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Basil: A Source of Aroma Compounds and a Popular Culinary and Ornamental Herb*

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Basil, one of the most popular culinary herbs in North America is sold as a fresh-cut and dried processed product. There are over 40 cultivars available (De Baggio and Belsinger 1996), with many developed specifically for the fresh and/or ornamental markets. The popular cultivars for the fresh market and garden have dark green leaves and white flowers, with a rich spicy pungent aroma due to the presence of linalool/methylchavicol/1,8-cineole. Lesser known cultivars vary in growth habit, size, and color, and can contain a wide range of aromas including, lemon, rose, camphor, licorice, woody, and fruity. The popularity of basil has led to an infusion of many introductions into the marketplace. For example, new cultivars, both All-American selections, include the new fusarium resistant lemon basil, 'Sweet Dani', a tall (65–70 cm), up-right plant with an intense lemon aroma (Morales and Simon 1997) and 'Siam Queen', an attractive plant with purple flowers on a dense dark green foliage. This paper will address the diversity of basil in the North American market and potential new uses for the natural products of this species.

DIVERSITY IN BASIL

The genus *Ocimum*, Lamiaceae, collectively called basil, has long been acclaimed for its diversity. *Ocimum* comprises more than 30 species of herbs and shrubs from the tropical and subtropical regions of Asia, Africa, and Central and South America, but the main center of diversity appears to be Africa (Paton 1992). It is a source of essential oils and aroma compounds (Simon et al. 1984, 1990), a culinary herb, and an attractive, fragrant ornamental (Morales et al. 1993; Morales and Simon 1996). The seeds contain edible oils and a drying oil similar to linseed (Angers et al. 1996). Extracts of the plant are used in traditional medicines, and have been shown to contain biologically active constituents that are insecticidal, nematicidal, fungistatic, or antimicrobial (Simon 1990; Albuquerque 1996).

Most commercial basil cultivars available in the market belong to the species *O. basilicum*. Darrah (1980, 1984) classified the *O. basilicum* cultivars in seven types: (1) tall slender types, which include the sweet basil group; (2) large-leafed, robust types, including 'Lettuce Leaf' also called 'Italian' basil; (3) dwarf types, which are short and small leafed, such as 'Bush' basil; (4) compact types, also described, *O. basilicum* var. *thyrsiflora*, commonly called 'Thai' basil; (5) *purpurascens*, the purple-colored basil types with traditional sweet basil flavor; (6) purple types such as 'Dark Opal', a possible hybrid between *O. basilicum* and *O. forskolei*, which has lobed-leaves, with a sweet basil plus clove-like aroma; and (7) *citriodorum* types, which includes lemon-flavored basils.

In addition to the traditional types of basil, other *Ocimum* species have been introduced into the North American horticultural trade with new culinary and ornamental uses and may be potential sources of new aroma compounds. However, interspecific hybridization and polyploidy, common occurrences within this genus (Harley et al. 1992), have created taxonomic confusion making it difficult to understand the genetic relationship between many basils (Grayer et al. 1996). In addition, the taxonomy of basil is complicated by the existence of numerous botanical varieties, cultivar names, and chemotypes within the species that may not differ significantly in morphology (Simon et al. 1990). A system of standardized descriptors, which include volatile oil, has more recently been proposed by Paton and Putievsky (1996) and this should permit easy communication and identification of the different forms of *O. basilicum*. Investigations to revise the genus are underway at the Royal Botanical Garden, Kew, London (Paton 1992) and at Delaware State University.

The perfume, pharmacy, and food industries (Simon et al. 1990) use aromatic essential oils, extracted from the leaves and flowers of basil. Several aroma compounds can be found in chemotypes of basil such as citral, eugenol, linalool, methylchavicol, and methylcinnamate and are traded in the international essential oil market. These chemotypes are commonly known by names based on geographical origins such as Egyptian,

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Table 1. Comparative evaluation of North American commercially available *Ocimum* basil cultivars. Plant density was 12,000 plants/ha.

		Plant characteristics						
				Color				
Cultivar	*Ocimum* species	Height (cm)	Spread (cm)	Leaf	Stem	Flower	Spike	Days to flowering
African Blue	Dark Opal × *kilimandscharicum*	44	49	green	pale-purple	pink	pale-purple	88
Anise	*basilicum*	55	44	green-purple	pale-purple	light-pink	purple	98
Bush	*minimum*	23	29	green	green	white	green	109
Camphor	*kilimandscharicum*	58	49	green	green-purple	white	gray	92
Cinnamon	*basilicum*	44	49	green	purple	pink	purple	86
Dark Opal	*basilicum*	43	36	purple	purple	pink	purple	97
Dwarf Bush Fineleaf	*minimum*	20	31	green	green	white	green	115
East Indian	*gratissimum*	52	43	green	green-purple	gray	green-purple	114
Fino Verde	*basilicum*	44	44	green	green	white	green	104
Genovese	*basilicum*	49	46	green	green	white	green	95
Green	*gratissimum*	42	25	green	green-purple	white-gray	green-purple	123
Green Bouquet	*americanium* var. *americanum*	30	32	green	green	white	green	112
Green Globe	*minimum*	23	31	green	green	white	green	115
Green Ruffles	*basilicum*	29	29	light-green	light-green	white	light-green	110
Holy	*tenuiflorum*	37	41	green	pale-purple	pale-purple	purple	98
Holy Sacred Red	*basilicum*	40	35	purple	purple	pink	purple	103
Italian Large Leaf	*basilicum*	46	42	green	green	white	green	104
Lemon	×*citriodorum*	33	53	green	green	white	green	76
Lemon Mrs. Burns	×*citriodorum*	52	55	green	green	white	green	94
Lettuce Leaf	*basilicum*	41	41	green	green	white	green	105
Licorice	*basilicum*	53	52	green-purple	green-purple	pink	purple	102
Maenglak Thai Lemon	×*citriodorum*	34	50	green	green	white	green	73
Mammoth	*basilicum*	41	38	green	green	white	green	103
Napoletano	*basilicum*	41	41	green	green	white	green	104
New Guinea	×*citriodorum*	27	35	pale-green	pale-green	pink	pale-green	78
Opal	*basilicum*	36	35	purple	purple	pink	purple	99
Osmin Purple	*basilicum*	40	32	purple	purple	pink	purple	101
Peruvian	*campechianum*	30	37	green	green	pale-purple	green	98
Purple Bush	*minimum*	24	28	purple-green	purple	pale-purple	purple	109
Purple Ruffles	*basilicum*	34	29	purple	purple	bright purple	dark-purple	134
Red Rubin Purple Leaf	*basilicum*	42	38	purple	purple	pink	purple	106
Sacred	*tenuiflorum*	32	32	green	pale-purple	pale-purple	gray	90
Spice	*americanium* var. *pilosum*	34	48	green	green	pink	green-purple	76
Spicy Globe	*americanium* × *basilicum*	21	30	green	green	white	green	115
Sweet	*basilicum*	49	42	green	green	white	green	100
Sweet Fine	*basilicum*	48	43	green	green	white	green	96
Sweet Thai	*basilicum*	35	44	green	purple	pink	purple	74
Thai (Companion Plants)	*basilicum*	41	47	green	purple	pink	purple	82
Thai (Richters)	*basilicum*	35	36	green	pale-purple	pink	purple	100
Thai (Rupp Seeds)	*basilicum*	36	52	green	green	white	green	72
Tree	*gratissimum*	48	38	green	green-purple	white-gray	green-purple	120
Tulsi or Sacred	*tenuiflorum*	45	41	green-purple	purple	pale-purple	purple-green	99

[z]1 (highly vigorous) to 5 (lacks vigor)
[y]1 (highly uniform) to 5 (lacks uniformity)
[x]1 (no damage) to 5 (severe damage)

Vigor rating (1 to 5)[z]	Uniformity rating (1 to 5)[y]	Japanese beetle rating (1 to 5)[x]	Yield/plant		Essential oil yield %(vol/gdwt)	Major aroma compounds
			Fresh wt. (g)	Dry wt. (g)		
2.0	1.0	1.0	651	121	2.34	linalool (55%), 1,8-cineole (15%), camphor (22%)
1.8	2.5	4.6	640	129	0.62	linalool (56%), methylchavicol (12%)
2.0	1.3	1.0	545	92	1.18	linalool (59%), 1,8-cineole (21%)
1.6	2.5	1.0	755	163	5.22	camphor (61%), 1,8-cineole (20%)
2.5	3.1	1.0	638	131	0.94	linalool (47%), methylcinnamate (30%)
2.5	2.7	1.0	445	74	1.08	linalool (80%), 1,8-cineole (12%)
2.0	2.0	1.3	443	75	0.95	linalool (55%), methylchavicol (4%)
3.3	2.6	1.0	409	101	0.35	eugenol (62%)
2.7	3.2	2.0	868	211	0.50	linalool (48%), methylchavicol (7%)
2.8	2.5	3.6	734	137	0.90	linalool (77%), 1,8-cineole (12%)
3.0	1.8	1.0	211	50	0.29	thymol (20%), *p*-cymene (33%)
2.8	3.3	1.6	533	96	0.82	linalool (36%), 1,8-cineole (31%)
1.6	2.1	1.0	573	92	0.96	linalool (54%), 1,8-cineole (25%)
3.1	2.0	3.0	478	74	0.55	linalool (33%), 1,8-cineole (18%)
2.7	2.5	3.5	236	58	0.93	β-caryophyllene (75%)
2.8	2.6	1.0	361	55	0.83	linalool (77%), 1,8-cineole (14%)
2.1	2.0	4.0	626	113	0.83	linalool (65%), methylchavicol (18%)
2.0	1.8	1.0	432	118	0.27	linalool (24%), citral (19%)
2.0	2.1	1.0	883	177	1.28	linalool (61%), citral (16%)
2.1	2.0	4.0	824	129	0.78	linalool (60%), methylchavicol (29%)
1.3	2.1	5.0	732	144	0.43	linalool (58%), methylchavicol (13%)
2.1	1.1	1.0	473	138	0.23	citral
2.3	2.1	5.0	703	111	0.77	linalool (60%), methylchavicol (32%)
2.0	1.5	4.5	635	108	0.89	linalool (66%), methylchavicol (10%)
3.3	2.0	1.0	339	75	0.69	methylchavicol (92%)
2.2	2.2	1.0	516	78	0.91	linalool (80%), 1,8-cineole (13%)
2.0	1.5	1.0	343	53	0.66	linalool (77%), 1,8-cineole (15%)
3.3	2.3	1.0	347	83	1.26	linalool (14%), 1,8-cineole (36%)
3.1	1.6	1.0	348	54	1.12	linalool (82%), 1,8-cineole (11%)
3.6	3.0	1.0	294	42	0.49	linalool (55%), 1,8-cineole (20%), methylchavicol (6%), methyleugenol (9%)
2.1	2.0	1.0	403	63	0.74	linalool (70%), 1,8-cineole (9%), methylchavicol (10%), methyleugenol (6%)
4.8	2.6	1.0	216	52	0.65	β-caryophyllene (45%)
1.3	2.6	1.0	517	132	0.22	1,8-cineole (32%), methylchavicol (16%), β-bisabolene (33%)
2.0	1.3	1.0	504	78	0.88	linalool (55%), 1,8-cineole (23%)
1.8	2.1	3.6	651	114	0.84	linalool (69%), 1,8-cineole (11%), methylchavicol (13%)
1.5	3.3	1.0	631	129	0.98	linalool (86%), 1,8-cineole (6%)
2.3	2.1	1.0	723	168	0.40	linalool (6%), methylchavicol (60%)
2.0	3.5	2.0	536	111	0.75	linalool (12%), methylchavicol (65%)
1.8	2.1	1.6	443	86	0.52	methylchavicol (90%)
1.8	1.8	1.0	463	139	0.25	linalool (15%), methylchavicol (13%)
3.0	2.3	1.0	368	89	0.51	eugenol (62%)
3.1	3.3	2.6	314	77	0.93	methyleugenol (33%), β-caryophyllene (41%)

French, European, or Reunion basil (Heath 1981; Sobti et al. 1982; Simon et al. 1990; Marotti et al. 1996). The European type, a sweet basil, is considered to have the highest quality aroma, containing linalool and methylchavicol as the major constituents (Simon et al. 1990). The Egyptian basil is very similar to the European, but contains a higher percentage of methylchavicol. The Reunion type, from the Comoro Islands, and more recently from Madagascar, Thailand, and Vietnam, is characterized by high concentrations of methylchavicol (Marotti et al. 1996). Methylcinnamate-rich basil has been commercially produced in Bulgaria (Simon et al. 1990), India, Guatemala, and Pakistan (Marotti et al. 1996). A basil from Java (Simon et al. 1990), and Russia and North Africa (Marotti et al. 1996) is rich in eugenol.

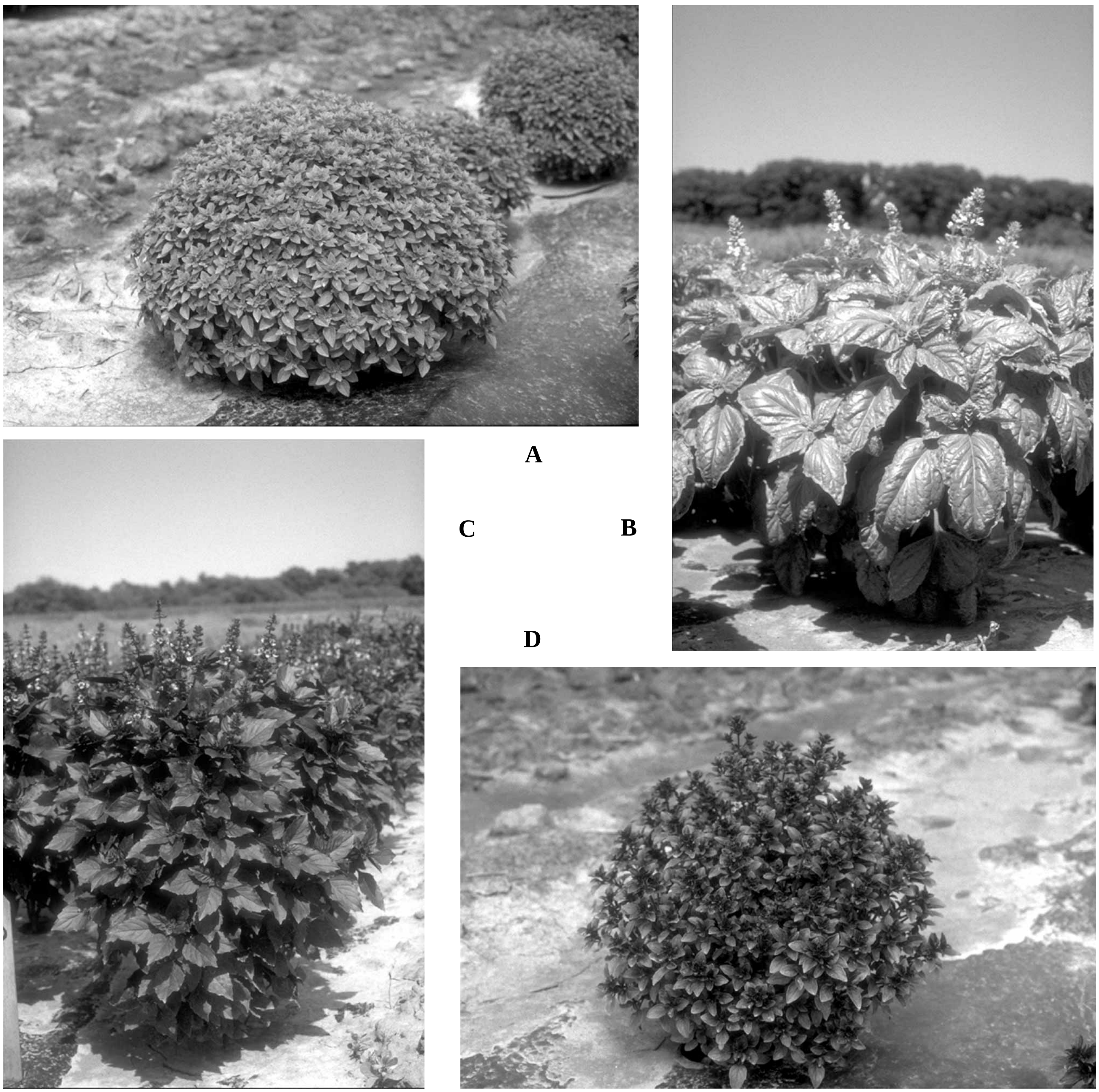

Fig. 1. Variation in basil (*Ocimum basilicum)* cultivars. (A) 'Bush' basil, a green leafed compact ornamental; (B) 'Sweet' basil, a popular, tall fresh market basil; (C) 'Dark Opal', a purple ornamental that is a rich source of anthocyanins; (D) 'Purple Bush', a compact ornamental with green-purple leaves.

CULTIVAR EVALUATION

In 1996, commercially available basils were evaluated at Lafayette, Indiana for horticultural attributes, commercial potential, essential oil yield and composition, and anthocyanin content. A total of 86 entries, including 42 different cultivars, were transplanted May 23 (Replication 1) and May 31, 1996 (Replications 2 and 3) in a randomized block design. Each plot consisted of a twin row of plants, 2 m long, 0.5 m apart, with plants spaced 0.5 m apart within the row for a density of 12,000 plants/ha. Entries were evaluated for appearance, shape, size, uniformity and vigor, biomass yield (fresh and dry weight when harvested at full bloom), extractable oil yield, and susceptibility to Japanese beetles. The harvested plant was first weighed, dried at 37°C, and oils extracted. The major volatile oil constituents were determined from GC and/or GC/MS analysis, as previously described (Charles and Simon 1990).

Basil as an Edible Ornamental Herb

The cultivars displayed a wide diversity in growth habit, flower, leaf and stem colors, and aromas (Table 1, Fig. 1). Many of the cultivars evaluated belong to the "Sweet" basil group, with 'Genovese', 'Italian large leaf', 'Mammoth', 'Napoletano', and 'Sweet' dominating the American fresh and dry culinary herb markets. Several others like 'Sweet Fine' appear similar to 'Sweet' basil though its leaves tend to be smaller. The lemon-scented cultivars ('Lemon' and 'Lemon Mrs. Burns') differed from each other in days to flower, and total oil content, but not in citral content. The 'Maenglak Thai Lemon' basil, which varied in appearance from the other lemon basils, is an attractive ornamental. Among the purple basils, 'Osmin Purple' and 'Red Rubin Purple Leaf' were the most attractive and best retained their purple leaf color. Anthocyanins in purple basils are genetically unstable leading to an undesirable random green sectoring and reversion over the growing season (Phippen and Simon 1998). Several basils with dwarf growth habit were developed as ornamental border plants including 'Bush', 'Green Globe', 'Dwarf Bush', 'Spicy Globe', and 'Purple Bush'. A group of ornamental basils were selected and named for their characteristic aroma including 'Anise' (methyl chavical), 'Cinnamon' (methylcinnamate), 'Licorice' (methylchavicol), and 'Spice' (β-bisabolene).

Many of the cultivars lacked uniformity, which suggests that further selection to improve these lines for such characters as earliness, modified appearance, and/or insect and disease resistance is feasible. Wide variation was observed on the degree of foliar damage caused by Japanese beetle.

Basil as a Source of Essential Oils and Aroma Compounds

Basil plants evaluated in this study contained a wide variety of oil compounds reflecting a diversity of available aromas and flavors. Many contained a combination of linalool and methylchavicol and/or 1,8-cineole, reflecting the traditional sweet basil aroma. Others had distinct aromas. The predominant aroma compound was eugenol (62%) in 'East Indian' and 'Tree' basil; camphor (61%) in 'Camphor' basil; thymol in 'Green' basil; β-caryophyllene in 'Holy' and 'Sacred' basil; and methylchavicol in 'New Guinea', and 'Thai - Richters' basil. Several purple cultivars ('Holy Sacred Red', 'Opal', and 'Osmin Purple') were rich in linalool (ca. 77%), as was the green cultivar 'Sweet Fine' (86%). Citral was the predominant compound in all the lemon-scented basils. However, few of these cultivars could compete as industrial sources of these compounds. Surprisingly, 'Camphor' basil, a very vigorous cultivar, was found to have relatively high oil yield (>5% dry weight).

Basil as a Source of Anthocyanins

The intensely purple pigmented basils available as culinary ornamentals prompted an examination of eight commercial cultivars as a potential new source of anthocyanins. The anthocyanins present in purple basils were analyzed utilizing high performance liquid chromatography, spectral data, and plasma-desorption mass spectrometry (Phippen and Simon 1998). Fourteen different anthocyanins were identified. Eleven of the pigments were cyanidin based with cyanidin-3-(di-*p*-coumarylglucoside)-5-glucoside as the major pigment. Three minor pigments based on peonidin were identified. Purple basils can be an abundant source of acylated and glycosylated anthocyanins and could provide a unique source of stable red pigments to the food industry

Table 2. Comparison of purple basil to other natural anthocyanin fruit and leaf sources for total anthocyanin yield. Modified from Phippen and Simon (1998).

Source	Plant organ sampled	Total anthocyanins (mg/100gfw ± SD)	No. of identified anthocyanins
Grape (*Vitis labrusca* 'Concord')	Fruit skin	25.2±2.9	16
Purple basil (*Ocimum basilcum* 'Purple Ruffles')	Leaf	18.8±0.7	14
Perilla (*Perilla frutescens* 'Crispa')	Leaf	18.1±0.6	6
Plum (*Prunus domestica* L. 'Stanley')	Fruit skin	15.9±2.1	2
Purple sage (*Salvia officinalis* 'Purpurea')	Leaf	7.8±1.0	5
Red cabbage (*Brassica oleracea* 'Cardinal')	Leaf	7.8±1.4	6
Red raspberry (*Rubus idaeus* 'Heritage')	Fruit	1.0±0.7	2

Table 3. Total extractable anthocyanin yields among commercial purple basil cultivars as compared to perilla. Modified from Phippen and Simon (1998).

Cultivar	Seed source	Total extractable anthocyanins[z] (mg/100 g fw ±SD)
Dark Opal	Richters	16.3±1.8
	Rupp Seeds	18.7±0.8
Holy Sacred Red	Rupp Seeds	8.8±0.6
Opal	Companion Plants	12.8±0.4
	Nichols Garden Nursery	11.7±0.6
Osmin Purple	Johnny's	18.0±0.8
Purple Bush	Richters	6.5±1.1
Purple Ruffles	Richters	18.5±0.7
	Shepard's Garden Seeds	17.9±0.8
	Johnny's	15.9±0.5
	Ball Seed	18.7±0.8
Rubin	Richters	17.4±0.8
Red Rubin	Johnny's	17.4±0.8
Red Rubin Purple Leaf	Shepard's Garden Seeds	18.3±0.5
Perilla frutescens var. *crispa*	Shepard's Garden Seeds	18.0±0.6

[z]Anthocyanins were extracted from leave tissue with acidified methanol (0.1% HCl) for 3 h at 4°C. Samples were filtered and analyzed by reverse phase HPLC.

(Table 2). The large leafed cultivars 'Purple Ruffles', 'Rubin', and 'Dark Opal' had an average extractable total anthocyanin content ranging from 16.6–18.8 mg per 100 g fresh tissue (Table 3), while the ornamental small leafed cultivar 'Purple Bush' had only 6.5 mg per 100 g fresh tissue.

CONCLUSIONS

The diversity in basil based on appearance, flavors, fragrances, industrial, edible, and drying oils, and natural pigments offers a wealth of opportunities for developing new culinary, ornamental, and industrial crops. The high variation of basil cultivars to damage by Japanese beetles suggests the presence of an active ingredient that either could be useful in commercial traps or serve as a deterrent.

A number of basils have commercial potential for the production of industrial products. ‘Camphor’, a cultivar from Africa, should be investigated further as a potential industrial source of camphor, while ‘East Indian’ and ‘Tree’ basils as a potential source of eugenol. Purple basils contained very high concentrations of total anthocyanins and are an abundant source of total anthocyanins and may serve as a potential new source of stable red pigments for the food industry.

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