Genotype and Growing Location Effects on Phytosterols in Canola Oil

Anwar A. Hamama[a], Harbans L. Bhardwaj[a,*], and David E. Starner[b]

[a]Agricultural Research Station, Virginia State University, Petersburg, Virginia 23806, and [b]Northern Piedmont Agricultural Research and Extension Center, Virginia Tech, Orange, Virginia 22960

ABSTRACT: There is little information available about phytosterols in canola (*Brassica napa* L.) oil and the effects of genotype and growing locations from Virginia and the mid-Atlantic region of the United States, a potential area for the establishment of domestic production to provide edible oil. Our objectives were to characterize the phytosterols, phospholipids, unsaponifiable matter, and FA in oil from Virginia-grown canola. Among 11 canola genotypes grown at two locations during 1995–1996 significant variations existed for oil content and FA profiles, but not for contents of phospholipids, unsaponifiable matter, total phytosterols, campesterol, stigmasterol, and β-sitosterol. Total phytosterol content in the oil of Virginia-grown canola varied from 0.7 to 0.9% with a mean of 0.8%. This concentration compared favorably with oil from Canadian canola, which typically contains 0.5 to 1.1% total phytosterols. The mean contents of brassicasterol, campesterol, stigmasterol, β-sitosterol, Δ^5-avenasterol, and Δ^7-stigmastenol as percentages of total phytosterols in Virginia-grown canola were: 9.7, 32.0, 0.6, 49.3, 4.99, and 3.5%, respectively. Growing location did not affect phytosterols in Virginia-grown canola oil but had significant effects on contents of phospholipids, and saturated (myristic, stearic, and arachidic) and unsaturated (palmitoleic, linoleic, linolenic, eicosenoic, and erucic) FA.

Paper no. J10521 in *JAOCS 80,* 1121–1126 (November 2003).

KEY WORDS: Δ^5-Avenasterol, brassicasterol, campesterol, canola oil, fatty acids, phospholipids, Δ^7-stigmastenol, stigmasterol, β-sitosterol, unsaponifiable matter.

Consumer interest in canola (*Brassica napus* L.) oil is increasing because of its low saturated FA content (5 to 8%), high monounsaturated FA content (up to 75%, with 51 to 70% being oleic acid), and moderate concentration of PUFA. Canola oil consumption in the United States increased from zero prior to 1986 to the equivalent of over 8,100,000 ha of production in 1994 (1).

Most of this oil was imported from Canada. In 1998, the United States imported approximately 419,000 tonnes of canola oil from Canada with a seven-year average of approximately 355,000 t (www.canola-council.org). Land devoted to canola production in the United has increased from 62,727 ha in 1991 to 608,249 ha in 2000, but consumption of canola oil in the United States still outpaces production at the rate of nearly 3 to 1 (1). These figures indicate notable opportunities to develop domestic production of canola and to diversify the U.S. cropping system. Recent research has indicated that, depending upon genotype and location, canola seed yields of up to 4000 kg/ha are possible in Virginia as compared to Canadian yields of 964–1323 kg/ha (2,3).

In humans, consumption of plant-derived sterols can reduce blood pressure (4), and consumption of β-sitosterol may be beneficial in the treatment of hypercholesterolemia (5). Phytosterols also serve as natural intermediates for synthesis of hormonal sterols and other related pharmaceuticals (5). Canola and low-erucic-acid rapeseed oils typically contain 0.5 to 1.1% total sterols, and the total sterol component consists of 5.0 to 13.0% brassicasterol, 24.7 to 38.6% campesterol, 0.2 to 1.0% stigmasterol, 45.1 to 57.9% β-sitosterol, 2.5 to 6.6% Δ^5-avenasterol, and 0.0 to 1.3% Δ^7-stigmastenol (6–8). Since low-temperature-induced FA desaturation in rapeseed (*Brassica* sp.) is known to occur (9–13), both the genetic background of the plant and planting location can affect phytosterol concentration and composition (14). Information about sterols in canola oil produced in Virginia is unavailable, nor is it known whether the concentrations of phytosterols in canola oil produced in Virginia are comparable to those in oils produced at other locations.

The objectives of these studies were therefore to characterize the effects of canola genotypes and growing location on the oil content of phytosterols, phospholipids, unsaponifiable matter, and FA and to determine differences, if any, between oil produced in Canada and that produced in Virginia.

MATERIALS AND METHODS

All reagents were HPLC grade and were obtained from Sigma-Aldrich Corporation (St. Louis, MO) unless otherwise stated.

Plant material. Seed from 11 canola (*B. napus*) genotypes (Table 1), grown in randomized complete block design field experiments with four replications each at Orange (38°14′ N and 78°07′ W) and Petersburg (37°15′ N and 77°30.8′ W), Virginia, during the 1995–1996 crop season were evaluated for contents of oil, FA, phospholipids, unsaponifiable matter, and phytosterols.

Oil extraction. The canola seeds were thoroughly ground in a centrifugal grinding mill (Krups type 2003 B). The oil was extracted from 1 g of ground seed at room temperature by homogenization (15) for 2 min in 10 mL hexane/

*To whom correspondence should be addressed at Agricultural Research Station, Box 9061, Virginia State University, Petersburg, VA 23806. E-mail: hbhardwj@vsu.edu

isopropanol (3:2, vol/vol) with a Biospec Model 985-370 Tissue Homogenizer (Biospec Products, Inc. Racine, WI) and centrifuged at 4000 × *g* for 5 min, as described by Bhardwaj and Hamama (16). Oil extraction was repeated two more times for each sample to ensure full oil recovery, and the three extracts were combined. The hexane-lipid layer was washed by shaking with 10 mL of 1% $CaCl_2$ and 1% NaCl in 50% methanol and then separated from the combined extract by centrifugation at 1000 × *g* for 2 min. The washing procedure was repeated, and the purified lipid layer was removed by aspiration and dried over anhydrous Na_2SO_4. The oil percentage (g/100 g dry basis) was determined gravimetrically after drying under vacuum at 40°C and stored under nitrogen at −10°C until analysis.

FA. FAME were prepared by an acid-catalyzed transesterification method as described by Bhardwaj and Hamama (16) and Dahmer *et al.* (17). The oil samples (5 mg) were vortexed with 2 mL sulfuric acid/methanol (1:99, vol/vol) in 10-mL glass vials containing a Teflon-coated boiling chip. The open vials were placed in a heating block at 90°C until the sample volume was reduced to 0.5 mL. After cooling to room temperature, 1 mL of hexane, followed by 1 mL of distilled water, was added. The mixture was vortexed, and the upper hexane layer containing the FAME was taken and dried over anhydrous Na_2SO_4. The hexane phase containing FAME was transferred to a suitable vial and kept under N_2 at 0°C for GC analysis.

Analyses of FAME were carried out as described by Bhardwaj and Hamama (18) by using a SUPELCOWAX 10 capillary column (25 m × 0.25 mm i.d., 0.25 µm film thickness; SupelcoWax, Inc., Bellefonte, PA) in a Varian model Vista 6000 GC equipped with an FID (Varian, Sugar Land, TX). An SP-4290 Integrator (Spectra Physics, San Jose, CA) was used to determine relative concentrations of the FA detected.

Peaks were identified by reference to the retention of FAME standards and quantified by using heptadecanoic acid (17:0) as an internal standard. The concentration of each FA was calculated as a percentage (w/w) of the total FA.

Unsaponifiable matter. Canola oil samples (0.2 g) were saponified with 20% (wt/vol) of methanolic KOH overnight at room temperature (19). The unsaponifiable fraction (UNSAP) was extracted three times from saponified lipids with diethyl ether. The combined ether extracts were washed several times with distilled water until the washings were neutral to phenolphthalein indicator. The UNSAP extract was dried under N_2, determined gravimetrically, and expressed as a percentage (w/w) of canola oil.

Sterols. Sterols in the unsaponifiable material (5 mg) were silylated, along with 50 µg of cholesterol as an internal standard, by 1 mL *N,O*-bis(trimethylsilyl) trifluoroacetamide (BSTFA) in 1% trimethylchlorosilane (TMCS) in glass vials with Teflon-lined caps at 80°C for 60 min, then concentrated under N_2 (20). The sterol trimethylsilyl (Me_3S_i) ether derivatives were dissolved in 100 µL ethylacetate and analyzed in the same instrument specified above, equipped with an HP-1 fused-silica capillary column, cross-linked polydimethylsiloxane (30 × 0.25 mm i.d. × 0.25 µm film thickness; Hewlett-Packard, Avondale, PA). Helium was used as a carrier gas at 25 cm/s with a split ratio of 1:100. Oven, injector, and detector temperatures were maintained at 260, 300, and 310°C, respectively. The peaks were identified by comparison of retention times with Me_3S_i derivatives of standard sterols (Sigma; Matreya, Pleasant Gap, PA) prepared under the same conditions, and with relative retention times reported in the literature (21–23). Cholesterol, the reference sterol, was used for determining a response factor. Phytosterol concentrations were expressed as a percentage (w/w) of oil. The concentration of each individual sterol was expressed as the percentage (w/w) of total phytosterols.

Phospholipids. Total phospholipids in canola oil were determined spectrophotometrically with chromogenic solution according to Raheja *et al.* (24). The chromogenic solution was prepared as follows: Solution A: 120 mL of 13.3% (wt/vol) ammonium molybdate in distilled water. Solution B: 80 mL of solution A, 40 mL of concentrated hydrochloric acid, and 10 mL of elemental mercury, mixed by shaking for 30 min, then filtered through Whatman #1 filter paper. Solution C: 200 mL concentrated sulfuric acid mixed with the filtrate of solution B and diluted with 40 mL of solution A. The chromogenic solution was prepared by mixing 25 mL of solution C, 20 mL distilled water, 45 mL of methanol, and 5 mL of chloroform. The oil (0.1 mL) was mixed with 0.2 mL chromogenic solution. The mixture was heated at 90°C for 10 min, then cooled to room temperature; then 5 mL chloroform was added. The chloroform layer was carefully removed, and the developed color was read in a Spectronic 20 spectrophotometer (Bausch & Lomb Inc., Rochester, NY) at 710 nm against the blank. For quantification, PC standards (Sigma) ranging from 50 to 1000 µg were used under the same conditions.

All data were analyzed using the ANOVA procedure of SAS, version 8 (25). The means with respect to cultivars and growing locations were compared using Fisher's protected LSD at a 5% level of significance. The Pearson correlation coefficients were calculated to determine the relationships between various pairs of traits.

RESULTS AND DISCUSSION

Significant variation existed among 11 canola genotypes for oil content and FA profile but not for total PUFA (Table 1). The mean concentrations of even carbon saturated (14:0 to 22:0), unsaturated (16:1, 18:1, 18:2, 18:3, 20:1, 22:1), monounsaturated (16:1, 18:1, 20:1, 22:1), and polyunsaturated (18:2, 18:3) FA in oil from Virginia-grown canola were 6.9, 93.1, 65.5, and 27.6%, respectively. These concentrations agree well with those previously reported (6,13) for Canadian-grown canola (6.0, 94.0, 61.9, and 29.7%, respectively) and fit well with the Codex standard of FA in canola and low-erucic-acid rapeseed oils (7,8).

The total phytosterols in the oil of Virginia-grown canola varied from 0.7 to 0.9% with a mean of 0.8% (Table 2). There was a lack of variation among canola genotypes for the contents of phospholipids, unsaponifiable matter, total phytos-

TABLE 1
Cultivar Differences for Oil Content (%, w/w) and FA Composition (% of total FA, w/w), Averaged over Two Locations, from Canola Grown in Virginia During 1995–1996

Cultivar	Oil	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:0	20:1	22:0	22:1	SFA[a]	USFA[a]	MUFA[a]	PUFA[a]
488-7H	39.0	0.1	4.5	0.4	1.5	63.3	18.1	8.6	0.4	2.2	0.3	0.7	6.7	93.3	66.6	26.7
Cascade	38.8	0.1	4.8	0.4	1.4	64.2	18.8	8.6	0.4	1.2	0.2	0.0	6.7	93.3	65.9	27.4
Ceres	38.8	0.1	5.5	0.5	1.3	61.2	20.7	8.3	0.4	1.4	0.2	0.3	7.5	92.5	63.5	29.0
Falcon	37.9	0.1	5.5	0.6	1.2	60.4	21.1	9.1	0.4	1.4	0.1	0.1	7.4	92.6	62.5	30.2
HN020-91	38.9	0.1	4.9	0.5	1.4	64.1	19.4	7.9	0.3	1.3	0.2	0.1	6.8	93.2	65.9	27.3
HN031-91	39.0	0.1	4.9	0.5	1.4	63.5	19.8	7.9	0.5	1.2	0.2	0.2	7.0	93.0	65.3	27.7
HN120-91	39.8	0.1	4.9	0.5	1.4	64.4	18.5	8.4	0.4	1.3	0.2	0.1	6.9	93.1	66.3	26.9
HN9331	40.9	0.0	4.4	0.4	1.5	64.6	20.7	6.0	0.4	1.6	0.1	0.4	6.4	93.6	67.0	26.7
HN9332	40.3	0.1	4.8	0.5	1.5	63.4	19.2	8.8	0.4	1.2	0.1	0.0	6.9	93.1	65.1	28.0
Jetton	38.8	0.1	5.0	0.5	1.4	64.8	18.5	7.8	0.4	1.4	0.1	0.1	7.0	93.0	66.7	26.3
Pendleton	41.0	0.1	5.0	0.5	1.4	64.1	19.5	7.7	0.3	1.2	0.2	0.1	7.0	93.0	65.7	27.2
Mean	39.4	0.1	4.9	0.5	1.4	63.5	19.5	8.1	0.4	1.4	0.2	0.2	6.9	93.1	65.5	27.6
LSD (0.05)	1.4	NS	0.4	0.1	0.1	2.3	1.8	1.0	NS	0.3	NS	0.2	0.5	0.5	2.4	NS

[a]SFA, saturated FA (14:0, 16:0, 18:0, 20:0, 22:0); USFA, unsaturated FA (16:1, 18:1, 18:2, 18:3, 20:1, 22:1); MUFA, monounsaturated FA (16:1, 18:1, 20:1, 22:1); PUFA, 18:2 and 18:3; NS, not significant.

terols, campesterol, stigmasterol, and β-sitosterol (Tables 2 and 3). However, the contents of brassicasterol in oil from Virginia-grown canola varied from 7.3 to 11.7% of the total phytosterols with a mean of 9.7%. Our results for brassicasterol are in agreement with those of Vlahakis and Hazebroek (14), who observed significant variation among nine canola genotypes and reported that the content of brassicasterol varied from 10.1 to 17.2% of the total phytosterols with a mean of 12.5%. In our study, the differences among 11 Virginia-grown genotypes for the content of campesterol in oil were not significant. However, Vlahakis and Hazebroek (14) observed significant differences for the content of campesterol in nine canola genotypes. The variation for campesterol among 11 Virginia-grown genotypes was of lesser magnitude (29.8 to 34.6% with a mean of 32.0%) than that observed among the nine canola genotypes (32.7 to 42.3% with a mean of 36.1%). These differences are obviously due to differences in genotypes, but the growing location also may have an effect on the content of campesterol. The contents of Δ^5-avenasterol in our study varied from 3.5 to 6.1% of the total phytosterols with a mean of 5.0%, whereas the content of Δ^7-stigmastenol varied from 2.5 to 5.2% with a mean of 3.5%.

The contents of phytosterols in oil from Virginia-grown canola are in the range reported by Codex standards for the level of desmethyl sterols in canola and low-erucic-acid oils (7,8) and compare well with the data from Canadian canola, which has been reported to contain typically 0.7% total phytosterols, 13.8% brassicasterol, 27.6% campesterol, 0.5% stigmasterol, 52.3% β-sitosterol, 1.9% Δ^5-avenasterol, and 2.3% Δ^7-stigmastenol (6). Comparing Canadian-grown canola with Virginia-grown canola, we found 17.9% more phytosterols, 13.7% more campesterol, 13.8% more stigmasterol, and 34.1% more Δ^7-stigmastenol than the Canadian canola oil. However, the oil from Virginia-grown canola contained 29.9% less brassicasterol, 5.8% less β-sitosterol, and 16.8% less Δ^5-avenasterol than did the Canadian canola oil.

TABLE 2
Cultivar Differences for Oil Characteristics[a], Averaged over Two Locations, from Canola Grown in Virginia During 1995–1996

Cultivar	Phospholipids (% of oil, w/w)	UNSAP (% of oil, w/w)	Phytosterols (% of UNSAP, w/w)	Phytosterols (% of oil, w/w)
488-7H	2.5	1.9	46.8	0.9
Cascade	2.4	2.0	36.0	0.7
Ceres	2.6	1.8	44.9	0.8
Falcon	2.5	1.9	45.6	0.9
HN020-91	2.5	2.1	43.4	0.9
HN031-91	2.1	1.9	39.5	0.7
HN120-91	2.8	1.9	40.7	0.8
HN9331	2.5	1.9	45.9	0.9
HN9332	2.8	1.8	49.2	0.9
Jetton	2.7	1.9	48.2	0.9
Pendleton	2.2	2.0	45.7	0.9
Mean	2.5	1.9	44.0	0.8
LSD (0.05)	NS	NS	NS	NS

[a]UNSAP, unsaponifiable fraction; for other abbreviation see Table 1.

TABLE 3
Cultivar Differences for Composition of Phytosterols (% of total phytosterols, w/w), Averaged over Two Locations, from Canola Grown in Virginia During 1995–1996

Cultivar	Brassicasterol	Campesterol	Stigmasterol	β-Sitosterol	Δ^5-Avenasterol	Δ^7-Stigmastenol
488-7H	7.3	32.1	1.0	49.4	5.5	4.8
Cascade	8.1	34.6	0.4	47.2	5.7	3.9
Ceres	9.2	32.2	0.3	49.7	4.8	3.8
Falcon	11.2	32.9	0.7	48.5	3.7	3.0
HN020-91	10.9	31.2	0.9	48.6	6.0	2.5
HN031-91	7.5	33.6	0.8	49.7	5.2	3.2
HN120-91	9.7	29.8	0.4	48.8	6.1	5.2
HN9331	11.6	30.9	0.7	50.2	3.8	2.8
HN9332	11.7	32.1	0.4	50.0	3.5	2.5
Jetton	9.8	30.2	0.7	49.4	5.7	4.1
Pendleton	9.4	32.2	0.2	50.6	4.9	2.7
RRT[a]	1.10	1.25	1.33	1.52	1.58	1.69
Mean	9.7	32.0	0.6	49.3	5.0	3.5
LSD (5%)	2.6	NS	NS	NS	0.7	0.8

[a]Relative retention times compared to cholesterol (RT = 16.56 min). For abbreviation see Table 1.

Further studies, in which similar plant materials are grown in Virginia and Canada, would be needed to clarify whether these differences were a result of different cultivars or growing locations.

Location did not affect contents of phytosterols (Table 4). Oil from canola grown at the Orange location had significantly higher phospholipids (+9.5%), higher saturated FA (+8.8%), and lower unsaturated FA (–0.7%) than did that from the Petersburg location. In general, warm and dry growing conditions during seed maturation increase the level of saturated FA, whereas cooler and moist growing conditions during seed maturation favor the production of PUFA (9–13). We were unable to locate any information regarding effects of growing location on phytosterols in canola oil. However, the existence of significant effects of growing location and temperature regimes on phytosterols in soybean oil has been reported (14). In addition, these authors have listed five studies in which effects of growing temperatures on phytosterols have been documented. We speculate that cooler temperatures (Table 5) at Orange (10.5°C) as compared to the Petersburg location (12.1°C) may be responsible for higher phospholipid levels and 18:2 FA (+9.5 and +5.5%, respectively) in oil in canola produced at the Orange location. The mean historical temperature during the canola growing period (September through June) at Orange (9.8°C) is 1.3°C lower than that at Petersburg. During our study (September 1995 to June 1996), the mean temperature at the Orange location was 10.5°C as compared to 12.1°C at the Petersburg location (Table 5). The precipitation at both locations was similar during our study (8.7 and 8.6 cm). The general lack of growing location effects on phytosterols in our study indicates that both Virginia locations could be used to produce good-quality canola oil.

We calculated Pearson correlation coefficients (Table 6) to determine associations between concentrations of FA and

TABLE 4
Growing Location Effects[a] on Contents of Phospholipids, Unsaponifiable Matter, Phytosterols, and FA Composition in Oil from Canola Grown at Two Locations in Virginia During 1995–1996

Characteristic	Orange, VA	Petersburg, VA	Characteristic	Orange, VA	Petersburg, VA
Oil (%)	39.7	39.1	FA (%)		
Oil fraction (g/100 g oil)			14:0	0.1	0.0[a]
Phospholipids	2.7	2.4[a]	16:0	5.0	4.9
Unsaponifiable matter	1.9	1.9	16:1	0.4	0.5[a]
Phytosterols	0.9	0.8	18:0	1.6	1.2[a]
Sterol (% of total phytosterols)			18:1	63.0	63.9
Brassicasterol	9.9	9.5	18:2	20.0	19.0[a]
Campesterol	31.2	32.7	18:3	7.5	8.7[a]
Stigmasterol	0.6	0.5	20:0	0.4	0.3[a]
β-Sitosterol	49.6	48.9	20:1	1.6	1.2[a]
Δ^5-Avenasterol	5.1	4.9	22:0	0.2	0.2
Δ^7-Stigmastenol	3.6	3.4	22:1	0.3	0.0[a]
			SFA	7.2	6.6[a]
			USFA	92.8	93.4[a]
			MUFA	69.3	65.7
			PUFA	27.5	27.7

[a]Significant differences between locations at $P > 0.05$ level are indicated by a superscript "a." For abbreviations see Table 1.

TABLE 5
Temperature (°C) and Precipitation (cm) Means at Orange and Petersburg, Virginia, During the 1995–1996 Canola Growing Season

	Orange, VA		Petersburg, VA	
Month	Temperature	Precipitation	Temperature	Precipitation
September	19.4(19.9)[a]	8.9 (9.0)[a]	20.6(21.1)[a]	9.7(8.5)[a]
October	15.0(13.6)	15.6(10.2)	16.2(14.8)	13.0(9.0)
November	5.3 (8.3)	10.3 (9.2)	6.8 (9.8)	7.3(8.1)
December	0.8 (2.6)	5.6 (7.7)	2.0 (4.5)	4.3(8.3)
January	0.3 (0.2)	18.2 (7.1)	1.2 (2.1)	11.8(8.2)
February	0.8 (1.7)	9.7 (7.0)	3.2 (3.7)	7.5(8.0)
March	4.4 (7.0)	6.2 (8.7)	6.2 (8.9)	6.9(9.2)
April	12.8(12.4)	7.2 (7.9)	14.4(14.1)	7.3(7.5)
May	16.4(17.5)	13.4(11.3)	18.2(18.9)	8.1(9.8)
June	23.1(22.1)	15.9 (8.7)	23.9(23.3)	11.0(9.2)
Mean	10.5(9.8)	8.7(10.5)	12.1(11.1)	8.6(8.7)

[a]Values in parentheses are 30-yr (1961–1990) means.

phytosterols by using 5 or 1% levels of significance (* and **, respectively). Total phytosterol content was negatively associated with the content of 18:3 FA (–0.3*). The content of brassicasterol was positively correlated with the content of 18:2 FA (+0.5**). The content of campesterol was positively correlated with the contents of total unsaturated FA (+0.4*), total PUFA (+0.5**), and 18:3 FA (+0.5**), indicating the feasibility of simultaneously increasing the contents of these nutritionally desirable components of edible oils. The content of campesterol was negatively correlated with the contents of total saturated FA (–0.3*), monounsaturated FA (–0.4**), 18:0 (–0.3*), 18:1 (–0.4*), and 20:1 (–0.3*) FA. The content of stigmasterol exhibited a positive correlation with the content of 20:1 (+0.4*) FA. The contents of β-sitosterol were positively correlated with the contents of total saturated FA (+0.3*), monounsaturated FA (+0.4*), and 18:1 (+0.3*) FA and negatively correlated with the contents of total unsaturated FA (–0.3*), PUFA (–0.4**), and 18:3 (–0.4*) FA. The content of Δ^5-avenasterol was positively correlated with the contents of monounsaturated FA (+0.5**) and 18:1 (+0.4**) FA and was negatively correlated with PUFA (–0.5**) and 18:2 (–0.5**) FA. The content of Δ^7-stigmastenol was positively correlated with the contents of 18:2 (+0.4*) and 20:1 (+0.3*) FA.

The correlations between phytosterol components were generally not significant. The only significant positive correlations were observed between contents of total phytosterols and brassicasterol (+0.4**) and the contents of stigmasterol and Δ^5-avenasterol (+0.3*), indicating that their concentrations could be simultaneously increased by a breeding program. Negative correlations existed between the contents of brassicasterol and Δ^5-avenasterol (–0.6**); brassicasterol and Δ^7-stigmastenol (–0.4*), campesterol, and β-sitosterol (–0.8**); and campesterol and Δ^5-avenasterol (–0.4*), indicating that it would be difficult to increase their concentrations simultaneously through a breeding program.

These results suggest that genetics of the plant affected the distribution of phytosterols. However, the total phytosterol concentration in canola oil was not affected by the genotype or the growing location. Furthermore, the results indicated that oil from Virginia-grown canola was comparable in phytosterol content to that grown in other locations.

ACKNOWLEDGMENTS

This research was supported by funds allocated to Virginia State University and Virginia Polytechnic Institute and State University (Virginia Tech) by the National Canola Research Program (Mid-Western Region) of the U.S. Department of Agriculture through Southern Illinois University–Carbondale. Contribution of Virginia State University, Agricultural Research Station, Journal Article No. 232.

TABLE 6
Significant Pearson Correlation Coefficients[a] Between Phytosterols and FA in Oil from Canola Grown at Two Locations in Virginia During 1995–1996

Characteristic	Correlation coefficient	Characteristic	Correlation coefficient
Phytosterols–FA			
Total phytosterols and 18:3	–0.3*	Phytosterol–phytosterol	
Brassicasterol and 18:2	+0.5**	Total phytosterol and brassicasterol	+0.4**
Campesterol and USFA	+0.4*	Stigmasterol and Δ^5-avenasterol	+0.3*
Stigmasterol and 20:1	+0.4*	Brassicasterol and Δ^5-avenasterol	–0.6**
β-Sitosterol and 18:1	+0.3*	Brassicasterol and Δ^7-stigmastenol	–0.4*
β-Sitosterol and 18:3	–0.4*	Campesterol and β-sitosterol	–0.8**
β-Sitosterol and SFA	+0.3*	Campesterol and Δ^5-avenasterol	–0.4*
β-Sitosterol and USFA	–0.3*		
β-Sitosterol and MUFA	+0.4*	FA–FA	
β-Sitosterol and PUFA	–0.4**	PUFA and 18:0	–0.3*
Δ^5-Avenasterol and 18:1	+0.4**	PUFA and 18:1	–0.4*
Δ^5-Avenasterol and 18:2	+0.5**	PUFA and 20:1	–0.3*
Δ^5-Avenasterol and MUFA	–0.5**	PUFA and 18:3	+0.5**
Δ^5-Avenasterol and PUFA	–0.5**	PUFA and SFA	–0.3*
Δ^7-Stigmastenol and 18:2	+0.4*	PUFA and MUFA	–0.4**
Δ^7-Stigmastenol and 20:1	+0.3*		

[a]Correlation coefficient significant at 5% (*) and 1% (**) level, respectively. For abbreviations see Table 1.

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[Received December 13, 2002; accepted August 5, 2003]