# Fruit thinning in organic apple growing with optimized timing and combination strategies including (new) natural spray products and mechanical rope-devices

## Fruchtausdünnung im ökologischen Apfelanbau mit optimiertem Timing und Kombinationen von (neuen) natürlichen Mitteln und mechanischer Ausdünnung mit dem Fadengerät

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### Abstract

The aim of our study was to find new thinning methods for organic apple production able to fulfil the standards of Bio-Suisse, the main label organisation of the organic food sector in Switzerland.
The 14 trials reported were carried out during flowering period in 2003 and 2004 on the cultivars Pinova, Gala, Maigold, Elstar, Golden Delicious and Otava at different sites. The results confirm the good efficiency of mechanical thinning with the rope thinner and the thinning potential of vinasse, a by-product of molasses. Different vinasse products were tested (K-Vinasse, light-vinasse, N-Vinasse) and it was observed that those containing less nitrogen had a minor thinning effect. To avoid phytotoxicity on leaves, the concentration of N-Vinasse should not exceed 10 %. It seems that for Gala higher concentrations are needed, 7.5-10%, whereas with Maigold the efficacy of N-Vinasse was the same with the 2.5 % concentration as with 5 % and 10 %. On the other hand, partly good results were obtained when N-Vinasse was over-concentrated to 12 %, applied at warm weather and rinsed with clear water 4-6 hours later to avoid the phyto-toxic effect ("burn & rinse" method). Corn Oil, a commercial product from New Zealand, gave encouraging results. Lime sulphur didn't effectuate a significantly better thinning effect. The best method tested (fruit set reduction by 44 % and 26 % higher flower bud set next year) was achieved with a combination of rope thinner and N-Vinasse: rope thinner to thin the peripheral branches and to exert a physiological stress; and N-Vinasse to thin the inner parts of the canopy that the ropes can't reach. Other tested products did not show satisfying effects. Trials also confirmed the importance of applying these thinning agents at least two times, at the appropriate phenological stage of flowering period (F,) $F_2$ (full bloom) and G (= $F_2$ of the one-year old shoots). Hitting also the flowers of the one-year old shoots is important to break bi-annual bearing. Pollen tube growth was assessed by fluorescence microscopy. Almost complete inhibition of pollen tube germination was observed with Lime Sulphur and over-concentrated N-Vinasse (12 %) whereas with N-Vinasse at 5 % inhibition was 50 % less compared to untreated styles. Some contradictory results between different trials we ascribe to the air temperature during and after the treatments. It seems that treatments with N-Vinasse should be carried out at warm and sunny days above 16, better 18-20 deg. C. to maximize phytotoxicity on the styles; whereas we recommend to apply the rope thinner during periods of cold and clouded weather to maximize the thinning effect due to physiological stress and shortage of assimilates to the fruitlets. Concrete practical recommendations are given.

**Keywords:** Apple, organic, fruit thinning, blossom, pollen, germination, vinasse, rope thinner molasse, kitchen salt, lime sulphur, corn oil, Gala, Golden Delicious, Pinova

### Introduction

In certified organic apple production the use of chemical-synthetic thinning agents or plant hormones for crop regulation is not allowed. In some countries organic growers can use lime sulphur and oil products and achieve partly satisfying thinning results - but not sufficiently regularly. In Switzerland, however, neither of the mentioned products is allowed. As an alternative to very laborious hand thinning, Swiss growers can use the rope thinning device (Bertschinger et al. 1998). The disadvantages of the rope thinner are damages to the shoots, a too intensive physiological stress and the insufficient thinning effect in the inner parts of the canopy where the ropes cannot reach the flower buds. By increasing the travel speed of the tractor to 9-12 km $h^{-1}$

damages on shoots and leaves can be avoided (Weibel and Walther 2002); however, there is still a solution lacking to thin the inner parts of the tree. In a nutrition experiment for organic apple production, using N-Vinasse (a by-product of molasses) as a foliar fertilizer we accidentally discovered that N-Vinasse has a considerable thinning effect when applied during flowering period. Thus we started preliminary thinning experiments with N-Vinasse in 2001. The advantage of N-Vinasse is that it is an already approved product in organic agriculture for plant nutrition with no adverse side effects on beneficial insects (in contrast to oils, lime sulphur or soaps). It would be very complicated to get the organic registration approval for a specific growth regulator.
In our trials during 2003 and 2004 we aimed to develop practical recommendations for the optimal use of N-Vinasse and the rope device for organic crop load regulation. In particular we wanted to attain more detailed information on:

1) Thinning effect and phyto-toxic side effects of different concentrations of N-Vinasse
2) Importance of different application rates of N-Vinasse
3) Importance of different phonological stages
4) Comparison of different vinasse products to lime sulphur, corn oil, rope thinner
5) Potential of the “Burn and Rinse” approach (applying a high, phytotoxic molasse dose to “burn” the flower organs, followed 4-6 hours later by a treatment with clear water to rinse away the surplus, phytotoxic vinasse from the foliage.
6) Sensitivity of different cultivars to the treatments, concentrations etc.
7) Mode of action of the different products (inhibition of pollen tube growth)

## Material and Methods

The trials were carried out on a commercial organic fruit farm of family E. Vogt at Remigen in Switzerland (450 m above sea level, 9.1 deg. C average year temp.; 900 mm average rainfall, sandy loam; Ah layer with 3.3 % humus, 20 % clay, 32 % sand, 48 % sand, pH($H_2O$) 5.5-5.9) and at the fruit experimental station of Agroscope Wädenswil at Utwil (440 m above sea level, 7.7 deg. C average year temp.; 920 mm average rainfall, sandy loam; Ah layer with 4.0 % humus and pH($H_2O$) 6.6-7.4). The detailed experimental information is given in Tab. 1.

When the treatments started all plots showed a more than medium to high flowering intensity. Three times after the last treatment we assessed i) incidence of phytotoxic effects on leaves and fruitlets, ii) crop charge, iii) russetting on fruits and iv) retarded shoot elongation (over-vigorous shoot growth as a compensation reaction to a treatment induced physiological shock with a temporally stop of growth). The counting of the fruit set was carried out after June drop. At all directions of the compass representative branches (2-5 per sector) all flower clusters were counted and classified by the number of fruit they carried (0, 1, 2, ≥ 3), thus allowing to calculate both, the number of flower buds and the number of fruit per flower bud. All times the 1year old shoots were counted separately from those on the older wood.

In order to assess the treatments’ influence on bi-annual bearing, the results of thinning efficacy were completed with a counting of the flower set in the following spring. Therefore flowering buds and leaf buds were counted separately in order to achieve a quantitative, relative flowering intensity (percentage).

The statistical analyses were carried out with ANOVA tests including testing the residuals for normal distribution. Where ANOVAs showed significant treatment influences ($p \leq 0.05$) multiple mean comparisons were carried out with a direct, post-ANOVA Tukey test at the same error probability level (JMP v. 5.1; SAS inc.).

To assess the mode of action of the different products, we measured in 2003 the inhibition of pollen tube growth. Therefore, just before spraying the trees, we had tagged 10 newly opening, thus not yet pollinated, inflorescences per tree and treatment in the “small plots” (50 flowers per treatment) with a coloured plastic ribbon. Five days later we “harvested” the tagged inflorescences and conserved them in sodium-sulphite. To colour the styles we used 0.1 % aniline blue before autoclavation. Then petals and stamens were removed with a scalpel. In the remaining organs, style and ovary, the pollen grains and tubes could be counted under the fluorescent microscope.

**Tab.1:** Description of trials and treatments carried out in 2003

| Site, Plot description | cultivar (trees per plot) | Trial theme; products, application rate, concentration and phenological stage |
|---|---|---|
| **Trials at Remigen** | | |
| "Big plots", 2 randomized replications per treatment (1000 l water/ha). Treated with usual turbo sprayer | Pinova[1] (18)<br>Otava[2] (21) | **Tests with promising methods under close to practice conditions**<br>1) untreated control<br>2) rope thinner (2 x at $F_2$ and $F_{2\ 1ys}$*)<br>3) N-Vinasse Biorga (90 g N/l), 5 vol.% (2 x at $F_2$ and $F_2$ 1ys)<br>4) N-viasse Biorga (90 g N/l), 5 vol.% (2 x at $F_2$ and $F^2$ 1ys)<br>5) N-Vinasse Biorga (90 g N/l), 5 vol.% (1x at $F_2$)<br>6) K-Vinasse Biorga (87 g K/l) 5 vol.% (2x at $F_2$ and $F_2$ 1ys)<br>7) Rope thinner (1 x at $F_2$) + N-Vinasse 5% (1 x at $F_2$ 1ys) |
| "Small Plots" (treated by backpack sprayer), no block replications of the treatments | Pinova[3] (5) | **Preliminary tests with new products**<br>1) untreated control<br>2) N-Vinasse 12 vol. % + rinsing after 4 h with clear water ("burn and shower"), (2 x at $F_2$ and $F_{2\ 1ys}$*)<br>3) N-Vinasse Biorga 5 vol.% (2 x at $F_2$ and $F_{2\ 1ys}$)<br>4) K-Vinasse Biorga (87 g K/l) 5 vol.% (2x at $F_2$ and $F_{2\ 1ys}$)<br>5) Vinasse-light Biorga (30 g N/l, 30 g K/l) 5 vol.% (2 x at $F_2$ and $F_{2\ 1ys}$)<br>6) Formulated Corn Oil (NZ) % % (2 x at $F_2$ and $F_{2\ 1ys}$)<br>7) Lime Sulphur (Polisenio) 2 vol. % (2 x at $F_2$ and $F_{2\ 1ys}$<br>8) Salt water 10 % (2 x at $F_2$ and F2 $_{1ys}$)[6] |
| | Maigold[4] (5)<br>Gala[5] (5) | **Concentration series with N-Vinasse**<br>1) untreated control<br>2) N-Vinasse 2.5 vol.% (2 x at $F_2$ and $F_{2\ 1ys}$)<br>3) N-Vinasse 5.0 vol.% (2 x at $F_2$ and $F_{2\ 1ys}$)<br>4) N-Vinasse 10.0 vol.% (2 x at $F_2$ and $F_{2\ 1ys}$) |
| | Maigold[4] (5) | **Optimal application stage of N-Vinasse**<br>1) untreated control<br>2) N-Vinasse 5 vol.% (2 x at F and $F_2$)<br>3) N-Vinasse 5 vol.% (3 x at F, $F_2$ and $F_{2\ 1ys}$)<br>4) N-Vinasse 5 vol.% (2 x at $F_2$ and $F_{2\ 1ys}$)<br>5) N-Vinasse 5 vol.% (1 x at $F_2$)<br>6) N-Vinasse 5 vol.% (3 x at $F_{2\ 1ys}$) |
| Conditions during application | | F (king flower open); April 22; 20,0 deg. C; 0 mm rain; 29 % rel. H.<br>$F_2$ (full bloom); April 24; 24.3 deg. C.; 0 mm rain; 63 % rel. H.<br>$F_{2\ 1ys}$ (F2 on 1y. old shoots); April 28; 21.7 deg. C; 1.1 mm; 92 % rH. |
| **Trials at Wädenswil (Golden) and Uttwil (Gala)** | Golden Delicious[7] (8)<br>Gala[8] (8) | **Optimal application stage of N- and K-Vinasse"**<br>1) N-Vinasse 7.5% (1 x at $F_2$)<br>2) N-Vinasse 7.5% (2 x at $F_2$ and $F_{2\ 1ys}$)<br>3) N-Vinasse 7.5% (3 x at $F_2$ and $F_{2\ 1ys}$ and H)<br>4) K-Vinasse 7.5% (1 x at $F_2$)<br>5) K-Vinasse 7.5% (2 x at $F_2$ and $F_{2\ 1ys}$) |
| Conditions during application | Wädenswil | $F_2$ (full bloom); April 28; 13.0,0 deg. C; 0 mm rain; 64 % rel. H.<br>$F_{2\ 1ys}$ ($F_2$ 1y. old shoots); April 30; 13.0 deg. C; 0 mm rain; 78 % rel. H.<br>H (Ending Bloom); Mai 2; 18.0 deg. C; 64 % rel. H. |
| | Uttwil | $F_2$ (full bloom); April 28; 15.8 deg. C; 0 mm rain; 55 % rel. H.<br>$F_{2\ 1ys}$ ($F_2$ 1y. old shoots); Mai 1; 15.5 deg. C; 0 mm rain; 55 % rel. H.<br>H (Ending Bloom); Mai 5; 21.0 deg. C; 47 % rel. H. |

* $F_2$ (full bloom) on 1year old shoots, mostly 2-5 days later than $F_2$ on older wood
[1] Rootstock J-TE-E (in 1st replicate), M9 vt in 2nd replicate, 1st leaf in 1999, 1 x 3 m planting distance, free spindle
[2] Rootstock J-TE-E; 1st leaf in 2000, 1 x 3 m planting distance, free spindle
[3] Rootstock M9v; 1st leaf in 1997, 1 x 3 m planting distance, free spindle
[4] Rootstock JM27; 1st leaf in 1993, 1 x 3.2 m planting distance, free spindle
[5] Rootstock M9vt; 1st leaf in 1992, 0.80 x 2.70 m planting distance, free spindle
[6] 10 % conc. by mistake, should have been 1 %. Very severe phyto-toxicity
[7] Rootstock P22; 1st leaf in 1995; 0.8 x 3.4 m planting distance, free spindle
[8] Rootstock M9 T337; 1st leaf in 1998; 0.6 x 3.5 m planting distance, free spindle

**Tab.2:** Description of trials and treatments carried out in 2004

| Site, Plot description | cultivar (trees per plot) | Trial theme; products, application rate, concentration and phenological stage |
|---|---|---|

| **Trials at Remigen** | | |
|---|---|---|
| “Big plots”, 2 randomized replications per treatment (1000 l water/ha). Treated with usual turbo sprayer | Pinova[1] (18)<br><br>Elstar[2] (18) | **Tests with promising methods under close to practice conditions**<br>1) Untreated Control<br>2) Rope thinner 1x<br>3) Rope thinner 1x + N-Vinasse 5 % 1x<br>(Biorga-N 90 g N/l, 20 g K/l)<br>4) N-Vinasse 5 % (3 x at F, $F_2$ and $F_{2\ 1ys}$)<br>5) N-Vinasse 5 % (2 x at $F_2$ and $F_{2\ 1ys}$)<br>6) N-Vinasse 12% (2 x at $F_2$ and $F_{2\ 1ys}$)<br>7) K-Vinasse 3 x (3 x at F, $F_2$ and $F_{2\ 1ys}$)<br>Biorga-K (87 g K/l, 30 g N/l)<br>8) Light Vinasse 5 % (3 x at F, $F_2$ and $F_{2\ 1ys}$)<br>Bioga-Light (30 g N/l, 30 g K/l)<br>9) Corn Oil 5 % (3 x at F, $F_2$ and $F_{2\ 1ys}$)<br>10) Lime Sulphur 2 % (3 x at F, $F_2$ and $F_{2\ 1ys}$) Polisenio |
| “Small Plots” (treated by backpack sprayer), no block replications of the treatments | Golden Delicious (18) | Risk for russeting and preliminary tests with vinegar,<br>1) untreated control<br>2) N-Vinasse 5 % (3 x at F, $F_2$ and $F_{2\ 1ys}$)<br>3) N-Vinasse 12 vol. % + rinsing after 4 h with clear water (“burn and shower”), (2 x at $F_2$ and $F_{2\ 1ys*}$)<br>4) Corn Oil 5 % (3 x at F, $F_2$ and $F_{2\ 1ys}$)<br>5) Vinegar 5 % (3 x at F, $F_2$ and $F_{2\ 1ys}$)<br>organic apple vinegar (Coop), 45 g acetic acid/l<br>6) Vinegar 10 % (3 x at F, $F_2$ and $F_{2\ 1ys}$)<br>organic apple vinegar (Coop), 45 g acetic acid/l |
| | Topaz (18) | **“Concentration series with N-Vinasse”**<br>5) untreated control<br>6) N-Vinasse 2.5 vol.% (2 x at $F_2$ and $F_{2\ 1ys}$)<br>7) N-Vinasse 5.0 vol.% (2 x at $F_2$ and $F_{2\ 1ys}$)<br>8) N-Vinasse 10.0 vol.% (2 x at $F_2$ and $F_{2\ 1ys}$) |
| | Maigold[4] (5) | **“Optimal application stage of N-Vinasse”**<br>7) untreated control<br>8) N-Vinasse 5 vol.% (2 x at F and $F_2$)<br>9) N-Vinasse 5 vol.% (3 x at F, $F_2$ and $F_{2\ 1ys}$)<br>10) N-Vinasse 5 vol.% (2 x at $F_2$ and $F_{2\ 1ys}$)<br>11) N-Vinasse 5 vol.% (1 x at $F_2$)<br>12) N-Vinasse 5 vol.% (3 x at $F_{2\ 1ys}$) |
| Conditions during application | | F (king flower open); April 30; 13.6 deg. C; 0 mm rain; 70 % rel. H.<br>$F_2$ (full bloom); Mai 3; 14.0 deg. C.; 0 mm rain; 68.3 % rel. H.<br>$F_{2\ 1ys}$ (F2 on 1y. old shoots); Mai 10; 11.0 deg. C; 0 mm; 79 % rel. H. |
| **Trials at Wädenswil (Golden) and Uttwil (Gala)**<br><br>(treated by backpack sprayer) | Golden Delicious7 (8) | **“Optimal application stage of N- and K-Vinasse”**<br>1) N-Vinasse 5 % (1 x at F)<br>2) N-Vinasse 5% (2 x at F and $F_{1ys}$)<br>3) N-Vinasse 5% (3 x at F and $F_{1ys}$ and H)<br>4) K-Vinasse 5 % (1 x at F)<br>5) K-Vinasse 5% (2 x at F and $F_{1ys}$)<br>6) K-Vinasse 5% (3 x at F and $F_{1ys}$ and H) |
| (treated by backpack sprayer) | Gala8 (8) | **“Optimal application stage and concentration of N-Vinasse”**<br>1)-3) N-Vinasse 5 %, 7.5 %, 10 % (1 x at F)<br>4)-6) N-Vinasse 5 %, 7.5 %, 10 % (2 x at F and $F_{1ys}$)<br>7)-9) N-Vinasse 5 %, 7.5 %, 10 % (3 x at F and $F_{1ys}$ and H) |
| Conditions during application | Wädenswil | F (king flower open); April 30; 17.0 deg. C; 0 mm rain; 51 % rel. H.<br>$F_2$ (full bloom); Mai 3; 12.0 deg. C; 0 mm rain; 59 % rel. H.<br>$F_{2\ 1ys}$ ($F_2$ 1y. old shoots); Mai 10; 10.8 deg. C; 58 % rel. H. |
| | Uttwil | F (king flower open); April 29; 19.5,0 deg. C; 0 mm rain; 51 % rel. H.<br>$F_2$ (full bloom); Mai 3; 17.0 deg. C; 0 mm rain; 59 % rel. H.<br>$F_{2\ 1ys}$ ($F_2$ 1y. old shoots); Mai 11; 16.6 deg. C; 58 % rel. H. |

* $F_2$ (full bloom) on 1year old shoots, mostly 2-5 days later than $F_2$ on older wood

[1] Rootstock J-TE-E (in 1st replicate), M9 vt in 2nd replicate, 1st leaf in 1999, 1 x 3 m planting distance, free spindle

[2] Rootstock M 27, 1st leaf in 1998; 1 x 3 m planting distance, free spindle

[3] Rootstock M9 vt; 1st leaf in 1997, 1 x 3 m planting distance, free spindle

[4] Rootstock M27; 1st leaf in 1993, 1 x 3.2 m planting distance, free spindle

[5] Rootstock M9vt; 1st leaf in 1992, 0.80 x 2.70 m planting distance, free spindle

[6] 10 % conc. by mistake, should have been 1 %. Very severe phyto-toxicity

[7] Rootstock P22; 1st leaf in 1995; 0.8 x 3.4 m planting distance, free spindle

[8] Rootstock M9 T337; 1st leaf in 1998; 0.6 x 3.5 m planting distance, free spindle

**Tab. 3:** pH and Conductivity of the tested products

| Product | pH | Conductivity |
|---|---|---|
| N-Vinasse 5% | 4.96 | 14.13 |
| K-Vinasse 5% | 5.27 | 10.67 |
| Light Vinasse 5% | 4.22 | 9.6 |
| Corn Oil 5% | 7.24 | 1.13 |
| Lime-sulphur 2% | 9.75 | 5.76 |
| Salt 10% | 7.14 | 20 |

## Results

Because June drop was exceptionally high in 2003 and relatively high in 2004, even control trees were highly, almost too much thinned. This partly explains why we did not observe large differences between the treatments. Statistical analysis confirmed these observations.

### 1. Practical-like plots in 2003

Considering the fruit charge in the practical-like plots of both cultivars Pinova and Otava, multifactorial analysis revealed no cultivar effect but a significant treatment effect ($p < 0.0001$) as well as an interaction between treatment and cultivar ($p = 0.0009$). Thus, for the following analyses cultivars were considered separately.

With Pinova, treatments had a significant statistical effect ($p < 0.0001$) and branches age was almost significant ($p = 0.0584$). There was no interaction between both parameters. We found, compared to control trees with $\bar{x} = 67 \pm 4$ fruit/100 flower clusters a significantly thinning effect of minus 25% in trees when thinned with a rope thinner ($\bar{x} = 50 \pm 3$ fr/100 flcl) and of 40% when the rope thinner was combined with N-Vinasse ($\bar{x} = 40 \pm 3$ fr/100 flcl) ($p < 0.05$ with Tukey-Kramer; Fig.1). Two applications of N-Vinasse also tended to decrease the fruit charge (-12%; $\bar{x} = 59 \pm 4$ fr/100 flcl) but it was not significantly different from the control trees. K-Vinasse had a slightly fruit-keeping (fertilising?) effect with a slightly higher fruit set than untreated control ($\bar{x} = 0.72 \pm 0.03$ fr/cl) and their leaves were particularly green and vigorous. Trees treated only 1x with N-Vinasse application did not show any difference from control trees ($\bar{x} = 0.65 \pm 0.04$ fr/100flcl). When analysing 1-year-old branches and older branches separately, we obtained the same treatment ranking and significance of differences.

In spring 2004 the return to bloom of these Pinova plots reflected, with significant differences, the thinning effect of the treatments in 2003: highest flower set with 46.7 % flower buds on the total number of buds was found in the combined treatment “rope thinner plus N-Vinasse”. The untreated control, K-Vinasse 5% 2 x and N-Vinasse 5 % 1x had lowest return to bloom rates (34.1 to 39.9 % flower buds per total buds; Fig. 2).

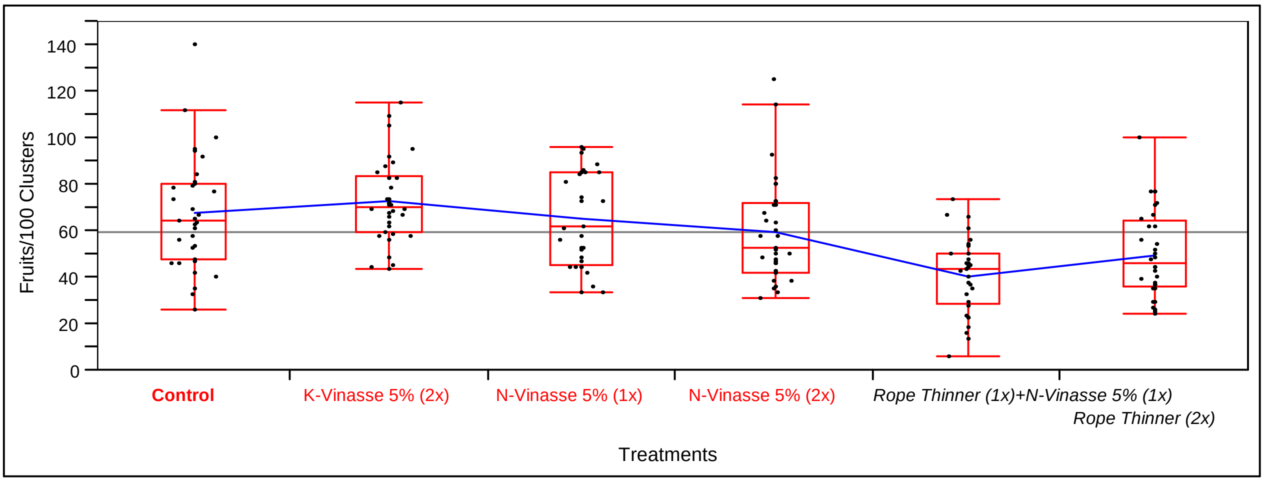


**Figure 1:** Effect of 5 different thinning methods on cultivar Pinova in the practical-like plots at Remigen 2003

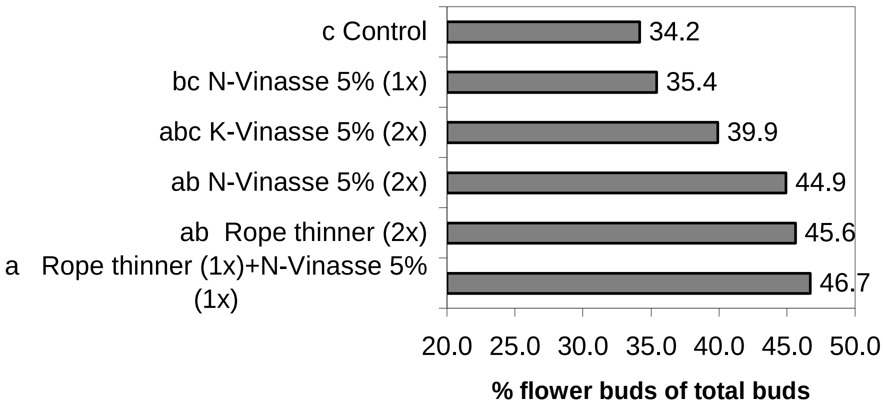


**Figure 2:** Return to bloom in spring 2004 with cultivar Pinova, practical-like plots. Percentage of flower buds of total number of buds in 5 different thinning treatments.

With cultivar Otava in the practical-like plots the factors treatment with $p = 0.0498$ and branch age with $p < 0.0001$ showed both significant effects on fruit charge but not the interaction between the two factors. With this variety, on these young trees and in the condition with a very high natural June drop the different treatments resulted in very similar fruit charges, varying between 51 ± 3 fruit/100 fruit clusters for control trees and 66 ± 6 for trees treated with N-Vinasse 1x; thus even performing a fruit-keeping, fertilizing effect. Analysing old and new branches of Otava separately did not reveal any difference either. Accordingly, the return to bloom results with Otava didn't reveal relevant treatment differences (data not shown).

## 2. Small plots in 2003

The different new products tested in these small plots of cultivar Pinova revealed no significant thinning effect, except for the overdosed treatment with kitchen salt, where serious leaf burning occurred and the mean fruit charge per 100 fruit clusters went down to almost zero ($\bar{x}$ = 7 ± 2). The concentration recommended was much too high (10 instead of 1 %), so that trees almost died. K-Vinasse ($\bar{x}$ = 70 ± 2) and the "Burn and Rinse"-method (N-Vinasse 12% + rinsing with water) had with $\bar{x}$ = 70 ± 6 fr/100flcl a 53% lower fruit charge than control trees ($\bar{x}$ = 148 ± 13). However, due to a high variation between the trees this difference was not significant (Fig. 3). Lime-sulphur had no better result than the other products.

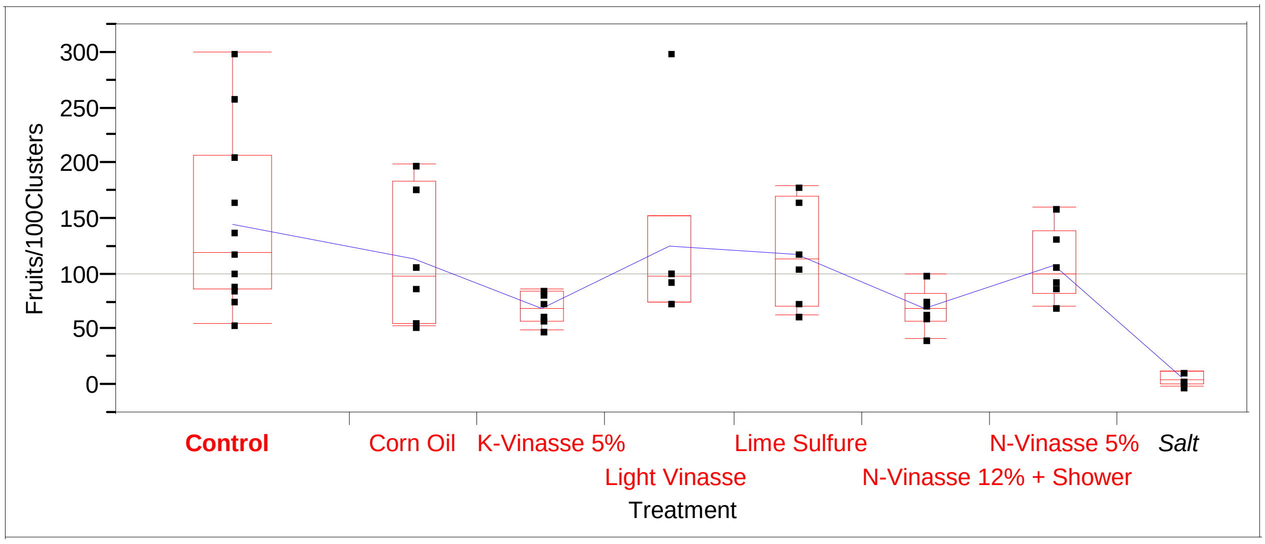


**Figure 3:** Thinning effect on cultivar Pinova (small plots) of 7 different thinning treatments. Remigen 2003

### 3. tage and frequency of N-Vinasse application (2003)

In this experiment with cultivar Maigold the treatment effect was almost significant ($p = 0.0505$) and branche age had a high significant effect ($p < 0.0001$). There was no interaction between both factors. The lowest fruit charge was found with 3 applications (-23%; $\bar{x} = 53 \pm 10$ fr/100 flcl) and highest at untreated control trees ($\bar{x} = 70 \pm 9$). There was no significant difference between the phenological stage and the frequency of applications due to an inconsistent results in treatment F, $F^2$. When we considered only the young branches, there was no significant difference between treatment either, but a tendency that young branches treated at $F^2_{1y}$ stage to have less fruits per cluster (-33 %, $\bar{x} = 32 \pm 6$ for treatment at F,$F^2$,$F^2_{1y}$, $40 \pm 3$ for $F^2_{1y}$ and $41 \pm 7$ for $F^2$, $F^2_{1y}$) compared to control trees ($\bar{x} = 48 \pm 8$) and trees not treated at $F^2_{1y}$ (Fig.3). When considering only old branches, there was a significant difference between trees treated at $F^2$ stage ($\bar{x} = 74 \pm 0.3$) and at $F^2_{1y}$ stage only ($\bar{x} = 92 \pm 8$), proving that the N-Vinasse application acts specifically on newly opened inflorescences. Furthermore, trees treated at these blooming stages showed a significant lower fruit charge than trees treated only by $F^2_{1y}$ stage. Return to bloom followed the same trend, however with no significant differences (data not shown).

### 4. Effect of different N-Vinasse concentrations

The factor concentration interacted significantly with the cultivar. With Maigold all three concentrations (2.5, 5.0 and 10 %) caused a significant but similar effect with a reduction of around 23% ($\bar{x} = 54$ fr/100 flcl) compared to 70 at untreated control ($p = 0.02$). Phytotoxic reactions increased slightly with increasing concentrations (data not shown). The Gala trees had a higher fruit charge, sometimes twice than Maigold. With Gala, treatment and branch age had a significant effect ($p = 0.0332$ and $p = 0.0018$, respectively): Only trees treated with 10% N-Vinasse had a lower charge ($\bar{x} = 90 \pm 1$) than the control ($\bar{x} = 113 \pm 21$). Whereas N-Vinasse 2.5% had an almost a fruit-keeping effect ($\bar{x} = 155 \pm 22$), and with 5 % no difference to the control occurred.

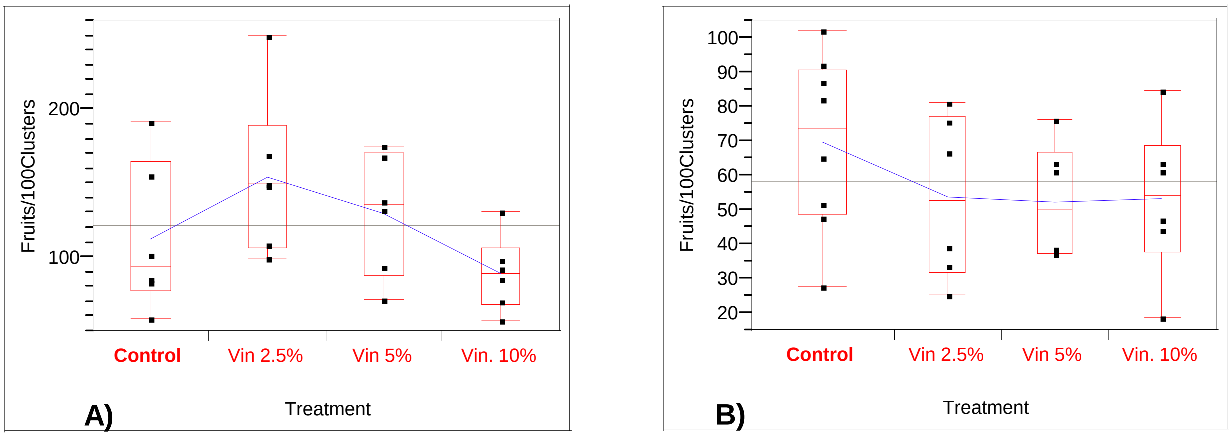


**Figure 4:** Number of fruit per cluster in A) Gala and B) Maigold trees for different concentrations of N-Vinasse.

## 5. Trials at Wädenswil (Golden D.) and Uttwil (Gala) in 2003

In the parallel experiments with Gala in Uttwil and Golden Delicious in Wädenswil to test the effect of application frequency (1, 2 and 3 applications) and the difference between N- and K-Vinasse (always at 7.5 % concentration) only on Gala with treatments N-Vinasse 2 and 3 times applied a significant, but still too little thinning effect of 18 % and 24 %, respectively, could be found. We assume that this lack of efficacy is due to unfavourable low air temperatures mainly while the applications at F and $F^2$ (13 deg. C with Golden, 15 deg. C with Gala, Tab. 1). Unfavourable was also the fact, that the third application when it was warmer (above 18 deg.) was too late in terms of the number of open inflorescences (rather stage H than $F^2$ on on-year-old shoots). Consequently, only on Gala and with the treatments 2 and 3 times N-Vinasse there was a 14 % higher, thus slightly better return to bloom Index to be found compared to control (data not shown).

## 6. Pollen germination and pollen tube growth

After square root transformation of the data, the treatments with kitchen salt and lime-sulphur revealed a significant lower number of grown pollen tubes at the top third of the styles (Fig. 5). In contrast to that, K-Vinasse seemed to have even a positive influence on tubes growth, tubes being significantly more numerous than in control blossoms. No significant difference was found for the other treatments on the number of pollen tubes.
On the stigma surface, however, blossoms treated with lime-sulphur, kitchen salt, 12% Vinasse, 5% Vinasse and Corn Oil all had significantly less germinated pollen than untreated ones, with a maximum of minus 82% by the ones treated with lime-sulphur and 12% Vinasse (Pic. 1). Stigmata surfaces of blossoms treated with salt, lime-sulphur and 12% Vinasse showed a deteriorated surface. Tubes longer than top third were only observed with blossoms treated with K-Vinasse and 5% N-Vinasse.
In the concentration experiments with Gala, we found significantly less germinating pollen on the style surface of Gala flowers treated with 10% N-Vinasse, but at the top third of the style, no difference was found between 10% and control. On the contrary, there were more pollen tubes in flowers treated with 2,5% N-Vinasse than by control. The same observation was made with Maigold, where we found a significant decrease of germinating pollens on the surface of stigmata exposed to 10% N-Vinasse. But there we counted slightly more pollen at the top third of the style compared to the control.

The behaviour found on the pollen germination and the pollen tube growth are in good accordance with the findings in the field experiments.

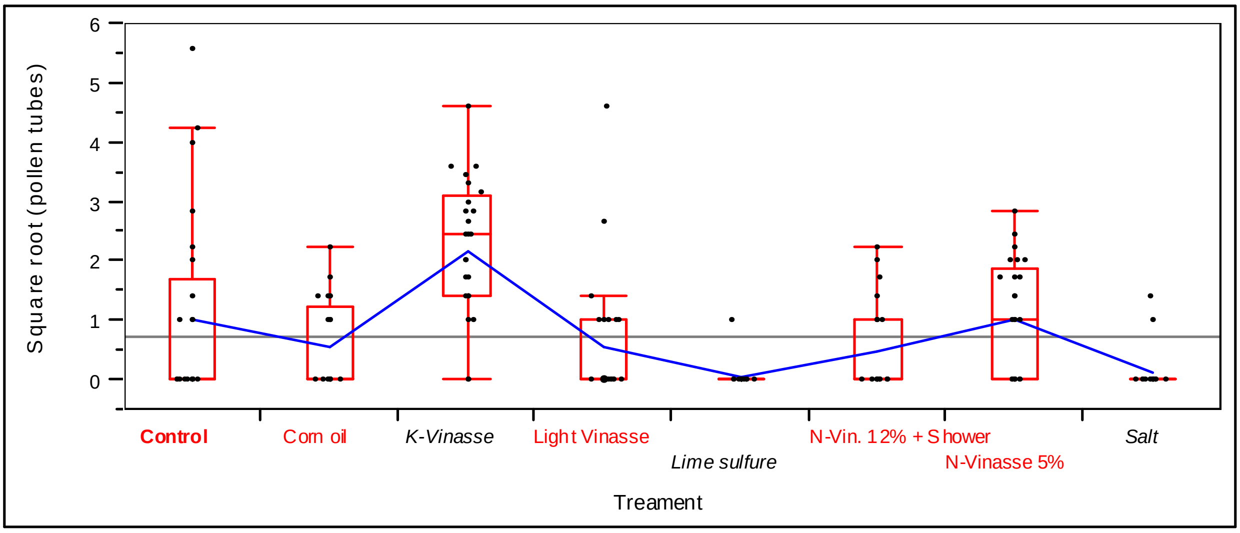


**Figure 5:** Square root of the number of pollen tubes within the first third of the style length of flowers subjected to 7 thinning methods compared to control.

## 7. Pinova practical-like plots 2004

In 2004 the fruit charge in the practical-like plots of both cultivars Pinova and Elstar cultivars, was significantly influenced by factors cultivar and treatment (both $p < 0.0001$). Interaction between treatment and cultivar was also significant ($p < 0.0001$). Thus, for the following analyses cultivars were considered separately.

With Pinova, treatments and branch age had a significant statistical effect ($p < 0.0001$). We found a significantly thinning effect of 22% in trees when thinned with a rope thinner ($\bar{x}$ = 78.7 ± 4.2 fruits/100 flower clusters) and of 28% when the rope thinner was combined with N-Vinasse ($\bar{x}$ = 85.5 ± 4.9 fr/100 flcl) compared with control trees ($\bar{x}$ = 110.00 ±5.1 fr/100 flcl) ($p < 0.05$ with Tukey-Kramer; Fig.6). The other products and methods gave similar results that were not significantly different from the control trees between 91.2 and 102.8 fr/100 flcl).

Return to bloom in 2005 was in neither treatment different from the untreated control (53.2 % flower bud/total buds; data not shown)

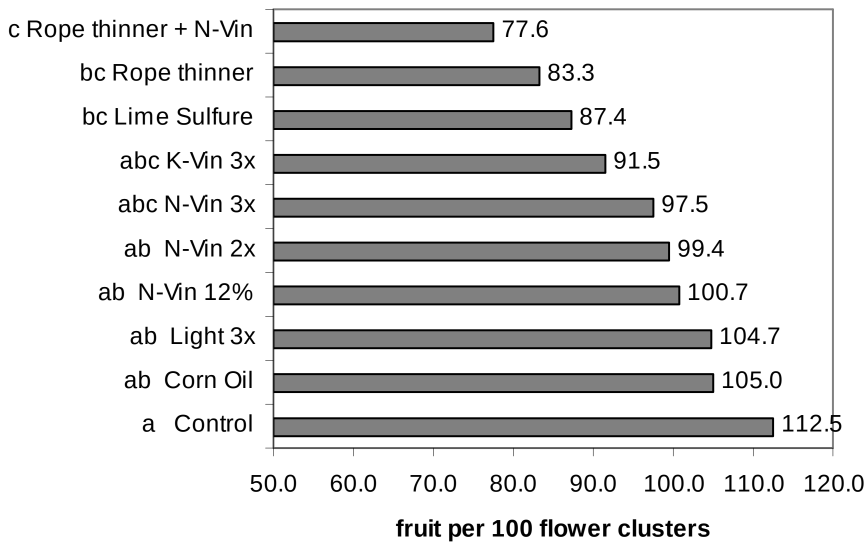


**Figure 6:**
Effect of 9 different thinning methods on cultivar Pinova. Remigen 2004

With Elstar, the factor branch age (with $p < 0.0001$) had a significant effect on fruit charge but not the treatment or the interaction between both parameters (data not shown). The treatment effect on fruit charge was varying between 62.1 fruits/100 flcl for trees thinned with lime sulphur and 72.6 for trees thinned with the rope thinner. Analysing old and new branches separately did not reveal any treatment difference neither.

## 8. Small plots to test new products in 2004

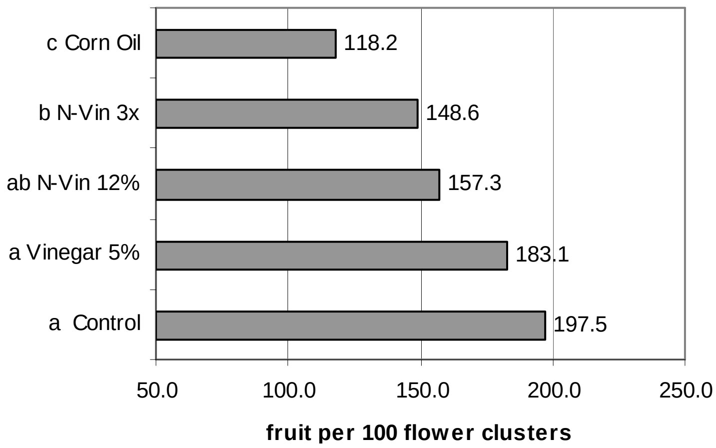


**Figure 7:** Effect of different thinning agents on cultivar Topaz. Remigen 2004 (results of vinegar 10% not shown because of missing data).

There were significant cultivar and treatments effects (p <0.0001) on the fruit charge between Golden Delicious and Topaz trees. The interaction treatment x cultivar was also statistically highly significant (p <0.0001). There was no treatment effect with Golden D. but a significant effect with Topaz: trees treated with Corn Oil carrying 54% less fruit ($\bar{x}$ = 97.57 ±19.30 fr/100flcl) than the control ($\bar{x}$ = 197.5.4 ±12.20 fr/100 flcl; Fig. 7). The N-Vinasse treatments either 3 x or 12 % + rinsing also showed acceptable thinning effects (with around 150 fruits/100 flcl). The tests with organic vinegar at 5 % concentration revealed no significant thinning effect (neither with 10 %, these data are not shown due to missing data). No phytotoxic reactions could be distinguished on these trees.

## 9. Parallel experiments at Uttwil (Gala) and Wädenswil (Golden D.) in 2004

In the parallel trials at Uttwil with Gala and at Wädenswil with Golden D. to test again the influence of frequency (1,2,3 times), concentrations (5, 7.5 and 10%, with Gala only) of N-Vinasse and K-Vinasse (with Golden D. only), we found to some extent contra dictionary results. With Golden D. neither the N- nor the K-Vinasse (always at 5 % concentration) induced a significant thinning effect (data not shown). With Gala, however, (Fig. 8) there were clear and good thinning effects with N-Vinasse, when applied at least 2 times. E.g. 2 applications at 7.5 % effectuated just the ideal fruit load as achieved with hand thinning (50 fr/100 flcl, see vertical line left) and was even better than the chemical standard (81 fr/100 flcl, line right). In concentrations of 7.5 and 10 % a 3-fold application lead to overthinning (37 and 28 fr/100 flcl, respectively). The reason for the well working thinning effect with Gala we suppose in the ideal temperatures during all 3 applications of 19.5, 17.0 and 16.6 deg. C; whereas in the trial with Golden day temperatures were considerably lower at 17.0, 12.3 and 11.0 deg. C. (Tab. 2).

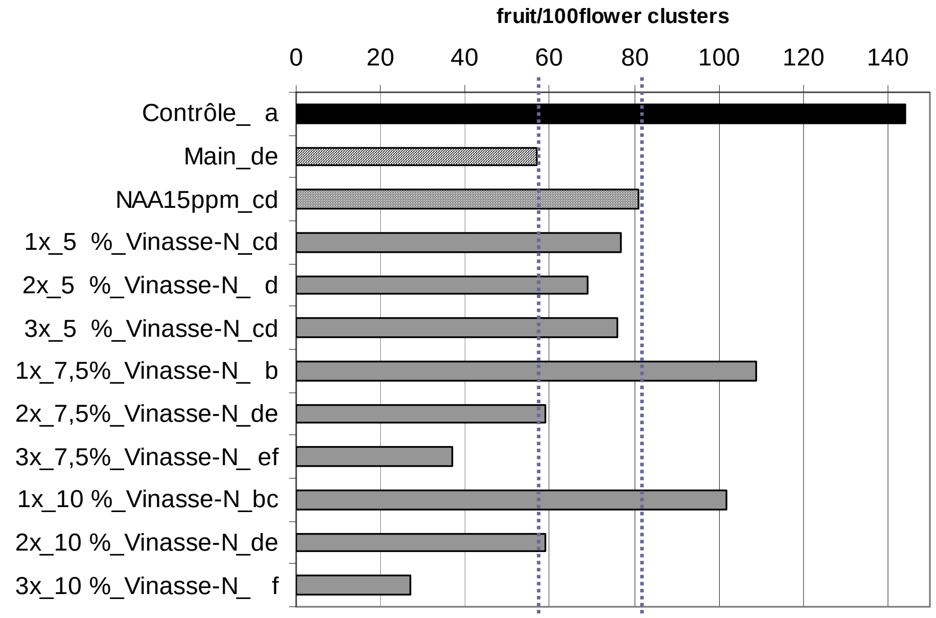


**Figure 8:** Effect of different thinning treatments with cultivar Gala at Uttwil 2004. The line on the left is the reference of optimal fruit load (hand thinning), the line on the right is the fruit load achieved with the chemical standard treatment.

### 10. Observations on side effects

In both years, field observations on negative or positive side effects of the different treatments were consistent with the quantitative results. Only rarely, we observed small necrosis on leaf boarder with N-Vinasse 12% + rinsing smaller leaves with 3 x N-Vinasse, as well as slight stress symptoms (retarded leaf and shoot growth) with lime sulphur. As expected the use of the rope thinner driven at high speed 10 km/h caused only slight stress. All these phytotoxic reactions disappeared after two weeks.

## Discussion

At Remigen, in both years, there occurred a relatively high natural June drop which “hides” to a certain extent the thinning effect of the treatments. Nevertheless, with Pinova in both years the treatment effects were significant and proved the good thinning potential of i) the rope device (Bertschinger et al. 1998), ii) of the N-Vinasse when applied at least 2 times or iii) by the “burn and rinse” method and iv) of the combination of the two treatments, presently the most efficient organic thinning method (Weibel and Chevillat, 2004). The reason for a good success of the combined method is not only the fact, that the rope thinner touches the outer and the N-Vinasse the inner part of the tree; but it also combines two complementary modes of action: the rope thinner triggers a physiological shock that finally leads to a shortage of assimilates in the fruitlets and their abscission, and the N-Vinasse acts phytotoxic to the sensitive flower organs and thus inhibits pollen germination or pollen tube growth. Operated at high speed (9-11 km/h) the rope thinner didn’t cause relevant damages on leaves and wood as already shown by Weibel and Walther 2002 and Walther 2002.

On the other hand there were repeatedly “disappointing” results with the N-Vinasse treatments e.g. with Otava and Golden (Wädenswil) in 2003 or with Elstar and Golden at both sites in 2004. There, the sub-optimal efficacy can be partly explained by the fact that it was not always possible to apply the N-Vinasse when a maximum of inflorescences were open. However, combining the experiences of all the 14 trials described, we suppose that beside application at the good moment (phonological stage), it is decisive to apply the treatment at the adequate temperature. It seems that day temperatures should be above 16 deg. C. better 18-20 deg. C. for N-Vinasse treatments to provide a good efficacy.

Matching blooming time for blossoms on old and young wood separately is critical to obtain optimum thinning results and has already been pointed out by Dennis (2000). Flowers on old wood normally open a few days before the ones on one-year-old wood. Although final fruit set on these shoots is low, flower thinning on new branches is important to control bi-annual bearing, because they carry a lot of inflorescences that for a while will become gibberelin-dispensing fruitlets.

The concentration experiments with Maigold and Gala indicated that for optimal results the N-Vinasse concentration can/should be adapted to the cultivar. However the experience teaches us that the range between to week and too strong effects varies between 5-10 %. These observations are in agreement with the results obtained in South Tyrol by Kelderer et al. (2004): they found a thinning effect with Vinasse products, in some cases better than with lime sulphur. On the other hand they observed more severe phytotoxic effects, like rust and necrosis than we did. To overcome the risk of phytotoxicity we developed the “burn and rinse” method, where we spray N-Vinasse at a high, certainly tissue “burning” dose of 12 % but “rinse” the trees with clear water 4-6 h later. The thinning effect with “burn and rinse” was satisfactory and caused less phytotoxicity compared to 10% N-Vinasse. Thus, we consider “burn and rinse” as feasible thinning method.

Alternative products like Light- and K-Vinasse or vinegar, in general showed too little effect. With these products we even observed a partly fertilising, fruit keeping effect.

In experiments carried out in New Zealand a formulated Corn Oil had a good thinning effect (Steven McArtney, personal communication), but we could not consistently confirm these results. However, the effect of Corn Oil was in the range of lime-sulphur application. We therefore carried out refined experiments with Corn Oil in 2005.

Microscopic analyses did not reveal a clear inhibition of the pollen tube growth by the new products, except for Lime-sulphur and salt. However, it seems that some products deteriorate the style surface, preventing pollen germination there. Indeed, in some cases, we could observe a desiccation of the stigmata surface. This could be due to osmotic reactions induced by the high product concentration. We also observed significantly less germinated pollen on the stigmata of blossoms treated with Corn Oil, N-Vinasse 5% and N-Vinasse12% followed by water rinsing. But, when the pollen tubes have already germinated and grown down the style, it is likely that the products have no influence anymore and that even a fertilisation effect can occur. In addition, these products may act on other physiological or hormonal processes, too. Our complementary analyses of pH showed that pH of Vinasse products were in the optimal pH range of 4.5-6 for pollen germination (Holdaway-Clarke et al. 2003). But salt and lime-sulphur, as well as Corn Oil pH (7.24, Tab. 3) were clearly over this range so that pollen growth could be inhibited already by a pH-induced desiccation effect.

## Conclusions

To achieve a successful thinning effect with the methods presented here it is decisive that for each method at the day of application the weather conditions (air temperature) and the phonological stages are optimal. On basis of the present results (including not yet published experiences of 2005) we recommend for organic fruit thinning:

1) to apply the rope device one or two times at stage E-F, to minimize direct damages at high driving speed (9-11 km/h) and preferably at cold, cloudy days to increase the triggered physiological shock that will induce a shortage of assimilates followed by abscission of the young fruitlets.
2) and / or
3) to apply N-Vinasse with concentrations between 5-10 % (vol.) at least two times at stages (F), $F^2$ (full bloom) and at $F^2$ of the one-year old shoots during warm sunny days above 16 deg. C, better 18-20 deg. C. The amount of water should be high, preferably 1500 l/ha. As an alternative, especially when flowering period is short or the cultivar is sensitive to phytotoxicity or russeting, the “Burn and Rinse method” can be applied.

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