Comparing Hemp Seed Yields (*Cannabis sativa* L.) of an On-Farm Scientific Field Experiment to an On-Farm Agronomic Evaluation Under Organic Growing Conditions in Lower Austria

Christian R. Vogl
Gunilla Lissek-Wolf
Andreas Surböck

ABSTRACT. Hemp seed yields of the variety Fedora-19 in an on-farm scientific field experiment on small plots and in an on-farm evaluation in 11 hemp fields under practical organic growing conditions in Lower Austria were compared to give a realistic view of the variability of yields. Dry matter seed yields from the on-farm field experiment ranged

Christian R. Vogl is Assistant Professor and Andreas Surböck is Research Assistant, Institute of Organic Farming, University for Natural Resources and Applied Life Sciences, Vienna, Austria.

Gunilla Lissek-Wolf was a graduate student at the Institute of Organic Farming and is now Research Assistant, Research Institute for Organic Farming (FIBL), Berlin, Germany.

Address correspondence to: Christian R. Vogl (E-mail: christian.vogl@boku.ac.at).

The authors thank the farmers who allowed them to enter their fields, and to take samples and measurements. This was not possible without damage to the crop, and therefore the authors especially appreciate their patience and support. All of the study results have been reported back to them. The authors also thank Jürgen Friedel, Michael Harlan Lyman, Cristina Flitner, the anonymous reviewers and the editor for their valuable comments on this paper.

This study was funded by the EC CRAFT-FAIR project 9558.

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

Digital Object Identifier: 10.1300/J237v09n01_05

from 127 to 143 g m^{-2}. Under practical growing conditions, yields ranged from 34 to 151 g m^{-2} in the sample plots. The reported hemp seed yield after combine harvesting, drying, and cleaning was between 324 kg ha^{-1} and 717 kg ha^{-1}. The results of the experiment show that harvesting by hand considerably influences yields. Yields of the manual harvest in sample plots indicate a high correlation with yields harvested by the combine harvester ($R^2 = 0.91$). The commercial yield is 71% of the yields recorded in sample plots in the fields. Our data questions the transfer of results and conclusions drawn from the data of scientific field experiments that employ manual harvest to that of practical circumstances, and support the notion of on-farm research.

KEYWORDS. On-farm research, methodology, experimental design, edge effect, hemp seed, manual harvest

INTRODUCTION

Scientific agricultural research is primarily based on scientific experiments on small plots, at well-known and well-monitored sites at research stations, or on experiments in pots under controlled conditions (e.g., in green houses). The state of the art tool for agricultural research on the performance of crop varieties in Austria, including hemp varieties, is experimenting on small plots in designs that allow for statistical analysis. In Austria, the testing of crop varieties, including hemp varieties, is done through the Federal Program for Testing of Varieties (Staatliche Sortenprüfung) using small plots in randomized blocks or lattices with three to four replications. The size of the small plots varies between 10 and 18 m^2, depending on the species (BMLF, 1999). The form and size of the small plots have significant influence on the experimental error. The growth and productivity of plants situated on the edge of a plot are different from those situated within the plot (Rosselló and Fernández de Gorostiza, 1993). In addition, plants in small plots are handled and cultivated with great care. These limitations are considered in experimental designs, but nevertheless, small plots show yields that are 10-15% above yields under practical growing conditions (BMLF, 1999). Therefore, usually the yield results of varieties are presented in relation (%) to one or more well-known standard varieties (BFL, 1999a;

BFL, 1999b; LAKO, 1999; BMLF, 1999). This practice shall ensure the comparison between new and older varieties.

In many cases, as in that of hemp in Austria, there is no "known standard" which can be used for comparison under domestic growing conditions. In addition, from previous on-farm evaluations of the performance of hemp (Vogl and Hess, 1995) and from scientific literature (Table 1), we know that the variability of hemp yields is high.

In the absence of known standards for the comparison between tested and known varieties, a different experimental design had to be developed. To give farmers an estimate of the variability of yields under practical growing conditions, we combined two approaches for on-farm research.

Scientific experiments under on-farm conditions have been less common in Austria due to their limitations, i.e., less control over the conditions of the experiment and less knowledge on the history and actual status of the site.

Nevertheless, on-farm experiments gained importance during recent decades due to the debate over the appropriateness and value of scientific agricultural research for farmers in diverse and risk prone areas. In tropical and subtropical countries, on-farm experiments have been intensively discussed as a means of addressing the variability of soils, climate and management practices present in the diversity of regions in those countries. Research under these diverse conditions can result in scientific findings of greater practical relevance (Chambers et al., 1998; Chambers, 1999; Lockeretz and Stopes, 2000).

Even in regions with a temperate climate, e.g., in organic farming research in Europe, on-farm experiments are discussed as a means of evaluating the variability of environmental conditions. They cannot be masked and equalized by synthetic fertilizers and pesticides as in con-

TABLE 1. Yields of hemp seed for the variety Fedora-19 according to different sources.

Yields of seeds t ha^{-1}	**Sources**
1.44	Mediavilla, 1995
1.18	Krüger, 1996
1.03	Krüger and Honermeier, 1996
1.10-1.21	Mediavilla et al., 1997
0.31	Buttlar et al., 1997; Buttlar, 1998
1.80	Vogl, 1999

ventional farming (Lindenthal et al., 1996), due to the strict regulation of organic farming and the prohibition of synthetic inputs (Darnhofer and Vogl, 2003). As a consequence, research intending to address, e.g., testing of species or varieties for organic farming, also has to be done under on-farm conditions, as some recommend (Lindenthal et al., 1996; Lockeretz and Stopes, 2000).

On-farm experiments can be done in several ways (Lockeretz and Stopes, 2000). We distinguish here, for the purpose of this paper, between two opposite approaches. There is, on one hand, the agronomic approach that prioritizes classical *scientific on-farm field experiments* with the maximum control of *ceteris paribus* conditions possible. Here the farmer is not a player at all. He just permits the use of his plots for a certain period of time. The experiment here focuses on the response of the variety under controlled conditions of soil and management.

The other approach is not focused on the effects of certain factors under controlled conditions, but under continuously recorded and highly diverse conditions. The interest is placed on the interaction of the observed factor(s) with the various natural, social, or other conditions and especially with the totality of "farmers' practices." This external evaluation of farming practices is done without any control over what farmers do (*on-farm evaluation of farmers' practices and its results*). We do emphasize here that this is not participatory research as we understand the term *participatory*, because even in this second approach farmers are observed and do not take action in the actual planning, or in the other steps of the research. It is an applied scientific approach that combines methods of natural science research and social sciences. The in-depth understanding of the intervening variables can lead to a better understanding of the farming system, and is one prerequisite to modeling, i.e., the prediction of the performance of variables under changing social and natural conditions (Lockeretz and Stopes, 2000).

Our approach was firstly to conduct an on-farm scientific field experiment on small plots, and secondly to carry out an on-farm evaluation in hemp fields under practical growing conditions. The aim of this paper is to compare both, and to give a more realistic view of hemp yields, rather than relying on data that is based only on scientific small plot experiments.

METHODS

Both the site of the on-farm scientific experiment and the fields for the on-farm agronomic evaluation under practical growing conditions were located on organic farms in the north-west of Lower Austria (a region called the *Waldviertel*) at 500 to 600 m above sea level. The climate in this region is generally cool. The long-term mean annual rainfall is 664 mm, and the mean temperature is 7.0°C. In 1999, the amount of rain was lower than the long-term mean, particularly in June and August, and the temperatures were generally above average, particularly in September. Many farmers grew hemp for seed and straw in this region at that time. The recently decreased interest in growing hemp is a result of the lack of appropriate processing facilities for straw.

Scientific On-Farm Experiment

At the experimental site, total rainfall between April 1999 and September 1999 was 322 mm (long-term mean: 385 mm in the growing period), and the average temperature was 15.7°C mm (long-term mean: 13.8°C in the growing period). The soil type was a carbonate free cambisol (Table 2). Management at this farm (Table 3) was typical for the management practices in the region.

TABLE 2. Nutrient content of the soil at the site of the on-farm scientific 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 on-farm scientific 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

The research was carried out at a farm that had been certified as organic since 1993. A randomized block design and small plots (8 m × 3 m; plot area 24 m^2) were used for the testing of 20 hemp varieties. The plots were arranged in four replications. Sowing took place on the 7th of May, with 13 cm between rows and a sowing depth of 3 cm at 20 kg of seed per hectare.

The seeds were harvested by hand on the 20th of September 1999, immediately before the usual time of the field harvest at the hemp plots of the other organic farmers. One square meter of the small plots was harvested from the central rows of each plot. Harvesting involved the removal of the inflorescences only, which were dried for 3 days at 40°C in open paper bags in a drying room, especially built and equipped for drying of plant material, of about 20 m^3. Every day the bags and the inflorescences in the bags were moved to ensure access of the heated air to all inflorescences. Immediately after drying the inflorescences were threshed with a small-plot combine.

On-Farm Agronomic Evaluation Under Practical Growing Conditions

A list of organic farmers growing hemp in the region near the experimental site (max. distance: 20 km) was obtained and 11 individual farms were then randomly selected for the purposes of the on-farm agronomic evaluation. Agronomic on-farm evaluation under practical growing conditions was carried out using 1 m^2 randomized sampling plots, with at least four replications, in hemp fields on the selected farms. Soil nutrient content (Table 4) and several other agronomic attributes (see summarized selection of the data in Table 5) were recorded in interviews with farmers. The cultivation methods on the hemp fields were similar, particularly with respect to sowing, where all farmers used the same variety (Fedora 19) at a seed rate of 20 kg ha^{-1} and a seeding depth of 3 cm. Row widths were all around 12 cm, with one exception, where the farmer chose a row width of 25 cm. All fields were sown in the last 10 days of April (Table 5) and hemp started to flower in the 2nd week of July.

The weather patterns at the on-farm sites were similar to those at the scientific experiment. The characteristics and nutrient content of the soils in each of the fields are given in Table 4. The soils were all light, and in most cases were dry and highly permeable. Soil pH varied from 5.2 to 6.5. On September 15th, the inflorescences of the seed-carrying plants were cut by hand, dried and yields measured. These activities

TABLE 4. Soil type and nutrient content in the fields evaluated in the on-farm evaluation.

Field	Certified organic since	Soil Texture	Soil type	pH	P_2O_5 (mg 100 g^{-1})	K_2O (mg 100 g^{-1})	N_{in} (kg ha^{-1}) June	N_{in} (kg ha^{-1}) September
		0 to 25 cm soil depth					0 to 75 cm soil depth	
A	1994	L-sL	Cambisol	5.6	7	13	108	33
B	1995	sL	Stagnosol	5.7	8	14	42	20
C	1995	lS	Cambisol	6.0	25	8	23	19
D	1995	lS	Cambisol	6.2	14	19	27	19
E	1992	sL-lS	Cambisol	5.3	4	13	27	20
F	1989	sL	Cambisol	6.4	16	14	35	18
G	1995	sL	Cambisol	6.5	22	15	27	22
H	1995	sL	Cambisol	5.4	8	14	30	31
I	1993	sL-lS	Cambisol	5.7	12	8	35	16
J	1995	L	Cambisol	6.0	10	13	38	16
K	1995	sL	Stagnosol	5.2	9	11	19	12

L: loam; sL: sandy loam; lS: loamy sand

TABLE 5. Usual practices for the cultivation of hemp by the farmers on their fields used in the on-farm evaluation (cultivation of hemp in 1999).

Crops 1998	Barley, rye, red clover (+ grasses), oats-barley-mix or rye-barley-mix
Fertilization 1998	Manure (10-18 t/ha), Compost (5-16 t/ha) or Slurry: ±12 m^3/ha
Soil management 1998	Plow + harrow or cultivator
Catch crop 1998/99	If so: California bluebell, plus, e.g., Narbonne vetch, buckwheat or pea
Turning the soil	Usually spring 1999
Fertilization Spring 1999	Manure (10-27 t/ha), Compost (8-16 t/ha) or Slurry (10 m^3/ha)
Plowing up 1999	Plow + Harrow
Seed bed preparation	Seed bed combination or curry-comb
Sowing	Between 20 and 30 of April
Distance between rows (cm)	12.5
Seeds per ha (kg)	20
Cultivar	Fedora-19

were done as in the scientific on-farm experiment. In addition, harvest by combine harvester for all fields was realized between 17th and 21st of September. Yields immediately after harvest (fresh) and after drying and cleaning were recorded.

One-way analysis of variance and the Student-Newman-Keuls-Test were carried out with the program SPSS (version 7.5.2) for Windows

(SPSS Inc., 1997). The influence of the factor farm was considered significant at $P \leq 0.05$.

RESULTS

Dry matter seed yields of Fedora-19 from the manual harvest at the on-farm field experiment ranged from 127 to 143 g m^{-2}. In the sample plots under practical growing conditions, yields from manual harvest ranged from 34 to 151 g m^{-2} (mean: 72 g m^{-2}). The influence of the factor "farm" is significant with the highest yield at farm A (Table 6).

The reported hemp seed yields immediately after combine harvesting ranged from 445 to 1,071 kg ha^{-1}, and after drying and cleaning from 324 kg ha^{-1} to 717 kg ha^{-1}. The moisture content of the hemp seeds ranged from 17% to 22% at harvest time, and the final weight of seeds to be sold fell, on average, 30% below the reported yield after the combine harvest (Table 7).

DISCUSSION AND CONCLUSION

Fedora-19 reached the highest mean yield in the field experiment, followed by the manual harvest at the sample plots on fields and fol-

TABLE 6. Yields in g m^{-2}, standard deviation, and indication of significant differences according to the results of the Students-Newman-Keuls Test of the hemp variety Fedora-19 at different organic farms surveyed in sample plots harvested by hand and grown under practical conditions.

Farm	**Yields** (g m^{-2})	**Standard deviation**	**Significant differences***
K	33.7	11.8	a
C	35.0	1.7	a
G	50.6	10.3	ab
B	59.2	26.6	ab
D	62.2	10.9	ab
I	66.7	30.0	ab
H	78.1	25.6	ab
F	79.8	18.4	ab
J	87.0	40.5	ab
E	89.7	40.2	ab
A	151.4	19.4	c

*Farms indicated with different letters show significant differences in their yields for the factor "farm" at a level of $P < 0.05$.

TABLE 7. Hemp growing area and seed yields of the variety Fedora-19 at organic farms as indicated by the harvest report of the harvester after combine harvest, and after drying and cleaning.

Farm Code	Area	Yield before drying and cleaning	Humidity	Loss 1*	Loss 2**	Losses 1+ 2	Yield after drying and cleaning
Unit	ha	kg ha^{-1}	%	kg ha^{-1}	kg ha^{-1}	%	kg ha^{-1}
A	2.4	912	17.2	126	94	24	692
B	3.6	603	19.9	112	58	28	433
C	1.1	445	19.4	79	42	19	324
D	1.4	643	21.7	144	67	33	432
E	1.0	660	21.7	148	62	32	450
F	4.2	1071	22.3	253	101	33	717
G	1.8	589	18.3	92	53	25	444
H	6.0	688	21.9	151	113	38	424
I	1.8	472	19.0	80	50	28	342
J	7.0	524	20.5	94	56	29	374
K	3.6	602	19.9	112	58	28	432

*Weight loss after drying
**Broken or empty seeds, weedy seeds, stones

lowed by combine harvest. The yields of the field experiment and of the manual harvest at the sample plots confirm the data of other authors, who report seed yields of Fedora-19 well above 1 t ha^{-1} (Table 1) and who recommend Fedora-19 as a valuable variety to produce seed (Bócsa and Karus, 1997).

Results show the considerable influence of harvesting by hand, as also discussed by Mediavilla et al. (1997), i.e., of combine harvest vice versa. The manual harvest in the sample plots predicts the harvest by combine harvester (Figure 1; Pearson correlation significant at $P < 0.05$; $R^2 = 0.91$). The amount of seed reported as having commercial quality (after combine harvest, dried and cleaned) is 71% of the yield recorded in the sample plots (Table 8).

According to our observations, our manual harvest was done with great care and therefore with few losses. Combine harvest led to the shedding of seed prior to harvest and, indeed, losses, i.e., seeds that had fallen to the ground, were observed. Combine harvesters used in the region are ordinary harvesters with some adaptation, but not specialized equipment for hemp seed. Our data shows that under these growing and harvesting conditions, our on-farm yields with combine harvest are lower than most of the yields reported in scientific literature (Table 8) and that the variability of yields between farms is high. This confirms

FIGURE 1. Scatter plot for yields of hemp seed (R^2 = 0.91) harvested with combine harvester (x-axis) and harvested manually in sample plots under practical growing conditions (y-axis)

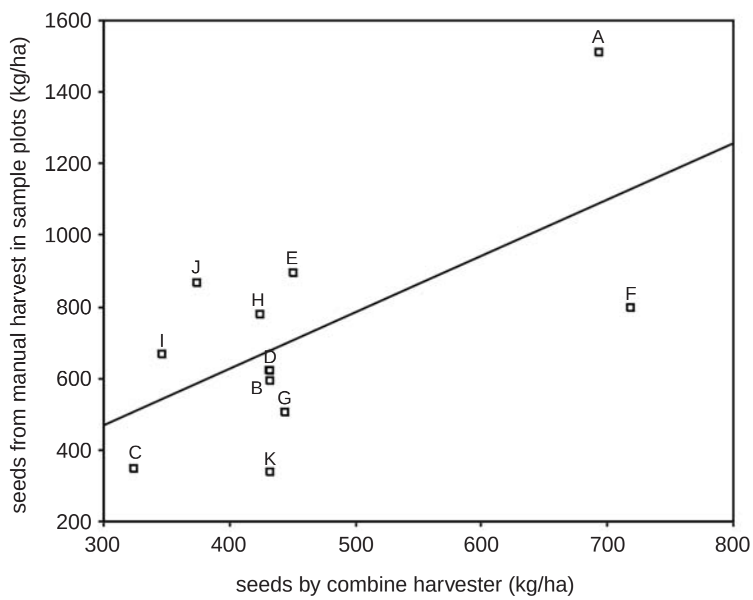


TABLE 8. Dry matter yield of seeds of the hemp variety Fedora-19.

Parameter	Range of yields	Mean of yields
A. Literature (kg.ha^{-1}) (Table 1)	310-1,800	-
B. Scientific on-farm field experiment (kg.ha^{-1})	1,267-1,435	-
C. Sample plots under practical growing conditions (kg.ha^{-1})	337-1,514	720
D. Combine harvest fresh at fields C (kg.ha^{-1})	445-1,071	655
E. Combine harvest after drying and cleaning (kg.ha^{-1})	324-717	460
		Percentage
F. E (for every farm) in % of C (for every farm), then mean; %	-	71

reports on the possibility of low hemp yields of Vogl and Hess (1995), Mediavilla et al. (1995), Mediavilla et al. (1997), and Buttlar et al. (1997).

Our data questions the transfer of results and the respective conclusions drawn from data of scientific field experiments on manually harvested tested varieties to practical circumstances in cases where standard varieties are not known locally and cannot be used for comparison. In these cases we support Lockeretz and Stopes's notion (2000) in favor of on-farm research:

- research to be conducted under a wider range of growing conditions.
- research to more realistically reflect the circumstances of working farms.
- researchers to benefit from farmers' expert knowledge of a farming system, and to allow the farmer's management ability and preferences to be a part of the study.
- researchers access to an early indication of whether a new variety is likely to be attractive to farmers.

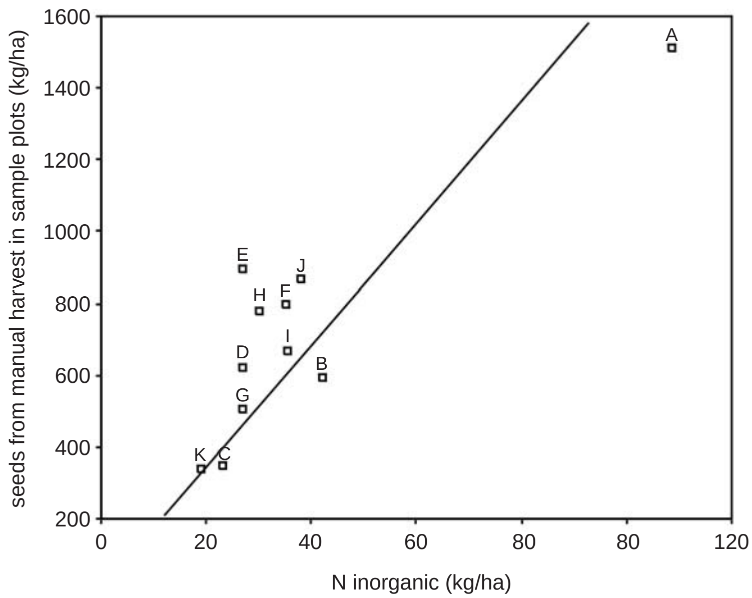
To ensure practicability, on-farm research as demanded above is not enough. One does not have to do only scientific on-farm experiments, but also to record and evaluate the response of the system under practical growing conditions without exercising control over the farmers' management.

On-farm researchers often avoid leaving the management of an experiment to the farmers, fearing that it introduces too much variability, and thereby makes it impossible to analyze the results and draw solid conclusions. We maintain, however, that the way farmers manage their fields, with all of the resulting variation among farmers, is an essential part of the real farming condition. Agronomic on-farm evaluation conducted under maximum farmer management is the only valid way of testing technology, provided the farmers treat the experiment fields in the same way as they treat their other fields. Variability should be analyzed and explained, rather than artificially controlled by the researchers (Lockertz and Stopes, 2000; Mutsaers et al., 1997).

One explanation for the variability of yields is the available N at the plots (Figure 2). The correlation between yields of manual harvest, and available N at sowing time is significant at a level of $P < 0.01$ ($R^2 = 0.92$). We believe that the combination of scientific on-farm experiments, and on-farm evaluations under practical growing conditions as presented here, are a good starting point to address the variability of yields of new varieties. To analyze the underlying factors for variability, a multi-factorial model would have to be established. This is difficult to achieve, as the number of intervening factors is high: nevertheless, it is a challenge for future work.

We present our approach here to encourage scientific methodological discussion on the topic. We want to encourage further development of on-farm research methods in favor of improved understanding of both the variability of hemp yields and of the underlying variables.

FIGURE 2. Scatter plot for hemp seed yields (R^2 = 0.92) harvested manually (y-axis) and inorganic N (kg/ha) at sowing time (x-axis)



REFERENCES

BFL, 1999a. Wintergetreide–Wertprüfung 1998. Leaflets of the Federal Agency for Agriculture No. 16, Vienna, Austria.

BFL, 1999b. Ölsaaten, Wertprüfung 1998, Wertprüfung 1997. Leaflets of the Federal Agency for Agriculture No. 15, Vienna, Austria.

BMLF, 1999. Ergebnisse aus Feldversuchen 1999. Report No. 74. Federal Agency for Agrobiology, Linz, Austria.

Bócsa I. and M. Karus, 1997. Der Hanfanbau: Botanik, Sorten, Anbau und Ernte. C. F. Müller, Heidelberg, Germany.

Buttlar H.-B., 1998. Personal information.

Buttlar H.-B., F. Höppner, U. Menge-Hartmann, K. Scheffer and B. Mispelhorn, 1997. Europäische Hanfsorten im Standortvergleich zweier deutscher Anbauregionen. In: Biorohstoff Hanf 97, Proceedings for the Symposium "Biorohstoff Hanf," Frankfurt an Main, Feb. 27-March 02. Nova-Institut (eds.), Hürth, Germany.

Chambers, R., 1999. Rural Development. Putting the Last First. Pearson Education Longman Ltd., Essex, UK.

Chambers, R., A. Pacey and L.A. Thrupp, eds., 1998. Farmer First. Farmer Innovation and Agricultural Research. Intermediate Technology Publications, London, UK.

Darnhofer, I. and C.R. Vogl, 2003. Certification and accreditation of the organics in Austria: Implementation, strengths and weaknesses. In: Lockeretz, W. (editor). Ecolabels and the Greening of the Food Market. Friedman School of Nutrition Science and Policy, Tufts University, Boston, Massachusetts, USA.

Krüger, K., 1996. Faserhanf: Einfluß der Sorte auf das Ertragsverhalten. Pages 128-129 in: Jahresbericht der Lehr- und Versuchsanstalt für Integrierten Pflanzenbau e. V., Güterfelde, Germany.

Krüger, K., and B. Honermeier, 1996. Faserhanf: Pflanzenbaulicher Ringversuch Faserhanf. Pages 130-131 in: Jahresbericht der Lehr- und Versuchsanstalt für Integrierten Pflanzenbau e. V., Güterfelde, Germany.

LAKO, 1999. Versuchsergebnisse 1998, Mais, Öl- und Eiweißpflanzen. Landwirtschaftliche Koordinationsstelle für Bildung und Forschung (ed.), Tulln, Austria.

Lindenthal, T., C.R. Vogl and J. Hess, 1996. Forschung im Ökologischen Landbau. Integrale Schwerpunktthemen und Methodikkriterien. Förderungsdienst 2c/1996, Viena, Austria.

Lockeretz, W. and C. Stopes, 2000. Issues in on-farm research. Pages 3-8 in: Krell, R. and R. Zanoli (editors). Research Methodologies in Organic Farming: On-Farm Participatory Research. REU Technical Series No. 63. Food and Agriculture Organization of the United Nations, Rome, Italy.

Mediavilla, V., E. Spiess, B. Zürcher, P. Bassetti, M. Konermann, J. Spahr, S. Christen, E. Moismann and P. Aeby, 1997. Erfahrungen aus dem Hanfanbau 1996–Preliminary report. In: Biorohstoff Hanf 97, Proceedings for the Symposium "Biorohstoff Hanf," Frankfurt an Main, Feb. 27-March 02. Nova-Institut (eds.), Hürth, Germany.

Mediavilla, V., O. Pittet, P. Bassetti, E. Mosimann, R. Brenneisen and I. Slembrouck, 1995. Erste Resultate aus dem versuchsweisen Anbau von Hanf in der Schweiz. In: Biorohstoff Hanf 95, Proceedings for the Symposium "Biorohstoff Hanf," Frankfurt an Main, March 2-5. Nova-Institut (eds.), Hürth, Germany.

Mediavilla, V., 1995. Hanf 1994. Internal Report of: Eidgenössischen Forschungsanstalt für Landwirtschaftlichen Pflanzenbau Zürich-Reckenholz, Switzerland.

Mutsaers, J.J.W., G.K. Weber, P. Walker and N.M. Fisher, 1997. A Field Guide for On-Farm Experimentation. IITA/CTA/ISNAR, Ibadan, Nigeria.

Rosselló, J.M.E. and M. Fernández de Gorostiza, 1993. Technical guidelines for field variety trials. FAO (ed.), Plant Production and Protection Paper No. 75, Food and Agriculture Organization, Rome, Italy.

Vogl, C.R. and J. Hess, 1995. Hemp growing and research 1995 in Austria. J. Int. Hemp Assoc. 2 (2): 98-100.

Vogl, C.R. and J. Hess, 1999. Organic Farming in Austria. American J. Alt. Agric. 14(3): 137-143.

Vogl, C.R., 1999. Ertragsleistung und Nährstoffabfuhr von Hanf (*Cannabis sativa* L.) und ihre Beeinflussung durch Anbaumaßnahmen unter den Bedingungen des Ökologischen Landbaus in Niederösterreich. Doctoral-Thesis, University for Natural Resources and Applied Life Sciences, Vienna, Austria.

RECEIVED: 7 February 2003
ACCEPTED IN REVISED FORM: 28 November 2003