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# Effect of nitrogen, phosphorus and potassium fertilisation on herbage yield and quality and plant parasitic nematode populations in an irrigated rhodes grass (*Chloris gayana*) pasture in Oman

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## Abstract

Three fertiliser experiments with rhodes grass for hay production were carried out for more than a year under sprinkler irrigation in an arid environment. The objective was to examine the effects of different levels of major nutrients on dry matter yields and on plant parasitic nematodes. There were 5 N, 4 P and 5 K levels. The dry matter yield response to N was curvilinear with the highest rate of 840 kg/ha/yr N increasing yields from 13 to 53 t/ha/yr. No significant responses to P and K application were recorded. The harvest x N level interaction was non-significant, indicating similar trends in response to 5 N levels over 12 successive harvests. Although high rates of N and K reduced the nematode populations significantly, there was no correlation between these populations and the dry matter yield of pasture. Of the 3 nutrients applied, only N increased N and K concentrations in dry matter, and decreased P%. An application of 120 kg/ha/harvest N is suggested to obtain high dry matter yields in rhodes grass under a cutting regime.


## Introduction

Consequent to the recent increase in demand for meat and meat products in the Arabian Gulf, animal pressure on grazing land has increased enormously (Anon. 1989) and led to rapid degradation of grazing lands. Due to its high dry matter yield, favourable economics of its cultivation, and its superiority over other tropical perennial forage grasses, the cultivation of rhodes grass (*Chloris gayana*) has been increasing over the last few years as an alternative forage to lucerne (*Medicago sativa*) in the Sultanate of Oman (Prakash 1989). It is grown on many farms where it is either fed as a green forage or cut for hay and fed to cattle and goats. The hay is also sold to the nomadic *bedu* tribes to be fed to camels and goats.

The fertiliser requirements of this grass under sprinkler irrigation in the Arabian environment have not been well established, although it is reported to respond to N rates as high as 1200 kg/ha/yr under central pivot irrigation at Marmul in the virgin desert soils, and provide an annual dry matter yield of 35 t/ha (Anon. 1988). Further, little is known of the P and K requirements of this forage in this region, though intensively cultivated soils in northern coastal Oman seem to have moderate amounts of these elements.

One of the beneficial effects of the application of such high levels of N (particularly ammonia N) and K (Sinha 1984; Rodriguez-Kabana 1986; Timans 1990; Castro *et al.* 1991) was a reduction in plant parasitic nematodes in the soil. Information on the possible effects of these nutrients on plant parasitic nematodes and grass, particularly in arid environments, is lacking, particularly from the Arabian environments. Hence, the objective of the experiments reported here was to examine the effects of N, P and K fertilisers on productivity of rhodes grass and associated soil nematodes.

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## Materials and methods

### *Experimental site*

Three trials were laid out at the Agricultural Research Centre, Rumais on the northern coast of the Sultanate of Oman (23 °40 'N, 57 °50 'E in the south-eastern Arabian peninsula) on a calcareous sandy loam soil (Aridiosols with Orthents (USDA 1975); Table 1) in an arid environment. After the removal of citrus plantations in 1984, the site was left fallow until the establishment of the trials in November 1989. The seeds of rhodes grass cv. Callide obtained from Australia were sown on November 29, 1989 at a rate of 12 kg/ha. The meteorological observations during the experimental period are provided in Table 2. The electrical conductivity of irrigation water was 80 mS/cm.

### *Layout*

The trials were laid out in a randomised complete block design, each with 3 replications. The plot size was 5 m × 3 m. Each plot consisted of 9 rows, 5 m in length, with a row spacing of 30 cm. Replications were made perpendicular to the sprinkler lines.

**Table 1.** General soil properties of the experimental field at the Agricultural Research Centre, Rumais.

| Parameter | Value |
|---|---|
| Course sand (%) | 30 |
| Fine sand (%) | 60 |
| Silt (%) | 5 |
| Clay (%) | 5 |
| EC (mS/cm) | 500 |
| pH (1:5 water) | 8.5 |
| Exchangeable Na[1] (cmole ($Na^+$)/kg) | 0.12 |
| CEC (cmole/kg) | 2.60 |
| Available P[2] (mg/kg) | 18.92 |
| Available K[1] (cmole ($K^+$)/kg) | 0.19 |

[1]Method of Ramirez-Munoz (1968).
[2]Method of Bray and Kurtz (1945).

### *Treatments*

*N experiment.* Five N levels (0, 30, 60, 90 and 120 kg/ha N as urea (46% N)) were used at each harvest giving annual rates of 0, 210, 420, 630 and 840 kg/ha N. The basal P and K levels, decided on the results of a preliminary observation trial (Anon. 1985), were 33 kg/ha P and 62 kg/ha K. The complete dose of P and K was banded at 5 cm depth immediately before sowing.

**Table 2.** Maximum, minimum and mean daily temperatures, and monthly rainfall during the experimental period.

| | | | Temperature | | | |
|---|---|---|---|---|---|---|
| Year | Month | Harvest no. | Max. | Min. | Mean | Rainfall |
| | | | | (°C) | | (mm) |
| 1989 | Nov. | | 28.2 | 15.0 | 22.4 | 15.0 |
| | Dec. | | 27.2 | 12.5 | 19.6 | 21.5 |
| 1990 | Jan. | | 26.4 | 13.0 | 20.7 | 28.5 |
| | Feb. | 1 | 28.4 | 16.5 | 21.7 | 42.6 |
| | Mar. | 2 | 32.8 | 17.8 | 23.3 | 0.0 |
| | Apr. | | 35.4 | 18.9 | 29.0 | 0.0 |
| | May | 3 | 38.5 | 24.5 | 33.6 | 0.0 |
| | June | 4 | 43.4 | 28.5 | 33.6 | 0.0 |
| | July | 5 | 44.6 | 29.8 | 34.4 | 0.0 |
| | Aug. | | 42.1 | 25.6 | 29.4 | 0.0 |
| | Sep. | 6 | 38.2 | 24.9 | 29.5 | 0.0 |
| | Oct. | 7 | 32.4 | 22.4 | 28.4 | 0.0 |
| | Nov. | | 29.4 | 17.5 | 22.2 | 0.5 |
| | Dec. | | 28.4 | 14.3 | 19.5 | 8.4 |
| 1991 | Jan. | 8 | 31.5 | 19.4 | 28.3 | 52.4 |
| | Feb. | | 29.4 | 17.4 | 23.4 | 35.4 |
| | Mar. | 9 | 31.5 | 19.4 | 28.3 | 52.4 |
| | Apr. | | 36.4 | 19.2 | 31.4 | 2.0 |
| | May | 10 | 39.5 | 26.4 | 35.2 | 0.0 |
| | June | 11 | 42.4 | 29.2 | 36.2 | 0.0 |
| | July | | 45.4 | 28.6 | 38.5 | 0.0 |
| | Aug. | | 43.4 | 26.4 | 30.2 | 0.0 |
| | Sep. | 12 | 37.5 | 23.5 | 31.5 | 0.0 |

*P experiment.* Four levels of P (0, 33, 66 and 99 kg/ha P) were applied as triple superphosphate (21% P) banded at 5 cm depth before planting. A basal dose of K at the rate of 62 kg/ha K and N (60 kg/ha N after each harvest) was applied.

*K experiment.* Five levels of K (0, 62, 83, 104 and 124 kg/ha K) were applied as potassium sulphate (43% K) before sowing at 5 cm depth. In this trial, each plot received a basal dose of 33 kg/ha P before sowing and 60 kg/ha N after each harvest.

All the plots were sprayed with chelated micronutrients (iron, zinc and copper) after every second harvest. The experiments were irrigated every 4–5 days in winter (September–March) and 2–3 days in summer (April–July) for an average duration of 3 hours, each application amounting to 25 mm/ha. The weeding was done with an inter-row weeder after each harvest.

### Observations

*Dry matter yield.* Twelve harvests were made on February 2–5, March 28–30 (first winter harvests), May 6–7, June 3–4, July 9–10, September 3 (first summer harvests) and October 31, 1990, January 8, March 12 (second winter harvests), May 8, June 22 and September 2, 1991 (second summer harvests). In the first 5 harvests, the whole plots (15 $m^2$ area) were cut at 10 cm height by hand; in subsequent harvests they were mown. Subsamples from each harvest were dried at 70 °C for 4 days for determination of dry matter yields.

*Nutrient composition.* N, P and K concentrations in plant samples were determined following wet oxidation digestion for P and K and Kjeldahl digestion for N (Jones 1988).

*Nematode populations.* Each plot was examined for nematodes by collecting five 3 cm diameter cores of soil to a depth of 20 cm on November 27, 1989 before planting the experiments and again on September 10, 1991. The Cobb's decanting and sieving method (Cobb 1918) and modified Baermann funnel technique (Schindler 1961) were used to extract the nematodes.

## Results

Nitrogen application had highly significant effects on dry matter yield and nitrogen concentrations in rhodes grass (Table 3), but the

**Table 3.** Dry matter yields and nitrogen concentrations in dry matter of rhodes grass in response to 5 nitrogen levels for 12 harvests.

| Harvest date | N level (kg/ha/cut) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 30 | 60 | 90 | 120 | | 0 | 30 | 60 | 90 | 120 |
| | | | (t/ha) | | | | | | (%N) | | |
| 1990 | | | | | | | | | | | |
| Feb. 2–5 | 0.95 | 1.50 | 2.08 | 3.05 | 3.08 | | 1.10 | 1.02 | 1.06 | 1.16 | 1.28 |
| Mar. 28–30 | 0.82 | 1.85 | 2.12 | 3.10 | 3.15 | | 1.12 | 1.02 | 1.07 | 1.17 | 1.30 |
| May 6–7 | 1.50 | 3.58 | 5.24 | 7.52 | 7.54 | | 1.04 | 0.99 | 1.01 | 1.10 | 1.20 |
| June 3–4 | 3.20 | 7.86 | 11.60 | 11.82 | 12.25 | | 1.04 | 0.97 | 0.98 | 1.08 | 1.19 |
| July 9–10 | 3.80 | 7.42 | 9.54 | 11.75 | 12.10 | | 1.04 | 0.94 | 0.99 | 1.08 | 1.20 |
| Sep. 3 | 1.80 | 3.52 | 4.92 | 7.50 | 7.52 | | 1.08 | 1.01 | 1.02 | 1.10 | 1.18 |
| Oct. 31 | 0.52 | 2.42 | 3.54 | 6.56 | 7.35 | | 1.10 | 1.01 | 1.02 | 1.11 | 1.20 |
| 1991 | | | | | | | | | | | |
| Jan. 8 | 0.60 | 1.94 | 3.52 | 5.40 | 6.32 | | 1.12 | 1.00 | 1.08 | 1.15 | 1.30 |
| Mar. 12 | 0.85 | 2.56 | 4.32 | 6.62 | 8.21 | | 1.09 | 1.02 | 1.06 | 1.16 | 1.29 |
| May 8 | 1.65 | 3.60 | 4.94 | 7.14 | 8.56 | | 1.04 | 0.98 | 1.00 | 1.08 | 1.21 |
| June 22 | 1.64 | 3.85 | 4.56 | 6.52 | 7.54 | | 1.04 | 0.97 | 0.99 | 1.09 | 1.22 |
| Sep. 2 | 4.20 | 4.34 | 6.80 | 6.85 | 6.82 | | 1.09 | 1.00 | 1.02 | 1.10 | 1.25 |
| Cumulative DM (7 harvests; 1990) | 12.59 | 28.15 | 39.04 | 51.30 | 52.99 | Mean | 1.08 | 0.99 | 1.03 | 1.12 | 1.24 |
| Cumulative DM (12 harvests) | 21.53 | 44.44 | 63.18 | 83.83 | 90.44 | | | | | | |

LSD (Yield) ($P<0.01$)
Harvests — 1.31.
N levels — 2.16.

LSD (%N) ($P<0.05$)
Harvests — 0.09.
N levels — 0.11.

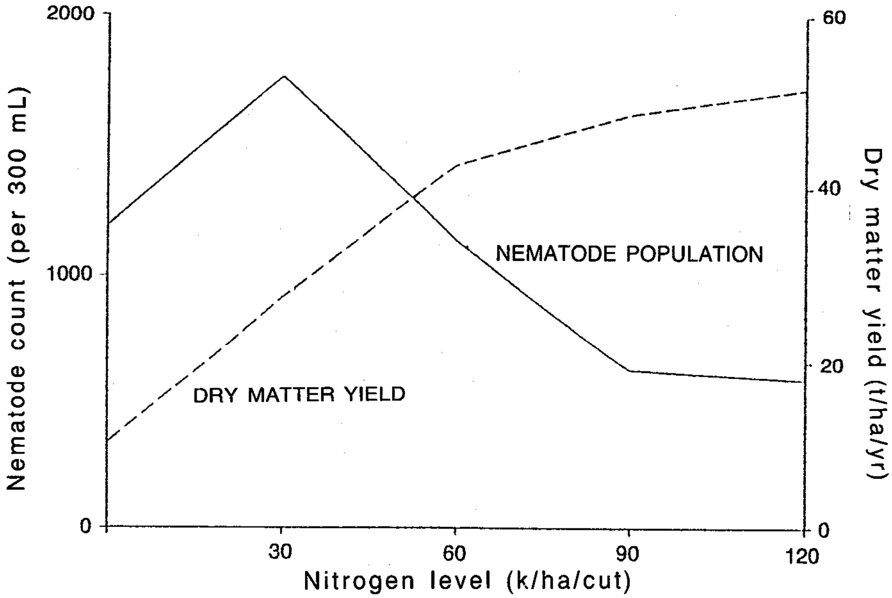


**Figure 1.** Effect of application of nitrogen fertiliser on nematode count and dry matter yield in rhodes grass.

response did not change significantly with time. N application resulted in improved dry matter yields even up to the maximum level of 120 kg/ha and the relationship was curvilinear (Figure 1 and Table 3). There was no yield response to either K or P (not shown). The high yields recorded in the first summer were not repeated in the second. Nitrogen concentrations in plant tops were higher in winter than in summer.

Nitrogen application increased the average N and K concentrations, but decreased P% (Table 4). Applications of P and K did not affect the N, P and K concentrations.

The initial nematode populations were negligible since the experimental site was fallowed for 5 years after removal of the citrus plantation. The effects of N and K application on composition of the total nematode populations after the twelfth harvest were significant (Table 5). *Pratylenchus* spp. were the predominant species in the N and K experiments. The plant parasitic nematode, *Mulkorhynchus phaseoli*, which was the dominant species in the P trial, was completely absent in N and K experiments. This was probably due to the patchy distribution of nematodes in the soil. The N and K application levels were negatively associated with total nematode populations. Increasing the N levels beyond 30 kg/ha drastically reduced the nematode populations. No such marked response could be observed in respect of K, with a significant reduction in total nematode populations

**Table 4.** Mean nitrogen, phosphorus and potassium concentrations in dry matter of rhodes grass in response to application of 3 fertiliser nutrients.

| | N levels (kg/ha/harvest) | | | | | P levels (kg/ha) | | | | K levels (kg/ha) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 30 | 60 | 90 | 120 | 0 | 33 | 66 | 98 | 0 | 62 | 83 | 104 | 125 |
| N% | 1.08 | 0.99 | 1.03 | 1.12 | 1.24 | 1.03 | 1.05 | 1.02 | 1.00 | 0.98 | 0.96 | 0.97 | 1.04 | 0.99 |
| P% | 0.13 | 0.10 | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 | 0.09 | 0.11 | 0.08 | 0.09 | 0.09 | 0.08 | 0.08 |
| K% | 1.56 | 1.64 | 1.63 | 1.59 | 1.73 | 1.65 | 1.66 | 1.69 | 1.68 | 1.62 | 1.66 | 1.65 | 1.63 | 1.68 |
| LSD | | | | | | | | | | | | | | |
| N% | 0.07 (P<0.05) * | | | | | | ns | | | | | ns | | |
| P% | 0.01 (P<0.01) ** | | | | | | ns | | | | | ns | | |
| K% | 0.14 (P<0.05) * | | | | | | ns | | | | | ns | | |

**Table 5.** Nematode composition after the final harvest of soil receiving the highest fertiliser rates, and correlations between fertiliser application rates and nematode counts.

| Nematode species | Fertiliser applied | | |
|---|---|---|---|
| | N | P | K |
| | | (%) | |
| *Pratylenchus brachyurus* | — | — | 82.4 |
| *Mulkorhynchus phaseoli* | — | 91.3 | — |
| *Tylenchorynchus* spp. | 9.6 | 7.7 | 6.6 |
| *Pratylenchus* spp. | 81.2 | 1.0 | 11.0 |
| *Macroposthonia* spp. | 9.2 | — | — |
| r (application rate vs total nematode counts) | $-0.63^{**}$ | $-0.32^{ns}$ | $-0.51^{*}$ |
| Number of observations | 15 | 12 | 15 |

only at high application rates (104 kg/ha K and above). However, dry matter yields and nematode populations were not significantly correlated in any study (r values: $-0.480$, $-0.104$ and 0.259 for N, P and K, respectively).

## Discussion

Application of irrigation and high rates of N fertiliser produced extremely high yields of rhodes grass in this very hot, arid environment. The curvilinear effects of summer rainfall and N application rates on grass yields have also been reported in tropical and subtropical regions of Australia (Gilbert and Clarkson 1993). Responses to high N application rates were also evident in the large scale production farm of the Desert Agricultural Project at Marmul, Sultanate of Oman in the Nejd desert of south-eastern Arabia (Anon. 1988). However, at Marmul, the dry matter yield with the application of 1200 kg/ha/yr N was only 35 t/ha compared with our 53 t/ha from 840 kg/ha/yr N. There are 2 possible reasons: the soil was brought into cultivation for the first time; and the cultivar used (cv. Katambora from Kenya) was sensitive to extremely cold night temperatures experienced in the desert interior in winter.

Increased dry matter production with higher rates of N application was also observed in several large scale farms in northern coastal Oman. On many of these farms, application of 600 kg/ha/yr N produced yields of 35–40 t/ha/yr. Similar marked responses to high rates of N under rain-grown conditions during the summer months have also been reported in the subtropics and tropics of Queensland (Teitzel *et al.* 1991; Reason *et al.* 1993).

In our experiments, there were no responses to applied P and K. Responses may have occurred if the experiments were to continue for 2 or more years without any further application of these nutrients. However, the authors have noted that, on farms where P and K fertilisers were not applied during the previous 2–3 years, symptoms of deficiency have not developed. In general, a reduction in dry matter yields occurred within 2 years of planting, probably due to the death of grass clumps. It is, however, essential to make an initial application of P and K to the virgin desert soils as found at Marmul and to soils where soil tests suggest deficiencies.

Of the 3 nutrients applied, only N affected the concentrations of the 3 elements in the dry matter. Improvements in N and K and low P concentrations in leaf tissue, caused by the application of N, have also been reported recently (Reason *et al.* 1993). However, the N concentrations in dry matter decreased in all treatments in the summer months, probably because of high temperatures experienced in summer (Colman and Lazenby 1970), as well as a growth-dilution effect.

The application of N and K fertilisers decreased nematode populations. Application of N fertiliser achieved this result while increasing dry matter production. Deleterious effects of nitrogenous fertilisers on soil nematodes were also observed by Sinha (1984), Rodriguez-Kabana (1986) and Timans (1990). In the present investigation, higher K application rates reduced the soil nematode populations, without improving the dry matter yields. The unfavourable effect of K as $K_2SO_4$ on root-knot nematode (*Meloidogyne incognita*) were observed by Jagdale *et al.* (1985). Castro *et al.* (1991) found that $KNO_3$ was more effective than KCl in checking this nematode species in tomatoes. The negative effects of K ions on nematode populations may be due to the increased layers of sclerenchymatous cells in the root tissue preventing the infection and feeding by nematodes, as observed by Sinha (1984). Such effects were not evident with P application. In all 3 cases, the relationship between nematode populations and dry matter yields was non-significant. This report assumes significance because of the complete lack of information on soil nematodes in pasture soils in the Arabian environments.

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