Effects of irrigation, defoliation, associated grass and nitrogen on lucerne (*Medicago sativa*) as a component of pastures in sub-coastal central Queensland

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Abstract

An experiment was carried out over 4 years to explore the effects of differences in soil moisture and defoliation frequency on the performance of lucerne grown alone or with green panic or Molopo buffel grasses. Treatments included supplementary irrigation, 6 or 12 weekly defoliation and 0 or 110 kg/ha N. Supplementary irrigation significantly reduced the rate of decline of lucerne populations and increased their dry matter yield. In the early years more frequent defoliation increased lucerne yield. Grass yield was also markedly increased by irrigation. Irrigation did not significantly increase soil N build-up.

Lucerne competed strongly against the grasses, in the first 2 years but there were increased grass yields in the 3rd and 4th years. This could be attributed to high lucerne yields in earlier years and better moisture conditions in the last year. Lucerne increased the N concentration of the grass component of the pasture, and had increased total soil nitrogen in the 0–15 cm layer by the 4th year.

Nitrogen fertilizer increased grass dry matter yield more consistently than lucerne, but, as it did not increase grass N concentration, forage quality was poorer. By the 4th year N applications had increased total soil N.

Resumen

Se condujo un experimento durante 4 años con el fin de explorar el efecto de diferentes niveles de humedad del suelo y de la frecuencia de defoliación sobre M. sativa *cutivada sola o en asociación con* Panicum maximum *var Trichoglume (green panic) o con* Cenchrus ciliaris *(buffel Molopo). Los tratamientos utilizados fueron: irrigación suplementaria, defoliación a intervalos de 6 o 12 semanas y aplicación de O o 110 kg ha-1 N. El riego suplementario disminuyó significativamente la tasa de reducción de la población de* M. sativa *e incrementó su rendimiento en materia seca. La defoliación frecuente aumentó el rendimiento de* M. sativa *durante los años iniciales. El rendimiento de los pastos también se incrementó marcadamente con el riego. La acumulación de N en el suelo no se incrementó significativamente con el riego.*

A pesar que en los primeros 2 años M. sativa *compitió vigorosamente en la asociación, en los subsiguientes años hubo un incremento en el rendimiento de las gramineas en la pastura. Lo anterior podría atribuirse al elevado rendimiento de M. sativa en los años iniciales y a las mejores condiciones de humedad en el último año.* M. sativa *incrementó la concentración de N en la gramínea asociada. Así mismo aumentó el N total de la capa 0-15 cm del suelo en el 4o año.*

La fertilización nitrogenada incrementó más consistentemente el rendimiento de la gramínea que M. sativa, *pero el forraje fue de baja calidad debido a que la concentración de N en la gramínea no aumentó con la fertilización. El contenido total de N en el suelo fue incrementado en el 4o año con la fertilización nitrogenada.*

Introduction

Lucerne (*Medicago sativa*) is one of the legumes available for use in raingrown pastures in much of southern and central Queensland. However, there is contradictory evidence of its effects on

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the production of associated grasses in mixed pastures (Cameron and Mullaly 1969, 1970; Cameron 1973). At times, grass growth is stimulated by lucerne; at others, it is depressed.

The present experiment was designed to examine the effects of differences in soil moisture and defoliation frequency on the performance of lucerne as a companion for 2 grasses widely planted in sub-coastal, central Queensland. It was hoped the results would clarify some of the findings in an earlier study by Cameron and Mullaly (1969, 1970) that suggested that rain in the winter-spring period may have been one of the factors causing effective stimulation of associated grasses by lucerne. The irrigation treatment devised for this experiment was aimed at maintaining reasonable growing conditions over the normally dry winter-spring period, without being a full irrigation treatment.

As well, the earlier study was harvested every 3 months, whereas 6-weekly rotations are normally recommended for lucerne-based pastures (Cameron 1973): so a comparison of these 2 frequencies was included in the present experiment. Cameron and Mullaly (1970) suggested the lucerne component of their pasture added *c* 100 kg/ha of N to the soil each year, so, after 12 months, it was decided to add a N treatment at this rate as a standard against which to gauge the lucerne effect.

Materials and methods

Site

The site was located on the deep levee soils along Callide Creek near Biloela, Queensland. The soil was a dark greyish-brown gradational friable earth (Gn 3.43), (Northcote 1971) with a fine sandy clay loam surface texture, grading to a dark medium clay at depth. Surface pH was 6.7, and acid-extractable phosphorus (Kerr and von Stieglitz 1938) was >200 ppm to 1 metre. Soluble salt levels were low (<0.001 per cent) throughout the profile. This is the major soil type of the Callide Valley irrigated lucerne industry but also grows excellent raingrown lucerne/grass pastures.

The area had been used for irrigated annual crops over previous years. It was fallowed over the summer of 1967/68 prior to planting in March 1968.

Design

The experimental design was a 2 x 2 x 2 x 5 split-split-split-plot randomized block of 3 replications with a base plot size of 3 m x 27 m. Treatments were:

A. *Irrigation* (as main plots), nil and supplementary
B. *Defoliation period* (as the first split), 6 and 12 weekly defoliation
C. *Pasture species* (as the second split)
   (i) *Panicum maximum* var. *trichoglume* cv. Petrie (green panic)
   (ii) *Panicum maximum* + *Medicago sativa* cv. Hunter River (lucerne)
   (iii) *Cenchrus ciliaris* cv. Molopo (Molopo buffel)
   (iv) *Cenchrus ciliaris* + *Medicago sativa* cv. Hunter River
   (v) *Medicago sativa* cv. Hunter River
D. *Fertilizer nitrogen*, nil and 110 kg/ha N
   This split was applied after the first 12 months of the experiment. The plots of this split were 3 m x 27 m.

Management

Inoculated lucerne seed, 3 kg/ha, and seed of the 2 grasses, 2 kg/ha, were hand-broadcast into a fine seedbed on March 12, 1968. The seed was covered by a light harrowing and 25 mm irrigation applied.

The site was lightly grazed and slashed to control weeds during establishment. Irrigation, and defoliation treatments were started on August 24, 1968. In the supplementary irrigation treatment 40 mm of irrigation water was applied when less than 20 mm of rain was received in the previous 28 days. Months when supplementary irrigation was applied are indicated in Table 1.

The 12-weekly defoliation, of both the 12 and 6 weekly plots, was by common grazing with dairy cattle over 4 to 5 days. Slashing to 5 cm followed when necessary to reduce excess stubble. The intermediate 6-weekly defoliations were applied by slashing to 5 cm.

Nitrogen (as ammonium nitrate) was applied in two 55 kg/ha N dressings in spring and autumn. The first application was made on August 20, 1969.

Plots not sown to lucerne were kept free of volunteer lucerne plants by hand chipping.

Table 1. Monthly rainfall, mean monthly temperature and mean monthly evaporation for Biloela Research Station

Year	Spring			Summer			Autumn			Winter			Total
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	
	Rainfall (mm)												
1967/68	0	81	106	203	199	91	106	56	53	0	27	25	977
1. 1968/69	23	14*	99*	58	3*	24*	14	2*	49*	9*	7*	5*	307
2. 1969/70	2*	108	35	83	73	19	25*	12*	0	23*	0*	20	400
3. 1970/71	61*	32	100	105	179	290	23*	6*	8*	34	6*	62*	906
4. 1971/72	26	71	81*	96	144	127	34	9*	44	15*	0*	20*	667
	Mean Rainfall (mm)												
Mean (49 years)	21	53	72	96	106	115	66	39	37	38	31	21	695
	Mean Evaporation (mm)												
Mean (18 years)	132	157	150	188	180	152	127	99	104	76	76	99	1540
	Mean Maximum Temperature (°C)												
Mean (18 years)	27	30	32	33	34	32	31	28	25	20	22	24	
	Mean Minimum Temperature (°C)												
Mean (18 years)	8	13	16	18	20	19	17	12	9	6	5	5	

* Approximately 40 mm of irrigation was applied to the supplementary irrigation treatments during the months indicated.

Measurements

Plant counts of lucerne and sown grass were made annually in 10 random 0.4 m x 1 m quadrats per sub-plot. Dry matter yield was determined by cutting a 5 m x 1 m strip at 5 cm height from each plot prior to the defoliation period. Fresh weight was determined in the field and a subsample hand-separated into grass, lucerne and other species and inert and oven-dried at 90 °C for 24 hours. Nitrogen was determined on grass samples from each harvest by the phenate method following Kjeldahl digestion — with a Technicon (R) autoanalyser.

Total and mineral soil N were determined for 0–15 cm and 15–30 cm depths on samples from four 5 cm cores per treatment collected in September 1969 and 1972. Total N was determined by Kjeldahl digestion. Nitrate and ammonium were extracted with 2N potassium chloride and determined using a micro-distillation technique (Bremner 1965).

Seasonal conditions

Rainfall received during the experiment and mean monthly rainfall, temperature and evaporation are shown in Table 1.

Rainfall during the first and second years of the experiment was well below average with dry periods occurring in the late summer, autumn and winter of each year (Table 1). The 16 months from June 1968 to September 1969 received only 361 mm of rain. As a result, supplementary irrigation was applied fifteen times in the first 2 years. This raised total water received by this treatment to near average rainfall.

The drought was followed by 674 mm of rain in the November to February period of 1970/71 and an average summer in 1971/72. However dry periods prevailed at most other times over the last 2 years. As a result, 11 supplementary irrigations were necessary over the last 24 months of the trial.

Results

Main effects of supplementary irrigation

Lucerne established well but populations declined with time. Supplementary irrigation reduced the rate of decline and by June 1972 there were 0.7 plants/m^2 compared with 0.2/m^2 without irrigation.

There was a significant increase in lucerne yield in years 1, 2 and 3 but not in the 4th year.

Supplementary irrigation increased grass yield in years 1 and 4 and other species and inert yield in years 1 and 2 but had no significant effects on grass N concentration, total soil N, or mineral soil N.

Main effects of defoliation frequency

Six-weekly harvesting increased lucerne yields in the first 2 years. Six-weekly cutting significantly

Table 2. Main effects of treatments on plant populations, yields and grass N concentrations

Period	Irrigation		Defoliation		Grass species		Lucerne Alone	Applied N	
	Nil	Irrig	6 Wkly	12 Wkly	Green Panic	Buffel		Nil	N
Lucerne population[1] (plants/m²)									
9/68	2.4	1.7*	—	—	1.9	2.1	2.1	—	—
12/69	1.9	1.9	2.0	1.7	1.8	1.8	2.0	1.8	1.9
11/70	1.0	1.7*	1.3	1.3	1.2	1.3	1.4	1.3	1.3
12/71	0.3	1.6**	0.6	0.6	0.5	0.6	0.6	0.7	0.5**
6/72	0.2	0.7**	0.4	0.5	0.4	0.5	0.5	0.5	0.4**
Lucerne yield (t/ha)									
Year 1	3.4	6.3**	6.0	3.7	4.7	4.7	5.2		
Year 2	0.9	2.5**	1.8	1.5*	1.5	1.6	1.9	1.6	1.7
Year 3	0.6	2.1*	1.6	1.2	1.3	1.0	1.8	1.4	1.3
Year 4	0.9	2.3	2.2	1.0	1.4	1.5	1.9	1.5	1.7
Total (Yr 2–4)	2.3	6.9*	5.6	3.7	4.2	4.1	5.6	4.6	4.6
Grass yield (t/ha)									
Year 1	0.8	3.6**	1.6	2.8	1.5	2.9**	—	—	—
Year 2	2.1	2.7	2.0	2.9	1.7	3.1**	—	2.0	2.8*
Year 3	5.2	6.5	4.5	7.2*	4.7	7.1**	—	4.7	7.0**
Year 4	3.7	4.8**	2.6	5.9**	3.4	5.1**	—	3.2	5.3**
Total (Yr 2–4)	—	—	9.1	15.9**	9.5	15.5**	—	9.9	15.1**
Other species and inert material (t/ha)									
Year 1	0.6	1.2*	1.1	0.8	0.9	1.0*	0.8	—	—
Year 2	0.2	0.7**	0.4	0.5	0.4	0.5*	0.4	0.4	0.5**
Year 3	1.0	0.8	0.9	0.9	0.8	0.5	2.0	0.8	1.1**
Year 4	1.7	2.2	1.7	2.2	1.8	1.0*	4.1	1.6	2.2**
Total (Yr 2–4)	2.9	3.7	3.0	3.6	3.1	2.0*	6.5	2.8	3.8**
Grass N concentration (%)									
2/69	2.1	1.9	2.1	1.8	2.2	1.8*	—	—	—
2/70	1.8	1.6**	1.7	1.6	1.8	1.5**	—	1.7	1.7
2/71	1.2	1.0	1.2	1.0*	1.1	1.1	—	1.0	1.1*
3/72	0.9	0.9	1.1	0.7**	1.0	0.8**	—	0.9	0.9

increased grass N concentration but depressed grass yields in years 3 and 4. This effect occurred mainly in late summer (details not presented).

Defoliation frequency had no significant effect on lucerne population, other species and inert or total and mineral soil N.

Main effects of companion grass

Companion grass did not significantly affect lucerne yield in any year, nor did the depression due to the presence of a sown grass compared with lucerne planted alone reach a significant level except for the total lucerne yield for years 2 to 4 (5.6 *vs.* 4.2 and 4.1 t/ha, $P < 0.05$).

Though there were some significant differences in lucerne populations with the 2 grasses early in the trial they were too small to be of consequence.

Buffel grass had higher yields and lower N concentrations than green panic.

Companion grass did not significantly affect total or available soil N although total soil N under green panic was higher than under Molopo buffel ($P < 0.05$).

Main effects of planting lucerne

In years 1 and 2, grass yield was lower with lucerne present but was higher in years 3 and 4 (Table 3). Total grass yield for years 2 to 4 was also increased ($P < 0.05$). Total pasture yield was increased by planting lucerne except in year 2. Nitrogen concentration of grass was always significantly increased by the presence of lucerne. Lucerne increased total soil N ($P < 0.05$) after the 1st year. There was no effect on available soil N.

Main effects of nitrogen application

Nitrogen fertilizer had no significant effect on lucerne yield but did reduce lucerne populations

Table 3. Effect of lucerne on pasture yields, and grass and soil N concentrations

Period	Grass Alone	Grass + Lucerne	Lucerne alone
Total pasture yield (t/ha)			
Year 1	4.2	6.9**	5.9
Year 2	3.6	3.7	2.3
Year 3	6.0	8.2**	3.8
Year 4	4.7	8.1**	6.0
Total (Yr 2–4)	14.4	19.9**	12.1
Grass yield (t/ha)			
Year 1	3.1	1.3**	
Year 2	3.0	1.8**	
Year 3	5.5	6.2*	
Year 4	3.4	5.1**	
Total (Yr 2–4)	11.8	13.2*	
Grass N concentration (%)			
2/69	1.3	2.7**	
2/70	1.3	2.1**	
2/71	1.0	1.2**	
3/72	0.8	0.9*	
Total soil N (%)			
1968	0.112	0.115	0.115
1969	0.107	0.111*	0.105
1972	0.107	0.114*	0.113

slightly in the last 2 years (Table 2). Grass yields were increased by the application of N but there was little effect on N concentration. By 1972, both total and available soil N in the 0–15 cm layer had been significantly increased by applying N fertilizer.

Important interactions

There were few significant interactions involving lucerne. There was a stronger response in grass yield to applied N in the absence of lucerne in years 2 and 3. There was also a strong interaction between N application and pasture species on total dry matter yields.

Soil mineral N in the 0–15 cm layer in 1972 increased from 10.4 ppm N to 14.7 ppm N without irrigation but remained at 8.5 ppm with irrigation.

Discussion

This study has confirmed the value of lucerne as a companion legume for pasture grasses (Cameron and Mullaly 1970). Over the 2 drought years grass yields with lucerne were depressed, but they were stimulated over later years when rainfall was higher. It was only in the 2nd year that total yield of grass with lucerne was not significantly greater than that of lucerne sown on its own. Application of N consistently increased grass yield but, as has frequently been recorded, e.g. Henzell (1963), grass N concentration was largely unchanged. On the other hand, lucerne increased grass N concentration. The nutritive quality of the forage would have been further improved by the presence of the lucerne itself.

Total soil N declined in unfertilized grass pasture whereas it was maintained under lucerne. It is of interest that there was no increase in soil N under lucerne even with supplementary irrigation, where the higher moisture may have been expected to enhance N fixation.

We consider competition for moisture between lucerne and grass to be an important factor in maintaining the lucerne in grass-lucerne pastures in the central Queensland environment. However, attempts to measure soil moisture to depth, using a neutron moisture meter, were not successful. It is essential in any future study that the soil moisture status be monitored.

Noticeable thinning of the lucerne stands occurred over the wet 1970/71 summer in the non-irrigated treatment. While a more dense stand was maintained in the irrigated treatment, where plants had not been so subject to drought, a loss in stand occurred in the following year. This severe loss of stand following drought breaking rains has been noted on several occasions in southern Queensland (Cameron 1973) and requires closer investigation.

There would be some merit in seeking legumes with a lower moisture requirement than lucerne for these lower rainfall area, but it is doubtful if such a plant could persist with a resilient species such as buffel grass. Of the tropical legumes tested, only *Stylosanthes scabra* cv. Seca has persisted with such grasses (W.H. Burrows, personal communication). Hence, there are still good reasons for continuing to use the temperate legumes, lucerne, or, in more southerly inland areas of the State, the annual *Medicago* spp. (Wylie and Bourne 1975) as a source of N for typical grasses. The results presented here and by Cameron and Mullaly (1970) show that lucerne can, on soils to which it is adapted, continue its role as a useful pasture legume.

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