

EFFECT OF LEGUMES ON SOIL MINERAL NITROGEN AND RESPONSE OF POTATOES TO NITROGEN FERTILIZER

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ABSTRACT

In a long-term field trial red clover and alfalfa were grown once every four years as a main crop and could be regarded as green fallow crops. When the legumes were grown, oats was grown as a reference crop. The effect of the legumes on nitrogen fertilizer requirement and yield of the subsequent potato crops was studied. To obtain an estimate of the amount of nitrate which may leach out, the study included measurements of soil mineral nitrogen.

Beneficial effects of growing red clover and alfalfa compared with oats were a substantially lower nitrogen fertilizer requirement of the subsequent potato crop (67-99 kg N per ha) and much higher tuber yields without nitrogen fertilizer application (up to 15 t/ha). Adverse effects, however, were a somewhat lower tuber yield with the optimum application rate of nitrogen fertilizer and probably heavier leaching losses in the long run.

With respect to nitrate leaching it is concluded that caution should be exercised to use legumes as green fallow crops.

INTRODUCTION

Since 1944 a long-term field trial has been carried out in which legumes are grown once every four years as the main crop. In the intervening three years cash crops are grown. Due to the high costs of inorganic nitrogen fertilizer at the time of the start of the trial, the aim of the research was to provide the cash crops with nitrogen fixed by the legumes. Nowadays, leguminous main crops are not used as organic nitrogen fertilizers due to the very low cost of inorganic nitrogen fertilizers. However, the results of the trial can now be used to investigate whether leguminous crops can be grown as green fallow crops.

Due to grain and sugar surpluses in the EEC there is increasing pressure to take land out of production. Obviously, leaving land fallow creates environmental problems, because nitrogen mineralization of organic matter and nitrification of mineralized ammonium continue. In the absence of a crop the nitrate cannot be taken up and is thus subject to leaching. This can be overcome by growing a cover crop during the fallow period.

In this paper the effect of growing red clover and alfalfa once every four years as green fallow crops on nitrogen fertilizer requirement and yield of potatoes, and on soil mineral nitrogen will be presented.

MATERIALS AND METHODS

Since 1944 a long-term experiment (IB 0004) has been carried out on the experimental farm "Dr. H.J. Lovinkhoeve" of the Institute for Soil

Fertility. The soil type is a heavy loam with an organic-matter content of about 2%. In the experiment red clover (*Trifolium pratense* L.) and alfalfa (*Medicago sativa* L.) are grown once every four years as the main crop without application of nitrogen fertilizer. The legumes are sown in April, mown in June and August, and plowed down in November. In the years when the legumes are grown, oats (*Avena sativa* L.) is grown as a reference crop with eight levels of nitrogen fertilizer. The crop is sown in March and harvested in August. In the other three years winter wheat (*Triticum aestivum* L.), spring barley (*Hordeum vulgare* L.), sugar beet (*Beta vulgaris* L.) and potatoes (*Solanum tuberosum* L.) are grown simultaneously on different parts of the field. The crop rotation is potatoes, winter wheat, sugar beet, spring barley, potatoes, interrupted once every four years by the legumes or the reference crop. Each year eight levels of nitrogen fertilizer are applied to the potatoes, winter wheat, sugar beet and spring barley. The levels of nitrogen fertilizer are associated with the plots. There are three replicates. Soil mineral nitrogen (i.e. nitrate and ammonium) content is measured colorimetrically with a Technicon Autoanalyser (Ris et al., 1981) after extraction with 1 M NaCl or (from 1986 onwards) 1 M KCl.

This paper deals with results obtained in the period 1968-1987, especially with potatoes (cv. Bintje). The nitrogen response curves and the optimum application rates of nitrogen fertilizer are calculated as described elsewhere (Neeteson and Wadman, 1987).

Preliminary results of the trial were published earlier (Grootenhuis, 1977).

RESULTS AND DISCUSSION

In the experimental period under consideration (1968-1987) legumes were grown in 1968, 1972, 1976, 1980, and 1984.

The average nitrogen response curves of the potatoes in the first year after the legumes are shown in Fig. 1. The shape of the nitrogen response curve of potatoes after the legumes was flatter than after oats (Fig. 1) indicating a smaller nitrogen fertilizer requirement after legumes.

Average data on nitrogen fertilizer requirement and potato yields in the first, second, and third year after the legumes are presented in Table 1. In the first year after the legumes the optimum application rate of N fertilizer for potatoes was 67-99 kg/ha lower than after oats, whereas in the second and third year hardly any effect of the legumes on the optimum application rate of N fertilizer was found (Table 1). Tuber yield without nitrogen fertilizer was substantially (up to 15 t/ha) higher after the legumes, even in the second and third year (Table 1). However, the yield at the optimum application rate of nitrogen fertilizer, was somewhat lower than with oats as the preceding crop (Table 1). It is not clear whether this is due to the beneficial effect of oats as a preceding crop or to an unfavorable effect of red clover and alfalfa.

Data on soil mineral nitrogen before and after the winter period in 1984-1987 on plots which did not receive nitrogen fertilizer and on those receiving the highest level of nitrogen fertilizer are given in Tables 2 and 3. On the plots with legumes or oats in 1984, potatoes, winter wheat, and sugar beet were grown in 1985, 1986, and 1987, respectively. In early spring, on plots without added nitrogen fertilizer, the amount of soil mineral N in the 0-60 cm layer was larger after the legumes than after oats, even in the third year (Table 2). It is likely that the larger amount of soil mineral nitrogen, in combination with a faster nitrogen

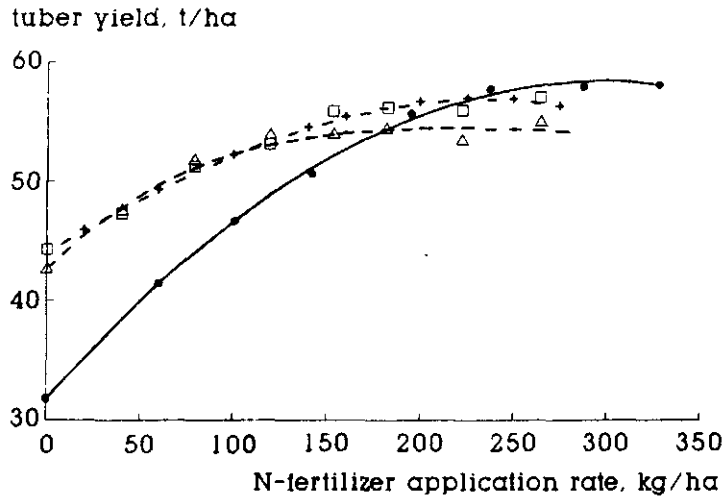


FIGURE 1. Nitrogen response curves of potatoes in the first year after oats, red clover, and alfalfa. The curves are average curves for 1969, 1973, 1977, 1981, and 1985. Trial IB 0004.

—●— = oats, +--+--+ = red clover, - - - Δ - - - = alfalfa

TABLE 1. Average optimum application rate of nitrogen fertilizer (N_{op}), and average tuber yield of potatoes without nitrogen fertilizer ($0N^v$) and with N_{op} in the first, second and third year after oats, red clover, or alfalfa. IB 0004, 1968-1987.

Reference or leguminous crop	Potatoes			
	Year after reference or leguminous crop	N_{op} , kg/ha	Tuber yield, t/ha	
			$0N^v$	N_{op}
Oats	1	285	31.8	58.2
Red clover		218	44.0	56.8
Alfalfa		186	46.6	54.4
Oats	2	237	33.3	52.9
Red Clover		227	38.0	51.0
Alfalfa		239	39.2	50.6
Oats	3	277	29.1	54.6
Red clover		251	36.1	49.9
Alfalfa		258	33.7	53.1

mineralization rate during the growing period, was responsible for the higher tuber yields on plots without application of nitrogen fertilizer (Table 1). When the legumes were plowed down (November 1984 in Tables 2 and 3), the amount of soil mineral nitrogen was (slightly) larger after oats had been grown. The oat crop was harvested two months earlier and it is likely that nitrogen mineralization between harvest of the oats and the plowing down of the legumes increased soil mineral nitrogen in the absence of a crop. In October 1985, however, the amount of soil mineral nitrogen without nitrogen fertilizer was higher after the legumes than after oats, even in the 60-100 cm layer (Table 2). This was also found in November 1986 at the highest level of nitrogen fertilizer (Table 3). The legumes, therefore, probably increased nitrate leaching in the second and third winter period after they were grown, because soil mineral nitrogen which is present shortly before the winter period can be regarded as potentially subject to loss due to leaching in the form of nitrate. Based on his own experiments and on data from the literature on direct measurements of nitrate leaching after legumes, Kolenbrander (1982) indeed concluded that legumes increase nitrate leaching.

TABLE 2. Soil mineral nitrogen before and after the winter period in 1984-1987. Oats (without nitrogen fertilizer), red clover and alfalfa were grown in 1984. Potatoes (1985), winter wheat (1986), and sugar beet (1987) were grown without nitrogen fertilizer. Trial IB 0004.

Date	Soil mineral nitrogen, kg/ha					
	0-60 cm			60-100 cm		
	Oats	Red clover	Alfalfa	Crop 1984 Oats	Red clover	Alfalfa
November 1984	11	11	14	14	10	5
March 1985	15	30	41	5	5	5
October 1985	18	25	32	10	19	24
April 1986	14	28	32	0	14	29
November 1986	22	30	26	10	14	14
March 1987	18	26	26	10	14	19
November 1987	8	4	8	5	5	5

From the results presented here it can be concluded that beneficial effects of red clover and alfalfa used as green fallow crops, compared with oats, are a lower nitrogen fertilizer requirement of the subsequent potato crop and a higher tuber yield without nitrogen fertilizer, the latter even in the second and third year after the legumes. Adverse effects are a somewhat lower tuber yield of the subsequent potato crops at the optimum application rate of nitrogen fertilizer and probably heavier nitrate leaching losses in the long run. With respect to nitrate leaching the results presented here indicate that caution should be exercised in using legumes as green fallow crops. Grass without application of nitrogen fertilizer is probably a better green fallow crop.

TABLE 3. Soil mineral nitrogen before and after the winter period in 1984-1987. Oats (at the highest level of nitrogen fertilizer: 140 kg/ha), red clover and alfalfa were grown in 1984. Potatoes (1985), winter wheat (1986), and sugar beet (1987) were grown at the highest level of nitrogen fertilizer (400 kg/ha for potatoes after oats, 320 kg/ha for potatoes after red clover and alfalfa; 260 kg/ha for winter wheat after oats, 210 for winter wheat after red clover and alfalfa; 320 kg/ha for sugar beet). Trial IB 0004.

Date	Soil mineral nitrogen, kg/ha					
	0-60 cm			60-100 cm		
	Crop			1984		
	Oats	Red clover	Alfalfa	Oats	Red clover	Alfalfa
November 1984	25	14	11	10	5	5
March 1985	18	41	45	10	5	5
October 1985	87	97	79	48	58	67
April 1986	29	43	36	29	38	48
November 1986	41	56	49	24	34	38
March 1987	26	26	30	34	29	34
November 1987	11	15	11	5	5	5

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