

Supporting Online Material Mäder *et al.*, 1071148

### **DOK Trial Description**

The field experiment was set up in 1978 in the vicinity of Basle (at Therwil, Switzerland; 7° 33' E, 47° 30' N) by the Swiss Federal Research Station for Agroecology and Agriculture, Zürich-Reckenholz (CH) and the Research Institute of Organic Agriculture, Frick (CH). Four farming systems were compared differing mainly with respect to fertilization strategy and the concept of plant protection management (table S1).

The organic systems biodynamic (BIODYN) and bioorganic (BIOORG) were fertilized with farmyard manure (FYM) and slurry corresponding to 1.2 (1st and 2nd crop rotation period) and 1.4 (3rd crop rotation period) livestock units per hectare. Fertilization intensity of the organic systems is based on the fodder produced in the respective crop rotation and reflects the intensity typically found on Swiss organic farms. One conventional system was fertilized with the same amount of FYM as the organic systems and, in addition, with mineral fertilizers up to the recommended level of the plant-specific Swiss standard recommendation (system CONFYM). The other conventional system was unfertilized during the first crop rotation, but was then amended with mineral fertilizers exclusively (system CONMIN), mimicking a stockless system. The conventional systems were farmed according to the national rules of integrated plant production since 1985, which is a type of good agricultural practice.

Plant protection was conducted according to the guidelines of the biodynamic and bioorganic systems. In the conventional systems, pesticides were only applied if economic thresholds for infections were exceeded according to the integrated scheme of plant protection.

The crop rotation was identical in all systems (table S2). In the third crop rotation, barley was replaced by a third year of grass-clover. Crop rotation was a compromise between organic and conventional rotations in practice.

The grass-clover mixture was sown in drills after rotary harrowing the cereal stubble field. Soil tillage was similar in all treatments. The soils were ploughed to a depth of 18 to 20 cm before planting potatoes, winter wheat, cabbage, or beets (beetroots). The same varieties and grass-clover mixtures were cultivated in each system.

The soil type is a haplic luvisol on deep deposits of alluvial Loess. It contains 15% sand, 70% silt, and 15% clay. The field trial was designed as a randomized block with four replicates including three crops planted simultaneously in each system every year. Single plot size was 5 m by 20 m. There was a buffer zone strip (6 m) planted with grass, which was regularly mulched between the experimental plots (fig. S1). The climate at the experimental site is rather dry and mild with a mean precipitation of 785 mm per year and an annual mean temperature of 9.5°C.

Farmer groups from the respective farming systems helped in designing the experiment and still are guiding the staff running the experiment. Plots are managed by both farmers and technicians.

**Fig. S1.** DOK field trial design: treatments under study.

				<b>Crop 1998</b>
CONFYM	BIOORG	BIODYN	CONMIN	grass-clover ley
CONFYM	BIOORG	BIODYN	CONMIN	beetroots
CONFYM	BIOORG	BIODYN	CONMIN	winter wheat
BIODYN	CONMIN	CONFYM	BIOORG	beetroots
BIODYN	CONMIN	CONFYM	BIOORG	winter wheat
BIODYN	CONMIN	CONFYM	BIOORG	grass-clover ley
BIOORG	CONFYM	CONMIN	BIODYN	winter wheat
BIOORG	CONFYM	CONMIN	BIODYN	grass-clover ley
BIOORG	CONFYM	CONMIN	BIODYN	beetroots
CONMIN	BIODYN	BIOORG	CONFYM	grass-clover ley
CONMIN	BIODYN	BIOORG	CONFYM	beetroots
CONMIN	BIODYN	BIOORG	CONFYM	winter wheat

**Table S1.** Main differences between the farming systems of the DOK trial. The CONMIN plots remained unfertilized during the first crop rotation (1978–1984). The biodynamic preparations (P) consist of the following: P 500: cow-manure fermented in a cow horn; P 501: silica fermented in a cow horn. These were applied at rates of 250 and 4 g ha<sup>-1</sup> respectively. Composting additives are yarrow flowers (P 502, *Achillea millefolium*, L.), camomile flowers (P 503, *Matricaria recutita*, L.), stinging nettle (P 504, *Urticaria dioica*, L.), oak bark (P 505, *Quercus robur*, L.), dandelion flowers (P 506, *Taraxacum officinale*, Wiggers), and valerian flowers (P 507, *Valeriana officinalis*, L.). A decoction of field horsetail (*Equisetum arvense*, L.) is applied once during the vegetative growth of wheat and potatoes as a protective agent against plant diseases at rates of 1.5 kg ha<sup>-1</sup>. Herbicides (1 to 2 treatments yr<sup>-1</sup>). Fungicides (2 to 3 treatments yr<sup>-1</sup>) based on threshold values, plant growth regulators were applied routinely to winter wheat. Insect control was required regularly in potatoes and rarely in winter wheat.

Farming systems	Organic systems		Integrated systems	
	biodynamic <b>BIODYN</b>	bioorganic <b>BIOORG</b>	with manure <b>CONFYM</b>	without manure <b>CONMIN</b>
<b>Fertilization</b>				
Farmyard manure (FYM)	composted FYM and slurry	rotted FYM and aerated slurry	stacked FYM and slurry	–
Livestock units per ha	1.4	1.4	1.4	–
Mineral fertilizers	–	small amounts of rockdust, K Magnesia	NPK fertilizer as supplement	exclusively mineral NPK
<b>Plant protection</b>				
Weed control	mechanical	mechanical	mechanical and herbicides	mechanical and herbicides
Disease control	indirect methods	indirect methods, CuSO <sub>4</sub> on potatoes until 1991	fungicides (thresholds)	fungicides (thresholds)
Insect control	plant extracts, biocontrol	plant extracts, biocontrol	insecticides (thresholds)	insecticides (thresholds)
<b>Special treatments</b>	biodynamic preparations		plant growth regulators	plant growth regulators

**Table S2.** The crop rotation in the DOK field trial

Year	1978–1984	1985–1991	1992–1998
	1. Crop rotation period	2. Crop rotation period	3. Crop rotation period
1	Potatoes	Potatoes	Potatoes
	Green manure	Green manure	
2	Winter wheat 1	Winter wheat 1	Winter wheat 1
	Fodder intercrop	Fodder intercrop	Fodder intercrop
3	White cabbage	Beetroots	Beetroots
4	Winter wheat 2	Winter wheat 2	Winter wheat 2
5	Winter barley	Winter barley	Grass-clover 1
6	Grass-clover 1	Grass-clover 1	Grass-clover 2
7	Grass-clover 2	Grass-clover 2	Grass-clover 3

**Table S3.** Methods for determining soil fertility (methodological information to accompany Fig. 2 in the text.)

<b>Method</b>	<b>Crop, year of the study</b>	<b>Reference</b>
Percolation stability	winter wheat, 1993	water percolation rate with soil aggregates 1 to 2 mm
Aggregate stability	winter wheat, 1999	stable aggregates > 250 µm after wet sieving
Bulk density	winter wheat, 1991	weight of an undisturbed soil sample
pH	winter wheat, 1998	in water suspension (1:10; wt/vol)
Organic carbon	winter wheat, 1998	wet oxidation
Phosphorus	winter wheat, 1998	double lactic acid extract
Potassium	winter wheat, 1998	double lactic acid extract
Calcium	winter wheat, 1998	HCl/H <sub>2</sub> SO <sub>4</sub> -extract
Magnesium	winter wheat, 1998	double lactic acid extract
Microbial biomass	winter wheat, 1998	chloroform fumigation extraction
Dehydrogenase activity	winter wheat, 1998	reduction of 2,3,5-triphenyltetrazolium chloride (TTC) to triphenyl formazan (TPF)
Protease activity	winter wheat, 1991	casein hydrolyzation
Alcaline phosphatase activity	winter wheat, 1991	hydrolysis of phenylphosphate
Saccharase activity	winter wheat, 1991	hydrolysis of sucrose
Mycorrhiza	winter wheat, grass-clover, 1989–1993	percentage of root length colonized by mycorrhizal fungi
Earthworm biomass	winter wheat, beetroots, potatoes, 1990, 1991, 1992	hand sorting
Earthworm abundance	winter wheat, beetroots, potatoes, 1990, 1991, 1992	hand sorting and classification
Carabid activity density	winter wheat, 1988, 1990, 1991	pit fall trapping
Staphylinid activity density	winter wheat, 1988, 1990, 1991	pit fall trapping
Spider activity density	winter wheat, 1988, 1990, 1991	pit fall trapping

**Table S4.** Energy input per unit land area (GJ ha<sup>-1</sup>) in the 2nd crop rotation ( $n = 3$ ) Difference BIOORG and CONFYM = 36%, Difference between BIODYN and CONMIN = 53%. Note: grass-clover sawing in the year of barley cultivation. Source: T. Alföldi, Research Institute of Organic Agriculture [Forschungsinstitut für biologischen Landbau (FiBL)], internal report.

Crop	BIODYN	BIOORG	CONFYM	CONMIN
Potatoes	26.39	28.42	39.85	40.69
Winter wheat 1	12.52	11.56	18.88	19.74
Beetroots	16.31	15.14	28.53	31.56
Winter wheat 2	10.31	9.79	20.49	21.81
Barley	8.82	9.62	16.29	15.78
Grass-clover sawing year	6.43	7.63	6.78	6.75
Grass-clover 1st year	3.91	4.27	5.22	11.75
Grass-clover 2nd year	4.86	6.48	9.98	20.47
Sum	89.55	92.91	146.02	168.55
Mean (energy input per year, sum/7)	<b>12.79</b>	<b>13.27</b>	<b>20.86</b>	<b>24.08</b>
Mean% (CONFYM = 100%)	61	64	100	115

**Table S5.** Energy input per unit crop yield (GJ/metric tons dry matter) in the 2nd crop rotation ( $n = 3$ ).

Crop	BIODYN	BIOORG	CONFYM	CONMIN
Potatoes	4.23	3.70	3.81	3.98
Winter wheat 1	3.51	2.93	4.01	4.22
Beetroots	1.91	1.75	2.48	3.67
Winter wheat 2	2.60	2.35	3.90	3.88
Barley	2.46	2.68	3.39	3.19
Grass-clover sowing year	2.83	3.35	3.44	3.92
Grass-clover 1st year	0.27	0.29	0.34	0.83
Grass-clover 2nd year	0.42	0.53	0.70	1.62