The Effect of Fertilisation on the Performance of Barlinka Table Grapes on Sandy Soil, Hex River Valley *

D. Saayman and J.J.N. Lambrechts

Department of Soil and Agricultural Water Science, University of Stellenbosch, 7600 Stellenbosch, South Africa

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The response of Barlinka table grapes on grayish, sandy soil to irrigation-applied N fertilisation levels, patterns of N application, crop load and stock P and K fertilisation, were evaluated over a 12-year period in the Hex River Valley. Under the conditions of the trial, an N level of about 100 kg ha^{-1} appeared to be optimum for shoot growth and grape quality. Bunch and crop mass benefited from increased N levels, apparently due to better berry set. Increased N levels also appeared to preserve greenness of bunch stems better during cold storage but N levels higher than 105-120 kg ha^{-1} reduced colour and sugar content of berries. Applying 67% of total seasonal N during the pre-bloom to veraison period and the rest after harvest, as against a 50:50 distribution, had a slight, positive effect on shoot growth and bunch size, again apparently caused by better berry set. Indications of a small, positive response of shoot growth to stock P fertilisation were obtained. Potassium applied in this manner was found to be ineffective due to leaching and regular irrigation-applied K fertilisation had to be adopted. Increased crop load had a marked negative effect on shoot growth and grape quality, in the latter case comparable in magnitude to that of too high N levels. A balanced crop load of 22 bunches per vine with a shoot mass of 1,822 kg, was calculated for this trial, but a crop load of 18-19 bunches per vine appeared to be the maximum that still ensured the best quality.

The fertilisation of vines often appears to be a subject of conflicting opinion, probably because of difficulties encountered in obtaining reliable results with fertilisation in practice as well as under controlled experimental conditions (Delas, 1992). This is not too surprising when viewed in the light of the vine's perennial nature, its obvious hardiness, deep rooting nature, long season in which to acquire the nutrients needed and the varying ability of different soils to supply these nutrients (Malherbe, 1962; Winkler *et al.,* 1974; Champagnol, 1978a).

Amongst the macro-elements, nitrogen (N) is the element which is the most likely to give a response, mainly in terms of improved vigour. Champagnol (1971) found that N always has a positive effect on vegetative growth but that yield is only increased in the case of low vigour cultivars like Aramon and not in the case of vigorous cultivars like Carignan. Nitrogen fertilisation decreases photosynthetic intensity and increases respiration intensity, a reflection of stimulated metabolism.

Lacking convincing experimental fertilisation results, earlier attempts at arriving at recommendations adopted an indirect approach. According to Delmas (1971), Muntz started calculating the removal of elements by French vineyards since 1895 and arrived at an amount of 30-50 kg N ha^{-1} yr^{-1} for Bordeaux vineyards, with variations depending on cultivar, locality and vintage. Delmas (1971) proposed N needs of 50-60 kg N ha^{-1} yr^{-1} for high-quality vineyards (50-60 hL ha^{-1} production) and 90-110 kg N ha^{-1} yr^{-1} for high-production vineyards.

In Charente, Lafon *et al.* (1965) found a 67 kg N ha^{-1} uptake by leaves, shoots and bunches of Ugni blanc for a production of 120 hL ha^{-1} (about 20 t ha^{-1}). This N uptake peaks at flowering and stops at veraison when shoot growth stops, with a strong migration of N and potassium (K) from leaves to bunches during ripening. This pattern was different from that found for warmer regions like the Midi in France and North Africa, where N uptake recommences during ripening. This was ascribed to differences in cultivars and climate. For a production of 160 hL ha^{-1} (26-27 t ha^{-1}) and assuming that leaves return to the soil, N exporation was calculated at 37 kg ha^{-1}. This small amount and the long period of uptake implied that many soils would naturally be able to supply the amounts of N needed.

For Alsace and a production of 74 hL ha^{-1}, Marocke *et al.* (1977) calculated mean N uptake by leaves, shoots and crop of 54 kg ha^{-1}, with 69% diverted to the vegetative parts and the rest to the crop. Based on a fertilisation trial with Gewürztraminer on granitic soil, they come to the same conclusion as their colleagues in Germany, namely that only elements exported need to be replaced for the majority of situations. According to Schaller & Löhnertz (1991), Wagener first published data on grapevine nutrition in Germany in 1917, recommending 140 kg N ha^{-1}, 20 kg phosphourus (P) ha^{-1} and 100 kg K ha^{-1} for quantity production and 95 kg N ha^{-1}, 15 kg P ha^{-1} and 70 kg K ha^{-1} for quality production. However, there is little evidence that this was the basis for fertilisation between the two world wars.

From 1950 German agriculture, including viticulture, was reconstructed with the emphasis on production, resulting in high fertilisation levels. Pollutions of rivers caused growing concern and fertilisation levels of vineyards remained virtually a secret, although Gärtel pub-

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lished recommendations, based on old data, of 80-130 kg N ha^{-1}, 40-50 kg P ha^{-1} and 250-300 kg K ha^{-1} for sandy soils and 100-160 kg N ha^{-1} 1, 40-50 kg P ha^{-1} and 200-250 kg ha^{-1} for loess. During the seventies, 60-88 kg N ha^{-1} was recommended, taking organic matter content of the soil into account. The present levels is a maximum of 50-60 N ha^{-1}, applied just before the 6-7 leaf stage when vines start absorbing N (Schaler & Löhnerts, 1991). In Switzerland 60-80 kg N ha^{-1} is recommended on sandy soil and 50-70 kg N ha^{-1} on medium to heavy textured soil (Anon, 1970).

For Bordeaux, Delas *et al.* (1982) were of the opinion that about 30 kg N ha^{-1} is an acceptable norm. They found a significant stimulation of Botrytis infection with N fertilisation of 100 kg ha^{-1}, but also by using the rootstock SO4. Different mechanisms were obviously involved because N fertilisation increased the N content of must, whereas this was not the case with SO4. More recently Delas (1991) reported that the aim of fertilisation in Bordeaux has changed from obtaining higher yields towards ensuring high quality. It is known that higher yields reduce quality due to lower alcohol, fewer anthocyanins and polyphenols and less aroma, i.e. an indirect effect of excessive N. In hydroponic studies where vigour and yield were kept comparable, the direct effect of high N nutrition were also lower alcohol, colour and anthocyanins content. In field trials increased Botrytis infection caused by high N levels appeared to be counteracted by K fertilisation. In another field trial with Merlot N fertilisation increased vigour but reduced yield because of berry shatter and reduced sugar and phenolic compounds, and increased the acid and N content of berries (Delas, 1993).

According to Winkler *et al.* (1974) the vineyards east of the Rocky mountains are less responsive to N fertilisation than those in Europe, but more so than Californian vineyards. Assuming that leaves and shoots are returned to the soil, exportations of 7,6-15,3 kg N were calculated for a 7,8 t ha^{-1} crop. In situations where a response can be expected, about 45-78 kg N ha^{-1} was recommended, with smaller quantities of 24-45 kg N ha^{-1} for coloured table grape cultivars such as Tokay and Emporer.

Peacock *et al.* (1982) found late fall (after leaf fall) N applications to be ineffective on Thompson Seedless on sandy soil because of leaching during winter. They admitted that the effect of early fall N fertilisation was still unknown and expressed doubt as to its possible unwanted stimulation of renewed shoots growth. Later work (Peacock *et al.,* 1989) showed that veraison and after harvest N fertilisation of Thompson Seedless of 112 kg ha^{-1} was more effective than budbreak N applications in terms of labelled N contents of leaf and dormant tissue, the N in the latter parts strongly supporting early spring growth. In another experiment Peacock *et al.* (1991) also found veraison and after-harvest N applications to be more effective than bud break and bloom applications in increasing petiole nitrate contents of Thompson Seedless, but that N fertilisation had no effect on Flame Seedless in this respect. Nitrogen fertilisation reduced sugar content but did not effect berry mass, acidity or pH. Veraison or after-harvest N fertilisation also did not stimulate late season shoot growth.

For Australia Robinson (1992) reported only rare responses to N fertilisation, mainly in the raisin grape regions where yield response can be obtained with 30-60 kg N ha^{-1}. A negative response to N fertilisation with ammonium sulphate of Shiraz was ascribed to soil acidification and consequent lower P availability (Tulloch & Harris, 1970; Seeliger & French, 1971).

Up till 1920 when "complete" fertliser mixtures for vineyards were introduced, vineyards in South Africa were fertilised with August-applied farmyard manure, supplemented in certain cases with basic slag, bone meal, guano or superphosphate (Daneel, 1937; Burger, 1951). The use of these mixtures became fairly common, but this was still considered to be only additional to farmyard manure, which was progressively supplemented with sheep manure from the Karoo as vineyard plantings extended. The use of cover crops (natural weeds) in winter was encouraged to protect the soil against erosion and leaching and to serve as an indicator of the nutritional status of the soil (Burger, 1951). Daneel (1937) regarded natural weeds as lacking in fibre and recommended lupins as cover crop. He expressed doubts as to the practice of supplementing dwindling supplies of manure with straw, which may cause an N negative period, but stated that the incorporation of prunings into a furrow between the rows would have the desired effect. Although Reinecke (1935) found that lime and K improved the sugar content of red Muscat d'Alexandrie in Constantia, Du Toit (1937) reported that the extensive use of K was being stopped because its beneficial effect on quality was overrated. During and after the Second World War, fertilisers became unavailable and emphasis shifted to the use of blue lupins as cover crop to supply N.

Perold (1926) based his fertilisation recommendations for vineyards on the nutrient exporation data of Muntz and claimed that it worked well for South African conditions. He regarded manure as the best fertiliser, with 9 t ha^{-1} as adequate to satisfy the N and K needs of vineyards. Table grapes should receive more N and he recommended 20 t ha^{-1} manure. Malherbe (1962) quoted nutrient removal by vines of 16,3 kg N, 2,4 kg P and 25 kg K for a crop of 10 t ha^{-1} and recommended an annual fertilisation programme for fruit trees and wine grapes of 22-88 kg N, 17-26 kg P and 45-90 kg K per hectare.

For wine grapes Coetzee (1963) recommended a split application at bud break and bloom of 44 kg N, 40 kg P and 80 kg K as a normal programme. The programme of Saayman (1975) was based on nutrient removal data obtained in a field study of vineyards in the Bonnievale region (Saayman, 1973) and recommended replacement of 2,2 kg N, 0,78 kg P and 5,0 kg K for each ton of grapes produced. This was subsequently updated (Saayman, 1981, 1982), using the nutrient uptake data of

4,0 kg N, 0,7 kg P and 3,0 K per hectare for pot-grown Chenin blanc recommended by Conradie (1980, 1981) but restricting N fertilisation to a maximum of 42 kg ha^{-1} for quality production and 100-120 kg ha^{-1} for mass production.

In a long-term field trial at Stellenbosch only sight stimulation of shoot growth of Chenin blanc was experienced with N application rates of 56 and 96 kg ha^{-1} (Conradie & Saayman, 1989). It was estimated that the natural N-supplying capacity of the soil was nearly sufficient to satisfy the N demand of the vines and that only about 40 kg ha^{-1} additional N was justified for the particular soil. Subsequent work of Conradie (1991) indicated that the division of absorbed N between permanent, vegetative and reproductive parts, 26%, 41% and 33% respectively, is genetically controlled and appears to remain constant for different cultivars and ages. During the budbreak-bloom phase the vine is very dependent on reserve N. During the bloom-veraison stage most of newly absorbed N is diverted to the vegetation, whereas bunches receive most of their N from shoots, which in turn are replenished with newly absorbed N and not from leaves. From veraison bunches are the main accumulators of N from other organs (not from newly absorbed N), whereas 50% of leaf N is translocated to permanent parts, the latter also accumulating 67% of newly absorbed N. This pattern is probably different in cool climate countries.

For table grapes and fruit in the Western Cape, Van Niekerk & Fourie (1951) assumed that a 30 t ha^{-1} stand of a leguminous cover crop like lupins will fix 380-544 kg N ha^{-1} and will supply the necessary N,P and K in the desired ratio to vines and trees. If rye is used as cover crop, 35 kg N ha^{-1} in autumn was recommended for the cover crop and 69 kg N ha^{-1} in spring after incorporation of the cover crop. The fertilisation programme for table grapes proposed byWolf & Van Niekerk (1959) was based on the quantities of nutrients removed by the crop and amounted to a single spring application of 244 kg N, 36 kg P and 163 kg K per hectare for a production level of 24 t ha^{-1}. Van Niekerk & Pienaar (1967) lowered these recommendations to 150 kg N, 30 kg P and 136 kg K for table grapes with a production of 24 t ha^{-1}, with N split into three equal increments at budbreak, 6 weeks later and after harvest. These recommendations were increased again by Van Niekerk *et al.* (1971) to 195 kg N ha^{-1} of 40 kg P ha^{-1} and 160 kg K ha^{-1}, the P and K split into two increments, applied at budbreak and after harvest. More recent N recommendations for table and raisin grapes were based on soil types: 120 kg N ha^{-1} for sandy soil, 100 kg N ha^{-1} for medium to heavy textured soil and 50 kg ha^{-1} for dark, alluvial soil, split into three increments at budbreak, bloom and immediately after harvest (Saayman, 1984).

Chambers *et al.* (1993) investigated the effect of 60, 120 and 180 kg N ha^{-1} on the incidence of Botrytis infection of Barlinka table grapes. Although little to no effect was observed in the vineyard, N fertilisation significantly increased Botrytis on grapes after cold storage, but seasonal variation was even greater. High N levels tended to reduce colour and to increase the incidence of dry stems.

Whereas the fertilisation of wine grapes is based on numerous studies and sound experimental data, this appears to be lacking in the case of table grapes. Here, production apparently is of higher priority than quality aspects. Also, because of a higher income gained by table grapes compared to wine grapes, higher than recommended fertilisation levels are often applied by producers. To determine the optimum N fertilisation level for table grapes in practice, as well as the effects of potassium and phosphourus, a long-term experiment was started in the Hex River Valley on a sandy soil, where a reaction could be expected.

MATERIALS AND METHODS

Details of the experimental lay-out have been described by Saayman & Lambrechts (1995) and only relevant aspects are presented here. The soil was a grayish, almost pure sand, containing about 5% silt plus clay, 0,5% organic C, 22 mg P kg^{-1} and 19 mg K kg^{-1}. The experimental vineyard was planted in 1978, all plots initially receiving 45 kg N ha^{-1} dissolved in the irrigation water that was applied by drippers and micro-sprinklers. From the 1978/79 season weekly-applied differential N fertilisation levels of 24, 48 and 72 kg N ha^{-1} yr^{-1} were applied and factorially combined with two different seasonal patterns of N application, two irrigation systems and three crop levels, all treatments replicated four times. These N levels were increased to 35, 70 and 105 kg N ha^{-1} yr^{-1} during 1980/81 and from 1985/86 to 60, 120 and 180 kg N ha^{-1} yr^{-1}. One seasonal N application pattern consisted of 67% of total N applied from commencement of irrigation (usually mid-October, 2-3 weeks before bloom) until January (2-3 weeks before veraison), and the remaining 33% over a 4 week period immediately after harvest. In the other N application pattern total N was split equally between these two periods.

The three crop levels were 15, 22 and 29 bunches $vine^{-1}$ from the 1984/85 season. Because of a diminishing availability of data vines that were free of 'red leaf' (Saayman & Lambrechts 1993), the experimental lay-out was reduced during the two final seasons, *inter alia* by abandoning the 50:50 seasonal N application pattern treatment and retaining only the 22 bunches $vine^{-1}$ crop level.

Initially bypass fertilisation tanks were used to apply the N fertiliser, but from 1983/84 they were replaced with water-powered, diaphragm dosage pumps, which were in turn replaced by electrically driven dosage pumps before the 1990/91 season. The N source used was initially aqueous urea, but was replaced with liquid ammonium nitrate (19% N) from 1985 in response to the findings of Du Preez (1983) that urea is less efficient on soils which have less than 6% clay, a low pH and a low organic material content.

On a split plot basis, superphosphate and KCl were deeply incorporated during soil preparation as stock fertilisation with the aim of increasing the P and K concentrations in the soil to 50 mg kg^{-1} and 100 mg kg^{-1} respectively. Because of generally low K concentrations detected in the soil and leaves, differential K fertilisation was eventually abandoned and a blanket application of 250 kg ha^{-1} in the form of KCl applied on the soil surface before the 1982/83 season. From 1986/87 a blanket amount of 200 kg ha^{-1} yr^{-1} dissolved KCl was applied in the same manner as for N.

Grapes were harvested at 17-18°B, weighed and the colour of bunches assessed on a 1-6 scale, with 1 being almost black and 6 almost green. For each plot a carton of export quality grapes was packed, protected by a paper SO_2 generator, and stored at -0,5°C for four weeks, followed by one week at 10° C. After this, grapes were evaluated for greenness of stems, cracking of berries, Botrytis infection and SO_2 damage. The sugar and acid contents of berries were measured, using standard Nietvoorbij methods. Shoot mass was determined by weighing winter prunings.

Data were subjected to analysis of variance, using Genstat and Statgraphics software. Because repetitions and treatments changed during the duration of the trial, treatment means, using seasons as repetitions in time, were compared in order to obtain indications of the mean long-term or cumulative effect of treatments.

RESULTS AND DISCUSSION

Shoot Growth: Throughout the 12 years of measurements, no significant effect of seasonal N application pattern on shoot growth was found for individual seasons (data not shown). Concerning the mean long-term effect, it was found that the 67:33 N application pattern slightly (3%) but highly significantly (P= 0,0002) increased shoot growth compared to the 50:50 pattern. On the strength of this result, when the experimental layout had to be reduced from 1990/91, the 50:50 N pattern treatment was dropped.

Increasing N fertilisation levels almost consistently increased shoot growth significantly (Fig. 1), the considerable seasonal variation mainly caused by variations in crop load (Saayman & Lambrechts, 1995). During the period of low N levels (1981-1985), in three out of five seasons, 70 kg N ha^{-1} appeared to be too little to significantly increase shoot growth over the lowest rate of 35 kg N ha^{-1}, whereas an amount of 105 kg N ha^{-1} was consistently superior to 35 kg N ha^{-1} during all five low-N levels seasons. When N levels were increased from

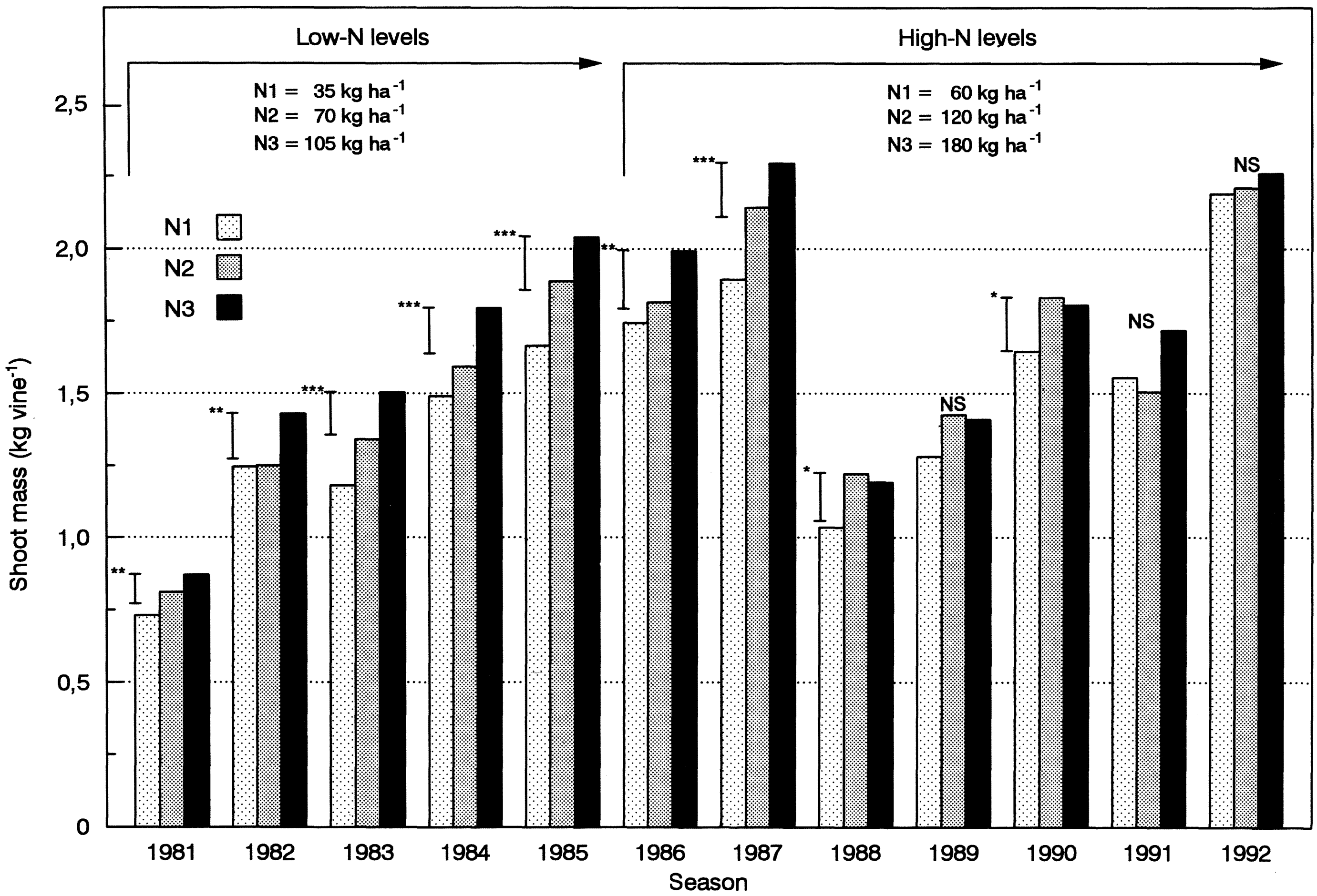

FIGURE 1
Effect of N level on the vigour of Barlinka/Ramsey on sandy soil, *Nietvoorbij* Experimental Farm, De Doorns, Hex River Valley.

1985/86 an N level of 180 kg ha^{-1} initially induced a significantly higher shoot mass than 60 kg N ha^{-1}, as well as 120 kg N ha^{-1} during 1986/87. After this responses were erratic, 120 kg N ha^{-1} often appearing to be superior to 180 kg N ha^{-1}.

To cope with the change in N levels from 1985/86 when estimating the long-term effect of the different N levels, the 60 kg N ha^{-1} treatment of the initial low-N levels period was assumed to be comparable to the 70 kg N ha^{-1} treatment of the second high-N levels period. This 60-70 kg N ha^{-1} level was then taken as a reference N rate which overlapped the two N level periods. According to Fig. 2 shoot mass increased up to an N level of 105 kg N ha^{-1}, from where no further significant increases occurred, indicating that for this trial, with a mean production of about 30 t ha^{-1}, about 100 kg N ha^{-1} was optimum for shoot growth. This is less than half the 244 kg ha^{-1} originally proposed by Wolf & Van Niekerk (1959) for table grapes and considerably less than the 150-195 kg ha^{-1} advised by the former Fruit & Fruit Technology Research Institute (Van Niekerk & Pienaar, 1967; Van Niekerk, Terblanche & Deist, 1971), which was responsible for table grape research in South Africa until the end of 1981. It is also less than the 120 kg ha^{-1} N that was subsequently calculated to be sufficient for table and raisin grapes on sandy soil (Saayman, 1984). This optimum amount of N fertilisation is expected to be still lower for heavier textured soils with their greater N minilisation and nutrient retention capacities.

A stock fertilisation of P and K before planting did not have a significant effect on shoot growth in individual seasons (data not shown). However, cumulatively over the 12 year duration of the trial significant mean increase in shoot growth was obtained (P=0,0073). However, this stimulation of shoot growth by P and/or K was very small (from 1,569 to 1,603 kg vine^{-1}) and probably has few practical implications. The experimental design did not allow a distinction to be made between P and K. Because the K content of the soil could not be increased to or maintained at the target level of 100 mg kg^{-1}, a blanket amount of 250 kg K ha^{-1} was surface applied before the 1982/83 season and from 1986, 90 kg K ha^{-1} each season through the irrigation systems. In view of this the slight long term stimulation of shoot growth can most probably be ascribed to the effect of P. Reports on responses of vines to P fertilisation are rare in the literature. In Australia growth and yield responses of Shiraz were obtained only after eight years of P fertilisation. The increased yield was ascribed to more berries per bunch (Tulloch & Harris, 1970). On coastal sand in southern France, Champagnol (1978b) found that P fertilisation improved vigour and alleviated leaf symptoms of chloride injury. He proposed that the more than threefold increase in fresh material of the barley cover crop

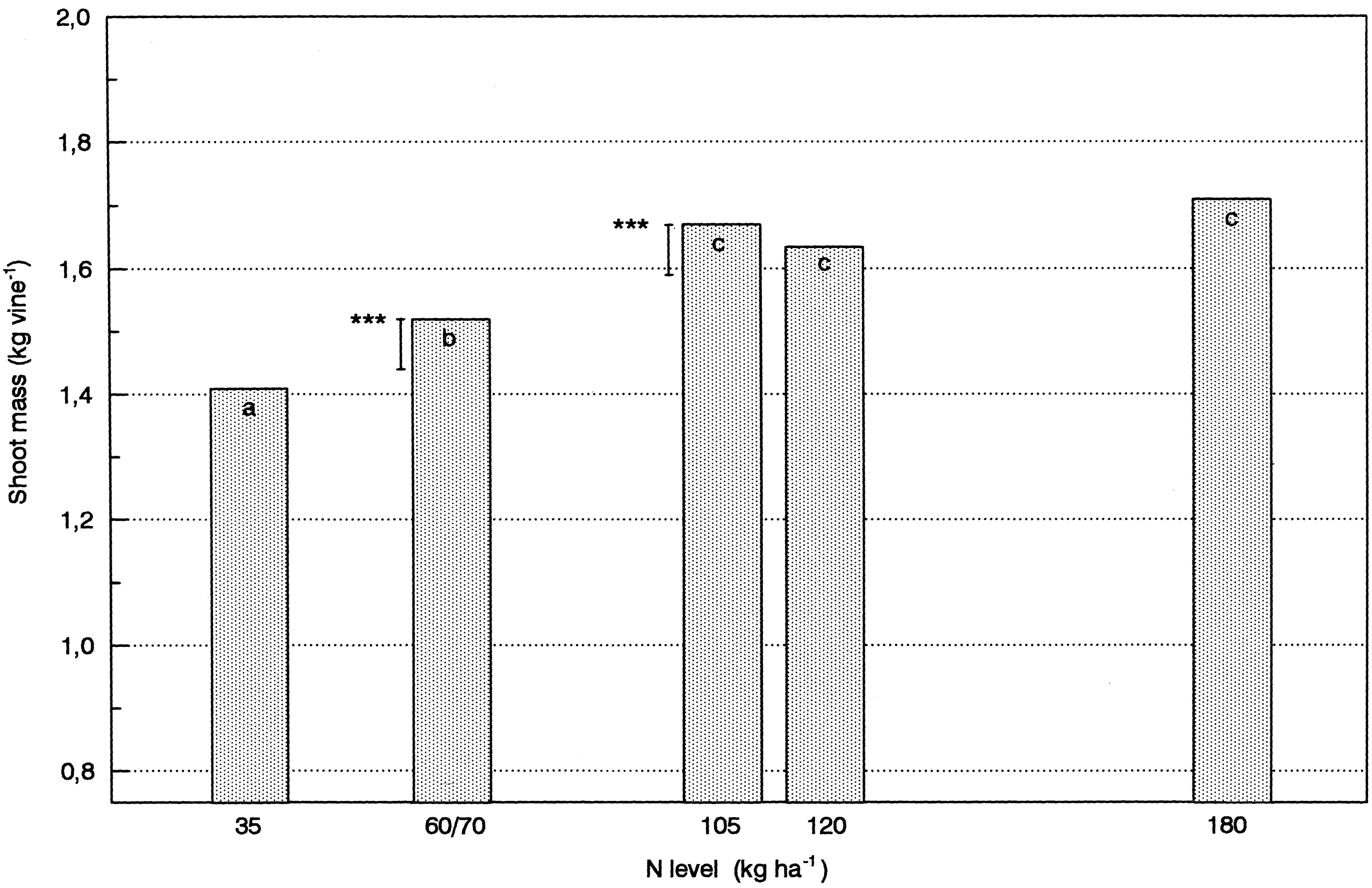

FIGURE 2
Long-term effect of N level on shoot growth of Barlinka/Ramsey, *Nietvoorbij* Experimental Farm, De Doorns, Hex River Valley.

due to P fertilisation may have contributed to this result. In South Africa no seasonal response of Chenin blanc to P fertilisation was observed, but a cumulative response in terms of both shoot growth and yield over an 11 year period could be demonstrated (Conradie & Saayman, 1989).

Yield and Quality: Compared to the 50:50 seasonal N application pattern, the 67:33 pattern increased bunch mass significantly in one out of the five low-N levels seasons. Higher yields were obtained during four out of five high N levels seasons and colour was negatively affected by the 67:33 N application pattern only in the 1986/87 season (data not shown).

The mean effects on crop characteristics over the 10 year period when differential seasonal N patterns were applied are shown in Table 1. Because bunch number per vine was controlled and did not differ between N application patterns, the higher mean crop mass per vine obtained with the 67:33 N application pattern can be assumed to be the result of larger bunches than was the case with the 50:50 N application pattern. The larger bunches can in their turn be ascribed to more berries per bunch, as berry mass did not differ between treatments, indicating improved berry set. However, these differences were small, in practice amounting to a mean gain of about 0,73 t ha^{-1}.

Conradie (1991) found that Chenin blanc bunches receive N during the bloom-veraison phase mostly from shoots and not from leaves, the shoots in their turn being replenished by newly absorbed N. The higher N dosage during the bloom-preharvest period by the 67:33 N application pattern probably allowed greater transfer of N to bunches *via* this N distribution pattern, stimulating increased berry set. The slight (3%) mean shoot growth stimulation obviously had no negative effect in this regard. Although sugar content of berries was not negatively affected by the higher preharvest N dosage, acid concentrations were increased, but did not effect packing or export quality.

Concerning N application levels, in two out of the five initial low-N levels seasons, the highest 105 kg ha^{-1} level increased crop mass significantly over the lowest 35 kg N ha^{-1} level. During one of these seasons it was also superior to the intermediate 70 kg N ha^{-1} level. During the following seven high-N levels seasons, the highest level of 180 N ha^{-1} increase crop mass significantly over the two lower N levels during two seasons. These increases could largely be ascribed to increased bunch masses (data not shown). Colour was negatively affected only once by a level of 180 kg N ha^{-1} and did not coincide with an increased bunch or crop mass, whereas the effect of N levels on the amount of grapes having packing or export quality was irregular and inconsistent (data not shown).

To evaluate the long-term effect of N levels on production and grape quality parameters, the same procedures was followed as described above for shoot growth. According to Table 2 the highest bunch mass was obtained with 105 kg N ha^{-1}, still higher N levels having no additional effect. This was largely reflected in crop mass. However, berry mass seems to be negatively

TABLE 1
Mean effect of nitrogen application pattern over a 10-year period on production and quality parameters of Barlinka/ Ramsey; *Nietvoorbij* Experimental Farm, De Doorns, Hex River Valley.

Parameter measured	N application pattern 67:33	50:50	Significance level (P)
Bunch mass (g)	600,2	587,1	0,0036
Crop mass (kg $vine^{-1}$)	10,45	10,12	0,0110
Berry mass (g)	6,69	6,61	0,1815
Colour rating*	2,03	2,01	0,4291
Sugar conc. (°B)	17,25	17,42	0,1235
Acid conc. (%)	0,467	0,450	0,0359
Bunches packed (%)	78,4	77,5	0,0676
Export quality (%)	42,6	42,2	0,5405

* Evaluated on a 1 – 6 scale, with 1 = well coloured and 6 = almost green.
67:33 67% of total N applied during pre-bloom to véraison; 33% during four weeks after harvest.
50:50 50% of total N applied during pre-bloom to véraison; 50% during four weeks after harvest.

affected by the high 180 kg N ha^{-1} level. The bunch mass of this treatment was comparable to that of the 105 kg N ha^{-1} level, which implies that, in the absence of excessively stimulated shoot growth (Fig 2), the high N level also increased berry set, but in this case to the detriment of eventual berry size.

Colour and sugar content of berries were negatively affected by N levels higher than 105 kg N ha^{-1} and 120 kg N ha^{-1} respectively, but this, together with reduced berry size, apparently was of such negligible magnitude that it had no appreciable impact on grapes classed as fit for packing or export. Chambers *et al.* (1993) also found that high N fertilisation levels caused reduced colouring of Barlinka grapes.

No significant effects of stock P and K fertilisation on crop characteristics could be identified. The fact that these treatments were applied on a split plot basis, making statistical testing for significance in differences of means less sensitive, may have contributed to this lack of results.

Storage characteristics: Out of the eight seasons when effects of N application patterns on quality aspects of cold stored grapes were measured, the 67:33 pattern only once had a positive significant effect on greenness of stems and neck cracking (not in the same season) respectively compared to the 50:50 N application pattern (data not shown). Evaluated over the duration of the trial, the 67:33 N application pattern had a very slight positive mean effect of the greenness of stems (2%), but had no significant effect on berry cracking, SO_2 or Botrytis damage, compared to the 50:50 N application pattern (data not shown).

In two out of the 10 seasons when effects of different N levels were measured, the higher N level(s) had a slight positive effect on greenness of stems and reduced neck cracking during two other seasons (data not shown). According to the long-term mean effects shown in Table 3, the high N levels were slightly more effective in preserving greenness of bunch stems after cold storage, but had no siginificant effect on the other quality parameters measured. The indications of a positive effect of the higher pre-harvest N dosages or N levels on greenness of stems after cold storage have no logical explanation and are contrary to the findings of Chambers *et al.* (1993).

Botrytis was never a serious problem over the duration of the trial and even when grapes were stored without SO_2 protection during 1992, no effect of N level was obtained (data not shown). Chambers *et al.* (1993) found

TABLE 2
Mean effect of nitrogen application level over a 10-year period on production and quality parameters of Barlinka / Ramsey; *Nietvoorbij* Experimental Farm, De Doorns, Hex River Valley.

Parameter measured	N application level (kg ha^{-1})*					Significance level(P)
	35	60/70	105	120	180	
Bunch mass (g)	585,4	590,1a	625,5b	610,7b	617,8b	0,0001
Crop mass (kg $vine^{-1}$)	10,5	10,6	11,3c	10,7ab	11,1bc	0,0012
Berry mass (g)	6,69ab	6,71a	6,70ab	6,53b	6,31c	0,0015
Colour rating**	1,94a	2,0a	1,94a	2,10b	2,13b	0,0139
Sugar conc. (°B)	17,51a	17,47a	17,42ab	17,41a	17,24b	0,0190
Acid conc. (%)	0,44a	0,45a	0,44a	0,45a	0,46a	0,0513
Bunches packed (%)	81,1a	79,5a	82,0a	81,0a	77,6a	0,3321
Export quality (%)	45,9a	45,8a	50,4a	49,2a	42,7a	0,0559

* a,b: Figures in rows followed by the same symbols do not differ significantly ($p \leq 0,05$).
** Evaluated on a 1 – 6 scale, with 1 = well coloured and 6 = almost green.

TABLE 3.
Mean effect of nitrogen application level over a 10-year period on quality parameters of Barlinka grapes after cold storage.

Parameter measured	N application level (kg ha^{-1}) *					Significance level(P)
	35	60/70	105	120	180	
Green stems (%)	46,1a	46,9a	47,6ab	48,5bc	50,0c	0,0027
Botrytis rot (%)	0,67a	0,71a	0,73a	0,86a	1,07a	0,3263
Neck cracks (%)	5,11a	5,05a	5,26a	4,70a	4,19a	0,0534
Ordinary cracks (%)	0,051a	0,027a	0,032a	0,036a	0,041a	0,3281
SO_2 (%)	0,20a	0,22a	0,24a	0,23a	0,21a	0,8269
Total damage (%)	6,12a	6,13a	6,49a	5,94a	5,63a	0,3732
Firmness (%)	85,4a	85,0a	84,9a	82,6a	82,1a	0,1560

a,b: Figures in rows followed by the same symbols do not differ significantly ($p \leq 0,05$).

that N fertilisation increased Botrytis rot damage but that this was overshadowed by seasonal effects. Clearly certain conditions prevailing in a specific vineyard (locality, foliage density, row orientation, sanitary measures) are predominant in determining its susceptibility to Botrytis and may override any N effect, as was probably the case in this trial.

Crop Load: The pronounced depressing effect of increasing crop load on shoot growth have already been reported (Saayman & Lambrechts, 1995). High crop loads also significantly decreased bunch mass regularly from 1983 as well as colour of bunches during all of the ten seasons when it was measured and sugar concentration in berries in two out of the eight seasons of measurement (data not shown). The mean long-term effects of increasing crop load were also smaller bunches, weaker colouring and lower sugar concentrations, culminating in less grapes of packing and export quality (Table 4). For the mean shoot mass of 1,822 kg vine^{-1} of this trial and using the formula proposed by Saayman & Lambrechts (1995), a balanced crop load would be 22 bunches per vine, which in terms of the parameters in Table 4 may already be too high for the best quality.

Compared to the data in Table 2, it is evident that the negative effect of a high crop load was comparable to that of too high N levels in terms of bunch mass and colour. A too high crop load is apparently even more detrimental in terms of grapes suitable for packing or export than too high N levels. If a crop load of 18-19 bunches vine^{-1} is assumed to be compatible with acceptable quality, this would have ensured a production of 26,7 t ha^{-1} in this trial. This is more than sufficient to pack 4 000 cartons of grapes, leaving a margin of 25% grapes not suitable for packing.

TABLE 4
Mean effect of crop load over a period of 10 seasons on some characteristics of Barlinka bunches; *Nietvoorbij* Experimental Farm, De Doorns, Hex River Valley.

Parameter measured	Crop load (bunches vine^{-1}) 15	22	29	Significance level (P)
Bunch mass (g)	629a	587b	565c	0,0000
Berry mass (g)	6,62a	6,67a	6,67	0,5750
Colour rating*	1,797a	2,067b	2,180b	0,0000
Sugar conc. (°B)	17,50a	17,29ab	17,12b	0,0120
Acid conc. (%)	0,452a	0,460a	0,454a	0,0856
Bunches packed (%)	83,5a	77,0b	73,4b	0,0003
Export quality (%)	48,7a	42,7b	37,2c	0,0006

a,b: Figures in rows followed by the same symbols do not differ significantly ($p \leq 0,05$).
* Evaluated on a 1 – 6 scale, with 1 = well coloured and 6 = almost green.

CONCLUSIONS

This trial succeeded in demonstrating the positive effect of N fertilisation of Barlinka on sandy soil. Strong evidence was obtained that under the adaphic, genetic and crop load restrictions of this trial, an amount of about 100 kg N ha^{-1} was optimum in terms of shoot growth and grape quality. It can be assumed that this quantity would be less for heavier textured or more organically rich soils with their greater N mineralisation capacities. It also appeared that the concentration of total seasonal N dosages in the pre-bloom to veraison period had a slight beneficial effect on shoot growth, compared to a more even distribution over the season. Because shoot growth was not excessively stimulated by this treatment, it also appeared to be beneficial to berry set, resulting in a slightly increased crop mass. However, indications were also obtained that excessively improved berry set caused by too high N levels leads to smaller berries, loss of colour and reduced sugar concentrations and consequently to losses in terms of grapes suitable for packing.

Applying a stock fertilisation of K cannot be recommended on this sandy soil because of the soil's inability to absorb and retain sufficient quantities of K. It is recommended that K be applied through the irrigation systems in the same manner as N from pre-bloom to veraison and for four weeks after harvest. The indications obtained that P had a slight long-term positive effect on shoot growth apparently have very few practical implications.

Apart from previously reported marked depressive affects of crop load on shoot growth, too high crop loads have marked negative effects on grape quality, comparable to those of excessive N fertilisation, especially in terms of bunch mass, colour and sugar content of berries, resulting in a significant reduction in grapes suitable for packing. For the conditions of this trial a crop load of 22 bunches vine^{-1} (about 6 bunches m^{-2} trellising surface) was calculated to be in balance with the mean 1,822 kg vine^{-1} vigour, whilst a crop load of 18-19 bunches vine (about 5,25 bunches m^{-2} trellising surface) appeared to be optimum for grape quality.

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