THE EFFECT OF INTERCROPPING OATS AND A LEGUME ON NITROGEN ECONOMY

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ABSTRACT

The effect of intercropping oats and a legume on the distribution of nitrogen in the forage at different stages of growth was studied. Using Tama ryegrass as a test crop the availability of the nitrogen fixed by the legumes to a subsequent crop was also assessed.

Forage oats were grown in alternate rows with lupins or peas. Oats were sown at 100 or 150 plants/m² and lupins or peas at 25 or 50 plants/m². Nitrogen (N) concentration in the intercropped forage peaked at about 5% 105 days after sowing (DAS). The highest N concentration in sole crop lupins was 3.2% also at this time. The oat/lupin mixture had the highest N concentration and produced a higher N yield per unit area than the oat/pea mixture or any sole crop.

The yield of Tama ryegrass was increased when grown following intercrops compared with growing after sole oats. Tama produced 201, 317 and 843 g/m² after intercrops at 90, 120 and 210 DAS compared to 189, 279 and 776 g/m² respectively after oats alone. The dry matter yield of Tama was higher at the early and late stages following the oat/lupin combination, producing 201 and 843 g/m² as against 196 and 832 g/m² respectively after oat/pea at 90 and 210 DAS. The Tama yield at 120 DAS after the oat/pea mixture was 317 g/m² compared with 282 g/m² after the oat/lupin combination. The yield of Tama however, was highest following sole crop lupins at the early and late harvests than after the intercrops. N-concentration in Tama was highest (4.8%) when grown following the intercrops compared with 3.8% when Tama was grown after sole crop peas. Although the oat/pea intercrops contribution to N-accumulation was higher (4.8%) in Tama, the N-yield per unit area was higher (35.2 gN/m²) following the sole crop lupin. Implications for forage quality and soil N are considered.

Additional Key Words: *Dry matter, nitrogen concentration, nitrogen yield, sole crop, test crop*

INTRODUCTION

Biological nitrogen fixation is important to meet the nitrogen demands of crop production. The costs of nitrogen fertilizer and problems associated with its efficiency of utilization have created renewed interest in the growing of legumes to furnish nitrogen.

Legumes increase soil nitrogen levels (White *et al.*, 1978; National Academy of Science, 1979) and provide a cheap form of readily available nitrogen (N) which in some cases can benefit non-legume companion crops (Virtanen *et al.*, 1937; Williams, 1970) and succeeding crops (Agboola and Fayemi, 1972; Rhodes, 1980; Askin *et al.*, 1982; Janson, 1984; McKenzie and Hill, 1984) via N-rich plant residues (Herridge, 1982).

Non-legume forage crops contribute nothing directly to soil nitrogen. Consequently as there are fewer and shorter periods in crop rotations in which nitrogen is supplied biologically the requirement for additional nitrogen from other sources is increased (Janson, 1984). If a short term forage legume was incorporated into a cropping system or used instead of a conventional non-legume forage then this could become an important nitrogen contributor in the system.

Lupins have been cultivated in New Zealand for many years, predominantly in Canterbury, mainly as a forage crop and also to improve soil fertility (White, 1961; Rhodes, 1980). Several reports also indicate that lupins can provide a substantial amount of high quality forage for both cattle and sheep (Burtt and Hill, 1981; McKenzie and Hill, 1984) and can fix up to 176 kg of N/ha for a succeeding crop (Rizk, 1966).

Peas as forage crops have been used for many years in Europe and North America to augment summer forage production and to conserve for later use as a supplement to winter feed (Brundage *et al.*, 1979; Johnson, 1979). Studies in New Zealand have shown that several lines of peas are capable of producing dry matter yields comparable to other forage crops (Armstrong *et al.*, 1984) and fix between 17 and 83 kg N/ha (Mahler *et al.*, 1979; Rhodes, 1980; Askin, 1983) over a wide range of environmental conditions. To reduce lodging forage peas can be grown with cereals such as oats.

The objectives of this study were:

i) to evaluate the contribution of two legumes to N accumulation in intercrop forage when grown in association with a cereal and
ii) to evaluate the N benefit of the leguminous crops to a succeeding crop of Tama ryegrass.

MATERIALS AND METHODS

The trial ran for 12 months from October 1984 to September 1985. The first phase was the growing of the intercrops in a factorial design with randomized complete blocks with 5 replicates. Oats at 100 (low) and 150 (high) plants/m² were sown in alternate rows with lupins or peas at 25 (low), 50 (high) plants/m². Rows were 15 cm apart.

The trial site was located on a Templeton silt loam (Cox, 1978) which was of low nitrogen status. Its previous cropping history was: tickbeans and peas (1981-82), oats and fallow (1982-83) and Tama ryegrass (1983-84). Intercrops were sown on 11 October 1984 with a 'Stanhay' precision seeder in 15 cm rows with plots 1.5 m by 16m and were sampled 60, 87, 105 and 120 days after sowing. After removal of the intercrop stubble, a test crop of *Lolium multiflorum* cv. 'Grassland Tama' was direct drilled into the trial site on 5 March 1986 at 25 kg/ha. The trial was irrigated when the gravimetric soil moisture content fell to 14% measured on a dry weight basis.

Sampling

Intercrop plots were sampled by taking one 0.2 m^2 quadrat which contained 2 rows each of oats and legumes at 60, 87 and 105 days after sowing (10 Dec. 1984, 6 and 24 Jan. 1985 respectively). A final harvest of the intercrops was taken at 120 days (8 Feb. 1985) by cutting two 0.2 m^2 quadrats from each plot.

The Tama was sampled by cutting three 0.25 m^2 quadrats from each plot at 90 and 120 days after sowing on 2nd June 1985 and 2nd July 1985. A final harvest was taken by cutting one 0.25 m^2 sample from each plot 210 days after sowing on 30 September 1985.

Measurements

The accumulation of dry matter and nitrogen concentration of the intercrops and the Tama ryegrass was measured (Hassan *et al.*, 1985). Nitrogen was measured using micro-Kjeldhal digestion and auto-analyser measurement of total nitrogen. The nitrogen analysis of Tama made at final harvest is reported for samples from only one replicate.

RESULTS

The climate at the trial site during the growth of the intercrop and during the growth of the test crop was not favourable. The season was warmer and drier than the long term average. Mean monthly rainfall during the experimental period was only of 62% of long term average (Fig. 1).

Plant Nitrogen in Intercrop Forage

Accumulation of total nitrogen in the intercrops followed a different trend from dry matter accumulation. Nitrogen accumulation in the intercrops was higher than in any of the sole crops. A maximum N concentration of 4.9%, which was equivalent to 20.0 g N/m^2 for the high oat population with lupins was compared with the highest value from the sole crop of 18.2 g/m^2 from lupins (Table 1). However, the rapid increase in the accumulation of dry matter during this period could not compensate for the decline in N-concentration leading to lowered N-yields.

Dry matter Accumulation in Tama Ryegrass

At all stages of growth, yield of Tama was higher when it was grown after most of the intercrops than when it was grown after the oats.

The highest yield of Tama grown after the intercrops was 201, 317 and 843 g/m^2 at 90, 120 and 210 days after

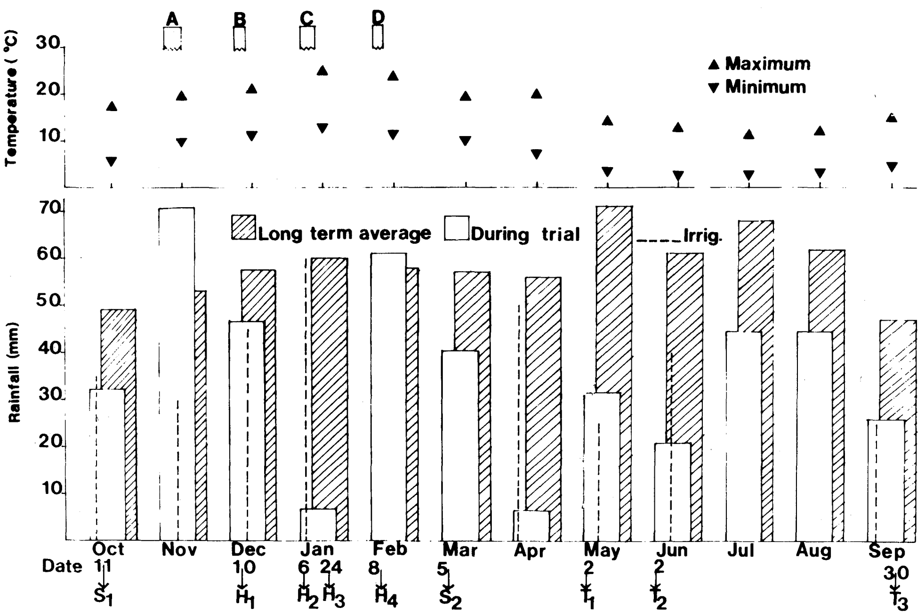

Figure 1: Mean monthly temperature and rainfall from October, 1984 until September, 1985: and events of field operations. (S_1 = intercrops sowing, S_2 = test crop sowing, H_1, H_2, H_3, H_4 = intercrop harvests: T_1, T_2, T_3 = test crop harvests. A = 8-10 nodes in peas, 6 leaf in oats, 4-8 leaf in lupins: B = boot in oats, flower in peas: C = milk in oats, flower in lupins, pod fill in peas: D = hard dough in oats, pod yellow in peas, pod fill in lupins).

TABLE 1: The effect of plant population and legume species on the nitrogen concentration and nitrogen yield of oats grown as an intercrop and as a sole crop.

Factor	Days after sowing 105 days N (%)	N yield (g N/m²)	120 days N (%)	N yield (g N/m²)
Leg. species				
oat – lupin	4.8	29.5	2.8	24.3
		N.S.		**
oat – pea	4.2	29.3	2.6	16.3
S.E.		0.57		0.52
Oat Pop. *Leg. species				
low oat – lupin	4.6	29.1	2.7	21.9
		N.S.		**
low oat – pea	4.3	29.6	2.6	17.4
high oat – lupin	4.9	29.9	2.9	26.7
		N.S.		**
high oat – pea	4.1	29.0	2.5	16.2
S.E.		0.81		0.74
C.V. (%)		8.7		11.4
Significance	N.S.	N.S.	N.S.	**
Sole oat	1.1	7.5	0.9	5.6
Sole lupin	3.2	18.0	2.0	18.2
Sole pea	2.9	16.1	1.3	10.0
S.E.	not calculated		not calculated	
C.V. (%)	not calculated		not calculated	

TABLE 2: Dry matter yield of Tama ryegrass (g/m²) grown after intercropped oats and legumes.

	Days after Sowing 90 days	120 days	210 days
Leg. species			
oat – lupin	194	277	798
	N.S.	**	N.S.
oat – pea	194	309	806
S.E.	2.53	5.29	32.1
Oat Pop. * Leg. species			
low oat – lupin	201	277	787
	*	N.S.	N.S.
low oat – pea	191	302	832
high oat – lupin	187	277	810
	*	N.S.	N.S.
high oat – pea	196	316	779
Leg. Pop. * Leg. species			
oat – lupin (low)	191	282	754
	N.S.	*	N.S.
oat – pea (low)	195	300	805
oat – lupin (high)	198	272	843
	N.S.	*	N.S.
oat – pea (high)	193	317	806
S.E.	3.58	7.48	45.3
Sole oats	189	279	776
Sole lupins	203	287	965
Sole peas	198	285	921
S.E.	5.08	10.5	67.5
C.V. (%)	5.8	8.1	18

sowing respectively, compared to 189, 279 and 886 g/m² for the three harvests of Tama grown after sole oats.

The population of oats in the mixture had a significant effect on the yield of Tama at 90 days. Oats at low populations contributed significantly towards higher yield of Tama ($P \leqslant 0.05$, Table 2). On the other hand, the legume population had a significant effect on the yield of Tama at 120 days. At high legume populations, peas in the mixture made a significant difference in Tama yield at 120 days ($P \leqslant 0.05$). Similarly, using peas as the legume species in the intercrops also made a significant difference to Tama yield and 309 g/m² were produced after 120 days compared to 277 g/m² from the lupins in the mixture ($P \leqslant 0.001$). The yield of Tama grown after the lupins was always higher than that obtained following the growth of other sole crops. At the final harvest the yield of Tama grown after sole lupins was also higher than the yield for any other combination of intercrops.

Nitrogen Analysis of Tama

Table 3 shows the N concentration and the total amount of N/m² harvested in the Tama ryegrass following the intercropping trial.

Tama grown after the intercrops accumulated 4.8% N, higher than the 3.7% N found in the herbage of Tama grown after sole oats and sole lupins, and the 3.8% in the herbage of Tama grown after sole peas. The population of oats in the mixture had a major effect on nitrogen concentration in the Tama, as did the population of legumes. Following the high population of lupins, the N yield of Tama was higher (33.6 g N/m²) compared to that after the high populations of peas (27.3 g N/m²). On the other hand, peas at low population contributed towards higher N-yield in Tama. Although the N-yield of Tama grown after intercrops was higher than in Tama grown after the sole crop oats the contribution to N-yield from the sole lupin crop was higher than for the intercrops.

DISCUSSION

The climate during the entire trial period was generally unfavourable for the growth of intercrops and of Tama ryegrass. However, it had been previously shown that the intercrops were able to produce large quantities of forage greenfeed (Hassan *et al.*, 1985). This study shows that the N yield of the forage from intercrops is also improved and compares well with other forages. Further, the legumes in the forage from intercrops not only improved feed quality (as measured by N%) but also conferred some yield benefit to a succeeding non-legume forage crop. The difference in the N accumulation of the intercrops at the different stages of growth of the components (Fig. 1) indicates that the timing of utilization of quality forage can be planned by

TABLE 3: Nitrogen concentration and nitrogen yield in Tama ryegrass grown after intercropped oats and legumes. Samples of Tama were taken 210 days after sowing.

Factors	N concentration (%)	N yield (g N/m²)
Leg. species		
oat – lupin	3.7	29.6
		N.S.
oat – pea	3.6	29.1
S.E.		2.23
Oat Pop. * Leg. species		
low oat – lupin	3.4	26.8
		N.S.
low oat – pea	3.5	28.7
high oat – lupin	4.0	32.5
		N.S.
high oat – pea	4.8	29.6
Leg. Pop * Leg. species		
oat – lupin (low)	3.4	25.7
		**
oat – pea (low)	3.8	31.0
oat – lupin (high)	4.0	33.6
		**
oat – pea (high)	3.4	27.3
S.E.		1.58
C.V.		17.0
Sole oats	3.7	28.3
Sole lupins	3.7	35.2
Sole peas	3.8	30.0
S.E.	not calculated	not calculated
C.V. (%)	not calculated	not calculated

choosing suitable forage legumes for use as intercrops. The deterioration of the forage quality of the intercrops about 120 days after sowing is also the point when total yield starts to fall. Burtt (1981) reported that in a lupin crop which produced nearly 1000 g/m² total dry matter, maximum N yield was 33 g N/m². The yield of approximately 30 g N/m² obtained from 950 g DM/m² of legume/cereal forage obtained in this trial comapres favourably with this (Table 1, Hassan *et al.*, 1985). Further, the dry matter yield of 843 g/m² of Tama provided approximately 34 g N/m² which is an additional benefit contributed to the Tama by the legume component of the intercrops. The higher N accumulation of the intercropped oats can be attributed to the benefits of the legume in the association as reported by Virtanen *et al.* (1937) and Agboola and Fayemi (1972).

Many reports in the literature show that legumes usually increase soil fertility and improve the productivity of succeeding crops. Yield of non-legume crops have increased when sown after legumes (Rhodes, 1980; Russell, 1980; Askin *et al.*, 1982; Askin, 1983 and McKenzie and Hill, 1984). This study has confirmed that legumes are beneficial to a succeeding ryegrass crop. Of most importance, however, is the differences in the dry matter yield of Tama ryegrass which is dependant on the stage of growth of the legume component. The amount of nitrogen finally accumulated in the Tama ryegrass varied depending upon the presence of lupin and peas. However, the contribution of lupins to the dry matter production of the intercrop the subsequent dry matter and nitrogen yield of Tama ryegrass was greater than that of peas.

Legumes are known to make a significant contribution to the growth and yield of associated crops (Hodgson, 1956; Hassan *et al.*, 1985) or to succeeding crops (McKenzie and Hill, 1984). This study has also shown that dry matter yield, N accumulation and N yield was greatly influenced by the plant population of the component legumes.

CONCLUSION

1. As a component in intercrops grown for forage, legumes can provide a substantial amount of high quality greenfeed.
2. Legumes grown in an intercropping system can confer marked benefits in soil nitrogen fertility to a following crop.

Further study of these cropping systems are required to elucidate other benefits.

ACKNOWLEDGEMENTS

The New Zealand Ministry of Foreign Affairs for the award of a scholarship and the Government of Bangladesh for granting study leave to M.T. Hassan; Lincoln College Research Committee for providing funds; Mr K. Stevenson, Miss M.L. McCloy, Mr G. Meijer, Mr D. Heffer, Mr D. Jack, Mr D. Fowler and staff of Field Service Centre for technical help.

REFERENCES

Agboola, A.A., Fayemi, A.A. 1972. Fixation and excretion of nitrogen by tropical legumes. *Agronomy Journal 64:* 409-412.

Armstrong, S.D., Jermyn, W.A., Russel, A.C., Banfield, R.A. 1984. Summer forage production from field peas. *Proceedings Agronomy Society of New Zealand 14:* 55-56.

Askin, D.C. 1983. Nitrogen fixation in peas (*Pisum sativum* L.). Ph.D. thesis, Lincoln College, University of Canterbury, New Zealand.

Askin, D.C., White, J.G.H., Rhodes, P.J. 1982. Nitrogen fixation in grain legumes. *Proceedings 2nd Australian Agronomy Conference, Wagga Wagga July 1982,* Australia: 292.

Brundage, A.L., Taylor, R.L., Burton, V.L. 1979. Relative yields and nutritive values of barley, oats and peas harvested at four successive dates for forage. *Journal of Dairy Science G2:* 740-745.

Burtt, E.S. 1981. The potential of *Lupinus angustifolius* cv. Uniharvest in Canterbury as a summer greenfeed for lambs. M.Agr.Sc. thesis, Lincoln College, University of Canterbury, New Zealand.

Burtt, E.S. and Hill, G.D. 1981. Dry matter accumulation and nutritive value of lupins (*Lupinus angustifolius*) and their potential as a summer forage. *Proceedings Agronomy Society of New Zealand 11:* 45-50.

Cox, J.E. 1978. Soil and agriculture of part Paparua County, Canterbury, New Zealand. *New Zealand Soil Bureau Bulletin.* No. 34.

Hassan, M.T., Love, B.G., Hill, G.D. 1985. The effect of growing cereal/legume mixtures on total biomass accumulation. *Proceedings Agronomy Society of New Zealand 15:* 75-79.

Herridge, D.F. 1982. Assessment of nitrogen fixation. (In) Nitrogen Fixation in Legumes. Ed. Vincent, J.M. pp. 123-136.

Hodgson, H.J. 1956. Effect of seeding rate and time of harvest on yield and quality of oat-pea forage. *Agronomy Journal 48:* 87-90.

Janson, C.G. 1984. Autumn-sown forage legumes for intensive arable cropping system. *Proceedings Agronomy Society of New Zealand 14:* 61-64.

Johnson, G. 1979. Forage peas. A cheaper option. *Livestock Farming 17:* 35-36.

Mahler, R.L., Bezdick, D.F., Witters, R.E. 1979. Influence of slope position on nitrogen fixation in dry peas. *Agronomy Journal 71:* 348-351.

McKenzie, B.A. and Hill, G.D. 1984. Nitrogen uptake and transfer from spring-sown lupins, barley or fallow to a ryegrass test crop. *Proceedings Agronomy Society of New Zealand 14:* 95-99.

National Academy of Science. 1979. Tropical Legumes: resources for the future. National Academy of Sciences. Washington D.C.

Rhodes, P.J. 1980. Nitrogen fixation by peas and lupins. M.Agr.Sc. thesis, Lincoln College, University of Canterbury, New Zealand.

Rizk, S.G. 1986. Atmospheric nitrogen fixation by legumes under Egyptian conditions. *Journal of Microbiology of U.A.R.1:* 33-45.

Russell, J.S. 1980. Consequences, crop pasture rotation and soil fertility. *Proceedings 1st Australian Agronomy Conference, Lawes, Queensland Agricultural College 1980:* 15-29.

Virtanen, A.I., Laine, T., Hansen, V.S. 1937. Investigations on the root nodules bacteria of leguminous plants XIX influence of various factors on the excretion of nitrogenous compounds from the nodules. *Journal of Agricultural Sciences, Cambridge 27:* 332-348.

White, D.H., Elliott, B.R., Sharkey, M.J., Reeves, T.J. 1978. Efficiency of land use systems involving crops and pastures. *Journal of the Australian Institute of Agricultural Science 44:* 21-27.

White, J.G.H. 1961. Lupins. *Canterbury Chamber of Commerce Agricultural Bulletin No. 386.* 5p.

Williams, W. 1970. White clover in British agriculture. *Proceedings British Grassland Society, White Clover Research Symposium:* 1-10.