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INSTITUTE FOR FOREST ECOLOGY UNIVERSITY FOR PEDOLOGY

RESEARCH REPORT 2/1992

ENVIRONMENTAL COMPATIBILITY OF BACTOSOL

FOR USE ON GOLF GREEN

Summary report on
field tests in 1990 and 1991

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ENVIRONMENTAL COMPATIBILITY OF BACTOSOL WHEN USED ON GOLF GREENS

A comparison of organic and artificial fertilisers

Summary report on field tests 1990/1991

1. Objective

The object of the tests was to determine the nutrient discharge, particularly the nitrate and ammonium discharge, with seepage water from grass surfaces under open land conditions after treatment with BACTOSOL in comparison with conventional fertilisers. The findings and data obtained in this way were to be used as the basis for assessment of the environmental compatibility (groundwater contamination) of various fertiliser when used on sports fields and golf greens and to provide indication of the possibilities for environmentally sound application of BACTOSOL for utility grass areas and ski slopes.

2. Method

2.1 Test area

A golf green was specially planted for this project in spring 1990 by G.G. Hauser Golf Comp., Erlaaerstraße 97, 1223 Vienna (Austria). The green consisted of equal sectors of 20 m² each separated by plastic sheets. The substrate consisted from top to bottom of 20 cm quartz sand, 10 cm gravel, an 8 cm drainage pipe, and a water-impermeable plastic sheet separating the sectors from each other (figure 1). The drainage pipes were laid with a slight gradient emptying into collection pits in which were installed seepage water tanks with calibrated overflow and smple separator with a capacity of 55 litres to the overflow and an overflow canister of 27-litre volume. In the middle of the green a sprinkler was installed. To determine the outdoor precipitation a simple rain gauge was installed in order to correct any excessive over- or under-estimates of the rainfall. In addition, a precise record was kept of artificial watering and plant protection measures.

The fertiliser composition can be seen from table 1. The pure nutrient application during the two vegetation periods (1990 and 1991) is shown in table 2.

Table 1: Main nutrient contents of fertilisers used

FERTILISER	%N	%P	%K	%Mg
BACTOSOL	8.0	2.5	4.0	1.5
RASENFLORANID	19.6	2.2	7.4	1.2
VOLLKORN, spez.	15.6	2.1	10.4	1.5

The grass was sown on 11 April 1990. Germination took place in all sectors equally on 25 April 1990.

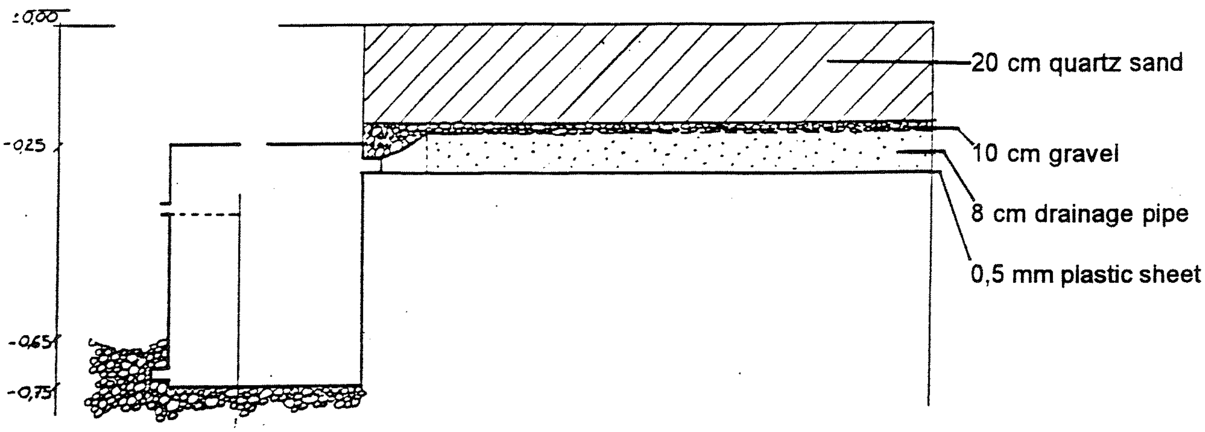


Figure 1: Cross-section of green sector

Table 2: Total nutrient application in g/m² during the two vegetation periods (1990 and 1991)

FERTILISER	N 1990/91	P 1990/91	K 1990/91	Ca 1990/91	Mg 1990/91
BACTOSOL	88	27.5	44.0	66.0	16.5
RASENFLORANID	76	8.4	28.1	6.7	4.6
VOLLKORN spez.	90	12.2	60.3	14.0	8.8

2.2 Grass growth, nutrient content and soil analyses

To audit the nutrient flows (nutrient extraction) through grass cutting the grass sectors were cut from 14 May to 28 October 1990 and from 14 May to 29 October 1991 dependent on the sward growth using a metal frame with defined area of 0.09 m² and electric shears. The grass samples were collected with the aid of a wet vacuum cleaner and dried to constant weight at 105 °C.

The surface cut-grass masses were determined weekly in 1990 and fortnightly in 1991 and grass samples ground to < 0.5 mm and prepared for analysis.

In May and November 1991 five soil samples per sector were taken from the top 20 cm (quartz sand down to the gravel) by means of a digging cylinder. The grass roots were isolated from the substrate, washed with deionised water and then treated like the surface grass samples.

The following chemical analysis procedures were used:

- **total nitrogen** as per Kjeldahl
- **sulphur** by LECO sulphur analysis through incineration in oxygen stream and measurement by means of an infra-red detector of SO_2 given off
- **phosphorus, potassium, magnesium and sodium**: wet ashing of 500 mg oven-dried, ground samples with nitric acid/perchloric acid mix at 200 °C; phosphorus determined by flow-injection spectrometry, metals by AAS
- **chloride** (only surface biomass): 1000 mg oven-dried, ground sample was shaken with a mixture of 0.1 M nictric acid and 10 % glacial acetic acid and then filtered; chloride determination by titration with silver ions produced by coulometry and measurement of ammetric end-point display by means of AMINCO chloride titrator

The following chemical parameters were examined in the test substrate:

- **pH**: by electrometry in suspensions of fresh soil material in 0.01 m $CaCl_2$and deionised water
- **carbon**: WÖSTHOFF CARMHOMAT ADG 8 by incineration of oven-dried samples in oxygen stream and determination of CO_2 given off by conduction measurement
- **total nitrogen** and **total phosphorus** were determined in the organic material
- **potassium, calcium, magnesium and sodium available to plants** in 0.1 m $BaCl_2$ buffered to pH 8.2 were poured over 5 g air-dried soil, the sample left standing overnight, shaken the following day for 2 hours and then filtered; cations determined by AAS
- **chloride**: air-dried soil was shaken with 0.1 M HNO_3 and filtered; chloride determination as for organic material
- Fresh soil material was extracted with deionised water from soil samples acquired in November 1991 to determine the nitrate and ammonium nitrogen contents (see seepage water sample method).

2.3 Quantity assay and chemical examinations of seepage water

Samples were taken every week of the seepage water collected with the aid of the collection equipment (for precise description see research report 4/1991).

The water level in the collection and overflow tanks was measured and the weekly amount of seepage water determined using a conversion table. The samples were pumped from the collection and overflow tanks and the tanks completely vacuumed every week. On arrival at the laboratory the samples were filtered immediately through 0.2 µm filters and stored until analysis at 4 °C.

- **pH**: by eletrometry
- **potassium, calcium and sodium concentrations** by AAS
- **chloride, nitrate and sulphate concentrations** by liquid chromatography using a DIONEX ion chromatograph
- **ammonium concentrations** following gas diffusion by colorimetry through flow-injection analysis (FIA from TECATOR)

To verify all readings obtained at the institute, reference samples from the Sample Exchange Programme of Wageningen Agricultural University were also analysed.

3. Results

3.1 Grass and soil samples

Figure 2a shows the cumulative development of the dry grass masses per m² for the different treatments during the 1991 vegetations period from May to October.
Figure 2b shows the annual totals of surface dry matter harvested by cutting in g/m² for the various fertilisers and the 1990 and 1991 vegetation periods.
In figure 3a the root distribution with soil depth and total dry root masses for the different fertilisers are shown, while figure 3b shows the dry root masses in the top 20 cm in g/m² on sampling in May and November 1991.
Figure 3c gives the nitrogen distribution, and figure 3d the carbon distribution in the top 20 cm of the soil sectors with different fertilisers.
Table 3 summarises all nutrients readily available to plants ($BaCl_2$ / water-extractable) in the top 20 cm of the sector substrates with different fertilisers.

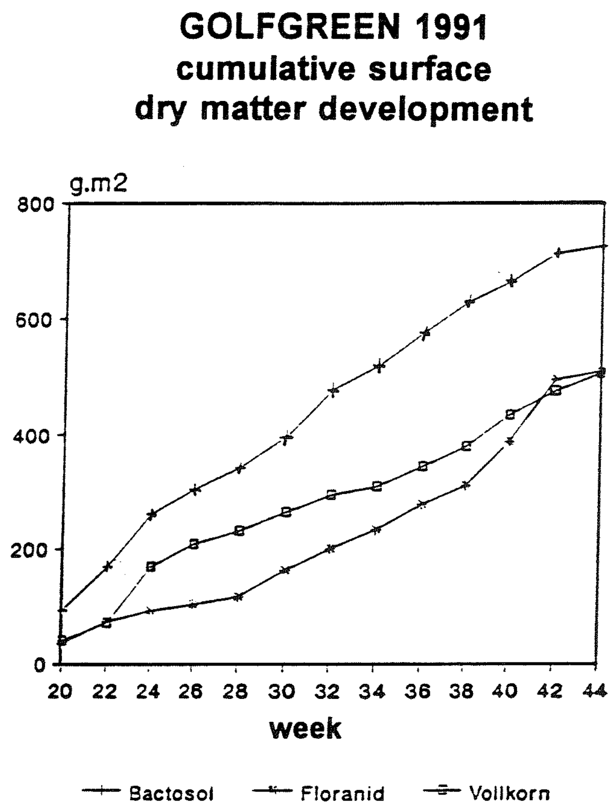


Figure 2a: Cumulative dry matter development in g/m² dry matter for sectors treated with different fertilisers in the 1991 vegetation period (May to October)

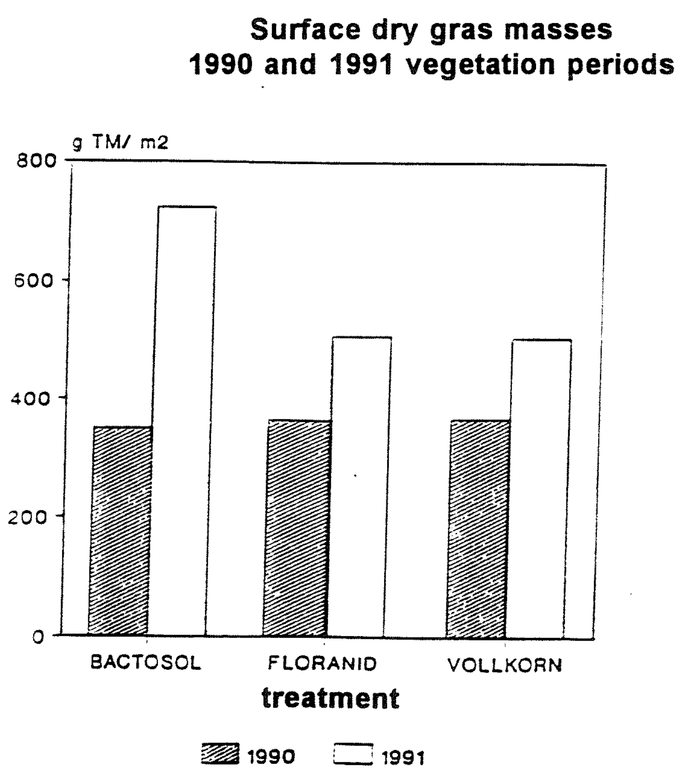


Figure 2b: Cut grass totals in g/m² dry matter for sectors treated with different fertilisers in the 1990 and 1991 vegetation periods (May to October)

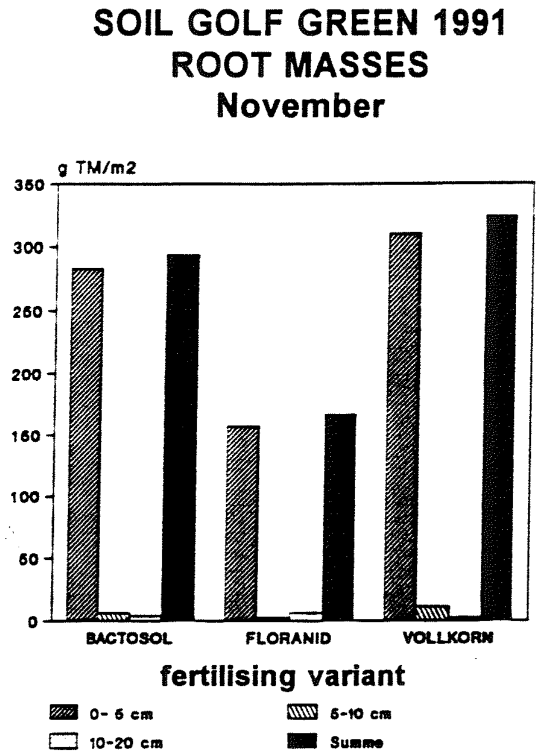


Figure 3a: Root masses (dry matter in g/m²) at different soil depths and as total for 20 cm soil depth, November 1991 harvest

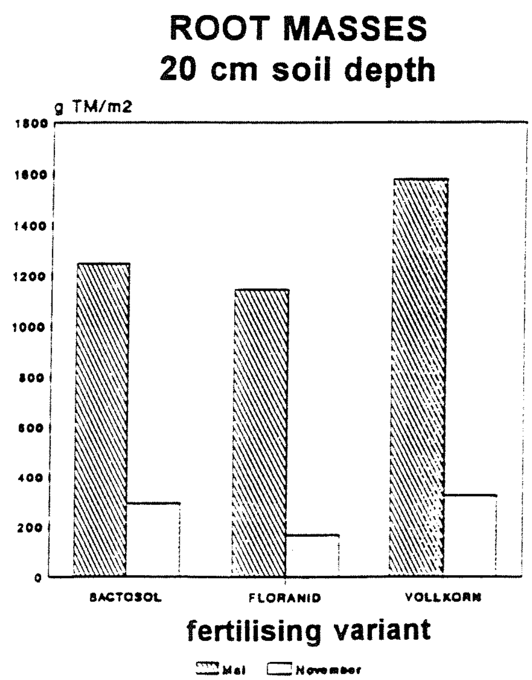


Figure 3b: Comparison of root masses in top 20 cm soil in g/m² on sampling in May and November 1991

SOIL GOLF GREEN 1991
NITROGEN MASSES

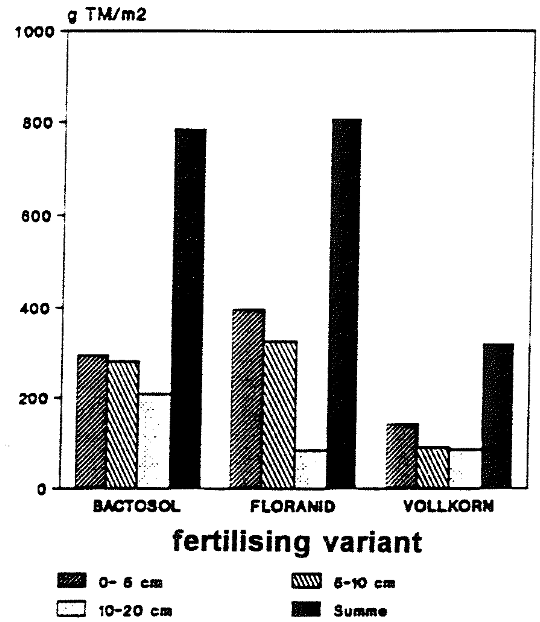


Figure 3c: Nitrogen masses (g/m² N) at different soil depths and as total for 20 cm soil depth, November 1991 harvest

CARBON MASSES

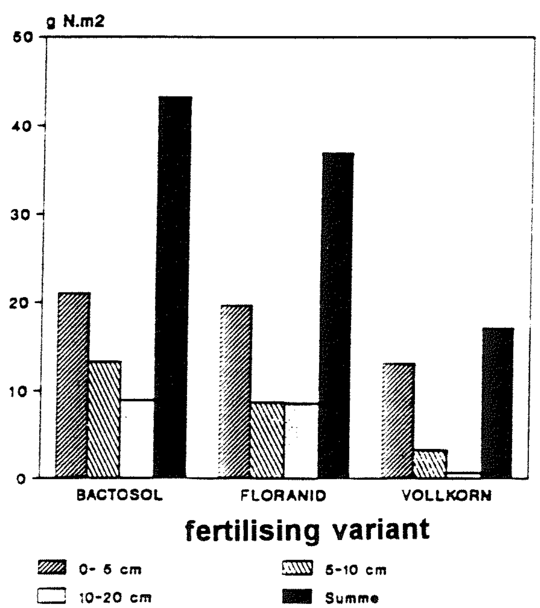


Figure 3d: Carbon masses (g/m² N) at different soil depths and as total for 20 cm soil depth, November 1991 harvest

Table 3: **Nutrient masses (g/m²) in the top 20 cm of sector substrates with different fertilisers in November 1991 using different determination procedures**

DÜNGER	Gesamt			BaCl2-extrahierbar				
	g C/m2	g N/m2	g P/m2	g K/m2	g Ca/m2	g Mg/m2	g Na/m2	g Cl/m2
BACTOSOL	784,85	43,21	59,44	9,53	470,29	19,94	5,62	4,31
FLORANID	807,22	36,95	42,50	5,91	459,70	41,70	5,79	3,60
VOLLKORN	318,93	17,17	71,08	19,45	631,66	48,15	7,62	2,35
	Wasser-extrahierbar							
		g NO3/m2	g PO4/m2	g K/m2	g Ca/m2	g Mg/m2	g Na/m2	g Cl/m2
BACTOSOL		nbb.	1,57	4,56	30,41	4,71	6,39	3,27
FLORANID		nbb.	0,68	4,31	31,71	4,62	5,93	3,06
VOLLKORN		nbb.	1,15	8,29	32,80	3,89	4,61	2,05

Figure 4 shows the nutrient content in % of the dry root mass in May 1991.

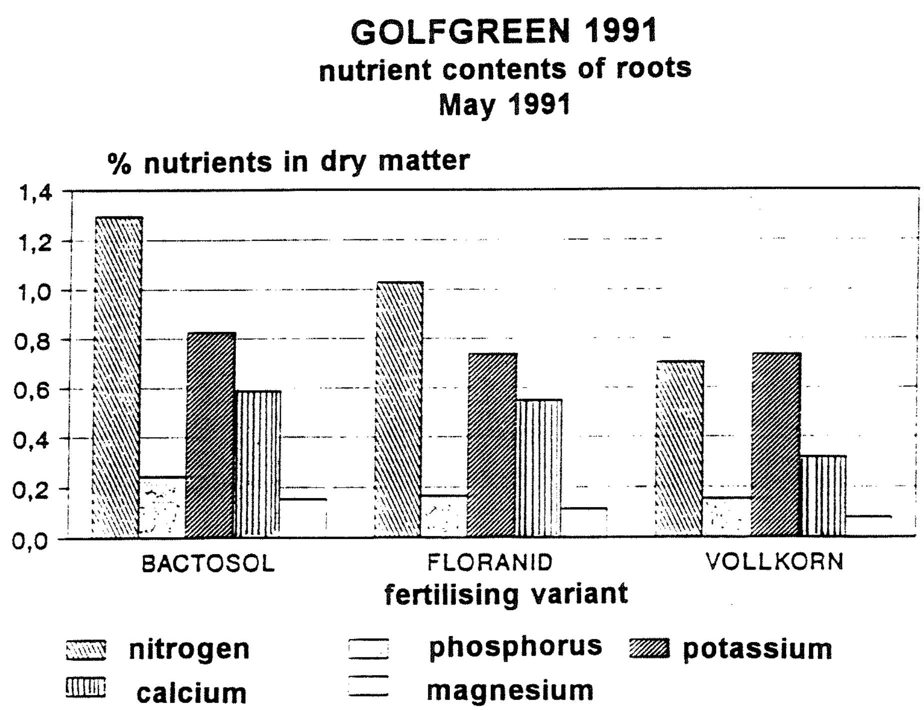


Figure 4: Nutrient content in % of the dry root mass in May 1991

Figures 5a and 5b show the mean nutrient content of the cut grass in g/kg surface dry matter in the 1990 and 1991 vegetation periods.

Table 4 shows the nutrient extraction with the cut grass in the 1990 and 1991 vegetation periods.

GOLF GREEN 1990 / 91
mean nutrient content of cut grass

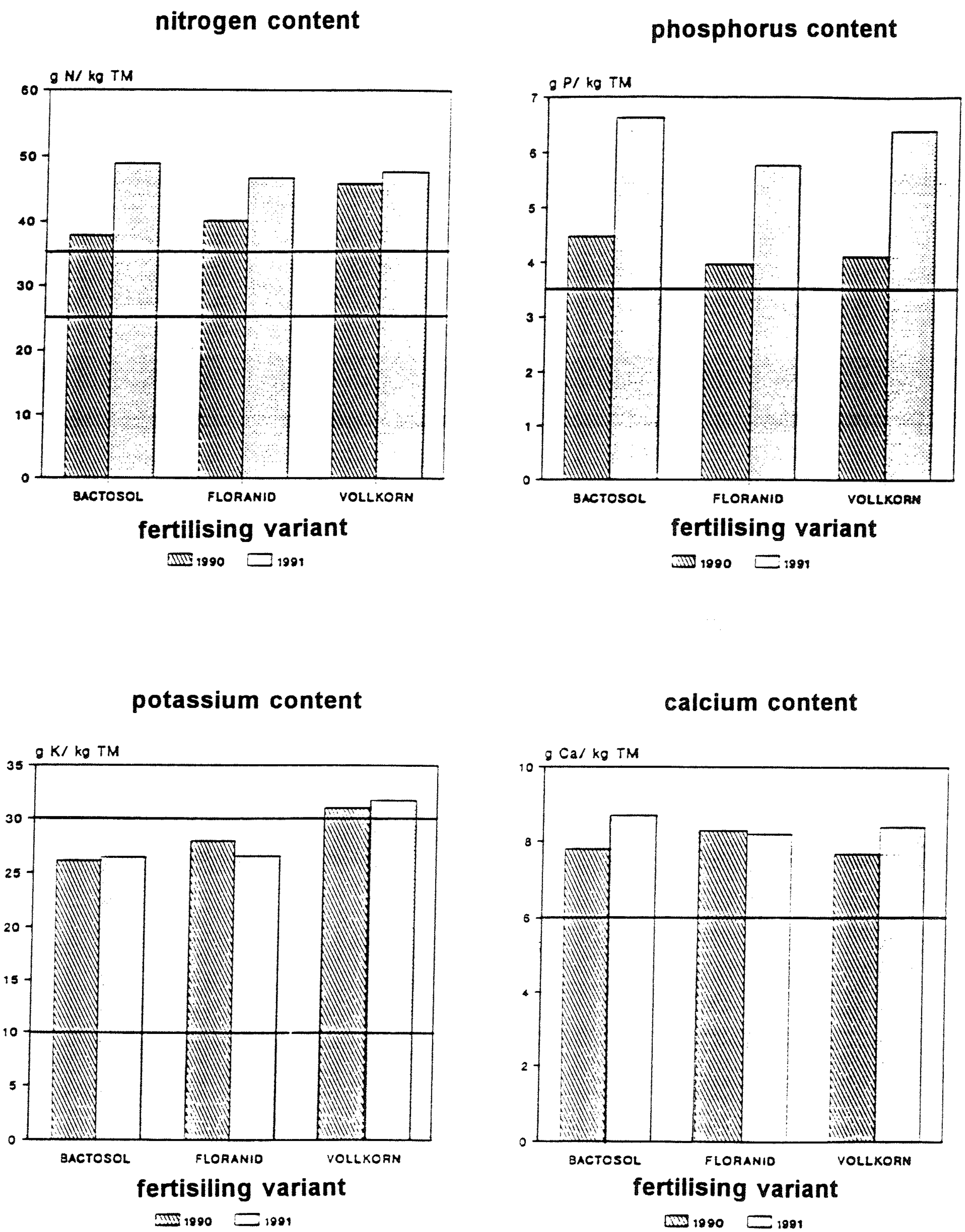


Figure 5a: **Mean annual nutrient content of cut grass in g/kg dry matter in 1990 and 1991 vegetation periods. The limit values for adequate supply and surplus supply are entered (reference book of Austrian Fertiliser Advice Centre, 1991)**

GOLF GREEN 1990 / 91
mean nutrient content of cut grass

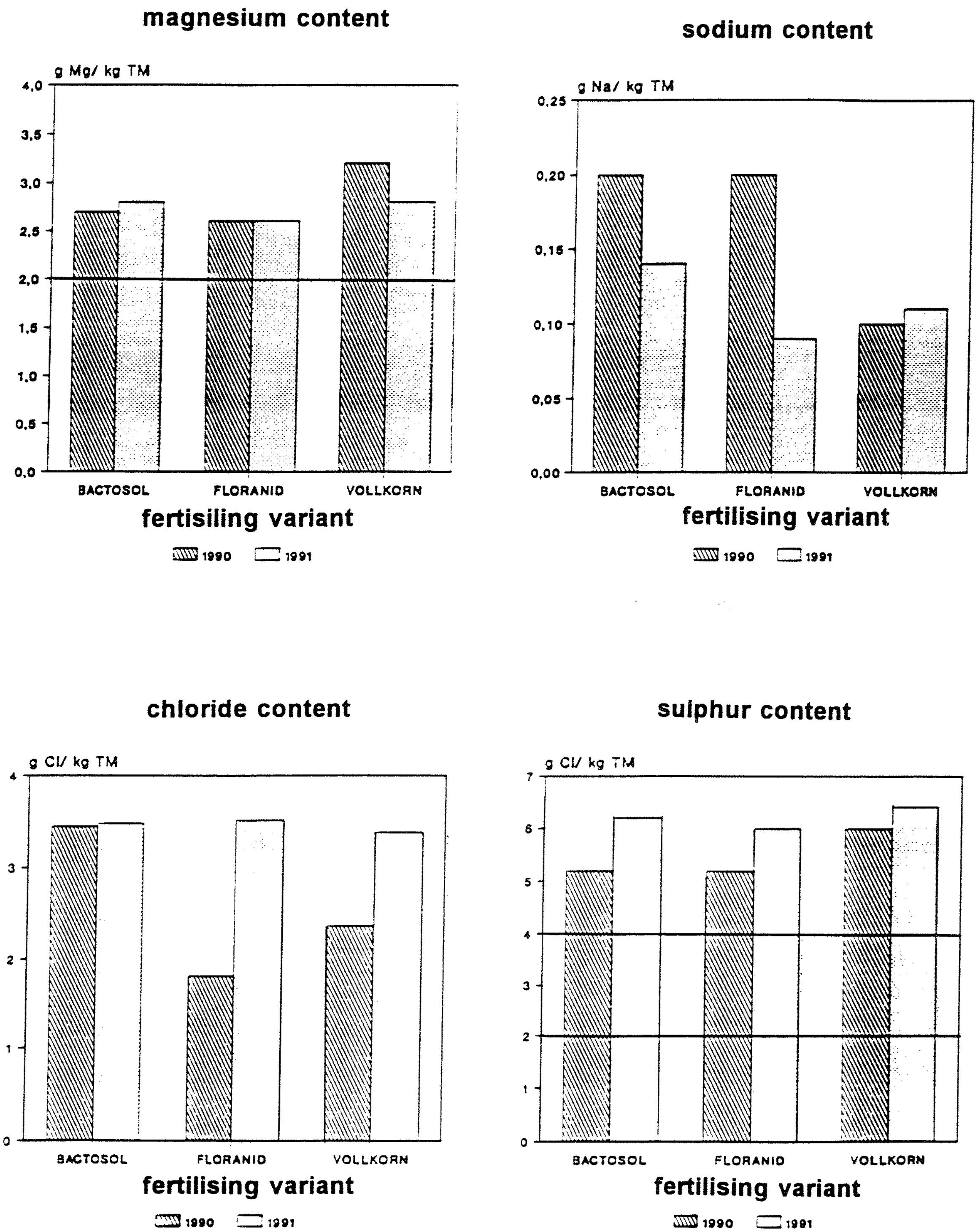


Figure 5b: Mean annual nutrient content of cut grass in g/kg dry matter in 1990 and 1991 vegetation periods. The limit values for adequate supply and surplus supply are entered (reference book of Austrian Fertiliser Advice Centre, 1991)

Tabelle 4: **Nutrient extraction with cut grass in g/m² in 1990 and 1991 vegetation periods.**

DÜNGER	Jahr	TMg/m2	g N/m2	g P/m2	g K/m2	g Ca/ m2	g Mg/m2	g Na/m2	g Cl/m2	g S/m2
	1990	350	13,23	1,57	9,14	2,73	0,95	0,07	1,20	1,82
BACTOSOL	1991	723	32,35	4,78	19,12	6,29	2,04	0,10	2,52	4,47
	1990	365	14,64	1,45	10,18	3,03	0,95	0,07	0,66	1,90
RASENFLORANID	1991	509	23,77	2,94	13,47	4,18	1,31	0,05	1,79	3,07
	1990	367	16,81	1,51	11,38	2,83	1,17	0,04	0,87	2,20
VOLLKORN spez.	1991	506	24,12	3,24	16,03	4,25	1,41	0,06	1,71	3,24

3.2 Seepage water samples

Figure 6 shows a comparison of the seepage water volume measured in the differently treated sectors for the 1990 and 1991 vegetation periods. Figure 7 to 10 show the development of the cation and anion contents in seepage water in the variously fertilised grass sectors in mg/l for the 1991 vegetation period. Figure 11 and 12 show the total amounts of substance discharged with the seepage water in the 1990 and 1991 vegetation periods.

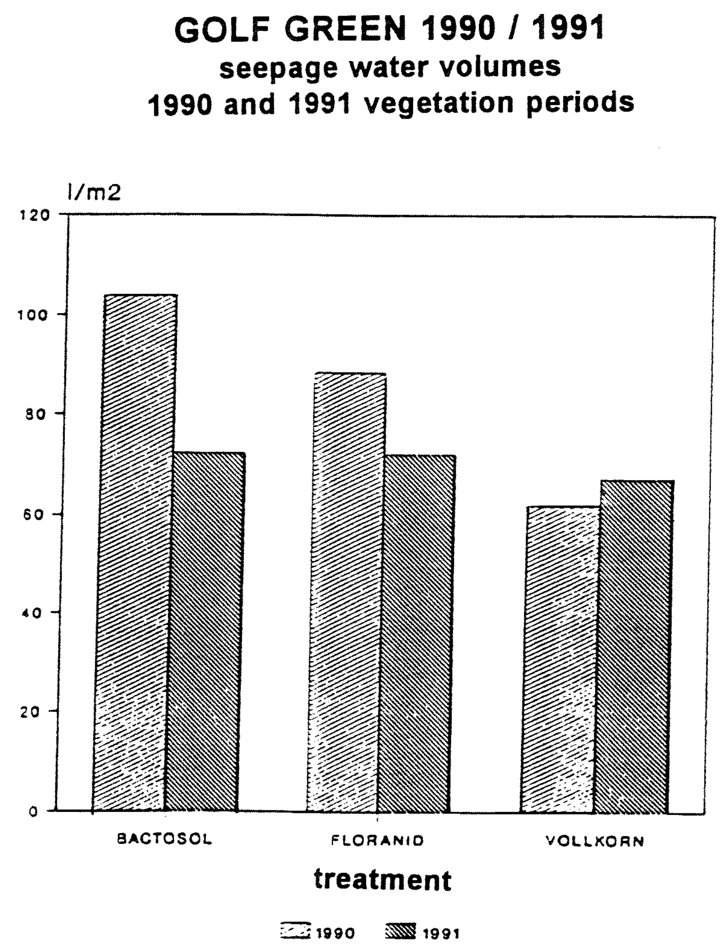
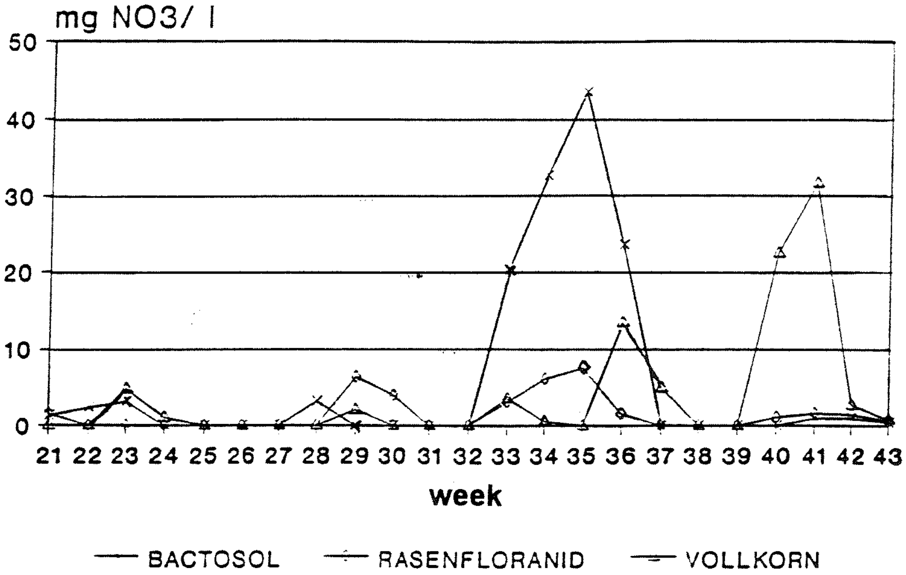


Figure 6: **Seepage water volumes in l/m² measured in the differently treated sectors for the 1990 and 1991 vegetation periods.**

GOLF GREEN 1991
NITRATE CONTENT IN SEEPAGE WATER



AMMONIUM CONTENT IN SEEPAGE WATER

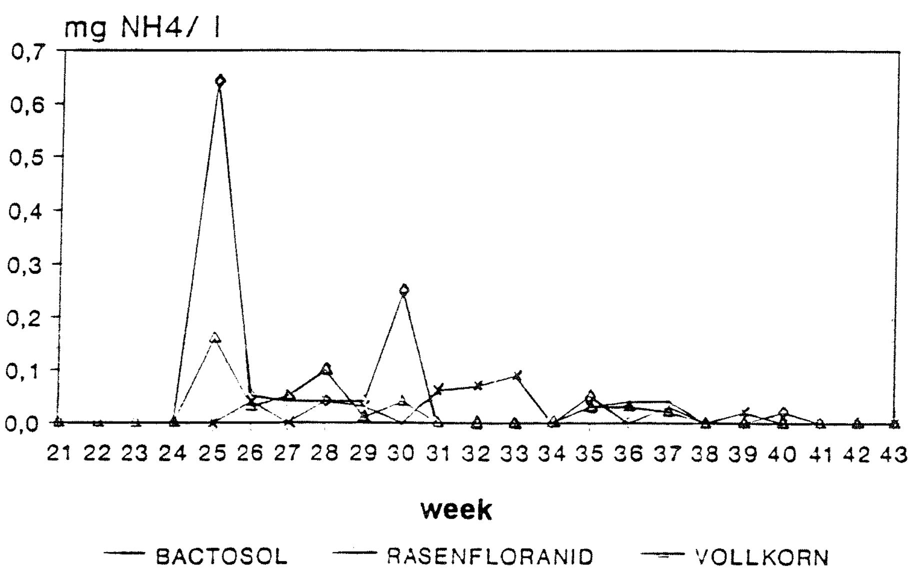
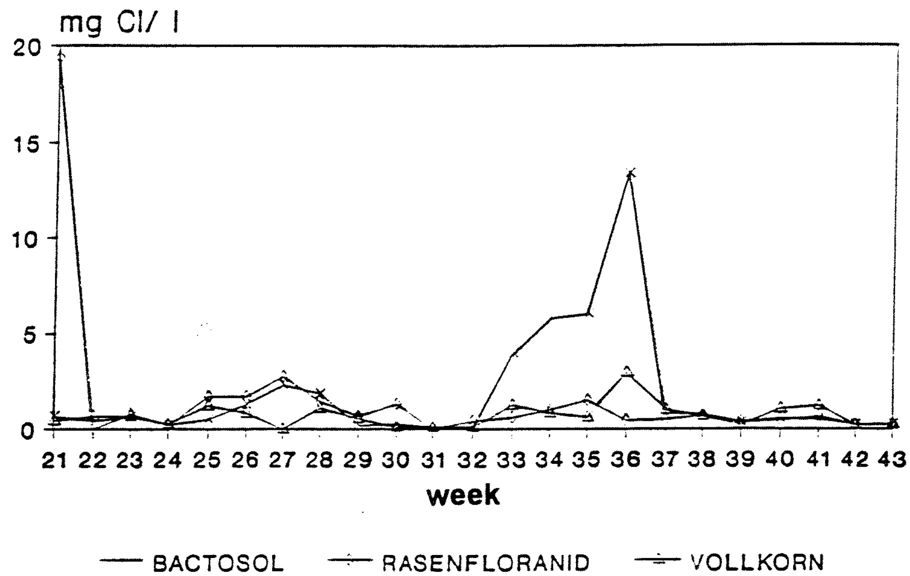


Figure 7: **Nitrate and ammonium content in seepage water in mg/l in 1991 vegetation period.**

GOLF GREEN 1991
CHLORIDE CONTENT IN SEEPAGE WATER



SULPHATE CONTENT IN SEEPAGE WATER

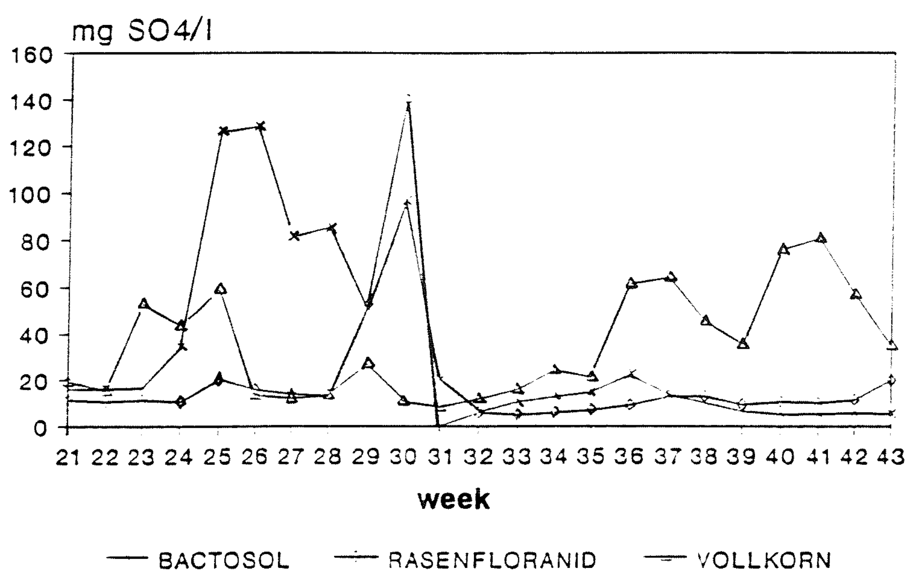
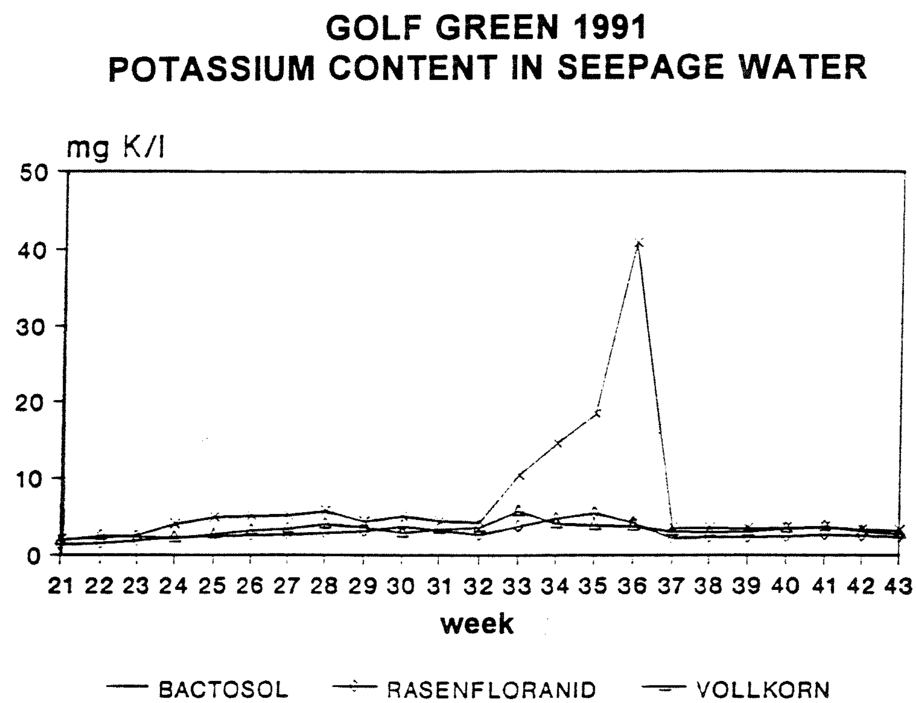


Figure 8: **Chloride and sulphate content in seepage water in mg/l in 1991 vegetation period.**



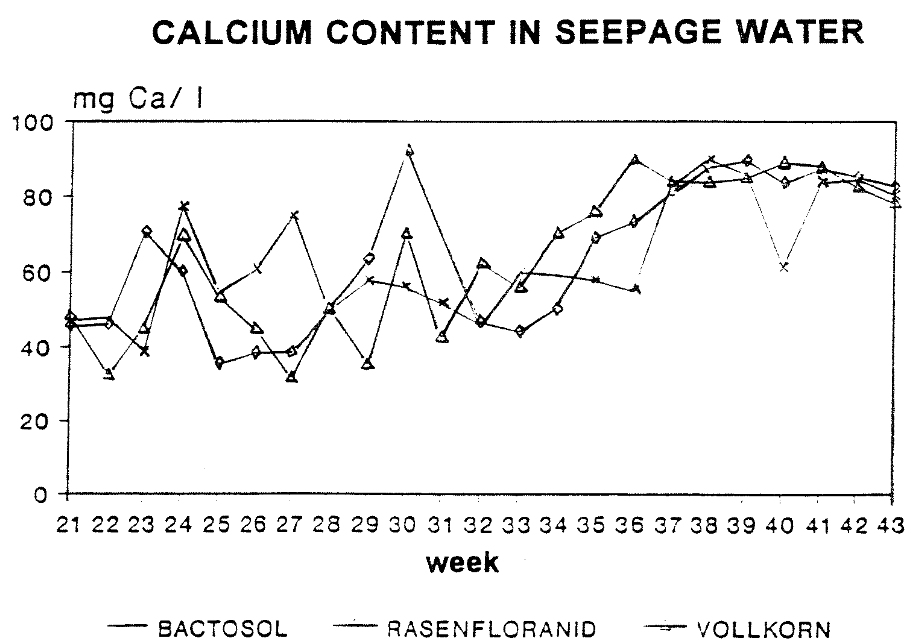
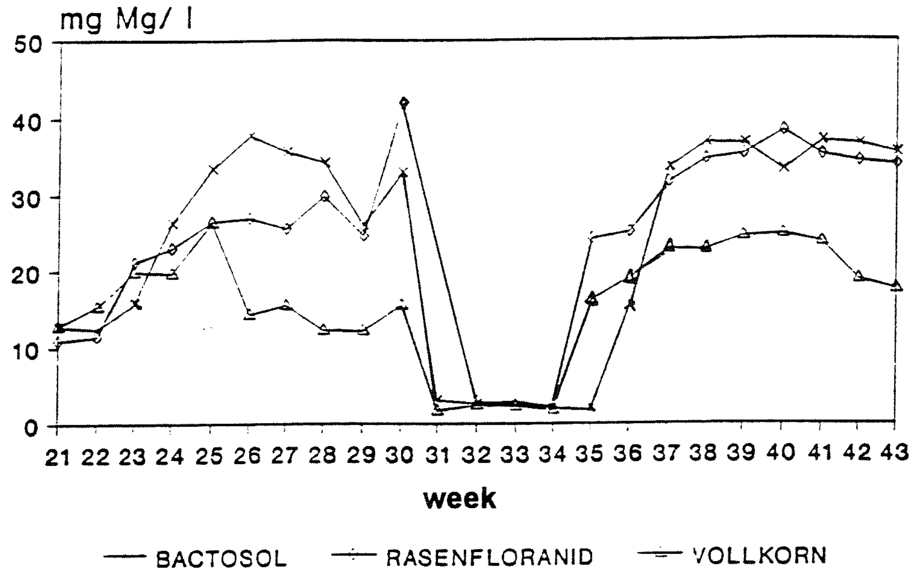


Figure 9: **Potassium and calcium content in seepage water in mg/l in 1991 vegetation period.**

GOLF GREEN 1991
MAGNESIUM CONTENT IN SEEPAGE WATER



SODIUM CONTENT IN SEEPAGE WATER

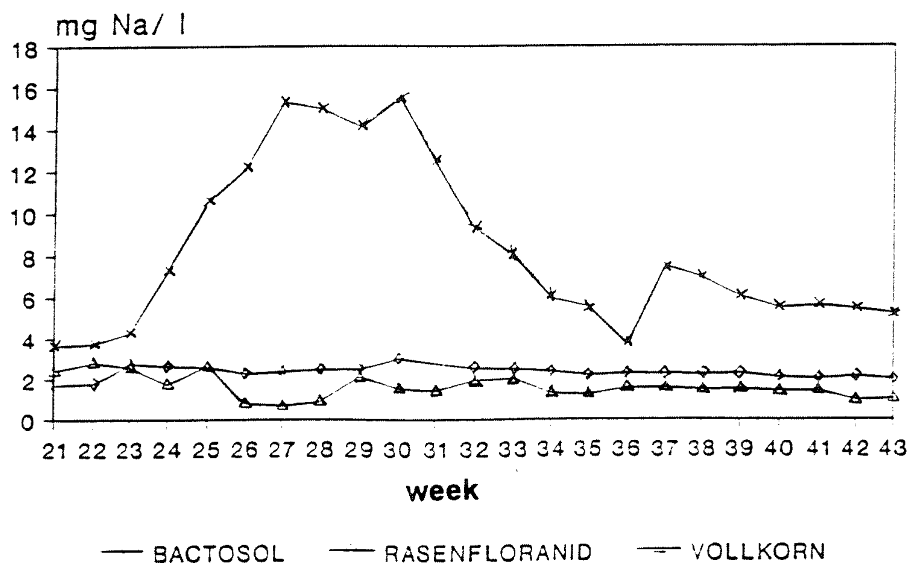


Figure 10: **Magnesium and sodium content in seepage water in mg/l in 1991 vegetation period.**

GOLF GREEN
1990 and 1991 vegetation periods

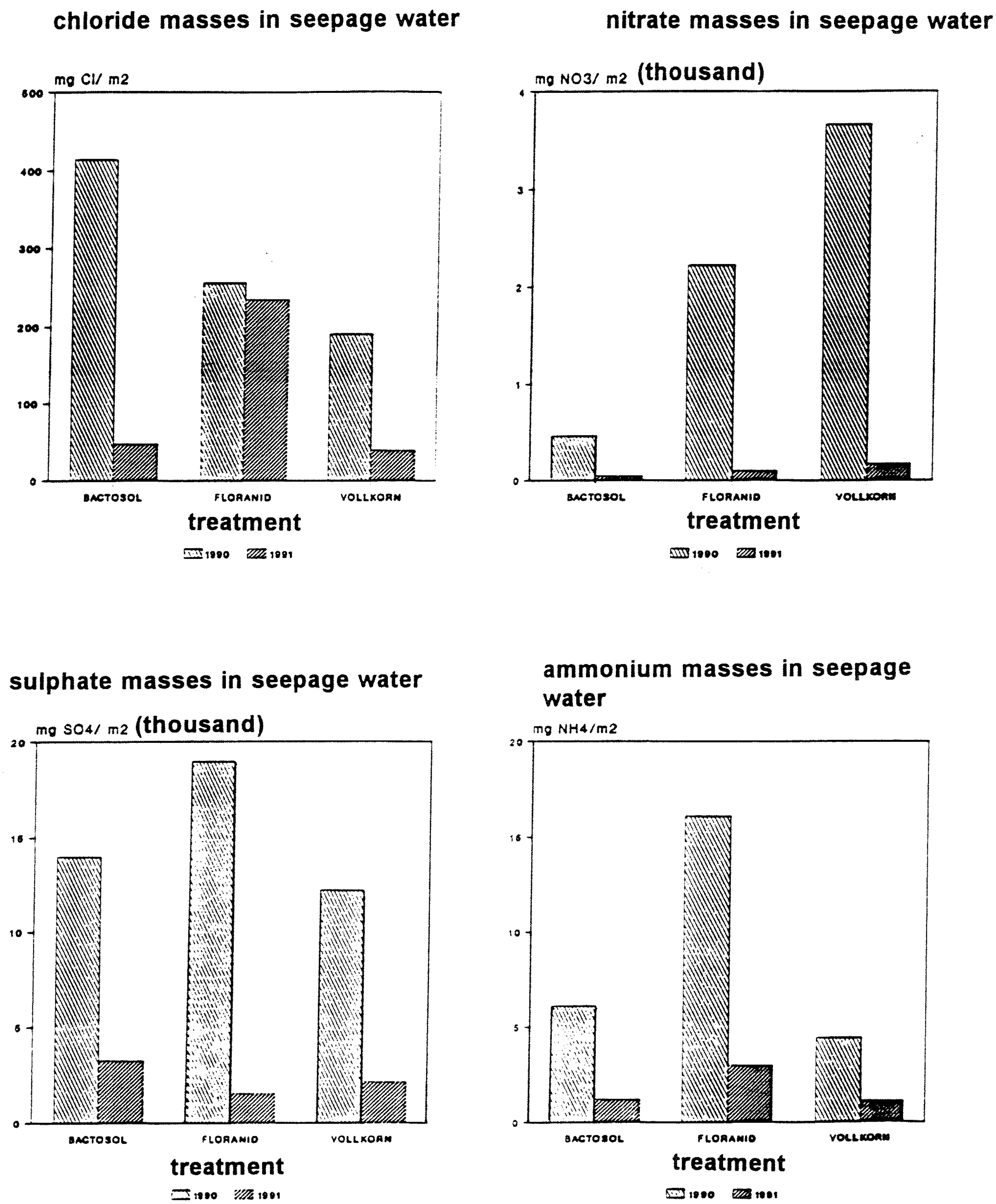


Figure 11: **Annual anion totals in seepage water in mg/m² in 1991 vegetation period.**

GOLF GREEN
1990 and 1991 vegetation periods

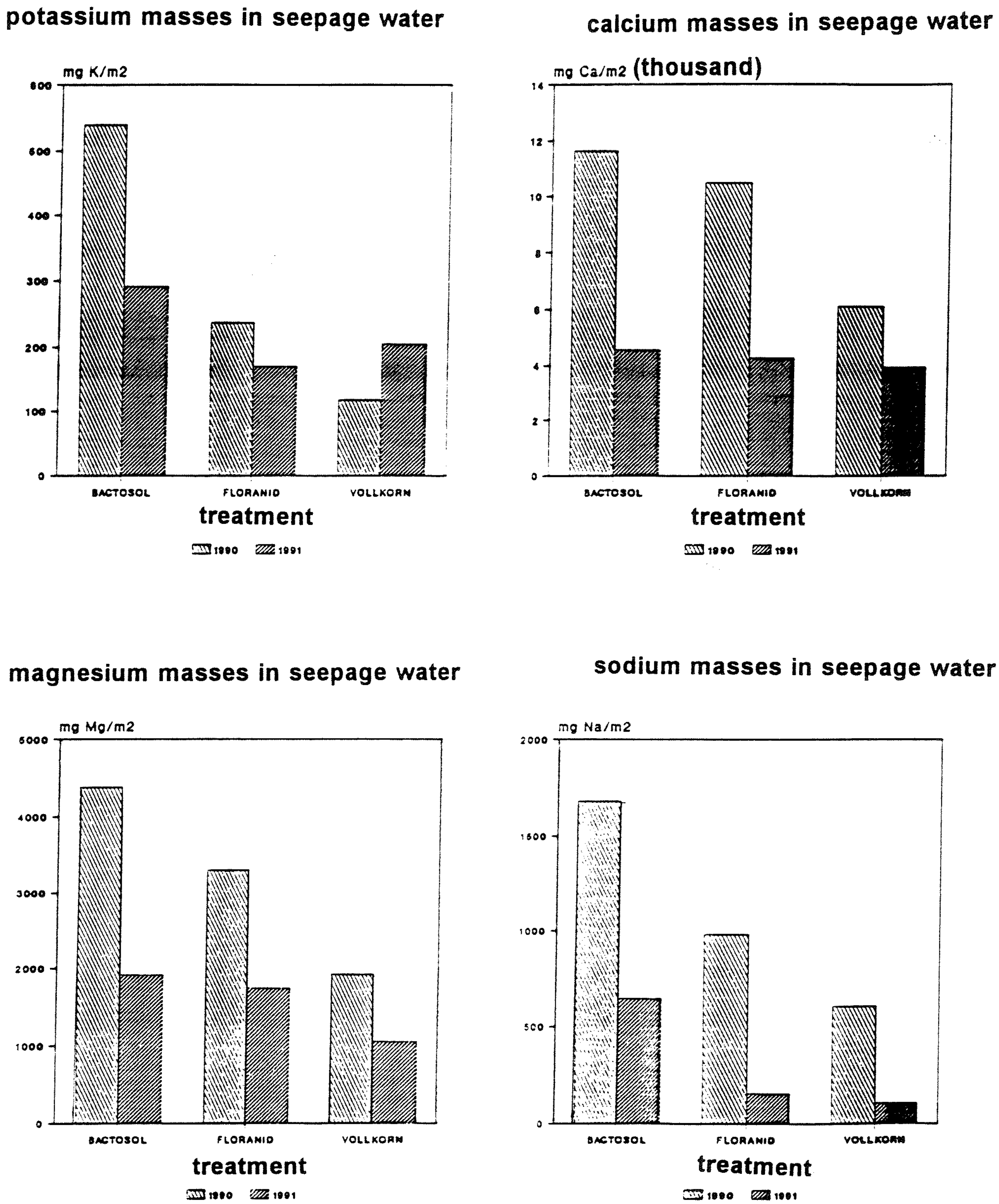


Figure 12: Annual cation totals in seepage water in mg/m² in 1991 vegetation period.

4. Discussion of results

The dry matter developments for 1991 summarised in figure 2a for grass sectors treated with the same amount of nitrogen (ef. table 2) but different fertiliser qualities show the surface biomass developed continuously during the 1991 vegetation period. The grass sector fertilised with BACTOSOL achieved the highest surface dry matter production of over 700 g/m² while the values for the sectors treated with FLORANID and VOLLKORN spezial were 100 g/m² less on average. The cut masses obtained are comparable with those cited in the relevant literature (ef. SKIRDE, 1972, 1947 and 1976, MEHNERT and MÄDEL, 1982). The values for all types of fertilisers are much higher than those for 1990 (figure 2b) which would appear to indicate that genuine consolidation of the grass sectors does not take place until the second vegetation period.

The fact that BACTOSOL produced the best comparative growth results is at oods with the date published by SKIRDE (1989) where grass surfaces treated with BACTOSOL showed less grass growth and smaller root masses than those treated with FLORANID.

Figures 3a and 3b summarise the root masses for the top 20 cm of the grass sectors in May, a time of very high root masses (ef. SKIRDE, 1972). The highest mass was achieved in the VOLLKORN sector, followed by BACTOSOL and then by FLORANID.

More than 95 % of the root masses was in the top 5 cm of soil. In absolute terms therese values are only one tenth to one third of those reported elsewhere (BOEKER, 1978, HEMMERSBACH, 1983, NONN, 1988) although is should be take into account that as subsurface biomass production is dependent on the grass mixture used and the survival of the grass surface, these values are of restricted utility for comparison purposes. SKIRDE (1977), for example, observed an increase in dry root mass and a shift in the depth of the root horizon more than three years after the original planting. The ratio between surface and subsurface dry matter is as follows: BACTOSOL 2,5 : 1; FLORANID 3,1 : 1; VOLLKORN 1,6 : 1. In other words there is an evident shift towards the surface in the BACTOSOL and FLORANID sectors, no doubt due to the newness of the grass area and the abundant nutrient supply.

The fertiliser quality apparently has an effect on the survival of the roots as well (e.f. figure 3b). Thus 17,7 % of the dry root mass which had been present in up to 20 cm soil depth in May still survived in November in the BACTOSOL sector, compared with 10,9 % in the FLORANID sector and 15,4 % in the VOLLKORN sector.

The highest nitrogen levels in the substrate were found in the soil sector treated with BACTOSOL. This would appear to indicate that with good grass growth and low nitrate contamination of the seepage water (see next section) the organically bound nitrogen release is ecologically acceptable. The nitrogen level in the substrate was nevertheless only one fifth of that found in older sport fields. The small amount of organic substance in the test substrate is obviously one of the contributing factors here (RIEM VIS, 1976). Figures 3c and 3d show an apparent link between carbon and nitrogen.

The soil values listed in table 3 clearly reflect the effect of fertiliser although there were considerable differences between the cation masses extracted with water and barium chloride. For example, 50 % of the potassium was available in water-extractable form compared with less than 10 % for calcium. It is encouraging to note that no measurable nitrates were found in the water extract with any of the fertilisers and phosphate levels were also low.

With regard to the nutrient content of the roots in May 1991, as shown in figure 4, the highest levels were achieved for all measured elements with BACTOSOL.

As to the average element levels in cut grass (figure 5), nitrogen, phoshorus and calcium increased from 1990 for 1991 in all sectors. Although the potassium and magnesium levels did not develop with the same uniformity, the average absolute values were all within or in excess of the limit values for adequate supply in the reference book published by the Austrian Fertiliser Advise Centre (1991) (ef. MÜHLSCHLEGEL and MEHNERT, 1974).

The nutrient extracted in g/m² with cut grass (table 4) showed a high reading for the BACTOSOL sector which is clearly linked with the high dry matter production in this sector. In other words the application of the same amounts of nitrogen produced in the same nitrogen levels in teh surface biomass but much greated dry matter production, without significant dilution of other nutrients. Nutrient extraction was generally higher in 1991 than in the 1990 vegetation period. This is attributable to the higher dry matter production and to the higher rate of fertilised nutrient absorption.

This test was carried out essentially to establish the comparative effect on seepage water quality of BACTOSOL as an organic fertiliser, a synthetic organic special grass fertiliser and a conventional rapidly dissolving inorganic fertiliser.

The differences in seepage water volumes were not as marked in 1991 as they had been in 1990 (ef. figure 6) which would appear to indicate that the grass had consolidated and that the drainage and collection tanks were functioning properly.This is somewhat surprising in as much as the same amount of seepage water was registered in all sectors, including the BACTOSOL sector, in spite of the considerably greater dry grass mass production in this sector, so that the water consumption per dry matter unit must have been lower (ef. table 2).

With organic fertiliser, as in 1990 (ef. GLATZEL and SIEGHARDT, 1991), an increase was perceived from August 1991 in the environmentally relevant nitrate anion concentration in seepage water (figures 7 to 10), with the peak being achieved in the second half of the month. With VOLLKORN, on the other hand, the increase does not occur until autumn. This phenomenon is probably due to the massive presence of a nitrifaction population in the soil, with the potassium concentration (as ion partner) and chloride level (as partner for the free H^+) in the seepage water evidently increasing at the same time (ef. figures 8 and 9). The change in the soil population as the sole explanation for this phenomenon is give further credibility by the fact that the increase in nitrate concentrations occured in a period of very little precipitation, when nitrate mobility is very low (ef. TEN ELSEN, 1990).

The nitrate concentrations never achieved the levels observed in 1990, however (GLATEL and SIEGHARDT, 1991).

The high sulphate levels in May and June might be explained by the release of sulphate from the degradation of organic substances and their elution with seepage water. In absolute terms, however, they wer significantly lower in 1991 than in 1990. The extremely small magnesium concentrations in seepage water registered in the 31st and 34th weeks are no doubt attributable to a growth surge (figure 2a) and the resultant increased absorption of this element in the biomass. The higher sodium concentration in the seepage water of the organically fertilised sector is due to the fertiliser composition.

According to the annual totals for amounts of substances extracted with the seepage water, as shown in figures 11 and 12, BACTOSOL had the lowest nitrate values of all types of treatment, with levels in 1991 being just one ninth of the 1990 concentration. Altogether the nitrate content in seepage water was significantly lower in 1991 than it had been in 1990 although nitrogen applications were only slightly reduced. Chloride contamination in the seepage water declined except the FLORANID secotr, the cation extraction was down in all sectors.

The nitrogen balance shown in table 5 confirms the extremely low levels for BACTOSOL compared with conventional fertilisers. The seepage water in the BACTOSOL section was only lightly contaminated with nitrate and ammonium and 48 % of the nitrogen remained in the system. In other words the percentage of fertiliser remaining effective was only slightly inferior to that of the organic/synthetic RASENFLORANID and the inorganic VOLLKORN Spezial, while the seepage water contamination was lower.

As BACTOSOL is an organic fertiliser (approx. 75 % organic substance), i.e. one containing carbon, the danger is much lower than with purely mineral fertiliser of nitrogen compounds in particular entering into the seepage water during the autumn and winter months as a result of the low growth and large amounts of mineralised nutrients occuring through biomass degradation, as these compounds cannot be bound because of the *a priori* low carbon content in the substrate (sand) (RIEM VIS, 1976; SKIRDE, 1973).

Table 5: Nitrogen balance as total for 1990 and 1991 vegetation period (April to October), all figures in g/m²

nitrogen fraction	BACTOSOL	FLORANID	VOLLKORN
NH_4N seepage water	0.01	0.02	0.01
NO_3N seepage water	0.12	0.53	0.23
total N grass mass	45.58	38.41	40.93
total N fertiliser	88.00	76.00	90.00
N remaining in system	48 %	49 %	54 %

In the following table the substances balance as total for the two vegetation periods is shown, all figures being g/m².

Table 6: Substance balance for 1990 and 1991 vegetation periods (April to October), all figures in g/m². (A positive percentage indicates that the fertilised substances remain in the system; a negative percentage indicates input which cannot be explained by fertilising.)

BACTOSOL

ELEMENT	FERTILISER	CUT	SEEP H_20	DIFFERENCE	PERCENTAGE
N total	88.00	45.58	n.a.	42.30	48.1
N sol.	4.40	n.a.	0.12		
P	27.50	6.35	n.a.	21.15	76.9
K	44.00	28.26	0.83	14.91	33.9
Ca	66.00	9.02	15.72	41.26	62.5
Mg	16.50	2.99	6.29	7.22	43.8
Na	4.34	0.17	2.33	1.84	42.4
Cl	6.60	3.72	0.46	2.42	36.7
S	14.66	6.29	3.37	5.00	34.1

FLORANID

ELEMENT	FERTILISER	CUT	SEEP H_2O	DIFFERENCE	PERCENTAGE
N total	76.00	38.41	n.a.	37.06	48.8
N sol.	35.76	n.a.	0.53		
P	8.36	4.39	n.a.	3.97	47.5
K	28.12	23.65	0.41	4.06	14.4
Ca	6.73	7.21	14.77	- 15.25	- 226.6
Mg	4.64	2.26	2.05	0.33	7.1
Na	0.46	0.12	1.14	- 0.80	- 173.9
Cl	1.29	1.92	0.49	- 1.12	- 86.8
S	25.65	4.97	6.85	13.83	53.9

VOLLKORN

ELEMENT	FERTILISER	CUT	SEEP H_2O	DIFFERENCE	PERCENTAGE
N total	90.00	40.93	n.a.	48.84	54.3
N sol.	86.42	n.a.	0.23		
P	12.18	4.75	n.a.	7.43	61.0
K	60.32	27.41	0.32	32.59	54.0
Ca	13.97	7.08	10.06	- 3.17	- 22.7
Mg	8.76	2.58	2.98	3.20	36.5
Na	0.81	0.10	0.71	0.00	0.0
Cl	1.39	2.58	0.23	- 1.42	- 102.2
S	40.72	5.44	4.80	30.48	74.9

In general it would appear that because of the natural organic binding of nutrients and the slow mineralisation occuring as a result in the BACTOSOL sector, good sward growth is guaranteed and seepage water contamination through nutrient discharge remains small.

The slow and long-lasting nitrogen fertilising effect and minimal seepage water contamination can thus be explained by the small amount of readily soluble nitrogen compounds. With chloride as well, most of the substance input with BACTOSOL remained in the system and was not eluted. (It should be pointed out that the irrigation water was apparently very hard and chlorinated and that an appreciable amount of calcium and chloride entered into the system in this way.) At all events the organic binding of minerals had a positive effect on the substance balance.

5. Conclusions

These tests were designed to investigate whether BACTOSOL offers a useful alternative to conventional fertilisers for grass surfaces with account taken of sports requirements (playability, dense and right sward) and also of the demand for minimal environmental contamination through nutrient discharge.

- The sector fertilised with BACTOSOL had the highest cut masses and low nitrate contamination in the seepage water. In other words a higher percentage of fertiliser was invested in the biomass. The synthetic organic fertiliser RASENFLORANID and the inorganic fertiliser VOLLKORN spezial had approximately the same cut mass development.

- With all three fertilisers, the nutrient content of the surface grass mass was within or in excess of the limit for adequate supply.

- The least root development in May was observed in the sector fertilised with RASENFLORANID. The performance of BACTOSOL was only marginally inferior to that of VOLLKORN in this respect. Compared with other utility grass surfaces all values were well below the norm, no doubt due to the recent planting of the grass and the relatively high fertiliser application.

- The nutrient content of the May roots for all determined elements was highest in the BACTOSOL sector.

- BACTOSOL produced much better results than FLORANID special grass fertiliser and VOLLKORN spezial inorganic all-purpose fertiliser in terms of seepage water contamination, nutrient exploitation and biomass production.

- Nitrification surges occured in summer 1990 and 1991 at different times in both the organically fertilised sectors and in the inorganic VOLLKORN sector. Nitrate release peaks of this type tend to occur more frequently after long dry periods because of the high nitrate mobility.

- In general the amount of nitrogen applied appears to have been too high even in the 1991 vegetation period. Adequate supply would probably by provided with 10 to 20 g/m² N.

The seepage water contamination would also be negligible, as rightly demanded in environmental compatibilty studies (ef. DOHMEN, 1989). It should not be forgotten, that besides the main task of minimising environmental contamination, optimised fertilising also help bring about financial savings.

- With low individual doses and higher application frequency equal amounts of fertiliser produce lower nutrient discharge.

- Very late fertiliser application to improve frost resistance could result, particularly with mineral fertilisers, in excessive nutrient elution during vegetative rest and large amounts of precipitation. This danger is less acute with organic, slow-release fertilisers.

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