REVIEW OF CROP PRODUCTION AND WEED CONTROL: STATE OF ARTS AND OUTLOOK

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I Introduction

Survey based on ENOF database

About 130 documents related to the optional terms given above as keywords, were found in the ENOF database. Most of the contributions came from Northern European countries than from countries in Southern Europe confirming the results given in the Chapter dealing with crop protection. Since projects found in the database do not fully cover the information available on research available for the topic of crop production and weed control in Europe, the following contribution is extended by information gained from other sources and sub-coordinator's current knowledge. Selfevidently, interactions exist with topics mentioned as well in other White Book chapters underlining the holistic approach of Organic Agriculture.

Oriented on the research programmes under way the items were differentiated in seven sub-chapters: 1. crop rotation, precrop effects and nutrient management 2. strip cropping 3. product quality 4. vegetable growing 5. breeding 6. biodynamic preparations and 7. weed control. The number of hits found in ENOF's data base related to the keyword mentioned in subchapter's headlines is given in brackets.

Introduction: Aims and principles of Organic Agriculture

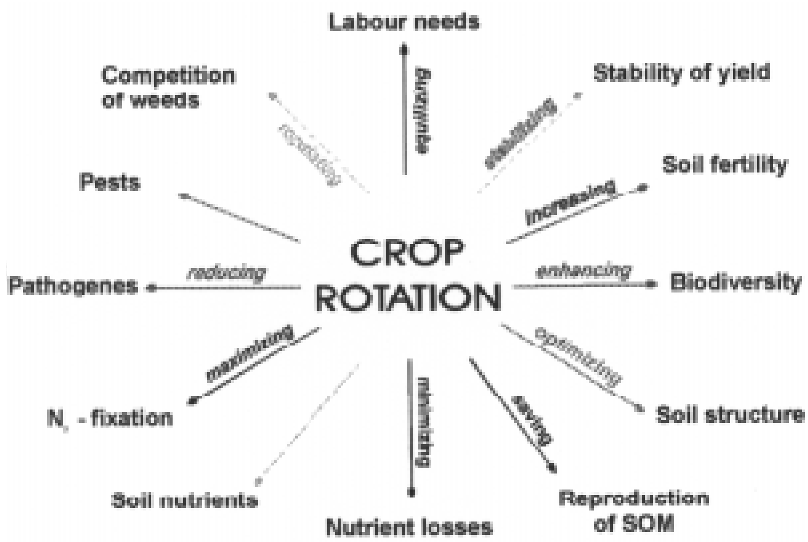
Organic Agriculture pursues its mission running an *organ*isational principle: to organise and manage a mixed farm within a nearly closed system, an *organ*ism alike (Köpke, 1995). Since site conditions are individual properties by definition, a farm can be conceived as an individual entity (Koepf, 1981). In comparison to mainstream agriculture, organic agriculture depends more on specific site conditions and is therefore forced to combine the best site-adapted elements to a holistic approach (Köpke, 1999a). Under central European conditions and humid temperate climate, organic agriculture's relationship within environmental quality is enhanced by a mix of crop and life stock farming that creates diversified production systems (Baars, 1998/99; Köpke, 1999a).

II Main Areas of research

1. Crop rotation (68), precrop effects (30) and nutrient management (60)

Consequently agronomic strategies are based on the cornerstone of agronomy, the design of an optimal site-adapted crop rotation. In Organic Agriculture optimal rotation has to fulfil several functions (Table 1). Diversification of crop rotation homogenises the labour demand in the farm. It stabilises the yields, it regulates weed competition, it controls pests and reduces pathogens. Optimal rotation has to optimise the soil structure, it has to increase soil fertility saving the reproduction of soil organic matter maximising nitrogen fixation, mobilising other nutrients from soil and minimising nutrient losses. Most of these aspects are directly related to stability of yields. No wonder that during the last decades must research activities in Organic Agriculture were oriented on crop rotation and nutrient management. These topics did receive special attention in concerted action AIR3-CT94-1940 (Fertilization Systems in Organic Agriculture, FERSY), too.

Table 1. Functions of an optimal site-oriented crop rotation



In relation to nutrient management in contrast to conventional agriculture, Organic Agriculture has to deal with scarcity of nutrients. From this point of view *management* has to be considered as the *optimised combination of resources* that are restricted (nitrogen) (several hits found in database for Aberdeen, U. K., Fargnières, France, Bonn, Germany, Wageningen, Netherlands) or have to be unlocked by achieving the optimised utilisation (e.g. potassium and phosphorus via increased rooting density and efficiency of nutrient absorption (hits to Wageningen, Netherlands, Bonn, Germany, Partala, Finland (mycorrhizal fungal communities)). Nutrient management can therefore be defined as a systematic target –oriented organisation of nutrient flows (Köpke, 1995). The holistic approach under the aspects of nutrient management in practice means: Nearly closed cycles of nutrients and organic matter within the farm. Mainstreams of nutrient flows are fixed in the long term by organising and optimising the site adapted optimal crop rotation (Köpke, 1998; Watson *et al*., 1998).

Strategies making the nitrogen in the system internally available via N_2-fixation can also be based on basic research performed by scientists not primarily oriented on Organic Agriculture. A broad spectrum of publications dealing with this subject exists. Most research projects which are oriented on Organic Agriculture focused on fodder legumes in pure stands or grown in combination with grasses (e.g. Høgh-Jensen, 1996; Høgh-Jensen & Schjoerring, 1996; Schmidtke, 1997). Nearly all institutions which delivered projects to ENOF´s database do run experiments oriented on this topic having several intersections to the research areas reported in the chapters of this White Book (hits on research oriented on sustainable ley-arable farming systems were found: Aberdeen, U.K.; Partala, Finland; Müncheberg, Germany; Brussels, Belgium; Bonn, Germany).

Only few field experiments were oriented on grain legumes such as faba beans, peas or lupines. During the last two decades different approaches to estimate the amount of symbiotically fixed nitrogen without using sophisticated methodologies have been developed. Although species used for nitrogen fixation are quite different all over Europe, a general relationship can be used. In pulses the amount of symbiotically fixed nitrogen is closely correlated to grain yield and the amount of N in grains (Hauser, 1987, 1992; Köpke, 1987/1996). The amount of N-fixed can therefore be derived from the amount of grains produced. Highest amounts of N-fixed can be achieved by selecting those species which are best adapted to given site conditions and by further selection of the highest yielding variety within the highest yielding species. Farmers ought to decide on an individual site basis whether they may expect higher yields from faba beans, peas, lupines, chick peas, lens etc.. All other agronomic strategies which can increase grain yields of pulses will simultaneously further increase nitrogen fixation (Köpke, 1995).

Similar strategies were developed for fodder legumes. Dinitrogenfixation can be maximised by selecting those species and cultivars which are best adapted to given site conditions. Clear relationships between dry matter yield and nitrogen fixation in fodder legumes exists. The higher the percentage of clover in grass/clover mixtures and the yield per cut in those stands, the higher the amount of symbiotically fixed nitrogen (Boller, 1988). Meanwhile coefficients and charts exist from which the amount of nitrogen which is symbiotically fixed by pulses or fodder legumes can be estimated based either on mean nitrogen content of grain yield or in the case of grass/clover mixtures by estimating or measuring the amount of dry matter yield produced and the share of clover in the yield mass.

Positive precrop effects are mainly determined by available nitrogen to following crops. This nitrogen must not be derived from legume residues but can be soil-borne N as a function of the soil milieu formed by the legumes (e.g. Huber, 1988; Köpke, 1987/96). Precrop effects were quantified for faba beans up to 100 kg N/ha fertiliser-nitrogen-equivalence. In grass/clover mixtures N-budget is often calculated as negative, but optimised soil structure can enhance growth of following crop. Hence, precrop effect is primarily driven by the soil structure status and its further dynamics which are not fully understood.

Beside the aspect to maximise nitrogen fixation nutrient management has to focus on keeping the nitrogen potentially available in the long term via optimised sink to source relationships. Beside directly applied farm produced manure and composts (Piorr, 1992; Bachinger, 1995a, b; Stein-Bachinger, 1996,) optimisation of nutrient flows is regulated by the amount of nitrogen fixed by legumes and via adequate sinks for nitrogen in following non-leguminous crops. Residual nitrogen, i.e. nitrate in the liquid phase, has to be minimised to avoid nitrate losses via leaching during periods where no plant sinks can act.

By selecting the appropriate site specific strategy, an efficient use of N-fixed and soil borne N is ensured by sinks of following or undersown non-legumes (Köpke, 1996). Legumes leave reasonable high amounts of nitrate in the soil after harvest. These amounts of rest N are suspected to be leached during winter and early spring and to get lost from the farming system in the liquid phase. It's quite obvious that this effect is a function of weather conditions during winter and effects of soil milieu, i. e. mobilisation or immobilisation conditions modifying the nitrogen based precrop effect of pulses of fodder crops which is potentially high but can not be predicted precisely in terms of plant available nitrogen and its effect on yield on the long term.

Consequently some research projects do report on strategies to hinder nutrients to disappear out of the farm based on:

–contra movement (liquid phase: especially nitrogen; in some cases on light soils potassium and phosphorus, too).

–retardation (solid phase: erosion control, mulch cover), or

–fixation (hindering gaseous losses by using the absorption complex e. g. NH_3 emission from farmyard or compost heaps, respectively).

In the liquid phase oriented on nitrate, downward flow has to be hindered by creating sinks, for instance via efficient nitrogen uptake by growing plants. Leaching is avoided by orienting vertical downward flow vertically upward (contra movement). Accumulation of soil nitrate under pulse crops is a function of the relatively low rooting-density of the legumes and the heterogeneous root-distribution. Accumulation of soil nitrate can be avoided via narrow row distances, inter-cropping with non-legumes or undersown brassicas due to a more homogeneous distribution and a more homogeneous uptake of soil nitrate as a function of the rooting pattern (Justus & Köpke 1995; Justus, 1996).

Meanwhile these different strategies to avoid nitrate losses and to optimise precrop effects of pulses can be differentiated oriented on the given site conditions. On soils having a high release of soil borne nitrogen intercrops or weeds can reduce aphids in beans driven by the amount of nitrogen taken up by the legumes (one example underlining that pests [and diseases] can be regarded as a function of unbalanced plant nutrition, Patriquin *et al*., 1988; Justus, 1996). On these soils non-legumes are used as intercrops. Concepts to reduce nitrate losses when growing grass/clover mixtures in humid climate have to focus on postharvest and postploughing conditions. Transfer of symbiotically fixed nitrogen to following crops after ploughing grass/clover mixtures can be optimised by minimising prewinter mineralisation, in particular by:

–proper timing of ploughing – for example delaying the primary cultivation of grass/clover in autumn; and/or

–reducing tillage intensity (deapth, frequency), while still maintaining the standard crop rotation (wheat following grass/clover); or

–changing the crop rotation using catch crops acting as nitrate sinks following grass/clover mixture to fix pre winter mineralised nitrogen followed by summer crops; or

–cultivating main crops that show a high nitrogen uptake before winter (i. g. rapeseed) (Hess, 1989).

The above mentioned strategies are elements of recently published comprehensive studies on Organic Agriculture in water catchment areas (Haas *et al*., 1998; Agöl-Bund, 1997). One further hit in the database on water quality in a water protection area was found for Leipzig, Germany.

Looking on non-legumes as following crops efficiency of nutrient uptake is of greatest interest. Under this aspect optimal rooting systems consist of a high rooting-density of fine, young and active roots having higher nutrient uptake especially K and P when compared to rooting systems consisting of the same root mass invested in thicker roots (Claasen, 1994; Köpke, 1994). It is quite clear that the soil volume is better influenced by the rhizosphere of the first case mentioned.

Optimised crop rotation performed in mixed farm systems with farmyard of different rottening stage supplied show increased soil fertility. Meanwhile a broad spectrum of parameters characterising soil fertility, soil microbial biomass and activities is available. (Several contributions on theses topics see in Mäder & Raupp, 1995). To study the effects of organic farming systems for developing sustainable soil fertility, long term effects have to be evaluated. Funding of long-term field experiments like the DOC trial in Therwil, Switzerland (Alföldi *et al.*, 1995), the long-term trial in Darmstadt, Germany (Raupp, 1995) and a long-term trial performed in Sweden (Granstedt, 1995) is urgently recommended. Some other long term field experiments do exist but might be given up in the next future due to limited funding resources (e.g. systems – field trial in Göttingen, Germany). Important information that might be gained from these experiments especially oriented on soil physical, soil, microbial and biochemical parameters is feared to be lost.

A joined project focussing on organic matter dynamics and N-mineralization in organic farming systems (University Wageningen, Luis Bolk Insitute, Flower Bulb Institute, Research Station for arable farming in field production of vegetables, Netherlands) should be brought into interaction with those researchers running the above mentioned long term experiments.

2. Strip-cropping (2)

In mixed farms soil fertility is maintained and extended beside growing of fodder crops by using predominantly farm produced manures and composts. These tools are not available in stockless farms. Green fallows consisting of grass and clover can be used in set-aside programmes of the EC for the transition to Organic Farming – a chapter, a whole ENOF-workshop dealt with (Isart & Llerena, 1996). Amounts of up to 275 kg N/ha have been accumulated with grass/red clover or lucerne mixtures with just two cuts (Dreesmann, 1993; Dreesmann & Köpke, 1990). Since the shoot mass of green fallows cannot be harvested, mineralisation of green fallow residues produce high soil nitrate contents under following crops. A considerable amount of this nitrate can be suspected to be leached in rainy summers. Beside the above mentioned grass/clover strategies, management of green fallow has to pay special attention either to the competition of stands in order to control the source (N supply by reducing the percentage of clover) or by using grass/clover cuts for manuring and soil covering in strip-cropping cereal stands. Strip-cropping of spring wheat where residues of grass/clover are used as mulch for weed control and N source gave higher yields and protein contents of grains and therefore higher baking quality by avoiding lodging due to thicker and shorter culms as a function of higher number of margin rows when sown in east-west direction (Schulz-Marquardt *et al*., 1994, 1995). This procedure ought to be legalised as it might be a true efficient way to produce organic cereals which do not pollute ground water with an «untimely» mineralised N outside the growing season. A similar procedure of soil fertility management can be used in vegetable production where grass/clover mulch layers beside acting as an N-source can control weeds efficiently. Modifications such as bi-cropping systems (Clements & Donaldson, 1997, Clements et al. 1997), or double row – seeding of wheat into grass/clover stands can be run successfully under special site conditions where sufficient precipitation can fulfill water uptake needs of the crops combined.

Strip cropping systems are considered to be suitable for stockless arable farms but not yet used in projects oriented on these farm types (crop rotation project, Witzenhausen, Germany).

One hit was found in the database concerning cereal/clover intercropping and the sanitary effect on cereal diseases (Reading, U. K.) confirming results of Weber *et al*. (1994, 1995). Links exist to a set-aside management project announced by Godden (Brussels, Belgium).

3. Product quality (55)

At least 11 % protein content of wheat grains are regarded as necessary for sufficient baking quality. Positive precrop effects of nitrogen fixing precrops cannot fulfill these aims with confidence. Use of liquid manure applied to growing *cereal* stands were proved by several authors to increase grain nitrogen content and *baking quality* efficiently. On the other hand relationship to *gluten quality* as a function of cultivars and manuring has not been deeply investigated. Moreover, recent results have shown that some varieties can bring high baking volume with protein content lower than 11 % (Wirries & Büning-Pfaue, 1995; Wirries, 1998).

Regarding *whole meal products* further investigations are proposed to be carried out whether the current baking technology developed for flour can be improved. Regarding baking quality modified or new parameters have to extend the spectrum of parameters that fit to whole meal processing.

A joined project is run by the Swedish Agriculture University in Uppsala together with the Czech University of Agriculture (Prague, Czech Republic) comparing product quality from different farming systems and suitable varieties chosen for malting and baking purposes. A project located in Gembloux (Belgium) is focussing the production of high baking quality of wheat in Organic Farming, having links to some other Belgium researchers.

Meanwhile recommendations were given for high quality wheat varieties. Gluten of different wheat qualities in Organic Agriculture is analysed by DSC. Results will be compared with those of the quantitative determination of high-molecular-weight-subunits of reduced gluten by RP-HPLC, of force/stretch-diagrams of the complete gluten and those of other well known methods. This project is run bound into the researcher group «Optimising strategies in Organic Agriculture», OSIOL, (DFG-project, Bonn, Germany) aiming the prediction of baking quality on the analysed flours.

One hit was found concerning development of product quality in Finish Organic Agriculture performed in cooperation with the Swedish University of Agricultural science.

From the concerted action FERSY one task for further research in *potatoes* was described as follows: Effects of manuring (and other cultivation factors on histological parameters like tissue strength and skin stability) should be investigated with regard to effective analytical methods, physiological background of the parameters and the significance for crop production and nutrition. Shelf-life of potatoes including a broad spectrum of parameters including degradation tests was investigated by the researcher group OSIOL (Bonn, Germany). Similar analysis has been performed in Czechoslovakia covering analysis of dry matter, starch, nitrate, ascorbic acid, glucoalcaloids, sensoric analysis and shelf life. Links exist to laboratories in Germany and Vienna, Austria.

Most of these parameters characterising product quality are necessary to be analysed in several other vegetables produced as baby food or for adults nutrition. Further efforts should be followed in evaluating so called «picture-forming» methods (sensitive cristallization, circular chromatography and «Steigbilder» or capillary-dynamolysis). Product samples of different origin or which were derived from field experiments with different treatments and which were put into codes were assigned with great accuracy (Alföldi *et al*., 1996, further research on quality see: Raupp (Ed.) 1996). «Picture-forming» methods should be investigated and developed more intensively with respect to characterise product quality better.

4. Vegetable production (15)

Demand for organically produced vegetables in industrialised European countries is high. Highly specialised vegetable producers can fulfil needs of several leafy crops with short vegetation periods and fast development and showing high demand for nutrients only by purchasing considerable amounts of organic manure from outside the farm. Cooperation with other farms e.g. livestock producers having surplus of organic manure is necessary. A tool to optimise organic farming might be the so called eco-balance or life-cycle-assessment (LCA) by which imbalances can be analysed and compensated by cooperating farms also under the aspect of efficient nutrient flows (Köpke & Geier, 1998/99).

Conditions for vegetable production in mixed farms can be described as follows: Sustainable soil fertility is mainly based on optimal and increased production of soil organic matter. Self reliance regarding humus production is based on the cultivation of crops producing high amounts of root- and shoot-residues and the application of farmyard manure. Calculations to quantify reproduction of soil organic matter which have been developed in the former GDR (Asmus, 1992; Kundler *et al*., 1981) and are oriented on farmyard manure as the reference can be performed by using available software (Hülsbergen & Gersonde, 1992).

Increasing the amount of soil organic matter results in higher C_t and N_t-contents of the soil. Higher or increased rates of mineralisation result in higher soil nitrate contents. The extended soil N_t-pool can increase nitrate losses when plant sinks, i.e. efficient uptake by plants, act inadequately.

Strategies to use brassica underseeds or catch crops act merely temporary. Uptake of cereals and potatoes is often limited as an effect of «untimely» plant available nitrogen and limited N sink of the shoots and the harvested organs. All strategies mentioned in Chapter 1 act therefore suboptimal if the soil nitrate pool is steadily increased. Alternatively a part of the nitrogen in the liquid phase can be bound into the solid phase via transferring for instance brassica fodder crops to farmyard manure. Farmyard manure can bind nitrogen in solid less reactive nitrogen compounds. Nevertheless also this strategy is often partly effective on the long term. Consequently, the high sink capacity of brassica catch crops can focus attention on brassica cash crops grown as vegetables acting as efficient sinks for nitrogen realising high export of nitrogen when sold. Two strategies of growing vegetables were described by Köpke (1996). First: growing vegetables integrated or apart from rotation as proposed by the investigated rotation oriented in field experiments. It is assumed that a «rotation-integrated» vegetable production is optimal for conditions were based on site and rotation the need for increased soil organic matter is high on all fields covered by the rotation of the farm. Second: For farms having conditions of high soil fertility, i.e. high nitrogen mineralisation rates, the concept of «rotation-external» production (separated vegetable production) should be studied.

Only two hits were found concerning economic perspectives in vegetable production (Lelystad and Gravenhage, The Netherlands). Without any doubt increasing consumers demand oriented on organic vegetable produce has to be responded by intensified research in organic vegetable production.

5. Breeding (7)

Site-oriented choice of cultivars plays a key role for successful Organic Agriculture. Several times suitability of modern cultivars for Organic Agriculture has been denied . Root systems of modern cultivars were regarded as less efficient under the conditions of Organic Agriculture. Selection and breeding programmes performed under condition of poor soils resulted in N-efficient cultivars of *winter wheat* available on the German seed market since 1994. Some of them show similar characteristics as defined for ideotypes well adapted to Organic Agriculture, e.g. lower tillering, higher thousand-grain-weight and single ear yield. If these N-efficient genotypes do have a root morphology better adapted to Organic Agriculture is quite unclear. Breeding of *barley* oriented on nitrogen efficiency is given by one hit (Perugia, Italy).

As mentioned in subchapter 7 (weed control) the competitiveness of a crop beside row spacing and plant density depends on the cultivar's morphology (Holt, 1995; Wicks *et al*., 1994). Proper choice of cultivars can decisively influence light competitiveness, especially under Organic Farming conditions. Higher shading ability in cereals is a function of shoot length and soil coverage during tillering and shooting, leaf inclination, leaf area index and shoot length (Köpke & Eisele, 1997; Eisele & Köpke, 1997a). Similar results were gained for *potatoes* (Korr *et al*., 1996). Here, leafy cultivars gave higher competition power compared to cultivars having a growth habit predominantly shaped by the stalks and having a lower leaf area index.

In spring *barley* shading ability was decisive until the end of tiller formation. In the latest stages of plant development importance of morphological parameters influencing shading ability depended on the site-condition. Parameters of the flag leaves were proved to be helpful for estimating shading ability during later stages of development (Müller, 1998).

Since modern breeding programs based on genetically modified organisms are omitted in Organic Agriculture and reservations do exist against breeding programs oriented on hybrid cultivars, breeding programs dedicated to Organic Agriculture only and of Organic Agriculture origin are heavily discussed. Future answers will depend on decisions made by middle-class breeders. If they consider Organic Agriculture as steadily growing, promising a bigger future seed market, they will follow classical breeding methods further. Nevertheless possibilities and limits for breeding programs oriented on site-adapted cultivars have to be found out for Organic Agriculture.

Another hit was found concerning the development of chickpea germplasm resistant to *Ascochyta* blight and *Fusarium* wilt, (Cordoba, Spain), all indicating that no intensive breeding activities primarily oriented on Organic Agriculture can be found beside mainstream breeding activities.

6. Biodynamic Preparations (6)

No equivalent exists in other systems of agriculture to the so called biodynamic preparations developed and used in biodynamic agriculture only. Experimental evidence for the effects of these preparations is meanwhile accumulated over more than 7 decades. An overview concerning research results on biodynamic preparations is given by Koepf (1981, 1993). Use of the preparations by farmers is mostly oriented on the whole farm organism. Research is focussing on the different influences, biodynamic preparations have shown on soil and plant parameters and especially product quality. More recent results derived from reviewing several results gained by different authors and at different sites have shown that biodynamic preparations can fulfil regulatory functions, balancing disorders and one-sided influences (Raupp & König, 1996). Newer hints do show higher effectiveness when applied in combination with poisonous plant extracts (Fritz, 1999).

Results from long-term experiments such as the DOK-trial in Therwil, Switzerland, showing remarkable differences in several soil and plant parameters when compared with treatments that received mineral fertilizers or fresh farmyard manure instead of aerobically composted farmyard manure. Since biodynamic preparations 502-507 are applied together with composted manure no clear *ceteris paribus* results are available.

A joined project is assigned by Louis-Bolk-Institute (The Netherlands) together with the Institute for Biodynamic Research (Darmstadt, Germany), FIBL (Frick, Switzerland) and Ludwig-Bolzmann-Institute (Vienna, Austria). Experiments were run in order to study lettuce growth affected by biodynamic preparations measuring a broad spectrum of physiological parameters under different growing conditions.

Considering the innovative potential of biodynamic preparations, urgent research needs can clearly be announced.

7. Weed-Control (48)

Compared to conventional agriculture weed species diversity is higher in Organic Agriculture (Frieben & Köpke, 1996). Higher economic damage thresholds are tolerated in Organic Agriculture. General preventive tools to regulate weed flora are the optimal design of crop rotation, clean seeds, tillage procedures, manuring, choice of variety, seeding date, seeding density and spacing. Direct control is performed by using tine harrows and howing machines. Since energy use and costs are high, thermal methods are used in vegetables, maize and valuable row crops only. Recently, machinery using air pressure have been developed but seem to have no clear future to be used as a direct control method.

Preventive control is based on increased competition of crops against weeds. Ehlers (1997) showed that lower water use efficiency in Organic Agriculture is assumed to be caused by higher unproductive water loss, especially during early plant growth. Vigorous plant growth can be enhanced via higher nutrient (N-availability) as a function of cultural intensity. Higher water use efficiency is given with higher leaf area index that can be driven by bigger seeds. Furthermore use of a tine harrow during early growth stages can disturb pore continuity and initially reduce evaporation loss. The warmer soil can mineralise higher amounts of soil-borne nitrogen, improving plant growth and leaf area index resulting in reduced unproductive water loss and a shorter period to reach maximum CGR. Some of the evaporation loss might be reduced as well by optimised spacing, narrow row distances, broadcast seeding or single grain seeding (Köpke, 1999b). This strategy distributes the relative restricted canopy in early growth stages more uniformly and is supported by using cultivars having more planophile leaves with high shading ability to suppress weeds (Eisele & Köpke, 1997a, b), which for their part can cause further unproductive loss of water but which can normally be controlled by two passes with a tine harrow after the first three leaves of cereals have emerged. Fast soil coverage is furthermore ensured by high seed quality based on healthy grains of greatest size (Piorr, 1991; Schauder *et al*., 1992; Dornbusch *et al*., 1992; Dornbusch, 1998; Derrick & Ryan, 1998)

Other investigations have shown that photocontrol of weeds resulted in 11 out of 12 field experiments in about 20 to 80 % less emergence of annual weed seedlings. Tillage during the night caused significant lower density of weed species such as *Abutilon theophrasti*, *Alopecurus myosuroides*, *Veronica hederifolia* and *Sonchus arvensis* (Gerhards *et al*., 1998). Photocontrol of weeds combined with GPS-driven machinery might have a future in Organic Agriculture when combined with spacing (reduced row distance and reduced seed density), sowing direction (east-west instead of north-south using of passive shading given by the rows) combined with cultivars showing a much more sufficient ground shading as a function of morphology, shoot length and leaf inclination (Eisele & Köpke, 1997a, b; Gooding *et al*., 1998).

Although during the last two decades knowledge to control weeds without using herbicides has made some efforts some problematic weeds can be enhanced by conditions typical for organic farming. Often docks (*Rumex* spec.) are relicts of a former high input of nitrogen in conventional farming. No clear strategy to control docks exists. The problem of controlling this geophyt is given under nearly all site conditions of grasslands in Europe. Masalles *et al*. (1997) followed the approach of non-chemical weed control via better knowledge of population dynamics in *Rumex obtusifolius* which is found in alfalfa-winter cereals crop rotations in Spain. Approaches followed in IGER, Aberystwyth, Wales are oriented on destroying the roots mechanically and burying the residues with deeper ploughing. No doubt, that further intensive research has to be performed to solve this problem.

Vicia hirsuta is one of the most problematic seed-weeds in Organic Agriculture in Central-Europe (Eisele, 1995). This plant is adapted to low nitrogen availability and low plant densities combined with a high dormancy and longer vitality of the hugged coated seed, responsible for the increase in the soil seed bank after conversion to organic farming. Successful control strategies are still required and already under development. The approach is to increase the crop competitiveness via selection of competitive cultivars, higher N-supply and seed-densities which are combined with varied soil cultivation and crop rotation. Mechanical weed control strategies were tested and investigations on seed dormancy are performed. It is expected that liquid manure in early spring can reduce growth of *Vicia hirsuta* in cereal stands but might enhance on the other side *Galium aparine*. Until now it is quite unclear, to which extend a dormancy breaking by frost can be used to reduce the soil seed bank. First results show that this tool can be used combined with reduced tillage and successful use of mechanical weed control.

One hit exists in the database indicating development of a small scale weed control technology (Juva, Finland). Effects of mechanical and thermic weed control in sugarbeets, potatoes, sunflower, rapeseed and wheat are studied in Leipzig, Germany. Population dynamics of weeds and profitability of weed control in arable crop production is studied in Wageningen, weed control by mechanical weeding on cereals (howing) in Evreux, France.

No doubt that detailed analysis of specific site conditions in Europe will show weed problems for Organic Agriculture which are still unknown yet. Beside the general well known aspects of weed control mentioned above, specific site oriented strategies have to be developed and might be performed successfully with joined research programmes consisting of local experts, farmers and members of well educated extension service supplemented with foreign experts.

III Conclusions: Outlook on future research

Research necessities:

• In order to optimise nutrient management *more knowledge concerning the rhizosphere and plant-microbial interactions is needed*.

• *More research* effort is needed *into grain legumes grown in southern Europe* covering the topics of N_2-fixation, water consumption and precrop effects.

• *More research effort* is needed *into strategies hindering gaseous losses of nitrogen* from soil, plant, farmyard or compost heaps and stables in order to optimise nutrient (nitrogen) flow within farms.

• *More research* input is needed *into crop to weed interactions, covering again rhizosphere interaction and all other aspects of system stability* (weed feeding predators, acting as hosts etc.).

• *Strip-cropping systems* as an example of polyculture have to be studied further as a cropping strategy *especially for stockless farms, for erosion control and higher product quality* (baking quality in cereals).

• *Intensive research* especially *on soil* and *soil microbial activity* in view of sustainable agriculture (organic versus conventional) has to be performed *in still existing long-term field experiments*. Important information that can be gained from these experiments especially oriented on soil physical, soil microbial and soil-biochemical parameters is feared to be lost.

• *More research effort* is needed *to describe product quality especially of vegetables* but also of potatoes better. Parameters that are able to characterise shelf-life better have to be studied more intensively. *In cereals parameters to describe high quality wheat varieties under conditions of restricted nitrogen availability* have to be investigated.

• In order to characterise product quality better further efforts should be followed in *evaluating so-called «picture-forming» methods* such as sensitive cristallization, circular chromatography and “Steigbilder” or capillary-dynamolysis.

• Compared to cereal production *research activity in vegetable production has to be urgently intensified*. Research topics were described looking on nitrogen availability, optimised use of organic manure, crop rotation and optimised positive precrop effects, questions of product quality, sensoric analysis and shelf life as a function of production strategies.

• Organic Agriculture plays a key role in *on-site preservation of endangered cultivars*. Possibilities and limits for *breeding programmes oriented on site-adapted cultivars have to be developed* for Organic Agriculture.

• *Regulatory functions of biodynamic preparations* balancing disorders and one-sided influences *are only initially understood*. *More research effort must be expanded on biodynamic preparations*, their effect on compost processes, soil and plant. Urgent research needs can clearly be announced.

• Several indirect methods to control weeds were identified. These approaches have to be studied more deeply. *Special strategies on problematic weeds* such as *Rumex* species, *Vicia hirsuta* and *Cirsium arvense* (in grassland and under dry conditions) *are urgently needed*.

• *Use of process-life-cycle-assessment in agriculture has to be deepened* and to be used in order to optimise farming procedure looking on impact categories that are typically influenced by agriculture. It is proposed to *start with analysing and compensating imbalances of nutrient and energy flows via co-operating farms*.

• *All mentioned research needs have to be oriented on site-specific solutions.* Co-operation between scientists, advisors and farmers performing *joined on-farm research by using so-called pilot farms* which can better *provide local solutions* is proposed.

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