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Old Dominion U., Norfolk, Va.

A STUDY OF THE EFFECT OF LIGHT ON THE EMISSION OF TERPENES FROM CERTAIN WOODY PLANTS

by

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MATERIALS AND METHODS

A Varian Aerograph Model 1400 single column gas chromatograph, equipped with a hydrogen flame ionization detector was used in this study. The hydrogen flame detector was utilized in this study because it responds specifically and linearly to the number of carbon atoms in an organic compound.

Air samples were passed through a 6 foot by 0.125 inch O.D., stainless steel column, packed with 5% carbowax 20M on acid-washed chromosorb W, 60/80 mesh. The thermal regions were maintained at 120°C for the injector, 60°C for the column, and 180°C for the detector. The operating flow rates for nitrogen, hydrogen and air were 15 ml/min., 30 ml/min., and 300 ml/min. respectively. The electrometer of the gas chromatograph was operated at maximum attenuation (IX) and at a sensitivity range of 10^{-11} amps per millivolt (amps/m.v.). A Varian Aerograph Model A-25 10 inch potentiometric strip chart recorder was operated at a setting of 1 mv. and a chart speed of 0.5 inches per minute (in/min.). In conjunction with the strip chart recorder a Varian Aerograph 200 Series disc integrator and a Model 610 automatic printer were used. Some pure terpene compounds, the ones most frequently emitted by woody plants, were used for standardization. The standards used were isoprene, alpha pinene, beta pinene, camphene, myrcene, alpha terpineol and limonene.

The following woody plants were utilized in this study: Atlantic White Cedar (Chamaecyparis thyoides), American Holly (Ilex opaca), Sweet gum (Liquidambar styraciflua), Red Bay (Persea borbonia), Loblolly pine (Pinus taeda), Live oak (Quercus virginiana), Willow oak (Quercus phellos) and Bay berry (Myrica pensylvanica).

Plants 2 or 3 feet in height were collected from various sites in the Great Dismal Swamp, Suffolk, Virginia with the exception of bay berry which was collected at Duck, North Carolina. The plants were maintained in a greenhouse to allow an acclaimation period of at least two weeks before analysis.

The plants were enclosed in plexiglass ch mbers. Two of the chambers were 1 foot square by 3 feet high, and one was 2 feet high by 3 feet wide by 1 foot deep both were equipped with rubber septum ports for air sampling.

A Hamilton model 1002 gas t'ght syringe, with a 2 inch 23 gauge needle was used for taking 1 ml. air samples from the chambers. Lodge and Pate (1966), reported that the use of hypodermic needles as critical orifices in air sampling experiments were more than satisfactory.

The plants were placed inside the plexiglass chambers on a table in the laboratory and the chambers were sealed with 2 inch aluminized duct tape. Duplicate sets of samples were collected from each plant in each chamber.

The first sampling set, constituted the control i.e. plants not illuminated, during subsequent sampling sets the plants were illuminated with 150 watt Westinghouse flood lamps, placed 1 foot from the base of the chambers. The light intensity given off by each lamp was approximately 300 lux. In each sampling set 1 ml. air samples were taken from each of the plants in a group at the end of 1, 3, 5, and 7 hours. All of the 1 ml. samples were injected directly into the gas chromatograph immediately after withdrawal from the chambers. After each group of plants were analysed their leaves were dried at 105°C for 48 hours and weighed.

RESULTS AND DISCUSSION

Six distinct terpene components were resolved from the 8 plants analyzed by gas chromatography, but only 5 of these components were definitely identified. The sixth chemical component had a retention time of 0.39 minutes and appeared in the samples taken from the 2 oak species (Table 1). This component is probably one of the lighter hydrocarbon compounds such as butene. The hemiterpene, isoprene, was the only terpene emitted by all the plants in this study (Table 1). Alpha pinene, a monoterpene, was emitted by 4 of the 8 plants in this study. It was also noted that Beta pinene was emitted by all the Alpha pinene producers except Atlantic White Cedar. The shrubs in this study, redbay and bayberry, were the only 2 plants to emit myrcene. The Willow and live Oak, were the only 2 plants to emit exactly the same components, but the components differed quantitatively for the 2 plants (Table 1, 5 and 7).

The quantitative output of terpene components by each plant varied considerably during the illumination-sampling period (Tables 3). However, upon further investigation the terpene output seemed to be related to total leaf surface area per plant and total dry leaf weight per plant. The correlation coefficient between these factors and terpene output was greater than 0.9 (Table 2).

During this study three things were continually observed. One, the temperature inside the plant chambers would gradually rise from 25°C to 30°C during the illumination period. Two, heavy condensation formed on the inside walls of most of the chambers, within an hour or two, after illumination and remained throughout the sampling period. Three, there was considerable variability in the level of detectable terpenes available for sampling among the plants studied.

The increase in temperature within the chambers during the illumination period is attributable to the heat emanating from the flood lamps. However, air temperatures within the chambers never rose above 30°C.

The condensation that formed on the inside walls of the chambers resulted from plants undergoing increased transpiration. This is logical since transpiration is temperature dependent. Following the temperature increase the relative humidity inside the chambers rose to or near 100%, and excess moisture condensed on the relatively cooler chamber walls.

The variability in the level of terpenes emitted by each plant could be attributed to several factors: 1) differences in the total leaf surface and leaf biomass (Table 2), 2) adhesion of vapors to chamber walls, which were laden with condensate, 3) terpene photo disintegrated, and 4) reduction in terpene emissions due to stomatal closure due to excess water loss.

Tables 3-9 present the log of the areas for each component emitted by each of the plants during the illumination period. The data for isoprene, Alpha pinene, camphene, Beta pinene and the unknown showed a steady decrease in the level of detectable terpenes, through the course of study. However, Alpha and Beta pinene components emitted by loblolly pine showed a gradual increase during the last hour of illumination. Myrcene, the component emitted by the 2 shrubs redbay and bayberry was the only component emitted to display a somewhat different behavior (Table 6 and 9).

TABLE I

COMPOSITION OF VAPORS EMITTED FROM THE PLANTS ANALYZED

BOILING POINT (°C) RETENTION TIME (min): TERPENE :	? 0.39 UNKNOWN	34 1:00 ISOPRENE	155-156 2:12 ALPHA PINENE	159-160 2:26 CAMPHENE	164-165 2:50 BETA PINENE	167 2:64 MYRCENE
PLANT						
Chamaecyparis thyoids		X	X	X		
Ilex opaca		X				
Liquidambar styraciflua		X	X		X	
Myrica pensylvanica		X	X		X	X
Persea borbonia		X				X
Pinus taeda		X	X		X	
Quercus phellos	X	X		X		
Quercus virginiana	X	X		X		

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TABLE 2

LEAF MEASUREMENT AND WEIGHTS FOR THE PLANTS IN THIS STUDY

PLANT	TOTAL NUMBER LEAVES PER PLANT	TOTAL LEAF SURFACE AREA PER PLANT (cm^2)	TOTAL DRY LEAF WEIGHT PER PLANT (gm)
C. thyoides	350	8,750.0	21.70
I. opaca	70	2,005.8	14.92
L. styraciflua	16	2,040.0	4.00
M. pensylvanica	77	3,765.3	7.30
P. borbonia	29	728.6	1.60
P. taeda	360	1,080.0	9.00
Q. phellos	140	7,700.0	14.00
Q. virginiana	120	5,382.0	14.95

TABLE 3

QUANTITATIVE COMPOSITION OF VAPORS FROM ATLANTIC WHITE CEDAR

TIME IN HRS.	COMPONENT	*AREA (mm^2)	% COMPONENT OF TOTAL AREA	*NANOLITERS/ml of SAMPLE
1	Isoprene	603	95.87	1,200.0
	Alpha pinene	19	3.02	37.9
	Camphene	7	1.11	11.3
	TOTAL	629	100.00	1,249.2
3	Isoprene	376	88.89	800.0
	Alpha pinene	36	8.51	71.8
	Camphene	11	2.60	17.8
	TOTAL	423	100.00	889.6
5	Isoprene	362	90.05	700.0
	Alpha pinene	31	7.71	61.8
	Camphene	9	2.24	14.5
	TOTAL	402	100.00	776.3
7	Isoprene	262	91.93	500.00
	Alpha pinene	17	5.96	34.00
	Camphene	6	2.11	9.68
	TOTAL	285	100.00	543.68

* AREA WAS COMPUTED BY PEAK HEIGHT METHOD

* NANOLITERS COMPUTED BY: $\frac{\text{area unknown}}{\text{area standard}}$ X DILUTION FACTOR = QUANTITY UNKNOWN

TABLE 4

QUANTITATIVE COMPOSITION OF VAPORS FROM AMERICAN HOLLY

TIME IN HRS.	COMPONENT	AREA (mm^2)	% COMPONENT OF TOTAL AREA	NANOLITERS/ml of SAMPLE
1	Isoprene	330	100	705
3	Isoprene	296	100	632.50
5	Isoprene	180	100	385
7	Isoprene	146	100	312

TABLE 5

QUANTITATIVE COMPOSITION OF VAPORS FROM LIVE OAK

TIME IN HRS.	COMPONENT	AREA (mm^2)	% COMPONENT OF TOTAL AREA	NANOLITERS ′ al of SAMPLE
1	Unknown	74	12.17	---
	Isoprene	516	84.87	1.100
	Camphene	18	2.96	29.1
	TOTAL	608	100.00	1,129.1
3	Unknown	68	11.41	---
	Isoprene	486	81.54	1,000
	Camphene	42	7.05	67.8
	TOTAL	596	100.00	1,067.8
5	Unknown	54	13.24	---
	Isoprene	316	77.45	600
	Camphene	38	9.31	61.3
	TOTAL	408	100.00	661.3
7	Unknown	23	6.55	---
	Isoprene	302	86.04	600
	Camphene	26	7.41	42
	TOTAL	351	100.00	642

TABLE 6

QUANTITATIVE COMPOSITION OF VAPORS FROM RED BAY

TIME IN HRS.	COMPONENT	AREA (mm^2)	% COMPONENT OF TOTAL AREA	NANOLITERS/ml of SAMPLE
1	Isoprene	150	90.91	310.00
	Myrcene	15	9.09	48.25
	TOTAL	165	100.00	358.25
3	Isoprene	129	91.49	275.00
	Myrcene	12	8.51	38.50
	TOTAL	141	100.00	313.50
5	Isoprene	126	82.89	270.00
	Myrcene	26	17.11	83.50
	TOTAL	152	100.00	353.50
7	Isoprene	86	81.13	183.50
	Myrcene	20	18.87	64.25
	TOTAL	106	100.00	247.75

TABLE 7

QUANTITATIVE COMPOSITION OF VAPORS FROM WILLOW OAK

TIME IN HRS.	COMPONENT	AREA (mm^2)	% COMPONENT OF TOTAL AREA	NANOLITERS/ml of SAMPLE
1	Unknown	50	13.16	---
	Isoprene	320	84.21	682.50
	Camphene	10	2.63	16.13
	TOTAL	380	100.00	698.63
3	Unknown	56	10.16	---
	Isoprene	459	83.30	977.50
	Camphene	36	6.53	58.00
	TOTAL	551	99.99	1035.50
5	Unknown	20	4.12	---
	Isoprene	450	92.59	960.00
	Camphene	36	3.29	25.75
	TOTAL	486	100.00	985.75
7	Unknown	13	2.75	---
	Isoprene	435	92.16	927.50
	Camphene	24	5.08	38.75
	TOTAL	472	99.99	966.25

TABLE 8

QUANTITATIVE COMPOSITION OF VAPORS FROM LOBLOLLY PINE

TIME IN HRS.	COMPONENT	AREA (mm^2)	% COMPONENT OF TOTAL AREA	NANOLITERS/ml of SAMPLE
1	Isoprene	84	24.14	180.00
	Alpha pinene	156	44.83	311.00
	Beta pinene	108	31.03	234.50
	TOTAL	348	100.00	725.50
3	Isoprene	76	24.52	162.50
	Alpha pinene	142	45.80	283.00
	Beta pinene	92	29.68	183.25
	TOTAL	310	100.00	628.75
5	Isoprene	64	28.07	136.50
	Alpha pinene	94	41.23	187.25
	Beta pinene	70	30.70	199.75
	TOTAL	228	100.00	523.50
7	Isoprene	56	68.29	119.50
	Alpha pinene	16	19.51	32.00
	Beta pinene	10	12.20	21.50
	TOTAL	82	100.00	173.00
9	Isoprene	50	48.08	106.50
	Alpha pinene	38	36.54	75.75
	Beta pinene	16	15.38	34.75
	TOTAL	104	100.00	217.00

TABLE 9

QUANTITATIVE COMPOSITION OF VAPORS FROM BAY BERRY

TIME IN HRS.	COMPONENT	AREA (mm^2)	% COMPONENT OF TOTAL AREA	NANOLITERS/ml of SAMPLE
1	Isoprene	174	61.26	370.00
	Alpha pinene	74	26.06	147.50
	Beta pinene	5	1.76	10.85
	Myrcene	31	10.92	99.50
	TOTAL	284	100.00	627.85
3	Isoprene	162	57.45	[illegible]
	Alpha pinene	68	24.11	135.50
	Beta pinene	9	3.19	19.53
	Myrcene	43	15.25	138.83
	TOTAL	282	100.00	638.86
5	Isoprene	158	57.25	337.50
	Alpha pinene	28	10.15	55.75
	Beta pinene	6	2.17	13.00
	Myrcene	84	30.43	269.75
	TOTAL	276	100.00	676.00
7	Isoprene	134	70.16	285.00
	Alpha pinene	16	8.38	32.00
	Beta pinene	4	2.09	8.68
	Myrcene	37	19.37	118.75
	TOTAL	191	100.00	944.43
9	Isoprene	102	54.55	217.50
	Alpha pinene	14	7.49	28.00
	Beta pinene	3	1.60	6.50
	Myrcene	68	36.36	217.50
	TOTAL	187	100.00	469.50

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