Effect of Ridging on the Performance of Young Grapevines on a Waterlogged Soil

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The effect of ridging on root development, vegetative growth and yield of young grapevines, cv. Chenin blanc/99R, was studied in a field trial on a soil naturally waterlogged during winter and early summer. Ridging tended to improve root efficiency as well as general grapevine performance compared to unridged soil. There was no significant difference in vegetative growth of grapevines planted on 400 mm-high double row, 600 mm-high double row or 400 mm high single row ridges. Yield, however, decreased where the surface to volume ratios of double row and single row ridges were less than 0,6 and 1,0 respectively. This implied that excessively dry and warm soil conditions had occurred during ripening where the ridges were too large. Irrigation in combination with ridging resulted in significantly improved vegetative growth and higher yield compared to the unripped control treatment. Preliminary ripping of compacted subsoil to a depth of 550 mm tended to improve vegetative growth and yield of ridged as well as unridged treatments. Ridging had no significant effect on total soluble solids, total titratable acidity and pH of musts.

Waterlogging is a common soil physical restriction to root development and functioning. Approximately 15% of the soils of the Western Cape are classified as waterlogged (Ellis *et al.*, 1988). Grapevines, one of the major crops in this region, are adversely affected by poor aeration caused by waterlogged conditions during early summer (Kobayashi, Iwasaki & Sato, 1963; Saayman, 1981). Vigour and lifespan under waterlogged conditions are probably further reduced by root-rotting pathogens (Northcote, 1973). As grapevines are a permanent crop, waterlogging can only be remedied by appropriate soil preparation.

Internal drainage of vineyard soils is normally improved by using specialized deep-delving techniques to modify the soil profile in combination with conventional subsurface drainage (Van Huyssteen, 1988). However, due to heavy clay or unstable subsoil structure, conventional soil preparation techniques often do not improve internal drainage effectively, resulting in poor grapevine performance. As an alternative, heaping up of the topsoil in continuous bands or ridges was proposed to increase available soil depth and improve internal drainage (Van Zyl, 1985). Ridging of waterlogged soil to improve production of agricultural crops has been applied for centuries (Storer, 1905). Production of asparagus (Fieldhouse, Moore & Brasher, 1968), wheat (Sweeney & Sisson, 1988), citrus (Steinhardt *et al.*, 1971), sugar cane (Camp, 1982) and deciduous fruit (Du Preez, 1985) has been enhanced by more favourable rooting conditions brought about by ridging. No literature could be found regarding the effect of ridging on grapevine response. As far as is known Myburgh & Moolman (1991a, 1991b, 1993) were the first to show that ridging improved the internal drainage soil aeration and temperature regimes in the root zone of periodically waterlogged vineyard soils. Consequently this study was undertaken to quantify the effect of ridges of varying dimensions on the root development, shoot growth, nutritional status and yield in the same waterlogged vineyard in which the abovementioned soil physical parameters were studied.

MATERIALS AND METHODS

Experimental layout: A ridging trial was established during November 1984 on the Nietvoorbij Experimental Farm on a low-lying, hydromorphic soil of the Katspruit form (MacVicar *et al.*, 1977). This soil, with a naturally compacted subsoil, is typical of the waterlogged soils of the Western Cape (Ellis *et al.*, 1988). Ten treatments were replicated five times in a randomised block design (Table 1). *Vitis vinifera* L. cv. Chenin blanc, grafted onto 99 Richter, were established in September 1985. Due to poor shoot growth on some treatments all vines were pruned back to two buds during 1986 and 1987. During the third growing season (1987/88) vines were trained onto a lengthened Perold system (Zeeman, 1981). Eight experimental vines were selected on each plot. To eliminate overlapping treatment effects at least three border rows and two vines were allowed for between experimental plots. The plots measured 12,0 x 13,2 m for the single row treatments and 15,0 x 13,2 m for the double row treatments.

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TABLE 1
Treatments applied in a ridging trial with grapevines.

Treatment no.	Preliminary tillage	Ridge dimension	Water supply
T 1	shallow plough	unridge	dryland
T 2	ripped	unridge	dryland
T 3	shallow plough	600 mm high, 1,5 m wide, double row	dryland
T 4	shallow plough	400 mm high, 1,5 m wide, double row	dryland
T 5	shallow plough	400 mm high, bell shaped, single row	dryland
T 6	shallow plough	600 mm high, 1,5 m wide, double row	irrigated
T 7	ripped	600 mm high, 1,5 m wide, double row	dryland
T 8	ripped	400 mm high, 1,5 m wide, double row	dryland
T 9	ripped	400 mm high, bell shaped, single row	dryland
T 10	ripped	600 mm high, 1,5 m wide, double row	irrigated

Soil of the control treatment (T1) was ploughed to a depth of 250 mm and the larger clods broken up with a disc-harrow. In a second, unridged treatment (T2) the soil was ripped to a depth of 550 mm with the wiggle plough described by Van Huyssteen & Saayman (1980). The planting width for T1 and T2 was 1,2 m between vines and 3,0 m between adjacent rows. For the high double row ridging treatment (T3) the topsoil was heaped up with an articulated grader to form a ridge 600 mm high. The distance between centres of adjacent ridges was 5,0 m. Topsoil was scraped from the trough in such a way that no wheel traffic occurred on the loose soil of the ridge. Ridges were trimmed by hand to obtain a 1,5 m-wide flat crest to accommodate two vine rows. In total the topsoil depth was increased to 600 mm. Two vine rows were planted 1,2 m apart on the ridges and individual vines 1,2 m apart in the row. To minimize root competition for nutrients and water, vines of the two rows were staggered to form a zig-zag pattern on the ridge.

A low double row ridge treatment (T4) was obtained in a similar fashion to T3, except that the topsoil was heaped up only to a total height of 400 mm. To create a single row ridge treatment (T5) the topsoil as ploughed from the trough to form a bell-shaped ridge 400 mm high and 1,0 m wide at the base. Four passes on each side with a two-furrow mould board plough, drawn by a light crawler tractor, were necessary to obtain ridges of the desired dimensions. The single row ridges were 3,0 m apart and therefore the same planting width as for T1 and T2 was used. An additional double row treatment (T6), similar to T3, was included to study the effect of supplementary irrigation on grapevine performance on ridges. Water was applied with 280°, 32 $l.h^{-1}$ micro sprinklers. The irrigation system was operated at 80 kPa so that the wetted strips were the same width as the ridge crests. Tensiometers were installed in the vine row at 300 mm and 600 mm depths on two replications of T6. Irrigation was applied when tensiometer readings at 600 mm reached -60 kPa (Myburgh & Moolman, 1991a).

To observe the effect of preliminary tillage in combination with ridging, the soil of treatments, T7, T8, T9 and T10 was ripped to a depth of 550 mm with the wiggle plough before being ridged to the same dimensions as R3, T4, T5 and T6, respectively. Treatment 10 was also irrigated with micro sprinklers. Treatments T7, T8, T9 and T10 were included merely for observation and consequently no parameters except shoot mass and yield were measured. Weeds were controlled mechanically in the work rows and troughs, and chemically on the vine banks and ridges.

Soil parameters: Ridge dimensions were measured during 1988. Soil surface to volume ratios of ridges were calculated from measurements of their cross-sectional areas and the distances along the the soil-air interface of the cross-sections. Two vertical posts, each fitted with a row of horizontal pegs 100 mm apart, were planted in the troughs on either side of a ridge (Fig. 1). The distance along the soil surface between posts as well as the horizontal distance between them was measured. A metre stick, fitted with a spirit level, was used to measure the horizontal distance from the post to the side of the ridge. This procedure was repeated at each peg starting at the bottom one which was always 100 mm above the soil surface. Measurements were plotted on scale enabling outlines of cross-sections to be drawn. The latter were then cut out and their areas measured with an electronic area meter (Li-Cor). Three cross-sections were measured per ridge on all replications of T3, T4 and T5. To quantify initial soil compaction, bulk density was measured during 1986 on four replicates of the control treatment. for this purpose, undisturbed soil cores of known volume were taken over 300 mm depth increments to a depth of 1,5 m.

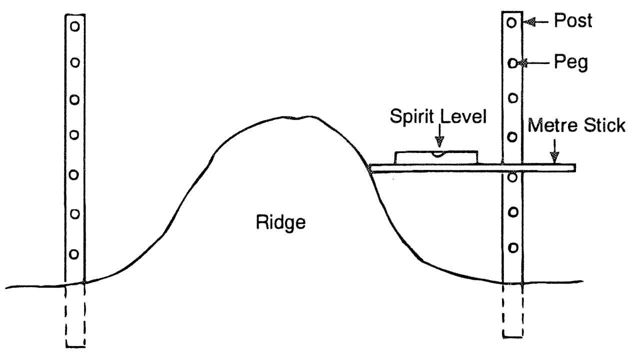

FIGURE 1
Apparatus for measuring cross-section areas of ridges.

Plant parameters: Root distribution was plotted using the profile wall method of Böhm (1979). A trench of at least 1,5 m deep was dug perpendicular to the vine row and centred on the row between two experimental vines, with the longest sides 150 mm from each vine. After the roots were exposed a 250 mm x 250 mm portable grid system, 1,0 m high and 1,5 m wide, was placed against the profile wall for the mapping of the roots. Roots were classified into three classes, namely fine (< 1,0 mm diameter), medium (1-5 mm diameter) and thick (> 5,0 mm diameter). Roots were plotted on two replications of T1, T3 and T5 during December 1990.

Shoot elongation was measured weekly on three representatives shoots per replication on T1, T2, T3, T4, T5 and T6. Measurements were made from 1987-09-17 until 1987-10-28 at which time the vines were trained onto the first wire. At this stage most of the shoots were trimmed which made further reliable measurement impossible. Shoot mass was determined annually at pruning from 1986 to 1989 on all treatments.

Nutritional status was assessed by leaf analyses. Leaves opposite to bunches were sampled during December 1987 on all replicates of T1, T2, T3, T4, T5 and T6. Petioles were separated immediately after sampling. Laminae as well as petioles were analysed for N, P, K, Na, Ca and Mg according to standard Nietvoorbij laboratory procedures. During the fourth growing season (1988/89) yield was determined on all replicates of all treatments. All treatments were harvested on the same day. Berry samples, taken on all replicates of T1, T2, T3, T4, T5 and T6 were analysed for total soluble solids, total titratable acidity and pH by standard Nietvoorbij laboratory procedures.

Data were analysed using STATGRAPHICS and means were separated by Student's Q-test.

RESULTS AND DISCUSSION

Surface to volume ratio: Measuring ridge dimensions showed that ridge construction was close to the original after three years. Limited weathering had occurred only on the shoulders of the ridges. Narrow single row ridges (T5) had higher soil surface to volume ratios than the wider double row ridges (T3 and T4) (Table 2). However, for a given cross-sectional ridge configuration, surface to volume ratios decreased with increasing height. This implied that in, relation to volume, soil surface increased relatively slowly. Soil water and temperature regimes, however, are mainly controlled by the increase in exposed surface or ridge height. This probably contributed to the lower soil water content and higher temperatures found in higher double row ridges (Myburgh & Moolman, 1991a; 1993).

TABLE 2
Average soil surface to volume ratios of ridges as influenced by cross-sectional configuration and height.

Treatment	Surface to volume ratio
600 mm-high double row ridge (T3)	0,57
400 mm-high double row ridge (T4)	0,73
400 mm-high single row ridge (T5)	1,03

Root distribution: Examples of root distributions of the unridged control (T1), the 600 mm-high double row ridge (T3) and the 400 mm-high single row (T5) are presented in Figures 2 and 3. Ridged treatments tended to have fewer roots in the top soil layer. This applied to all the root diameter classes and suggested that the excessive drying of the top soil during the post-harvest period restricted development of shallow roots (Myburgh & Moolman, 1991a). The tendency towards higher root concentration in the 0-250 mm layer of T1 may be due to higher soil water content measured during late summer. Apart from this, waterlogged conditions during spring could also have restricted root penetration to deeper soil layers. Naturally compacted subsoil was a further possible reason for poor root penetration on T1 (Table 3). This was confirmed by the fact that deep root development on the unridged treatment tended to follow the cracks between the large soil structural units (Fig. 2). Close examination showed that the majority of fine roots in the cracks were dead. Similar findings were reported by Northcote (1973) and Smart & Coombe (1983). This suggests that there is an annual cycle during which an abnormal number of grapevine roots die back under waterlogged conditions and are largely regenerated later in the growing season. In the ridged soil the majority of the fine roots were active due to the improved internal drainage and aeration of the soil profile (Myburgh & Moolman, 1991b). In comparison to unridged soil, deeper top soil above the compacted and waterlogged restriction at 900 mm and 700 mm for the high and low ridges, respectively, improved root development in the ridged soil (Fig. 3). Since grapevine roots concentrated mainly in the ridges, the available soil volume can be seriously reduced by compaction due to wheel traffic on the ridges if the troughs are too narrow (Van Zyl, 1985).

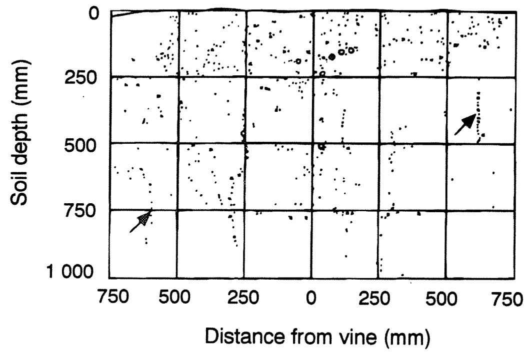

FIGURE 2

Grapevine root distribution plotted in a waterlogged soil. Arrows indicate roots following cracks between large structural units.

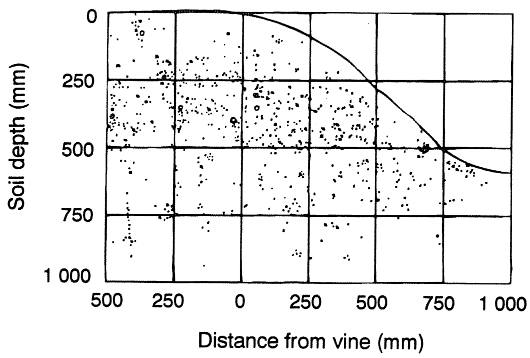

FIGURE 3

Grapevine root distribution plotted in a 600 mm-high double row ridge on a waterlogged soil.

TABLE 3
Average bulk density of unridged waterlogged soil measured in a ridging trial.

Soil depth (mm)	Bulk density (kg.m)
0 - 300	1470
300 - 600	1540
600 - 900	1755
900 - 1200	1805
1200 - 1500	1760

Shoot growth: In comparison to the unripped control (T1), improved drainage (Myburgh & Moolman, 1991a), aeration (Myburgh & Moolman, 1991b) and soil temperature (Myburgh & Moolman, 1993) conditions in ridges increased shoot elongation during early summer (Fig. 4). No significant difference, however, was measured between the various ridged treatments (T3, T4 and T5) and the ripped unridged treatment (T2). This suggested that shattering the compacted subsoil tended to improve internal drainage to such an extent that shoot growth was enhanced on the unridged soil.

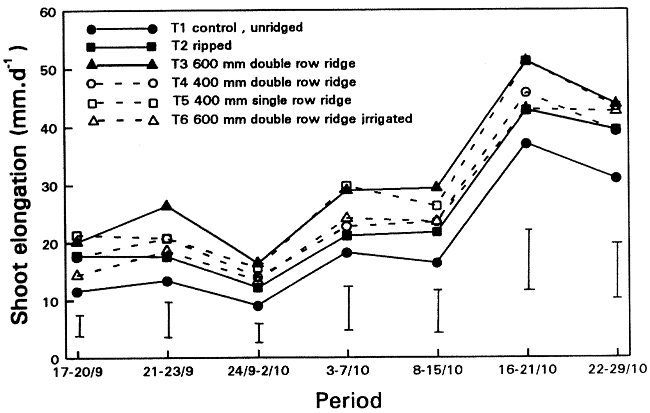

FIGURE 4

Average grapevine shoot elongation as influenced by ridging during early summer of the 1987/88 season. Vertical bars indicate LSD ($p \leq 0,05$).

Improved shoot elongation resulted in a tendency towards more total vegetative growth for the ridged treatments as quantified by shoot mass at pruning (Fig. 5). Due to the specific experimental design most of the unridged plots were bordered on both sides by the outside troughs of ridged plots. Although unridged, these plots can therefore be regarded as land beds. This could have improved drainage and consequently negated differences between ridged and unridged treatments. Additional loose soil increased rooting volume, improved internal drainage and tended to increase shoot growth on the unridged ripped treatment (T2). Where preliminary ripping was done, shoot mass of the ridged treatments showed a similar tendency (data not shown).

Since water supply was not limited, the shoot growth of the irrigated ridged treatment (T6) was significantly higher than most of the treatments during the first two seasons. However, during the 1987/88 and 1988/89 seasons average shoot growth of T6 stabilized while the shoot mass of the other treatments still continued to increase. This suggests that vines on the irrigated ridges developed faster compared to the dryland ridges. The effect of irrigation on unridged soil was not determined. This drawback will be addressed in an ongoing study in the same vineyard.

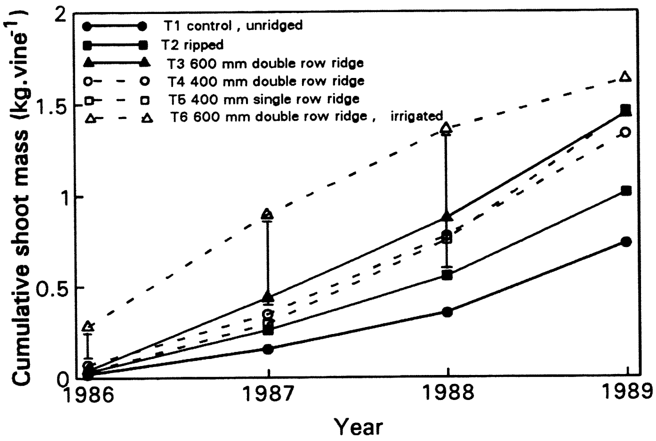

FIGURE 5

Cumulative grapevine shoot mass over the first four seasons after planting as influenced by ridging under waterlogged soil conditions. Vertical bars indicate LSD ($p \leq 0,05$).

Nutritional status: The significantly lower N content of the irrigated treatment (T6) was probably caused by a higher degree of leaching (Table 4). Stronger shoot growth and vine vigour of T6 could also have increased the N demand which resulted in lower concentrations. Phosphorus and K content tended to be lower for treatments where the root zone was drier and warmer (Myburgh & Moolman, 1991a, 1993). The uptake of Ca and Mg, however, tended to increase under drier and warmer soil conditions. Sodium content showed no difference between treatments. Analyses of petioles gave similar results (data not shown).

TABLE 4
Leaf analyses of four-year-old Chenin blanc measured during December 1987 in a ridging trial.

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Na (%)
T1	2,30	0,41	1,23	2,34	0,29	0,04
T2	2,21	0,27	1,05	2,52	0,28	0,03
T3	2,45	0,30	0,94	2,50	0,32	0,03
T4	2,32	0,31	0,97	2,48	0,32	0,03
T5	2,11	0,25	1,14	2,62	0,29	0,04
T6	1,88	0,42	1,15	2,22	0,26	0,03
LSD ($p \leq 0,05$)	0,36	NS**	NS	NS	NS	NS

* For description of treatments refer to Table 1.
** Not significant.

Yield: Ridging tended to increase the first full yield under dryland conditions (Table 5). However, the highest ridges produced the lowest yields. This could have been caused by extremely low soil water content and high temperatures measured in the root zone of ridged soil during the ripening phase (Myburgh & Moolman, 1991a; 1993). On the double row ridge treatments these conditions became critical to yield when surface to volume ratios of the ridges were less than 0,6 (Fig. 6). Measured ratios varying between 0,51 and 0,64 explain the relatively poor average yield of the 600 mm-high dryland ridges (T3). Yield of the single row ridges (T5) was less than 20 $t.ha^{-1}$ when the surface to volume ratio for a specific replication was lower than 1,0 (data not shown). Plant water stress induced by inadequate water supplies during ripening generelly results in reduced berry mass in grapevines (Van Zyl, 1984). Ridging in combination with irrigation (T6 & T10), however, increased yield significantly. The tendency towards higher yields on ripped treatments corresponds with improved vegetative growth (data not shown).

TABLE 5
Yield, total subtle solids (TSS), total titratable acidity (TTA) and pH of Chenin blanc grapes measured in a ridging trial during the 1988/89 season.

Treatment*	Yield ($t.ha^{-1}$)	TSS (°B)	TTA ($g.l^{-1}$)	pH
T1	13,5	17,9	9,32	3,0
T2	15,2	17,9	9,42	3,0
T3	15,3	18,1	8,88	3,1
T4	18,3	17,6	8,70	3,1
T5	17,3	17,2	8,94	3,2
T6	21,6	17,7	8,06	3,2
T7	14,7	–	–	–
T8	19,2	–	–	–
T9	18,3	–	–	–
T10	23,1	–	–	–
LSD ($p \leq 0,05$)	7,7	NS**	NS	NS

* For description of treatments refer to Table 1.
** Not significant.

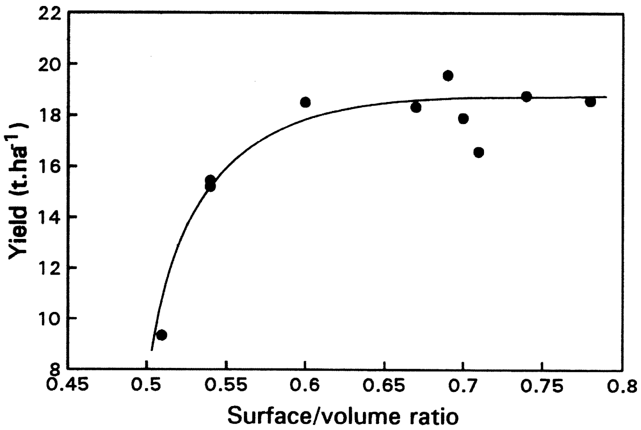

FIGURE 6
Yield of Chenin blanc grapevines during the 1987/88 season as influenced by soil surface to volume ratio of double row ridges (curve fitted by eye).

Total soluble solids and pH were not affected by ridging, preliminary ripping or irrigation (Table 5). Total titratable acid, however, tended to be lower for the ridged treatments, suggesting that drier and warmer soil conditions may accelerate the ripening process.

CONCLUSIONS

Improved internal drainage, aeration and soil temperature in ridges resulted in stronger vegetative growth during early summer. Excessive drying out and high soil temperatures from December until harvest probably negated these positive effects. This resulted only in a tendency towards higher total vegetative growth and yield. Adverse soil physical conditions during ripening resulted in a yield loss when the soil surface to volume ratios of double row ridges were less than 0,6. In practice this means that double row ridges should be lower than 400 mm and at least 1,5 m wide at the crests. These dimensions are readily obtainable if the centrelines of the ridges are 4,5 m apart and the topsoil is deeper than 300 mm. In single row ridges drying out and high temperatures were more pronounced and consequently surface to volume ratios of less than 1,0 resulted in lower yields. This means that single row ridges should be lower than 400 mm and not narrower than 1,0 m at the base. The crests should be flat and approximately 500 mm wide.

Ridging in combination with supplementary irrigation, however, increased vegetative growth and the first full yield significantly. For this reason ridging is recommended only where irrigation water is available. Although ripping without ridging had a positive effect on grapevine performance, it is doubted if this would be the case under normal waterlogged conditions without some kind of drainage. Preliminary ripping of the compacted subsoil before ridging tended to increase yield. Due to the relatively low cost involved, preliminary ripping is therefore recommended. This will also facilitate easier ridge construction.

Ridging had no effect on total soluble solids and pH of musts. The effect of ridging on these parameters and the assessment of crop coefficients for grapevines on ridges under different irrigation systems are part of an ongoing study in the same vineyard.

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