# Hemp (*Cannabis sativa* L.) as a Resource for Green Cosmetics: Yield of Seed and Fatty Acid Compositions of 20 Varieties Under the Growing Conditions of Organic Farming in Austria

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**ABSTRACT.** The interest in hemp (non-drug *Cannabis sativa* L.) for skin care and cosmetic use is due to the high content of oil, especially unsaturated fatty acids in seed with technological and therapeutic effects. In a field trial on an organic farm, seed weight and content of fatty acids

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The authors are grateful for helpful comments of the anonymous reviewers, Cristina Flitner and Alexander Ploner on the draft for this paper.

Research was funded by the European Commission through the project FAIR-CRAFT 9558. Seeds were provided by the breeders or their representatives in Austria or France.

Journal of Industrial Hemp, Vol. 9(1) 2004
http://www.haworthpress.com/web/JIH

Digital Object Identifier: 10.1300/J237v09n01_06

of 20 hemp varieties were surveyed on three different harvest dates. The dry matter seed yields ranged from 27-149 g $m^{-2}$. The varieties Ferimon-12, Fedora-19, and Bialobreszie produced high seed yields on all three harvest dates but yields were not significantly different from a large group of other varieties. Contents of palmitic acid range from 3.1 to 4.1%, of stearic acid from 0.1 to 1.9%, of oleic acid from 3.7 to 9.2%, of linoleic acid from 44.8 to 60.2%, of α-linolenic acid from 18.2 to 27.4%, and of γ-linolenic acid from 1.6 to 4.7%. The genotype has no significant influence on fatty acid content. All 20 varieties tested show high quantities of fatty acid depending on the harvest date, so that no variety can be favored. Results confirm that hemp is a very good source of fatty acids for skin care and cosmetic use. 

**KEYWORDS.** Hemp, seed yield, variety, harvest date, renewable resources, skin care, oil, palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, dermatology, organic farming, cosmetics

## *INTRODUCTION*

During the past years, Austria has experienced a dramatic increase in organic farming relative to the other European Union (EU) countries. Almost 9% of the farms in Austria are certified organic, meaning an area of 345,375 ha, or 10% of the total cultivated farmland (Vogl and Hess, 1999). The increasing market for organics in the EU and in Austria does not only demand organic products for human consumption, but also products based on organically grown non-food renewable resources for textiles or cosmetics (Nova-Institut, 1998; Tovar and Harting, 2001; Hartl and Vogl, 2002; Hartl and Vogl, 2003; Vogl and Hartl, 2003).

Hemp (*Cannabis sativa* L.) is a plant that can satisfy a certain portion of this demand. It has received increasing attention during the last decade because of its wide range of possible uses. Hemp seeds and oil are of high nutritional value (Mölleken, 1999) and are used for human consumption (e.g., in cheese, bread, salad, and chocolate) in many European countries. Seeds are also processed for technical purposes, to produce colors and soaps. Fibers and stalks are seen as an environmentally sound renewable resource for industrial uses, like insulation materials, geo-textiles or paper (Nova-Institut, 1996). A promising market exists also for skin care products based on organically grown hemp seed oil (Nova Institut, 1996).

The interest in hemp for skin care is due to the high content of oil (25-35%) in seeds of hemp, and a favorable unsaturated fatty acid profile comprised of 50-60% linoleic acid (C18:2ω6) and 20-25% α-linolenic acid (C18:3ω3). The oil of hemp also contains a substantial portion of γ-linolenic acid (C18:3ω6) that is of potential for example in the medical treatment of neurodermatosis and psoriasis (Anstey et al., 1990; Fiocchi et al., 1994; Pate, 1999; Wright and Burton, 1982).

These three fatty acids are interesting for skin care. They are structural compounds of the phospholipids in the cell membranes and influence several cell membrane functions such as fluidity, the transport of electrolytes, and the activity of hormones. They also stimulate the immunology of the cells (Thews et al., 1999).

The cutaneous permeability barrier is located in the stratum corneum of the skin and is mediated by lipid-enriched membrane multi-layers with a specific lamellar structure. The lipids in the intercellular areas consist primarily of ceramids, cholesterol and free fatty acids (Schürer, 1996). In the subcutic tissue of adults (males 15-65 years), the relative percentages of all fatty acids are: palmitic acid (C16:0) 22.9%, stearic acid (C18:0) 5.77%, oleic acid (C18:1) 48.2%, C18:2ω6 10.2%, and C18:3ω3 0.58% (Ciba Geigy, 1984). A favorable portion of these fatty acids improves the gliding of a skin care cream and the smoothness of the skin (Christin, 1986; Träger, 1989).

Organic farmers stand a good chance at providing organically grown hemp seeds for the green cosmetic industry. In Austria, as in other European countries, cultivation of hemp is not prohibited (Vogl and Hess, 1995). For farmers who grow organic hemp in order to sell seed or oil to the cosmetic industry, the selection of the most appropriate variety and the timing of the harvest of hemp seed poses a challenge. This is due to continuous ripening of the seeds over a long period (a few weeks). Ripe seeds fall to the ground while others are still green (Mediavilla et al., 1997). Mature seed shows evident differences in its content of various compounds (fatty acids, tocopherols, phytosterins and even oil and protein content) in comparison to immature seeds (Panék et al., 1991; Mölleken et al., 2000).

To facilitate the organic growing of hemp with the aim of producing organic cosmetics, this paper presents the yields and contents of the major fatty acids of 20 varieties of organically grown hemp, harvested on three different dates.

## METHODS

The agronomic part of the research was carried out at an organic farm in Lower Austria using a randomized block design for small plots (Table 1). The soil was a sandy loam with a humus content of 2.4%, a pH-value of 6.3 (Table 2). Management practices preceding the crop were typical for hemp in the region (Table 3). Twenty varieties from six countries were provided from the breeders or seed retailers and included in the field trial: Irene and Secueni (Rumania); Benino and Bialobrzeskie (Poland); Kompolti (Hungary); Fasamo (Germany); USO 11, USO 14, USO 31 (Ukraine); Ferimon 12, Fedora 17, Fedora 19, Felina 32, Felina 34, S-204, Epsilon 68, Fedrina 74, S-206, Futura 75 and Futura 77 (France). Only Kompolti is dioecious; all others were monoecious or "unisexual." For details on varieties see De Meijer (1995).

TABLE 1. Technical details of the experiment.

| Parameter | Specification |
|---|---|
| Design | Randomized blocks |
| Size of plots | 24 $m^2$ each |
| No. of Replications | 4 |
| Date of Sowing | 7th of May 1999 |
| Distance between rows | 13 cm |
| Sowing depth | 3 cm |
| Plant density | 150 plants/$m^2$ |
| Site | Organic farm, Waldviertel, Austria, 500 m a. s. l. |
| Average annual rainfall | 599 mm (385 mm in the growing period) |
| Average annual temperature | 7.3°C (13.8°C in the growing period) |
| Total rainfall, April-September 1999 | 322 mm |
| Average temperature April-September 1999 | 15.7°C |
| Soil type | Calcium-free brown earth on gneiss |

TABLE 2. Nutrient content of the soil at the site of the experiment.

| Soil depth | pH | $P_2O_5$ (mg 100 $g^{-1}$) | $K_2O$ (mg 100 $g^{-1}$) | $N_{in}$ (kg $ha^{-1}$) at sowing | $N_{in}$ (kg $ha^{-1}$) at harvest | $N_{tot.}$ % | TOC % |
|---|---|---|---|---|---|---|---|
| 0-25 cm | 6.3 | 8 | 17 | 52.2 | 8.7 | 0.09 | 1.4 |
| 25-50 cm | 6.2 | 3 | 12 | 55.9 | 4.3 | 0.05 | 1.1 |
| 50-75 cm | 6.2 | 3 | 7 | 14.9 | 0.0 | 0.04 | 1.1 |

$N_{in}$: inorganic nitrogen: mineralised nitrogen (= nitrate + ammonium)
$N_{tot.}$: total nitrogen: sum of organic and inorganic nitrogen
TOC: total organic carbon

TABLE 3. Management practices on the plot of the experiment.

| Practice | Explanation |
|---|---|
| Crop 1998 | Oats |
| Fertilization | 20 t $ha^{-1}$ cattle manure in autumn 1998 |
| Catch crop 1998/1999 | California bluebell & Mustard |
| Soil management autumn 1998 | Cultivator (then sowing of catch crop) + 28 Oct. plow and plowing in of catch crop |
| Soil management spring 1999 | March, 27: 1 × Harrow + April, 1: 1 × Harrow |
| Seed bed preparation | Seed bed combination before sowing |

Differences between varieties in terms of their photoperiodic behavior were observed. The first varieties to flower were USO-31 and USO-14, in the week July 12th-18th. The last varieties to begin to flower–Futura-75, Futura-77 and Kompolti–did so three weeks later, in early August. The seeds began to mature in much the same variety order. The only difference was that the period in which the different varieties' seeds began to mature was spread over a longer period of time, from the middle of August to the end of September, a period of more than five weeks.

For cosmetic purposes–due to legal standards–it is of great importance to use hemp varieties with a minimum of THC content in the oil. Therefore all varieties of the EU catalogue for commercial varieties of crops (Commission of the EU, 1989) have been used for the trial, as well as additional varieties that were in discussion for inclusion on the list at that time. Varieties on this list must contain less than 0.3% THC in dry matter. The seeds of hemp do not contain any cannabinoids at all (Mölleken and Husmann, 1997). THC that originates from the seed shells or other parts of the plant might contaminate the seeds and therefore the pressed oil. Only the use of hemp oil from seeds with carefully cleaned shells guarantees that cosmetic products are free from any cannabinoids.

The seed was harvested on three dates (1st: 7th of September and 2nd: 20th of September, 3rd: 4th of October). Timing was chosen as the equivalent of an early, medium and late harvest date for the variety normally used by farmers in the growing region, but also to ensure that each variety was harvested on at least one occasion when the seed harvest could be considered mature (Mediavilla et al., 1998: Code 2205–50% of seeds hard). The only disease observed during the trail was gray mould in the inflorescences, caused by *Botrytis cinerea*. Harvest later than 4th of Oct. 2001 would have resulted in losses of seed yield of economic proportion.

On each harvest date, one square meter of plants was harvested from the central rows of every plot. Harvesting involved the removal of the inflorescences only, and these were then put into a paper bag. The harvests were dried for 3 days at 40°C, and then threshed using a small-plot combine. Then the seeds were cleaned and dried again for 36 hours at 38°C. The clean, dry seed samples were then weighed to obtain yield data for each variety.

For the analyses of the fatty acids, two random samples of each variety from every harvest date were taken. The fatty acids of the seeds were extracted in methylene chloride ($CH_2Cl_2$). They were then methylated with trimethylsulfonium hydroxide (TMSH) into methylesters and stabilized with butylhydroxytoluole (BHT). Methylpalmitate (C17:0) was then added as the internal standard (ISTD). The following parameters were used for the gaschromatographic analyses: GC 6000 Vega Series 2, Carlo Erba Instruments, column: Chrompack CP-Sil 88 Fame 50 m, i.d. 0.25 mm, injection temperature: 240°C, detector 240°C (FID), gas $H_2$, split 1:10, temperature program: 70°C-240°C (10°C/min 240°C, 1 min isotherm), injection: 0.5-1 µl.

Analysis of oil content was not the aim of the project; nevertheless it was done with three varieties that cover the range from early to late maturing varieties (USO-31, Felina-34, Futura-77) to show variation. The determination of the oil content was done with the usual Soxhlett-extraction. Here, petrol ether was used as the organic solvent. One hundred gram hemp seeds were pulverised and extracted for two hours.

The data were evaluated and analyzed in SPSS (Statistical Package of Social Sciences), using analysis of variance (One way ANOVA) and the Student-Newman-Keuls Test to identify significant differences between varieties. A Tukey-Test was run to assess significant differences between fatty acid contents. In the tables shown, mean values with different letters indicate significant differences between these mean values at a level $p \leq 0.05$. Means with the same letter are not significantly different.

## *RESULTS*

### *Yields of Seed*

At the 1st harvest, the seeds of Kompolti had only just begun to form, so no seed could be harvested from this variety. The dry matter seed yields of the other varieties ranged widely, from 57 g $m^{-2}$ to 143 g $m^{-2}$. Five homogenous subgroups were identified with no significant differences of seed yields within the group, but significant differences between groups. Fedora-19, Bialobreszie, and Ferimon-12 ranked on top, but there were no significant differences between the ten most productive varieties. USO-31 and Futura-77 both yielded only 57 g $m^{-2}$, together with Kompolti, the lowest level of production on this harvest date (Table 4).

Fedora-19 and Ferimon-12 again achieved very high yields on the 2nd harvest date, but Felina-32 produced by far the highest yield of the 2nd harvest, at 148 g $m^{-2}$. The seed yields of 16 varieties, from Felina-32 to Felina-34, had a range of 31.5 g $m^{-2}$ and there were no significant differences between the yields of these varieties. All these varieties obtained significantly higher yields than the three early-maturing USO varieties. The first seeds of Kompolti had begun to harden by this harvest date, but the yield was, at 27 g $m^{-2}$, still very low and significantly lower than the yields from the other varieties (Table 4).

The results of the 3rd harvest were very similar to those of the 2nd harvest. Again, there was a large group with no significant differences between seed yields of different varieties. The group extended from Irene (106 g $m^{-2}$) through to S-204 (145 g $m^{-2}$). Ferimon-12 (141 g $m^{-2}$) and S-204 (145 g $m^{-2}$) produced by far the greatest amount of seed in the 3rd harvest. According to the Student-Newman-Keuls-Test, the yields of all these varieties were again significantly higher than those of the three USO varieties and Kompolti, the latter again producing the lowest yield of all: 54 g $m^{-2}$ (Table 4).

### *Fatty Acids*

Significant differences could not be found for any of the harvest dates in the fatty acid composition between the varieties using the Student-Newman-Keuls Test nor using the Tukey-Test. The LSD-Test does show significant differences between the highest yielding varieties and the lowest yielding varieties for almost all fatty acids and harvest dates. Nevertheless, we do not present these results here because multiple t-tests with such a high number of varieties are not robust (e.g., Munzert, 1992). We do show here the results of every variety sorted according to fatty acid content for every harvest. This should allow an easier comparison of these results with the results of other authors in further studies.

TABLE 4. Seed dry matter yield, standard deviation and results of Student-Newman-Keuls Test of 20 hemp varieties on three harvest dates.

**1st harvest date**

| Variety | Yield (g $m^{-2}$) | Std. Dev. | Test NK | | | | |
|---|---|---|---|---|---|---|---|
| Fedora19 | 143.0 | 22.6 | A | | | | |
| Bialob. | 140.5 | 10.4 | A | | | | |
| Ferimon12 | 133.2 | 13.5 | A | | | | |
| Fedora17 | 123.9 | 32.1 | A | B | | | |
| S-204 | 123.9 | 16.7 | A | B | | | |
| Felina32 | 119.9 | 15.2 | A | B | | | |
| Fasamo | 113.9 | 10.4 | A | B | C | | |
| Epsilon68 | 108.4 | 9.6 | A | B | C | | |
| S-206 | 107.1 | 1.4 | A | B | C | | |
| Beniko | 106.2 | 15.1 | A | B | C | D | |
| Irene | 94.5 | 21 | | B | C | D | E |
| Secueni | 91.6 | 16.8 | | B | C | D | E |
| Felina34 | 83.3 | 10 | | | C | D | E |
| Fedrina74 | 81.9 | 5.1 | | | C | D | E |
| USO14 | 76.7 | 21.7 | | | C | D | E |
| USO11 | 71.0 | 6 | | | | D | E |
| Futura75 | 68.2 | 10.7 | | | | | E |
| Futura77 | 57.3 | 9.8 | | | | | E |
| USO31 | 57.1 | 26.9 | | | | | E |
| Kompolti | - | - | | | | | |

**2nd harvest date**

| Variety | Yield (g $m^{-2}$) | Std. Dev. | Test NK | | |
|---|---|---|---|---|---|
| Felina32 | 148.0 | 15.8 | A | | |
| Ferimon12 | 138.3 | 13.6 | A | | |
| Fedora19 | 137.2 | 8.8 | A | | |
| S-206 | 135.7 | 18.4 | A | | |
| Bialob. | 134.7 | 14.2 | A | | |
| Fedrina74 | 134.2 | 10.1 | A | | |
| Epsilon68 | 131.0 | 10.3 | A | | |
| Fasamo | 128.2 | 15.7 | A | | |
| S-204 | 127.6 | 7.1 | A | | |
| Fedora17 | 127.6 | 20.0 | A | | |
| Beniko | 125.9 | 21.7 | A | | |
| Futura75 | 124.2 | 13.1 | A | | |
| Irene | 123.8 | 28.5 | A | | |
| Secueni | 117.0 | 10.6 | A | | |
| Futura77 | 116.9 | 12.9 | A | | |
| Felina34 | 116.5 | 10.2 | A | | |
| USO11 | 80.0 | 12.0 | | B | |
| USO14 | 72.6 | 11.2 | | B | |
| USO31 | 67.8 | 22.6 | | B | |
| Kompolti | 27.4 | 3.8 | | | C |

**3rd harvest date**

| Variety | Yield (g $m^{-2}$) | Std. Dev. | Test NK | | |
|---|---|---|---|---|---|
| S-204 | 145.1 | 11.0 | A | | |
| Ferimon12 | 141.3 | 20.7 | A | B | |
| Fedora19 | 126.7 | 23.7 | A | B | |
| Bialob. | 126.6 | 19.4 | A | B | |
| S-206 | 121.0 | 16.1 | A | B | |
| Fedora17 | 120.5 | 12.8 | A | B | |
| Felina34 | 118.8 | 16.2 | A | B | |
| Epsilon68 | 116.8 | 4.0 | A | B | |
| Fedrina74 | 116.4 | 12.4 | A | B | |
| Fasamo | 114.6 | 5.8 | A | B | |
| Felina32 | 114.5 | 17.2 | A | B | |
| Futura77 | 111.2 | 26.7 | A | B | |
| Beniko | 106.7 | 16.0 | A | B | |
| Futura75 | 106.6 | 10.7 | A | B | |
| Irene | 105.6 | 13.6 | A | B | |
| Secueni | 103.8 | 18.3 | | B | |
| USO11 | 73.4 | 18.3 | | | C |
| USO14 | 68.0 | 17.5 | | | C |
| USO31 | 65.6 | 15.1 | | | C |
| Kompolti | 53.8 | 4.4 | | | C |

TABLE 5. Percentage of palmitic acid (C16:0) in seed of 20 hemp varieties on three harvest dates.

| **1st harvest (% acid)** (mean = 3.5) | | **2nd harvest (% acid)** (mean = 3.1) | | **3rd harvest (% acid)** (mean = 3.7) | |
|---|---|---|---|---|---|
| **Variety** | **%** | **Variety** | **%** | **Variety** | **%** |
| Felina-32 | 3.1 | USO-14 | 2.6 | Irene | 3.0 |
| Futura-77 | 3.2 | S-206 | 2.7 | Secueni | 3.2 |
| Fedrina-74 | 3.3 | S-204 | 2.8 | Felina-34 | 3.3 |
| USO-31 | 3.3 | USO-11 | 2.8 | S-204 | 3.4 |
| Secueni | +3.4 | Fedora-19 | 2.9 | Epsilon-68 | 3.5 |
| Fasamo | 3.4 | Ferimon-12 | 3.0 | Fedora-19 | 3.5 |
| Fedora-17 | 3.5 | Futura-77 | 3.0 | USO-11 | 3.6 |
| Ferimon-12 | 3.5 | Fedora-17 | 3.0 | S-206 | +3.6 |
| S-206 | 3.5 | Futura-75 | 3.1 | Futura-75 | 3.7 |
| Irene | +3.5 | Bialobrezie | 3.1 | USO-14 | +3.7 |
| Beniko | 3.6 | Fasamo | 3.1 | Bialobrezie | 3.8 |
| USO-14 | 3.7 | Kompolti | 3.2 | Fedrina-74 | +3.8 |
| Felina-34 | +3.7 | Secueni | 3.2 | Beniko | +3.8 |
| Fedora-19 | +3.7 | Beniko | 3.2 | Felina-32 | +3.9 |
| Epsilon-68 | +3.7 | Felina-34 | 3.2 | Kompolti | +3.9 |
| Futura-75 | +3.8 | Irene | 3.3 | Ferimon-12 | +3.9 |
| USO-11 | +3.9 | Fedrina-74 | 3.4 | Futura-77 | +4.0 |
| Bialobrezie | +3.9 | Felina-32 | 3.5 | USO-31 | +4.1 |
| S-204 | +3.9 | USO-31 | 3.5 | Fedora-17 | +4.1 |
| Kompolti | - | Epsilon-68 | 3.6 | Fasamo | +4.1 |

+ . . . indicates the harvest date at which the respective variety had the highest content of the fatty acid in relation to other harvest dates of the same variety.

The highest contents of palmitic acid are achieved on the 3rd harvest by USO-31, Fedora-17, and Fasamo (4.1%) (Table 5). All varieties achieve their highest contents of palmitic acid in the 1st or the 3rd harvest, none in the 2nd harvest. On the 3rd harvest higher contents are achieved than in the 1st harvest for the highest yielding varieties.

The content of stearic acid (C18:0) ranges at 1st harvest from 0.1 to 1.5%, at 2nd harvest from 0.2 to 1.9%, and at 3rd harvest from 0.1 to 1.8%. High contents are achieved on all harvest dates depending on the variety (Table 6).

The content of oleic acid (C18:1ω9) ranges from 3.7 to 8.8% at the 1st harvest, from 4.1 to 9.2% at the 2nd harvest, and from 2.1 to 9.1% at the 3rd harvest. Most varieties, including early ripening varieties, have

TABLE 6. Percentage of stearic acid (C18:0) in seed of 20 hemp varieties on three harvest dates.

| **1st harvest (% acid)** (mean = 0.6) | | **2nd harvest (% acid)** (mean = 1.0) | | **3rd harvest (% acid)** (mean = 0.7) | |
|---|---|---|---|---|---|
| **Variety** | **%** | **Variety** | **%** | **Variety** | **%** |
| Kompolti | - | Beniko | .2 | S-206 | .1 |
| Futura-77 | .1 | Secueni | .4 | Futura-75 | .1 |
| Ferimon-12 | .2 | Ferimon-12 | +.6 | Ferimon-12 | .2 |
| Fasamo | .2 | Fasamo | .8 | Futura-77 | .2 |
| USO-31 | .3 | USO-14 | .8 | Epsilon-68 | .2 |
| Futura-75 | .3 | Fedora-17 | .9 | S-204 | .2 |
| Secueni | .3 | Futura-75 | +.9 | USO-11 | .3 |
| Felina-34 | .3 | Felina-32 | .9 | Kompolti | .4 |
| S-204 | .3 | Kompolti | +.9 | Fedora-19 | .5 |
| Fedrina-74 | .3 | USO-11 | .9 | Fedora-17 | .5 |
| Beniko | .3 | Felina-34 | +1.0 | Beniko | +.6 |
| Felina-32 | .3 | Fedora-19 | 1.0 | Secueni | +.9 |
| Epsilon-68 | .4 | S-206 | 1.1 | Felina-34 | 1.0 |
| Irene | .5 | Bialobrezie | 1.1 | Irene | 1.0 |
| Bialobrezie | .7 | USO-31 | 1.1 | Fasamo | +1.1 |
| Fedora-17 | +1.2 | Futura-77 | +1.1 | Fedrina-74 | 1.1 |
| S-206 | +1.3 | S-204 | +1.2 | Bialobrezie | +1.3 |
| USO-14 | 1.3 | Irene | +1.4 | USO-14 | +1.4 |
| USO-11 | +1.4 | Fedrina-74 | +1.8 | USO-31 | +1.4 |
| Fedora-19 | +1.5 | Epsilon-68 | +1.9 | Felina-32 | +1.8 |

+ . . . indicates the harvest date at which the respective variety had the highest content of the fatty acid in relation to other harvest dates of the same variety.

the maximum at the 2nd or the 3rd harvest (Table 7). The variety S-206 increases its acid content from 3.7% at the 1st harvest to 9.1% at the 3rd harvest, while the acid content, e.g., of Futura-77 decreases from 7.3% at the 1st harvest to 2.1% at the 3rd harvest.

The content of linoleic acid (C18:2ω6) ranges from 48.8 to 57.2% at the 1st harvest, from 51.9 to 60.2% at the 2nd harvest, and from 44.8 to 59.7% at the 3rd harvest. Most varieties (13) reach their peak of linoleic acid at the 2nd harvest. Only Epsilon-68, Secueni, Futura-77, and Irene achieve their highest contents at the 3rd harvest (Table 8).

The contents of α-linolenic acid (C18:3ω3) range from 19.2 to 27.9% at the 1st harvest, 18.2 to 25.5% at 2nd harvest, and 18.8 to

TABLE 7. Percentage of oleic acid (C18:1ω9) in seed of 20 hemp varieties on three harvest dates.

| **1st harvest (% acid)** (mean = 5.8) | | **2nd harvest (% acid)** (mean = 7.3) | | **3rd harvest (% acid)** (mean = 5.6) | |
|---|---|---|---|---|---|
| **Variety** | **%** | **Variety** | **%** | **Variety** | **%** |
| S-206 | 3.7 | USO-11 | 4.1 | Futura-77 | 2.1 |
| Irene | 3.9 | Bialobrezie | 4.8 | Futura-75 | 3.5 |
| S-204 | 3.9 | USO-14 | 5.5 | Fedora-19 | 3.9 |
| USO-11 | 4.1 | Fasamo | 6.1 | Fedora-17 | 4.1 |
| Fedora-19 | 4.2 | S-206 | 6.3 | Bialobrezie | 4.1 |
| USO-14 | 4.8 | Kompolti | +6.5 | Kompolti | 5.1 |
| Epsilon-68 | 4.9 | Fedora-17 | +6.7 | Fasamo | 5.3 |
| Bialobrezie | +6.0 | Ferimon-12 | +6.9 | Felina-34 | 5.4 |
| Ferimon-12 | 6.0 | Futura-77 | 7.1 | Ferimon-12 | 5.4 |
| Fasamo | +6.2 | Futura-75 | +7.4 | Fedrina-74 | 5.5 |
| Fedrina-74 | 6.2 | Irene | +7.6 | S-204 | 5.7 |
| Beniko | 6.3 | Felina-32 | 7.9 | USO-11 | +5.7 |
| Secueni | 6.4 | Beniko | +8.0 | Secueni | 5.8 |
| Felina-34 | 6.5 | S-204 | +8.0 | Epsilon-68 | 6.2 |
| Fedora-17 | 6.5 | USO-31 | +8.0 | Irene | 6.4 |
| Futura-75 | 6.6 | Fedrina-74 | +8.8 | Beniko | 6.4 |
| Futura-77 | +7.3 | Secueni | +8.9 | USO-14 | +6.7 |
| USO-31 | 7.5 | Felina-34 | +8.9 | Felina-32 | 7.9 |
| Felina-32 | +8.8 | Fedora-19 | +9.0 | USO-31 | 8.0 |
| | | Epsilon-68 | +9.2 | S-206 | +9.1 |

+ . . . indicates the harvest date at which the respective variety had the highest content of the fatty acid in relation to other harvest dates of the same variety.

27.4% at the 3rd harvest (Table 9). The contents of γ-linolenic acid range between 1.6 and 4.7% at the 1st harvest, 1.8 and 4.0% at the 2nd harvest, and 2.0 and 4.4.% at the 3rd harvest (Table 10).

## *DISCUSSION*

### *Yields of Seeds*

The varieties tested vary considerably in terms of the timing of seed maturity. Seed yields from early-maturing varieties, e.g., Ferimon-12 or Fedora-19, did not generally differ much between harvests, as also ob-

TABLE 8. Percentage of linoleic acid (C18:2ω6) in seed of 20 hemp varieties on three harvest dates.

| **1st harvest (% acid)** (mean = 54.1) | | **2nd harvest (% acid)** (mean = 56.3) | | **3rd harvest (% acid)** (mean = 53.0) | |
|---|---|---|---|---|---|
| **Variety** | **%** | **Variety** | **%** | **Variety** | **%** |
| S-206 | 48.8 | USO-31 | 51.9 | USO-31 | 44.8 |
| Beniko | 51.7 | Epsilon-68 | 52.3 | Ferimon-12 | 47.4 |
| Secueni | 51.9 | Secueni | 54.1 | S-206 | 48.5 |
| Bialobrezie | 52.9 | Fedrina-74 | 54.7 | USO-11 | 50.6 |
| Felina-32 | 53.3 | Beniko | +55.0 | Felina-32 | 50.9 |
| USO-11 | 53.6 | Bialobrezie | +55.4 | USO-14 | 51.4 |
| Epsilon-68 | 53.9 | USO-11 | +56.0 | Fasamo | 51.9 |
| S-204 | 53.9 | Fedora-19 | +56.0 | S-204 | 52.1 |
| Ferimon-12 | 54.0 | Felina-32 | +56.2 | Kompolti | 52.5 |
| Felina-34 | 54.2 | Kompolti | +56.5 | Fedrina-74 | 52.8 |
| USO-31 | +54.2 | Fedora-17 | +56.8 | Fedora-19 | 53.1 |
| Futura-75 | 54.6 | Futura-75 | +56.9 | Beniko | 53.7 |
| Fedora-19 | 54.8 | Irene | 57.1 | Fedora-17 | 54.2 |
| USO-14 | 55.2 | Felina-34 | +57.4 | Bialobrezie | 54.2 |
| Fedora-17 | 55.2 | S-206 | +57.5 | Felina-34 | 55.2 |
| Irene | 55.8 | Futura-77 | 57.9 | Epsilon-68 | +55.9 |
| Fasamo | 56.6 | Fasamo | +58.0 | Futura-75 | 56.2 |
| Fedrina-74 | +56.7 | Ferimon-12 | +58.5 | Secueni | +57.6 |
| Futura-77 | 57.2 | S-204 | +58.6 | Futura-77 | +58.2 |
| | | USO-14 | +60.2 | Irene | +59.7 |

+ . . . indicates the harvest date at which the respective variety had the highest content of the fatty acid in relation to other harvest dates of the same variety.

served by Basetti et al. (1998). The reason might be that the weight of mature seeds, that fall to the ground, is constantly compensated by newly ripening seeds during the final phase of the vegetation period. This was possible due to favorable growing conditions during September and October at the site of the trial.

The later-maturing varieties, on the other hand, all produced a low yield at the first harvest, because most of their seed still had not reached maturity. Their seeds subsequently matured and hardened, such that the yields from late-maturing varieties were much higher by the time of the second harvest. Harvesting in 1999 was done much earlier than usual because of the dry and warm weather conditions in August and September. This also helped the later-maturing varieties to produce good, hard

TABLE 9. Percentage of α-linolenic acid (C18:3ω3) in seed of 20 hemp varieties on three harvest dates.

| **1st harvest (% acid)** (mean = 22.5) | | **2nd harvest (% acid)** (mean = 21.8) | | **3rd harvest (% acid)** (mean = 23.0) | |
|---|---|---|---|---|---|
| **Variety** | **%** | **Variety** | **%** | **Variety** | **%** |
| USO-11 | 19.2 | Felina-34 | 18.2 | Futura-77 | 18.8 |
| Fasamo | 19.8 | Fedrina-74 | 19.0 | Fasamo | 19.3 |
| Fedora-17 | 21.0 | Felina-32 | 19.2 | Felina-32 | 19.6 |
| USO-14 | 21.1 | Irene | 19.7 | Irene | 19.9 |
| USO-31 | 21.1 | Epsilon-68 | 20.5 | Beniko | 21.3 |
| Felina-32 | +21.2 | USO-31 | 21.0 | Fedora-17 | 21.4 |
| Futura-77 | 21.2 | S-204 | 21.2 | Bialobrezie | 21.4 |
| Futura-75 | 21.4 | Beniko | 21.5 | Fedrina-74 | 21.5 |
| S-204 | 21.7 | Ferimon-12 | 21.5 | Epsilon-68 | 22.7 |
| Felina-34 | 22.0 | Fasamo | +21.6 | USO-14 | +23.0 |
| Fedora-19 | 22.2 | Kompolti | 22.0 | Secueni | 23.1 |
| Bialobrezie | 22.5 | Fedora-17 | +22.3 | Futura-75 | +23.4 |
| Fedrina-74 | +22.8 | Futura-77 | +22.4 | Kompolti | +24.0 |
| Epsilon-68 | +23.3 | Fedora-19 | 22.4 | Felina-34 | +24.0 |
| Irene | +23.5 | USO-14 | 22.6 | S-204 | +25.3 |
| Ferimon-12 | 23.6 | Futura-75 | 22.7 | USO-11 | 25.3 |
| Beniko | +24.3 | Secueni | 22.7 | USO-31 | +25.4 |
| S-206 | +27.1 | S-206 | 24.4 | S-206 | 25.8 |
| Secueni | +27.9 | Bialobrezie | +25.5 | Fedora-19 | +27.0 |
| | | USO-11 | +25.5 | Ferimon-12 | +27.4 |

+ . . . indicates the harvest date at which the respective variety had the highest content of the fatty acid in relation to other harvest dates of the same variety.

seeds earlier and at a time when weather conditions were still good. Their yields then dropped at the final harvest. Our observations match those of Basetti et al. (1998), who states that worsening growing conditions in the final stages of the vegetation period lead to higher shedding of ripe seeds. Shedding and losses of seeds may be caused by predation of birds too. In our field experiment this has been observed at rare occasions only, probably due to large hemp fields surrounding the site of the field experiment.

In addition, increases in *Botrytis cinerea* infection between the second and third harvests were greater in the inflorescences of late-maturing varieties, thereby contributing to greater seed shedding in these cases (data not shown here).

TABLE 10. Percentage of γ-linolenic acid (C18:3ω6) in seed of 20 hemp varieties on three harvest dates.

| **1st harvest (% acid)** (mean = 2.9) | | **2nd harvest (% acid)** (mean = 2.6) | | **3rd harvest (% acid)** (mean = 2.8) | |
|---|---|---|---|---|---|
| **Variety** | **%** | **Variety** | **%** | **Variety** | **%** |
| Fedrina-74 | 1.6 | Futura-77 | 1.8 | Fedora-19 | 2.0 |
| Secueni | 1.7 | Bialobrezie | 1.9 | Futura-75 | 2.1 |
| Bialobrezie | 1.8 | Futura-75 | 1.9 | Secueni | +2.2 |
| Felina-34 | 2.2 | Epsilon-68 | 2.2 | S-206 | 2.3 |
| Fedora-19 | 2.3 | S-206 | 2.2 | Fedora-17 | 2.3 |
| Epsilon-68 | 2.3 | Secueni | 2.2 | Kompolti | 2.4 |
| Ferimon-12 | 2.4 | Felina-32 | 2.2 | USO-11 | 2.4 |
| Futura-77 | 2.4 | Irene | 2.4 | Felina-34 | 2.5 |
| Fedora-17 | 2.5 | Kompolti | +2.4 | Epsilon-68 | +2.5 |
| Futura-75 | +2.5 | Ferimon-12 | 2.5 | USO-14 | 2.6 |
| USO-14 | 2.5 | Fasamo | 2.5 | Ferimon-12 | +2.7 |
| Beniko | 2.6 | Fedora-19 | +2.5 | USO-31 | 2.7 |
| S-204 | +3.1 | USO-31 | +2.7 | S-204 | 2.9 |
| USO-11 | 3.3 | USO-14 | +2.7 | Futura-77 | +2.9 |
| Irene | +4.0 | Fedrina-74 | 2.7 | Felina-32 | 3.0 |
| USO-31 | 4.5 | S-204 | 2.8 | Beniko | +3.2 |
| S-206 | +4.5 | Fedora-17 | +3.1 | Irene | 3.5 |
| Fasamo | +4.7 | Beniko | +3.2 | Bialobrezie | +3.9 |
| Felina-32 | +4.7 | Felina-34 | +3.5 | Fedrina-74 | +4.1 |
| | | USO-11 | +4.0 | Fasamo | 4.4 |

+ . . . indicates the harvest date at which the respective variety had the highest content of the fatty acid in relation to other harvest dates of the same variety.

The varieties Ferimon-12, Fedora-19, and Bialobreszie (Table 4) produced high seed yields on all three harvest dates. Ferimon-12 and Fedora-19 were among the three most productive varieties on each date, Bialobreszie always among the five highest-yielding varieties. Felina-32 yielded the most seed of all varieties at the 2nd harvest, S-204 at the 3rd harvest, but neither of these two varieties produced such relatively high yields at the other harvests. If varieties have to be selected we would, under our growing conditions, select those that were at every harvest in the group of the highest yield. All these high yielding varieties should be included in further field trials on seed yields in the study area. As interactions between site and variety are possible, for further research at other sites we suggest continuing work with a wide spectrum of varieties, and over a number of seasons, as our results originate from one year only.

As expected, the late dioecious variety Kompolti reached low yields under the present growing conditions, because of the occurrence of male plants in the crop. Other poor yielding varieties include the early varieties USO-11, USO-14, and USO-31. This was unexpected. The statement that early varieties show high seed yield potential and late varieties show low yield potential (Bòcsa and Karus, 1997; Dipenbröck et al., 1999) can therefore not be confirmed with our data, as also stated by Buttlar von et al. (1995). But the performance of USO-varieties should be tested again. In our trial, USO-varieties were the first to be infested with *Botrytis cinerea* and this might be the reason for the low yields.

### *Contents of Fatty Acids*

Hemp seeds are a good source of the polyunsaturated fatty acids that are of great interest for cosmetic purposes (Anstey et al., 1990; Christin, 1986; Fiocchi et al., 1994; Träger, 1989; Wright and Burton, 1982). This can be confirmed, as all 20 varieties tested show good qualities in their fatty acid composition. All varieties contain fatty acids that are fundamental components of epidermal lipids (Ciba Geigy, 1979; Yang et al., 1995). C18:2ω6 and C18:3ω6 improve the structure of the skin and have a positive effect on dry and rough skin (Nova-Institut, 1998; Leson et al., 1999).

Furthermore, the quantities of these fatty acids in the varieties tested are high, in relation to seeds of other plant species (Mao-Qiang et al., 1993; Deferne and Pate, 1996; Schürer, 1996). In the case of C18:2ω6, which is important for the integrity of the epidermal barrier, and which is integrated into the skin (Mao Qiang et al., 1993; Schürer, 1996), the contents lay above 50% (% of the total of fatty acid contents) in all tested varieties.

The content of C18:3ω3 in the tested varieties (between 20 and 30% of the total fatty acid content) is remarkable. Skin care products with high amounts of C18:3ω3 can be used for patients with topical dermatitis such as neurodermatis and psoriasis. Here hemp oil is a good source in addition to borage oil (21-25% of the total fatty acid content) and evening primrose oil (6-14% of the total fatty acid content) (Anstey et al., 1990; Fiocchi et al., 1994; Wright and Burton, 1982; Deferne and Pate, 1996; Nova-Institut, 1998).

Concerning the contents of fatty acids, we cannot favor nor exclude any variety and any harvest date yet. Further studies should be done on this topic.

## *CONCLUSION*

The identification of varieties and harvest dates favored for cosmetic purposes is a long-term commitment, where sites with different environmental conditions have to be included. The unavailability of a wide range of certified seeds together with the high costs of trials and the subsequent chemical analysis present limitations for these efforts. Nevertheless, our results confirm that hemp is a very good source for fatty acids for skin care and cosmetic use. Therefore, these challenges should be met in future projects that continue testing and processing hemp seed oil into organic skin care products.

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RECEIVED: 29 January 2003
ACCEPTED IN REVISED FORM: 24 November 2003