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VITICULTURAL EXPERIMENTS

BIOSOL

1988 - 1994

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BIOSOL - Experiments *R* 1988 - 1994

Experiences and results from the Rhineland vine-growing region

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CONTENTS

1. INTRODUCTION

The wide field of application of *BIOSOL* includes viticulture. Its successful use in viticulture is the result of many years of experience gleaned from experiments and practice. The first experiments with viticulture were performed in Austria in 1984. This report describes the results of experiments performed in the vine-growing region on the right and left banks of the Rhine between Basle and Mainz (the *R* series of experiments). The *R* series of experiments started in 1988. The following describes the results obtained during the first 7 years. It is presented according to criteria which characterise *BIOSOL's* main mode of action.

2. THE *R* SERIES OF VITICULTURAL EXPERIMENTS

2.1 EXPERIMENTS AND SYSTEMS

The investigations were centred on 14 experimental sites which were established in a total of 9 vineyards. Six of these experiments (*R1 - R6*) are being continued as long-term experiments and 8 experiments (*R20 - 27*) were concluded. These experiments are or were designed as comparative experiments in which the results for each *BIOSOL* plot were measured against the results for a corresponding control plot. The control plots were treated in accordance with the usual practice for the area.

The most common method of fertilization used in the area is conventional mineral fertilization. The mineral fertilization was not applied consistently - the vineyards were constantly adapting the amounts after exchanging experiences. In addition, the mineral fertilization would be suspended or supplemented for several years with the mineral fertilizer being replaced or supplemented by sheep's dung (*R1*), marc compost (*R2, R3*) and chicken dung (*R4)*.

The vineyards involved in two of the concluded experiments were "organic vineyards". In these the *BIOSOL* plots were tested in relation to plots which only received organic fertilizer. The organic fertilizers used were farmyard manure and coarse meal of castor (*R25*) and bark compost and coarse meal of castor (*R21*). These "organic vineyards" were particularly characterised by the extreme spraying methods (blue vitriol + Allaun + potassium phosphite + sodium silicate), the luxuriant green cover, the absence of weed control and the soil treatment in the existing cultivation.

One special form of control plot is unfertilized and slightly fertilized very lush sites (*R5/SB*, *R6/SB*); some of these very lush sites are natural troughs (*R6*) and some of them are the result of the inhomogeneous construction of vine terraces and are found on valley sides (*R5*).

The standard *BIOSOL* variant is the *BIOSOL* plot with 800 kg of *BIOSOL* per hectare. Experiments with increasing applications tried the 400 kg, 600 kg and 1000 kg variants (*R4*) and the 600 kg, 800 kg and 1000 kg variants (*R2*). In two cases (heavy, biologically inactive soils, see Figure 4), initial doses of 2000 kg per hectare were applied (*R6/5B*, *R6/WB*).

The *BIOSOL* treatment involves a whole package of measures. This includes measures for the supplementation of *BIOSOL* fertilizers consisting of the application of a magnesium additive tailored to the actual needs of the individual sites and of similar trace element leaf fertilizers. Supplements were not always used nor were they used at all sites. The fertilization and cultivation measures were the responsibility of the vine grower.

Improvement and revitalization experiments concerned structurally degraded sites with cold soils with a greatly inhibited vine vitality.The phenomenological appearance of the vines is the extremely short-shooted, calamine-leafed (= compressed, deformed leaf shape) witch's broom stem. These experiments mainly concerned old systems (*R25, R31, R32/GT, R32/R*), but one special case involved stunted new systems on heavy soils (*R6, R33*).

These systems, which at the start were close to death, were monitored frequently for *BIOSOL* revitalization without using control plots - only experiment *R25* used control plots. As a result, the normalization of the system with the revitalization measures was evaluated. In all cases, initial doses of 1000-2000 kg of *BIOSOL* per hectare were used in conjunction with leaf fertilization according to individual requirements.

The presentation also includes some examples of pure *BIOSOL* practice. The inclusion of pure practice cases without control plots is used to round off and extend the empirical base. Partial results from 20 practice cases (*R30/1-3, R31/WB, R32/MTK, R32/SB, R34/WB, R35/SB, R28/RR, R50/SB-R60/SB*) are included in the presentation of the results.

2.2 Types of experiment

The eight most important vine varieties were included in the experiments. White wine varieties were by far the majority. The investigations were performed in productive vineyards. Results from the planting out to the period of production are only available in two cases (*R32/SB, R33/MTh).* The types of experiment and the associated experimental conditions are:

(1)	*Gutedel*	:	Long-term experiments *R1/G, R4/G, R6/G,* concluded experiment *R25/G.* Improvement experiments *R31-R6/G.*
(2)	*Müller-Thurgau*	:	Completed experiments *R20, R22, R23, R26*
(3)	*Nobling*	:	Completed experiments *R5/N, R21/N*
(4)	*Weißburgunder (Pinot blanc)*	:	Long-term experiments *R5/WB, R6/WB,* practice cases *R31/WB, R34/WB, R36/WB*
(5)	*Gewürztraminer*	:	Improvement experiment *R32/GT*
(6)	*Ruländer*	:	Improvement cases *R26/R, R32/R*
(7)	*Rheinriesling*	:	Concluded experiments *R27/RR, R28/RR*
(8)	*Spätburgunder (Pinot noir)*	:	Long-term experiments *R1/SB, R2/SB, R3/SB, R5/SB, R6/SB*, concluded experiments R20/SB, R22/SB, R24/SB and the practice cases *R33/SB, R32/SB, R35/SB, R36/SB.*

2.3 Sites

All site units typical of the upper Rhine vine-growing region between Basle and Mainz were used in the experiments. The units were identified by their surface shape; this surface shape also includes to a large extent the geological substrate and the soil type. The heights above sea level range according to the shape of the surface and the area of the Rhine between 350 m - 100 m, the exposures ranged from E (on the left of the Rhine), through S, to SW and W, the inclinations ranged from 0 ° - 33 °. The 5 most important types of large site are:

(1) Flat interfluvial *loess terraces* at 300-220 m above sea level
This unit is typical of the Baden vine-growing region and covers the majority of the sites involved in the experiment (*R1-25, R20-R21, R23-R25, R30/2-3, R31/G, R32, R34-R36*). The loess is structurally weak and compressed by the extensive levelling systems.

Restricted infiltration and penetration, inadequate aeration and signs of soft rot are characteristic to varying degrees. The levelling work has frequently resulted in the separate sedimentation of the humus and in the liberation of raw loess on the other side. The problems caused by the levelling have a particularly negative effect in areas of filled, usually underground troughs (*R23*) and in locations traversed by springs (*R32/GT, R32/R*). The cultivation in these moist layers reacts particularly sensitively to late frosts and to the sudden retardation of the conversion and release of material caused by cooling in the form of chlorosis and necrosis. In levelled troughs, soft rot is also triggered by the effects of the gases produced by the fermentation of compacted, anaerobically rotting organic material.

These loess sites usually require the standard amount of *BIOSOL* (800 kg/ha, see above). The revitalization of severely structurally-damaged loess soils necessitates an initial application of 1000-1200 kg *BIOSOL* per hectare; it is possible to reduce the amount used to the standard measure (*B8*) and later to 600 kg/ha (*B6*) from the third year.

(2) *Nearly flat sand/gravel terraces* at 100 m above sea level
This unit is typical of the Rhine/Main vine-growing area to the east of Mainz. There are only 2 experimental sites in this unit (*R26/MTh, R27/RR*). The structural degradations and compaction which are so typical of loess are only of subordinate significance in these very loamy sands and sandy loams. These sites are characterised by the fact that they react very quickly to revitalization measures and do not require higher initial applications of fertilizer.

(3) *Slopes, hill ridges and terrace faces* at between 300-230 m above sea level
These sites have an inclination of 15-30 °, they are found to the right of the Rhine with a SSW to W exposure (*R3, R6, R33, R57*), one site on the left of the Rhine has an SE exposure. The substrates at these sites are mainly tertiary marl, the Alsace profile lies on Keuper. The soils are heavy imperfectly drained, with water veins and they are cool in generally. They are characterised by the use of high initial quantities of *BIOSOL* for improvement (1500-2000 kg/ha).

(4) *Summits and steep slopes* in elevated edge positions at 350 m above sea level
One of the sites (*R31*/WB) is located on Jurassic limestone with a SW exposure and an inclination of 30 °. The plastic-heavy, relic soils are greatly broken up by the high stone content and warm. These sites require a standard *BIOSOL* application

(5) Loess-covered backs and sides of the *Kaiserstuhl* mountain at 300 m above sea level
These are south-facing sloping sites with an inclination of about 15 °. There are two enclosed sites in this position (*R22/MTh, R22/SB*). The sites have been levelled and their characteristics are generally the same as those of the other loess sites. Due to the exposure, the negative effects of the compaction are reduced, but their full effect may be seen in levelled troughs (*R32/MTh)*

2.4 Investigations, evaluation

The results were determined from extensive evaluations in the field. The evaluations in the field were performed in June and in the September ripening period. Grape samples were also taken in September and at the beginning of October. The crop results were only included in the calculations if the history of the grapes was known in full. The reports were based on the ripening dates.

The characteristics were defined according to vegetative vine attributes, morphological grape attributes and on the basis of the grape constituents (see (3.1)).

The grape constituents were determined in the field and in the laboratory. The on-site analysis was based on about 20 berries per stem, the laboratory analysis on about 500 berries per plot. The morphological attributes were determined once in the ripening phase, but the juice was analysed several times.The evaluations at the individual plots involved determining the condition of 15-20 randomly selected stems.

3. RESULTS

3.1 Evaluation criteria

The acquisition of the results and their evaluation were performed in accordance with the objective of the investigations. The objective of the investigations was to test the suitability for use and mode of action of *BIOSOL* in the Upper Rhine vine-growing district. As a general rule, evidence of suitability was taken to be all indicators of the presence of or improvements to vine vitality, vine health and performance. Suitable indicators evaluated were the attributes of the vegetative vine condition, the grape condition and the juice or must condition. The evaluation of the indicators was performed on a comparative scale. The comparisons were primarily with the results obtained from the control plots which had been treated in accordance with the usual practice for the area, or if changes in the condition occurred over time, also with the initial condition.

The indicators evaluated are listed below. The list is divided according to the groups described above, i.e. the attributes of the vegetative vine condition, the grape condition and the must condition.

(1) Attributes of the vegetative vine condition evaluated

- root condition (morphological records were only taken in guide cases or special cases)
- stem condition, with special attention being paid to stunted growth or the development of witch's broom
- shoot production and growth rate, with special attention being paid to shoot appearance and the ripening of the wood
- leaf condition and special attention to leaf appearance and leaf health (chloroses, infestation) and condition of the foliage wall

(2) Attributes of the grape bunch condition evaluated

- number of grape bunches per stem
- grape bunch appearance with particular attention being paid to uniformity of development, loose incomplete bunches and undeveloped retarded little berries
- ripening, with special attention being paid to uniformity of ripening
- infestation of the grapes, listing botrytis, oidium, peronospora and "Stiellähme" separately

(3) Attributes of the juice condition or must condition evaluated, constituents of the grapes

- specific gravity of the must on site (^{o}*Oe* from 20 berries per stem or 20 x 20 or 20 x 15 berries per plot)
- specific gravity of the must in the laboratory (^{o}*Oe* from 500 berries per plot)
- sugar content in the laboratory (500 berries per plot)
- total acid in the laboratory (500 berries per plot)
- pH in the laboratory
- total nitrogen concentration in the laboratory (500 berries per plot)
- nitrate content in the laboratory (500 berries per plot)

3.2 *BIOSOL* and the vegetative condition of the vines

3.2.1 General

The indicators of vine vitality are all vine organs, above and below ground. There are numerous things which impair vine vitality caused by poor soil quality and a wide range of observable cultivation errors. The cultivation errors include the preparation of the soil, fertilization, inappropriate plant protective methods and vitality-impairing raising methods: the errors act individually and in combination. Soil defects and cultivation errors produce specific indicators of impaired vitality. Improvement and remedial action are possible using *BIOSOL*; supplementary measures increased the success.

3.2.2 Root development, root type and vine vitality

The underground indicator of a vital vine is a deep-reaching, wide-spreading network of roots with side branches (*root network type*): there are no signs of soft rot or charring (see Figure 1, left-hand side). The formation of a root network is naturally restricted to loose, well aerated, penetrable soils which are unrestrained on all sides. These conditions are satisfied by light and medium heavy sandy-pebbly soils (*R26*, R27) and by heavy soils which are broken up by a high stone content (*R31/WB*).

Vine systems of the root network type are fully vital with simple *BIOSOL* applications. The standard amount (800 kg/ha) was the usual quantity of *BIOSOL* applied in the first two years, after this the application was reduced to 600 kg/ha. In productive vineyards, including the control plots, the basic root network had developed at the start, but it was not dense or complete. This was reflected above ground by a stunted vine with extremely short shoots in the centre of the boughs (see (3.2.3.1)).

The second common type of vine root is the *crack type* and its variants. Its main characteristics are the mainly vertical root orientation, the root system which is mainly confined to the vertical cracks and cracks in the soil and the dominance of the primary roots or the characteristic reduction of the secondary roots. The lateral extension of the primary roots from the accessible crevices in the mass of the soil is rare; an accumulation of lateral extended primary roots is found in the interfaces between different types of soil horizons or on stockwork boundaries in layers of soil.

The fine roots are arranged in the cracks as a root carpet on the crack walls. The laterally penetrating primary roots are only very slightly branched into secondary roots and show symptoms of all stages from fresh to charred. The formation of secondary roots is intensified to concentrated in the above-mentioned interface areas and thus intensifies the character of the root system; however, the majority of these fine roots are charred. In temporarily waterlogged interface areas or in interface areas over fermentation gas, no secondary roots form or the secondary roots are extremely charred.

The *crack type vine root* is characteristic of a root space confined by restricted penetration, inhomogeneous aeration and dampness penetration, temporary waterlogging and inhomogeneous nutrient distribution. The shape variants are various and graduated. Errors in cultivation and treatment aggravate the character of the crack type. The usual case is degraded, unprepared topsoil; extreme cases are deeply embedded and compacted, anaerobically fermenting organic masses.

The crack type is typical of the loess and marl soils. It is possible to cultivate vines in these types of soil producing full yields and top grape qualities and health with *BIOSOL* maintenance quantities of 600-800 kg per hectare (*B6, B8*). The complete vitalization of the vine, and in particular the reshaping of the crack root type into a network root type, is not possible. A stimulus for reshaping can only be achieved by using additional improvement quantities of 1000-2000 kg per hectare. A comparison with control plots shows that conventional intensification measures do not have a comprehensive or permanent improvement effect (see below).

R4 is an example of a crack root type site; the natural disadvantages are increased still further by the extremely degraded unprepared topsoil (see Figure 2). The stimulus to reshape the crack root type into a network root type was achieved by using vitalization quantities of 1000 kg of *BIOSOL* within a vegetation period. This stimulus did not take place in the control plots; the intensification of the control plots had a comparatively weaker effect and only on the overground condition of the vine and was accompanied by a reduction in the grape quality (see Figure 17).

Increased variants of the above example occur on exposure to the action of frost in combination with sometimes extreme compaction and serious errors in fertilization. One increased variant is the improvement experiment *R31/G*. The primary frost damage and the subsequent attempts to rectify the damage using increased amounts of mineral fertilizer and liquid pig's manure resulted in the formation of "witch's broom" (see below (3.2.3.1)) and the death of 37 % of the stems. The entire root system was reduced to charred stumps of the primary roots. The root system was revitalized using an additional improvement application of 2 x 1200 kg of *BIOSOL* per hectare; the young vines planted after this developed a root system which was a mixture of the root network and crack types.

The root development in improvement case *R32/GT* was very similar. The development of "witch's broom" started on an extremely compacted vine terrace with a moderate supply of hillside surface water after frost action. The room system developed as in *R31/G*, it was revitalized by improvement applications of 2 x 1200 kg of *BIOSOL* and sowing white clover. The phenomenology of this improvement case is described separately (see Figure 18).

Modifications to the crack root type are produced by introducing large area changes to the relief and rearranging the soil while laying the vine terraces. The formation of the root system is shown in example *R2/SB* (see Figure 3). Every man-made horizon and every natural horizon or boundary encourages the forked lateral extension of the root system. Charring of the lateral root system results in a suboptimum root condition resulting from the shortage of oxygen and the temporary waterlogging. In extreme cases, the condition leads to the development of subaerial humus horizons of charred root remnants. This development is found here and in raw loess.

The corresponding normal *BIOSOL* maintenance fertilization used in the experiments (*B6, B8, B10*) of between 600-1000 kg per hectare without additional measures maintains the vines in the best and qualitatively superior yield condition. The reshaping of the crack root type to the network root type, however, only commenced with the maximum maintenance dose. However, in this example, the reshaping of the root type during the dry years was not important with regard to yield. However, as individual periods of excess moisture have shown, reshaping is an insurance measure for moist years. The use of additional vitalization stimuli in the developmental doses of 1500 kg *BIOSOL* per hectare is also planned within the scope of experiments *R1/SB, R1/G*.

All the examples of crack root types so far come from loess soils. However, crack roots are also typical of marl and marly limestone soils (see Figure 4). The selected example *R6/WB* also shows the influence of deep acting ploughing measures with the formation interfaces.

This example is an extreme case because it is necessary to attempt to network the root system in the dense topsoil above the ploughed-in humus horizon producing moderate fermentation gases. The experiment was successful using 3 *BIOSOL* applications of 2000 kg per hectare and with additional leaf fertilization. The improvement of the root system was characterised by the elimination of stunted growth and a good yield.

A complex example of crack roots, *R6/WB* leads us to extreme cases of man-made damage. These cases are caused by a lethal impairment of the roots by fermentation gases from the subsoil: the source of the fermentation gas is excessively deeply incorporated organic matter combined with compaction. In example *R6/WB*, the damage caused by fermentation gas is only moderate because completely decomposed humus was only dug into the old topsoil; only a moderate amount of fermentation gas develops and only leads to the release of mercaptans, but not to the release of hydrogen sulphide.

If poorly rooted organic matter is ploughed in at plough pan depth, the death rates of the roots and vines are extreme, even in loose soil (see Figure 1, right-hand side). In such cases, the fermentation also leads to the formation of hydrogen sulphide in increased, clearly perceptible concentrations. The example shown (Figure 1) shows the advanced stage with mostly dead secondary roots and severely charred main roots. In such cases, improvement cannot be achieved with *BIOSOL* on its own. *BIOSOL* succeeded in revitalizing the case described only when the plough pan had been chipped away at the side by means of a bottom blade.

Often it is not possible to aerate the fermenting horizons because they are too deep. This is the result of deep incorporation of organic matter into the old cavities in the earlier relief of the vine terraces. *R23/MTh* is an example of this. Although the sickly roots were able to supply the vines without any outside aids, the system was very unstable and failed after exposure to a gentle late frost followed by cold, damp weather. The roots were no longer able to supply the vines sufficiently, in particular they suffered a shortage of nitrogen despite a higher than usual N-concentration in the soil solution (21 mg N/L). In the control plots, this lethal effect was partially compensated for by high levels of leaf fertilization with nitrogen. On the *BIOSOL* plot, the relapse (14.5 % stems with witch's broom, 1 % dead vines) was deliberately accepted. The damage was worst in the flat, underground and cold (soil) troughs.

Cases of damage of this type were common on levelled vine terraces. Sometimes the damage only occurred at the advanced productive stage, but then it was explosively and completely lethal. Vine terraces affected in this way had to be dug down to a depth of 4 m and the organic material exhumed. In these cases, *BIOSOL* was used to revitalize the newly installed vine terraces (*R58*). This was compared with mineral fertilizers (12000 kg of 40 potassium + 3500 kg superphosphate!) and with an organic fertilizer (*Ovital*). The root system on the *BIOSOL* vines developed into a root network type; the control plots only developed weak root systems of the initial crack type in coarse-blocky soil. The more vital system in the *BIOSOL* plots also produced the leaves with the greatest resistance to infestation (oidium+peronospora attack: *BIOSOL* 40 %, *Ovital* 70 %, *NPK* 100 %).

3.2.3 The vegetative overground vine condition

3.2.3.1 Vine development, stunted vines and witch's broom

The indicator of a vital vine is a strong growing stem with a uniform development of shoots which ripen at the correct time with a full foliage wall and with normal, not deformed and uniformly coloured leaves which are neither hyperchlorophyllated nor pale yellow or chlorotic and which change colour at the right time. This ideal form of vine requires the formation of a root network or root system which approximates the network type.

At the time of the experiments, most of the vines appeared to be vital as a result of being raised in lush conditions and hyperchlorophyllination; the nitrogen concentrations in the soil solutions varied between 15-60 mg N/L and the N_{min} values between 50-220 mg/N/100g. In critical sites (predominantly crack root type + processing and fertilization errors), the conventional fertilization was no longer able to maintain the apparent vitality so that a stunted vine condition dominated the systems. In extreme cases, the stunted vines had become witch's brooms.

Figure 5 shows an experimental system dominated by stunted vines. System *R4/G* was taken over as a moderately frost-damaged system of the crack root type (see Figure 2). The proportion of stunted vines varied between 6-30 % of the stems, the *BIOSOL* plots were distributed among the more greatly damaged areas of the system.

Within 3 years, the development of stunted growth increased in the control plots, but the development of the *BIOSOL* plots was different: the proportion of stunted growth in the standard *BIOSOL* plot *B8* (800 kg) fell slightly, but the proportion of the stunted growth in *B6* (600 kg) and *B4* (400 kg) increased as in the control plots. After 3 years the proportion of stunted stems in the control plots exceeded the proportion of stunted stems in *B8* and *B6*, and it was only the most poorly fertilized *B4* which contained more stunted vines than the control plots. During these 3 years the quality and the grape health and the general ripening condition of the *B*-plots was much better than they were in the control plots (see (3.2.3.2), (3.3)).

The stimulated vitalization from an additional 1000 kg of *BIOSOL* after the third year was not only evident from the root condition (see above (3.2.2)), it could also be seen in the rapid reduction in the amount of stunted growth. An additional factor which helped to reduce the stunted growth was cutting back the bough lengths which reduced the short shoots in the centre of the bough; the cutting back was performed in the same way on the control plots and the *BIOSOL* plots. Due to this and the fact that the fertilizer application was increased at the same time, the proportion of stunted vines fell markedly on the control plots as well. However, measured by the difference, in the comparison the *BIOSOL* was superior by an average factor of f=4.7. This superiority is even more evident when the quality and health of the harvest is taken into account (see 3.3), (3.4)).

The action and mode of action of *BIOSOL* described here is still efficient in extreme cases, i.e. for the improvement of witch's broom systems. Examples of this are systems *R31/G, R32/GT* and R25/G. All systems were taken over in an extremely frost-damaged condition which had been aggravated by individual mistakes in the cultivation. The results were influenced by the individual general methods of treatment employed by the vineyards.

The development in system *R25/G* was very informative, because the extreme plant protection practice employed there using an organic method of cultivation (see above (2.1)) severely restricted the revitalization process. It is interesting that here *BIOSOL* was tested in comparison with 2 organic fertilizers, i.e. farmyard manure (K_M) and castor oil plants (K_R).

The attributes which best explain the action and mode of action of *BIOSOL* are shown in Figure 6. The most interesting of these attributes for our purposes here is the degree to which the damaged stems die. The experiment started with a basic proportion of 21 to 24 dead stems. The percentage increase in the number of dead stems was: 62(K_M) : 62 (K_R) : 4 (B); which means that despite the unfavourable extraneous circumstances, the revitalization achieved by *BIOSOL* was better than that achieved by farmyard manure by a factor of f =14.

The improvement of *R31/G* and *R32/GT* was exactly the same, but even more effective. The high efficiency was the result of the fact that there was no incessant interference from the spraying practices in *R25/G* which produced compressed, deformed "calamine" leaves and short shoots. The greater efficiency was reflected in the fact that no further stems died and that the witch's broom reverted to normal types of growth. Figure 18 shows the phenomenology of the improvement and revitalization schedule using the example of *R23/GT*.

3.2.3.2 Shoots, shoot condition (number, appearance, wood ripeness)

The shoots and the shoot conditions are multifactorial and complex indicators of the early growth of a vine. The number of shoots is a very relevant attribute. Although the number of shoots was always evaluated, it is mainly predetermined by the vine care and pruning on the one hand and fertilization and spraying on the other, so that the attributal degree of difference is low.

On the other hand, there are 2 other shoot attributes which are hardly masked at all by the basic treatment used: these two attributes are the appearance and the ripeness of the shoots during the grapes' ripening period. This shoot appearance was differentiated as *normal shoots*, *short shoots* and *long shoots* and in this context is an essential criterion for separating the vital stems from the *stunted stems* and the *witch's broom stems* (see above). The third attribute is the *ripeness of the wood* of the shoots. The wood ripeness reflects the degree of the distribution of the autumn materials in the vine and is essential for the vine's preparation for winter. In the following, the results are presented separately according to individual examples and the average results for different varieties.

The average results for the different varieties with regard to *ripeness of the wood* demonstrate the maximum ripeness promotion by *BIOSOL* (see Figure 7). Although the difference between *BIOSOL* and all other control variants varies over the years, *BIOSOL* always had the most beneficial effect; the difference ratios produced superiority factors of f=1.1-2.2. The differences were less at the beginning than they were at the end of the experiment and they were lower in good ripening years. The reduction in the difference in the *Gutedel* 1992 was a complex result which was also caused by the maximum control adaptation in *R4/G* and the higher occurrence of stunted vines in the *B* plots in *R4* from the start (see above).

An individual analysis of the experimental sites reveals several additional aspects. First of all, the similarity in the development of stunted vines and decreasing wood ripeness should be noted: as the proportion of stunted vines increases (see Figure 5), the shoot maturity falls (see Figure 8). This synchronous process is modified because the vine tries to compensate for the delay in ripening under conditions of increased stunted growth (see Figure 8, also *B8: B6: B4*). The control plots are included in this attempted compensation. Although this reduced the difference in ripeness between the *BIOSOL* plots and the control plots in the period from 1991-1993, the ripeness level of the control plots (*K*-plots) was still far behind the ripening level of the *B*-plots.

The stimulated improvement in 1994 was nowhere near as clearly indicated by the shoot maturity as it was by the development of the vitalized roots and vines (see above). The true result of the vitalization using the example of shoot ripeness is extremely unclear due to the early evaluation date and therefore indicates delays in ripening as being a result of the improvement measures performed. The extreme drop in the ripeness from 1993 to 1994 is for the most part without doubt due to the date. However, taking into account the results of the improvement *R32/GT* (see below), it appears that specific reaction mechanisms for the vine vitalization are masked by this; this vine reaction mechanism was interpreted extremely speculatively as a compensation process between the favoured shoots in the 1991-1993 period and the disadvantaged root and stem systems.

The same reaction mechanism was observed on both the *K*-plots and the *B*-plots. This mechanism was buffered more in the *B* plots than it was in *K* plots; the superiority factor f=*B*:*K* rises from f=1.1-1.2 to f=1.3-1.4 after the stimulated improvement. At the same time the superiority of plot *B8*, which had been given a higher application, fell more than the superiority of *B6* and *B4*, which had been given lower applications.

The results of improvement experiment *R32/GT* confirm the speculative attempt at an explanation for *R4/G*, albeit to a modified extent. The reaction mechanism seen in *R4/G* is only seen in less damaged vines; in addition, as time goes by, the delayed ripening effects turn into stimulation effects. Severely damaged vines do not react to the improvement stimulus according to a differentiation of the effects according to root, stem and shoot. The *R4/G* system seems to have reacted to the improvement stimulus in the same way as the less damaged stems in system *R32/GT*.

A third type of reaction mechanism to *BIOSOL* is demonstrated by vines which are subjected to permanent stress from extreme spraying (see Figure 6). The shoot ripeness increased continually from the start of the experiment and after 4 years hovered around a low to medium ripeness level. Even years of excessive spraying did not affect this development; however, the same extreme excesses did depress the wood ripeness to extreme minimum levels in both the control plots.

It should be stressed in this context that the two control plots were treated with organic fertilizers, i.e. farmyard manure (K_M) and castor oil plants (K_R). The much greater promotion of wood ripeness by *BIOSOL* was observed throughout the period of the experiments; in normal years the superiority of *BIOSOL* was high (f=1.4-1.5) and rose extremely in extreme years (f=4.2!).

3.2.3.3 Leaf condition and foliage wall

Like the shoot condition, the leaf condition is a complex indicator of vitality. The condition may be analysed by breaking it down into individual attributes. Accordingly, the various indicators for *leaf appearance, leaf colour* and *leaf health* were evaluated precisely. The different types of *leaf appearance* (*normal, opulent, stumpy, stumpy-deformed + combinations*) can then be assigned to the different root, stem and shoot forms already discussed.

The leaf colour and leaf health on the other hand are of special significance with regard to the grape condition. The differentiation of the *leaf coloration* was from *hyperchlorophyllation* to (slightly) *lightened, yellowed,* to *chlorotic* and *necrotic* with further differentiation in accordance with the causes, i.e. according to the nature of the shortages or excesses. As specific nutrient deficiencies, the colour anomalies were not only reflected in the shape and uniformity of ripeness of the grapes, but also in their state of health in a narrower sense. For example, the evaluations were performed according to the nature and degree of the attack (*powdery mildew, peronospora, "Roter Benner" (red fire disease), insects*). Because of the equivalence of the attributes and to avoid repetitions the findings are listed with the grape condition.

As an overall indication of vitality, the actual foliage wall should be seen more as an indicator of vine vegetative growth and shoot appearance. The development is shown using the example of an improvement case, *R32/GT* which clearly demonstrates the action and mode of action of *BIOSOL* (see Figure 18). The foliage wall in the extremely damaged plants (witch's broom) only covered 10 % - 15 % of the frame height at the beginning of the experiment.

The stems reacted in the same way to the onset of the *BIOSOL* application, but differed in the degree of revitalization. The improvement of the foliage wall was gradual, in phases. Recuperation characterised the start of the *BIOSOL* application with the standard maintenance application and the additional stimulation from the improvement application, including the additional accompanying measures (trace element-leaf fertilization, sowing white clover). The maintenance applications produced a partial revitalization of 35-65 % (of the frame height) and the specific improvement measures achieved complete revitalization.

This example also shows that greatly damaged vines react in a much more restrained manner to vitalization stimuli than those which are less damaged; however, the time delay is made up when all measures are intensified. Against this background of results, we should remember the shoot ripening which takes place in the reverse way (see Figure 8 and (3.2.3.2)); during this the development of the wood ripening of greatly damaged stems is more intensive than the development of the less damaged stems. Like the similar improvement processes for the stem condition and wood ripening in *R4/G* which were evaluated in the opposite way, this should be viewed as a compensation reaction by the vine.

3.3 *BIOSOL* and the grape condition

3.3.1 General

All the grape attributes which characterise the vine vitality may be used as described to demonstrate *BIOSOL's* action and efficiency. Just like the root, stem and shoot attributes, these grape attributes are their appearance, their morphological ripening condition and their state of health. The fourth, important grape attribute was the average number of grape bunches per stem.

However, the number of grape bunches is also determined to a great extent by the pruning method used, particularly by the degree of fertilization which changes over time and even from stem to stem. The number of grape bunches per stem should be primarily understood as a physiological measurement of gross yield. The physiological measurement of net yield is produced by calculating all grape bunches lost due to disease and yield-reducing grape bunch appearances. The only small differences between the physiological measurements of the gross and net yields for the *B* grapes are a specific characteristic of the *BIOSOL* effect.

3.3.2 Number of grape bunches, mass yield and physiological gross yield

The comparison of the number of grape bunches with the statistical parameters for the grape bunch yield and grape bunch health shows that *BIOSOL* is primarily a quality-promoting fertilizer and secondly a fertilizer which promotes the mass yield. This result is also reflected in the comparison of the *BIOSOL* plots with the control plots. The higher mass yield from the control plots is produced when all *BIOSOL* calculations are taken into account, i.e. including those which were below the *BIOSOL* standard application of 800 kg per hectare (*B8*), right down to 600 kg (*B6)* and 400 kg (*B4*). This fact is clearly demonstrated using results differentiated according to variety which oscillate at first and then stop (see Figure 9); the deviation with *Müller Thurgau* is one of those deviations which need to be explained separately.

This overall result requires greater explanation and definition. First it should be established that the higher the *BIOSOL* maintenance application selected, the more closely the grape bunch mass yields from the *BIOSOL* plots approximate the mass yields from the control plots. In the case of *BIOSOL* standard plots *(B8)*, the number of grape bunches from the *B* and *K* plots are scattered around an approximately common axis; over the course of the years, on one occasion the *B8* plot became more productive (f=1.02-1.08) and then it was the turn of the control plots once again (f=1.01-1.26). Consequently, the mass yield is primarily determined by the amount of fertilizer. Mass yields which are greater than the amounts produced from the *BIOSOL* standard plots are counter to modern production objectives and applications which exceed the maintenance application for the *BIOSOL* standard plot are counter to the concept of the product as an environmentally friendly fertilizer. The exception to the *BIOSOL* self-imposed restriction is all cases of improvement.

The result achieved with the *Müller Thurgau* variety is a special case. The result for this variety was extremely dominated by one site *R23/MTh*. This site had received an extremely irregular supply of nutrient and was also subjected to stress from fermentation gas from the subsoil (see also (3.3.2)). In these basic conditions and without any additional weather stress, the *BIOSOL* greatly exceeded the *K* result (f=1.2-1.4). When the entire *R23/Mth* experiment was aborted due to the weather (see (3.2.2)) the result from the other sites was transparent. The product concept mentioned above prohibited the only possible improvement measure, namely increasing the quantity on an over-fed site which is not suitable for grape vines.

3.3.3 Grape development, uniformity of bunches and grapes

The uniformity of the development of bunches and grapes is an indicator of harmonious vine nourishment and is also an important yield factor. This indicator was evaluated using the reciprocal feature, i.e. the total number of loose incomplete bunches and bunches with undeveloped, retarded little berries. The results are shown in diagrams showing the average results for the varieties (see Figure 10) and the individual results of the tests (see Figure 6). Both the average results for the variety and the results of the individual experiments confirm that the action of *BIOSOL* promotes uniformity of development.

The range in loose, incomplete bunches was extraordinary over the years. Counting the *BIOSOL* and the control plots, the number of bunches affected ranged from 1 % - 35 % (see Figure 10). This range is due less to the temporal irregularity of harmonic nutrition and more to the irregularity of the annual weather conditions, i.e. their effect on the flowers. However, this also means that the plots with fewer loose incomplete bunches are also better able to withstand unfavourable weather conditions.

The *BIOSOL*:control comparison showed that in all years and for all varieties *BIOSOL* restricted the development of loose, incomplete bunches more than the control treatment. *BIOSOL's* superiority was considerable, frequently extreme (F=1.1 - 3.0); this was determined with all varieties.

This result has numerous partial effects and side effects. One partial aspect is the restriction of the development of loose, incomplete bunches in systems under specific stress. This kind of stress is the extreme spraying in system *R25/G* (see Figure 6). Although in such cases, an attempt was made to bring the *K* plots to the *BIOSOL* amount, this never succeeded and after the adjustment experiment they relapsed to the average difference.

Another partial result is the fact that in extreme improvement cases, *BIOSOL* superiority is only established after initial delays, but then progresses in leaps and bounds. An example of this kind of result is that achieved for all the *Weißburgunder* (White Burgundy) and its extent is determined decisively by the developments in system *R6/WB*.

3.3.4 Bunch ripening, uniformity and non-uniformity

The external indication of uniform ripening is the uniform coloration of the grapes in a bunch and the *uniform colour* of the bunches. The differences in colour are very noticeable with *Spätburgunder* (Late Burgundy) from the blue:green contrast; the green:yellow contrast of the white grape bunches is less striking, but simple to evaluate. The uniform ripening of the bunches and berries is another specific expression of the restricted vitality of vines which are not nourished uniformly. The uniformity of ripening may also be determined from must yield and must quality and is therefore an important evaluation attribute. The reciprocity attribute is the proportion of non-uniformly ripened bunches. The extraordinary superiority of *BIOSOL* is evident when averaged for all varieties (see Figure 11) and in specific individual cases (see Figure 12,18).

The *uniformity of ripening* is a multifactorial result. The non-uniformity fluctuates greatly in individual years; during the period of the experiment and including all the control and *BIOSOL* results, the proportion of unripened bunches covered 1-60 % of all grapes (see Figure 11). The temporal non-uniformity is the result of the fact that the evaluation deadlines were not all exactly the same, but particularly the adaptation of the control plots in relation to the *BIOSOL* results. Despite all readjustments, the difference between the *BIOSOL* plots and the control plots was extremely high with all varieties; the differences indicate a *BIOSOL* superiority by a factor f=2:1 to f=18:1.

The results of individual experiments demonstrate the occurrence of these very obvious differences (see Figures 12, 18). Site example *R25* shows that under stress, *BIOSOL* can provide uniform grape nutrition better than other fertilizers. The stress in question has already been mentioned several times, extreme spraying, particularly in the "organic" vineyards; however, the comparison with *R25* also shows that even the standard organic fertilizer *farmyard manure* produces a much lower uniformity of nutrition or ripening. This result is also confirmed by the variety *Nobling*; the *Nobling* result was mainly determined from another "organic" vineyard (*R21*).

Example *R2/SB* is proof that the *uniformity of ripening* is not merely a question of the amount of fertilizer applied (see Figure 12). A comparison of *B10:B8:B6* clearly shows that neither does the maximum dose always produce the greatest delay in ripening nor does the minimum dose always produce a maximum of ripening uniformity. Although the *BIOSOL* variants do show a tendency towards increased uniformity as the amount applied increases, the clear tendency of the result is still far below the standard *BIOSOL* dose.

The gradation comparisons from *R2* are to be extended by the inclusion of improvement experiments, in which maximum amounts of *BIOSOL* were used. All improvement cases revealed a very similar picture, with the original degree of damage having a modifying action. Extremely damaged "witch's brooms" had a sort of "pre-improvement" reaction even to standard doses (*B8)* with an extreme increase in non-uniformity of ripening; however, after an additional application of improvement doses of *BIOSOL* this non-uniformity soon diminished (see Figure 18). This result is notable because the maximum uniformity of ripening occurred 2 years before the development of the maximum crop; the development of the phenomena which are usually associated with this took place asynchronously.

The results for the *Weißburgunder* variety (Figure 11) shows that the reduction in the uniformity of ripening may occur as an expression of the improvement, but does not necessarily have to take place. The reduction in uniformity in 1992 resulted from a dominant individual case (*R5/WB)*. When the maximum improvement dose was applied (3 x 2000 kg, *R6/WB*), there was no comparable preliminary effect; rather the uniformity tended to develop towards a relative and absolute maximum.

3.3.5 Grape health, grape infestation and grape losses

The health of the grapes is expressed in a minimum parasitic infestation and minimum berry and bunch losses, which are due to problems with the supply of nutrition in the vine and bunch structure. These two expressions of insufficient grape quality have a largely common origin, i.e. damage to the vitality of the whole vine system. In this way, they correspond with all other common expressions of vine vitality (see above). The *BIOSOL* experiments have so far been able to explain the mutual complementary and sometimes substitutable information on the different attributes of vine vitality.

Accordingly, grape health is the most striking quality criterion for the entire condition of a vine. Therefore, it is immediately obvious that the *BIOSOL*, which has a positive effect on all the vitality attributes of the vines discussed so far, has by far the greatest phytogenic health action. This is shown in the following using the average results for different varieties and the results of individual experiments.

The most dominant types of damage were fungal; the majority of grape losses were due to infestation by *botrytis, oidium* and *peronospora*. However, the damage found also included *"Stiellähme"*, which was definitely the result of poor nutrition. These 4 types of damage were assessed individually according to the proportion of infested grapes and marked according to the intensity of the infestation. The *infestation loss* is the product of the *percentage infestation* and the *infestation intensity*. It is differentiated according to variety by means of average values for each variety (see Figure 13). Specific aspects of the grape infestation are discussed on the basis of the proportion of infested grapes at characteristic sites (see Figures 14, 15, 16).

The analysis of the damage differentiated according to variety shows that on average up to 8 % of the grapes are lost to diseases (see Figure 13). However, the standard deviations are high. Infestation loss and scatter decrease as all the cultivation and protective measures approach the optimum for the site in question (see *Weißburgunder)*. The results of the *BIOSOL* plots are always in the minimum range of the loss field. The differences in the losses from the *BIOSOL* plots and the control reached maximum levels; the resulting *BIOSOL* superiority ratio was extreme (B:K=f=3:1 - 20:1).

The majority of the symptoms of disease shown by the grapes was *botrytis* infestation, followed by *peronospora*. Up to 45 % of the grapes could be infested with *botrytis*. The *peronospora* infestation was on average about half the value; but in the case of an epidemic more than 70 % of the grapes could be infested (see Figure 16). The oidium infestation of the grapes was much less (< 10 %). Infestation with *"Stiellähme"* had a very wide range and could affect 17 % of the grapes (see Figures 14, 15, 16).

Taking all occurrences into account and under the most varied of site and treatment conditions, the infestation of the *BIOSOL* grapes was always the lowest. Example *R25/G* (see Figure 16) shows that neither extreme spraying technology nor the use of farmyard manure can decisively hinder the fungal attack. In average years, the proportion of infested *BIOSOL* grapes was less than 3 % and rarely exceeded the 10 % level even in the event of an epidemic; in these cases *BIOSOL* was superior to the two other organically fertilized control plots by the factors f=2.9 (*botrytis)*, f=3 (*oidium*), f=2.7-7.8 (*peronospora*).

The resistance to *"Stiellähme"* at this site was the great exception. There was no *"Stiellähme"* at all; the control plots and the *BIOSOL* plots were the same.

In addition to the general *BIOSOL* superiority, example *R2/SB* demonstrates the mode of action of graduated amounts of *BIOSOL* on a site with the crack-type root (see (3.2.2), see Figure 3). Using the examples of a *botrytis* attack and a *peronospora* attack, we can see that over time, all applicational amounts, which are used not just for pure maintenance, but also to achieve the maximum site and root improvement, also produce the greatest amount of healthy bunches. From this it is also evident that from the middle of the experimental period, the following sequence of action set in: *B10* > *B 8* > *B6*. The consequence of this for the treatment of sites requiring improvement is that pure maintenance fertilization with standard and minimum amounts of *BIOSOL* is less purposeful than immediate improvement with improvement doses and then reducing the doses to the minimum maintenance dose.

The attack of *"Stiellähme"* deviates slightly from the above pattern *B10* > *B6* > *B8*. However, the superiority of the standard plot *B8* does demonstrate the effectiveness of the constant reaction mechanism. If the complete site has not been given full improvement, the standard plot looks after the bunches more harmoniously than *B10* and *B6;* this harmony is reflected in a minimum level of *"Stiellähme"* attack.

Example *R4/G* augments the above example (see Figure 15). In the initial phase the *botrytis* attack in the *BIOSOL* plots fell continuously. The sequence of attack in this system which is dominated by stunted stems was *B8* > *B6* > *B4*. This sequence means that if the site is not developed using improvement quantities, any maintenance quantity above the required minimum promotes an attack. The improvement stimulus resulting from the additional quantity of 1000 kg/ha produced a reversal similar to *R2*: the sequence of attack was *B4* > *B6* ~ *B8*. Therefore *R4/G* confirms the quality of improvement measures on sites requiring improvement and the time-differentiated-staggered dose recommendation from *R2/SB* (see above).

The improvement stimulus from *BIOSOL* improvement doses may lead to a slight increase in the infestation of the grape bunches as in *R4/G*. However, this is only temporary (see *R32/GT*, Figure 18, see *Weißburgunder*, Figure 13). The temporary increase in infestation is more evident if the improvement is not assisted adequately by supplementary measures (*R32/GT*).

With the additional application of maximum improvement doses, the infestation stimulus is either non-existent or applies to hardly 1 % of the grapes (see *R5/WB*, *R6/WB*, Figure 13).

3.4 *BIOSOL* and grape content, must condition

3.4.1 General

The must condition was determined from several of the grape components (see (Figure 3.1)). The analyses were performed on site and in the laboratory. The field analyses only determined the specific gravity of the must (°*Oe*, 20 berries per stem), all other data were determined in the laboratory. The field determination was performed during the autumn evaluation which varied generally and in time. This was also a reason for the temporal range of the must ranges; the *Oe* drop in 1993 and 1994 was completely due to the very early date. This does not really affect the informative value - the *BIOSOL* : control comparison is fully retained. The laboratory analyses were performed at several ripening dates and hence provide an insight into the development of the ripening.

3.4.2 The specific gravity of the must (°*Oe*) according to field measurements

The specific gravity of the must is generally an indicator of the sugar content and is hence an important criterion of the must quality. Although by deduction, the natural sugar content of the grapes is a partial indicator of the vine vitality and the correct material conversion, the Oechsle degrees or sugar content do not always correspond to the other indicators of ripeness and vitality. One example of this is the relatively high sugar content of unripe, grass-green berries.

In such cases, the discrepancy between sugar content and general unripeness should be evaluated as an indicator of imperfect material conversion; phenomena of this kind are frequently observed at particular sites (e.g. *R1/G-K*). During the *R* series of experiments, phenomena were observed which are designated pre-phenomena and post-phenomena: this is a way of saying that individual indicators of vitality react more quickly than others to improvement stimuli. Experience so far has shown that a higher sugar content tends to be a post-phenomenon.

The frequent discrepancy between the sugar content level and the other quality attributes is most clearly expressed by the fact that sugar-rich grapes are more likely to be subject to parasitic attack. This example proves that although the specific gravity of the must is a source of information, its significance can only be evaluated against the background of all other attributes. This means that the requirement for fertilizers and protective measures may be stated in terms of positive action. *BIOSOL* is able to satisfy this requirement, not merely within the terms already discussed, but also with regard to the sugar content of the grape juice.

The results differentiated by variety reveal two things: the general superiority of *BIOSOL* and the sometimes justifiable deviation from this (Figure 19). The superiority of *BIOSOL* (f=1.01-1.08) is much less with regard to the specific gravity of the must than it is for the attributes of the grape bunches (see above (2.3)) and the vegetative attributes of the vines (see above (3.2)). This should be interpreted as meaning that all the other requirements of the vines must be satisfied before the formation of the sugar content in the berries, i.e. this is a special form of post-phenomena, which confirms the result obtained for the *Weißburgunder* variety. The requirements resulting from the large amount of stunted vines and witch's broom, which is determined from the average variety, confirm the superiority of *BIOSOL*, which is less pronounced here. The control treatments, which are not as suitable for covering the other requirements of the vines (see above (3.2., (3.3)) are closer to the *BIOSOL* result.

In deviation from this generally occurring efficiency structure, the *Weißburgunder* control plots did better than the *BIOSOL* result in the first two years of the experiment. This is a particularly good example of a post-phenomenon. The *Weißburgunder* soils first had to be given expensive improvement treatment and only when all the other vine attributes had recovered, did the specific gravity of the must from the *BIOSOL* plots overtake the specific gravity of the must from the control plots. One individual case which typifies the phenomenology of the entire restoration project is revitalization case *R32/GT* (see Figure 18).

In another individual case (*R1/SB*), very small differences were observed between the *BIOSOL* results and the control results and once the control plot was clearly superior (Figure 20). There is no satisfactory explanation for this result. However, the crack-type soil requires improvement treatment and it is intended to investigate the effect of the improvement measures in the next few years.

The yearly results for a comparable soil requiring improvement treatment (*R2/SB)* varied with the quantity of *BIOSOL* applied (see Figure 20). This type of relationship has already been observed with the grape ripening and with the grape infestation (see above). In the advanced ripening stage, there were hardly any differences between the ripening of the individual *BIOSOL* variants, in particular, the maximum and the minimum variant, were exactly the same; and analogous to this and analogous to the infestation resistance, the specific gravity of the must from *B6* and *B10* were approximately the same in the years 1990-1992. In the early stage of ripening (1993, 1994), the standard plot and the minimum plot had a high must specific gravity, but this only means that maximum doses cause a slight delay in the ripening.

The current example *R2/SB* is a clear demonstration of the unwanted consequences of excessive forcing of the vines on the control plots. This similarity of the control plots to the *BIOSOL* plots which had been achieved at great expense was paid for by maximum levels of parasitic infestation. In the year of the greatest similarity (1990), the control grapes suffered the maximum level of *peronospora* attack. The following years the *botrytis* and *"Stiellähme"* infestation reached their maximum. The following reduction in the forcing of the control plots did not, however, lead to any significant improvement in the grapes' state of health, although the difference from the specific gravity of the must from the *BIOSOL* plots increased.

In addition to the general superiority of *BIOSOL*, the example *R4/G* demonstrates the biosol-internal pre-phenomena and post-phenomena (see Figure 20). In the first two barren years, in addition to the maximum degree of barrenness relative to *B8* and *B10*, the minimum *BIOSOL* plot also produced the highest specific gravity of the must and in the year of the improvement stimulus (1994) also had the highest sugar content. In the meantime, however, during the stage of advanced barrenness (1993) the standard plot produced the must with the highest specific gravity.

This result illustrates two things: the delayed improvement action of the standard *BIOSOL* dose (*B8*) and the re-establishment of the original relationships after the first improvement stimulus. In fact, on soils which require restoration, the standard dose is really only a maintenance dose and not an improvement dose and although the additional improvement stimulus from one-off low additional doses is reflected in the appearance, it is not reflected in the specific gravity of the must. This very subtle reaction mechanism, however, confirms once again that the required improvement stimuli should be added immediately and that it is possible to return to minimum maintenance applications of *BIOSOL* when the improvement has taken place.

The two individual examples *R25/G* and *R23/MTh* are interesting for various reasons (see Figure 20). Example *R25/G* shows that on the site which has been mentioned several times before which is characterised by extreme spraying methods and control plots with farmyard and castor oil plants, BIOSOL's superiority is also reflected in the specific gravity of the must.

System *R23/MTh* was subjected to stress from fermentation gas and was destroyed after exposure to the action of late frost (see also (3.2.2), (3.3.2)). The *BIOSOL* grapes reacted to the onset of additional stress by producing a higher level of natural sugar content than the control grapes.

3.4.3 Acid and acid structure

Acid is one of the main taste criteria in the grape juice. The acid taste is a complex perception value and is governed as much by the overall acid structure as the *overall acid concentration (c)*. Parameters which characterise the structure more precisely are the degree of dissociation of the dissociated acid content ("free acid", *pH*) and the *acid composition*. The free acid and its non-dissociated residue, the *carboxyl content*, are both detectable to the senses. The two acid components of the grape juice are *tartaric acid* and *malic acid*; the *tartaric acid* is the stronger of the two and provides more taste in the same overall acid concentration.

Only the *overall acid concentration* and the *pH* value were analysed during this series of experiments; the rest of the structural environment will have to be determined by inference. Although the data available is definitely still insufficient, it does nevertheless point to the significance of the overall condition of the vine on the acid structure. The main mode of action of *BIOSOL* is to stabilise the *pH* at a lower level, which is the direct result of a different type of fruit acid composition and buffering.

The *overall acid composition* and the *pH* values for the grape juices were recorded in ranges from the initial values to the final values (see Figures 21, 22). The initial acid values ranged between 208-194 mVal H^+/L and the analysed final values ranged between 136-111 mVal H^+/L. The dissociated acid ranged from a maximum of *pH* 2.87-2.80 and a minimum of *pH* = 3.47 - 3.27. The acid structure is characterised by the fact that there is no simple linear relationship between the *overall acid concentration* and the *pH*. The *pH* values do not increase linearly with the fall in the *acid concentration*, instead the *c/pH* relationship takes the form of a simple stepped curve; this is demonstrated particularly clearly by the example of Spätburgunder (Figure 21).

The first thing shown by the configuration of the *c/pH* field is that, at the given *acid concentration*, the *pH* values fluctuate widely in a range from 3/10 to 4/10 *pH* units. This means that the acid behaviour is determined by the composition of the acid; according to this, with the same overall acid concentration, the lower the value of the associated *pH* value, the greater the dominance of *tartaric acid* over *malic acid*.

The stepping of the *c/pH* field points to another fact. The stepping means that the *pH* rises discontinuously as the *acid concentration* decreases. Accordingly, the ripening process includes buffer phases. The lower the initial *pH* values, the more pronounced the buffering.

Within the *c/pH* field, the *BIOSOL* and the control musts take on their own, separate sections. The *BIOSOL* must is in the section with the lower *pH* values, the control must in the section with the higher *pH* values. Accordingly, the acid in the *BIOSOL* must is dissociated to a greater degree than the acid in the control must. This indicates a different type of acid and points to the conclusion that the *BIOSOL* musts are dominated mainly by the *tartaric acid* while the control musts are dominated more by the *malic acid*.

The differences between the *BIOSOL* and the control musts in the same sites do not have a simple orthogonal alignment in the *c/pH* section. The *acid concentrations* in the control musts are always higher than those in the *B-musts* and are also combined with the higher *pH* values; therefore, the differential alignment slopes at an acute angle to the acid axis.

This demonstrates that the *BIOSOL* musts have a stronger buffering capacity. The mean degree of the differential alignment is plotted on the graphs (see Figures 21, 22).

The position of the individual sites in the two sections is essentially determined by the vine condition. In the control musts the *pH* value increases as the vine moisture increases. In the *BIOSOL* musts, the more consistently concomitant measures were added to the *BIOSOL* application, the greater the drop in the *pH* value. Accordingly, the sites closest to the low *pH* values express a greater degree of harmonious vine condition.

Taking all aspects into consideration, the main positive effect of *BIOSOL* on the acid character of the musts is the increased *pH* buffering. This means that an acid taste is retained to a large extent as the acid breaks down. In this connection, it is worth mentioning the location of the musts of extremely cultivated vines from "organic vineyards"; the *BIOSOL* musts and the control musts from these kinds of vine systems *(R21/N, R25/G)* are arranged in the lower range of each section. This means that the increased buffering of the musts is a positive aspect of "organic" viticulture.

3.4.4 Sugar : acid structure

3.4.4.1 Natural sugar content and acid degradation

The sour acid taste depends upon the sugar or the *sugar:acid* ratio just as much as upon the actual *acidity*. There are still numerous gaps in the empirical base for this subject; but the data available are still sufficient to demonstrate that *BIOSOL's* special mode of action is in the intensified building up of *sugars* and the restriction of *acid* degradation.

During the grape ripening phase, the building up of *sugar* and the degradation of acid are two contradictory processes (see Figure 23, 24). This is paralleled in the *c/pH* development mentioned above. And as the *acid* degradation progresses, the *sugar* build-up is not rectilinear, but takes the form of a double-stepped curve. This curve is characterised by its steep end branch. In this extra area, the sugar content develops with an approximately constant acid concentration; the *sugar* formed in this ripening phase is accompanied by virtually no *acid* loss. The extra area starts with the *pH* buffer area in the *c/pH* field.

The sugar content curve is divided into different areas, the musts of the varieties investigated cover variety-specific *sugar : acid* fields. The *BIOSOL* and control musts always occupy separate fields within a variety field. In the *Spätburgunder* field, the control musts occupy the central section and fan out in the second sugaring stage without entering the extra area. With the white wine varieties, the field distribution is modified so that the *B* musts occupy the lower sections with the narrower *sugar:acid* quotients.

This means that relative to the acid, the sugar content of the *BIOSOL* juices develops more moderately than the sugar content of the control juices. In the control musts, the average varieties at first had more sugar than the *BIOSOL* musts, with the same acid concentration. The development of the control musts does not continue in the same way in the second stage of sugar development. Here the *BIOSOL* musts experience an extra leap in sugar development (see extra area) without undergoing extreme acid losses.

3.4.4.2 The sugar:acid ratio and the *pH* development

The *sugar:acid* structure is determined not only by the relationship between the acid and the sugar, but also by the dissociation behaviour of the acids during the process of sugar formation.

The strongest acid dissociation retains the acid taste component.

This structure is evident if the *sugar:acid* quotient is compared to the *pH* (see Figures 25, 26, 27). This also reveals the advantages of *BIOSOL*.

The increase in the sugar content of the grape juice is accompanied not just by a reduction in the acid concentration, but also by the dissociation of the acid and an increase in the *pH* values. The *pH* values do not increase in a linear relationship to the reduction in the *sugar: acid* quotient, but with curves with continuous or stepped falling gradients, the continuous, simple fall in the gradient characterises the *Spätburgunder* must (see Figure 25), the double-step shape characterises the musts produced by the white wine varieties (see Figures 26, 27).

The *pH* values occupy ranges from which the sections in the diagrams mentioned are produced. In all variety fields, the *BIOSOL* must occupies the lower section with lower *pH* values. This means that with the same *sugar:acid* quotients, the *BIOSOL* must is more acid than the control must. The differences between the control musts and the *BIOSOL* musts are at vertical angles to the *sugar:acid* axis; this means that despite the higher sugar content, the acids in *BIOSOL* musts dissociate more readily.

The change in the must condition with vine improvement measures should be noted. In a special case *R32/GT* (see Figure 27), the improvement stimulus also achieved an intensified stimulus to dissociate,

with the same increase in sugar content. Hence, the entire improvement process is nothing more than an intensified reflection of the mode of action of *BIOSOL*.

3.4.5 Sugar, acid condition and nitrogen

Nitrogen and its various compounds are not quality parameters for the grape must. From certain aspects, the nitrogen in the grape juice could be seen as a quality-impairing attribute: the incorporation of organic nitrogen compounds (albumin) may result in pressing problems and inorganic *nitrate* has to be viewed as a symptom of insufficient incorporation capacity of the system as a whole. Above all, it is very difficult to evaluate the *pH* behaviour of the *nitrate* ions in a mixed section containing dissociated and undissociated fruit acids, hydrogen ions included, and the alkali and alkaline earth salts of the fruit acids.

The *sugar* and *acid* content of the grapes is only in a physiological causal relationship with the *nitrogen* through the assimilation process which is essentially controlled by the *nitrogen*; although the acid behaviour may be determined by the *nitrate* concentration in the must. The evaluation of the entire must content structure *sugar:acid* + *acid* behaviour: *nitrogen* must therefore assume that the quantity of *sugar* used by the *nitrogen* unit is as high as possible and nitrogen-induced changes to the acid condition will be positive if they intensify the acid must character while retaining the acid structure (3.4.3). The previous empirical basis of evaluation is still very narrow, but it does provide an insight into the positive mode of action of *BIOSOL* (see Figures 28, 29, 30, 31, 32, 33, 34, 35).

As a general rule it is true that rising *sugar* concentrations (Figures 28, 29) and rising overall *acid* concentrations (see Figure 30) occur in conjunction with rising *nitrogen* concentrations. In this context, *sugar* increases (see Figure 31) and *acid* increases (see Figures 32, 33) are also linked to rising *nitrate* concentrations. The entire reference field is differentiated according to variety and reveals *Spätburgunder* and *Gutedel* to be the maxima and minimum of the *nitrogen* enrichment.

The different cultivation of the vines is expressed in the fact that the *BIOSOL* musts occupy the sections for the varieties with the lower *nitrogen* concentrations while the control musts occupy the sections with the higher *nitrogen* concentrations.

Accordingly, at the same *nitrogen* concentration, the *BIOSOL* musts have higher *sugar* and *acid* concentrations; this means a higher degree of quality productivity with *BIOSOL* cultivation and a lower degree with the control cultivation.

For specific varieties, the *nitrogen* concentrations of the control musts are higher than the *nitrogen* contents of *BIOSOL* musts. However, the higher *nitrogen* concentrations in the control musts are only linked to higher *acid* concentration; the *sugar* enrichment reaches its maximum below the *nitrogen* maximum and is higher in the *BIOSOL* must than it is in the control must. The action of nitrogen on the character of the acid is the opposite to its action on the *acid* content and is evidently controlled by its *nitrate* component (see below).

The data available indicate both *pH* reductions with rising *nitrate* concentrations (see Figure 34), and increases in the proportion of *free acid* in the *overall acid* (see Figure 35). These decreases and increases take place without any indication of a change to the *acid* structure according to (3.4.3). The action merely takes the form of a relative intensification of the acid character of the juices, with the *BIOSOL* musts which are more acid at the beginning (see (3.4.3) and Figures 25, 26, 27) and the control musts reducing their *pH* in parallel. These effects of the *nitrate* ions on the *pH* are evaluated as transformations: it has to be assumed that the *alkali* and *alkaline earth tartrates* and *malates* are transformed into *nitrates* and that the *tartrate* and *malate* ions are transformed into their acids. Evidently *BIOSOL* intensifies the whole transformation process and hence the overall quality structure of the must.

4. SUMMARY

The action and the mode of action of *BIOSOL* were studied in the Upper Rhine wine growing region over the past seven years. The investigations included a wide range of locations and a wide range of vine varieties. The study examined the effect on all vitality attributes of the vines and the most important quality features of the grapes and must. Special emphasis was placed on vine vitalization experiments. The evaluation was based on defined quality criteria and comparisons with the local, conventional and alternative organic vine cultivations.

On the basis of the results of this test series *R*, the action and the mode of action of *BIOSOL* may be characterised as follows:

(1) *BIOSOL* promotes the development and the vitality of all vine organs, both overground and underground. The root promotion includes the development of the site, the elimination of charring stimuli and hence the development of the root system according to the root network type. The stems look normal, *stunted vines* and *witch's broom* can be cured. The shoot condition is characterised by *normal shoots* and complete *wood ripening*. The leaf condition is characterised by *normal shape, normal coloration* and greatly reduced *leaf diseases;* the *foliage wall* is complete.

(2) The obvious great benefit of *BIOSOL* is its positive influence on the grape condition. The *uniform development* and *uniformity of ripening* of berries and bunches always achieve the maximum possible. In particular the *infestation resistance* is increased to the maximum level; the grapes are healthy, their phytogenic health is perfect.

(3) The third benefit of *BIOSOL* is to achieve a high-quality grape juice. The component structure is typically characterised by increased natural sugar content, increased dissociation of acids with a lower overall acid content and lower concentrations of nitrogen, entrapped nitrate.

The action and mode of action is modified by the conditions at the location and site. The *BIOSOL* application and all accompanying measures should therefore be adjusted to match the requirements at the site in question. The standard maintenance dose *B8* produces vine vitality and yield in average soils. The weaker maintenance dose *B6* is a limit dose which still produces vitality and yield on average damaged soils. The minimum dose *B4* can only be used as a maintenance dose on perfect soils or improved soils.

Site improvement is vital on dense, sluggish soils and recommended for average soils which include ploughed soils. The improvement measures required should be applied at the start and the maintenance fertilization should only be applied later. The improvement should be achieved using *BIOSOL* improvement doses. The average improvement dose is 2 x 1500 kg of *BIOSOL* per hectare; extreme cases require 3 x 2000 kg. The subsequent maintenance fertilization phase permits the dose to be reduced to *B6 - B4* with no problems.

There are numerous types of additional measures ranging from site-specific soil applications, particularly of magnesium, to supplementary leaf fertilization right up to sowing green cover to loosen the ground. The *BIOSOL* variants and the accompanying measures form a matched packet of measures which is adapted for each specific site and location.