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Untypical ageing off-flavour and masking effects due to long-term nitrogen fertilization

A. Linsenmeier[1)], D. Rauhut[2)], H. Kürbel[2)], O. Löhnertz[1)] and S. Schubert[3)]

[1)] Forschungsanstalt Geisenheim, Fachgebiet Bodenkunde und Pflanzenernährung, Geisenheim, Deutschland
[2)] Forschungsanstalt Geisenheim, Fachgebiet Mikrobiologie und Biochemie, Geisenheim, Deutschland
[3)] Justus-Liebig-Universität Gießen, Institut für Pflanzenernährung, Gießen, Deutschland

Summary

The off-flavour UTA (untypical ageing) of wines produced from the vintages 1996-1999 within the scope of a long-term N fertilization experiment was compared to the o-aminoacetophenone (AAP) concentrations found in these wines. The wines were made of plants treated with 0, 60 and 150 kg N ha^{-1}·N fertilization led to higher UTA intensities and AAP concentrations in aged wines; due to stronger fruity aromas with increasing N fertilization, young wines were able to mask AAP. Controls had a stronger masking effect in older wines, caused by antioxidants (phenols) and possibly higher alcohols. Moreover, at the same AAP level, wines from the vintages 1996 and 1998 exhibited lower UTA intensity than wines from 1997 and 1999. This is influenced by N supply, yield and time of harvest which can not be separated from each other.

K e y w o r d s : N-Fertilization, untypical ageing, o-aminoacetophenone, antioxidative capacity, masking effect.

A b b r e v i a t i o n s : untypical ageing (UTA), o-aminoacetophenone (AAP), indole-3-acetic-acid (IAA).

Introduction

According to empirical results, untypical ageing (UTA) is caused by various stress conditions of the grapevine (Jakob 1993, Löhnertz 1996). 2-aminoacetophenone (AAP) as the causal agent of UTA was identified by Rapp *et al.* (1993). In the first studies about UTA, drought, high yield and reduced fertilization were assumed to be triggers (Pohl 1992, Jakob 1993). In wines made from treatments with permanent green cover UTA occurs more often (Wohlfahrt 1995, Schwab *et al*. 1996, Schwab 1998, Seiter 2000, Löhnertz *et al*. 2002). Dry weather has a negative influence (Schwab *et al*. 1996, Sponholz *et al*. 1997), but water deficiency leads to nutrient deficiency, because there is no medium of transport. Moreover, nitrogen deficiency has been considered as a factor causing UTA, as shown by negative correlations between N in must and UTA in wine (Gessner *et al*. 1995). So far, only very few and contradictory studies have been carried out on the effect of N fertilization. Schwab *et al*. (1996) found a slightly reduced occurrence of UTA with increasing N fertilization. In a 15 years experiment, Müller (1999) did not detect any effect of N fertilization on the occurrence of UTA in wines. Seiter (2000), however, observed that N supply consistently affected the formation of UTA. This investigation was the only one in wich some AAP concentrations were measured. The exact odour threshold of AAP in wine is difficult to define (approximately 0.5-1.5 µg l^{-1}), since the threshold values can be affected by other compounds masking AAP. To our knowledge, viticultural impacts on these masking effects have not been examined yet. This investigation requires concurrent sensory and analytical determinations of AAP which have not been carried out so far in large scale. This present study evaluates the impact of N fertilization on UTA intensity in wine. The corresponding AAP values will be used to identify masking effects.

Material and Methods

F i e l d e x p e r i m e n t : The experiment was conducted in the Rheingau, Germany (50 °N, 8 °E) in a vineyard planted with Riesling vines on 5 C rootstock in 1977. Vines were cultivated in loamy sand, originating from tertiary sea sand containing 1.4 % humus, pH value was of approximately 7.6, available field capacity was of 28 % (v/v). The vines were spaced 1.3 m (within rows) by 1.9 m (between rows), and were pruned to 5 buds m^2. There was permanent green cover in every second row; soil management consisted of 4-5 times mulching resp. 5 times cultivation in the other row. Since 1986 the vineyard has been fertilized with different quantities of N (0, 30, 60, 90, 150 kg N ha^{-1} $year^{-1}$). The fertilizer was granular ammonium nitrate (27.5 % N). Vineyard management, especially P, K, Mg fertilization, was conducted according to commercial practice. Each N treatment was repeated 4 times and arranged in a completely randomized design. Each replicate contained 48 vines arranged in 4 rows of which the 2 middle rows were used for the experiment. Each replication was used for micro-vinification: Grapes were destemmed and crushed. The crushed grapes were pressed into must and allowed to settle for 24 h. After clarification musts were racked and inoculated with *Saccharomyces cerevisae* strain "Champagner Epernay Geisenheim". Fermentation took place in 10 l glass flasks. At the end of alcoholic fermentation, wines were racked, sulphurated (to 50 mg free SO_2 l^{-1}), filtrated and bottled. Must and wine samples were stored at -20 °C. Bottled wines were stored at 14 °C. In

Correspondence to: A. Linsenmeier, Forschungsanstalt Geisenheim, Fachgebiet Bodenkunde und Pflanzenernährung, Rüdesheimer Straße 18-20, 65366 Geisenheim, Germany. E-mail: linsenmeier@fa-gm.de

1999 at veraison a thinning was carried out. Due to an acetic acid rot a second thinning was necessary which delayed harvest date, so that no yield data are available.

Antioxidative potential: The antioxidative potential of frozen wines from 1998 and 1999 was determined in 2004 by means of a Photochem® Analyser (Analytik Jena). In the sample, superoxide radicals are produced, which react with the antioxidants. Free radicals react with a chemoluminescent substance; by means of the luminescence created, antioxidants are quantified as sum parameters. Water soluble antioxidative capacity (ACW) was determined as ascorbic acid equivalent. Lipid soluble antioxidative capacity (ACL) was determined as trolox equivalent.

Determination of o-aminoacetophenone: The aged, bottled wines were analysed in the Institute of Microbiology and Biochemistry of the State Research Institute Geisenheim. Extraction was carried out with pentane:dichlormethan (2:1). After concentrating extracts with a vigreux column, AAP was analysed by GC-MS using a Siemens Sichromat 2 with a DB-wax column (RAUHUT and KÜRBEL unpubl.). Vintages 1994-1998 were analysed in autumn-winter 2001/2002, the vintage 1999 was analysed in winter 2002/2003.

Sensory evaluation: UTA intensity of the wines was evaluated two times by quantitative descriptiv sensoric. UTA values were rated on a scale from 0 to 10. Reference standards were given to each estimation. In the first tasting replicates of the N fertilization trial (0, 60, 150 kg N ha^{-1}) were combined. Vintage 1996 was three years old, 1997 was two years old. The vintages 1998 and 1999 were first tasted 9 month or 1 year, respectively, after bottling. A second sensory evaluation was carried out in 2003 with wines from all replicates of the treatments 0, 60 and 150 kg N ha^{-1}.

Statistical analysis: To calculate the significance of means an ANOVA was carried out using Fischer´s test at a significance level of 5 %. Significant differences between means are indicated by different letters. The regressions were linear and significant at the 5 % level.

Results

Antioxidants: In the vintages 1998 and 1999, water soluble and lipid soluble antioxidants decreased with increasing N fertilization (Tab. 1). In 1998, values of the water soluble portions differed only slightly. On average, the zero treatment exhibited a consistently higher antioxidative potential in 1999. The values of antioxidants were lowered by 30 %.

Sensory evaluation: At the first sensory evaluation, the 1996 wines had considerably lower UTA values than those from 1997 tested simultaneously (Fig. 1). After a one-year-storage, the 1998 wines were considered to exhibit nearly no UTA, whereas the 1999 wines reached an average UTA value of 2.0 after the same storage time. Among the 1997 wines, at 150 N ha^{-1} the UTA value was twice as high as that of the two other treatments. In 1996, UTA intensity increased in tendency with N fertilization. In 1999, however, wines from the zero N treatment exhibited significantly the highest UTA intensity.

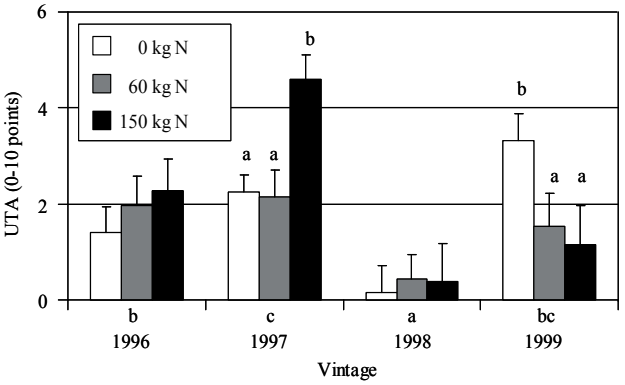

Fig. 1: First sensorical evaluation of UTA-intensity (0-10 points) of the vintages 1996-1999. Field replicates of the treatment 0, 30 and 150 kg N ha^{-1} were combined to one sample. Bars indicate standard error between the tasters. Significant differences between treatments (α = 5 %) are indicated by different letters above columns, significant differences between years are indicated at the x-axis.

A second sensory evaluation took place two years later in order to assure a natural UTA formation without artificial ageing. In general, UTA intensity was difficult to determine since it often coincided with reduced sulphur aroma and other off-flavours, especially in 1999, when UTA intensity was highest. In all years, wines produced from the zero N treatment had the lowest UTA values (Fig. 5). Whereas from 1996 to 1998, wines from the 150 kg N ha^{-1} treatment exhibited, on average, the highest UTA intensities, this was

Table 1

Water soluble antioxidative capacity (ACW, mmol l^{-1} ascorbic acid equivalent) and lipid soluble antioxidative capacity (ACL, mmol l^{-1} trolox equivalent) in wine as related to long-term nitrogen fertilization with 0, 30, 60, 90 and 150 kg N ha^{-1} in 1998 and 1999. For details see Tab. 2

N, kg ha^{-1}	ACW		ACL	
	1998	1999	1998	1999
0	0.61 ± 0.06	0.56 ± 0.12	0.79 ± 0.03 b	0.79 ± 0.05 b
30	0.64 ± 0.06	0.35 ± 0.09	0.80 ± 0.02 b	0.51 ± 0.11 a
60	0.63 ± 0.03	0.45 ± 0.06	0.78 ± 0.02 b	0.63 ± 0.05 a
90	0.59 ± 0.02	0.33 ± 0.01	0.75 ± 0.01 b	0.64 ± 0.04 ab
150	0.54 ± 0.11	0.35 ± 0.05	0.59 ± 0.08 a	0.63 ± 0.03 ab

true for the 60 kg N ha^{-1} treatment in 1999. In spite of significant effects of the year and of fertilization accounting for approximately 20 % each, a high residual variance accounting for more than 50 % of the total variance of UTA in wine could not be explained. This portion did not refer to the variance between judges, but to the variance between the field replicates of equally treated wines.

Regression AAP-UTA: With increasing AAP concentration, the UTA intensity of the wines increased (Fig. 2). This relationship was highly significant, but it only accounted for 30 % of the sensorical UTA intensity. In 1996, no correlation between AAP and UTA was found, however, the highest AAP concentration was only of 0.73 µg l^{-1}, all other values were below 0.6 µg l^{-1}. Thus, in many wines, the AAP concentration obviously did not reach the odour threshold. In 1998 and 1999, AAP concentrations of more than one µg l^{-1} were found; accordingly, UTA intensity was consistently higher, too. In these two years, the correlation between AAP and UTA was highest; R^2 was 0.22 and 0.30, respectively. The regression curves of 1996 and 1998 are below the 1997 curve and especially below the 1999 curve. At the same AAP concentrations, wines from 1996 and 1998 were considered to exhibit lower UTA intensity. At AAP values above the odour threshold (>0.6 µg l^{-1}), wines made from the zero treatment had UTA values which were one resp. two points lower than those of the 60 resp. 150 kg N ha^{-1} treatment exhibiting the same AAP concentrations. This fertilization effect was also found regarding individual vintages: the 1997 and 1998 wines were judged as UTA-free at 0.6 µg AAP l^{-1}; the highly fertilized treatments yielded wines exhibiting strong UTA intensity at the same AAP concentration. The 1999 wine showed the same effect at higher AAP values. UTA values below 2.5 correspond to an unconspicuous wine. Accordingly, 16 wines exhibiting UTA values below the odour threshold of 0.7 µg l^{-1} were considered as tainted with UTA (UTA value >2.5). Seven of these wines had been produced from each fertilized treatment, but only two had been made of the zero treatment. These two wines were produced from the vintages 1997 and 1999. On the other hand, the vintages 1996 and 1998 yielded 4 wines containing AAP concentrations of more than 0.7 µg l^{-1} which were not tainted with UTA. Yet,

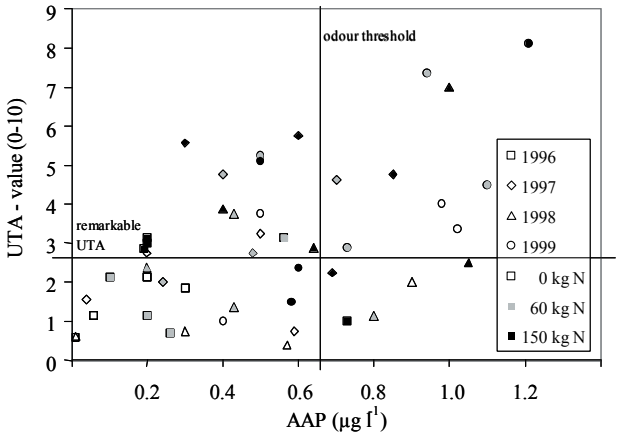

Fig. 2: Relation between AAP concentration in wine and sensorical UTA value as related to N fertilization with 0, 60 and 150 kg N ha^{-1} in the vintages 1996-1999 (n = 48).

an enormous variance even within the same treatment in the same year must be noted: In 1998, one wine produced from the 150 kg N ha^{-1} treatment had an UTA value of 7 at 1 µg AAP l^{-1}, another wine from the same treatment had an UTA value of only 2.5 at 1.05 µg AAP l^{-1}. In 1997, two wines produced from the 150 kg N ha^{-1} treatment at 0.3 µg AAP l^{-1} and 0.6 µg AAP l^{-1} resp. had UTA values of more than 5.5 each, whereas another wine from the same treatment had an UTA value of only 2.25 at 0.69 µg AAP l^{-1}.

Regression antioxidants-UTA: In 1998, a highly negative correlation (R^2 = -0.54) between the ACW value and UTA was found (Fig. 3). Yet, in 1999, R^2 was very low (0.13). With reference to both years, the coefficient of determination was of 0.34. Nearly all treatments of the two years were characterized by a negative correlation. The 60 kg N ha^{-1} treatment of 1999 is the only exception. The correlation between lipid soluble antioxidants (ACL) and UTA in the wine was slightly closer, (R^2 = 0.67 (1998) resp. 0.14 (1999)).

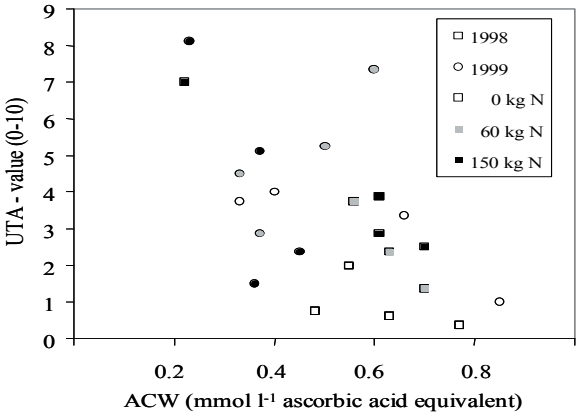

Fig. 3: Relation between water soluble antioxidative capacity (ACW) in wine and sensorical UTA value as related to N fertilization with 0, 60 and 150 kg N ha^{-1} in the vintages 1998-1999 (n = 22).

Regression yield-UTA: Fig. 4 also illustrates that yield increased with N fertilization, especially in 1997 and 1998, and that the yield in 1997 considerably exceeded those of 1996 and 1998. Grape yield was positively correlated with UTA and significantly accounted for 10 % of the variance. The UTA intensity of the 1996 wines was not affected at all by yield. In 1997, the impact of yield was slightly stronger. In 1998, however, a consistent correlation could be found (R^2 = 0.34). The differences in yield could not explain the high variance of UTA between the fertilization treatments of one year.

Discussion

Increasing N fertilization increased the likeliness of wines to exhibit UTA (Figs 1, 5). We have shown that, on average, AAP concentrations obviously increased with N-fertilization, too (Linsenmeier *et al*. 2007). These findings are contradictory to theories on UTA formation as well as to former results. Schwab *et al*. (1996) found higher UTA intensity in Müller-Thurgau wines at 50 kg N ha^{-1} fertiliza-

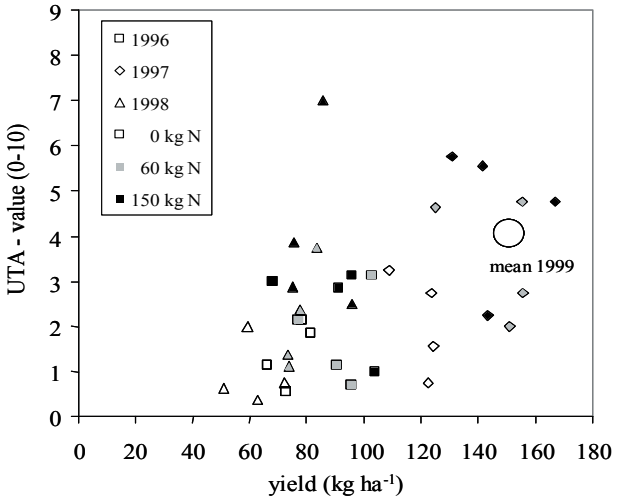

Fig. 4: Relation between yield and sensorical UTA value as related to N fertilization with 0, 60 and 150 kg N ha^{-1} in the vintages 1996-1998 (n = 36).

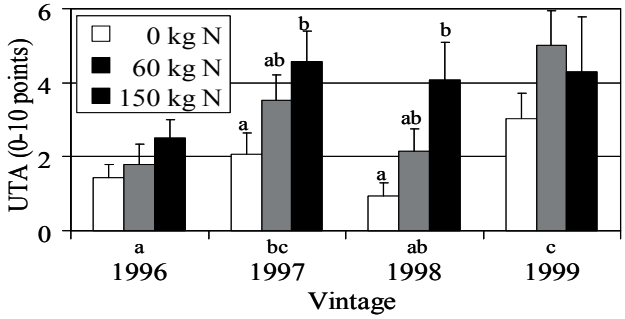

Fig. 5: Second sensorical evaluation of UTA-intensity (0-10 points) of the vintages 1996-1999. Field replicates of the treatments 0, 30 and 150 kg N ha^{-1} were evaluated individually (n = 4). Bars indicate standrd error between the replicaes. For detais see Fig. 1.

tion compared to the unfertilized treatment. On average, UTA values were slightly lower at 100 kg N ha^{-1} than in the zero treatment in their experiment. In Silvaner and Müller-Thurgau wines produced from various vineyards with permanent green cover Seiter (2000) found lower UTA intensity when fertilization was increased. If soil was cultivated once a year, no fertilization effect was found. Both studies were carried out without replicates, but these results were found in several years.

In the first sensory evaluation, the one-year-old 1998 wines were not tainted with UTA, whereas UTA intensity of the 1999 wines decreased with increasing fertilization. The AAP concentration of the 1998 wines, however, increased with fertilization, whereas in 1999, similar AAP concentrations were measured in all wines (Linsenmeier *et al*., in prep.). This discrepancy can be attributed to the masking effect of fruity aromas which are reduced in the older wines. Higher N supply led to an increase of sensory fruitiness as well as of the analytically measured fruity aromas (Linsenmeier *et al*. 2006). The impact of the year on amino acid storage in must considerably exceeded the highly significant impact of fertilization (Linsenmeier *et al*. 2004). Higher N supply explains the lower UTA intensity of the fertilized 1999 treatments. Higher N supply due to the effect of the year (Tab. 2) explains the fact that the UTA values in 1998 were lower than those in 1999. Yet, it has to be noted that the AAP analysis of the 1999 wines was carried out two years after the first sensory evaluation. At the time of this evaluation, the AAP concentrations of the zero treatment might in fact have exceeded those of the fertilized treatments as is suggested by the sensory results. This would require a faster AAP accumulation in wines produced from the zero treatment. Such dynamic effects in the course of AAP formation have not been examined yet.

The tasting of single field replicates indicated extreme differences in the UTA formation of the 4 wines produced from one fertilization treatment. This is confirmed by the corresponding results of AAP analyses (Linsenmeier *et al*., in prep.). Whereas fertilization is the primary cause of the differences between the treatments, all other factors are only "oberserved" as defined by statistics. The results of observed "independent" parameters and actively modified independent parameters can not always be compared. As expected, the correlation between AAP in the wine and sensory UTA intensity is highly significant. The residual variance of the regression between AAP and UTA allowed to deduce two masking effects: the effect of the year and the effect of fertilization. In spite of exhibiting the same AAP concentrations, the vintages 1996 and 1998 were less tainted with UTA than the vintages 1997 and 1999. Several effects my be responsible of which yield obviously is important. In 1996 to 1998, the impact of yield on UTA was 10 % (Fig. 4), whereas in these three years the AAP concentration was affected to 1 % by yield (Linsenmeier *et al*., in prep.). Thus, the higher yield of 1997 led to higher UTA intensity without affecting AAP concentrations. Moreover, in the must of 1996 and 1998, higher amino acid concentrations were found (Tab. 2), which results in higher amounts of fruity ester (Linsenmeier *et al*. 2006). The fruity aromas disappear in all wines, but the wines from the vintages with better N supply developed more positive aromas.

In general, early harvest is considered to cause UTA (Köhler *et al*. 1995, Wohlfahrt 1995, Gessner *et al*. 1998). In fact, the 1999 vintage, which was strongly tainted with UTA, was harvested two weeks earlier than the vintages 1996 and 1998 and, correspondingly, exhibited low values for total soluble solids (TSS), amino acids and minerals in must. Yet, the 1997 vintage was harvested only 4 d before the 1998 vintage and contained the same amounts of TSS in must (Tab. 2). In this experiment, no water deficiency occured (Linsenmeier *et al*. 2007). At equal AAP concentrations, fertilization caused higher UTA intensity, but in 1997 to 1999, the sensory effect masking AAP was weaker in the fertilized treatments. In spite of the high variance of yield within the fertilization treatments, yield can not explain the differences between AAP concentration and sensory UTA intensity. TSS did not have an impact on UTA, either (not shown). Which substances in wine cause these masking effects? Partly, the high amounts of residual sugar of the unfertilized treatments due to sluggish fermentation could have an impact, but this can not explain the differences in 1998, when all treatments were fully fermented. The antioxidative potential (Tab. 1, Fig. 3) correlated more consistently with UTA in wine than with AAP concentration (Linsenmeier *et al*. in prep.). Obviously, the antioxi-

Table 2

Mean temperature and sum of precipitation per year (data from the German Meteorological Service, Geisenheim), date of harvest, total soluble solids (TSS) and arginine content (Arg) in must in the years 1996-1999. Significant differences between years are indicated by different letters (α = 5 %)

	1996	1997	1998	1999
Mean temperature (°C)	9.2	10.5	10.6	11.1
Sum of precipitation (mm·year^{-1})	473	438	587	559
Date of harvest	31.10.	22.10.	26.10.	11.10.
TSS (Oe°)	87 ± 0.6 b	87 ± 1.0 bc	88 ± 0.7 c	82 ± 0.7 a
Arg (mg N l^{-1})	229 ± 10.0 c	38 ± 6.6 a	110 ± 7.8 b	28 ± 5.8 a

dants detected were exerting a masking effect on UTA intensity. This might be the case for phenols.

In this study, the masking effect of antioxidants seems to be more important than the scavenger effect of phenols. Since the antioxidative potential was only determined in 1998 and 1999, this theory requires further examination. Hoenicke *et al*. (2002) also found negative correlations between antioxidative capacity and UTA (R^2 = -0.36). Yet, in that study, the antioxidative capacity of superoxide scavengers was determined using an enzymatic method, whereas the corresponding values found by means of the PCL method in the present study yielded weaker correlations with UTA. Since no AAP was measured by Hoenicke *et al*. (2002) it is impossible to deduce to what extent the negative correlation was caused by reduced AAP accumulation or by a masking effect on UTA intensity.

The amount of higher alcohols decreased with fertilization (Linsenmeier *et al*. 2006). They contribute to the 'body of the wine' and might have reduced the sensory effect of AAP at low fertilization levels. The rest extract is often linked with the 'body of the wine'. Generally, unfertilized vines are considered to produce lower extract, but this would result in a better masking effect of UTA in the fertilized treatments, thus contradicting our results. In 1994, extract values increased with fertilization; in 1995, no impact was found (Prior 1997, Bleser 1999). The concentrations of minerals, correlating with extract according to Würdig and Woller (1989), did not indicate a negative fertilization effect: in the zero treatment, the concentrations of P and Mg were higher, but those of K were lower.

Various sulphur containing off-flavours were determined (e.g. methional, methionol, benzothiazol, ethyl-3-thiomethylpropionate). None of these aroma compounds correlated with UTA (not shown). Low UTA intensity at relatively high AAP values can be attributed to the masking effect of desirable aromas. On the other hand, in some cases, UTA intensity was high with AAP concentrations being below the odour threshold (Fig. 2). Moreover, AAP yields an aroma of acacia blossom, whereas the naphtaline note equally contributing to UTA might be caused by another substance (Fischer and Sponholz 2000, Seiter 2000). In this study, the high age of the wines might have caused some tasters to evaluate the normal ageing of the wine as UTA taint.

Without doubt, AAP is the aroma compound mainly responsible for the UTA off-flavour. Yet, for the reasons mentioned above, further UTA off-flavours were postulated, although no relationship could be found. Christoph *et al*. (1995) excluded TDN, vitispirane, anthranilic acid ethylester, anthranilic acid methylester and indole, because the corresponding amounts found in wines tainted with UTA were far below the odour threshold. e.g., the odour threshold of the latter compounds is at 100 µg l^{-1}, while only 5 µg l^{-1} anthranilic acid ethylester und 15 µg l^{-1} indole (Christoph *et al*. 1995) were measured. Gessner *et al*. (1999) did not find a typical UTA odour when scatol, indole, guajacol and anthranilic acid ethylester were added to white wines. According to our experiments, the odour threshold of scatol in 10 % EtOH is 0.1 µg l^{-1}. From one µg l^{-1} on, the aroma impression could be described by the tasters (moth balls, stuffy, naphtaline note). In wine, the addition of only one µg l^{-1} was significantly recognized in the triangle test, although, on average, this concentration does not have a negative effect yet. Only at >3 µg scatol l^{-1}, the wine was clearly tainted. Thus, scatol concentrations up to 100 ng l^{-1} (Hühn *et al*. 2002) can hardly cause UTA. The importance of aroma active substances similar to AAP found by Cilofi *et al*. (1995) has not been examined in any other study. Thus, it remains unclear if other off-flavours except AAP are responsible for UTA.

Table 3

Determination coefficient R^2 and regression coefficients m (slope) and b (intercept) according to the linear regression with the data of all years (1996-1999, n = 48), only the single fertilization treatments (0, 60, 150 kg N ha^{-1}, n = 16 each) and only the single years (n = 12 each). AAP (µg l^{-1}) as independent parameter and sensorical UTA-value (0-10 points) as dependent parameter. (Significant at α: + = 10 %, * = 5 %, ** = 1 %, *** = 0.1 %)

	1996-1999	0 kg N ha^{-1}	60 kg N ha^{-1}	150 kg N ha^{-1}	1996	1997	1998	1999
R^2	0.30***	0.29*	0.31*	0.13	<0.01	0.13	0.22^{+}	0.30*
m	3.37***	1.95*	2.32*	2.32	0.33	2.77	2.92^{+}	3.77*
b	1.19***	1.07*	1.73*	2.45*	1.65^{+}	2.01*	0.82**	1.03**

Conclusion

Complex matrix effects are responsible for the sensory intensity of UTA. In order to unterstand the impact of fertilization on UTA, the effect of N supply on the aroma compound AAP as well as on other negative (e.g. sulphur components) and positive compounds (e.g. fruity aromas, minerals) have to be observed separately. On average, wines from the stress years 1997 and 1999 exhibited higher UTA intensity. Yet, the fertilization effect was of similar importance, yielding higher UTA evaluation in wines produced from fertilized treatments. In 1997 and 1999, higher UTA intensity could partly be attributed to higher AAP concentrations. On the other hand, the vintages 1996 and 1998 had a stronger capacity to mask high AAP concentrations, due to a combination of low yield, higher N supply and later harvest. In contrast to former findings, the unfertilized - stressed - treatments yielded less UTA. This was mainly due to the higher AAP formation in the fertilized treatments. Yet, the unfertilized treatments had a higher masking capacity, too. Young wines profitted from N fertilization by accumulating fruity aromas. In older wines, though, N fertilization reduced the masking capacity of UTA, due to phenols and higher alcohols formed under stress conditions in the zero treatments. This might explain the contradiction between our findings and former descriptions of positive effects of N fertilization for the prevention of UTA. How to avoid UTA? According to the present results, a moderate N fertilization of 60 kg N ha^{-1} should be recommended. Although the renouncement of N fertilization resulted in lower AAP and UTA values, it can not be recommended due to other problems like sluggish fermentation. Late harvest is important for the prevention of UTA, provided weather conditions and grape health are no problem. Our experiments showed that, in a "UTA year" like 1999, UTA could not be safely avoided, although all recommended measures, e.g. soil cultivation in every second row, reduced yield, harvest as late as possible, were taken. Also in the stress year 1997 as well as in 1998, when N supply was sufficient, yield was low and harvest was late, wines clearly tainted with UTA were found within the fertilization treatments. Thus, it will still be necessary to search for a suitable viticultural management to prevent UTA.

References

Bleser, M.; 1999: Einfluss von N-Düngung und Begrünung auf die Gesamt-N-, Aminosäure-N- und Polyamin-N-Gehalte in Beeren, Mosten und Weinen von *Vitis vinifera* L. (cv. Riesling) im Verlauf zweier Vegetatonsperioden. Diss. Justus-Liebig-Univ. Gießen, Geisenheimer Berichte 42.

Christoph, N.; Bauer-Christoph, C.; Gessner, M.; Köhler, H. J.; 1995: Die „Untypische Alterungsnote im Wein", Teil I: Untersuchungen zum Auftreten und zur sensorischen Charakterisierung der „Untypischen Alterungsnote". Rebe Wein **48**, 350-356.

Ciolfi, G.; Garofolo, A.; Di Stefano, R.; 1995: Identification of some o-aminoacetophenones as secondary metabolites of *Saccharomyces cerevisiae*. Vitis **34**, 195-196.

Fischer, U.; Sponholz, R.; 2000: Die sensorische Beschreibung der Untypischen Alterungsnote. Der Deutsche Weinbau **3**, 16-21.

Gessner, M.; Köhler, H. J.; Christoph, N.; Bauer-Christoph, C.; Miltenberger, R.; Schmitt, A.; 1995: Die „Untypische Alterungsnote" im Wein, Teil II: Beschreibende Verkostung von UTA-Weinen; Beziehungen zwischen Sensorik und chemisch-physikalischen Analysenwerten. Rebe Wein **48**, 388-394.

Gessner, M.; Köhler, H. J.; Christoph, N.; 1998: UTA im Wein. Möglichkeiten zur Vermeidung der untypischen Alterungsnote. Der Deutsche Weinbau **18**, 18-20.

Gessner, M.; Köhler, H. J.; Christoph, N.; 1999: Die „Untypische Alterungsnote" im Wein, Teil VIII: Auswirkung von Inhaltsstoffen und Antioxidantien auf die Bildung von o-Aminoacetophenon. Rebe Wein **52**, 264-267.

Hoenicke, K.; Simat, T. J.; Steinhart, H.; Christoph, N.; Gessner, M.; Köhler, H. J.; 2002: „Untypical aging off-flavor" in wine: formation of 2-aminoacetophenone and evaluation of its influencing factors. Analyt. Chim. Acta **458,** 29-37.

Hühn, T.; Cuperus, S.; Pfliehinger, M.; Sponholz, W. R.; Bernath, K.; Platzwahl, W.; Grossmann, M.; Amadò, R.; Galli, J.; Friedmann, A.; 2002: Einfluß von Umwelt- und Substrateffekten auf die Bildung von wertgebenden Weininhaltsstoffen, 313-328. Int. Oenol. Symp. Int. Vereinigung Oenol., Betriebsführung und Weinmarketing e.V. Montpellier/Frankreich, 10.-12. Juni 2002.

Jakob, K.; 1993: Naphtalinton - läßt er sich vermeiden? Der Deutsche Weinbau **13**, 23.

Köhler, H. J.; Christoph, N.; Gessner, M.; Bauer-Christoph, C.; 1995: Die „Untypische Alterungsnote" im Wein, Teil III: Zusammenhänge zwischen dem Auftreten der „Untypischen Alterungsnote" und dem Reifestadium der Trauben (Lesetermin). Rebe Wein **48**, 424-430.

Linsenmeier, A.; Löhnertz, O.; Schubert, S.; 2004: Effect of different N fertilization of vine on the tryptophan, free and total indole-3-acetic acid concentrations. Vitis **43**, 157-162.

Linsenmeier, A.; Rauhut, D.; Diehl, H.; Schubert, S.; Löhnertz, O.; 2006: Einfluss unterschiedlicher Stickstoffversorgung auf Aromastoffgehalte und Aromaqualität von Weinen der Sorte 'Riesling'. Mitt. Klosterneuburg **56**, 84-93.

Linsenmeier, A.; Rauhut, O.; Kürbel, H.; Schubert, S.; Löhnertz, O.; 2007: Ambivalence of the influence of nitrogen supply on o-aminoacetophenone in Riesling wine. Vitis (in print).

Löhnertz, O.; Schultz, H. R.; Hünnecke, B.; Linsenmeier, A.; 2002: Weinbauliche Maßnahmen zur Vermeidung von UTA, 215-228. Int. Oenol. Symp. Int. Vereinigung Oenol., Betriebsführung Weinmarketing e.V. Montpellier/Frankreich 2002.

Löhnertz, O.; 1996: UTA und Rebenernährung. Streß macht alt. Das Deutsche Weinmagazin **18**, 18-23.

Müller, E.; 1999: 15 Jahre Stickstoffdüngungsversuche: Erfahrungen und Konsequenzen. Das Deutsche Weinmagazin **19**, 27-31, **20**, 29-32.

Pohl, H.; 1992: Probleme mit einem Fehlton. Der Badische Winzer **8**, 395-396.

Prior, B.; 1997: Einfluss der Stickstoffversorgung auf die löslichen Aminosäuren in den Organen von *Vitis vinifera* L. (cv. Riesling) und auf die Qualität des Mostes und des Weines. Diss. Justus-Liebig-Univ. Gießen, Geisenheimer Berichte **32**.

Rapp, H.; Versini, G.; Ullemeyer, H.; 1993: 2-Aminoacetophenon: Verursachende Komponente der „untypischen Alterungsnote" („Naphtalinton", „Hybridton") bei Wein. Vitis **32**, 61-62.

Schwab, A.; 1998: Extensivierung von Bodenpflege und Düngung und deren Auswirkung auf die Most- und Weinqualität. Deutsches Weinbaujahrbuch **49**, 93-101.

Schwab, A.; Peternel, M.; Köhler, H. J.; Heigel, K. P.; 1996: Die „Untypische Alterungsnote" im Wein, Teil IV: Beeinflussung durch weinbauliche Maßnahmen. Rebe Wein **49**, 181-187.

Seiter, P.; 2000: Der Einfluß von Stickstoffdüngung und Bodenpflege auf die Stickstoffversorgung der Rebe und die Weinqualität. Eine Studie zum Problem des „Untypischen Alterungstons". Diss. Albert-Ludwig-Universität Freiburg.

Sponholz, W. R.; Hühn, T.; Engelmann, A.; Sieben, A.; 1997: Mögliche Einflüsse weinbaulicher Parameter auf die Ausbildung des „Untypischen Alterungstons" bei Rieslingweinen. Vitic. Enol. Sci. **52**, 41-50.

Wohlfahrt, P.; 1995: Untypische Alterungsnote: Erfahrungen aus den vergangenen drei Jahren. Der Badische Winzer **8**, 383-388.

Würdig, G.; Woller, R.; 1989: Chemie des Weines. E. Ulmer Verlag,