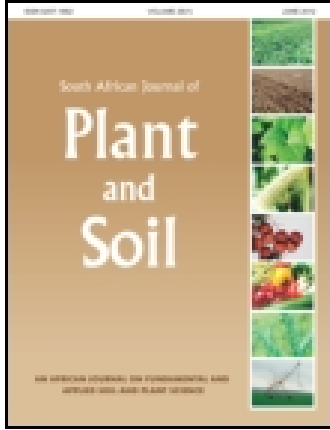


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## Effect of mineral oil and hydrogen cyanamide concentration on dormancy breaking in 'Golden Delicious' apple trees

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South African production areas receive insufficient winter chilling for apple production, necessitating the use of artificial means to break dormancy. Hydrogen cyanamide (HC) alone or in combination with mineral oil (oil) is used as a rest-breaking agent in many deciduous species. The effect of different concentrations of HC and oil on budburst, yield, fruit quality and vegetative growth of mature 'Golden Delicious' apple trees were evaluated; the objective was to determine the presence of interaction between the rest-breaking effect of HC and oil when combined at varied concentrations, and to determine appropriate concentrations of HC and oil, to enhance budburst, yield and fruit quality. Three trials were conducted in the Elgin valley (34 °S, 300 m) of the Western Cape, South Africa, in 1999 and 2000. The first trial evaluated four concentrations (0, 0.5, 1 and 2%) of Dormex<sup>®</sup> (hydrogen cyanamide 520 g·L<sup>-1</sup>) in combination with four concentrations of mineral oil (0, 1, 2, and 4%). The second trial used three concentrations (1, 2 and 4%) of Dormex<sup>®</sup> in combination with three concentrations of mineral oil (1, 2, 4%), plus an unsprayed control, and a treatment of 6% of DNOC Winter Oil<sup>®</sup>. The third trial included five treatments: 0.5% Dormex<sup>®</sup> + 3% oil, 1% Dormex<sup>®</sup> + 4% oil, 6% DNOC Winter Oil<sup>®</sup>, 6% oil and a non-sprayed control. All of the treatments were applied at the first visible signs of budburst. No synergistic effect was observed between oil and HC. Mineral oil at 4% plus 1 to 2% Dormex<sup>®</sup> were sufficient to break dormancy. Dormex<sup>®</sup> at 4% (2.08% HC) reduced fruit set and yield.

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### Introduction

Chilling requirements are a limiting factor for deciduous fruit production in many warm climate regions. Chemical rest-breaking treatments are needed as a practice to compensate for the lack of chilling. Inadequate winter chilling can modify the budburst pattern and lead to poor budbreak, delayed foliation and protracted bloom, as the major symptoms (Saure, 1985; Erez, 1987).

Oil was the first chemical used to break dormancy. Adding several chemical compounds later enhanced its effect. A combination of dinitro-*o*-cresol (DNOC) and mineral oil effectively breaks dormancy of apple buds and has been used extensively since the 1940s (Samish, 1945; Erez & Zur, 1981), however, due to environmental and health considerations its use was recently discontinued. Other products including calcium cyanamide, thiourea, and KNO<sub>3</sub>, proved effective but less efficient than DNOC (Erez *et al.*, 1971; Erez, 1995). The rest-breaking properties of hydrogen cyanamide (HC) were tested in several species since the 1980s, but only later in apples (Shulman *et al.*, 1983). HC alone, and in combination with mineral oil, has shown positive results in apple trees (Petri *et al.*, 1990; North, 1992). HC and oil (1.25+3%), and 5% DNOC oil gave similar budburst and fruit set on four-year-old 'Golden Delicious' trees (North, 1992). Research has determined the optimum combination of oil and HC for dormancy release in apple. Reducing the amount of HC reduces cost; however, the extent that increased oil concentration can reduce the use of HC is unknown. The interaction between these two rest-breaking treatments is not clear.

The objectives of this study were, firstly, to determine whether an interaction between the rest-breaking effect of HC and oil when combined at varied concentrations is present, and secondly, to determine appropriate concentrations of HC and oil, to enhance budburst, yield and fruit quality of 'Golden Delicious' apple trees, in a region with inadequate

winter chilling.

### Material and methods

Three rest-breaking trials were conducted on mature 'Golden Delicious' apples trees, one in the 1999/2000 season and two in 2000/2001, in commercial orchards in Elgin (34 °S, 300 m), Western Cape, South Africa. This area received ca. 610 and 605 Utah model chill units in 1999 and 2000, respectively. The following commercial rest-breaking products were used: Dormex<sup>®</sup> (hydrogen cyanamide 520 g·L<sup>-1</sup>), Budbreak<sup>®</sup> (mineral oil 863.3 g·L<sup>-1</sup>), and DNOC Winter Oil<sup>®</sup> (DNOC 3% v/v + mineral oil 72% v/v).

#### Trial 1

In 1999/2000 four-year-old 'Golden Delicious' apple trees of normal vigour on seedling rootstock at spacing of 4.5 x 1.5 m, were treated with different combinations of HC and oil on 6 September 1999. The treatments consisted of four concentrations of Dormex<sup>®</sup> (0, 0.5, 1 and 2% v/v) combined with four concentrations of Budbreak<sup>®</sup> oil (0, 1, 2 and 4% v/v), 16 treatments in total, laid out in a randomised complete block design with six replicates, using a 4x4 factorial structure and single tree plots. Treatments were sprayed to run-off using a handgun at the first signs of budburst, seen as "green tip" on isolated buds within the tree. It should be noted that under conditions of delayed foliation budburst is slow and protracted and by this stage most buds on the trees, while still closed, did show some swelling. Data collected included the total yield per tree (mass and number of fruits), and fruit quality, evaluated in a sample of 25 fruit per tree at the time of commercial harvest. Yield efficiency (kg·cm<sup>-2</sup> trunk circumference) and tree fruit density (fruit·cm<sup>-2</sup> trunk circumference) were calculated from total yield per tree and trunk cross sectional area measured ca. 25 cm above the soil surface. From one scaffold branch per tree the following data were

recorded: the number of burst and dormant buds on one-year-old shoots and two-year-old branches (after fruit set); the number of flowers; fruit set and the fruit set density (total fruit-cm<sup>-2</sup> branch cross sectional area measured 10 cm from the insertion point). In order to determine the effect of the treatments on fruit production the following season the yield (mass and number of fruit) was recorded at harvest in 2001. In this case, all trees were sprayed with 6% DNOC Winter Oil<sup>®</sup> in 2000 (the old "standard" commercial rest-breaking treatment).

### Trial 2

Twelve-year-old 'Golden Delicious' trees of normal vigour on seedling rootstock planted at 4.5 x 2.0 m, were sprayed with different combinations of HC and oil on 7 September 2000 at the same phenological stage as in Trial 1. The treatments consisted of three concentrations of Dormex<sup>®</sup> (1, 2 and 4% v/v) applied in combination with three concentrations of Budbreak<sup>®</sup> oil (1, 2 and 4% v/v); nine combinations in total. Two additional treatments were included: 6% DNOC Winter Oil<sup>®</sup> as the commercial treatment and a non-sprayed control. All treatments were sprayed to run-off using a handgun. The number of burst buds on one-year-old shoots and two-year-old branches was counted at full bloom and again after fruit set on one scaffold branch per tree; percentage budburst and fruit set were calculated. Yield, yield efficiency and fruit quality were determined. After harvest, vegetative growth and spur quality were measured on two 2-year-old branches per tree, randomly sampled from the mid peripheral section of the tree.

The experiment was laid out as a randomised complete block design with 11 treatments, 10 replications, and single tree plots. To determine the interaction between Dormex<sup>®</sup> and oil the data were analysed as a randomised complete block design with a 3x3 factorial structure. To compare with the two additional treatments the data were again analysed as complete randomised block design with 11 treatments.

### Trial 3

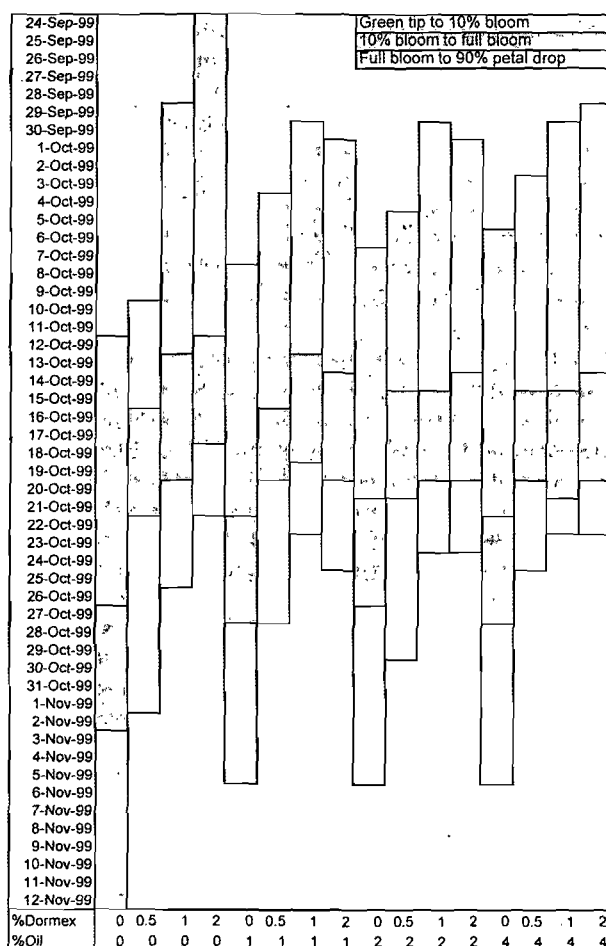
Seventeen-year-old 'Golden Delicious' trees of normal vigour on seedling rootstock planted at 4.5 x 2 m, were sprayed on 7 September 2000 (first "green tip") with the following rest-breaking treatments: 6% DNOC Winter Oil<sup>®</sup>; 6% Budbreak<sup>®</sup> oil; 0.5% Dormex<sup>®</sup> + 3% Budbreak<sup>®</sup> oil; 1% Dormex<sup>®</sup> + 4% Budbreak<sup>®</sup> oil; and a non-sprayed control. All treatments were sprayed to run-off, using a handgun, and same data as in Trail 2 were recorded. The experiment was laid out as a randomised complete block design with five treatments and ten replicates using single tree plots.

## Results

### Trial 1

HC and oil accelerated budburst and flowering and reduced the flowering period, reducing considerably the symptoms of delayed foliation (Figure 1). No interaction between the HC and oil effects was observed with the evaluated rates. During the season of application (1999/2000) HC influenced budburst, fruit set and yield (Tables 1 and 2). Oil affected only budburst significantly. Budburst increased with Dormex<sup>®</sup>

concentration and was ca. 45% more at the 1 and 2% rate on one-year-old wood (Table 1). Still significant, oil was less effective than HC but not dependent on rate. Oil did not affect yield (Table 1). Dormex<sup>®</sup> during 1999/2000 at 1 and 2% reduced set density, yield efficiency and yield (Tables 1 and 2). The increase in budburst combined with less fruit crop at 1% and 2% Dormex<sup>®</sup> in 1999/2000, resulted in large increases in yield during the next season (2000/2001) (Tables 1 and 2).



**Figure 1** Effects of Dormex<sup>®</sup> and mineral oil application in 1999 on the development of flowering on single branches of 'Golden Delicious' apple trees in Elgin, South Africa.

Fruit quality was not adversely affected by the rest-breaking treatments (data not shown). In the 1999/2000 season fruit were larger with 1% and 2% Dormex<sup>®</sup>, possibly due to a fruit thinning effect. In the 2000/2001 season, it should be mentioned that despite of the increased yield and fruit number the fruit mass was not reduced as expected (Table 2).

**Table 1** Effect of Dormex® and mineral oil application in 1999 on budburst, fruit set and yield of 'Golden Delicious' apple trees in Elgin, South Africa.

| Treatment  | Budburst (%)        |                 | Set density<br>(Number of fruit cm <sup>-2</sup><br>BCSA <sup>X</sup> ) | Yield efficiency<br>(kg cm <sup>-2</sup> TCSA <sup>Y</sup> ) |         | Fruit density<br>(Number of fruit cm <sup>-2</sup><br>TCSA <sup>Y</sup> ) |        |
|------------|---------------------|-----------------|---|--|---------|---|--------|
|            | Spurs               | 1-year-old wood |   | 2000   | 2001    | 2000  | 2001   |
| Dormex (%) |                     |                 |   |  |         |   |        |
| 0          | 49.3 c <sup>Z</sup> | 57.8 c          | 1.35 ba   | 0.149 a  | 0.155 b | 1.30 a  | 1.22 b |
| 0.5        | 59.3 c              | 67.1 b          | 1.67 a  | 0.180 a  | 0.163 b | 1.55 a  | 1.33 b |
| 1          | 75.9 b              | 82.8 a          | 1.04 b  | 0.104 b  | 0.232 a | 0.81 b  | 1.95 a |
| 2          | 86.2 a              | 84.8 a          | 0.43 c  | 0.060 c  | 0.233 a | 0.43 c  | 1.90 a |
| Oil (%)    |                     |                 |   |  |         |   |        |
| 0          | 60.7 c              | 66.9 b          | 1.07  | 0.130  | 0.176   | 1.11  | 1.44   |
| 1          | 73.4 ba             | 73.4 ba         | 1.13  | 0.128  | 0.208   | 1.04  | 1.72   |
| 2          | 63.6 bc             | 76.6 a          | 1.19  | 0.125  | 0.203   | 1.04  | 1.65   |
| 4          | 73.1 a              | 75.7 a          | 1.09  | 0.108  | 0.195   | 0.90  | 1.59   |
| Pr > F     |                     |                 |   |  |         |   |        |
| Dormex (D) | <.0001              | <.0001          | 0.0005  | <.0001   | 0.0090  | <.0001  | 0.0116 |
| Oil (O)    | 0.0169              | 0.0312          | 0.9784  | 0.6724   | 0.7273  | 0.5900  | 0.7469 |
| D x O      | 0.6312              | 0.3463          | 0.1051  | 0.5874   | 0.3394  | 0.5977  | 0.4881 |

<sup>X</sup>Branch cross sectional area.<sup>Y</sup>Trunk cross sectional area.<sup>Z</sup>Means followed by the same letter within the same column do not differ significantly at P = 0.05.**Table 2** Effect of Dormex® and mineral oil application in 1999 on yield and fruit mass 'Golden Delicious' apple trees in Elgin, South Africa.

| Treatment  | Yield (t ha <sup>-1</sup> ) |        |           | Number of fruit tree <sup>-1</sup> |        | Mean fruit mass (g) |        |
|------------|-----------------------------|--------|-----------|------------------------------------|--------|---------------------|--------|
|            | 2000                        | 2001   | 2000+2001 | 2000                               | 2001   | 2000                | 2001   |
| Dormex (%) |                             |        |           |                                    |        |                     |        |
| 0          | 23.1 ba <sup>Z</sup>        | 24.0 b | 47.1      | 137 a                              | 128 c  | 115.7 b             | 131.7  |
| 0.5        | 28.8 a                      | 27.2 b | 56.0      | 170 a                              | 151 b  | 116.9 b             | 127.1  |
| 1          | 17.7 b                      | 39.4 a | 57.1      | 94 b                               | 224 a  | 129.5 a             | 125.2  |
| 2          | 9.9 c                       | 39.0 a | 48.9      | 49 c                               | 218 a  | 133.3 a             | 126.1  |
| Oil (%)    |                             |        |           |                                    |        |                     |        |
| 0          | 22.3                        | 29.6   | 51.9      | 127                                | 163    | 122.6               | 124.6  |
| 1          | 21.5                        | 36.2   | 57.8      | 119                                | 204    | 124.3               | 128.7  |
| 2          | 18.8                        | 31.0   | 49.9      | 107                                | 171    | 123.5               | 127.3  |
| 4          | 16.7                        | 32.7   | 49.5      | 93                                 | 183    | 124.8               | 129.5  |
| Pr > F     |                             |        |           |                                    |        |                     |        |
| Dormex (D) | <.0001                      | 0.0106 | 0.4803    | <.0001                             | 0.0123 | 0.0006              | 0.4769 |
| Oil (O)    | 0.2980                      | 0.6752 | 0.6908    | 0.2417                             | 0.6531 | 0.9744              | 0.7065 |
| D x O      | 0.5244                      | 0.5110 | 0.4483    | 0.3556                             | 0.6610 | 0.8516              | 0.3211 |

<sup>Z</sup>Means followed by the same letter within the same column do not differ significantly at P = 0.05.**Trial 2**

As in the previous trial, no interaction was detected between the Dormex® and oil concentrations. No significant differences were found between 1% and 2% of Dormex® in bud burst, fruit and yield. Dormex® at 4% significantly reduced fruit set and yield. Increasing concentrations of oil did not significantly influence budburst and yield. (Tables 3 and 4). Average fruit mass increased with Dormex® concentrations. Dormex® at 4% resulted in larger fruit, again probably due to a thinning effect (Table 4). Unlike in the previous trial, no negative effect of 2% Dormex® was observed compared to

1% (Tables 1 and 3). Dormex® at 4% enhanced vegetative growth, increasing the number of shoots longer than 10 mm, and possibly increasing the number of leaves per spur. This was possibly due to the fruit thinning effect of this rate (Table 5).

When all combinations, and DNOC-oil, were compared to the unsprayed control, all nine Dormex® and oil combinations significantly increased budburst on 2-year-old wood, but not significantly on 1-year-old wood. While not always significantly better than the oil plus 1% or 2% Dormex®, 6%

DNOC-oil gave the highest yield (Tables 3 and 4).

**Table 3** Effect of Dormex® and mineral oil application in 2000 on budburst, fruit set and yield of 'Golden Delicious' apple trees in Elgin, South Africa.

| Treatment          | Budburst (%)       |                 | Fruit set (%) | Production efficiency<br>(kg cm <sup>-2</sup> TCSA <sup>Y</sup> ) | Fruit density<br>(Number of fruit cm <sup>-2</sup> TCSA <sup>Y</sup> ) |
|--------------------|--------------------|-----------------|---------------|---|--|
|                    | 2-year-old wood    | 1-year-old wood |               |   |  |
| Dormex (%)         |                    |                 |               |   |  |
| 1                  | 96 ab <sup>Z</sup> | 93 b            | 11.5 a        | 0.288 a   | 2.48 a   |
| 2                  | 98 a               | 95 ab           | 11.6 a        | 0.326 a   | 2.65 a   |
| 4                  | 95 b               | 97 a            | 8.7 b         | 0.131 b   | 0.97 b   |
| Oil (%)            |                    |                 |               |   |  |
| 1                  | 96                 | 94              | 11.6          | 0.245   | 2.02   |
| 2                  | 96                 | 94              | 9.2           | 0.244   | 1.98   |
| 4                  | 97                 | 95              | 11.0          | 0.255   | 2.09   |
| Pr > F             |                    |                 |               |   |  |
| Dormex (D)         | 0.0052             | 0.0445          | 0.0266        | 0.0001  | <.0001   |
| Oil (O)            | 0.3515             | 0.4181          | 0.1155        | 0.9084  | 0.9806   |
| D x O              | 0.4373             | 0.5979          | 0.4133        | 0.6461  | 0.8122   |
| Dormex(%) + Oil(%) |                    |                 |               |   |  |
| 1 + 1              | 93.6 ab            | 93.0            | 13.7          | 0.282 a   | 2.43 a   |
| 2 + 1              | 97.2 ab            | 96.5            | 10.9          | 0.303 a   | 2.53 a   |
| 4 + 1              | 96.0 ab            | 96.2            | 10.5          | 0.157 b   | 1.17 b   |
| 1 + 2              | 97.3 ab            | 93.7            | 8.7           | 0.283 a   | 2.40 a   |
| 2 + 2              | 98.4 ab            | 92.0            | 12.0          | 0.322 a   | 2.59 a   |
| 4 + 2              | 92.6 b             | 95.0            | 7.1           | 0.137 b   | 1.06 b   |
| 1 + 4              | 96.6 ab            | 92.4            | 12.3          | 0.297 a   | 2.58 a   |
| 2 + 4              | 99.0 a             | 96.0            | 12.0          | 0.355 a   | 2.84 a   |
| 4 + 4              | 95.1 ab            | 98.3            | 8.4           | 0.089 b   | 0.63 b   |
| Unsprayed control  | 75.0 c             | 81.7            | 11.5          | 0.282 a   | 2.57 a   |
| 6% DNOC-oil        | 90.5 b             | 88.8            | 9.4           | 0.362 a   | 2.91 a   |
| Pr > F             |                    |                 |               |   |  |
|                    | 0.0002             | 0.2122          | 0.1362        | <.0001  | <.0001   |

<sup>Y</sup>Trunk cross sectional area.

<sup>Z</sup>Means followed by the same letter within the same column do not differ significantly at P = 0.05.

**Table 4** Effect of Dormex® and mineral oil application in 2000 on yield and fruit size of 'Golden Delicious' apple trees in Elgin, South Africa.

| Treatment          | Yield (t ha <sup>-1</sup> ) | Number of fruit tree <sup>-1</sup> | Mean fruit mass (g) | Mean fruit diameter (mm) | Fruit length: diameter ratio |
|--------------------|-----------------------------|------------------------------------|---------------------|--------------------------|------------------------------|
| Dormex (%)         |                             |                                    |                     |                          |                              |
| 1                  | 45.5 a <sup>Z</sup>         | 350 a                              | 118.9 c             | 64.9 b                   | 0.963 a                      |
| 2                  | 47.1 a                      | 341 a                              | 127.0 b             | 65.7 b                   | 0.939 b                      |
| 4                  | 22.1 b                      | 149 b                              | 139.4 a             | 68.1 a                   | 0.943 ab                     |
| Oil (%)            |                             |                                    |                     |                          |                              |
| 1                  | 38.4                        | 282                                | 127.3               | 66.0                     | 0.948                        |
| 2                  | 37.5                        | 272                                | 130.3               | 66.4                     | 0.951                        |
| 4                  | 38.6                        | 284                                | 128.1               | 66.3                     | 0.945                        |
| Pr>F               |                             |                                    |                     |                          |                              |
| Dormex (D)         | <.0001                      | <.0001                             | <.0001              | <.0001                   | 0.0427                       |
| Oil (O)            | 0.9783                      | 0.9503                             | 0.5681              | 0.4711                   | 0.7229                       |
| D x O              | 0.4450                      | 0.5952                             | 0.9647              | 0.2084                   | 0.4342                       |
| Dormex(%) + Oil(%) |                             |                                    |                     |                          |                              |
| 1 + 1              | 44.9 a                      | 348 a                              | 118.2 cd            | 64.3 c                   | 0.956 ab                     |
| 2 + 1              | 43.4 a                      | 322 a                              | 125.9 bcd           | 66.3 bc                  | 0.939 b                      |
| 4 + 1              | 28.2 b                      | 189 b                              | 135.9 ab            | 67.2 ab                  | 0.951 ab                     |
| 1 + 2              | 45.9 a                      | 348 a                              | 120.7 cd            | 64.9 bc                  | 0.984 a                      |
| 2 + 2              | 46.5 a                      | 329 a                              | 128.9 bc            | 65.6 bc                  | 0.934 b                      |
| 4 + 2              | 21.9 b                      | 152 b                              | 140.2 ab            | 68.5 a                   | 0.936 b                      |
| 1 + 4              | 45.6 a                      | 354 a                              | 117.8 cd            | 65.4 bc                  | 0.951 ab                     |
| 2 + 4              | 51.9 a                      | 376 a                              | 126.3 bcd           | 65.2 bc                  | 0.943 ab                     |
| 4 + 4              | 14.8 b                      | 94 b                               | 142.9 a             | 68.6 a                   | 0.941 ab                     |
| Unsprayed control  | 45.5 a                      | 370 a                              | 113.7 d             | 66.3 bc                  | 0.931 b                      |
| 6% DNOC Winter Oil | 58.6 a                      | 431 a                              | 128.3 bcd           | 64.7 c                   | 0.953 ab                     |
| Pr > F             |                             |                                    |                     |                          |                              |
|                    | <.0001                      | <.0001                             | 0.0003              | <.0001                   | <.0001                       |

<sup>Z</sup>Means followed by the same letter within the same column do not differ significantly at P = 0.05.

**Table 5** Effect of Dormex® and mineral oil application in 2000 on vegetative growth and spur quality of 'Golden Delicious' apple trees in Elgin, South Africa.

| Treatment                 | Terminal shoot length (mm) | Shoot distribution according to length (%) |         |         | Mean length of shoots >10mm long (mm) | Number of leaves on spurs ≤5mm |
|---------------------------|----------------------------|--|---------|---------|---------------------------------------|--------------------------------|
|                           |                            | ≤5 mm                                      | >10 mm  | 5-10 mm |                                       |                                |
| <b>Dormex (%)</b>         |                            |  |         |         |                                       |                                |
| 1                         | 255.9                      | 68.6 a <sup>Z</sup>                        | 16.2 b  | 15.2 a  | 44.0 b                                | 2.9 b                          |
| 2                         | 251.8                      | 69.3 a                                     | 19.8 b  | 11.8 a  | 57.2 b                                | 3.4 a                          |
| 4                         | 234.3                      | 44.3 b                                     | 44.1 a  | 11.5 a  | 83.6 a                                | 3.4 a                          |
| <b>Oil (%)</b>            |                            |  |         |         |                                       |                                |
| 1                         | 246.5                      | 59.2                                       | 24.6    | 16.2    | 62.8                                  | 3.1                            |
| 2                         | 258.5                      | 65.2                                       | 31.3    | 10.9    | 68.4                                  | 3.4                            |
| 4                         | 234.9                      | 65.2                                       | 23.3    | 11.4    | 53.7                                  | 3.1                            |
| <b>Pr &gt; F</b>          |                            |  |         |         |                                       |                                |
| Dormex (D)                | 0.6441                     | 0.0001                                     | 0.0001  | 0.1572  | 0.0019                                | 0.0171                         |
| Oil (O)                   | 0.5613                     | 0.3336                                     | 0.1103  | 0.2109  | 0.5594                                | 0.2852                         |
| D x O                     | 0.3416                     | 0.5307                                     | 0.6154  | 0.4767  | 0.2942                                | 0.1872                         |
| <b>Dormex(%) + Oil(%)</b> |                            |  |         |         |                                       |                                |
| 1 + 1                     | 259.2                      | 65.7 ab                                    | 13.7 b  | 20.6    | 33.6 cd                               | 3.1 ab                         |
| 2 + 1                     | 273.8                      | 71.9 ab                                    | 13.9 b  | 14.2    | 49.6 cd                               | 3.2 ab                         |
| 4 + 1                     | 206.2                      | 40.1 c                                     | 45.0 a  | 14.9    | 100.3 a                               | 3.0 ab                         |
| 1 + 2                     | 246.6                      | 71.6 ab                                    | 19.5 b  | 8.9     | 55.2 bcd                              | 3.0 ab                         |
| 2 + 2                     | 252.1                      | 60.6 abc                                   | 27.5 ab | 11.9    | 57.1 bcd                              | 3.4 a                          |
| 4 + 2                     | 274.9                      | 42.7 c                                     | 45.4 a  | 11.9    | 90.3 ab                               | 3.7 a                          |
| 1 + 4                     | 259.3                      | 68.0 ab                                    | 15.0 b  | 17.0    | 41.1 cd                               | 2.5 b                          |
| 2 + 4                     | 224.0                      | 76.0 a                                     | 15.5 b  | 8.5     | 66.7 abc                              | 3.5 a                          |
| 4 + 4                     | 215.2                      | 51.0 bc                                    | 41.6 a  | 7.4     | 56.5 bcd                              | 3.5 a                          |
| Unsprayed control         | 225.7                      | 65.4 ab                                    | 17.4 b  | 17.2    | 19.9 d                                | 3.0 ab                         |
| 6% DNOC Winter Oil        | 252.2                      | 65.2 ab                                    | 21.8 b  | 13.0    | 35.8 cd                               | 2.9 ab                         |
| <b>Pr &gt; F</b>          |                            |  |         |         |                                       |                                |
|                           | 0.7209                     | 0.0009                                     | <.0001  | 0.5469  | 0.0030                                | 0.0375                         |

<sup>Z</sup>Means followed by the same letter within the same column do not differ significantly at P = 0.05.

**Table 6** Effect of rest-breaking treatment application in 2000 on bud-break, fruit set and yield of 'Golden Delicious' apple trees in Elgin, South Africa.

| Treatment          | Bud-break (%)        |                 | Fruit set (%) | Production Efficiency (kg cm <sup>-2</sup> TC SA <sup>Y</sup> ) | Fruit density (Number of fruit cm <sup>-2</sup> TC SA <sup>Y</sup> ) | Number of fruit tree <sup>-1</sup> |
|--------------------|----------------------|-----------------|---------------|---|--|------------------------------------|
|                    | 2-year-old wood      | 1-year-old wood |               |   |  |                                    |
| 6%Oil              | 58.3 bc <sup>Z</sup> | 69.0 a          | 16.1          | 0.250   | 2.44   | 361.0                              |
| 0.5%Dormex + 3%Oil | 72.0 abc             | 82.1 a          | 14.8          | 0.241   | 2.46   | 408.0                              |
| 1%Dormex + 4%Oil   | 77.2 ab              | 85.4 a          | 13.2          | 0.273   | 2.69   | 372.8                              |
| Unsprayed control  | 50.3 c               | 51.1 b          | 14.8          | 0.239   | 2.39   | 364.7                              |
| 6%DNOC Winter Oil  | 89.4 a               | 85.9 a          | 14.0          | 0.295   | 2.95   | 421.7                              |
| <b>Pr &gt; F</b>   |                      |                 |               |   |  |                                    |
|                    | 0.0099               | 0.0007          | 0.9058        | 0.7470  | 0.8797   | 0.9270                             |

<sup>Y</sup>Trunk cross sectional area.

<sup>Z</sup>Means followed by the same letter within the same column do not differ significantly at P = 0.05.

### Trial 3

All rest-breaking treatments increased budburst on 1-year-old wood. On 2-year-old-wood only the 1% Dormex® plus 4% oil, and the 6% DNOC Winter Oil® treatments increased budburst. No effect of the treatments on fruit set and yield were observed (Table 6). Vegetative growth on 1-year-old shoots and fruit quality were not affected in this trial (data not shown).

### Discussion

Combinations of HC and mineral oil (mixed in the spray tank) can be used to break dormancy and promote more uni-

form budburst in 'Golden Delicious' apple trees when sprayed at the first signs of budburst or "green tip". No interaction was observed between varied rates of HC and oil. In fact, the rate of oil showed similar response in budburst and yield at concentrations between 1 and 4% (Tables 1 and 3). When mixed with oil, HC increased budburst with increasing rate. However in terms of yield, HC appeared to show an optimum rate between 1 and 2% Dormex®, in 1999 at 2% a reduction in yield or thinning effect was observed. This response was possibly due to flower bud damage by the high rates (2 and 4%). Later and higher rates of HC can cause phytotoxicity (Erez, 1987; Lee, 1994; Richardson *et al.*, 1994).

The problem may reside in the intensity of bud endo-dormancy at the time of application, which influences the efficacy of dormancy breaking and tissue sensitivity to HC (Erez, 1995; Faust *et al.*, 1997). Applications at bud swelling stage have shown less phytotoxicity (Lee, 1994; Petri & Stuker, 1995). The increased budburst combined with lower fruit set and yield observed with high rates of HC could also result from increased competition from vegetative growth with fruit set. Further trials to determine the dynamics between rest-breaking and the resultant shoot growth, flowering, and fruit set are in progress.

An important improvement in budburst was observed on one-year-old shoots that included increased spur numbers and possibly improved spur quality. Petri & Stuker (1995) also observed this effect on 'Gala' apples trees after two or three seasons of combined hydrogen cyanamide and oil application. As observed in our data, the number of flower clusters the following season was increased. Rest-breaking treatment also normalised and hastened the flowering period (Lee, 1994; Petri & Stuker, 1995; North, 1989).

### Conclusions

No synergistic (or antagonistic) effects on budburst and yield were observed when mineral oil and hydrogen cyanamide were combined at different concentrations. The combination of mineral oil and HC is an effective rest-breaking treatment for 'Golden Delicious' apple trees. Mineral oil at 1 to 4% plus Dormex<sup>®</sup> at 1% (0.52% HC) is able to break dormancy without reducing yield or negatively affecting fruit quality. Dormex<sup>®</sup> at 4% (2.08% HC) reduced fruit set and yield. The improved budburst resulted in an increased number of spurs and dramatically improved the yield in the following season.

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