M 1733

DANIEL WOJCIK

THE QUEEN RECOGNITION PHEROMONE OF SOLENOPSIS INVICTA, PREPARATION OF (E)-6-(1-PENTENYL)-2H-PYRAN-2-ONE.

J. R. Rocca[1], J. H. Tumlinson, B. M. Glancey[2] and C. S. Lofgren[2]

Insect Attractants, Behavior, and Basic Biology Research Laboratory,
Agric. Res. Ser., USDA, P. O. Box 14565, Gainesville, FL 32604[3]

Summary. The title compound, I, prepared in five steps via four known α-pyrones, is responsible, in part, for "queen recognition" by red imported fire ant workers. IR, NMR and MS data are presented.

The red imported fire ant, Solenopsis invicta (Buren), is a widely distributed pest of the southern United States. The ants are notorious for their painful, persistent stings and in areas with clay-like soil their mounds can be very large and hard, capable of damaging farm equipment or contaminating harvests. A native of South America, S. invicta's range in North America has expanded, apparently unchecked by natural enemies for approximately 40 years and it now infests 230 million acres here. Attempts at control with conventional pesticides have met with considerable difficulty (4).

Evidence has been presented for a queen recognition ("discriminator"?, cf. ref. 5) pheromone for S. invicta which attracts workers and causes them to move "surrogate queens" (inanimate objects treated with queen extracts) into their nests as if they were bona fide queens (6). Such a pheromone might prove useful in designing effective control strategies specific for this ant. We therefore isolated the chemicals responsible for these behaviors by monitoring the purification of queen extracts with previously described bioassays (7a-c).
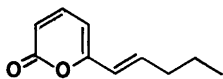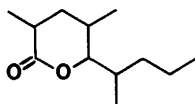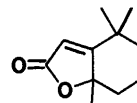

I   II   III

At least three substances appear responsible for "queen recognition" in this species. Details of the isolation of ca. 5-25 μg of these compounds from 18,000 fire ant queens and their spectral characterization will be published elsewhere (8). We have identified one of these pheromone components as an α-pyrone, (E)-6-(1-pentenyl)-2H-pyran-2-one (I), and describe here the first preparation of this compound. This same substance was reported as a volatile

metabolite from a soil fungus, Trichoderma viride, but no comparison was made then to synthetic material (9). A paper describing the synthesis of the second component of this pheromone, a saturated δ-lactone (II), will follow. The third substance, dihydroactinidiolide (III), has been synthesized previously (10); our identification was by spectral comparison to an authentic sample (11).

The method we have used to prepare I is shown in the following scheme. The 6-substituted-α-pyrones, IV-VII, are all known compounds. Our spectroscopic data for these compounds are given in (18) to supplement previously reported data. The initial condensation to give 6-trichloromethyl-2H-pyran-2-one, IV (77% dist. yield; mp. 60-2°, lit. 63-4°), and its subsequent hydrolysis to 2H-pyran-2-one-6-carboxylic acid, V (89% yield; mp. 229-31°, lit. 230-2°), were carried out according to Rey et al. (12). V was converted to 2H-pyran-2-one-6-carbonyl chloride, VI (97% dist. yield; mp. 65-8°, lit. 72-3°), using a 5 molar excess of thionyl chloride after the method of Wiley and Hart (13) with 0.05 mole equiv. of DMF (14). Rosenmund reduction of VI to 2H-pyran-2-one-6-carboxaldehyde, VII, is reported to proceed in 35% yield by Kurek and Vogel (15). We could obtain a 23% yield of somewhat impure material by their method of crystalliza- tion from xylene/hexane, but material of suitable purity (95+% by ^{1}H NMR) was obtained in ca. 10% yield (mp. 112-6°, lit. 124-5°) by precipitation from a solution of the crude product in Et_2O:acetone (4:1).
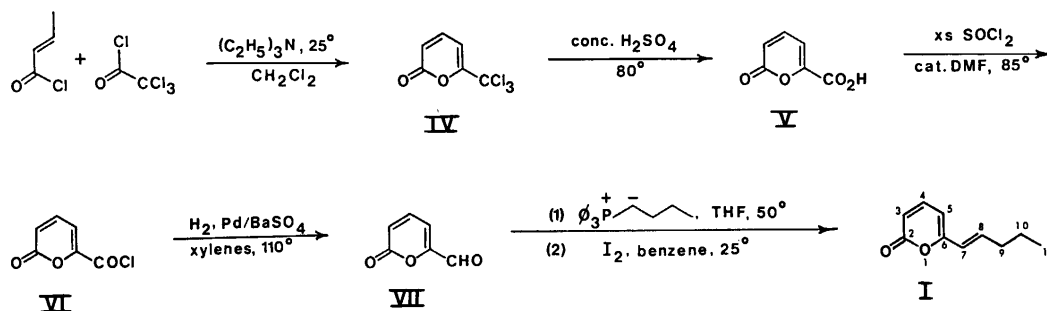
The final Wittig reaction was carried out as follows: (n-Butyl)triphenylphosphonium bromide (400 mg, 1 mmol, Aldrich Chem. Co.) was weighed in a dry flask with a magnetic stir-bar. The flask was fitted with a septum cap (other reagents added via syringe), placed under an atmosphere of dry argon, charged with 5 ml of dry THF (distilled from Na/Ph_2CO ketyl) and cooled to 0°. A 2.5-M solution of n-butyllithium in hexane (0.4 ml, 1 mmol, Alfa Prod.) was added and the ylid solution was warmed to 25°. The aldehyde VII (124 mg, 1 mmol) was added in 5 ml of dry THF and the reaction was warmed to 50° for 0.5 hr. The mixture was cooled to 25° and the solution adjusted to contain 25 ml of THF:Et_2O (3:2). Insoluble material was filtered and the filtrate was passed through 10 g of silica gel with Et_2O.

The ^{1}H NMR of this crude product in benzene-d_6 showed the expected $\underline{E}$ and $\underline{Z}$ unsaturated pyrones to be present in roughly equal proportions. The $\underline{Z}$ pyrone in this mixture was completely converted to the $\underline{E}$ isomer by a method proven successful in isomerizing other conjugated double bonds (16): the crude product was taken up in benzene, a few small crystals of iodine were added, and the solution was warmed in a water bath at 45-50° while removing the benzene and iodine on a rotary evaporator. (A ^{1}H NMR sample of the mixture in benzene-d_6 was free of the $\underline{Z}$ isomer within a few minutes after the addition of an I_2 crystal at 25°.)

The crude, isomerized material was purified by flash chromatography (17) on silica (25% acetone/hexane) to give a 175 mg sample. This was purified further by HPLC on silica (5% acetone/hexane) giving 36 mg (22% yield) of $\underline{I}$ as a pale yellow oil. Analysis by capillary GC on non-polar (30 m OV-101®, Kovat's Index = 1500) and polar (35 m SP-1000®, Kovat's Index = 2310) columns showed this sample to be 95-7% pure. Spectral data for $\underline{I}$ are given in (18). The pyrone was ultimately purified to 99+% (24 mg, 15% yield) by HPLC on silica for biological testing.

The synthetic pyrone, $\underline{I}$, is spectroscopically (IR, ^{1}H NMR, EIMS) and chromatographically (GC, 30 m SP-2340® cap. col.) identical with the natural substance. It is biologically active in combination with other pheromone components at $\underline{ca}$. 5 ng/rubber "surrogate queen" (weighing $\underline{ca}$. 20 mg). We believe this is the first report of the chemical identification of a queen pheromone from an ant.

Notes and References

(1) Deptment of Entomology & Nematology, Univ. of Florida under a cooperative agreement with the Insect Attractants Laboratory, Gainesville, FL. 32604

(2) Insects Affecting Man and Animals Laboratory, ARS, USDA, Gainesville, FL.

(3) Mention of commercial products does not constitute an endorsement by the USDA.

(4) S. L. Battenfield, ed.; Proc. of the Symp. on the Imported Fire Ant, Atlanta, GA; APHIS/USDA & EPA; (1982).

(5) C. D. Michner, Bull. Entomol. Soc. Am., 28, 7 (1982).

(6) B. M. Glancey; Proc. Tall Timbers Conf. on Ecol. Animal Control by Habitat Management-#7, Tall Timbers Research Station, Tallahassee, FL; 149 (1980).

(7) a) R. K. VanderMeer, B. M. Glancey, C. S. Lofgren, A. Glover, J. H. Tumlinson and J. Rocca, Ann. Entomol. Soc. Am., 73, 609 (1980); b) C. S. Lofgren, B. M. Glancey, A. Glover, J. Rocca and J. Tumlinson, Ann. Entomol. Soc. Am., 76, in press, (1983); c) B. M. Glancey, C. S. Lofgren, J. R. Rocca and J. H. Tumlinson, Sociobiology, 7, in press (1982).

(8) We propose to publish the isolation and identification in J. Chem. Ecology.

(9) M. O. Moss, R. M. Jackson and D. Rogers, Phytochemistry, 14, 2706 (1975).

(10) T. Sakan, S. Isoe and S. B. Hyeon, Tetrahedron Lett., 1623 (1967).

(11) A sample of (±)-III was kindly provided by Prof. M. Battiste and Dr. L. Strekowski, Dept. of Chemistry, Univ. of Florida, Gainesville.

(12) M. Rey, E. Dunkelblum, R. Allain and A. S. Dreiding, Helv. Chim. Acta, 53, 2159 (1970).

(13) R. H. Wiley and A. J. Hart, J. Am. Chem. Soc., 76, 1942 (1954).

(14) L. Fieser and M. Fieser, Reagents for Organic Synthesis, Vol. I, 286 (1967).

(15) J. T. Kurek and G. Vogel, J. Heterocyclic Chem., 5, 275 (1968).

(16) C. F. Wilcox, P. M. Lahti, J. R. Rocca, M. B. Halpern and J. Meinwald, Tetrahedron Lett., 1893 (1978).

(17) W. C. Still, M. Kahn and A. Mitra, J. Org. Chem., 43, 2923 (1978).

(18) The spectra for all compounds were recorded under the following conditions: FTIR--4 cm^{-1} resolution, Nicolet® 7199, ν in cm^{-1}; FT ^{1}H NMR--300 MHz, Nicolet NT-300, δ in ppm from TMS, J in Hz; FT ^{13}C NMR--75 MHz, NT-300, δ in ppm from TMS; GC EI MS - 70 eV, Finnigan® 1015/3200, reported as m/z (relative abundance).

For I (cf. ref. 9) - IR (CCl$_4$): 2958, 1744, 1655, 1540, 1361, 1095, 990, 966, 916. ^{1}H NMR (CDCl$_3$): 7.29 (dd, J = 6.7, 9.3, 1H/C-4); 6.70 (dt, J = 15.6, 7.2, 1H/C-8); 6.17 (d, J = 9.3, 1H/C-3); 5.99 (dt, J = 15.8, 1.4, 1H/C-7); 5.98 (d, J = 6.0, 1H/C-5); 2.21 (ddt, J = 7.2, 7.3, 1.2, 2H/C-9); 1.50 (tq, J = 7.3, 7.4, 2H/C-10); 0.94 (t, J = 7.4, 3H/C-11). ^{13}C NMR (CDCl$_3$, J$_{CH}$ in Hz): 162.1 (s) and 159.8 (s)/(C-2 and C-6); 143.9 (d, J = 163, C-4); 139.7 (d, J = 155, C-8); 121.7 (d, J = 158, C-7); 113.7 (d, J = 172, C-3); 103.1 (d, J = 168, C-5); 34.8 (t, J = 124, C-9); 21.9 (t, J = 128, C-10); 13.7 (q, J = 124, C-11). GC EI MS : 164 (44); 136 (10); 123 (22); 122 (58); 110 (34); 107 (81); 95 (66); 94 (100); 79 (54); 77 (49); 55 (39); 41 (27).

For IV - IR(CHCl$_3$): 3126, 3095, 1753, 1638, 1559, 1411, 1344, 1099, 995, 912, 816. ^{1}H NMR(acetone-d$_6$): 7.70 (dd, J = 6.9, 9.5, 1H/C-4); 7.10 (dd, J = 6.9, 0.7, 1H/C-5); 6.51 (dd, J = 9.5, 0.7, 1H/C-3). ^{13}C NMR(acetone-d$_6$): 159.1, 157.4, 143.7, 118.6, 103.3, 90.3.

For V - IR(KBr): 3300-2700, 3092, 1735, 1690, 1627, 1415, 1241, 1204, 1163, 1128, 887, 839. ^{1}H NMR(acetone-d$_6$): 7.66 (dd, J = 9.4, 6.6, 1H/C-4); 7.18 (dd, J = 6.6, 1.0, 1H/C-5); 6.56 (dd, J = 9.4, 1.0, 1H/C-3). ^{13}C NMR(DMSO-d$_6$): 160.4, 160.0, 149.6, 143.4, 120.0, 110.1.

For VI - IR(KBr): 3106, 3091, 1731, 1629, 1409, 1340, 1219, 1109, 1045, 1009, 923, 828. ^{1}H NMR(acetone-d$_6$): 7.77 (dd, J = 9.4, 6.7, 1H/C-4); 7.55 (dd, J = 6.7, 0.9, 1H/C-5); 6.75 (dd, J = 9.4, 0.9, 1H/C-3).

For VII - IR(KBr): 3107, 3078, 1715, 1688, 1629, 1356, 1210, 1187, 1106, 1045, 990, 920. ^{1}H NMR(acetone-d$_6$): 7.76 (dd, J = 9.4, 6.4, 1H/C-4); 7.21 (dd, J = 6.4, 1.0, 1H/C-5); 6.64 (dd, J = 9.4, 1.0, 1H/C-3); 9.56 (s, 1H/C-7). ^{13}C NMR(acetone-d$_6$): 184.4 (d, J = 187, C-7); 159.9 (s) and 155.6 (s)/(C-2 and C-6); 143.2 (d, J = 170, C-4); 122.7 (d, J = 174, C-3); 115.4 (d, J = 176, C-5).