

New Pyrethrum Synergists from Dihydrodillapiole and Furapiole<sup>†</sup>

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In order to discover more potent pyrethrum synergists, dihydrodillapiole and furapiole, two dillapiole-based compounds having considerable synergistic activity, were converted into various acyl and  $\alpha,\beta$ -unsaturated carbonyl derivatives. The synthesis, factor of synergism, spectroscopic data and structure activity relationships of these derivatives are reported.

Synergists play an important role in efficient, economic and practical formulations of pyrethrum. The synergistic activity of dillapiole (1-allyl-2,3-dimethoxy-4,5-methylenedioxy benzene), one of the major constituents (27%) of Indian dill (*Anethum sowa* Roxb.) seed oil, toward pyrethrum<sup>1</sup> and towards *N*-methyl carbamates has been reported earlier.<sup>2,3</sup> In an attempt to discover better synergists, a large number of derivatives of dillapiole have been synthesised by structural modifications. Amongst these, dihydrodillapiole (I) and furapiole (II) have shown considerably higher synergistic activity.<sup>4,5</sup> It was felt that further modifications of these two potent compounds may yield pyrethrum synergists of higher potency. In this paper the synthesis and synergistic activity of a large number of acyl derivatives of dihydrodillapiole and furapiole are reported. Further, an earlier work had shown that some  $\alpha,\beta$ -unsaturated carbonyl derivatives like 1-(2,3-dimethoxy-4,5-methylenedioxyphenyl) non-1-en-3-one possess very high activity.<sup>4</sup> Attempts therefore have now been made to synthesize such compounds from the acyl derivatives of dihydrodillapiole and furapiole by condensation with different types of aldehydes.

## RESULTS AND DISCUSSION

The acyl derivatives of both dihydrodillapiole and furapiole needed for this work were obtained by Friedel Craft's acylation in the presence of anhydrous zinc chloride in dry ether or dry methylene chloride. The formation of side products under these conditions was minimal. The yields, even under these conditions, were variable and not very good. The most important side reaction observed was the opening of the benzo-1,3-dioxole ring. This takes place with almost all the Lewis acids tried in these reactions and is very specific as reported earlier<sup>6</sup> with  $\text{BF}_3$ -etherate, excluding its use in the present case. With anhydrous  $\text{AlCl}_3$ , further complications due to demethylation were also observed.

None of the test chemicals showed any insecticidal activity up to the 1% level against *Tribolium castaneum* as the test insect. However, all of them showed a synergistic property toward pyrethrum. In the case of the acyl derivatives of dihydrodillapiole (III~XII), their factors of synergism ( $\text{LC}_{50}$  for pyrethrum/ $\text{LC}_{50}$  for pyrethrum + synergist)<sup>9</sup> varied from 2.3 to 4.0 as compared to 2.1 for the standard reference synergist, piperonyl butoxide (PBO) and 2.3 for dihydrodillapiole (Table I).

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TABLE I.  $R_M$  VALUES AND FACTOR OF SYNERGISM OF VARIOUS TEST CHEMICALS

| Structure No. | Compound   | $R_M$ Value | Factor of synergism |
|---------------|--|-------------|---------------------|
| I             | Dihydrodillapiole                                  | —           | 2.3                 |
| II            | Furapiole  | -0.13       | 5.2                 |
| III           | Acetyldihydrodillapiole                            | -0.45       | 2.3                 |
| IV            | Propionyl dihydrodillapiole                        | -0.31       | 2.5                 |
| V             | Butyryl dihydrodillapiole                          | -0.16       | 2.7                 |
| VI            | Valeryldihydrodillapiole                           | -0.04       | 3.1                 |
| VII           | Caproyl dihydrodillapiole                          | +0.11       | 3.5                 |
| VIII          | Heptanoyl dihydrodillapiole                        | +0.20       | 3.8                 |
| IX            | Octanoyl dihydrodillapiole                         | +0.35       | 4.0                 |
| X             | Pelargonyl dihydrodillapiole                       | +0.50       | 4.0                 |
| XI            | Decanoyl dihydrodillapiole                         | +0.75       | 3.9                 |
| XII           | Chloroacetyl dihydrodillapiole                     | -0.41       | 2.4                 |
| XIII          | Acetyl furapiole                                   | -0.50       | 3.2                 |
| XIV           | Propionyl furapiole                                | -0.31       | 2.8                 |
| XV            | Butyryl furapiole                                  | -0.09       | 2.7                 |
| XVI           | Heptanoyl furapiole                                | +0.20       | 1.6                 |
| XVII          | Octanoyl furapiole                                 | +0.35       | 1.6                 |
| XVIII         | Decanoyl furapiole                                 | +0.69       | 1.1                 |
| XIX           | Chloroacetyl furapiole                             | -0.45       | 1.5                 |
| XX            | Cinnamoyl dihydrodillapiole                        | -0.32       | 1.5                 |
| XXI           | 3,4-Methylenedioxy cinnamoyl dihydrodillapiole     | -0.45       | 1.0                 |
| XXII          | 4-Nitrocinnamoyl dihydrodillapiole                 | -0.58       | —                   |
| XXIII         | 4-Chlorocinnamoyl dihydrodillapiole                | -0.16       | 1.4                 |
| XXIV          | 3-(2-Furyl propenyl) dihydrodillapiole             | -0.43       | 1.8                 |
| XXV           | 2-Nonenoyl dihydrodillapiole                       | +0.60       | 4.5                 |
| XXVI          | Cinnamoyl furapiole                                | -0.57       | 1.1                 |
| XXVII         | 3,4-Methylenedioxy cinnamoyl furapiole             | -0.75       | 1.0                 |
| XXVIII        | 4-Nitrocinnamoyl furapiole                         | -0.69       | 1.2                 |
| XXIX          | 4-Chlorocinnamoyl furapiole                        | -0.37       | 1.5                 |
| XXX           | 3-(2-Furyl propenyl) furapiole                     | -0.65       | 2.1                 |
| XXXI          | 3,4-Methylenedioxy cinnamoyl benzene               | -0.37       | 1.5                 |
| XXXII         | 2,3-Dimethoxy-4,5-methylenedioxy cinnamoyl benzene | -0.20       | 1.8                 |
| XXXIII        | Piperonyl butoxide                                 | —           | 2.1                 |

The relationship between the synergistic activity of the acyl derivatives of dihydrodillapiole and their lipophilicity is shown in Fig. 1. The synergistic activity gradually increases with increasing length of the acyl chain up to 8~9 carbon atoms and then decreases, but the lipophilicity continues to increase linearly. In this respect these derivatives behave the same way as the other derivatives examined earlier.<sup>5)</sup> On the other hand, the furapiole derivatives (XIII to XIX) show opposite behaviour. Thus, as seen in Fig. 2, although the lipophilicity of the acyl derivatives of furapiole increases with an increase in the number of carbon atoms, there is a steep fall in their synergistic activity.

This result is very surprising, as in all the cases examined earlier, synergistic activity increased with the lipophilicity of the molecule at least up to a few carbon atoms. The reason for this unexpected behaviour is not known yet.

$\alpha,\beta$ -Unsaturated carbonyl compounds (XX~XXX), derived from (III) or XIII and various aromatic aldehydes, exhibited very poor synergism compared with the starting acetyl derivatives. The introduction of nitro, chloro, and methylenedioxy groups in these compounds failed to improve the synergistic efficacy. In this series only one compound, non-2-enoyl dihydrodillapiole (XXV), showed synergism much superior to both the starting

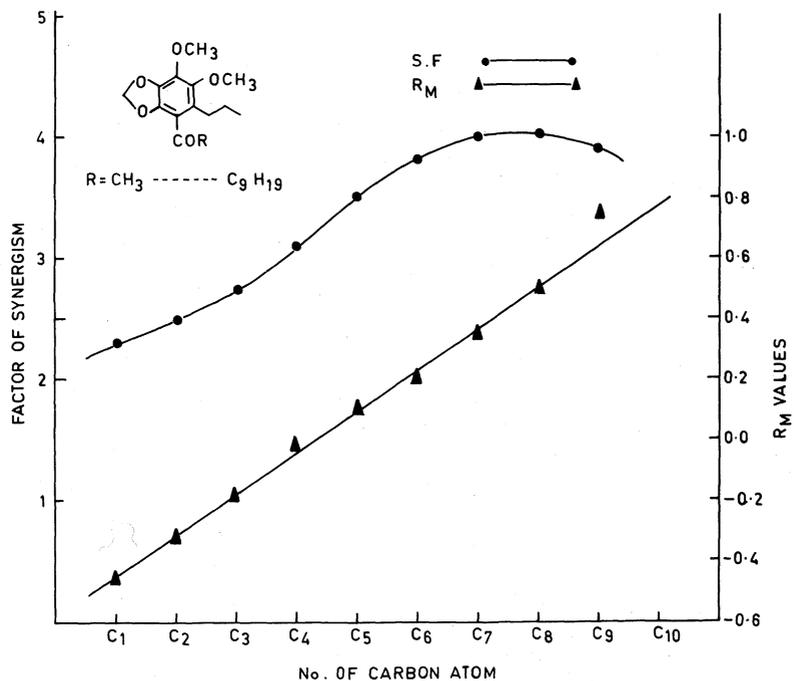


FIG. 1. Relationships between  $R_M$  Values, Factor of Synergism and Acyl Chain Length for Various Carbonyl Derivatives of Dihydrodillapiole.

▲—▲,  $R_M$  values; ●—●, factor of synergism.

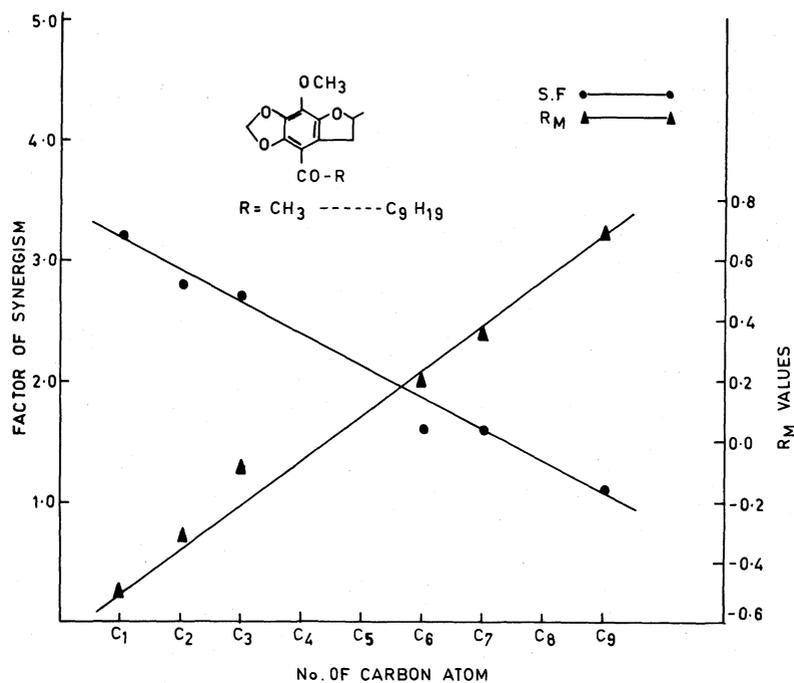
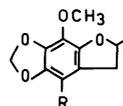
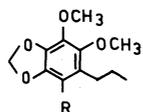


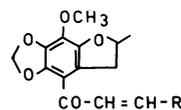
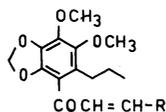
FIG. 2. Relationships between  $R_M$  Values, Factor of Synergism and Acyl Chain Length for Various Carbonyl Derivatives of Furapiole.

▲—▲,  $R_M$  values; ●—●, factor of synergism.



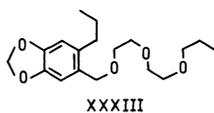
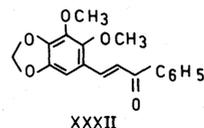
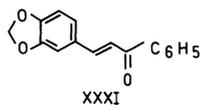
|      |                                      |
|------|--------------------------------------|
| I    | R = H                                |
| III  | R = COCH <sub>3</sub>                |
| IV   | R = COC <sub>2</sub> H <sub>5</sub>  |
| V    | R = COC <sub>3</sub> H <sub>7</sub>  |
| VI   | R = COC <sub>4</sub> H <sub>9</sub>  |
| VII  | R = COC <sub>5</sub> H <sub>11</sub> |
| VIII | R = COC <sub>6</sub> H <sub>13</sub> |
| IX   | R = COC <sub>7</sub> H <sub>15</sub> |
| X    | R = COC <sub>8</sub> H <sub>17</sub> |
| XI   | R = COC <sub>9</sub> H <sub>19</sub> |
| XII  | R = COCH <sub>2</sub> Cl             |

|       |                                      |
|-------|--------------------------------------|
| II    | R = H                                |
| XIII  | R = COCH <sub>3</sub>                |
| XIV   | R = COC <sub>2</sub> H <sub>5</sub>  |
| XV    | R = COC <sub>3</sub> H <sub>7</sub>  |
| XVI   | R = COC <sub>4</sub> H <sub>9</sub>  |
| XVII  | R = COC <sub>5</sub> H <sub>11</sub> |
| XVIII | R = COC <sub>6</sub> H <sub>13</sub> |
| XIX   | R = COCH <sub>2</sub> Cl             |



|       |   |
|-------|---|
| XX    | R = C <sub>6</sub> H <sub>5</sub>                     |
| XXI   | R = C <sub>7</sub> H <sub>5</sub> O <sub>2</sub>      |
| XXII  | R = C <sub>6</sub> H <sub>4</sub> NO <sub>2</sub> (p) |
| XXIII | R = C <sub>6</sub> H <sub>4</sub> Cl (p)              |
| XXIV  | R = C <sub>4</sub> H <sub>3</sub> O                   |
| XXV   | R = C <sub>6</sub> H <sub>13</sub>                    |

|        |   |
|--------|---|
| XXVI   | R = C <sub>6</sub> H <sub>5</sub>                     |
| XXVII  | R = C <sub>7</sub> H <sub>5</sub> O <sub>2</sub>      |
| XXVIII | R = C <sub>6</sub> H <sub>4</sub> NO <sub>2</sub> (p) |
| XXIX   | R = C <sub>6</sub> H <sub>4</sub> Cl (p)              |
| XXX    | R = C <sub>4</sub> H <sub>3</sub> O                   |



material and to the standard synergist, PBO. These findings in comparison with earlier work<sup>4</sup> indicate that  $\alpha,\beta$ -unsaturated aliphatic compounds are superior when compared with the corresponding aromatic compounds. Comparison of the activity of (XXXI) and (XXXII) with rest of the test chemicals shows that a shift in the position of the carbonyl moiety does not seem to significantly influence the synergistic activity.

Thus the results show that the synergistic effect of this type of pyrethrum synergist depends only partly on their lipophilicity, and the introduction of polar groups like nitro and

chloro as in XXII, XXIII, XXVIII and XXIX reduces the effect drastically. None of the compounds now reported are a better synergist than furapiole, although some of them are comparable to PBO.

#### EXPERIMENTAL

IR spectra were recorded on a Perkin Elmer-457 spectrophotometer. NMR spectra were recorded on a Varian A-60 spectrometer using TMS as the internal reference; chemical shifts are given in  $\delta$  values. Dihydrodillapiole and furapiole were synthesized as reported earlier.<sup>4,5</sup>

*General procedure for acylation of dihydrodillapiole (I)*

and furapiole (II). To a well stirred solution of the appropriate acid chloride (0.15 mol) and fused zinc chloride (0.1 mol) in dry methylene chloride (150 ml), was added dropwise dihydrodillapiole or furapiole (0.1 mol). The reaction mixture was stirred for 3~4 hr in an ice-bath, poured into cold water and extracted with methylene chloride. The extract was then washed free of acid and dried over  $\text{Na}_2\text{SO}_4$ . The acyl derivatives of dihydrodillapiole (III~XII) were obtained as colourless liquids after distillation under reduced pressure at an oil bath temperature of 200°C (yield ~70%). The acyl derivatives of furapiole (XIII~XIX) were obtained as colourless solids on crystallization from suitable solvents. All the acyl derivatives gave characteristic carbonyl peaks at 1660~1670  $\text{cm}^{-1}$  in their IR spectra. The following acyl derivatives of dihydrodillapiole and furapiole were synthesized by this method.

*Acetyl dihydrodillapiole (III)*. Anal. Found: C, 63.3; H, 7.3. Calcd. for  $\text{C}_{14}\text{H}_{18}\text{O}_5$ : C, 63.2; H, 6.8%. PMR ( $\text{CDCl}_3$ ) 0.91 (3H, t,  $J=6.5$  Hz,  $-\text{CH}_2\text{CH}_2\text{CH}_3$ ), 1.40 (2H, m,  $-\text{CH}_2\text{CH}_2\text{CH}_3$ ), 2.4 (3H, s,  $-\text{COCH}_3$ ), 2.6 (2H, t,  $J=6.5$  Hz,  $\text{ArCH}_2$ ), 3.66 (3H, s,  $\text{OCH}_3$ ), 3.97 (3H, s,  $\text{OCH}_3$ ), 5.88 (2H, s,  $-\text{OCH}_2\text{O}-$ ).

*Propionyl dihydrodillapiole (IV)*. Anal. Found: C, 63.9; H, 6.9. Calcd. for  $\text{C}_{15}\text{H}_{20}\text{O}_5$ : C, 64.3; H, 7.1%. PMR ( $\text{CCl}_4$ ) 0.92 (6H, m,  $2x\text{CH}_3$ ), 1.2~1.6 (2H, br m,  $\text{CH}_2\text{CH}_3$ ), 2.4~2.9 (4H, m,  $\text{ArCH}_2$  and  $-\text{COCH}_2\text{CH}_3$ ), 3.67 (3H, s,  $\text{OCH}_3$ ), 3.98 (3H, s,  $\text{OCH}_3$ ), 5.86 (2H, s,  $-\text{OCH}_2\text{O}-$ ).

*Butyryl dihydrodillapiole (V)*. Anal. Found: C, 65.8; H, 8.0. Calcd. for  $\text{C}_{16}\text{H}_{22}\text{O}_5$ : C, 65.3; H, 7.5%. PMR ( $\text{CCl}_4$ ) 0.92 (6H, t,  $J=7$  Hz,  $2x-\text{CH}_3$ ), 1.2~1.8 (4H, m,  $2x\text{CH}_2\text{CH}_3$ ), 2.3~2.83 (4H, m,  $\text{ArCH}_2$  and  $-\text{COCH}_2-$ ), 3.67 (3H, s,  $\text{OCH}_3$ ), 3.93 (3H, s,  $\text{OCH}_3$ ); 5.85 (2H, s,  $-\text{OCH}_2\text{O}-$ ).

*Valeryl dihydrodillapiole (VI)*. Anal. Found: C, 65.9; H, 8.1. Calcd. for  $\text{C}_{17}\text{H}_{24}\text{O}_5$ : C, 66.2; H, 7.8%. PMR ( $\text{CCl}_4$ ): 0.92 (6H, m,  $2x-\text{CH}_3$ ), 1.15~1.75 (6H, br m, methylenic protons); 2.15~2.85 (4H, m,  $\text{ArCH}_2$  and  $-\text{COCH}_2-$ ), 3.68 (3H, s,  $\text{OCH}_3$ ), 3.95 (3H, s,  $\text{OCH}_3$ ), 5.85 (2H, s,  $-\text{OCH}_2\text{O}-$ ).

*Caproyl dihydrodillapiole (VII)*. Anal. Found: C, 66.8; H, 8.5. Calcd. for  $\text{C}_{18}\text{H}_{26}\text{O}_5$ : C, 67.1; H, 8.1%. PMR ( $\text{CCl}_4$ ): 0.9 (6H, m,  $2x\text{CH}_3$ ), 1.2~1.8 (8H, br m, methylenic protons), 2.4~2.95 (4H, m,  $\text{ArCH}_2$  and  $\text{COCH}_2-$ ), 3.67 (3H, s,  $\text{OCH}_3$ ), 3.95 (3H, s,  $\text{OCH}_3$ ), 5.94 (2H, s,  $-\text{OCH}_2\text{O}-$ ).

*Heptanoyl dihydrodillapiole (VIII)*. Anal. Found: C, 68.2; H, 8.7. Calcd. for  $\text{C}_{19}\text{H}_{28}\text{O}_5$ : C, 67.9; H, 8.3%. PMR ( $\text{CCl}_4$ ) 0.92 (6H, m,  $2x\text{CH}_3$ ), 1.1~1.8 (10H, br m, methylenic protons), 2.46~2.83 (4H, m,  $\text{ArCH}_2$  and

$-\text{COCH}_2-$ ), 3.68 (3H, s,  $\text{OCH}_3$ ), 3.95 (3H, s,  $\text{OCH}_3$ ), 5.81 (2H, s,  $-\text{OCH}_2\text{O}-$ ).

*Octanoyl dihydrodillapiole (IX)*. Anal. Found: C, 69.0; H, 9.0. Calcd. for  $\text{C}_{20}\text{H}_{30}\text{O}_5$ : C, 68.6; H, 8.6%. PMR ( $\text{CCl}_4$ ): 0.90 (6H, m,  $2x\text{CH}_3$ ), 1.05~1.8 (12H, br m, methylenic protons) 2.2~2.8 (4H, m,  $\text{ArCH}_2$  and  $-\text{COCH}_2-$ ), 3.67 (3H, s,  $\text{OCH}_3$ ), 3.95 (3H, s,  $\text{OCH}_3$ ), 5.85 (2H, s,  $-\text{OCH}_2\text{O}-$ ).

*Pelargonyl dihydrodillapiole (X)*. Anal. Found: C, 69.1; H, 9.2. Calcd. for  $\text{C}_{21}\text{H}_{32}\text{O}_5$ : C, 69.2; H, 8.8%. PMR ( $\text{CCl}_4$ ): 0.91 (m, 6H,  $2x\text{CH}_3$ ), 1.2~1.8 (14H, br m, methylenic protons), 2.3~2.8 (4H, m,  $\text{ArCH}_2$  and  $-\text{COCH}_2-$ ), 3.67 (3H, s,  $\text{OCH}_3$ ), 3.95 (3H, s,  $\text{OCH}_3$ ), 5.85 (2H, s,  $-\text{OCH}_2\text{O}-$ ).

*Decanoyl dihydrodillapiole (XI)*. Anal. Found: C, 70.0; H, 9.4. Calcd. for  $\text{C}_{22}\text{H}_{34}\text{O}_5$ : C, 69.9; H, 9.1%. PMR ( $\text{CCl}_4$ ): 0.9 (6H, m,  $2x\text{CH}_3$ ), 1.15~1.75 (16H, br m, methylenic protons), 2.38~2.88 (4H, m,  $\text{ArCH}_2$  and  $-\text{COCH}_2-$ ), 3.78 (3H, s,  $\text{OCH}_3$ ), 3.96 (3H, s,  $\text{OCH}_3$ ), 5.86 (2H, s,  $-\text{OCH}_2\text{O}-$ ).

*Chloroacetyl dihydrodillapiole (XII)*. Anal. Found: C, 56.2; H, 6.1. Calcd. for  $\text{C}_{14}\text{H}_{17}\text{O}_5\text{Cl}$ : C, 55.9; H, 5.7%. PMR ( $\text{CDCl}_3$ ): 0.82 (3H, t,  $J=7$  Hz,  $-\text{CH}_2\text{CH}_2\text{CH}_3$ ), 1.15 (2H, m,  $\text{CH}_2\text{CH}_3$ ), 2.51 (2H, t,  $J=7$  Hz,  $\text{ArCH}_2-$ ), 3.73 (3H, s,  $\text{OCH}_3$ ), 3.82 (2H, s,  $-\text{COCH}_2\text{Cl}$ ), 3.96 (3H, s,  $\text{OCH}_3$ ), 5.83 (2H, s,  $-\text{OCH}_2\text{O}-$ ).

*Acetylfurapiole (XIII)*. Crystallized from pet. ether as colourless needles, mp 109°C. Anal. Found: C, 62.2; H, 6.1. Calcd. for  $\text{C}_{13}\text{H}_{14}\text{O}_5$ : C, 62.4; H, 5.6%. PMR ( $\text{CDCl}_3$ ): 1.45 (d, 3H,  $J=6.5$  Hz,  $-\text{CH}-\text{CH}_3$ ), 2.5 (3H,  $-\text{COCH}_3$ ), 3.65 (m, 2H,  $\text{Ar}-\text{CH}_2-$ ), 4.09 (s, 3H,  $\text{OCH}_3$ ), 4.9 (m, 1H,  $\text{O}-\text{CHCH}_3$ ), 5.95 (s, 2H,  $\text{OCH}_2\text{O}$ ).

*Propionyl furapiole (XIV)*. Crystallized from pet. ether as colourless needles, mp 95°C. Anal. Found: C, 64.1; H, 6.5. Calcd. for  $\text{C}_{14}\text{H}_{16}\text{O}_5$ : C, 63.6; H, 6.0%. PMR ( $\text{CDCl}_3$ ): 1.2 (t, 3H,  $J=7$  Hz,  $\text{COCH}_2\text{CH}_3$ ), 1.5 (d, 3H,  $J=6.5$  Hz,  $\text{CHCH}_3$ ), 2.9 (t, 2H,  $J=7$  Hz,  $\text{COCH}_2\text{CH}_3$ ), 3.65 (m, 2H,  $\text{ArCH}_2$ ), 4.12 (s, 3H,  $\text{OCH}_3$ ); 4.9 (m, 1H,  $\text{OCHCH}_3$ ) 5.94 (s, 2H,  $\text{OCH}_2\text{O}$ ).

*Butyryl furapiole (XV)*. Crystallized from pet. ether as colourless needles, mp 87°C. Anal. Found: C, 64.7; H, 6.4. Calcd. for  $\text{C}_{15}\text{H}_{18}\text{O}_5$ : C, 64.7; H, 6.5%. PMR ( $\text{CDCl}_3$ ) 1.0 (t, 3H,  $J=7$  Hz,  $\text{CH}_2\text{CH}_3$ ); 1.5 (m, 5H,  $\text{CH}_2-\text{CH}_3$  and  $\text{CH}-\text{CH}_3$ ), 2.8 (t, 2H,  $J=7$  Hz,  $\text{COCH}_2\text{CH}_2-$ ); 3.6 (m, 2H,  $\text{ArCH}_2$ ), 4.1 (s, 3H,  $-\text{OCH}_3$ ), 4.95 (m, 1H- $\text{CHCH}_3$ ), 6.0 (s, 2H,  $-\text{OCH}_2\text{O}-$ ).

*Heptanoyl furapiole (XVI)*. Crystallized from pet. ether as colourless plates mp 58°C. Anal. Found: C, 67.1; H, 7.9. Calcd. for  $\text{C}_{18}\text{H}_{24}\text{O}_5$ : C, 67.5; H, 7.5%. PMR ( $\text{CDCl}_3$ ) 0.9

(t, 3H,  $J=7$  Hz,  $-\text{CH}_2\text{CH}_3$ ); 1.15~1.9 (m, 11H,  $(\text{CH}_2)_4-\text{CH}_3$  and  $-\text{CHCH}_3$ ), 2.8 (t, 2H,  $J=7$  Hz,  $\text{COCH}_2\text{CH}_2-$ ), 3.6 (m, 2H,  $\text{ArCH}_2-$ ), 4.05 (s, 3H,  $\text{OCH}_3$ ), 4.9 (m, 1H,  $-\text{OCHCH}_3$ ), 5.95 (s, 2H,  $-\text{OCH}_2\text{O}-$ ).

*Octanoyl furapiole (XVII)*. Crystallized from pet. ether as colourless plates, mp 55°C. *Anal.* Found: C, 68.0; H, 7.8. Calcd. for  $\text{C}_{19}\text{H}_{26}\text{O}_5$ : C, 68.3; H, 7.8%. PMR ( $\text{CDCl}_3$ ) 0.9 (t, 3H,  $J=7$  Hz,  $\text{CH}_2\text{CH}_3$ ), 1.20~1.8 (m, 13H,  $-(\text{CH}_2)_5\text{CH}_3$  and  $-\text{CHCH}_3$ ), 2.86 (t, 2H,  $J=7$  Hz,  $\text{COCH}_2\text{CH}_2-$ ), 3.4 (m, 2H,  $\text{ArCH}_2-$ ), 4.05 (s, 3H,  $\text{OCH}_3$ ), 4.9 (m, 1H,  $\text{OCHCH}_3$ ), 5.98 (s, 2H,  $-\text{OCH}_2\text{O}-$ ).

*Decanoyl furapiole (XVIII)*. Crystallized from pet. ether as colourless powder, mp 53°C. *Anal.* Found: C, 69.7; H, 8.5. Calcd. for  $\text{C}_{21}\text{H}_{30}\text{O}_5$ : C, 69.6; H, 8.3%. PMR ( $\text{CDCl}_3$ ) 0.85 (t, 3H,  $J=7$  Hz,  $\text{CH}_2\text{CH}_3$ ), 1.15~1.6 (m, 17H,  $-\text{CH}_2(\text{CH}_2)_7\text{CH}_3$  and  $-\text{CHCH}_3$ ), 2.9 (t, 2H,  $J=7$  Hz,  $-\text{COCH}_2\text{CH}_2-$ ), 3.4 (m, 2H,  $\text{ArCH}_2-$ ), 4.09 (s, 3H,  $\text{OCH}_3$ ), 5.0 (m, 1H,  $-\text{OCHCH}_3$ ); 5.95 (s, 2H,  $-\text{OCH}_2\text{O}-$ ).

*Chloroacetyl furapiole (XIX)*. Crystallized from methanol as colourless needles, mp 147~149°C. *Anal.* Found: C, 55.1; H, 5.0. Calcd. for  $\text{C}_{13}\text{H}_{13}\text{O}_5\text{Cl}$ : C, 54.8; H, 4.6%. PMR ( $\text{CDCl}_3$ ) 1.38 (d, 3H,  $J=7$  Hz,  $-\text{OCHCH}_3$ ), 2.3~3.2 (br m, 2H,  $\text{ArCH}_2$ ), 3.7 (s, 2H,  $\text{COCH}_2\text{Cl}$ ); 3.94 (s, 3H,  $\text{OCH}_3$ ), 4.8 (m, 1H,  $\text{OCHCH}_3$ ), 5.8 (s, 2H,  $-\text{OCH}_2\text{O}-$ ).

*General procedure for the synthesis of  $\alpha,\beta$ -unsaturated ketones from Acetyl dihydrodillapiole and Acetyl furapiole (XX~XXX)*. To a well-stirred mixture of acetyl dihydrodillapiole or acetyl furapiole (0.1 mol), aqueous NaOH (20%, 10 ml) and ethanol (20 ml) maintained at a low temperature (ice bath) was added the appropriate aldehyde (0.1 mol) in ethanol (10 ml). The reaction mixture was gradually brought to room temperature and stirred until it became a semisolid viscous mass (2~3 hr). Water (100 ml) was added. The precipitated product was filtered and washed with cold water until free from alkali. It was finally crystallized from rectified spirit (yield 60~70%). All these compounds gave a characteristic peak at 1665~1670  $\text{cm}^{-1}$  for a carbonyl group, in their IR spectra. 3,4-Methylenedioxy cinnamoyl benzene (XXXI) was similarly prepared by condensation of piperonal and acetophenone. 2,3-Dimethoxy-4,5-methylenedioxy cinnamoyl benzene (XXXII) was prepared from dillapiole aldehyde and acetophenone in a similar manner.

*Cinnamoyl dihydrodillapiole (XX)*. Crystallized from methanol as light yellow needles mp 75°C. *Anal.* Found: C, 70.9; H, 5.5. Calcd. for  $\text{C}_{21}\text{H}_{22}\text{O}_5$ : C, 71.2; H, 6.20%. PMR ( $\text{CDCl}_3$ ) 0.95 (t, 3H,  $J=7$  Hz,  $-\text{CH}_2\text{CH}_3$ ); 1.5 (m, 2H,  $-\text{CH}_2\text{CH}_3$ ); 2.65 (t, 2H,  $J=7$  Hz,  $\text{ArCH}_2-$ ); 3.78 (s, 3H,  $\text{OCH}_3$ ); 4.05 (s, 3H,  $\text{OCH}_3$ ); 5.95 (s, 2H,  $-\text{O}-\text{CH}_2\text{O}-$ ); 7.1~7.7 (m, 7H,  $\text{C}_6\text{H}_5\text{CH}=\text{CH}-$ ).

*3,4-Methylenedioxy cinnamoyl dihydrodillapiole (XXI)*. Crystallized from methanol as yellow needles, mp 95°C. *Anal.* Found: C, 66.9; H, 6.0. Calcd. for  $\text{C}_{22}\text{H}_{22}\text{O}_7$ : C, 66.3; H, 5.5%. PMR ( $\text{CDCl}_3$ ) 0.95 (t, 3H,  $J=7$  Hz,  $\text{CH}_2\text{CH}_3$ ); 1.5 (m, 2H,  $\text{CH}_2\text{CH}_3$ ); 2.65 (t, 2H,  $J=7$  Hz,  $\text{ArCH}_2-$ ), 3.8 (s, 3H,  $2\times\text{OCH}_3$ ), 4.06 (s, 3H,  $\text{OCH}_3$ ) 5.86 & 5.95 (s, 4H,  $2\times\text{OCH}_2\text{O}-$ ), 6.6~7.6 (m, 5H,  $\text{C}_6\text{H}_3\text{CH}=\text{CHCO}$ ).

*4-Nitrocinnamoyl dihydrodillapiole (XXII)*. Crystallized from MeOH as bright yellow needles, mp 149~150°C. *Anal.* Found: C, 63.4; H, 5.8. Calcd. for  $\text{C}_{21}\text{H}_{21}\text{NO}_7$ : C, 63.2; H, 5.3%. PMR ( $\text{CDCl}_3$ ) 1.0 (t, 3H,  $J=7$  Hz,  $-\text{CH}_2\text{CH}_3$ ), 1.6 (m, 2H,  $\text{CH}_2\text{CH}_3$ ), 2.8 (t, 2H,  $J=7$  Hz,  $\text{ArCH}_2$ ); 3.8 (s, 3H,  $\text{OCH}_3$ ), 4.14 (s, 3H,  $\text{OCH}_3$ ), 5.98 (s, 2H,  $-\text{OCH}_2\text{O}-$ ), 7.2~7.9 (m, 5H,  $\text{C}_6\text{H}_4-\text{CH}=\text{CHCO}-$ ); 8.2 (d, 1H,  $J=9$  Hz,  $\text{Ar}-\text{CH}=\text{CH}-$ ).

*4-Chloro cinnamoyl dihydrodillapiole (XXIII)*. Crystallized from methanol as yellow coloured needles, mp 102~103°C. *Anal.* Found: C, 65.0; H, 6.0; Calcd. for  $\text{C}_{21}\text{H}_{21}\text{O}_5\text{Cl}$ : C, 64.9; H, 5.4%. PMR ( $\text{CDCl}_3$ ) 1.0 (t, 3H,  $J=7$  Hz,  $\text{CH}_2\text{CH}_3$ ); 1.2 (m, 2H,  $\text{CH}_2\text{CH}_3$ ), 2.7 (t, 2H,  $J=7$  Hz,  $\text{ArCH}_2-$ ), 3.8 (s, 3H,  $\text{OCH}_3$ ), 4.1 (s, 3H,  $\text{OCH}_3$ ), 5.95 (s, 2H,  $-\text{OCH}_2\text{O}-$ ), 7.2~7.8 (m, 6H,  $\text{C}_6\text{H}_4\text{CH}=\text{CH}-$ ).

*3-(2-Furylpropenoyl) dihydrodillapiole (XXIV)*. Light yellow coloured viscous liquid. *Anal.* Found: C, 65.9; H, 6.2. Calcd. for  $\text{C}_{19}\text{H}_{20}\text{O}_6$ : C, 66.3; H, 5.8%. PMR ( $\text{CDCl}_3$ ) 0.9 (t, 3H,  $J=7$  Hz,  $\text{CH}_2\text{CH}_3$ ), 1.5 (m, 2H,  $\text{CH}_2\text{CH}_3$ ), 2.65 (t, 2H,  $J=7$  Hz,  $\text{ArCH}_2-$ ), 3.78 (s, 3H,  $\text{OCH}_3$ ), 4.06 (s, 3H,  $\text{OCH}_3$ ), 5.91 (s, 2H,  $-\text{OCH}_2\text{O}-$ ), 6.5~7.52 (m, 5H,  $\text{C}_4\text{H}_3\text{O}-\text{CH}=\text{CHCO}$ ).

*2-Nonenoyl dihydrodillapiole (XXV)*. Colourless viscous liquid. *Anal.* Found: C, 70.0; H, 8.7. Calcd. for  $\text{C}_{21}\text{H}_{30}\text{O}_5$ : C, 69.6; H, 8.3%. PMR ( $\text{CDCl}_3$ ) 0.9 (t, 6H,  $J=7$  Hz, side chain methyls), 1.1~2.0 (br m, 12H,  $\text{CH}_2\text{CH}_3$  and  $-(\text{CH}_2)_5-\text{CH}_3$ ), 2.5 (t, 2H,  $J=7$  Hz,  $\text{ArCH}_2-$ ), 3.3~3.78 (m, 1H,  $\text{COCH}=\text{CH}-$ ), 3.8 (s, 3H,  $\text{OCH}_3$ ), 4.06 (s, 3H,  $\text{OCH}_3$ ), 5.85 (d, 1H,  $J=10$  Hz,  $-\text{COCH}=\text{CH}-$ ), 5.95 (s, 2H,  $-\text{OCH}_2\text{O}-$ ).

*Cinnamoyl furapiole (XXVI)*. Crystallized from MeOH as yellow needles mp 124°C. *Anal.* Found: C, 70.9; H, 5.5. Calcd. for  $\text{C}_{20}\text{H}_{18}\text{O}_5$ : C, 71.0; H, 5.3%. PMR ( $\text{CDCl}_3$ ) 1.4 (d, 3H,  $J=6.5$  Hz,  $-\text{CHCH}_3$ ), 3.4 (m, 2H,  $\text{ArCH}_2-$ ), 4.05 (s, 3H,  $\text{OCH}_3$ ), 4.9 (m, 1H,  $-\text{CHCH}_3$ ), 5.95 (s, 2H,  $-\text{OCH}_2\text{O}$ ), 7.1~7.8 (m, 7H,  $\text{C}_6\text{H}_5-\text{CH}=\text{CH}-$ ).

*3,4-Methylenedioxy cinnamoyl furapiole (XXVII)*. Crystallized from MeOH as bright yellow needles, mp 178°C. *Anal.* Found: C, 65.8; H, 5.0. Calcd. for  $\text{C}_{21}\text{H}_{18}\text{O}_7$ : C, 66.0; H, 4.7%. PMR ( $\text{CDCl}_3$ ) 1.5 (d, 3H,  $J=6.5$  Hz,  $\text{CHCH}_3$ ) 3.45 (m, 2H,  $\text{ArCH}_2$ ), 4.1 (s, 3H,  $\text{OCH}_3$ ), 5.0 (m, 1H,  $-\text{CHCH}_3$ ), 5.98 (s, 2H,  $-\text{OCH}_2\text{O}$ ), 6.73 (d, 1H,  $J=9$  Hz,  $\text{Ar}-\text{CH}=\text{CHCO}$ ); 7.05 (m, 3H, aromatic protons),

7.5 (d, 1H,  $J=9$  Hz, Ar-CH=CH-).

*4-Nitrocinnamoyl furapiole (XXVIII)*. Crystallized from MeOH as orange coloured needles, mp 233~235°C. *Anal.* Found: C, 63.0; H, 4.0. Calcd. for  $C_{20}H_{17}NO_7$ : C, 62.7; H, 4.4%. PMR ( $CDCl_3$ ) 1.45 (d, 3H,  $J=6.5$  Hz, -CHCH<sub>3</sub>), 3.3 (m, 2H, ArCH<sub>2</sub>-); 4.1 (s, 3H, OCH<sub>3</sub>), 4.9 (m, 1H, -CHCH<sub>3</sub>); 6.05 (s, 2H, -OCH<sub>2</sub>O), 7.7 (m, 5H, C<sub>6</sub>H<sub>4</sub>CH=CH-CO-), 8.25 (d, 1H,  $J=10$  Hz, ArCH=CH-).

*4-Chlorocinnamoyl furapiole (XXIX)*. Crystallized from MeOH as bright yellow plates, mp 184~185°C. *Anal.* Found: C, 64.1; H, 4.8. Calcd. for  $C_{20}H_{17}O_5Cl$ : C, 64.4; H, 4.6%. PMR ( $CDCl_3$ ) 1.46 (d, 3H,  $J=6.5$  Hz, CHCH<sub>3</sub>), 3.4 (m, 2H, Ar-CH<sub>2</sub>-), 4.1 (s, 3H, OCH<sub>3</sub>), 4.9 (m, 1H, -CHCH<sub>3</sub>), 6.06 (s, 2H, -OCH<sub>2</sub>O), 7.2~7.7 (m, 6H, ClC<sub>6</sub>H<sub>4</sub>CH=CH-).

*3-(2-Furylpropenoyl) furapiole (XXX)*. Crystallized from MeOH as light yellow plates, mp 134~135°C. *Anal.* Found: C, 66.3; H, 5.2. Calcd. for  $C_{18}H_{16}O_6$ : C, 65.9; H, 4.9%. PMR ( $CDCl_3$ ) 1.2 (d, 3H, CHCH<sub>3</sub>), 3.3 (m, 2H, ArCH<sub>2</sub>), 3.98 (s, 3H, OCH<sub>3</sub>), 4.9 (m, 1H, -CHCH<sub>3</sub>), 5.9 (s, 2H, OCH<sub>2</sub>O-), 6.3~7.6 (m, 5H, C<sub>4</sub>H<sub>3</sub>-OCH=CH-CO-).

*3,4-Methylenedioxy cinnamoyl benzene (XXXI)*. Crystallized from EtOH as light yellow needles, mp 120~121°C. *Anal.* Found: C, 76.0; H, 5.2. Calcd. for  $C_{16}H_{12}O_3$ : C, 76.2; H, 4.6%. PMR ( $CDCl_3$ ) 5.87 (s, 2H, -OCH<sub>2</sub>O-), 6.65~8.2 (m, 10H, Aromatic and -CH=CH- protons).

*2,3-Dimethoxy-4,5-methylenedioxy cinnamoyl benzene (XXXII)*. Crystallized from MeOH as light yellow needles, mp 75~76°C. *Anal.* Found: C, 68.9; H, 5.5. Calcd. for  $C_{18}H_{16}O_5$ : C, 69.2; H, 5.1%. PMR ( $CDCl_3$ ) 3.75 (s, 3H, OCH<sub>3</sub>), 3.92 (s, 3H, OCH<sub>3</sub>), 5.85 (s, 2H, -O-CH<sub>2</sub>O-); 6.7~8.1 (m, 8H, aromatic protons and Ar-CH=CH-).

*Formulation and bioassay.* The synergistic activity of all the test compounds was assessed as pyrethrum based emulsions at an insecticide to synergist ratio of 1:5 (w/w). Benzene solvent (10%) and Tween-80 emulsifier (0.2%) were maintained throughout in the spray emulsions. Two to three week old red flour beetles (*Tribolium castaneum*

Herbst) reared on wheat flour (free from pesticide) were used as test insects. The tests were conducted in three replications of fifteen insects each, as reported earlier.<sup>7)</sup> Data were subjected to probit analysis<sup>8)</sup> and factors of synergism were calculated from the LC<sub>50</sub> values.<sup>9)</sup> Piperonyl butoxide was used as a reference synergist. Purified pyrethrum extract (20%) was used for making a stock solution (4%) in benzene for biological screening.

*Lipophilicity of the test synergists.* Lipophilicity of the test compounds was determined by finding out the *R<sub>f</sub>* values on reverse phase TLC and then calculating the *R<sub>M</sub>* values by using the equation  $R_M = \log [(1/R_f) - 1]$ . Silica gel plates, after activation for 2 hr at 100°C, were coated with paraffin in hexane. The coated plates were spotted with the test compound and developed in an acetone-water mixture (70:30). The positions of all the keto compounds were visualised by spraying with 2,4-dinitrophenyl hydrazine reagent and/or dilute H<sub>2</sub>SO<sub>4</sub> spray followed by heating. *R<sub>f</sub>* values were measured and *R<sub>M</sub>* values were calculated from them.<sup>10)</sup>

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