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Yield and glucosinolates in mustard seeds and volatile oils in caraway seeds and coriander fruit.

I Yield and glucosinolate contents of mustard (*Sinapis sp., Brassica sp.*) seeds

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Abstract. Different varieties of yellow mustard (*Sinapis alba* L.), brown mustard (*Brassica juncea* (L.) Czern.) and black mustard (*Brassica nigra* (L.) W.D.J. Koch) were tested in 1983—1985 at three locations in Finland. The average seed yield of yellow mustard was 2220 kg/ha, it's sinalbine content being 2.2—5.2 g/100 g. There were no major differences between the tested varieties. Varieties 'Kirby' and 'Gisilba' produced the largest yields. 'Gisilba' and 'Ochre' had the shortest growth periods. The sinalbine content in yellow mustard seeds varied more between the years than between the varieties. The average yield of brown mustard was 1620 kg/ha. The variety 'Picra' was slightly better than the other varieties with respect to yield and early ripening. The sinigrine content in brown mustard seeds were approximately from traces to 4.4 g/100 g those of 'Domo', 'Blaze', 'Sv 8341001' and 'Trowse' being highest.

Black mustard yielded less than 700 kg/ha, the sinigrine content of the seeds being 1.8—4.5 g/100 g.

Key words: seed, yellow mustard, brown mustard, black mustard, sinigrine, sinalbine

Introduction

Mustard is grown on 120 hectares of land in Finland. That equals to a production of approximately 20 % of the self-sufficiency in mustard consumption (HÄLVÄ 1985). The species cultivated are yellow mustard (*Sinapis alba* L.) and brown mustard (*Brassica juncea* (L.) Czern.). There is a clear deficiency of varieties: the yellow mustard 'Trico' and the brown mustard 'Picra' are the major varieties grown. The growth period of 'Trico' is rather long for growing in Nordic countries. Thus there exists a need to a wider range of varieties which would be rich in glucosinolates and suitable for northern climates, with a relatively short growing period. There are only few studies concerning the cultivation of mustard in Finland.

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In addition to the above mentioned cultivars several new varieties were investigated in our study which is a part of a Herb Plant Research Project (1983—85). The purpose of the project was to determine the feasibility of large-scale herb production in Finland.

Materials and methods

Different varieties of yellow and brown mustard were tested and analysed in the years 1983—1985. Mustard was grown at three locations in Southern Finland: Helsinki (60° 14′N), Kangasala (61°28′N) and Jokioinen (60°48′N). Black mustard (*Brassica nigra* (L.) W.D.J. Koch) was also included in the study in 1985. The field tests in Jokioinen will be reported separately. Preliminary field tests were also carried out in Inari (69°04′N), in the north of Finland, but the growth period was too short to obtain a fully ripened crop there.

Seven varieties of yellow mustard from different origins were cultivated. 'Trico' and 'Sv 04108' were from Sweden, 'Albatros' and 'Gisilba' from West Germany, and 'Kirby' from England. 'Ochre' is widely cultivated in Canada and 'Hungarian' is a common type grown in Hungary.

The eight brown mustard varieties tested were 'Picra' (France), 'Domo' and 'Blaze' (Canada), 'Trowse' (England), Sv 8341001 (Sweden) and common varieties in Europe 'Pusa Bold', 'Prakash' and 'RLM 198'.

Only one black mustard variety, 'Giebra', was available.

Yellow mustard was sown at a density of 20 kg/ha and brown and black mustard at a density of 10 kg/ha. The field tests were carried out using the method of randomized blocks, with plots of 10 m^2, and from three to four replications. Crop was cultivated using normal farming practices. After harvest the seed crop was dried and the glucosinolates were analysed.

In yellow mustard sinalbine e.g. p-hydroxybenzyl glucosinolate, and in black mustard sinigrine e.g. 2-propenyl glucosinolate were determined. The determinations were carried out by HPLC (high pressure liquid chromatography). Before the determinations approximately 100 grams of seeds were ground for 30 seconds. One gram of ground seeds was extracted with 70 % methanol in an ultrasonic apparatus for 10 minutes at +65°C. After the extraction the solution was diluted to 100 milliliters with 50 % methanol. Immediately before the analysis the samples were purified by filtering. HPLC-determinations were performed using reverse phase ion pair liquid chromatography (C18-reverse phase-column).

The apparatus consisted of a Waters Model 6000 A pump, WISP-autosampler, Model M440 UV-absorbance detector with a wave length filter and dual-pen recorded. In the determination of sinalbine the column was eluted with acetonitrile water (70:30 vol %). The ion pair former used was 2 % 1-pentane sulphuric acid (0.5 M) in acetic acid (50 %). In the determination of sinigrine the column was eluted with 10 mM tetrabutyl ammonium hydroxyde (TBAH)- methanol (90:10 vol %), pH 3. TBHA was used as an ion pair former. The instrumental conditions were as follows: wavelength 313 nm (sinalbine) or 254 nm (sinigrine), flow-rate 2.0 ml/min and detector attenuation 0.1 ×. The injection volume was 10.

The data of the field tests were statistically evaluated by analysis of variance according to the year and location. The means were separated with the test of Duncan or Tukey (Steel and Torrie 1980).

Results and discussion

Yellow mustard

Mustard seeds germinated in 6—12 days. Insects (*Phyllotreta* sp., *Meligethes aeneus* Fabr. and *Plutella maculipennis* Curt.) were controlled with insecticides. The vegetation reached a height of 112—157 cm by the end of seed ripening. The vegetation of 'Albatros' was tallest. None of the varieties showed tendency to be flattened down. The growth period

Table 1. The growth periods (days) for yellow mustard varieties compared with 'Trico' during 1983—85 at two locations.

Variety	1983	1984		1985	
	1	1	2	1	2
Trico	115	119	142	121	123
Albatros	—	− 7	−19	—	—
Gisilba	—	−10	−22	−18	−10
Kirby	—	− 8	−18	—	—
Ochre	—	−10	−17	—	—
Hungarian	+ 0	—	—	—	—
Sv 04108	−10	− 3	− 5	+ 0	+ 1
Mean	112	113	129	115	120

Locations: 1 = Helsinki, 2 = Kangasala

was 105—121 days in Helsinki and 1—2 weeks longer in Kangasala (Table 1). The corresponding degree-days were 1203—1312°C and 1110—1214°C, respectively. 'Trico' had the longest growth period.

The average yield of yellow mustard was 2220 kg/ha in Helsinki and 1860 kg/ha in Kangasala (Fig. 1). 'Trico' was the control variety. In one trial out of six 'Trico' gave the largest yield. In the other trials there were no significant differences between 'Trico' and the other varieties. In 1984 'Kirby' yielded the largest crop, 3520 kg/ha, in Helsinki. The result differed significantly ($p < 0.05$) from 'Gisilba'. 'Kirby' also produced the largest crop in Kangasala. This yield and that of 'Albatros' differed significantly ($p < 0.05$) from that of 'Trico'. In 1985 there were no differences between the seed yields of varieties tested.

The weight of one thousand seeds varied between 6.0 and 6.7 grams, with the exception that the seeds of 'Trico' in a trial weighed only 4.6 grams.

The sinalbine content of yellow mustard was 2.2—4.9 g/100 g (Table 2). For comparison, seed samples from Canada were also analysed. There were no differences between the varieties in sinalbine content. Different years caused more variation than different varieties or locations. The sinalbine content was highest in 1983 and lowest in the rainy summer of 1984.

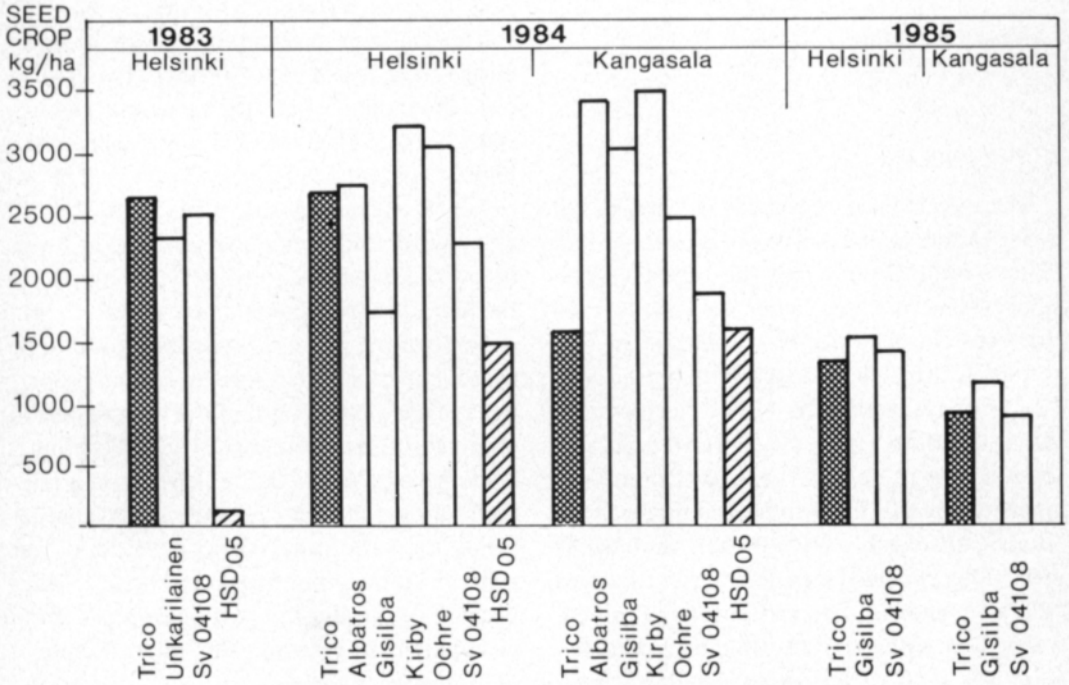

Figure 1. Seed yield of yellow mustard varieties compared with 'Trico' during 1983—85 at two locations.

Table 2. The amounts of sinalbine in yellow mustard seeds during 1983—85.

Variety	Sinigrine, g/100 g dry matter						
	1983	1984			1985		
	1	1	2	3	1	2	3
Trico	3.9—4.7	2.7—2.9	3.7—3.8	3.6—3.8	4.0—4.6	3.4—4.4	4.4—4.9
Sv 04108	4.1—4.7	3.3—3.5	2.9—3.0	—	3.0—3.7	3.6—3.7	—
Gisilba	—	3.2—3.3	3.0	3.3	3.7—4.7	3.5—3.6	3.6—3.8
Albatros	—	3.3—3.4	2.1—3.4	—	—	—	4.1—4.9
Kirby	—	3.2—3.3	2.8—3.0	3.2—3.3	—	—	4.0—4.4
Canadian sample	3.9—4.1						

Locations: 1 = Helsinki, 2 = Kangasala, 3 = Jokioinen

Table 3. The growth periods for brown mustard varieties compared with 'Blaze' in 1984 and 1985 at two locations.

Variety	1984	1985	
	1	1	2
Blaze	112	106	110
Domo	+ 5	+8	+2
Picra	−14	—	—
Pusa Bold	—	+0	+0
Prakash	—	−2	−2
Trowse	+ 2	−1	−2
RLM 198	—	−3	−2
Sv 8341001	—	+8	−3
Mean	110	107	109

Locations: 1 = Helsinki, 2 = Kangasala

Brown mustard

The vegetation reached a height of 113—142 cm by the end of the growth period. 'Blaze' and 'Domo' had the tallest vegetations. None of the varieties lay flat. In 1984 the seeds did not ripen by the end of the season in Kangasala. The growth period was 98—117 days, with 1110—1295° degree-days. 'Domo', 'Blaze' and 'Sv 8341001' had the longest growth period. That of 'Domo' was significantly ($p<0.05$) longer compared with 'Blaze', 'Prakash', 'Sv 8341001' and 'RLM 198'. The two last mentioned varieties and 'Picra' ripened in the shortest time (Table 3).

The average yield of brown mustard in Helsinki was 1620 kg/ha. In Kangasala the seed yield was as small as 580 kg/ha because of weeds (turnip rape) and crusted silt soil. The data of the latter was not statistically analysed because of the deficiency in the data received. The soil type proved to be unsuitable for the cultivation of mustard. The varieties showed only a few differences in yields. In one trial of three 'Picra' had a significantly ($p<0.05$) larger yield than the control variety 'Blaze'. No other differences were recorded. The results are presented in Figure 2. The weight of one thousand seeds was 2.4—3.3 grams, with the exception of the large seeds of 'Pusa Bold', which weighed 4.3 grams.

The sinigrine content of brown mustard varied from traces to 4.4 g/100 g. Differences were observed between the varieties, 'Domo', Blaze', 'Sv 8341001' and 'Trowse' having the highest content of sinigrine (Table 4). The varieties 'Picra', 'Prakash', 'Pusa Bold', 'Jo 21' and 'RLM 198' contained sinigrine at levels below the minimum (0.65 g/100 g) quoted in the literature (Melchior and Kastner 1974).

None of the mustard varieties proved to be clearly superior with respect to several properties such as yield, length of the growth period or glucosinolate contents. The yellow mustards 'Gisilba' and 'Ochre' ripened in a relatively short time but they did not have larger yields than the other varieties. 'Picra' was superior to the other brown mustard varieties because of the short growth period and good yield potential, however, the sinigrine content of 'Picra' was low.

In this study the results concerning the

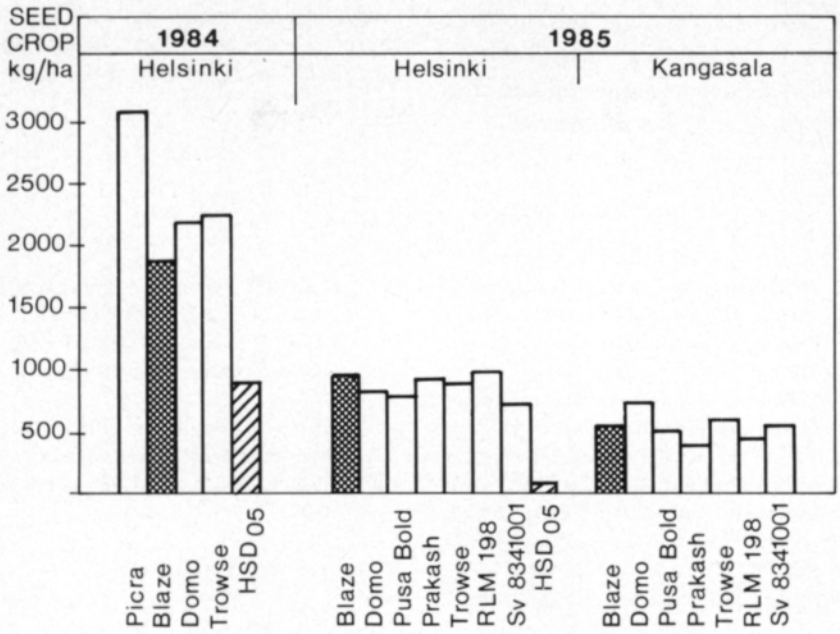

Figure 2. Seed yields of brown mustard varieties compared with 'Blaze' during 1984—85 at two locations.

Table 4. The amounts of sinigrine in brown and black mustard seeds during 1984—85.

Variety	Sinigrine g/100 g dry matter				
	1984		1985		
	1	3	1	2	3
Domo	2.8	2.5—2.9	1.7—2.1	2.0—2.3	4.1—4.4
Blaze	2.1	1.8	2.0—2.2	1.7—1.8	3.7—3.9
Prakash	—	—	0.6—0.9	0.4—0.5	1.3—1.6
Pusa Bold	—	—	0.4—0.5	0.3—0.4	0.9—1.1
Jo 21	—	1.4	0.8—0.9	0.6—0.8	3.0
Trowse	1.8—2.1	—	2.1—2.3	1.6—1.8	3.5—3.6
Giebra			1.8	2.5—2.9	4.4—4.5

Locations: 1 = Helsinki, 2 = Kangasala, 3 = Jokioinen

growth period and yields of yellow and brown mustards resemble those reported by PAHKALA (1984). A mustard study by VALLE, made as early as 1943, indicates that brown mustard ripens three weeks later than yellow mustard whereas in our study some brown mustard varieties ripened earlier than yellow mustard. Apparently there has been a considerable development in the mustard varieties. The seed crops of both species resemble those reported by HENRIKSEN (1975), NORDESTGAARD (1979) and PAHKALA (1984), but they are larger than the national and European averages (OSVALD 1959, ANON 1974, HÄLVÄ 1985). According to our study there exists a need for introducing mustard species with short growth periods, large yields and high glucosinolate contents.

Black mustard

The black mustard variety 'Giebra' yielded less than 700 kg/ha, the height of the vegetation being 120 cm. The ripening of seeds took 105 days in Helsinki and two weeks longer in

Kangasala. The sinigrine content of black mustard seeds was 1.8—4.5 g/100 g (Table 4). Black mustard yielded a small crop and thus varieties with higher yields are needed.

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References

Henriksen, K. 1975. Høsttidspunktets, høstmådens og vejrinsbetingelsernes indflydelse på frøudbytte og frøkvalitet hos gul sennep (*Sinapsis alba*). Tidsskr. Pl. avl. 79: 3: 337—356.

Hälvä, S. 1985. Consumption and production of herbs in Finland. J. Agr. Sci. Finl. 57: 231—237.

Melchior, H. & Kastner, H. 1974. Gewürze, botanische und chemische Untersuchung, Grundlagen und Fortschritte der Lebensmitteluntersuchung. 290 p. Berlin.

Nordestgaard, A. 1979. Stigende kvallstofmaengder til gul sennep. Stat. Pl. avlsfor Medd. 81: 1481: 1—4.

Osvald, H. 1959. Åkerns nyttoväxter. 59 p. Stockholm.

Pahkala, K. 1984. Sinappi — vaihtoehto öljykasvien viljelyssä. Koetoim. ja Käyt. 41: 51.

Steel, R.G.D. & Torrie, J.H. 1980. Principles and procedures of statistics, a biometrical approach. 633 p. New York.

Valle, O. 1943. Öljykasvien viljelymahdollisuuksista Suomessa. Erip. työväen kalenterista 1943. 7 s.

Anon, . 1974. Dyrkning of gul sennep. tidsskr Frøavl 62: 386—388.

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SELOSTUS

Sinapin (*Sinapis* sp., *Brassica* sp.) siemensato ja glukosinaattipitoisuus

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Eri sinappilajeja ja lajikkeita tutkittiin vuosina 1983—1985 kolmella paikkakunnalla: Helsingissä (60°14′N), Kangasalla (61°28′N) ja Jokioisissa (60° 48′N). Kokeet kuuluivat Maustekasvien tutkimusprojektiin (SA 01/813), jonka tarkoituksena oli selvittää laajamittaisen maustetuotannon mahdollisuuksia Suomessa. Uusien tuotantovaihtoehtojen tarve on ilmeinen nyt kun monista perinteisistä maataloustuotteista on ylitarjontaa. Sinapin viljelyala on Suomessa noin 120 hehtaaria, mikä vastaa 20 prosentin omavaraisuutta.

Keskimääräinen keltasinappisato (*Sinapis alba* L.) oli 2220 kg/ha ja siementen sinalbiinipitoisuus oli 2.2—5.2 g/100 g. Eri lajikkeiden välillä ei ollut suuria eroja. Seitsemästä tutkitusta lajikkeesta 'Kirby' ja 'Gisilba' olivat satoisimmat. Näistä jälkimmäisen ja 'Ochre'-lajikkeen kasvuajat olivat lyhyimmät. Sinalbiinipitoisuus vaihteli enemmän eri vuosien kuin eri lajikkeiden välillä.

Ruskeasinappi (*Brassica juncea* (L.) Czern) antoi satoa keskimäärin 1620 kg/ha. Sinigriinipitoisuus vaihteli hyvin pienistä pitoisuuksista 4.4 grammaan/100 g. 'Picra'-lajike erottui kuudesta tutkitusta lajikkeesta runsaan sadon ja aikaisuuden perusteella. Sen sinigriinipitoisuus oli kuitenkin melko alhainen verrattuna lajikkeisiin 'Domo', Blaze', 'Sv 8341001' ja 'Trowse'.

Mustasinapin (*Brassica nigra* (L.) W.D.J. Koch) sato jäi alle 700 kg/ha. Ainoa viljelyyn saatu lajike oli 'Giebra'. Siementen sinigriinipitoisuus oli 1.8—4.5 g/100 g. Mikään sinappilajikkeista ei osoittautunut muita paremmaksi useiden ominaisuuksien, kuten satomäärän, kasvuajan ja glukosinaattipitoisuuden perusteella. Tästä syystä tulisi edelleen kehittää ja etsiä lajikkeita, jotka soveltuisivat lyhyen kasvuajan sekä runsaan ja hyvälaatuisen sadon takia viljeltäviksi pohjoisissa ilmasto-oloissa.