NUTRITIONAL VALUE OF CROPS AS INFLUENCED BY ORGANIC AND INORGANIC FERTILIZER TREATMENTS

Results of 12 years' experiments with vegetables (1960–1972)

WERNER SCHUPHAN

(Geisenheim/Rh.)

The problem of fertilizing food plants, whether on an organic or inorganic basis, and the response to the nutritional value of the crops so treated are of tremendous interest all over the Western world (1). The so-called 'Organic – or Biological – Farming', or 'Biodynamic Management' in agriculture and gardening and the value of their products found favour with many people and entered the sharp limelight of public discussions.

The experimental work we have done in this special field from 1960 to 1972 should help to elucidate the real situation, 'Quantity – Quality,' and may reduce emotions in favour to more objectivity.

The background of this problem as seen overseas could be taken from a recent publication of an American food scientist. M. Salomon (1) made in 1972 the following statement:

'The organically grown food idea is not new but our present cultural responses are such that the concept takes on a whole new dimension leading to special diets, a kind of mysticism, a certain fear of anything chemical or artificial, and in the extreme may find expression in ancient religious practices and a questioning and turning against the establishment'.

In the same publication M. Salomon (1) pleads for

'strong definitive work with composts in comparison with chemical fertilizers and their effect on 'quality''.

Let us try to get rid of the myths and establish independent scientific inquiry instead. We have been trying to resolve these questions for 36 years (cit. in (2 and 3)). In the last 12 years we also made a small contribution to elucidate the role of biodynamic compost on yield and nutrition, disregarding all mystical beliefs.

In 1960 we started in Geisenheim long-term fertilizer experiments with vegetables including potatoes, fodder and sugar beets. Concrete framed plots – 10 square metres each – were used. 25 plots had been filled to a depth of 0,90 metres with a North German fen soil, and another 25 with a tertiary sand from a Geisenheim sand pit respectively. The surface layer of the latter had been mixed with fen soil to get a better waterholding capacity.

The fertilizer experiments 1960 – 1972 consist of the following treatments: 'NPK' including plots treated with 'Stable Manure', 'Stable Manure + NPK' 'Biodynamic Compost', all repeated fourfold, except the latter which were only single on the two soils.

There can generally be no question of the fundamental importance of repetition of experiments. This is true even if cultivation is carried out in concrete framed plots of 10 square metres filled with a homogenized soil – fen or sand – up to a height of 90 centimetres each. These are extremely favourable conditions for reproducibility of yield. We obtained a very good conformity in yield from 'stable manure' by using 4 repetitions, and the

Significance of Yield of **Potatoes** grown in Concrete framed Plots.
– Stable Manure –

Food Plant (Cultivar)	Year	Fen (F) or Sand (S)	Yield in 100 kg/ha Repetitions a	b	c	d	Mean	Statistically Significant $s_{\bar{x}}$ %
POTATOES („Saskia")	1964	F	193.5	210.7	215.2	119.3	**209.7**	**2.7**
		S	168.8	168.2	172.4	175.0	**170.8**	**1.0**

high significance of these results as shown in table 1 may also reflect reliable results in soil treatments with another organic manure, Biodynamic Compost, in single plots. This statement is strengthened by the fact that no single *annual* results are the base of our comparing conclusions but 12 years' results with repeated cultivation of the same crops.

The 'Biodynamic Compost' – following the special advice of its producers* – was given in extremely high amounts of 86 000 kg/ha, in comparison with relatively low amounts – as normally applied – as 'Stable Manure' of 30 000 kg/ha. This gave contributed to quite different amounts of organic matter: The 'Biodynamic Compost' 9 030 kg/ha, the stable manure 3 580 kg/ha only, in other terms 2 1/2 times less. The stable manure we received has generally been of a poor quality (low N-content) varying from year to year but to a fairly small extent. This may explain the results from 'Stable Manure', namely low yield of the crops and relatively high contents of minerals in the soils (Fig. 1, 2, 3).

Let me emphasize that my paper does not refer to any economic or

* We are greatly indebted to Dr. Heinze, Forschungsring für biologisch-dynamische Wirtschaftsweise in Darmstadt-Eschollbrücken for advises and for providing us with an original b.d.compost every year.

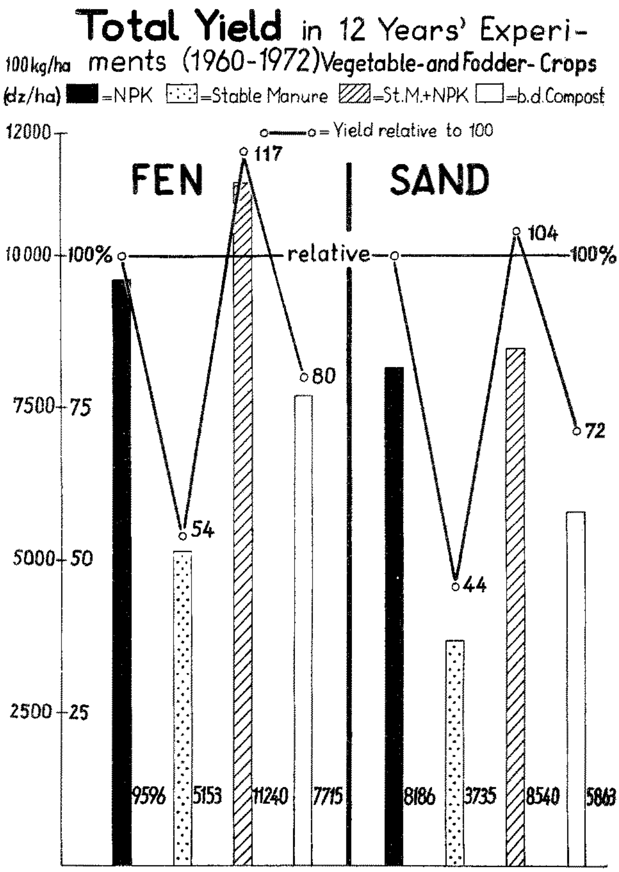

Fig. 1

social-political consequences of the problem in question. Here, only facts, which are derived from experimental work should be considered, demonstrating the role of inorganic and organic farming on the yield of crops and on criteria supporting human nutrition and health.

It seems to me that decisive arguments for and against the alternatives between inorganic or organic farming are generally not yet sufficiently understood; there is too much emotional involvement and general ignorance of the results of relevant physiological and biochemical experiments. Advocates as well as opponents of organic and – vice versa – of inorganic farming each feel entirely certain of a more or less strongly defined opinion towards such a difficult problem.

The result: Emotions prevail instead of knowledge derived from thorough scientific investigations.

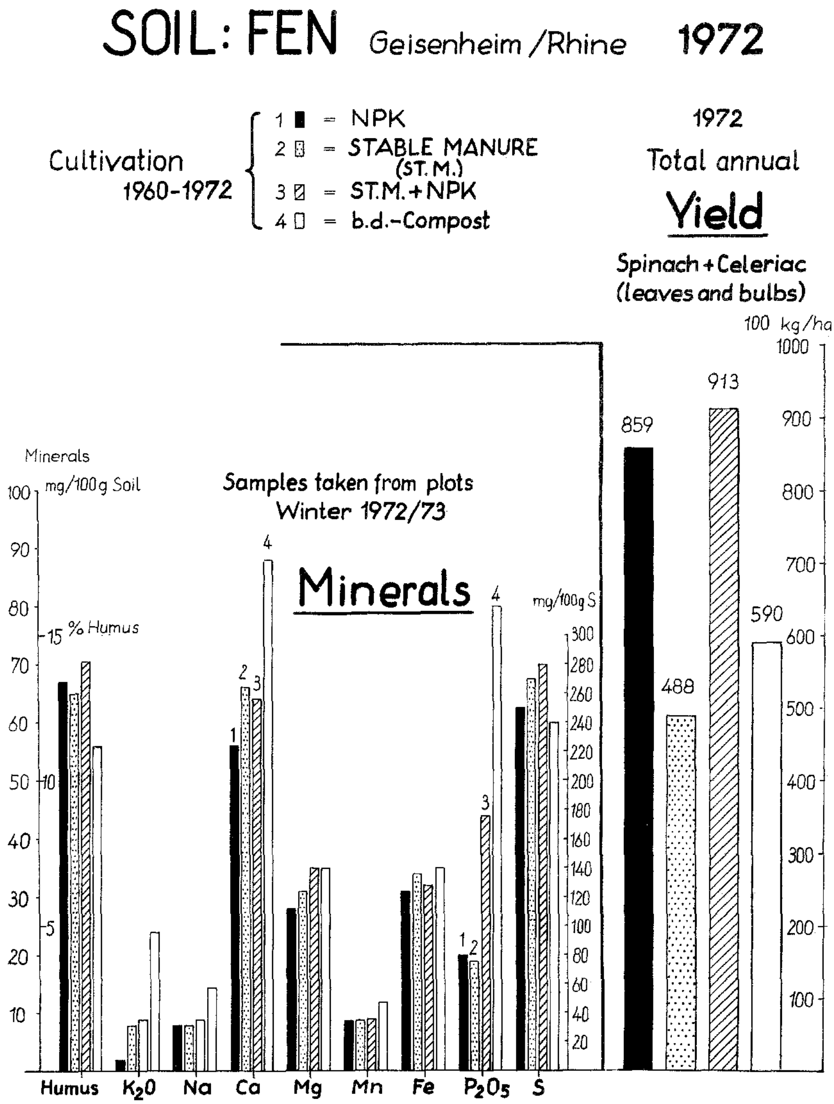

Fig. 2

A third, semi-official opinion hold by a representative of the Agricultural Research Service of the US Department of Agriculture, Washington D.C. earnestly denies any influence of either organic manure or inorganic fertilizers on the nutritive value of our foods (4).

8 crops – spinach, lettuce, savoy, potatoes, celeriac, carrots, fodder- and sugar-beets – were grown in rotation mostly as successional crops (2 crops

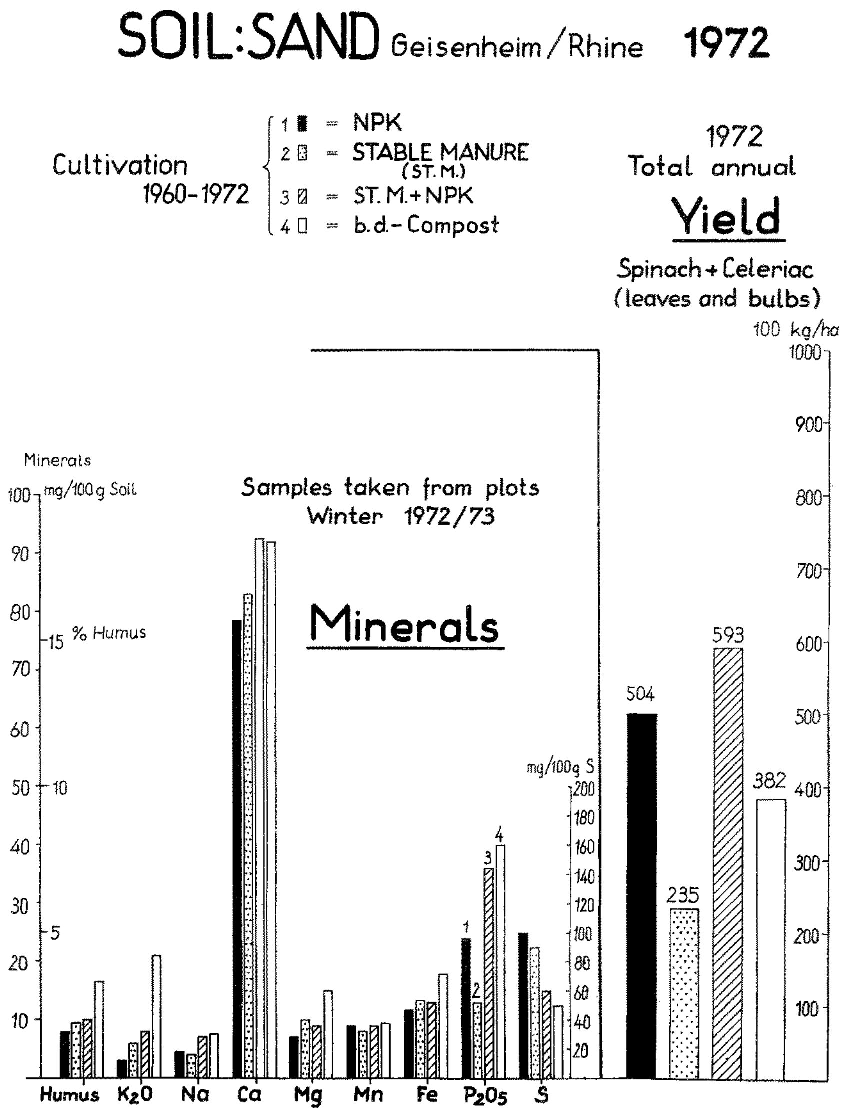

Fig. 3 (We have to ask for apology that hatching from the 3rd column (Ca) has been omitted).

per year), several times repeated in 12 years. Out of 8 crops we chose 4 – spinach, savoy, potatoes and carrots – according to their different morphological type indicated in Fig. 4. They represent all main types used, thus warranting averaging all our results.

Now, let me describe the results briefly, including only the most impor-

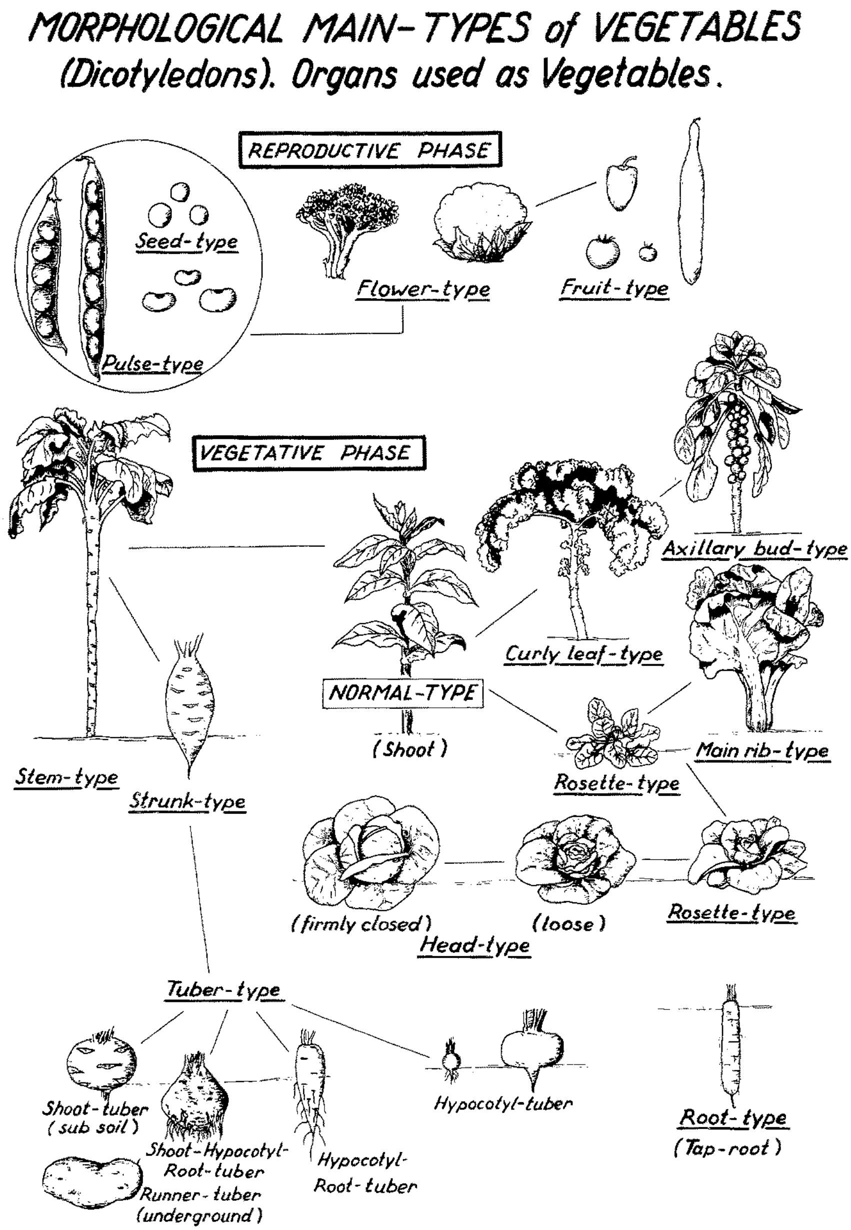
MORPHOLOGICAL MAIN-TYPES of VEGETABLES
(Dicotyledons). Organs used as Vegetables.
REPRODUCTIVE PHASE
Seed-type
Pulse-type
Flower-type
Fruit-type
VEGETATIVE PHASE
Axillary bud-type
Curly leaf-type
NORMAL-TYPE
(Shoot)
Main rib-type
Rosette-type
Stem-type
Strunk-type
(firmly closed)
(loose)
Rosette-type
Head-type
Tuber-type
Shoot-tuber
(sub soil)
Shoot-Hypocotyl-
Root-tuber
Runner-tuber
(underground)
Hypocotyl-
Root-tuber
Hypocotyl-tuber
Root-type
(Tap-root)

Fig. 4

tant facts. Some graphs may help to a better understanding.

1. The means of data for *total yield* of 8 crops on two different soils summing up 12 years' experiments are shown in a graph (Fig. 1). The means in yield are recorded absolutely in 100 kg/ha, and simultaneously on a percentage basis related to the yield of NPK-treatment, taken as 100%. Thus, yield decreases considerably due to 'Stable Manuring' as much as 46% on fen, and 56% on sand, followed by 'Biodynamic Compost' to a less pronounced degree with losses in yield of 20% and 28% respectively. In contrast to these findings 'Stable Manure + NPK' increases yield up to 17% on fen and to 4% on sand above the 100% level of 'Mineral Fertilizing (NPK)'.

These data reflect likewise the tremendous role of fertilizer practice on yield and the function of the soil as a significant environmental factor in yield.

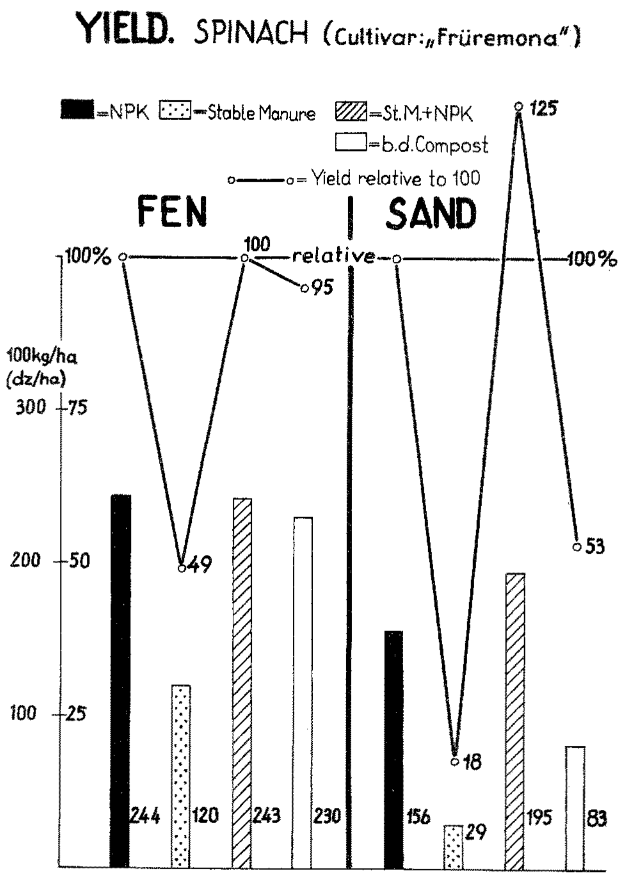

Fig. 5

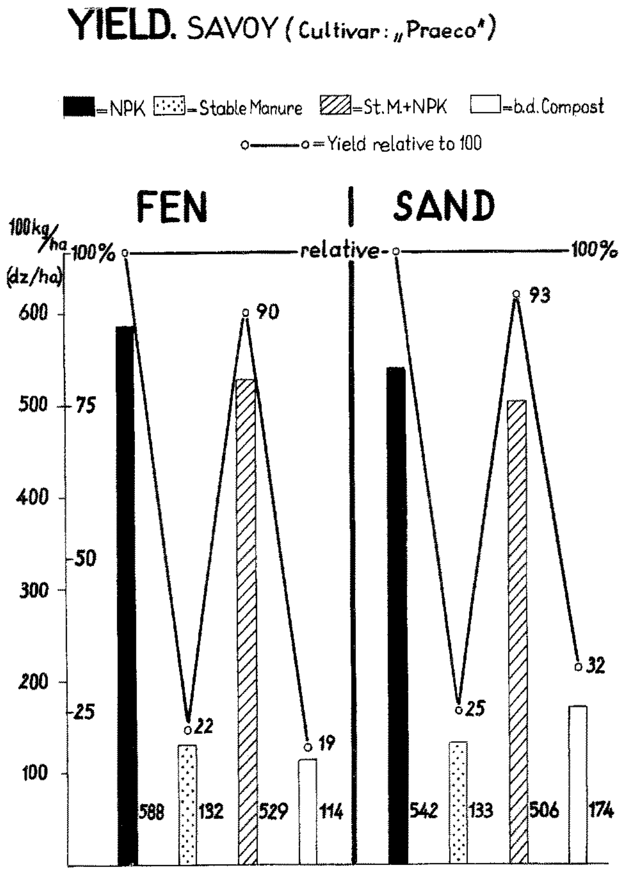

Fig. 6

2. Another factor of importance is the plant itself. Plants belong genetically to various genera, of which some distinct plant portions, sometimes genetically more or less modified in their morphology are used as human food (Fig. 4).

From Fig. 4 it may be easily recognized that those properties could influence individual results both in yield and in contents of nutrients. According to earlier extensive investigations on the effect of morphogenetic differentiations in *Brassica oleracea* L. (6) we know something about the relations between morphogenetic alteration and chemical composition in plants. Consequently, greater or less deviations from the mean data shown in Fig. 1 should be expected. This has to be born in mind, when the following graphs are shown (Fig. 5, 6, 7,8) using as special types 4 vegetables quite different in morphology, and consequently in physiology and

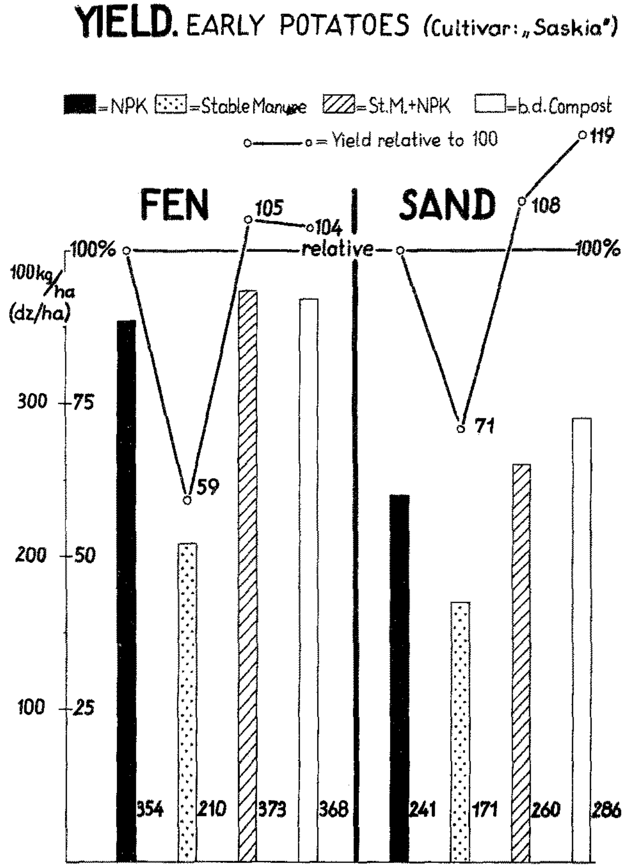

Fig. 7

biochemistry – spinach*, savoy**, potatoes*** and carrots**** representing in the same range: a rosette, a big terminal bud, a stem tuber and a storage root.

The 4 vegetables have been chosen out of 8 crops, of which yields – according to rotation in the same year (2 succeeding crops) and/or in following growing periods – are presented in two tables (Table 2 – FEN, Table 3 – SAND).

Highest yields in succeeding crops have been attained on fen in 1963 by Early Savoy + Carrots, followed in the range by Spinach + Celeriac in 1969. In single main crops Fodder Beets in 1968 were right on top in yield.

Now, let us discuss the effect of organic fertilizers on yield in our trials with 4 vegetables. The greatest depressions due to organic manuring in

* *Spinacia oleracea* L. ** *Brassica oleracea* L. var. *sabauda* L. *** *Solanum tuberosum* ssp. *tuberosum* **** *Daucus carota* L. ssp. *sativus*

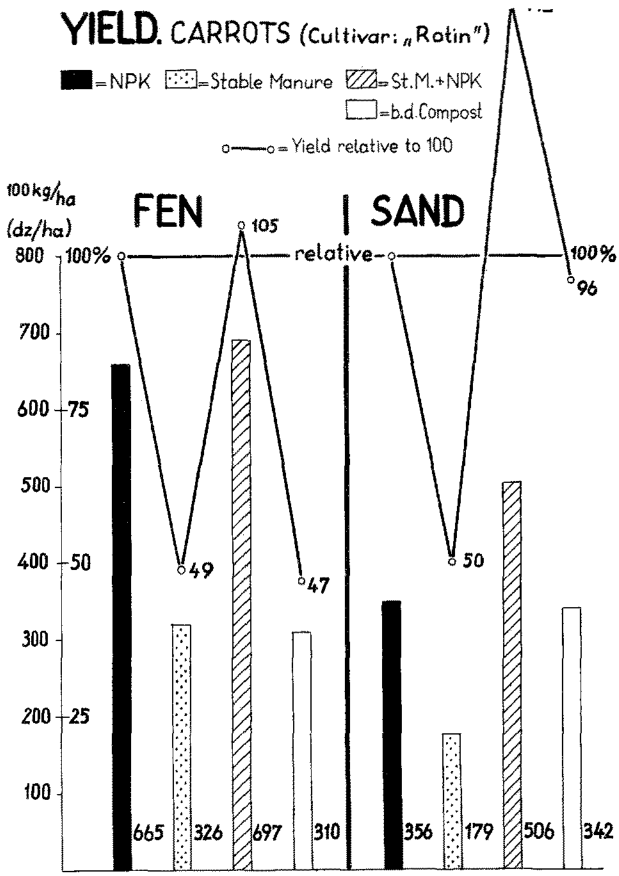

Fig. 8

comparison with mineral fertilizing (NPK = 100) are found in two descendants of plants living in waste places, in spinach (–5 to –82%) and in savoy (–68 to –81%). Both are leafy vegetables but only one (spinach) succeeded in rotation a main crop in the preceding year. This main crop received solely the organic manuring destined also for the following crops. Savoy had been a position as main crop. The two below ground products, potatoes as a main crop and carrots as a succeeding crop, decrease in yield comparably in lower rates, carrots –4 to –53%, potatoes in 'Stable Manure' down by –41%. Potatoes grown in 'Biodynamic Compost' showed above the control ('NPK') rather a surprising increase in yield both on fen and on sand of +4 to +19% respectively.

3. What happened in the soil during 12 years' experiment with organic and inorganic fertilizers? This may be answered by data determined in 1972 after harvest (Fig. 2 and 3).

Tab. 2

Total Annual Yield. SOIL : FEN Geisenheim/Rhg.

in 100 kg /ha (= dz/ha)

MAIN CROP = Capital Letters (received organic manure)

Nature →		MAIN CROPS and Succeeding Crops												
Year →		1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
a) →		POTATOES	FODDER BEETS	Spinach	EARLY SAVOY	POTATOES (EARLY)	SUGAR BEETS	Carrots	POTATOES (EARLY)	FODDER BEETS	Spinach	POTATOES (EARLY)	FODDER BEETS	Spinach
b) →		—	—	CELERIAC (leaves + bulbs)	Carrots	Lettuce	—	—	Spinach	—	CELERIAC (leaves + bulbs)	Spinach	—	CELERIAC (leaves + bulbs)
NPK	a)	216,4	1088,3	289,2	587,8	354,4	393,5	718,5	321,2	1153,1	332,0	320,1	513,2	243,9
"	b)	—	—	624,6	876,3	456,8	—	—	241,3	—	779,2	248,9	—	615,2
ST.M.	a)	**258,0**	**250,1**	23,9	**131,6**	**209,7**	**95,7**	435,8	**217,0**	**692,8**	75,9	**181,3**	**486,5**	119,8
"	b)	—	—	**153,2**	386,1	178,2	—	—	71,9	—	**466,3**	99,6	—	**368,4**
ST.M.+NPK	a)	**303,3**	**995,1**	319,2	**528,8**	**373,5**	**356,0**	733,8	**386,2**	**1218,9**	371,4	**323,9**	**609,9**	242,6
"	b)	—	—	**534,8**	931,8	495,6	—	—	274,0	—	**792,9**	315,3	—	**670,2**
b. d. C.	a)	**206,7**	**1023,3**	25,2	**114,1**	**367,6**	**250,8**	876,4	**400,3**	**672,5**	79,0	**344,9**	**342,5**	230,4
"	b)	—	—	**202,5**	364,9	272,2	—	—	138,0	—	**656,8**	221,2	—	**359,8**

Legend: NPK = Mineral Fertilizing; ST.M. + NPK; ST.M. = Stable Manure; b.d.C. = biodynamic Compost

NPK; N = 80 – 240 kg N/ha; P_2O_5; for the first year, (1960) 180, later 90 kg P_2O_5/ha; K_2O; 160 kg K_2O/ha -- Amounts of organic manures (Text followed Tab. 1) -- St.M. + NPK; N – P – K given as differences (Contents of N.P.K. minus contents in St.M.).

Tab. 3

Total Annual Yield. SOIL: SAND Geisenheim / Rhg.

in 100 kg/ha (= dz/ha)

MAIN CROP = Capital Letters (received organic manure)

Nature →		MAIN CROPS and Succeeding Crops												
Year →		1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
a) →		POTATOES	FODDER BEETS	Spinach	EARLY SAVOY	POTATOES (EARLY)	SUGAR BEETS	Carrots	POTATOES (EARLY)	FODDER BEETS	Spinach	POTATOES (EARLY)	—	Spinach
b) →		—	—	CELERIAC (leaves + bulbs)	Carrots	Lettuce	—	—	Spinach	—	CELERIAC (leaves + bulbs)	Spinach	Savoy	CELERIAC (Leaves + bulbs)
NPK	a)	193,9	1082,2	110,2	542,5	240,6	477,7	531,3	216,5	1073,6	188,1	39,3	—	156,4
〃	b)	—	—	571,2	500,6	311,6	—	—	127,5	—	369,9	268,8	341,3	347,7
ST.M.	a)	**161,9**	**349,3**	10,5	**133,2**	**170,8**	**110,5**	357,3	**141,7**	**510,4**	31,7	**84,8**	—	28,8
〃	b)	—	—	**177,7**	226,4	107,8	—	—	24,8	—	**307,0**	79,2	291,8	**206,6**
ST.M.+NPK	a)	**232,0**	**1035,6**	142,7	**505,7**	**260,5**	**372,7**	643,7	**253,8**	**921,5**	240,0	**50,9**	—	195,0
〃	b)	—	—	**548,7**	701,7	317,0	—	—	162,4	—	**338,2**	306,6	369,1	**397,9**
b.d.C.	a)	**143,5**	**548,2**	13,2	**173,8**	**286,0**	**341,7**	621,4	**279,0**	**785,8**	60,7	**148,0**	—	82,6
〃	b)	—	—	**256,2**	434,4	208,2	—	—	61,2	—	**396,7**	181,0	28,1	**298,8**

Legend: NPK = Mineral Fertilizing; ST.M. = Stable Manure; ST.M.+NPK; b.d.C. = biodynamic Compost

High contents of humus in the soil are supposed to perform a kind of regulatory function by keeping plants supplied with their nutrients. In a current flux 'in harmony' with the plant's actual need they build up plant constituents. In this particular case 'harmony' means the balance between the output of plant nutrients from the soil in a way corresponding to the plant's need. Thus, precursors of Nitrogen-N in humus, amino acids (5) and mineralized N-sources, will be released abundantly as plant nutrients when higher temperature and moisture in the soil give rise to a considerable increase in microbiological activity. This in turn should correspond with a high activity in life function of the 'acceptor' of nutrients, the living plant, likewise due to favourable growing conditions.

This is, somewhat simplified, the situation as found in a rather ideal model, in greenhouse grown cucumbers. The sun is heating the air and the soil is rich in humus, so the gardener looks for sufficient shading and humidity in soil and in air – to get optimum growing conditions.

Our expectations after 12 year's experimental work – that humus contents of soil would correspond to humus supply by organic matter – was not realized in fen, soil as shown in Fig. 2. Difficulties in comparing contents of humus and plant nutrients in fen and sand were pointed out by H. Vetter et al. (7) in 1973.

In 1972 our experiments finished provisionally representing yields which generally correspond in nature and relation with the means found in total yield of 12 years' experimentations (Fig. 1). Soil samples were taken after the harvest of the successional crop in 1972, spinach + celeriac.* Plots fertilized with 'Stable Manure' and with 'Biodynamic Compost' ranged below the level of humus contents found in plots provided with 'Stable Manure + NPK' and with 'NPK'. In 1972, the yield of total crop on fen was 43% less on 'Stable Manure', and 31% less on 'b.d. Compost' than on 'N.P.K.'

On sand (Fig. 3) we registered about the same range in relative losses in yield of –53% and –24% but the absolute yield varied on sand in another magnitude than the yield on fen namely 52% less with 'Stable Manure'. On sand the contents of humus rose with 'Stable Manure', with 'Stable Manure + NPK' and even more with 'Biodynamic Compost' compared with 'NPK'.

A causal explanation that higher yield would leave more root residues and so produce more humus would suit in fen but not in sand. Further statements related to this subject are not possible due to lack of special investigations.

Beside the humus there is considerable interest to know the fate of

* In every year after harvest soil samples were sent to the 'Landwirtschafliches Untersuchungsamt', Kassel-Harleshausen to be analysed. We are greatly indebted to the representatives of this station for their courtesy.

minerals in the soil after 12 years' treatment with organic and inorganic fertilizers.

The particular response to 12 years' treatment with 'b.d.Compost' on fen-plots leading to extremely high contents of K_2O, Na, P_2O_5, Ca and Mn

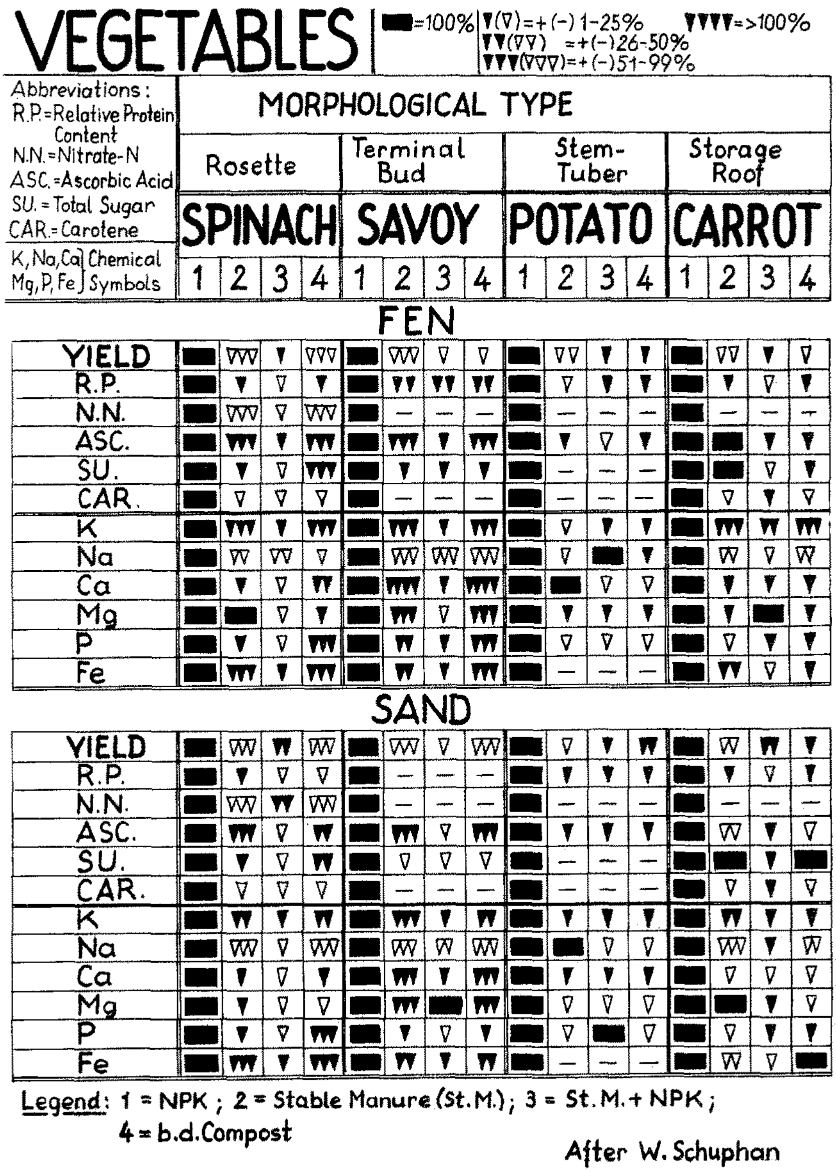

Fig. 9

compared with other fertilizer treatments might seem surprising. However, the extremely high amounts of 'b.d. Compost' given every year, and on the other hand the moderate or low yields harvested from those plots, easily provide an interpretation for this phenomenon.

One could be rather dismayed, that Mg – an important factor in human nutrition (8) – shows practically no difference in contents compared with 'Stable Manure + NPK'. The downward trend of 'S' is equally not expected as also the only slight increase of Fe on both 'Stable Manure' and 'b.d.Compost'.

On sand, the ratios for some minerals are generally similar, as shown in Fig. 3, but the magnitude in contents of some minerals (Mg, Fe, P_2 O_5 and S) is lower, sometimes even to a considerable extent. The contents of Mg in plots of 'b.d.Compost' on sand are higher than in other treatments.

4. Fig. 9 provides us with a quick survey of increase or decrease in yield, organic and inorganic plant constituents of 4 vegetables – spinach, savoy, potatoes and carrots – as influenced by 'Stable Manure', 'Biodynamic Compost' and 'Stable Manure + NPK' in relation to 'NPK'-fertilizing = 100.

Let us draw the most remarkable results to your attention, except the outcome on yield already mentioned:

The most convincing facts are much higher contents of minerals – except of sodium – due to organic fertilizing. Potassium and iron show the greatest increases, in savoy as magnesium and calcium. Contents of sodium, except in potatoes, are markedly decreased.

The most surprising result taken from Fig. 9 is the behaviour of nitrate-N in spinach. Organic manuring both with 'Stable Manure' and 'b.d.Compost' results in extremely low contents in nitrate-N (Tab. 4, 5). *No hazards to health whatsoever could be expected when such a 'Low-nitrate-Spinach' were fed to infants (9).*

Nitrate-N and free amino acids – both unwanted in human nutrition – are interrelated in the pathway of nitrogen-metabolism of plants. E. Schwerdtfeger (10) found increased amounts of free amino acids due to a built up dressing of food plants with nitrogen. The data in Table 6 report uniformly low contents of free amino acids due to organic manuring, both with 'Stable Manure' and 'b.d.Compost', but on the other hand higher contents from 'Stable Manure + NPK' and 'NPK' alone, obviously due to the N-component in the mineral fertilizer used.

The differences are pronounced both on fen and on sand for celeriac (bulbs and leaves), spinach, carrots, and for fodderbeets, on fen only.

A problem in quality research, important for pest control too, remains to be discussed:

Aphids feeding on plants use as protein source the mobile stream of soluble free amino acids in the vascular bundles (11, 12). Plants provided

Tab. 4

FEN

SPINACH (Means: 1962, 1969, 1972)

Manure, Chemical Fertilizer	Dry Matter %	Dry Matter Rel.	RP %	RP Rel.	NN mg/100g	NN Rel.	ASC mg/100g	ASC Rel.	SU %	SU Rel.	CAR mg/100g	CAR Rel.
NPK	6.21	100	81.9	100	33.5	100	29.9	100	0.60	100	2.5	100
ST.M.	8.81	**142**	85.6	**104**	1.4	**4**	53.1	**178**	0.71	**118**	2.3	**92**
ST.M.+NPK	6.02	97	81.1	99	32.3	96	30.2	101	0.58	97	2.4	96
b.d.C.	8.97	**144**	87.0	**106**	1.7	**5**	49.1	**164**	1.00	**167**	2.3	**92**

LETTUCE (1964)

Manure, Chemical Fertilizer	Dry Matter %	Dry Matter Rel.	RP %	RP Rel.	NN mg/100g	NN Rel.	ASC mg/100g	ASC Rel.	SU %	SU Rel.	CAR mg/100g	CAR Rel.
NPK	4.18	100	64.0	100			9.7	100	0.96	100		
ST.M.	5.98	**143**	79.7	**124**			15.4	**159**	1.56	**162**		
ST.M.+NPK	4.30	103	62.2	97			8.8	91	0.72	75		
b.d.C.	5.37	**128**	74.1	**115**			15.4	**159**	1.20	**125**		

CARROTS (Means: 1963, 1966)

Manure, Chemical Fertilizer	Dry Matter %	Dry Matter Rel.	RP %	RP Rel.	NN mg/100g	NN Rel.	ASC mg/100g	ASC Rel.	SU %	SU Rel.	CAR mg/100g	CAR Rel.
NPK	12.49	100	40.3	100			8.0	100	5.81	100	15.1	100
ST.M.	12.71	**102**	50.5	**125**			8.0	**100**	5.82	**100**	12.4	**82**
ST.M.+NPK	12.45	100	39.7	76			8.4	104	5.62	97	15.5	103
b.d.C.	12.95	**104**	48.9	**121**			8.1	**101**	5.92	**102**	14.5	**96**

SAVOY (1963)

Manure, Chemical Fertilizer	Dry Matter %	Dry Matter Rel.	RP %	RP Rel.	NN mg/100g	NN Rel.	ASC mg/100g	ASC Rel.	SU %	SU Rel.
NPK	8.01	100	38.7	100			41.8	100		
ST.M.	13.51	**169**	51.5	**133**			73.5	**176**		
ST.M.+NPK	8.72	109	51.2	132			44.0	105		
b.d.C.	15.71	**196**	54.1	**140**			80.1	**191**		

POTATOES (Means: 1964, 1967, 1970)

Manure, Chemical Fertilizer	Dry Matter %	Dry Matter Rel.	RP %	RP Rel.	NN mg/100g	NN Rel.	ASC mg/100g	ASC Rel.	SU %	SU Rel.
NPK	22.35	100	50.5	100			25.3	100		
ST.M.	21.73	**97**	49.1	**97**			27.7	**109**		
ST.M.+NPK	21.98	98	51.6	102			23.6	93		
b.d.C.	21.67	**97**	52.3	**104**			26.4	**104**		

CELERIAC (Means: 1962, 1969, 1972)

Manure, Chemical Fertilizer	Dry Matter %	Dry Matter Rel.	RP %	RP Rel.	NN mg/100g	NN Rel.	ASC mg/100g	ASC Rel.	SU %	SU Rel.
NPK	15.47	100	44.0	100			11.8	100	2.14	100
ST.M.	16.29	**105**	60.4	**137**			14.0	**119**	2.30	**107**
ST.M.+NPK	15.77	102	50.9	116			14.8	125	2.50	116
b.d.C.	15.79	**102**	54.7	**124**			14.1	**119**	2.25	**105**

Legend: RP = Relative Protein Content; ASC = Ascorbic Acid; CAR = Carotene
NN = Nitrate-N; SU = Total Sugar
NPK = Mineral Fertilizing
ST.M. = Stable Manure; b.d.C. = biodynamic Compost; Capital Letters = Main Crop
ST.M.+NPK

Tab. 5

SAND

SPINACH (Means: 1962, 1969, 1972)

Manure, Chemical Fertilizer	Dry Matter		RP		NN		ASC		SU		CAR	
	%	Rel.	%	Rel.	mg/100g	Rel.	mg/100g	Rel.	%	Rel.	mg/100g	Rel.
NPK	7.53	100	75.1	100	18.8	100	37.4	100	1.11	100	3.2	100
ST.M.	9.97	**132**	75.9	**101**	2.8	**15**	57.8	**154**	1.28	**115**	2.7	**84**
ST.M.+NPK	7.04	94	74.9	99	23.7	126	34.3	92	0.83	75	3.0	94
b.d. C.	9.43	**125**	71.6	**95**	0.5	**3**	48.8	**130**	1.56	**140**	2.6	**81**

LETTUCE (1964)

Manure, Chemical Fertilizer	Dry Matter		RP		NN		ASC		SU		CAR	
	%	Rel.	%	Rel.	mg/100g	Rel.	mg/100g	Rel.	%	Rel.	mg/100g	Rel.
NPK	5.04	100	66.3	100			15.4	100	1.08	100		
ST.M.	7.33	**145**	77.0	**116**			16.3	**106**	1.93	**179**		
ST.M.+NPK	5.03	100	72.3	109			15.4	100	1.07	99		
b.d.C.	6.03	**120**	79.2	**119**			14.1	**91**	1.42	**131**		

CARROTS (Means: 1963, 1966)

Manure, Chemical Fertilizer	Dry Matter		RP		NN		ASC		SU		CAR	
	%	Rel.	%	Rel.	mg/100g	Rel.	mg/100g	Rel.	%	Rel.	mg/100g	Rel.
NPK	12.49	100	42.9	100			6.3	100	5.79	100	12.7	100
ST.M.	12.28	**98**	44.8	**104**			4.3	**68**	5.78	**100**	10.8	**85**
ST.M.+NPK	12.32	99	32.3	75			6.8	109	5.89	103	13.5	106
b.d.C.	12.24	**98**	43.8	**102**			5.3	**84**	5.82	**100**	12.3	**97**

SAVOY (1963)

Manure, Chemical Fertilizer	Dry Matter		RP		NN		ASC		SU	
	%	Rel.	%	Rel.	mg/100g	Rel.	mg/100g	Rel.	%	Rel.
NPK	8.57	100	43.0	100			46.2	100	3.09	100
ST.M.	12.87	**150**	56.6	**132**			85.5	**185**	2.59	**84**
ST.M.+NPK	8.62	101	46.9	109			41.8	90	2.82	91
b.d. C.	12.68	**148**	55.4	**129**			75.7	**164**	2.98	**96**

POTATOES (Means: 1964, 1967, 1970)

Manure, Chemical Fertilizer	Dry Matter		RP		NN		ASC		SU	
	%	Rel.	%	Rel.	mg/100g	Rel.	mg/100g	Rel.	%	Rel.
NPK	22.51	100	47.5	100			28.3	100		
ST.M.	21.34	**95**	51.3	**108**			33.1	**117**		
ST.M.+NPK	22.55	100	52.8	111			32.2	114		
b.d. C.	22.02	**98**	50.6	**106**			33.0	**116**		

CELERIAC (Means: 1962, 1969, 1972)

Manure, Chemical Fertilizer	Dry Matter		RP		NN		ASC		SU	
	%	Rel.	%	Rel.	mg/100g	Rel.	mg/100g	Rel.	%	Rel.
NPK	14.61	100	46.3	100					2.10	100
ST.M.	16.36	**112**	67.7	**146**					2.22	**105**
ST.M.+NPK	14.68	100	55.4	120					2.02	96
b.d. C.	15.88	**109**	63.4	**137**					2.07	**98**

Legend: RP = Relative Protein Content; ASC = Ascorbic Acid; CAR = Carotene
NN = Nitrate-N; SU = Total Sugar
NPK = Mineral Fertilizing

Tab. 6

FREE AMINO ACIDS (in % fr. m.) calculated on the base of Leucin

	Spinach 1972	Savoy 1971	Potatoes 1967	Celeriac 1969 bulbs	Celeriac 1969 leaves	Fodder Beets 1968	Carrots 1966
FEN							
NPK	0,112		0,374	0,526	0,069	0,148	0,336
Stable Manure	**0,075**		**0,282**	**0,136**	**0,034**	**0,078**	**0,174**
ST.M. + NPK	0,099		0,317	0,324	0,077	0,128	0,346
b.d. Compost	**0,088**		**0,307**	**0,137**	**0,039**	**0,045**	**0,302**
SAND							
NPK	0,111	0,697	0,374	0,368	0,082	0,145	0,358
Stable Manure	**0,074**	**0,456**	**0,282**	**0,096**	**0,043**	**0,118**	**0,187**
ST.M. + NPK	0,109	0,458	0,317	0,273	0,099	0,159	0,352
b.d. Compost	**0,075**	**0,255**	**0,307**	**0,108**	—	**0,083**	**0,310**

After E. Schwerdtfeger

abundantly with nutrients, especially with nitrogen, are attacked by aphids above the norm (cit. in (13)). On the other hand plants manured organically are less or even not at all affected by aphids. It is well known that organically grown plants have a more solid collenchymatous thickening-system increasing the mechanical strength of cell walls and a decreased water content in plants tissues both favouring a protective effect against aphids.

In all likelihood, both criteria – lower contents of free amino acids and more collenchymatous thickening in organically grown plants – might provide greater protection against aphids in cultivated plants.

Fig. 10 shows for spinach interrelations in yield, contents of nitrate-N and free amino acids as influenced by organic and inorganic fertilizers. The three-dimensional graph demonstrates the effects clearly.

Fig. 9 gives rather a rough survey showing only gross differences in contents of nutrients and minerals depending on organic or inorganic fertilizing of both soils.

Tables 4 and 5 – in contrast to Fig. 9 – permit direct reference to analytical data. Benefit or the reverse due to organic farming may be judged by contents of nutrients in absolute and relative terms, the latter based on 'NPK' = 100 as usual.

A particular property of chemical fertilizer usage in crops is an increase

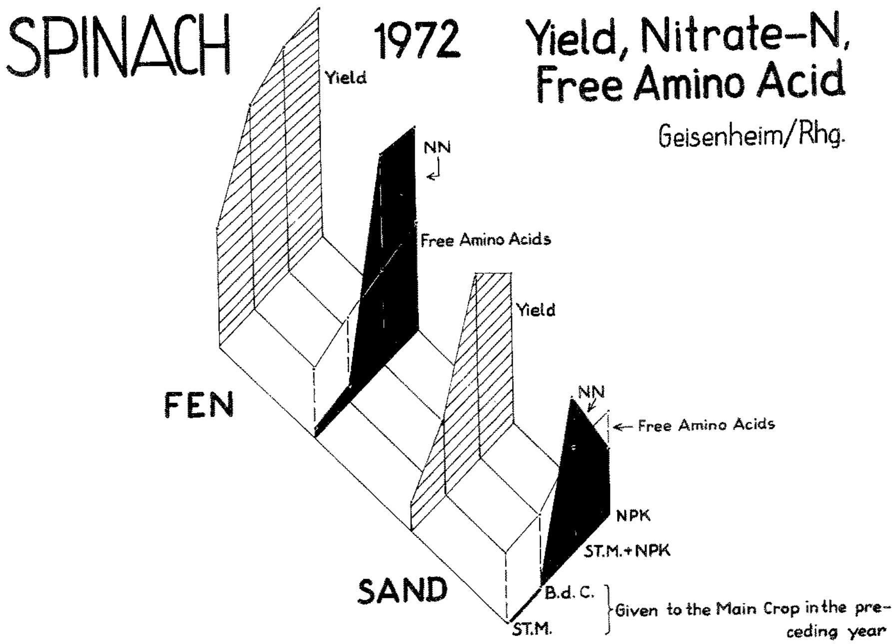

Fig. 10

of water contents in plant tissues; in other terms a decrease in dry matter. According to the Tables 4 and 5 there is a notable increase in dry matter both on fen and on sand in favour of 'Stable Manure' up to 69% and of 'b.d.Compost' even up to 96%. In belowground products the findings amounted to only small increases or even slight decreases in dry matter.

On fen-soil we found in spinach a tremendous increase in content of ascorbic acid due to organic fertilizers. The increase we noted was 78% in spinach treated with 'Stable Manure', and 64% in spinach fertilized with 'biodynamic Compost'. This order in sequence – St. M. first, b.d.C. second – should be kept in the following explanations. In sandsoil the increased contents of ascorbic acid amount 54 to 30% respectively. On sand the figures of Savoy are +85 and +64%.

Savoy on fen contains as much as 76 to 91% more ascorbic acid than NPK-fertilized samples, on sand +54 to +30%.

In lettuce the increase in ascorbic on fen-soil was found equal in both manuring treatments (+59%), while on sand relatively small shifts of +6 to 9% were noticed.

In the two below-ground products the differences were low (potatoes), or nil (carrots).

The response of carotene to organic manuring was uniformly negative both in carrots and spinach on both soils. Carotene is physiologically a

Tab. 7

Amino Acids in dependence of fertilizer treatment

GEISENHEIM/Rhg. 1970

After E. Schwerdtfeger

Crop (Cultivar)	Manure, Chemical Fertilizer	Melhionine In % of Crude Protein	Melhionine rel.	Cystine In % of Crude Protein	Cystine rel.	Histidine In % of Crude Protein	Histidine rel.	Glutamic Acid In % of Crude Protein	Glutamic Acid rel.	Lysine In % of Crude Protein	Lysine rel.
FEN											
Early Potato („Saskia")	NPK	1.75	100	0.70	100	1.64	100	15.65	100	5.26	100
	ST.M.	2.15	**123**	0.77	**110**	1.85	**113**	12.77	**82**	5.08	**97**
	ST.M.+NPK	1.75	100	0.75	107	1.38	84	16.25	104	5.25	100
	b.d.C.	1.95	**111**	0.78	**111**	1.69	**103**	13.26	**85**	5.07	**96**
Late Spinach („Früremona")	NPK	1.79	100	0.72	100	2.55	100	13.36	100	5.78	100
	ST.M.	2.63	**147**	0.78	**108**	2.21	**87**	10.81	**81**	5.49	**95**
	ST.M.+NPK	1.88	105	0.80	111	2.11	83	13.89	104	6.57	114
	b.d.C.	2.30	**128**	0.88	**122**	2.36	**92**	12.49	**93**	6.19	**107**
SAND											
Early Potato („Saskia")	NPK	1.61	100	0.78	100	0.72	100	15.11	100	5.61	100
	ST.M.	2.11	**131**	0.59	**76**	0.78	**108**	13.89	**92**	5.69	**101**
	ST.M.+NPK	1.80	112	0.71	91	0.80	111	14.80	98	6.20	109
	b.d.C.	1.98	**123**	0.69	**88**	0.88	**122**	14.20	**94**	5.90	**105**
Late Spinach („Früremona")	NPK	1.99	100	0.92	100	1.72	100	11.91	100	6.08	100
	ST.M.	2.37	**119**	0.88	**96**	1.88	**109**	10.48	**88**	6.18	**102**
	ST.M.+NPK	1.91	96	0.60	65	1.80	105	12.84	108	6.42	106
	b.d.C.	2.21	**111**	0.62	**67**	1.98	**115**	10.19	**86**	6.10	**100**

Legend: NPK = Nitrogen, Phosphorus, Kalium
ST.M. = Stable Manure
ST.M.+ NPK
b.d.C = biodynamic Compost
rel. = relative

'surplus product' of the plant metabolism its synthesis being promoted by mineral fertilizing and favourable ecological conditions.

The relative protein contents (protein-N in % of Total-N) of crops grown on fen are more or less favoured by organic manuring e.g. in spinach (+4 to +6%), in savoy (+33 to 40%), in lettuce (+24 to +15%), in celeriac (+37 to 24%), in carrots (+25 to 21%) and only slightly in potatoes.

On sand we have roughly similar data but mainly on a lower level, as shown in Table 5.

Now, let us make some comments upon the behavior of a couple of amino acids, (Tab. 7) determined by E. Schwerdtfeger in our succeeding crop 1970 (early potatoes + late spinach) for which the yield data may be taken from Table 2 and 3.

Out of 18 essential, semi-essential and non essential amino acids determined only some were chosen. A remarkable trend especially for the S-containing amino acids methionine and cystine is shown. Methionine is an important essential, and cystine a semi-essential amino acid.

Being impressed by particular results of a series of experiments since 1954, we raised in 1961 questions about the causes of a decrease in the biological value of protein (calculated as EAA-Indices (14)) observed in spinach due to a heavy nitrogen supply up to an excess (15). We could elucidate significantly that methionine plays a 'key' role in limiting the biological value of protein; thus, a decrease, due to high N-fertilization, of this S-containing methionine – important to metabolic processes in plants (transmethylating) – gives rise to a very distinct decrease in the biological value of proteins.

Now, let us first take from Table 7 the results found for contents of methionine due to organic and inorganic fertilizers. The contents of methionine are distinctly higher after organic manuring both with 'Stable Manure' and with 'b.d.Compost', ranging with one exception from +11 up to +47% respectively in both early potatoes and spinach. The semi-essential amino acid, cystine, also shows – but only on fen – higher values in comparison with NPK from +8 to +22%. Histidine, rich in N, tends to respond to organic manuring in early potatoes both on fen and sand, and in spinach also but exclusively on sand.

On the other hand there is a distinct tendency towards a decrease in contents of glutamic acid, and to a smaller extent of lysine, in vegetables treated with organic manures. Glutamic acid, found in rather high amounts in plants plays an important role in the plant's nitrogen metabolism. In the mind of some nutritionists lysine is by the way supposed to have a weighty share in acceleration in growth of young people in the Western civilized world. Animal foods are rich in lysine, plant foods are rather inferior in this respect. Unfortunately, though a rich supply of nitrogenous fertilizer to plants usually increases the lysine content, it causes considerable decreases in methionine, which is probably the more valuable amino acid.

We may come to the conclusion that organic manuring favours unequivocally one of the most important essential amino acid, the S-containing methionine. Breeders are very keen on improving genetically plant proteins by increasing their contents of methionine. We have made clear, however, that also techniques of cultivation – more precisely of fertilization – may help in this respect too.

In order to complete our statements on the value of organically grown crops it may be interesting to know that organoleptic tests failed to give any reliable results whatsoever.

Finally, attention is called to rather a fundamental point. These analytical findings – just discussed briefly – have been in favour of organically grown crops in respect of their 'nutritional value'. The question arises, is it really permissible to speak from a better 'nutritional value'? Is this notion not solely restricted to results gained from nutritional experiments with infants or adults? – Indeed, it is. Nevertheless, we claim it is valid to use this notion with regards to our findings. This may be explained as follows:
In long-term fertilizer experiments with stable manure (B) and stable manure + NPK (A) (1936 to 1944) we succeeded in gaining convincing results in feeding infants with vegetables derived from two different fertilizer treatments. According to the statements of the pediatrists in 1944 (cit. in (2)) treatment A proved manifestly superior to treatment B *on account of the higher contents of acaloric plant constituents such as vitamins, minerals and trace elements.* It is a matter of fact that we used in our experiments about the same constituents in order to characterize the 'nutrional value' which differed considerably due to fertilizer treatment. That is the reason why we might claim validity for expressing our results in nutritional values.

Before presenting results on higher contents of nutrients in organically grown crops with respect to human nutrition in the 'Summary' let us mention still another point.

Objections might be raised to the absence of some information upon the development in yield of different crops during twelve years' experimentation. Representatives of the biodynamic management schemes limit the low yielding period to five years from the beginning of their special management (21). However, after this period – they say – yields would rise considerably. This strong argument can only be checked in our experiments by the aid of annual meteorological data in connection with calculations of statistical significance. This in turn would necessitate a new manuscript, so, we decided to publish a separate paper in this journal (22).

In the following publication we may also try to refute some wrong conclusions saying that improved nutritional quality of some crops grown on organics might be simply due to the lower supply of easily resorbed nitrogen from these manures, compared with NPK.

A matter of fact – as shown in Table 2 and 3 – may clinch this argument. 'Stable Manure + NPK' surpasses considerably the amount of yields of NPK. Nevertheless, on sandsoil the percentage of qualifying substances such as carotene, sugar, ascorbic acid in carrots, ascorbic acid and Relative Protein Contents in potatoes are higher as with NPK alone. The same is true on fen for some substances in celeriac (ascorbic acid, sugar, Relative Protein Contents), in carrots (carotene, ascorbic acid) and in savoy (ascorbic acid, Relative Protein Contents).

SUMMARY

Worldwide attention in agricultural and in nutritional science is diverted to the controversy concerning 'Quality' versus 'Quantity' in connection with the alternatives of 'Organic Manuring' or 'Chemical Fertilizing' in relation to nutritional values in crops and their significance to human health.

Some contribution towards classification of these problems is presented by the statistically significant results of our 12 years' experiment on two soils, fen and sand, including different organic manures and chemical fertilizers, namely 1) 'Stable Manure', 2) 'Biodynamic Compost', 3) 'Stable Manure + NPK', and 4) 'NPK'.

The difficulties in getting enough organic manures have no bearing on the subject of these investigations. The same is true for any considerations of economics.

It could be shown by the aid of tables and annotated graphs that organic farming with 1) and 2) gave rise to considerable decreases in yield of 20 to 46% on fen, and of 28 to 56% on sand, in 8 crops grown in rotation or in succession within a year (2 crops/year). The losses in yield have been calculated in relation to means of yields given by 4) = 100.

These losses in yield the organic farmer must bear at his own expense, unless the nutritive value of his organically grown crops would rise to such an extent that low yield would be financially compensated by a higher price for his crops. That the consumer would benefit by a higher biological value of such products of 1) and 2) is beyond question, as confirmed by the following data based on 12 years' chemical investigations.

Crops (both on fen and sand) manured with 1) and 2) have in comparison with 4) = 100 contents on average higher.

a. in Dry Matter of	+23%	
b. in Relative Protein of	+18%	
c. in Ascorbic Acid of	+28%	
d. in Total Sugars of	+19%	
e. in Methionine of	+23%	(determined in potatoes and spinach only)
f. in Minerals such as		
/ in Potassium (K) of	+18%	
/ in Calcium (Ca) of	+10%	
/ in Phosphorus (P) of	+13%	
/ in Iron (Fe) of	+77%	(determined in spinach only)
/ in Magnesium (Mg) of	± 0%	

On the other hand detrimental and/or undesired constituents in crops show – due to organic manuring with 1) and 2) – average contents diminished in

a. Nitrates by	−93%	(determined in spinach only (1962, 1969, 1972))
b. Free Amino Acids by	−42%	
c. Sodium by	−12%	

Finally let me comment upon the analytical results on behalf of the consumer in a somewhat practical way.

Vegetables including potatoes are generally heated, by cooking in the household and restaurants or by blanching in processing plants. Their water-soluble constituents, minerals and trace elements, are not at all affected by a careful heating as usual, but on the other hand soluble vitamins of the B-complex and Vitamin C are affected but only to a certain extent.

However, all these water-soluble plants constituents are strongly diminished in the food as eaten, if the cooking or the blanching water gets lost by pouring off. No doubt, using 'hot pot' diets ('right across the kitchen garden') losses from vegetables and potatoes in minerals and trace elements are entirely eliminated and those in water-soluble vitamins are only limited to destruction by heating.

Therefore it may be concluded, that solely those diets including the cooking water or steam blanched products will justify the greater expense of a product richer in nutrients. Otherwise it would be rather illusive to claim for low yielding organically grown crops of high nutritional value, when the latter is carelessly wasted by foulty preparation ((3, pages 174–182; 187), 16, 17, 18, 20).

ZUSAMMENFASSUNG

Weltweite Beachtung schenkt man heute in Landwirtschaft und Ernährungswissenschaft der Streitfrage 'Qualität' oder Quantität' in Verbindung mit dem Nähr- und Gesundheitswert organisch oder chemisch gedüngter pflanzlicher Erzeugnisse.

Einen bescheiden Beitrag zur Lösung dieser Frage konnten wir durch statistisch gesicherte Ergebnisse aus unseren 12jährigen Versuchen auf Moor- und Sandboden gewinnen. Die Versuche wurden mit verschiedenen organischen und chemischen Düngern durchgeführt, so mit
1) 'Stallmist', 2) 'biologisch-dynamischem Kompost', 3) 'Stallmist + NPK' und 4) 'NPK'.

Es sei noch gesagt, daß Schwierigkeiten in der Beschaffung genügender Mengen an organischen Düngern ebensowenig Gegenstand dieser Arbeit sind wie Fragen der Wirtschaftlichkeit. Sie stehen somit außerhalb der Debatte.

Mit Hilfe von Tabellen und Spezialdarstellungen konnte gezeigt werden, daß organische Düngung mit 1) und 2) bedeutende Ernteverluste – auf Moor in Höhe von 20–46%, auf Sand in Höhe von 28–56% – bedingte. Die Ernteverluste wurden auf die geernteten Erträge bei 4) = 100 berechnet. 8 pflanzliche Erzeugnisse, in der Hauptsache Gemüse, dienten in mehrjährigen Kulturfolgen und in einjährigen Folgekulturen (zwei Kulturen je Jahr) der Auswertung.

Diese bedeutenden Ernteverluste müssen Erzeuger, die sich einem organischen Anbau verschrieben haben, in Kauf nehmen, wenn sie nicht die Vorteile eines höheren ernährungsphysiologischen Wertes ihrer organisch gezogenen Produkte finanziell geltend machen. Daß der Verbraucher durch einen höheren biologischen Wert organisch gedüngter Erzeugnisse mit 1) und 2) profitieren, steht außer Frage, wie durch folgende analytische Daten, die auf 12jährigen chemischen Untersuchungen basieren, bewiesen werden kann:

Die höheren durchschnittlichen Gehalte, die mit den organischen Düngungen 1) und 2) in pflanzlichen Erzeugnissen auf Moor und Sand erzielt werden konnten, bezogen sich auf:

a. Trockensubstanz =	+23%	
b. den Relativen Eiweißgehalt =	+18%	
c. Ascorbinsäure =	+28%	
d. Gesamtzucker =	+19%	
e. Methionin =	+23%	(nur in Kartoffeln und Spinat bestimmt)

f. Mineralstoffe, z.B.

/ Kalium (K) =	+18%	
/ Kalzium (Ca) =	+10%	
/ Phosphor (P) =	+13%	
/ Eisen (Fe) =	+77%	(nur im Spinat bestimmt)
/ Magnesium (Mg) =	± 0%	

Andererseits zeigen als Folge einer organischen Düngung Schadstoffe und/oder unerwünschte Inhaltsstoffe im Durchschnitt eindeutig geringere Gehalte:

a. Nitrat =	−93%	(nur im Spinat bestimmt (1962, 1969, 1972))
b. Freie Aminosäuren =	−42%	
c. Natrium =	−12%	

Lassen Sie mich noch zum Schluß in einer den Verbraucher betreffenden, praktisch orientierten Weise unsere analytischen Befunde kommentieren. Gemüse und Kartoffeln erhitzt man – abgesehen von wenigen Ausnahmen – beim Zubereiten, durch Kochen in Haushalt und in der Gastronomie bzw. durch Blanchieren in der Verarbeitungsindustrie. Ihre wasserlöslichen Inhaltsstoffe, die Mineralstoffe und die Spurenelemente, werden durch schonende, normale Hitzeeinwirkung überhaupt nicht, wasserlösliche Vitamine des B-Komplexes und Vitamin C dagegen in gewissen Ausmaß angegriffen.

Alle diese wasserlöslichen pflanzlichen Inhaltsstoffe erleiden jedoch beträchtliche Einbußen, wenn das Koch- oder Blanchierwasser fortgeschüttet wird, was mit Sicherheit im 'Eintopf' ('Quer durch den Garten') nicht geschieht.

Nur hiermit oder durch Mitverwendung von Gemüsebrühen bei der Zubereitung oder durch Dampfblanchieren bei industrieller Konservierung könnte sich der Aufwand werstofferhöhender, abser stark ertragssenkender organischer Düngungsmaßnahmen ernährungsphysiologisch auswirken. Im anderen Fall bleibt nur die Illusion einer besseren Qualität (3, S. 174–182, 187), 16, 17, 18, 19, 20).

REFERENCES

1. Salomon, M. (1972). Natural Foods – Myth or Magic. Assoc. Food & Drug Offic. of the U.S. *Quarterly Bull.* 36: *131–137.*
2. Schuphan, W. (1973). Experimental Contribution to the Problem of Improving the Nutritional Quality of Foods Plants. *QUAL. PLANT. – Pl. Fds. hum. Nutr.*, in press.
3. Schuphan, W. (1965). Nutritional Values in Crops and Plants. Faber & Faber, London.
4. Leverton, R. M. (1973). Nutritive Value of 'organically grown' foods. Commentary. *J. Amer. Dietet. Ass.* 62, No. 5: *501.*
5. Flaig, W., Heiliger, F. & Schmid (1969). C. Organische Stoffe, c) Aminosäuren, in Linser H. Hdb.d.Pflanzenernährung und Düngung 1 Bd. 1.Hälfte, S. 124.

6a. Schuphan, W. (1958). Biochemische Stoffbildung bei *Brassica oleracea* L. in Abhängigkeit von morphologischen und anatomischen Differenzierungen ihrer Organe. Ein Beitrag zur Züchtung von Nahrungsträgern hohen Biologischen Wertes. 1. Teil: Vegetative Organe. *Z. Pflanzenzücht.* 39: *127–186.*

6b. Schuphan, W. (1958). Beziehungen zwischen morphologischen Variationen und biochemischen Veränderungen bei *Brassica oleracea* L. *Naturwissenschaften* 45: *170.*

7. Vetter, H. & Früchtenicht, K. (1973). Abstufung der Nährstoff-Grenzwerte mit steigendem Humusgehalt. *Landw. Forsch.* 26: *1–9.*

8. Holtmeier, H. J. (1968). Das primäre und das sekundäre Magnesium-Mangelsyndrom in 'Ernährungswissenschaften' edited by L. Heilmeyer & H. J. Holtmeier, G. Thieme Verlag Stuttgart.
9. Schuphan, W. (1973). The Significance of Nitrates in Food and Potable Waters. *QUAL. PLANT.- Pl. Fds. hum. Nutr.*, in press.
10. Schwerdtfeger, E. (1969). Die freien Aminosäuren einiger Nahrungspflanzen in Abhängigkeit von ökologischen Faktoren. *Qual. Plant. Mater. Veg.* 18: *152–170.*
11. Schäller, G. (1961). Aminosäuren im Speichel und Honigtau der grünen Apfelblattlaus Aphis pomi deg. *Homoptera. Ent, exp. & appl.* 4: *73–85.*
12. Markkula, M. & Laurema, S. (1967). The effect of amino acids, vitamins, and trace elements on the development of acyrthosiphon pisum Harris (Hom., Aphidiae). *Annales Agriculturae Fenniae* 6: *77–80.*
13. Schuphan, W. (1970). Problematik düngungsbedingter Höchsterträge aus phytochemischer und ernährungsphysiologischer Sicht. *Qual. Plant. Mater. Veg.* 20: *35–64.*
14. Oser, B. L. (1951). Methods for integrating essential amino acid content in the nutritional evaluation of protein. *J. Amer. Dietet. Ass.* 27: *396–402.*
15. Schuphan, W. (1961). Methioningehalt und Eiweißqualität von Blattpflanzen in Abhängigkeit von der Stickstoffdüngung. *Qual. Plant. Mater. Veg.* 8: *261–283.*
16. Schuphan, W. (1973). Nutritional aspects in preparing and processing vegetables and fruit with special reference to experimental and empirical findings in periods of scarcity and oversupply of flood. *QUAL. PLANT.-Pl. Fds. Hum. Nutr.* in press.
17. Schuphan, W. (1971). Ernährungsphysiologische Aspekte bei der Zubereitung und Verarbeitung von Gemüse und Obst unter besonderer Berücksichtigung experimenteller und empirischer Erfahrungen in Mangel- und Überflußsituationen. *Qual. Plant. Mater. Veg.* 21: *45–72.*
18. Hentschel, H. & Overbeck, G. (1971). Experimentelle Ergebnisse über die Änderung des Gehalts an wertgebenden Inhaltsstoffen bei der Zubereitung und Verarbeitung von Gemüse. Mitt. I. Untersuchungsmaterial und technologische Versuchsmethoden. *Qual. Plant. Mater. Veg.* 21: *73–78.*
19. Wedler, A. (1971). dto. Mitt. II. Verschiedene Inhaltsstoffe. *Qual. Plant. Mater. Veg.* 21: *79–95.*
20. Schwerdtfeger, E. (1971). dto. Mitt. III. Eiweiß und Aminosäuren. *Qual. Plant. Mater. Veg.* 21: *97–110.*
21. – (1973). Biologischer Landbau im Meunungsstreit (A discussion between 11 partners). *Bild der Wissenschaft* 10, Nr. 8: *911–925.*
22. Schuphan, W. & Mühlendyck, E. (1974). Fluctuation of yield and nutritional value of crops due to treatments with organic and inorganic fertilizers under different ecological conditions (12 years' experiment, 1960–1972).

Author's address:
Prof. Dr. habil. W. Schuphan
Bundesanstalt für Qualitätsforschung
pflanzlicher Erzeugnisse
Rüdesheimerstrasse 12–14
D 6222 Geisenheim/Rh.
B.R.D.