HortScience 12(1):50. 1977.

Phyllotaxy Variability in *Pelargonium*[1]

Robert M. Skirvin[2] and Jules Janick
Department of Horticulture, Purdue University, West Lafayette, IN 47907

Additional index words. geranium

Phyllotaxy (the arrangement of leaves on the stem) in scented geranium is typically 2/5, i.e., in order to reach a leaf directly above another, it is necessary to maneuver 2 complete turns around the stem and pass 5 other leaves. We have observed variable phyllotaxy of certain clones of *Pelargonium*. For instance, in 'Rober's Lemon Rose' (RLR) (*Pelargonium graveolens* L'Heritier ex. Aiton) nearly all plants change their phyllotaxy from 2/5 to 1/2 (Fig. 1, 2) (3) on either the main axis or lateral shoots. Most plants show: a) a region of 2/5 (usually the oldest growth near the base of the plant), b) a region of 1/2 (the newest growth), and c) a variable (1/2 + 2/5) region between these two (Table 1). The 2/5 phyllotaxy is associated with vegetative growth, while the 1/2 or 1/2 + 2/5 phyllotaxy is associated with flowering. The phyllotaxy switch was reversible. Lateral buds developing within a phyllotactic region could segregate all 3 patterns (Table 1).

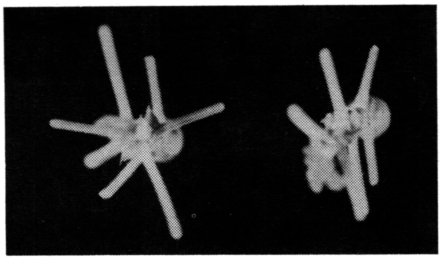

Fig. 1. Phyllotaxy variation in scented geranium. (left) 2/5, (right 1/2.

Changes in phyllotaxy were noted for various propagules of RLR and 'Attar of Rose' (*P. capitatum* (L.) L'Heritier ex. Aiton), 'Clorinda' (*P. domesticum* Bailey x *P. denticulatum Poir*) and an unidentified clone of garden geranium (*P. hortorum* Bailey). Although flowering was always associated with phyllotaxy change in RLR, this was not necessarily the case for the other cultivars.

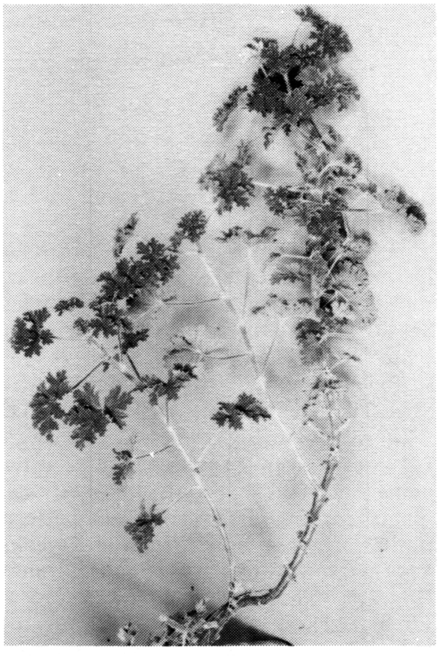

Fig. 2. Lateral shoots of 2/5 (basal) and 1/2 (apical) phyllotaxy arising from the main stem arising from a *dentated* clone (3) of 'Rober's Lemon Rose'.

Table 1. Phyllotaxy of lateral shoots derived from different regions of the main stem.

Phyllotaxy of main stem	n	No. of lateral shoots 2/5	*Phyllotaxy* variable	1/2
2/5	21	10	5	6
variable	17	8	5	4
1/2	25	5	10	10

Abo-El-Nil and Hildebrandt (1) have reported a change in the phyllotaxy of *P. hortorum* cv. Lady Ester. The original 'Lady Ester' clone had a 1/2 phyllotaxy while plants derived from tissue culture of 'Lady Ester' have a normal 2/5 phyllotaxy.

Although phyllotaxy changes have been associated with altered nutritional status, vigor, radiation application, and meristem injury (2), the most common cause is related to developmental stages such as the switch to flowering (2) or from juvenile to mature (4). *Pelargonium* appears to be a good experimental plant to attack the problem of phyllotactic change.

Literature Cited

1. Abo-El-Nil, M. M. and A. C. Hildebrandt. 1972. Morphological changes in geranium plants differentiated from anther cultures. *In Vitro* 7:258 (Abstr.)
2. Cutter, E. 1965. Recent experimental studies of the shoot apex and shoot morphogenesis. *Bot. Rev.* 31:7-113.
3. Skirvin, R. M. and J. Janick. 1976. Tissue culture induced variability in scented *Pelargonium* spp. *J. Amer. Soc. Hort. Sci.* 101:281-290.
4. Zimmerman, R. H. 1972. Juvenility and flowering in woody plants: a review. *HortScience* 7:447-455.

[1]Received for publication July 27, 1976. Journal Paper no. 6362 of the Purdue University Agricultural Experiment Station.

[2]Present address: Department of Horticulture, University of Illinois, Urbana, Illinois 61801.

HortScience 12(1):50–53. 1977.

Identification of Horticultural Crops by Remote Spectroscopic Techniques[1]

E. J. Brach and J. M. Molnar
Engineering Research Service and Ottawa Research Station, Research Branch, Agriculture Canada, Ottawa, Ontario, K1A OC6, Canada

Additional index words. onion, *Allium cepa,* pea, *Pisum sativum,* radish, *Raphanus sativus,* lettuce, *Lactuca sativa*

Abstract. **Remote spectroscopy was applied to identify horticultural crops including spring onion (*Allium cepa* L.), pea (*Pisum sativum* L.), radish (*Raphanus sativus* L.) and lettuce (*Lactuca sativa* L.) and to determine their maturity. Spectroscopic measurements were taken in the 350 – 700 nm, the 600 – 1800 nm, and the 1200 – 3680 nm ranges. Laser fluorescence spectroscopy was also used by exciting the plants with a 25 mW pulsed laser beam at 337.1 nm and an 18 mW continuous laser beam at 441 nm. The experiment demonstrated the potential of these techniques for the identification of horticultural crops by remote sensing.**

[1]Received for publication July 26, 1976. Contribution No. 613 from Engineering Research Service and No. 469 from Ottawa Research Station.

Brach et al. (1) determined lettuce maturity by remote spectroscopy, using a mobile laboratory attached to a greenhouse. Spectroradiometers measured spectral reflectance at the 350 to 700 and 600 to 3680 nm. Laser fluorometry was also employed, using exciting wavelengths of 337.1 nm, 25 mW from a pulsed laser beam and 441 nm from a 18 mW continuous wave laser beam.

We have utilized these devices to further investigate the identification of horticultural crops with remote spectroscopic techniques. This may be useful for airborne applications to assess the inventory of these crops for marketing purposes.

Several authors (3, 4, 5, 6, 7) have discussed the possibility of using the optical characteristics of leaves to identify crops, or to evaluate their maturity. The spectral quality and intensity of plant reflectance are dependent on leaf geometry, morphology and physiology and soil site and climate, which were taken into consideration in the experiments reported. The soil moisture

availability to the plant, the greenhouse climate and the spectral quality and intensity of irradiance were uniform for each crop. To correct for the effect of leaf geometry on plant reflectance, the seeding rate of each crop was selected to fully cover the experimental plot with foliage. However, there were some difficulties in this regard with the onions.

The spectrometer evaluates a 25 cm cross section of the plot canopy. Therefore, the average radiance of many leaves from a number of plants is measured, cancelling the individual leaf geometry effects.

'Yellow Globe Danvers' onion, 'Thomas Lexton' pea, 'Comet' and 'Cherry Belle' radish and 'Imperial 466' and 'Fulton Zero M1' lettuce were seeded in replicate 1.3 x 1.3 m plots on 3 dates (Dec. 15 1975, Jan. 22 and March 15, 1976). The plants were fertilized every 2 weeks with N-P-K (20-5-30) at the rate of 6 g/liter of water. The soil consisted of 1 peat:1 soil:1 sand 20 cm deep, maintained at 13 to 14°C. Temp was kept between 15 to 18°C during the day and at 13° at night. Measurements were taken at night under artificial light since uneven ice formation on the greenhouse roof prevented uniform transmittance of the natural radiant energy. Fifteen 500 watt filament lamps were used to irradiate the plants; 28% of the lamp power was in the UV and visible portion (200 to 720 nm) of the spectrum, while 72% was in the infrared region. The lamps were spaced so that each experimental plot was uniformly illuminated. The power and spectral output of the lamps within the time span of the experiment were constant within 3%.

Two distinctive peaks (P_1, P_2) at 550 and 740 nm and a valley (V_1) at 690 nm occurred in the reflectance curves of all the crops (Fig. 1). Crops differed quantitatively (amplitude) but not qualitatively (wavelength). Half bandwidth (HBW) also differed. P_1 corresponds to the high reflectance at 550 nm in the green and P_2 the high reflectance at 740 nm in the near infrared spectrum. V_1 corresponds to the chlorophyll absorption band at 690 nm in the red region. The amplitude of P_1 differs greatly between different crops seeded on the same date (172 for lettuce, 125 for pea and 79 for onion), whereas the spread in P_2 is not as great (148 for pea, 126 for lettuce and 106 for onion). The amplitude differences in V_1 for onion and pea were small whereas there was a 100% difference between lettuce and onion or pea. P_1 and P_2 values were normalized to V_1 (i.e., $P_1 - V_1$ and $P_2 - V_2$) and the ratios P_1/P_2 calculated (Table 1). There were daily variations, and the trend for the normalized values of P_1 and P_2 was to increase with maturity in each crop. Normalized values of P_1 and P_2 differed significantly between lettuce and radish and between lettuce and pea. The differences in the half bandwidth (HBW) between the crops were not consistent.

The spectral curves in the range 600

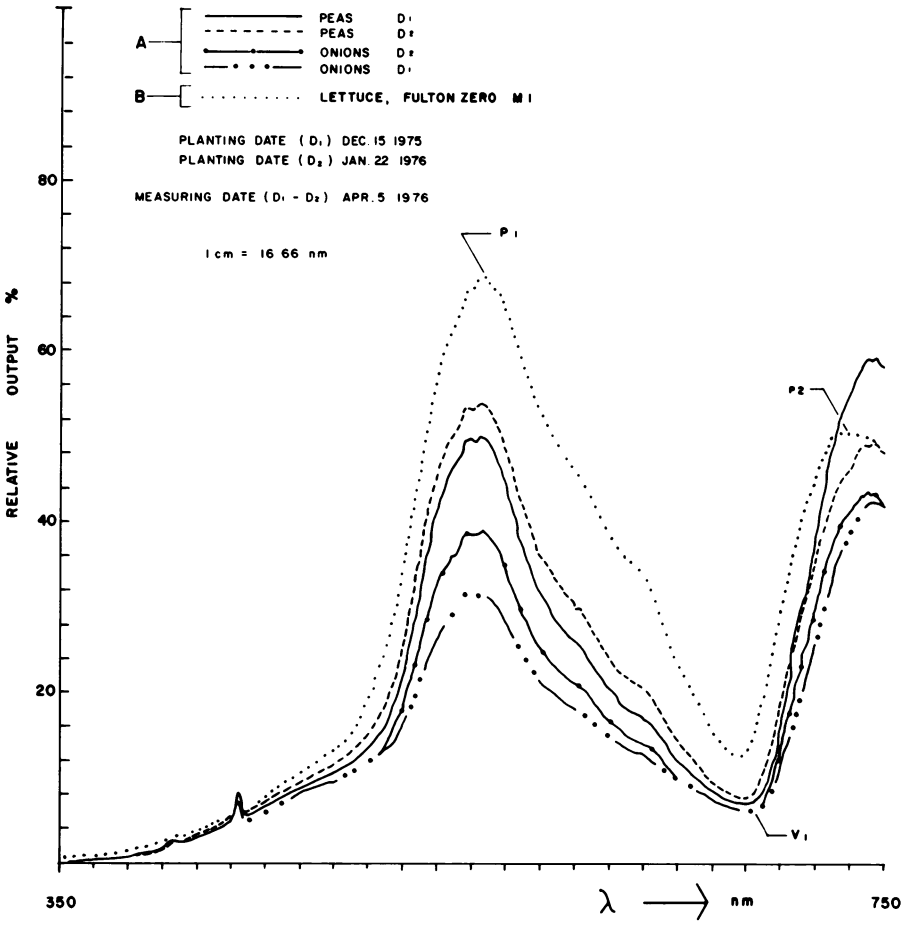

Fig. 1. Spectral curves in the visible range (350 to 750 nm) for pea, onion, and lettuce planted on 2 different dates, Dec. 15, 1975 (D_1) and Jan. 22, 1976 (D_2). P_1 indicates peak values at 556.6 nm, P_2 at 743.4 nm and V_1 indicates a valley point at 679.8 nm.

Table 1. Peaks (P_1, P_2) standardized to valley point V_1 of spectral curves in the visible range of the spectrum, the half peak (P_1) bandwidth HBW, and the ratio value of P_1, P_2 for onions, peas, radishes and lettuce. D_1 planted Dec. 15, 1975; P_1 at 556.6 nm; P_2 at 743.4 nm; V_1 at 679.8 nm.

Date sampled	Pea D_1				Lettuce cv. Fulton D_1				Onion D_1				Radish cv. Comet D_1				Radish cv. Cherry Belle D_1			
	P_1	P_2	P_1/P_2	HBW	P_1	P_2	P_1/P_2	HBW	P_1	P_2	P_1/P_2	HBW	P_1	P_2	P_1/P_2	HBW	P_1	P_2	P_1/P_2	HBW
Jan. 23	102	89	1.14	106.6	95	70	1.35	118	69	62	1.11	126	73	120	0.6	130	97	124	0.78	90.2
27	124	146	0.85	93.2	113	114	0.99	120.2					111	121	0.92	93.2	111	133	0.83	93.2
30	127	155	0.82	100	94	74	1.27	110.2					119	131	0.91	96.6	92	134	0.68	93.3
Feb. 2	116	146	0.79	96.6	141	132	1.06	91.8					108	126	0.86	100	100	139	0.72	89.0
	37	55	0.67	125	151	139	1.08	93.0												
12	72	69	1.04	108	124	137	0.9	88.5												
17	48	69	0.7	100	125	122	1.02	91.8												
19	70	72	0.97	129	134	130	1.03	96.0												
24	73	85	0.86	108	210	174	1.12	91.0												
Mar. 1	150	154	0.97	96			1.20	83.5												
18					156	152	1.02	66.5												
Apr. 5	107	130	0.82	91.6	140	94	1.49	116.9	119	90	1.34	91.6								

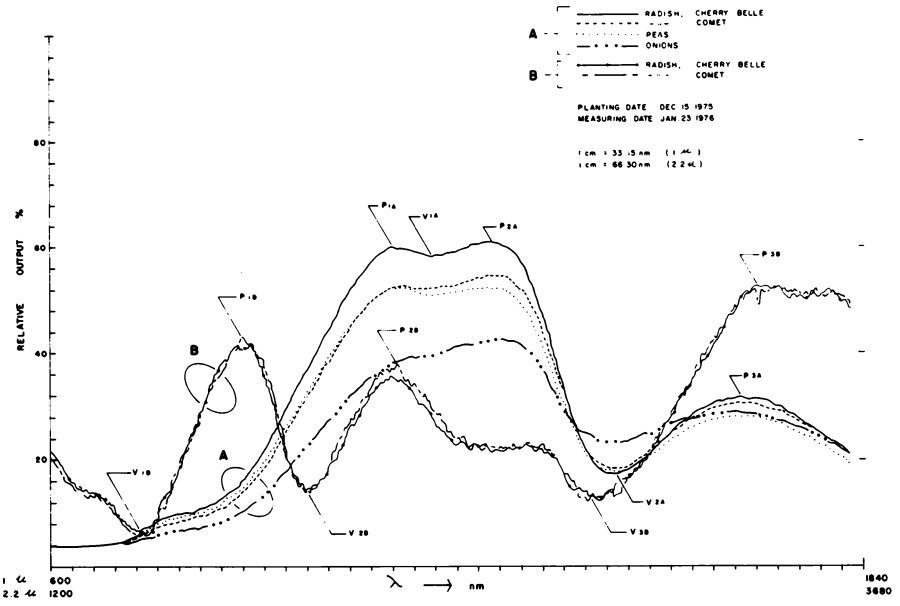

Fig. 2. Spectral curves for 2 radish cultivars (Comet, Cherry Belle), pea and onion. A. Infrared range 600 – 1800 nm; P_1 peak at 1123 nm, P_2 at 1279 nm, P_3 at 1677 nm, V_1 valley point at 1030 nm, and V_2 at 1478 nm. B. Infrared range 1200 – 3680 nm; P_1 peak at 1790 nm, P_2 at 2220 nm, P_3 at 3420 nm, V_1 valley at 1460 nm, V_2 at 1955 nm and V_3 at 2850 nm.

to 1840 nm of 2 cultivars of radish, pea and onion (Fig. 2) exhibited 3 peaks (P_1, P_2, P_3) at 1123, 1279 and 1677 nm and 2 valleys (V_1, V_2) at 1030 and 1478 nm. P_1 and V_1 appear only at a certain growth stage, which may serve as an index of maturity. V_2 at 1470 nm is a water absorption band. The mean values for V_2 of different crops fall within a very close range (36 to 42), but the other peaks and valley show considerable differences in their mean values (Table 2). The percentage differences in daily reflectance readings between various crops were large enough to use a means of crop identification. For example, on Feb. 24, 1976 the spectral reflectance values of P_1 for pea was 47%, radish 68% and lettuce 19% higher than that for onion. On Feb. 17 the reflectance values of P_3 for pea was 82%, for onion 44%, and for radish 108% higher than that for lettuce. The infrared range from 1200 to 3680 nm (Fig. 2B) does not show sufficient differences to serve for crop identification. The differences in reflectance at the peak and valley points noted above for the visible and near infrared (600 to 1800 nm) indicate that identification of the test crops is possible.

Onion, pea and radish were excited with a 337.1 nm, 25 mW pulsed laser beam. The fluorescence peak for each crop occurred at the same wavelength; approx 450 nm with a half bandwidth of 140 nm (Fig. 3A). The fluorescence yield was 73% for onion, 52% for radish and 36% for pea (Fig. 3A). Fig. 3B shows fluorescence curves of 2 radish and 2 lettuce cultivars. The plants were excited with a Helium Cadmium 441 nm wavelength laser. The emission or fluorescence curve covers from 650 to 750 nm. The fluorescence was wide band with a peak at 683 nm and an approximate HBW of 20 nm for the 4 plant species. Their fluorescence yield differed, however. The radish had 4 times the fluorescence yield of lettuce. The fluorescence curves of the 2 lettuce cultivars closely paralleled one another. Those of the 2 radish cultivars were similar over most of the curve, but at the peak 'Comet' had 8% higher yield than 'Cherry Belle'. This fluorescence curve with its 683 nm peak is due to chlorophyll fluorescence. The difference in fluorescence yield between lettuce and radish serves as an "identifier" between these crops. The differences between pea, onion and lettuce were not as great. Lettuce had a 20% higher fluorescence yield than pea, and 30% higher than onion. The 441 nm laser is, therefore, useful only to differentiate between radishes, which had an extremely high fluorescence yield, and the other 3 crops. It cannot be used to differentiate between lettuce and pea or onion.

Fig. 3C shows fluorescence curves taken with a "fluorescence enhancement" technique on 2 radish cultivars. The plants were excited simultaneously by 2 lasers at different wavelengths (337.1 and 441 nm). This produced a set of fluorescence curves entirely different from those obtained with a single laser. The 2 main fluorescence peaks at 440 nm and at 680 nm coincided with the Rayleigh scatter of the 441 nm and the second harmonics of the 337.1 nm lasers and were masked by scatter and, therefore, cannot be seen. However, the use of 2 exciting energies simultaneously produced greater resolution than when the plants were excited by one of the exciting energies. The fluorescence of the chlorophyll pigment was enhanced in the 705-745 nm region. The results in the 705-745 nm regions were very similar to laboratory test raadings (2) obtained with low-temp spectrofluorometry. At low temp (77°K) peaks at 686, 698, 718 and 725 nm can be resolved versus only one (680 nm) at room temp.

Thus, if the plants are excited with only 1 laser (441 nm), the 683 nm component will be resolved but when excited with both lasers (337.1 and 441 nm) fluorescence components at 725 nm can also be resolved. This is significant since it can be achieved with plants *in situ* and 10 m away. The fluorescence component at 725 nm indicated a 50% higher fluorescence yield for radish than for onion. As indicated previously with lettuce (1) the 725 nm component can be indica-

Table 2. Summary of peaks (P_1, P_2, P_3) and valleys (V_1, V_2) of spectral curves in the 600 – 1800 nm region of the spectrum, for lettuce, peas, onions and radishes seeded on Dec. 15, 1975. P_1 at 1.123 nm, P_2 at 1279 nm, P_3 at 1677 nm, V_1 at 1030 nm and V_2 at 1478 nm.

Date sampled	Pea D_1					Pea D_2					Onion D_1					Radish cv. Comet D_1					Radish cv. Cherry Belle D_1					Lettuce cv. Imperial 456 D_1					Lettuce cv. Fulton Zero D_1				
	P_1	P_2	P_3	V_1	V_2	P_1	P_2	P_3	V_1	V_2	P_1	P_2	P_3	V_1	V_2	P_1	P_2	P_3	V_1	V_2	P_1	P_2	P_3	V_1	V_2	P_1	P_2	P_3	V_1	V_2	P_1	P_2	P_3	V_1	V_2
Jan. 23	130	131	70	126	44						–	106	72	–	58	131	136	76	130	46	150	153	79	146	43	–	47	20	–	49	–	37	14	–	47
27	146	146	65	140	30						78	86	52	78	36	127	130	66	123	33	129	131	64	125	29	–	45	20	–	36	–	36	15	–	36
30	140	136	67	131	39						75	79	52	74	41	143	145	76	139	42	156	157	78	150	40	–	52	21	–	48	–	37	16	–	46
Feb. 2	128	125	64	120	37						105	110	69	104	50	148	157	80	145	44	156	157	79	150	40	–	51	21	–	46	–	36	16	–	45
9	150	141	66	135	35		81	52	–	34	70	80	50	70	35											79	86	31	78	39	–	49	18	–	35
12	136	125	56	120	29		81	50	–	32	69	75	45	68	31											92	94	31	88	34	63	68	23	62	33
17	135	133	62	125	30	100	105	55	99	28	76	83	49	75	34											100	108	34	100	31	73	78	26	71	28
19	147	140	68	135	39	143	147	75	140	42	95	96	50	89	37											107	109	34	102	41	68	76	24	67	49
24	140	136	70	130	40	140	140	73	135	43	95	93	49	88	35											113	110	33	102	45	87	90	27	82	45
Mar. 1	172	158	68	152	36	156	148	69	144	38	123	117	55	110	38																				
5																															126	115	32	108	32
18						146	130	52	127	28						180	177	78	172	42	198	189	80	185	40										

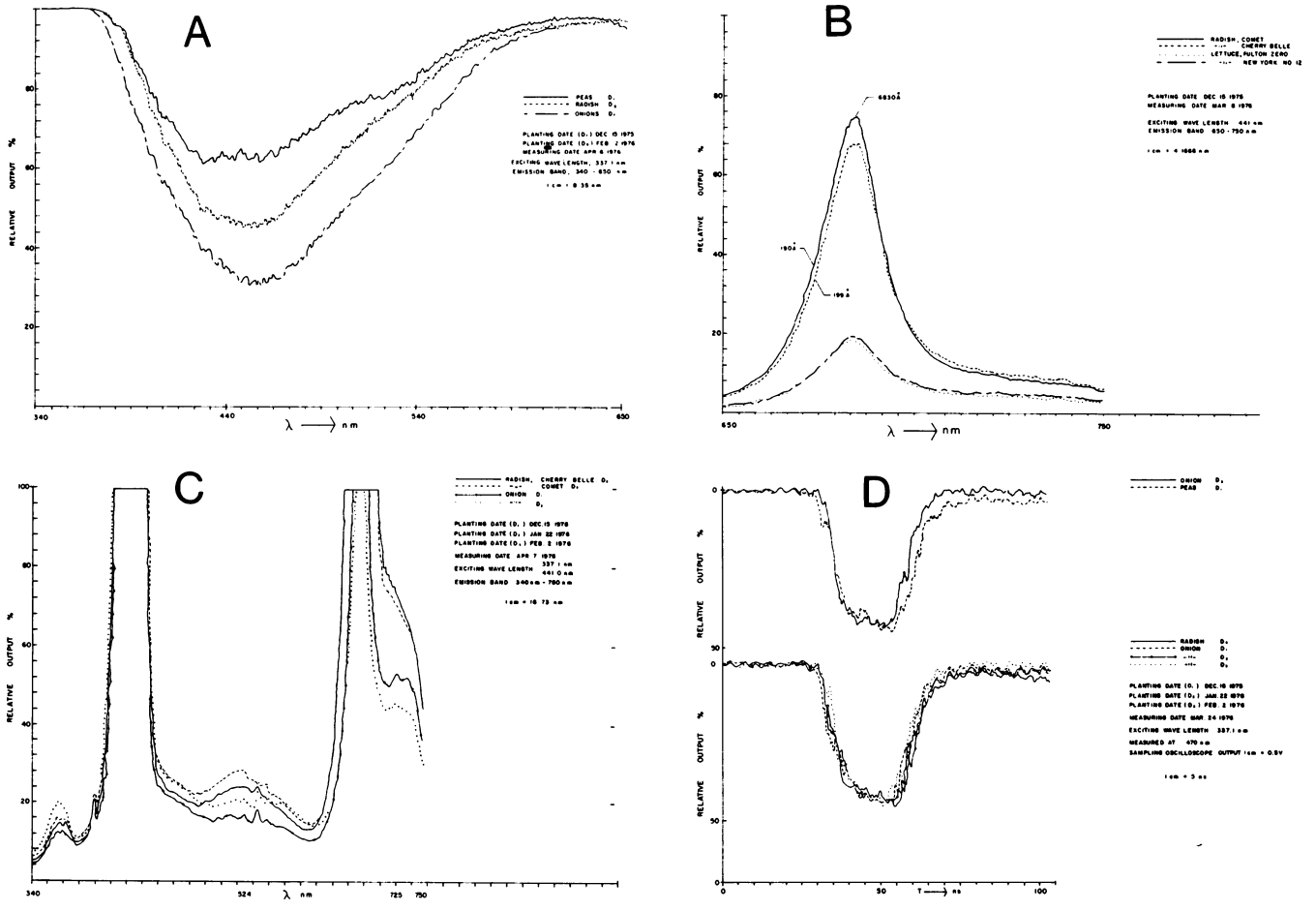

Fig. 3. Fluorescence spectra of radishes, onions, peas and lettuce: A. Excited by a 337.1 nitrogen pulsed laser. B. Excited by a 441 nm continuous wave laser. C. Excited with a "fluorescence enhancing" technique using 337.1 nm and 441 nm lasers. D. Fluorescence life time curves. Excited by a 337.1 nm laser, and measured at 470 nm.

tive of plant maturity. Two radish cultivars planted at the same time had identical fluorescence yield at 725 nm. The onions seeded on 2 different dates differed by 18% in fluorescence yield. Fig. 3C also indicated fluorescence components at 365 and 396 nm in the ultraviolet region and a wide band fluorescence component in the green region of the visible spectrum, but these components did not appear to contribute to identification.

Fig. 3D gives a fluorescence time decay curve for onions seeded on different days (D_1, D_2, D_3), radishes seeded late (D_3) and peas seeded early (D_1). The plants were excited with a 337.1 nm pulsed laser, and the fluorescence was studied with a sampling oscilloscope at 470 nm. This curve indicates a 23.5 ns decay time for crops (onion, radish) planted on the later date (D_3), 26 ns for onion and pea planted earlier (D_2) and 27 ns for onion planted the earliest (D_1). This does not differentiate between crops, but may reflect differences in maturity.

Spectroscopic results indicate that crop identification by remote sensing is possible at ground level provided one knows the crop calendar or the average planting date and density. The differentiation between crops was best in the 600 to 1800 nm infrared band with the 441 nm laser fluorometry technique and with the fluorescence enhancing technique. The experiment does not indicate specific spectral signatures for the various crops tested. Rather it shows that for specific wavelengths these crops react differently due to their morphological and physiological differences. Maturation again due to physiological or chemical changes alters these reactions.

Literature Cited

1. Brach, E. J., J. M. Molnar, and J. J. Jasmin. Detection of lettuce maturity and variety by remote sensing techniques. *J. Agr. Eng. Res.* (In press).
2. Butler, W. L. and D. W. Hopkins. 1970. Higher derivative analysis of complex absorption spectra. *Photochem. & Photobiol.* 12:439-450.
3. Gates, D. M. and W. Tantraporn. 1952. The reflectivity of deciduous trees and herbaceous plants in the infrared to 25 microns. *Science* 115:613-616.
4. ————, H. J. Keegan, J. C. Schleter, and V. R. Weidner. 1965. Spectral properties of plants. *Appl. Optics* 4:11-20.
5. Gausman, H. W., A. R. Cordenas, and A. J. Richardson. 1970. Relation of light reflectance to histological and physical evaluations of cotton leaf maturity. *Appl. Optics* 9:545-552.
6. Gaffney, J. J. 1973. Reflectance properties of citrus fruits. *Trans. Amer. Soc. Agr. Eng.* 16:310-314.
7. Allen, W. A., H. W. Gausman, A. J. Richardson, and C. L. Wiegaud. 1970. Mean effective optical constants of thirteen kinds of plant leaves. *Appl. Optics* 9:2573-2577.