SOIL MANAGEMENT WITH RESPECT TO NITROGEN MOBILIZATION AND NUTRIENT SUPPLY OF GRAPEVINES ON LOESS SOIL

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Abstract
The effects of different methods of soil management on the nutrient supply and the wine quality of organically grown `Grüner Veltliner` grapevines (wide-spaced high culture training system) were investigated in the winegrowing region Wagram of Lower Austria (municipality: Großriedenthal). Under permanent green cover the mineral nitrogen content in the soil was significantly lower than under green cover, which was loosened up or broken up. Regarding the nitrogen demand of the vine the best results of the mineral soil nitrogen content were found by loosening up the soil by the end of April and breaking it open two weeks later. Permanent green cover inhibited shoot length development and the total acidity of the must was lower. The content of yeast assimilable nitrogen and the yield were reduced, but must density as well as potassium and ash contents of the wine were slightly higher. There were no differences in the vinification of the grapes of the different origins. Significant differences in the sensory evaluation could not be related to different methods of soil cultivation.

Keywords: grapevine, soil management, nutrients, nitrogen supply, must contents, wine quality

1 INTRODUCTION

Today a quality-oriented production is essential in wine growing to be able to offer perfect products and sell them profitably. However, problems concerning the quality of grapes and wines occur regularly. The reasons for this can also be attributed to vineyard management. Beside essential factors, like the choice of scion and rootstock, spacing and trellising, there are a number of possibilities to influence quality and yield during the vegetation period. In biological winegrowing as well as in other growing systems close to nature, which rely on a cover crop in the intermediate zones, it is essential for optimal wine quality to concentrate on perfect nutrition of the vine – especially with respect to nitrogen. Especially in dry areas factors like cover crop, nutrition and water supply are important. In this respect the timing of nitrogen supply of the vine is essential. According to Löhnertz (1988) a significant uptake of nitrogen occurs only after sprouting. The main uptake of nitrogen takes place between flowering and the start of ripening. During this time two definite climaxes of uptake can be observed: the two weeks after flowering and the two weeks after the start of ripening. Taking this fact into consideration the nitrogen dynamics in the soil are of essential importance for the nutrition of the vine. According to Heigel (1995) there are lower nitrogen dynamics in the case of a continuous cover crop compared to an intermittent cover crop – in spite of sufficient mineral contents in the soil. The low contents of NO_3^- with continuous cover crop compared to intermittent cover crop are associated with low moisture contents, which decreases the availability of nutrients essentially. The lower nutrient uptake with continuous cover crop compared to intermittent cover crop is reflected in lower nitrogen contents of the leaves, but especially in low mineral and starch contents of the wood. According to Heigel (1995) the yield decreases with continuous cover crop compared to intermittent cover crop, however, without positive effects on must weight. Furthermore the extract values decrease significantly with the decrease of the vegetative and generative performance with a continuous cover crop. The wines from variants with intermittent cover crop were somewhat better rated than those with continuous cover crop. Moreover the residual extract values in wines from plots with open soil are in all the years higher than from those with a continuous cover crop. Maigre et al. (1995) also processed the grapes from the most important cover crop variants from 1989 to 1993 separately. In some cases wine quality was affected when competition from cover crop was too strong. The bouquet of these wines was masked and changed and showed bitterness and astringency on the palate. The musts from plots that showed stress from lack of nitrogen (caused by fertilization and /or cover crop) contained a lower content of compounds containing nitrogen. Duration of fermentation was closely correlated with the content of nitrogen compounds in must and the nitrogen content in the leaves. Erratic fermentation occurred if the nitrogen content in the leaves was lower than 1,6 %. Whenever stress occurred, the results could be observed analytically: an increase in the phosphorous content of the leaves, in must and wine; an increase in the calcium contents in leaves and must and a lower malic acidity content in must. Maigre and Aerny (2000) and Wagenitz (2000) found similar results. According to Steinberg (2000) the nutrition of the vine has to be organized in a way to meet the temporal and absolute demands for nutritional elements. Especially nitrogen demand can result in a temporary competition with the cover crop with respect to nitrogen supply as well as water supply. Nitrogen supply must be timed correctly. It must compensate for the withdrawal of approximately 25 to 30 kg/ha and it must be adjusted to soil management, humus content and weather conditions. Correct appliance of continuous and intermittent cover crop results in optimal water management, correct timing of nitrogen application, positive influence on the growth of vines, yield, quantity and quality and ecological aspects. According to Covers (1994) the temporal application of nitrogen in the soil can be adjusted to the demand of vines through correct soil management. During times of low nutrient demand the natural crop is allowed to grow. In autumn there should be a growing cover crop as long as possible to reduce eluviation losses during winter. According to Stotz (1994) an adequate nutrient supply of the vines with alternative nitrogen sources (a cover crop of legumes) is possible under different soil climatic local conditions without neglecting ecological and economic issues for longer periods. Hofmann (2000) notes, that a cover crop is essential for ecological soil management. It helps soil structure, increases the capacity to store water, prevents erosion and stabilizes nutrient supply by fixation of nitrogen and activating life in the soil. According to Delabays et al. (2000) a cover crop offers many advantages. It can, however, also have negative effects on cultivated plants, yield and quality. A good choice of an adequate cover crop can reduce these disadvantages. In our studies five different soil management variants have been performed and their influences on nutrient supply and on quality of must and wine were investigated.

2 MATERIALS AND METHODS

Location, climate and soil

The field tests were carried out in Neudegg, community Großriedental, district Tulln (Lower Austria). The region belongs to the wine growing area Wagram. The examinations were carried out in the location Wadenthal with the variety `Grüner Veltliner'. The area belongs to the pannonic climate. The pannonic climate is characterized by an average precipitation per year of less than 600 mm.

Table 1: Description of the soil at the location Wadenthal

Parameter	Description
Landscape	Wagram, higher terraces and hills
Soil type	Chernozem from loess
Water conditions	Moderately dry, moderate retaining capacity, moderate permeability
Kind of soil	A_{1p}, A_2: loamy silt, C: loamy silt, silt or sandy silt
Humus conditions	A_{1p}: medium, A_2: medium to low
Lime content	Severe, carbonate content : A_{1p} and A_2 horizon about 20 %, C horizon more than 30 %
Soil reaction	Alcaline
Tillage	Excellent
Natural soil value	Excellent, danger of water erosion
Soil weight	Medium – light
Depth	> 70 cm
Topsoil	> 40 cm
Relief	Flat to 0° - 5° slope

Soil samples were taken on the 1st of April and analyzed at the Federal Office and Research Centre for Agriculture (now Austrian Agency for Health and Food Safety) in Vienna. The analyses showed that the soil had a high content of lime. The supply with phosphor, potassium, iron, manganese, zinc and boron was sufficient or high (stage C and D). At a sampling depth to 20 cm phosphor and potassium showed a very high supply (stage E). With 40 mg per 1000 g the nutritional and functional element copper showed a very high supply (stage E).

Test arrangement

Since `Grüner Veltliner' is the main variety in Austrian wine growing, it was selected for the soil management tests. `Grüner Veltliner` had been grafted on the rootstock Kober 5BB.

We decided for five soil management variants (A, B, C, D, E) in long lots (Table 2).

Table 2: Soil treatment variants

Variant	Method	Date	Equipment and procedure
A	Cover crop in intermediate zone all year round		
B	Loosening the soil	April 29th	Subsoil cultivator: twice per intermediate zone
C	Breaking up the soil	May 20th	Subsoil cultivator and rototiller: twice per intermediate zone
	Breaking up the soil	July 4th	Plow and rototiller: twice per intermediate zone
	Sowing of cover crop	Aug. 11th	Rototiller: twice per intermediate zone; seed drill
D	Loosening the soil	April 29th	Subsoil cultivator: twice per intermediate zone
	Breaking up the soil	May 20th	Subsoil cultivator and rototiller: twice per intermediate zone
	Breaking up the soil	July 4th	Plow and rototiller: twice per intermediate zone
	Sowing of cover crop	Aug. 11th	Rototiller: twice per intermediate zone; seed drill
E	Loosening the soil	April 29th	Subsoil cultivator: twice per intermediate zone
	Breaking up the soil	July 4th	Plow and rototiller: twice per intermediate zone
	Sowing of cover crop	Aug. 11th	Rototiller: twice per intermediate zone; seed drill

The variant with undisturbed intermediate zone under cover crop all year round was to be compared with variants where at different times the soil in the intermediate zones was loosened or broken up. Between the variant-specifically tended intermediate zones there was in each case an intermediate zone, where the soil was not loosened and the cover crop was kept short all year round using a flail mower. The area under the vines was kept open in any case. The evaluation was carried out in both rows on both sides of a variant-specific intermediate zone. That means in two rows per variant with 113 vines per row. Soil cultivation in the intermediate zones was carried out with a subsoil cultivator, plow, rototiller and seed drill. Soil sampling was carried out at five fixed dates between the middle of May and the middle of September. Samples were taken from a depth between 0 to 60 cm using a hand drill and a mallet. From eight evenly distributed places samples were taken for each of the soil treatment variants at fixed dates. The samples of each variant were then thoroughly mixed and put into plastic bags. Cooled in boxes and refrigerators the samples were delivered to the Federal Office and Research Centre of Agriculture in Vienna and their content of mineral nitrogen was analyzed. From the beginning of July until harvest grape ripeness was determined in intervals of approximately seven days using must weight, pH and content of titratable acids. At the same time 100-berry weight was determined. The grapes were always transported in cooling boxes and processed and analyzed on the same day. 100 berries per variant and repetition were tested. Berries were taken evenly from both sides of the foliage, from the front and back of the cluster, and always from the upper, middle, and lower third of a single cluster. At first the 100-berry-weight was determined in the laboratory. Then the berries were crushed in the bags by hand and the juice was collected in test tubes. After sedimentation must weight (°Oe) was determined with a Seitz T/C refractometer. The pH-value was determined with a pH-meter (model CG 822). Contents of titratable acids (g/l) were determined using n/KOH (blue brine) until colour change (pH=7).
The harvest took place on 11th of September. The repetitions of the variants were always harvested separately into 400 kg plastic boxes and each box was weighed on a weighbridge at Großriedenthal. For vinification 20 kg grapes of each variant were brought to a laboratory in the cellar of the Department of Crop Sciences at the University of Natural Resources and Life Sciences, Vienna. There they were crushed and pressed in a hydrostatic vertical tube press. The juice was filled into 25 l glass containers and fermented at approximately 18°C. To monitor fermentation, the sugar content was determined daily. No pure yeasts were used on purpose. After fermentation the wines were filled into smaller containers, potassium pyrosulfite up to 70 mg/l SO_2 was added, and the containers were filled up. In the middle of December a control of the free sulphuric acid and an addition to 50 mg/l free SO_2 were carried out. On 16th of January filling took place.
The must samples from the analyses on berry ripeness of 1st, 11th and 31st of August and of 7th and 12th of September had been filled into plastic bottles and deep frozen at once. In December pH-value, contents of yeast assimilable nitrogen, sugar, ash, titratable acidities, tartaric acid, malic acid, citric acid, potassium, calcium, magnesium, copper and phosphor (P_2O_5) were determined.
The leaves for analysis were sampled on 7th of June, 21st of July and 19th of September. The sampling of 30 leaves per variant and date was carried out in the following way: One leaf was taken from 30 vines that were distributed regularly on a long lot. Always that leaf was taken, that was exactly opposite the fluorescence of the shoot next to the stem of each vine. The leaves were transferred in keep-fresh packages to the Department of Crop Sciences at the University of Natural Resources and Life Sciences, Vienna. After drying they were processed in a coffee grinder and filled into paper bags. The analysis of the contents of nitrogen, phosphor, potassium, calcium, magnesium, boron, iron, manganese, copper and zinc in the leaves were carried out at the Test Centre at Laimburg in South Tyrol.
Wine tasting was carried out in several groups with wine growers, innkeepers and laymen, applying two different methods. In the first method the tasters had to evaluate the wines according to an unstructured scale (0-100). The optimal value was 100. In the second method the wines had to be ranked. The number of wines in the respective test corresponded to the number of possible ranks. Rank 1 denoted the best value.
The test results were processed with the statistic package STATGRAPHICS 4.0 using variant analysis in combination with the F-test. The differences between the medium value groups were determined with the multiple range test. The differences of the medium values with different letters differed significantly. The following significance limits were used: Probability: $P <= 0.001$ = "Secured" = ***, $P <= 0.01$ = "Highly significant" = **, $P <=0.05$ = "Significant" = *, $P > 0.05$ = "Not significant" = n.s.

3 RESULTS AND DISCUSSION

The tests were carried out for one year under practical conditions and they proved, that it is possible applying well-timed soil treatments in intermediate zones with cover crop to reach a positive mineralization effect with nitrogen. It was proved that there were definitely less nitrogen dynamics in untreated soil than in loosened soil. This effect was also described by Perret et al. (1993), Kaltzin (1994), Heigel (1995), Rupp et al. (1995) and Hofmann et al. (2001). With a continuous cover crop, however, there was no sufficient supply of nitrogen during the two times of maximum demand of the vines, namely from the end of June to the end of July and during the two weeks from the start of ripening.
In our test it was possible to influence nitrogen mineralization by respective timing of soil treatments (Table 3).

Table 3: Mineral nitrogen content (NO_3^- and NH_4^+) in the soil (0-60 cm) depending on soil treatment and date of sampling.

Variant	Date				
	17.05.	**07.06.**	**19.07.**	**21.08.**	**18.09.**
A	25	33	23	32	32
B	52	60	27	27	37
C	n.a.	65	54	54	64
D	n.a.	71	50	59	68
E	n.a.	n.a.	36	59	68

n.a. = not analyzed

The timing was carried out in a way to enable a mineralization according to the demand of the vine, as described by Löhnertz (1988). During subsoil cultivation at the end of April in connection with breaking up the cover crop in the middle of May (Variant D), the values of mineral nitrogen in the soil were between 50 and 71 kg N/ha during the year. In untreated soil, however, the values were between 23 and 33 kg N/ha (Variant A). According to Redl et al. (1996) there should be N_{min}-contents of 60 to 70 kg N/kg at sprouting. Corvers (1994) managed a well-timed and adequate nitrogen supply through a loosening of the cover crop, well-timed breaking up or organic fertilizers. Fox (1996) found that treatment of the cover crop at the beginning/middle of May is adequate, even earlier under dry conditions. According to Rupp et al. (1995) an early treatment in April is even better than in May, because there are probably positive effects of precipitation in spring. Thus enough nitrogen could be supplied at the desired time (after flowering and before softening of the grapes). According to Dütsch et al. (1997) the winter cover crop should be integrated into the soil in May, if there is enough moisture left from the winter and there is enough water holding capacity in the soil. Thus there would be a sufficient nitrogen supply, especially between flowering and the beginning of ripeness. According to Ziegler (1998) the cover crop in the intermediate zones should be integrated into the soil at least by the middle of May to supply the vines with the nitrogen contained in the plants. Redl (1999) stresses the positive ecological and economical aspects of a cover crop under correct management. According to Redl (1999) the cover crop should be plowed in dry locations before the start of the critical time of main demand (middle/end of May). Mechanical soil treatment should lead to mobilization of nutrients. Steinberg (2000) thinks, that correct management of continuous and intermittent cover crop assures a supply of nitrogen at the right time and leads to perfect water management and vine growth.
In our investigations the growth of the vines was slightly influenced by soil treatment. The vines in the variant with a continuous cover crop usually had shorter shoots than those in the treated variants (Table 4).

Table 4: Shoot length (cm) depending on soil treatment.

Variant	Date	
	12.07.	**28.08.**
A	57 b	62
B	68.5 ab	78
C	81 a	81.5
D	72 ab	74
E		74
F-value	3.76*	1,0 n.s.

Also leaf area was influenced. It was significantly smaller in the untreated variant. The same was true for the leaf/fruit ratio. Also according to Kaltzin (1994) shoot growth was restricted due to increasing competition from cover crops. In addition Heigel (1995) described a massive reduction of shoot growth because of competition from the cover crop. Schwab and Peternel (1997) found significantly lower yields of top foliage and wood in the case of a long-term cover crop. Hofmann et al. (2001) described the gradual reduction of vegetative growth with a continuous grass cover. According to Corino et al. (1996) the green cover was the reason for the limits of vegetative growth. According to Dorigoni et al. (1991) the vegetative performance in open soil systems is better than that in systems with cover crops.
Concerning nutrients in leaves no differences due to soil treatment could be determined with the elements nitrogen, phosphor, calcium, boron, iron, manganese, copper and zinc in our one-year trial. In contrast Heigel (1995), Maigre et al. (1995), Maigre and Aerny (2000) and Wagenitz (2000) found lower nitrogen contents in leaves under a constant cover crop. Maigre et al. (1995) described an increase of calcium contents in the case of stress. From the results described in this paper a possible influence of soil treatment on the contents of potassium and magnesium is evident. With the untreated variant on all three dates the relatively highest amounts of potassium in the dry substance of the leaves were analyzed. The second highest value occurred in the variant where the subsoil was loosened only once in April. In contrast, the amount of magnesium in the dry substance of the leaves was lower in the variant with an undisturbed cover crop, compared to other variants of soil treatment.
In our investigations with permanent green cover, there was a tendency for lower total acid values (Table 5) especially at harvest time.

Table 5: Content of titratable acidity (g/l) in must during the year

Variant	Date							
	03.07.	**14.07.**	**30.07.**	**11.08.**	**21.08.**	**31.08.**	**06.09.**	**12.09.**
A	42.4 a	41.4 b	30.1	17.5	10.3	7.0	6.0	6.4 c
B	42.4 a	40.4 b	30 1	17.6	11.0	7.4	6.9	7.2 ab
C	41.9 a	41.2 b	32.6	18.6	10.5	7.6	6.6	7.6 a
D	40.8 ab	41.7 b	33.4	17.9	10.4	7.4	6.7	7.4 a
E	39.9 b	43.3 a	33.3	17.9	9.9	7.2	6.6	6.7 bc
F-value	3.62*	5.95**	2.69 n.s.	0.26 n.s.	2.24 n.s.	0.63 n.s.	4.59 n.s.	12.85**

Dorigoni et al. (1991) also noted low acid values with a cover crop in the extremely dry year 1988, but there were no differences in other years.

Furthermore in our investigations a numerically slight increase of must weight was observed with the variant with continuous cover crop. Moreover the contents of yeast- available nitrogen in the musts were generally high, with values between 262 and 334 mg N/l at harvest time. Comparing the soil treatment variants concerning the yeast-available nitrogen of musts, it was noted, that on all sampling dates throughout the year musts from untreated variants showed numerically lower values of yeast-available nitrogen (167 to 283 mg N/l) than musts from other variants (193 to 334 mg N/l) (Table 6).

Table 6: Yeast utilizable nitrogen in must (mg/l) during the year

Variant	Date				
	11.08.	**22.08.**	**31.08.**	**07.09.**	**12.09.**
A	167	283	n.a.	249	262
B	193	286	260	275	308
C	266	334	274	293	334
D	257	304	272	275	289
E	272	287	300	286	308

n.a. = not analyzed

Maigre et al. (1995) observed similar results. They found lower contents of compounds containing nitrogen in musts from trial lots, in which the vines were stressed by lack of nitrogen caused by fertilization or cover crop. The results of measurements by Schwab and Peternel (1997), Fox (1999), Maigre and Aerny (2000) and Wagenitz (2000) also showed these differences concerning nitrogen supply. Furthermore Maigre et al. (1995) noted increases of phosphor and calcium contents and a decrease of the malic acid content in must from stressed vines.

In our case berry-weight (g) and yield (kg/ha) (Table 7) also showed a numerical decrease in the variant without treatment of the intermediate zone.

Table 7: Yield depending on soil treatment

Variant	kg/vine	kg/ha
A	2.56	8800
B	3.21	11100
C	3.21	11100
D	3.80	13050
E	3.53	12150
F-value	1.85 n.s.	1.85 n.s.

Calculated yield/ha was 8800 kg in the variant with an undisturbed cover crop, while it was between 11100 kg and 13050 kg in the other soil treatment variants. Competition of cover crop and a possibly negative influence of the kind of cover crop on yield were also described by Dorigoni et al. (1991), Corino et al. (1996), Steinberg (2000) and Delabays et al. (2000). Fox (1999) also noted a decrease in yield with a continuous cover crop and Schwab and Peternel (1997) found a significantly lower yield with long-term continuous cover crops.

Concerning the fermentation of the musts no differences with regard to soil treatment could be found in our investigations in contrast to Heigel (1995), Maigre et al. (1995) and Wagenitz (2000). With wine from the untreated variant, wine analysis showed a slightly higher ash content, compared to wines from the other four soil treatment variants. There was a numerically higher potassium value in wine and in the dry substance of the leaves in the untreated variant. The extract values in this one-year trial were on a steady level with all wines, while Heigel (1995), Hinkel (1992) and Fox (1999) found a decrease of extract values with long-term continuous cover crop. Spring et al. (1996) described a possible impairment of wine quality with the variety `Chasselas' by the water and nitrogen competition from a grass cover crop. Tasting results showed significant statistical differences. However, there was no significant influence of the kind of soil treatment. In contrast Heigel (1995), Hinkel (1992) and Maigre et al. (1995) observed – with one exception – a negative evaluation of wines from soil treatment variants with a continuous cover crop, compared to wines from treated variants. Fox (1999) found that wines from variants with a long-term continuous cover crop were sensorically lower rated, in spite of lower yields. Wolfrath (1996) thinks that an untypical ageing flavor in wines from vineyards with a continuous cover crop depends on the weather during the year. Apparently there is no untypical ageing flavor after sufficient precipitation in spring and optimal temperatures. Schwab and Peternel (1997) made similar statements.

4 CONCLUSION

With a continuous cover crop there is no sufficient supply with nitrogen during the two periods of maximum demand of the vines, namely during two weeks after flowering and during two weeks after the start of ripening. It is possible to influence nitrogen mineralization by respective timing of soil treatments. The soil treatments have to be carried out in a way to enable a mineralization according to the demand of the vines. The best results of mineral nitrogen content in soil are after subsoil cultivation at the end of April in connection with breaking up the cover crop in the middle of May. Vines with a continuous cover crop show shorter shoots than those in the loosened up or plowed variants and leaf area of these vines is significantly smaller. The same is true for the leaf/fruit ratio. Furthermore there are tendencies for lower total acid values in must, for lower berry-weight and yield and for a decrease of yeast assimilable nitrogen in must. Therefore under pannonic climate conditions, which are characterized by low precipitation with an average of less than 600 mm per year, a continuous cover crop without loosening up or breaking up the cover crop is not productive for the nutrient supply of the vines.

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