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**Yield and Quality of Potato Tubers: Effects of Different Intensity and Kind of Manuring (Biodynamic or Organic)**

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Biodynamic farming is the oldest organic farming movement in Germany. Since Dr. Rudolf Steiner's "Course on Agriculture" held in 1924, the number of biodynamic farmers in Germany has grown continuously, with 1,317 farmers currently producing on 47,592 ha. One of the most distinctive aspects of biodynamic farming is the use of the so-called biodynamic preparations, which are applied in homeopathic doses. Biodynamic preparations are supposed to improve plant growth and food quality, minimising natural variations. This paper deals with investigations of influences of these preparations and increased manure application on potato yield and tuber quality. The results are drawn from extensive research on organic potato production carried out by several institutes of the University of Bonn, sponsored by the Deutsche Forschungsgemeinschaft (Bonn), and the Eden Foundation (Bad Soden).

### **Materials and Methods**

#### *Sites*

From 1994 to 1997 field trials were performed on two experiment stations in Germany. Site 1 was the Institute of Biodynamic Research near Darmstadt; site 2 was the University of Bonn's experimental farm for Organic Agriculture, Wiesengut/Hennef.

#### **Site 1: Darmstadt**

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Cultivar: ‘Granola’; preceding crop: spring wheat  
Soil: acid alluvial sands  
Climate: annual average temperature: 9.5°C; annual precipitation: 590 mm  
Experimental design: split-splot design in stripes, four replicates  
Factor 1: kind of fertiliser (OR = Organic, BD = Biodynamic. A mineral fertiliser treatment also was studied, but is not discussed in this paper)  
Factor 2: fertiliser level (cow manure): chosen to give desired N application (1, 2, 3 = 50, 100, 150 kg N/ha, respectively)  
No treatments were applied against late blight. Colorado potato beetles (CPB) were controlled using the bacterial preparation “Novodor” (*Bacillus thuringiensis*).

#### Site 2: Wiesengut

Cultivar: ‘Granola’; preceding crop: grass/clover mixture  
Soil: silty alluvial loams  
Climate: annual average temperature: 9.5°C; annual precipitation: 700-750 mm  
Experimental design: Latin rectangle, four replicates  
Factor 1: kind of fertiliser (OR = Organic, BD = Biodynamic)  
Factor 2: fertiliser level (cow manure): chosen to give desired N application rate (1, 2, 3, 4 = 0, 80, 160, 240 kg N/ha, respectively)  
The experimental field was integrated into a 6 ha potato field, cultivated under field conditions. 300 kg/ha of potassium magnesia and 250 kg/ha of rock phosphate were added before ploughing in March. Copper treatments against late blight and “Novodor” against CPB were applied as needed.

#### Method

- Dry matter content: oven drying at 105°C.
- Nitrate: photometric measurement (540 nm) with Lunge’s reagent.
- Potassium: flame photometric measurement after dry ashing.
- Flavour: tested by the Bundesforschungsanstalt für Ernährung (Karlsruhe, Germany).

Results were statistically evaluated by analysis of variance followed by Tukey's test. The standard deviation (sd) is reported as the error term against which effects are tested.

## Results

### *Tuber yield and dry matter content*

In all three years of the Wiesengut trial, the total tuber yield was slightly higher in the biodynamic plots. In the 1994 Darmstadt trial, the biodynamic yield was significantly higher than the organic. In the other two years, the two treatments had the same yield (Table 1). In comparison to the Wiesengut trials, the annual yield variance in the Darmstadt trials was low.

Tuber yield in the Darmstadt trials was significantly increased by manuring, whereas in the Wiesengut trials, manuring had a detectable effect only in 1996.

Table 1. Effect of kind and intensity of manuring on total tuber fresh weight and dry matter content, Darmstadt (DA) and Wiesengut (WG) trials. (OR = organic; BD = biodynamic; 1, 2, 3, 4 = fertiliser level; sd = standard deviation.)

Trial	Total tuber yield (t/ha)				Dry Matter (%)											
	OR	sd	BD	sd	1	2	3	4	OR	sd	BD	sd	1	2	3	4
<b>WG-95</b>	19.6	4.4	20.6	2.5	19.8	19.4	20.2	20.8	17.1	1.3	17.2	1.0	18.3a	17.5a	16.4b	16.3b
<b>WG-96</b>	38.2	2.1	38.6	2.7	36.6c	37.6cb	39.2ba	40.0a	18.1	1.0	17.9	1.0	18.5a	18.2ab	17.7b	17.7b
<b>WG-97</b>	24.1	2.3	24.6	3.3	24.0	23.8	24.9	24.7	16.0	0.7	16.0	0.7	16.6a	16.4a	15.6b	15.4b
<b>DA-94</b>	24.3b	4.4	27.0a	4.4	22.3c	25.6b	29.1a	-	15.4	0.8	16.4	0.8	16.3	15.6	15.7	-
<b>DA-95</b>	23.8	5.3	24.1	4.2	20.0c	23.8b	28.2a	-	18.2	0.8	18.7	0.6	18.7a	18.4ab	18.3b	-
<b>DA-96</b>	24.4	5.2	24.4	3.7	20.3b	25.5a	27.6a	-	19.2	1.1	19.2	0.8	19.9a	19.0b	18.6b	-

Values followed by different letters within kind or intensity of fertilisation of the same year are significantly different by Tukey's test ( $\alpha = 0.05$ ).

In the Wiesengut trials neither the dry matter content of the tubers nor the standard deviation differed among treatments (Table 1). In the Darmstadt trials the dry matter content of the biodynamic tubers was slightly higher than in the

organic tubers. In all trials except DA-94, tuber dry matter content decreased significantly with increased amounts of manure applied.

#### *Potassium and nitrate content of the tubers*

Apart from 1995, where the tubers of the organic plots had significantly higher potassium content than the biodynamic ones, potassium content in both trials did not vary with kind of manure (Table 2). In all trials except DA-94, tuber potassium content was significantly increased by manuring.

Table 2. Effect of kind and intensity of manuring on potassium and nitrate content of potato tubers, Darmstadt (DA) and Wiesengut (WG) trials. (OR = organic; BD = biodynamic; 1, 2, 3, 4 = fertiliser level; sd = standard deviation.)

Trial	Potassium (% dry matter)								Nitrate (ppm, fresh weight)							
	OR	sd	BD	sd	1	2	3	4	OR	sd	BD	sd	1	2	3	4
<b>WG-95</b>	2.04a	0.3	1.83b	0.3	1.64b	1.95a	2.06a	2.08a	90	19	92	12	88	90	97	90
<b>WG-96</b>	1.95	0.2	1.97	0.2	1.84b	1.92b	1.98ba	2.11a	74	13	73	15	67	74	75	78
<b>WG-97</b>	2.41	0.2	2.41	0.2	2.24c	2.37cb	2.47ba	2.56a	111	16	109	19	103	103	116	119
<b>DA-94</b>	1.69	0.4	1.70	0.4	1.63	1.79	1.68	-	156	33	130	26	140	145	144	-
<b>DA-95</b>	1.85	0.2	1.77	0.3	1.64b	1.86a	1.94a	-	178	45	175	14	181	180	168	-
<b>DA-96</b>	n.a.				-				129	44	123	34	108	136	134	-

Values followed by different letters within kind or intensity of fertilisation of the same year are significantly different by Tukey's test ( $\alpha = 0.05$ ).

In general, tuber nitrate content in the Darmstadt trials was high (Table 2). The limit of 100 ppm (fresh weight) for first quality potatoes, as required by Nitsch and Klein (1983), was exceeded in all years and treatments. In two years of the Wiesengut trial the nitrate content was slightly lower in the biodynamic plots (Table 2). Although excessive nitrogen was applied in the high-fertilisation treatments (240 kg N/ha), neither site showed a significant increase of the nitrate content of the tubers, as described for mineral fertilisers (Kolbe, 1996). Annual variations in potassium and nitrate content were much more evident.

### *Flavour: (results only for Darmstadt trial 1994 and 1995)*

The flavour of the potato tubers was not influenced by either the fertiliser level or by the kind of fertiliser. Nevertheless, in both years increasing mineral fertiliser application led to slightly decreasing flavour notes, which did not happen with the two organic treatments.

### **Discussion and Conclusion**

With analysis of variance, only two significant differences between organic and biodynamic manuring were detected. The significant increase of tuber yield in the biodynamic treatment agrees with other results of ours (slightly higher tuber yields in the biodynamic treatment) and those reported by Lücke and v. Boguslawski (1982). The higher tuber potassium content detected once in the organic treatment cannot be explained. Lower nitrate and higher dry matter contents in the biodynamic treatment were found only in the Darmstadt trials. In 9 cases the standard deviation was lower in the biodynamic treatment, whereas in the other cases it was either lower in the organic treatment (6 cases) or equal (8 cases). In the entire study the ratio was 31 (BD) to 30 (OR). Although present data show a small positive impact on yield and tuber quality, a clear advantage of using the biodynamic preparations cannot be established from these results.

The effects of manuring on yield were stronger on the sandy soil (Darmstadt), with low soil nitrogen content and high mineralisation rate of manure. In the Wiesengut trial, with its higher soil nitrogen content (preceding crop: grass/clover mixture), manuring affected tuber yield only slightly. Plant uptake and content of potassium was largely improved by manuring, whereas negative effects (decreasing d.m. content, slightly increasing nitrate contents) were not very pronounced. Therefore the amount of manure applied should be based on optimal shoot growth and sufficient potassium supply, thus promoting tuber yield and quality.

### **References**

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