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Short communication

Vineyard floor management improves wine quality in highly vigorous *Vitis vinifera* 'Cabernet Sauvignon' in New Zealand

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Abstract Five inter-row soil management techniques were applied to a vigorous *Vitis vinifera* 'Cabernet Sauvignon' vineyard in Hawke's Bay, New Zealand—a permanent chicory (*Chicorium intybus* var. *sativum* 'Puna') cover crop; chicory sprayed with herbicide before veraison; incorporated pine (*Pinus radiata*) sawdust and bare soil maintained using cultivation or non-selective herbicide. Both chicory treatments significantly reduced the soil water content and shoot growth late in the season compared to the other treatments. Petiole nitrate concentration and leaf size were lowest in the sawdust and both chicory treatments. The pruning weights in the two chicory treatments were reduced to about half those found in the other treatments. No significant differences among treatments were found in yield or other viticultural characteristics examined. Both chicory treatments resulted in advanced ripening (increased soluble solids and decreased titratable acids), increased anthocyanins, and reduced ammonia content of berries compared to other treatments. Sensory evaluation of wines produced from the cultivation (bare soil) and the permanent chicory cover crop treatment were conducted after 4 years of bottle age, and showed riper fruit aroma and flavour and a higher overall quality score in the chicory treatment. Competition imposed for two seasons using a permanent chicory cover crop has resulted in improved viticultural and oenological characteristics of a highly vigorous 'Cabernet Sauvignon' vineyard in a marginal site in New Zealand.

Keywords *Vitis vinifera*; grape vines; wine; chicory; cover crop; sawdust; cultivation; water; nitrogen; vigour; yield; anthocyanins; ammonia; titratable acids; soluble solids; pH; sensory evaluation

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INTRODUCTION

Overly vigorous shoot growth can occur in grapevines (*Vitis vinifera* L.) grown on sites where soils are deep, fertile, and have a high water-holding capacity. The problem can be further exaggerated in regular rainfall environments. Many normal viticultural practices such as weed control, fertilisation, irrigation, plant protection, and the use of disease-free plants or vigorous rootstock-scion combinations add to the problem of excessive vigour. An abundant supply of soil water and nutrients will promote a large root system which will result in vigorous top growth (Champagnol 1984).

Overly vigorous grapevines typically develop excessive shoot growth and dense canopies. Shoot growth also remains active late in the growing season and substantial lateral shoot growth is common (Smart et al. 1985a, 1988; Smart & Smith 1988). High numbers of large, dark green leaves occur on these vines leading to excessive shading (Shaulis et al. 1966; Shaulis & Smart 1974; Smart et al. 1985a; Koblet 1987). Canopies with too many shaded leaves result in several problems, including delayed fruit and wood ripening, reduced yields (Shaulis & Smart 1974; Smart et al. 1989), poor fruit quality, low bud fruitfulness (Kliewer 1982), and higher disease incidence (Rotem & Patti 1969). Smart (1985) and Smart et al. (1988) showed that the photosynthetic activity of shaded leaves is very low. Increased incidence of inflorescence necrosis (Jackson 1990) and bud necrosis (Perez & Kliewer 1990) have been linked to shaded canopies.

Techniques have been developed to help overcome problems associated with excess vigour. Canopy management techniques, such as divided canopy training, were identified by Smart & Smith (1988) to overcome the problems associated with excess shade. However, there is resistance by grapegrowers to the adoption of these techniques because of the high cost of installation and management. Under conditions of extreme vigour, even the divided canopy systems may fail to produce an ideal canopy and improved fruit quality. Growth regulators have also been applied to grapevines to reduce shoot growth but success has been minimal (Szyjewicz et al. 1984; Lavee 1990). Vine vigour and subsequent leaf shading has been reduced by restricting the size and activity of the vine root system including the use of cover crop competition (Van Huyssteen & Weber 1980; Morlat 1982; Perret & Koblet 1984; Lombard et al. 1988; Riemers et al. 1994), high density planting of grapevines (Buttrose & Mullins 1968; Kliewer & Fuller 1973; Archer & Strauss 1985; Archer et al. 1988), regulated irrigation to manage soil water deficits (Neja et al. 1977; Dry & Loveys 1998), and root pruning (Van Zyl & Van Huyssteen 1987; Saayman & Van Huyssteen 1993).

The potential of cover crop competition to reduce vegetative vigour and improve fruit composition has been demonstrated (Van Huyssteen & Weber 1980; Snaddon & Smart 1987; Williams 1993; Naylor et al. 1994). Fruit maturity can also be advanced (Naylor et al. 1994). These outcomes are all most desirable in cool, wet climates such as Hawke's Bay, New Zealand where a limited season length means late varieties like 'Cabernet Sauvignon' are often difficult to ripen.

Little research has concentrated specifically on the effects of soil management on both soil water supply and plant nitrogen concentrations, or the subsequent improvement of vine performance and fruit and wine quality of 'Cabernet Sauvignon'. The intention of this work was to investigate this and identify management practices which could improve the quality of 'Cabernet Sauvignon' grown in potentially high vigour locations.

MATERIALS AND METHODS

The trial began in 1994 in a 6-year-old vineyard (Phoenix Vineyard, Montana Wines, Hawke's Bay, New Zealand) established with *V. vinifera* 'Cabernet Sauvignon' grafted onto SO4 rootstock. The annual rainfall at the site is 764 mm year^{-1} which is evenly distributed through the year.

Vineyard site

The vines were part of a 10-ha block planted in Mangateretere silt loam on clay derived from mudstone (Griffiths 1997). This soil has a potential rooting depth of 300–600 mm with an available water capacity of 50–100 mm in this zone. The vines typically demonstrate high vigour with active vegetative growth occurring throughout the growing season. The vines were trained to a standard vertical shoot positioned (VSP) trellis and pruned to c. 25 buds on two replacement canes tied down to a fruiting wire at 800 mm. Vines were spaced at 1.8 m in north-south orientated rows that were 3.0 m apart. Budburst occurred on 10 October 1995 and 50% flowering occurred on 12 December 1995 which is typical phenology for this site. The vines were shoot positioned in mid December, normal practice in this vineyard. Summer trimming and topping to a height of 2.4 m above ground level was carried out 4 times. Leaf removal in the fruiting zone was done once at 20% veraison, normal practice in this vineyard. Cluster thinning on 13 January 1996 consisted of the removal of the second set fruit on vigorous summer laterals. The standard vineyard practice (removal of c. 20% of the primary crop) was not carried out in the trial.

A weed-free strip of 600 mm on each side of the vine row was maintained throughout the growing season.

Experimental design

The treatments were applied over a 2-year period (1994–96), with measurements taken in the second season (1996) of the trial only.

The experiment was laid out in a randomised block design with five treatments and five replicates (five plots per row). The total area used consisted of 11 rows, each containing 45 vines. The inter-row area on both sides of every second row was treated for each replicate and each plot consisted of nine vines. Two vines were selected from the centre three vines of each plot for sampling purposes.

In 1994, five inter-row floor treatments were applied and then maintained for a 2-year period. These were as follows.

Bare soil-herbicide

Bare soil was maintained for two seasons by spraying with a non-selective systemic herbicide glyphosate, beginning 2 weeks pre-budburst and then periodically during the season when necessary to maintain a weed-free vineyard floor. Plant residues were left on the soil surface to decompose. Undisturbed soil is a practice used in the district where the risk of spring frost is high.

Bare soil-cultivation

Bare soil maintained by cultivation to a depth of 200 mm once at budburst and again 60 days (D) after budburst (BB) (D>BB) which is at phenological stage 17 according to Eichhorn & Lorenz (1977). This treatment was included to determine whether cultivation alone caused any damage to the root system which could affect the results for the sawdust treatment. Periodic applications of glyphosate herbicide were used to keep plots weed free after cultivation.

Sawdust

Fresh pine sawdust (*Pinus radiata*) was spread over the inter-row soil surface at a rate of 170 m^3 ha^{-1} and disced into the soil to a depth of 200 mm. This was applied twice per season (1994/95 and 1995/96); once at budburst (late September) and again 60 days later (phenological stage 19) to maintain a high level of fresh material in the soil. Sawdust was chosen because of its wide C/N ratio (c. 350:1) and the ability to create a nitrogen deficiency through net immobilisation, ease of handling, and availability. Periodic applications of glyphosate herbicide were used to keep plots weed free.

Chicory-herbicide

Chicory (*Chicorium intybus* L. var. *sativum* DC, 'Puna') was established in a cultivated seedbed in spring 1994 (2 weeks before budbreak) at a seeding rate of 4 kg ha^{-1}. Chicory was chosen because of its ability to compete for water and nitrogen (deep root system). Once established, this was mown 5–6 times during both seasons to a height of 100 mm. Mowings were left on the soil surface to decompose. In the second year of the trial the chicory was treated with the desiccant herbicide Preeglone® (Imperial Chemical Industries PLC, Plant Protection Division, Fenhurst, England) as a non-selective, non-systemic burndown 2 weeks before veraison (phenological stage 33) and the plot was then kept free of new vegetation by applying Preeglone® when necessary. This treatment was designed to impose a short-term competition with relief at verasion.

Chicory-permanent

Chicory was established and mowed at the same time as treatment 4. Mowings were left on the soil surface to decompose. The chicory was maintained as a permanent cover crop for the duration of the trial.

Data collection

Soil moisture

Soil moisture was measured at 2-week intervals from phenological stage 15, using a time domain reflectometer (Trace system 1) (Soil Moisture Equipment Corp., Santa Barbara, United States) at 150, 300, and 500 mm depths both within the row (between the two sample vines and directly below the trellis) and between rows (opposite the in-row sampling points and in the centre of the interrow) in each plot. The sample probes were permanent.

Petiole nitrate

Six petioles per plot were randomly selected from exposed leaves opposite the distal cluster from the two sample vines at c. 2-week intervals (starting from phenological stage 17). The six petioles were combined and the sap extracted using a garlic crusher for nitrate determination using a Horiba, Cardy C141 compact ion meter (Horiba Ltd, Miyanohigashi, Kisshoin, Minami-ku, Kyoto, Japan).

Growth rates

During the season, four shoots per vine were tagged for each of the two sample vines per plot. Shoot length was measured from base to tip (base of last fully open leaf) at 2-week intervals (beginning at phenological stage 12). Growth rates were calculated based on the final shoot measurements. The number of laterals on these shoots and their length were measured once, 2 weeks pre-veraison (phenological stage 31). The weight of dormant cane prunings for both sample vines per plot was measured during the dormant period in 1996.

Canopy density

A canopy density assessment was carried out (phenological stage 35) using the point quadrat method after Smart & Robinson (1991). This was carried out in the zone immediately below the bottom tucking wire (4–6 leaves above the distal cluster) as the fruit zone was leaf plucked.

One leaf was removed per sample shoot (4 leaves per vine, 8 leaves per treatment replicate) and its size

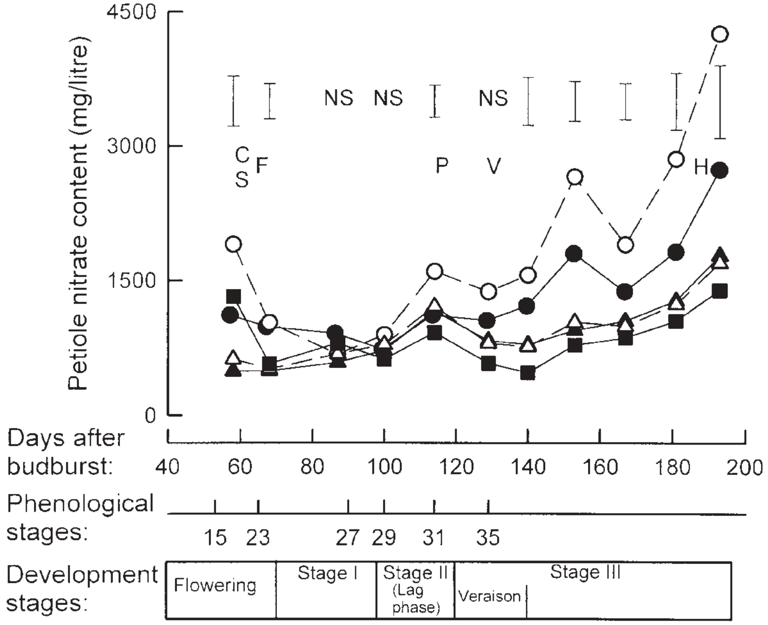

Fig. 1 Nitrate content of petioles opposite the basal cluster as affected by soil management treatments in *Vitis vinifera* 'Cabernet Sauvignon', Hawke's Bay New Zealand, 1995–96. Samples taken in the second season (1996) after treatment application (1994–96). (F, 50% flowering; V, 50% veraison; H, harvest; C, second cultivation; S, second sawdust addition; P, Preeglone applied to chicory. LSD ($P < 0.05$) bars are shown. NS indicates no significant difference. ●, bare soil-herbicide; ○, bare soil-cultivation; ■, sawdust; △ chicory-herbicide; ▲, chicory-permanent.)

determined using a LI-COR model 3100 area meter (LI-COR, Inc., 4308 Progressive Avenue, Lincoln, Nebraska 68504, United States). The leaf selected was from the fourth node above the distal cluster.

Yield

Fruit was harvested on 19 April 1996 (phenological stage 38), weighed, and clusters counted per vine. The distal cluster from each sample shoot was weighed (8 per treatment replicate) and the berry number counted.

Fruit composition

Fifty berries were randomly selected at harvest from each replicate. These were crushed and divided into two samples for analysis. Soluble solids, as °Brix, were measured with a temperature compensating handheld refractometer (Atago N1) (Atago Co. Ltd, 32 Honcho, Itabashi-ku, Tokyo, Japan). The supernatant was decanted off the solids and frozen for ammonia analysis using the technique described in Boehringer Mannheim (1995). Total anthocyanins were determined by spectrophotometric analysis (Iland 1988). pH (Radiometer (PHM 82) pH meter + (Radiometer Analytical, rue d'Alsace 69627, Villeurbanne CEDEX, Lyon, France) and titratable acidity were measured in the same sample (Iland 1988).

Vinification

Replicate wines were produced in 20-litre lots using standard microvinification techniques from the bare soil-cultivation and permanent chicory treatments as these exhibited the widest difference in fruit quality. Chaptalisation of the juice to 23°Brix was carried out on all treatments using sucrose. Before pressing, and again after the first racking, tartaric acid was added to acidify wines to a common pH (3.60). SO_2 levels were monitored and adjusted periodically post-fermentation until stable concentrations of free-SO_2 in the 15–20 ppm range were attained. Wines were cold-stabilised, egg-white fined, and bottled without filtration.

Sensory evaluation

The duplicate wines produced from the bare soil-cultivation and permanent chicory treatments were assessed after 4 years of bottle age because varietal Hawke's Bay 'Cabernet Sauvignon' is typically considered to be at optimum sensoric quality after a bottle age of 3–7 years. The panel consisted of 11 experienced senior wine students and wine professionals. The assessments took place in the sensory evaluation laboratory at the Eastern Institute of Technology, Hawke's Bay, New Zealand. Four 30–50-min sessions were held over 3 days. Three sets of three wines were sequentially presented to each panelist on each of the first two sessions. These triangle tests were used to determine whether differences existed either between treatments or duplicate wines within each treatment. Order of presentation of samples was balanced, and all wines were presented in blackened ISO tasting glasses to mask possible hue differences.

When significant differences within and between treatments were observed (critical values from table 5.10, Stone & Sidel (1985)), a Roseworthy Scorecard was used in sessions 3 and 4 to quantify these differences. The Roseworthy Scorecard is a 20-point scoring system which provides for allocation of points for specific quality categories: appearance (3); aroma (7); palate (8); overall (2). All panelists had previous experience with this scorecard.

At the same time as the scorecard assessment, panelists were also required to rate the perceived “ripeness” of the wine aroma (both ortho-nasally (“aroma”) and retro-nasally (“flavour”)) on two 146 mm horizontal line scales. Both scales were anchored at the extreme left with the phrase “green/ unripe” and the extreme right with “very ripe”. “Ripeness” was selected by the researchers following their informal assessment of the wines, which indicated possible differences between treatments for this attribute. The duplicate wines from the two treatments were assessed over two sessions for both quality score and ripeness. Order of presentation was balanced, and all samples were presented in clear ISO tasting glasses.

Statistical analysis

All viticultural data were analysed using the MINITAB® (Minitab Inc., State College, PA 16801 3008, United States) statistical package. An analysis of variance was carried out for the randomised block design, and least significant differences were calculated where significant F values were found. Sensory data were analysed using the Basic Stats and ANOVA/MANOVA modules within the StatSoft® Statistica Release 5.1 package (StatSoft Inc., Tulsa, OK 74104, United States).

RESULTS AND DISCUSSION

Effects of soil management practices on petiole nitrate content

The petiole nitrate content decreased or was stable until 100 days after budburst (phenological stage 29) in all soil treatments (Fig. 1). After this period petiole nitrate increased, being more rapid in the 4-week period preceding harvest. Nitrate content of petioles in all treatments was generally not significantly different from phenological stage 17 (58 D>BB) to phenological stage 35 (129 D>BB). However, following veraison (130 D>BB), the nitrate content in chicory-permanent, chicory-herbicide, and sawdust treatments were significantly lower than those found in both bare soil treatments. Bare soil-cultivation was significantly greater than bare soil-herbicide from 181 D>BB continuing to 200 D>BB. Petiole nitrate concentrations at harvest were within 1000–2000 mg/litre for sawdust and both chicory treatments, 2000–3000 mg/litre for bare soil-sprayed, and 4000–5000 mg/litre for the bare soil-cultivation treatment. In general, periods of decline in petiole nitrate content (at 60–95, 130, and 165 D>BB) correspond with low rainfall periods (Table 1) whereas peaks occur immediately after high rainfall periods (at 112 and 125 D>BB). This effect was expected, as water movement through the soil during periods of high rainfall will increase nitrate-nitrogen availability within the root zone. Petiole nitrate content continued to increase after 180 D>BB as a result of regular rainfall events.

Bare soil-cultivation resulted in the highest petiole nitrate concentration (Fig. 1) which is consistent with the observation that there is an increase in the available soil nitrogen content following cultivation (Raath & Saayman 1995; Kingery et al. 1996). This may be a short-term effect as only four cultivations were carried out over the 2-year period. Further years of cultivation could result in a gradual decline in the amount of nitrogen mineralised (Hart & Sparling 1989) and therefore reduce the uptake by grapevines.

Effects of soil management practices on soil water content

There was no significant difference in soil water content between the row and within the row (data not shown). The relative differences between treatments were similar at each of the three depths measured (150, 300, 500 mm). The data for soil water content at the depth of 500 mm are presented as this depth represents a majority of the grapevine root zone in an unrestricted soil volume (Archer et al. 1988). Generally, soil water content fell in all treatments until phenological stage 27 (87 D>BB) but it increased between phenological stage 29 (100 D>BB) and phenological stage 35 (143 days D>BB) before again declining (Fig. 2). Three major rainfall events totalling over 100 mm (Table 1) occurred during the period between 122 and 149 D>BB, resulting in the period of elevated soil moisture.

Water use by both chicory treatments reduced the soil water content significantly throughout the growing season (Fig. 2) compared to both bare soil and sawdust treatments. Soil water content steadily increased in the chicory-herbicide treatment after being sprayed (phenological stage 33) but this effect was not significant. This effect could be improved by applying the herbicide earlier.

Growth and canopy characteristics

Shoot length (Fig. 3) in both chicory treatments was less than that in the sawdust and both bare soil treatments with significant differences occurring at 87 D>BB (phenological stage 27). No further measurements were possible after this as the canopy was summer pruned. Growth rates calculated from the pooled measurements (30–87 D>BB) indicated an average vine shoot growth rate in this period of 1.12 cm day^{-1} for both chicory treatments compared with 1.48 cm day^{-1} for bare soil-herbicide treatment, and 1.55 cm day^{-1} for both sawdust and bare soil-cultivation treatments. This reduction in shoot growth rate is attributed to competition of the chicory for water and nitrogen and is consistent with other observations (Van Huyssteen & Weber 1980; Lombard et al. 1988; Tan & Crabtree 1990; Naylor et al. 1994). There were no significant differences for lateral growth, although visual inspections indicated that lateral growth was stimulated in all treatments after each trimming and topping operation, as would be expected.

Table 1 Daily rainfall (mm) for September–March 1996 at Twyford, Hawke's Bay, New Zealand (Hort Research). (BB, budburst; F, 50% flowering; V, 50% veraison; H, harvest. Days after budburst shown in italics are given in 20-day intervals.)

Date	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	0	10.5	24.4	0	0	0.2	0	3.7
2	0.1	0.8	15.5	0	0	0	1.2	0.2
3	0	0.5	0	0	0	0	15.4	2.6
4	0	0	2.3	0	0	0	0	0
5	0	4.5	0	0	0	*120* 0	0.9	*180* 0
6	0	1.2	1.2	0	0	0	1.3	9.4
7	0	0.1	0	*60* 0	3.7	12.1	5.2	11.4
8	0	0	0	0	0	14.2	0.2	0
9	0	4.4	0	0	0	2.7	0	0
10	0	BB 2	0.4	0	0	0	0	0
11	0	0	0	0	5.8	0	0.6	0.4
12	0	0	0	*65* F 0	0.3	0	0	0
13	0	5.1	0	0	2.2	0	0.1	0
14	0	0	0.2	0	3.6	*129* V 0	0	1.6
15	0	0	0.2	0	9.1	0	0	0
16	2.5	0	0	0	*100* 5.1	0	*160* 0.6	0
17	1.3	0.5	0	0	0	0	0	0
18	2.4	0.1	*40* 0	0	0	0	0	0
19	7.6	0	0	0	0	0	0.1	*194* H 4.8
20	0	0	0.8	0	0	1.8	0	3.3
21	0	0.9	2	0	0	19	0	22.3
22	1.6	0.7	0	0	0	13.7	2.1	2.2
23	0.5	0	0	4.2	0	17	1.4	0
24	0	1.6	3.9	17.4	5.6	0.01	0	0
25	0	0	11.7	3	0.2	*140* 0	0	0
26	0	0	0	6.1	16.8	0	0	0
27	0	0	0.3	*80* 0.1	11.7	5.6	0	0
28	0	12.4	0	0	15.5	0.6	0	0
29	1.3	*20* 0	0	0	0.9	0	0	0
30	0.3	0	0	0	0	–	2.3	20.1
31	–	0	0	0	0	–	33.1	–
Total	17.6	43.3	62.9	30.8	80.5	87	64.5	82

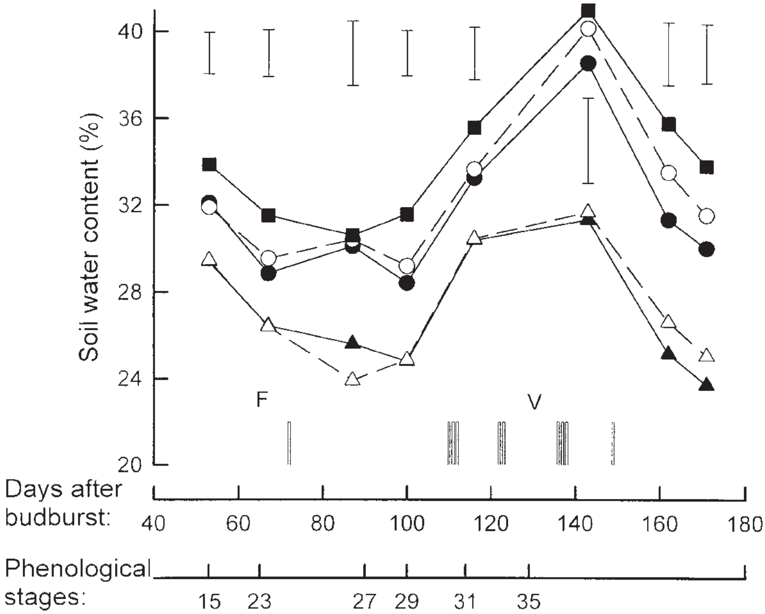

Fig. 2 Soil water content at a depth of 500 mm within the vine row as affected by soil management treatments in *Vitis vinifera* 'Cabernet Sauvignon', Hawke's Bay, New Zealand, 1995–96. Samples taken second season (1996) after treatment application (1994–96). (F, 50% flowering; V, 50% veraison; Bar, > 10 mm rainfall. LSD ($P < 0.05$) bars are shown. ●, bare soil-herbicide; ○, bare soil-cultivation; ■, sawdust; △ chicory-herbicide; ▲, chicory-permanent.)

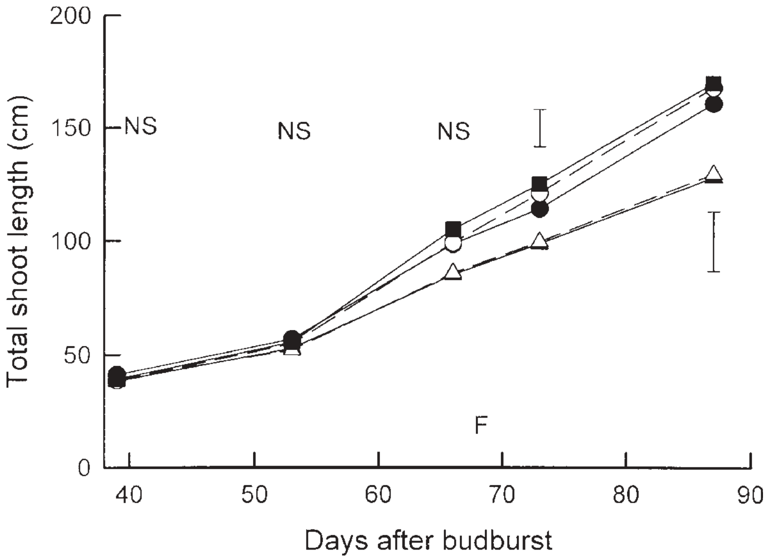

Fig. 3 Shoot length in soil management treatments in *Vitis vinifera* 'Cabernet Sauvignon', Hawke's Bay, New Zealand, 1995–96. Samples taken second season (1995) after treatment application (1994–96). (F, 50% flowering. LSD ($P < 0.05$) bars are shown, NS indicates no significant difference. ●, bare soil-herbicide; ○, bare soil-cultivation; ■, sawdust; △ chicory-herbicide; ▲, chicory-permanent.)

The number of leaf layers measured at phenological stage 35 (183 D>BB) were as follows (mean ± SD): bare soil-herbicide 2.72 ± 0.30; bare soil-cultivation 2.72 ± 0.30; sawdust 2.48 ± 0.28; chicory-herbicide 1.64 ± 0.31; chicory 1.42 ± 0.54. The number of leaf layers in chicory and chicory-herbicide treatments was not significantly different from each other but the two chicory treatments had significantly fewer leaf layers than the other three treatments. The number of leaf layers in the permanent chicory treatment was within the optimum range of 1–1.5 as recommended by Smart et al. (1989). A similar, though less substantial effect was found by Lombard et al. (1988) using grass as the cover crop.

Leaf size was significantly smaller in grapevines grown with both chicory and sawdust treatments compared with the other two treatments (Table 2).

Pruning weights and yield

Both chicory treatments resulted in a reduced dormant pruning weight which is consistent with previous cover crop trials (Lombard et al. 1988; Williams 1993; Wolpert et al. 1993; Naylor et al. 1994). Vine pruning weight varied as follows (kg vine^{-1} ± SD): bare soil-herbicide, 2.10 ± 0.22; bare soil-cultivation treatment, 2.78 ± 0.13 (1.17 kg m^{-1} of row); sawdust 2.61 ± 0.65; both chicory–herbicide and chicory-permanent were the same, 1.20 ± 0.45 (0.67 kg m^{-1} of row). The values for the chicory treatments lay within the optimum range of 0.3–0.6 kg m^{-1} proposed by Smart et al. (1989).

None of the yield components were affected by any of the treatments (Table 3). No significant differences were found for cluster number per vine, cluster weight, berry number per cluster, berry weight, and yield per vine. This occurred despite the impact that the competition from the chicory had on petiole nitrate content (Fig. 1), soil water content (Fig. 2), and consequently shoot growth (Fig. 3) and pruning weights. This lack of effect on yield was also found by Naylor et al. (1994) and may be because of the limited number of years that the vines have been subjected to competition. Cover crop competition trials established for periods of 3 years or more have reported yield reductions (Lombard et al. 1988; Wolpert et al. 1993). Yield reductions were also greater where the soils were of low fertility and/or low water holding capacity (Snaddon & Smart 1987).

Table 2 Effect of soil management on vegetative parameters of hedged *Vitis vinifera* 'Cabernet Sauvignon' vines in Hawke's Bay, New Zealand, 1996. (Values given the same letter do not differ significantly (LSD test; $P < 0.05$).)

Soil management treatments*	Shoot growth rate†	Leaf size‡	Leaf layer number§	Pruning weight¶
Bare soil-herbicide	1.48a	183a	2.72a	2.10a
Bare soil-cultivation	1.55a	181a	2.72a	2.78a
Sawdust	1.55a	163b	2.48a	2.61a
Chicory-herbicide	1.12b	140b	1.64b	1.20b
Chicory-permanent	1.12b	140b	1.42b	1.20b

*Soil management treatments were as follows: bare soil-herbicide, bare soil was maintained for two seasons by spraying with glyphosate herbicide; bare soil-cultivation, bare soil maintained by two cultivations and periodic glyphosate herbicide sprays; sawdust, two sawdust additions were spread between vine rows and cultivated into the soil; chicory-herbicide, a chicory cover crop was established between vine rows from seed and was treated with Preeglone® herbicide at veraison in the second year; chicory-permanent, chicory was established between vine rows from seed and was maintained as a permanent cover crop.

†Shoot growth rates are given as cm day^{-1} were calculated from the final measurement 87 D>BB (days after budburst).

‡Leaf size is for leaves from the fifth node on sample shoots selected at 183 D>BB.

§Leaf layer number was determined at 183 D>BB using the point quadrat method.

¶Pruning weights are given as kg per vine and were measured 7200 D>BB.

Table 3 Effect of soil management on yield and yield components of hedged *Vitis vinif*era 'Cabernet Sauvignon' vines, Hawke's Bay, New Zealand, 1996. (Values given do not differ significantly (LSD test; $P < 0.05$).)

Soil management treatments*	Yield (kg/vine)	Cluster weight (g)	Clusters /vine	Berry weight (g)	Berry no. /cluster
Bare soil-herbicide	8.18	214	41.8	1.40	152
Bare soil-cultivation	9.20	220	46.6	1.39	158
Sawdust	8.40	189	43.4	1.41	133
Chicory-herbicide	7.20	177	44.8	1.18	149
Chicory-permanent	7.58	169	45.2	1.20	146

*Soil management treatments were as follows: bare soil-herbicide, bare soil was maintained for two seasons by spraying with glyphosate herbicide; bare soil-cultivation, bare soil maintained by two cultivations and periodic glyphosate herbicide sprays; sawdust, two sawdust additions were spread between vine rows and cultivated into the soil; chicory-herbicide, a chicory cover crop was established between vine rows from seed and was treated with Preeglone® herbicide at veraison in the second year; chicory-permanent, chicory was established between vine rows from seed and was maintained as a permanent cover crop.

Fruit composition

Soil management had a significant effect on all the fruit composition measurements except pH (Table 4). More advanced fruit ripening was expected when imposed competition reduced vine vigour and canopy density, allowing improved light conditions. Soluble solids were significantly higher in both chicory treatments compared with bare soil-herbicide, bare soil-cultivation, and sawdust treatments (Table 4). This represented a substantial increase of >2°Brix. Increases in soluble solids and decreases in titratable acidity from cover crop competition were also found by others (Naylor et al. 1994; Snaddon & Smart 1987; Williams et al. 1993; Wolpert et al. 1993). The absence of a pH effect was also reported in trials by others (Williams et al. 1993; Wolpert et al. 1993). Titratable acidity was significantly and substantially lower in both chicory treatments (Table 4). Berry anthocyanin concentration was significantly higher in both chicory treatments compared with bare soil-herbicide, bare soil-cultivation, and sawdust (Table 4). This effect on anthocyanins owing to cover crop competition was also found by Williams et al. (1993). Berry ammonia concentration was lowest in both chicory treatments, moderate in sawdust, and high in both bare soil treatments (Table 4). The lower nitrogen content in the must could present some winemaking problems such as stuck fermentations (Monk et al. 1987; Bisson 1991; Rapp & Versini 1991; Goldspink & Frayne 1993) and H_2S production (Voss 1981 cited in Rapp & Versini 1991). However these problems, if anticipated, could be overcome by adding diammonium phosphate to the must (Boulton et al. 1995).

Sensory evaluation

Formal sensory evaluation of the wines after 4 years of bottle age showed the ripeness scores for the bare soil-cultivation and permanent chicory cover crop wines were 54.9 and 88.2, respectively, for aroma and 56.5 and 89.4, respectively, for flavour. These differences were significant for both aroma and flavour ($P < 0.0001$). The wines from the chicory plots may be considered to have 61% riper aroma and 58% riper flavour than the wines from the cultivation plots.

In Table 5, the scores for the wine quality assessment using the Roseworthy Scorecard are presented. The total score (maximum of 20) is 1.24 marks higher in the wines from the chicory treatment. Although the total scores given for the wines from both treatments would correspond to “non-award” and “bronze medal” status, within the New Zealand wine show system, the wines from the chicory treatment were rated significantly higher on all four components of the scorecard. The greatest relative differences between treatments were (in descending order) the scores allocated for “overall impression”, “aroma”, “palate”, and “appearance”. Assessment of the additional comments made by panelists on their scorecard sheets suggests that the wines from the cultivation treatment were considered harsher, less ripe, and of lower varietal intensity than the wines made from the chicory treatment (data not shown).

Table 4 Effect of soil management on composition of harvested fruit of hedged *Vitis vinifera* ‘Cabernet Sauvignon’ vines, Hawke’s Bay New Zealand, 1996. Fruit was harvested 194 days after budburst (19 April 1996). (Values given the same letter do not differ significantly (LSD test; $P < 0.05$).)

Soil management treatments*	Soluble solids (°Brix)	Titratable acidity† (g/litre)	pH	Ammonia (mg/litre)	Anthocyanins (A.U. at 520 nm)
Bare soil-herbicide	19.4a	10.77a	3.28	90.4a	27.56a
Bare soil-cultivation	19.1a	10.62a	3.32	88.4a	46.06ab
Sawdust	20.0a	9.75a	3.30	56.6b	42.36a
Chicory-herbicide	21.9b	8.17b	3.37	21.8c	74.74bc
Chicory-permanent	21.6b	7.66b	3.37	22.6c	81.00c

*Soil management treatments were as follows: bare soil-herbicide, bare soil was maintained for two seasons by spraying with glyphosate herbicide; bare soil-cultivation, bare soil maintained by two cultivations and periodic glyphosate herbicide sprays; sawdust, two sawdust additions were spread between vine rows and cultivated into the soil; chicory-herbicide, a chicory cover crop was established between vine rows from seed and was treated with Preeglone® herbicide at veraison in the second year; chicory-permanent, chicory was established between vine rows from seed and was maintained as a permanent cover crop.

†Titratable acidity was measured as tartaric acid.

Table 5 Quality scores, for Roseworthy scorecard assessment of *Vitis vinifera* 'Cabernet Sauvignon' wines produced after using different soil management practices* in 1994–96, Hawke's Bay, New Zealand. (wines 4 years old at time of assessment (harvested 19 April 1996)).

Scorecard parameter	Maximum possible score	Cultivation mean*	Chicory mean†	n^3	*F* ratio	*P*
Appearance	3	2.86	2.95	44	17.69	<0.001
Aroma	7	4.88	5.36	44	8.37	0.006
Palate	8	6.23	6.74	40	5.81	0.021
Overall	2	1.08	1.34	40	9.80	0.003
Total Score	20	15.15	16.4	44	38.59	<0.001

*Averaged across judges, replicate wines and replicate presentations.
†Number of assessments made.

Consistent with many sensory studies, panelists and the panelist × treatment interactions were significant sources of variation for both the profiling and scorecard data (data not shown).

CONCLUSIONS

Bare soil maintained by herbicide and/or cultivation are soil management practices that increase the availability of water and nitrogen in this fertile soil. These practices promote vine vigour as was observed by shoot growth rates, leaf layer number, leaf size, and pruning weights. The incorporation of sawdust reduced petiole nitrate concentrations and is attributed to increased net immobilisation of soil nitrogen. However the immediate effects on growth were limited, as the soil may have had high total nitrogen reserves.

Chicory was competitive with grapevines for both water and nitrogen, reducing vine vigour and making the vines more suitable for quality grape production with the existing trellising system. The maturity of fruit was also enhanced as a result of these canopy improvements. This effect is important for 'Cabernet Sauvignon' grown in cool climates such as Hawke's Bay, considered to be marginal for the production of this cultivar.

There were no immediate adverse effects on yield from cover crop competition, although this may occur in later years once the chicory cover crop has developed its potential root system. Yield reductions may eventually dictate where chicory is used, particularly in the following situations: low fertility soils, shallow soils, soils of low water holding capacity, or sites subject to low rainfall.

Organoleptic evaluation showed that improvements in vine canopy characteristics, and subsequent fruit quality from competition with chicory can result in improved overall sensoric quality of wines.

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