Medium and Low.

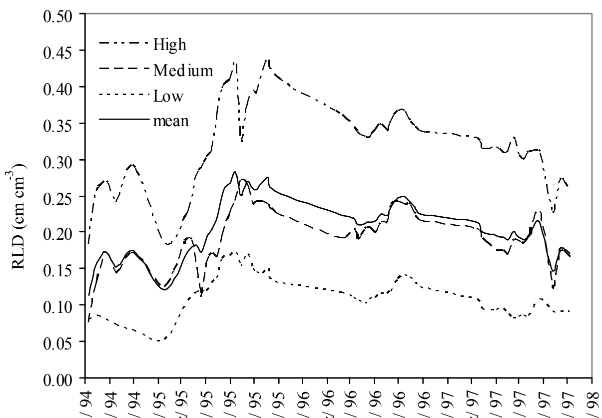

Fig. 3: Dynamic of mean root length density (RLD) for the vines of the groups High, Medium and Low during experiment time.

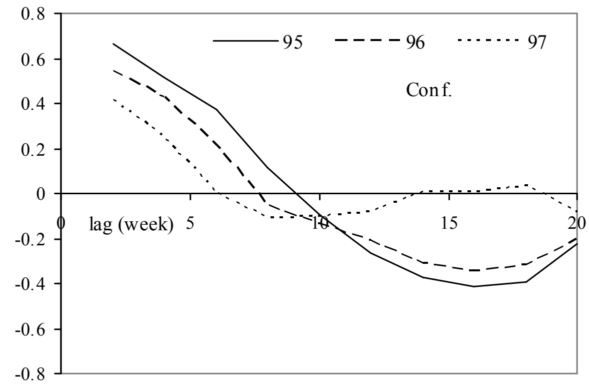

Fig. 5: Autocorrelation of root length density between observation dates in the years 1995-1997.

source of organic matter in the soil (RICHARDS 1983). Yet there is little knowledge about the scope of root mortality from vine roots. The estimated rate of root turnover is shown in the Table. As in the present experiment the level of RLD remained stable about 100 % of the annual production in RLD returned to soil. Compared with the total RLD in the deeper layers of soil 70 % root turnover was found. In soil depth of 1m every year 40 % of the established root system was turned over. The turnover rate here was calculated using the RLD as it was observed between the different dates. This RLD values have to be considered as netto production, between two observation dates there is a simultaneous root growth and death. So real root death will be underestimated. From spring (6.4.) to summer (26.8.) 1996 this hidden root mortality was estimated not only counting the total visible roots on the minirhizotron tube but also counting all roots that disappeared. In this time RLD increased by 25 % (netto), at the same time root death was 5 % of total RLD.

Table

Mean root turnover (%) calculated to maximal RLD and average RLD as base respectively for the vine groups High, Medium, Low and the geometric mean according to soil depth

RLD-base of turnover	Medium		High		Low		mean	
Soil depth (cm)	max	average	max	average	max	average	max	average
0-20	0	0	279	475	93	152	130	218
20-40	175	529	64	89	74	90	107	240
40-60	86	118	33	38	48	66	57	75
60-80	75	96	57	71	64	91	68	90
80-100	11	14	25	23	54	68	23	39

Conclusion

Periodicity of RLD was found to have a great range. Depending on the year and on the vine plants one or two maxima at slightly varying phenological states could be observed. In different soil layers the RLD dynamic was generally similar.

References

BÖHM, W.; 1979: Methods of Studying Root Systems. Ecological Studies 33, Springer Verlag, Berlin, Heidelberg, New York.

BUCKLAND, S. T.: CAMPBELL, C. D.; MACKIE-DAWSON, L. A.; HORGAN, G. W.; DUFF, E. I.; 1993: A method for counting roots observed in minirhizotrons and their theoretical conversion to root length density. Plant Soil **153**, 1-9.

FREEMAN, B. M.; SMART, R. E.; 1976: A root observation laboratory for studies with grapevines. Am. J. Enol. Vitic. **27**, 36-39.

GILL, R. A.; JACKSON, R. B.; 2000: Global patterns of root turnover for terrestrial ecosystems. New Phytol. **147**, 13-31.

KOBLET, W.; PERRET, P.; 1990: Beziehung zwischen Triebwachstum, Wurzelentwicklung und Assimilatwanderung in Topfreben. Vitic. Enol. Sci. **45**, 93-96.

LOUBSER, J. T.; MEYER, A. J.; 1986: Strategies for chemical control of root-knot nematodes (*Meloidogyne* spp.) in established vineyards. S. Afr. J. Enol. Vitic. **7**, 84-89.

MCLEAN, M.; HOWELL, G. S.; SMUCKER, A. J. M.; 1992: A Minirhizotron System for In Situ Root Observation Studies of Seyval Grapevines. Am. J. Enol. Vitic. **43**, 87-89.

MCMICHAEL, B. L.; TAYLOR, H. M.; 1987: Application and limitations of rhizotrons and minirhizotrons. In: H. M. TAYLOR (Ed.): 1987: Minirhizotron Observation Tubes: Methods and Applications for Measuring Rhizophere Dynamics, ASA Special Publ. **50**, 1-13.

MOHR, H. D.; 1998: Jahreszeitliche Bildung von Wurzelspitzen bei Freilandreben. Deutsches Weinbaujahrbuch **49**, 69-77.

POURTCHEV, P.; 2003: To the problem of depth of root system penetration of grapevine. Soil Sci. Agrochem. Ecol. **2**, 47-52.

REIMERS, H.; STEINBERG, B.; KIEFER, W.; 1994: Ergebnisse von Wurzeluntersuchungen an Reben bei offenem und begrüntem Boden. Vitic. Enol. Sci. **49**, 136-145.

RICHARDS, D.; 1983: The grape root system. Hort. Rev. **5**, 127-168.

SAAYMAN, D.; VAN HUYSSTEEN, L.; 1983: Preliminary studies on the effect of a permanent cover crop and root pruning on an irrigated colombar vineyard. S. Afr. J. Enol. Vitic. **4**, 7-12.

SCHMITT, K. O.; 2004: Dauerbegrünung im Weinbau. Die Winzer-Zeitschrift **19**, 36.

SMIT, A. L.; BENOUGH, A. G.; ENGELS, C.; VAN NOORDWIJK, M.; PELLERIN, S.; VAN DE GEJIN, S. C.; 2000: Root Methods - A Handbook. Berlin, Heidelberg, New York.

SOUTHEY, J. M.; 1992: Root distribution of different grapevine rootstocks on an relatively saline soil. S. Afr. J. Enol. Vitic. **13**, 1-9.

STEINBERG, B.; 1968: Untersuchungen über die Wurzelspitzenverteilung bei Pfropfreben (*Vitis vinifera* L.) in Normalanlagen des Rheingaus. Diss. Univ. Gießen.

UPCHURCH, D. R.; RITCHIE, J. T.; 1983: Root observations using a video recording Ssystem in mini-rhizotrons. Agron. J. **75**, 1009-1015.

VAN DER WESTHUIZEN, J. H.; 1980: The effect of black plastic mulch on growth, production and root development of chenin blanc vines under dryland conditions. S. Afr. J. Enol. Vitic. **1**, 1-14.

VAN ROOYEN, F. C.; 1980: The water requirements of table grapes. Decid. Fruit Grower **30**, 100-105.

VOS, J.; GROENWOLD, J.; 1987: The relation between root growth along observation tubes and in bulk soil. In: H. M. TAYLOR (Ed.): Minirhizotron Observation Tubes: Methods and Applications for Measuring Rhizophere Dynamics. ASA Special Pupl. **50**, 127-156.

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