THE EFFECT OF GROWING CEREAL/LEGUME MIXTURES ON TOTAL BIOMASS ACCUMULATION

M.T. Hassan, B.G. Love and G.D. Hill
Plant Science Department, Lincoln College, Canterbury

ABSTRACT

Forage oats were grown in association with lupins or peas to determine possible benefits of intercropping for biomass production. Oats at 100 and 150 plants/m² and the lupins or peas at 25 and 50 plants/m² were sown in 15 cm alternate rows. The sole crop treatments were oats at 300 plants/m² and legumes at 100 plants/m².

The intercrop combination of oat/lupin produced 5920 and 9500 kg/ha of total dry matter (TDM) at 87 and 120 days after sowing (DAS) compared with 5070 and 6380 kg DM/ha respectively from oats alone. The oat/pea combination produced 7640 kg DM/ha and oats yielded 6840 kg DM/ha at 105 DAS. In sole crops, oats produced more DM/ha than lupins or peas after 60 DAS and continued up to 105 DAS. Lupins contributed more towards intercrop TDM for most of the growth period, except at 105 days when peas made a greater contribution. This yield advantage by the intercrop combinations may be due to the benefits provided to the oats by the legumes when both are grown in association.

Additional Key Words: *intercrops, sole crops, dry matter, lupins, peas, oats*

INTRODUCTION

The need to increase the production of food and feed is of major concern in the world today. Productivity may be increased by relay cropping, multiple cropping and intercropping. These methods aim to produce more yield per unit area of land per unit of time and stabilize overall production. The major objectives of intercropping are to obtain a higher total yield in a crop season, to produce an additional crop without affecting the full yield of the base crop, to optimize the use of growth resources like light, water and nutrients and/or to stabilize yield (Donald, 1963; Trenbath, 1976; Willey, 1979, 1985).

In many areas of New Zealand pasture growth is frequently limited by insufficient rainfall in summer and low temperatures in winter. This may lead to inadequate feed production for sheep and cattle (Rickard, 1968). As little can be done to counter these enviromental factors, an important option may be to grow more forage to supplement pasture production and to conserve forage to increase winter feed supply.

Over the recent years, attention has been paid to oats (*Avena sativa* L.) and other cereals as forage crops in New Zealand (Hughes and Haslemore, 1981). Dry matter yields have been reported between 5 and 20 t/ha (Eagles *et al.*, 1979; Taylor and Hughes, 1979). Further, if legumes are included with the oats, the quality of feed produced may be improved.

Lupins have also been cultivated in New Zealand for many years, predominantly in Canterbury, mainly as a forage crop and to improve soil fertility (White, 1961; Rhodes, 1980). They can provide a reasonable quantity of high quality forage for both sheep and cattle (McKenzie and Hill, 1984). The crop has produced up to 20 t DM/ha in Canterbury (Herbert and Hill, 1978; Burt and Hill, 1981). It has been indicated that lupins can fix up to 176 kg/ha of nitrogen (Risk, 1966).

Forage peas are commonly grown in Europe and in North America to augment summer and winter feed supplies (Brundage *et al.*, 1979; Johnson, 1979). Dry matter yields up to 17 t/ha have been reported (Armstrong *et al.*, 1984). Peas can fix between 17 and 83 kg N/ha (Mahler *et al.*, 1979; Rhodes, 1980; Askin, 1983) over a wide range of environmental conditions.

Janson and Knight (1980) observed that legumes not only produce a reasonable quantity of high quality forage but also confer a substantial yield benefit to a succeeding non-legume crop. If legumes are integrated into an intercrop combination with a cereal for forage production it could be expected that the association would produce forage of better quality than by growing cereals alone. This experiment was therefore designed to test the hypothesis that oats when grown in association with legumes produce a higher dry matter yield than either oats or the legumes would produce when grown separately. It was also aimed at finding a best combination of oat/legume for intercropping and the effect of two levels of plant population on intercrop yield.

MATERIALS AND METHODS

The experiment was a factorial design with randomized complete blocks and 5 replicates. The treatments comprised of oats (*Avena sativa* cv. Anvil), at 100 (low) and 150 (high) plants/m² and legumes at 25 (low) and 50 (high) plants/m². The legume species used were lupins (*Lupinus angustifolius* cv. Uniharvest) and peas (*Pisum sativum* cv. Whero). The oats and lupin or peas were sown in alternate row. The experiment also included sole crop treatments of oats and legumes grown at 300 and 100 plants/m² respectively. The trial site was a Templeton silt loam (Cox, 1978). According to a MAF quick test the soil contained Olsen P 15, K 7, Mg

20, Ca 9 and a pH of 5.7. Its previous cropping history was tick beans and peas in 1981/82, oats and fallow in 1982/83 and Tama ryegrass in 1983/84.

The site was prepared by rotary hoeing. Superphosphate at 250 kg/ha was incorporated into the soil 2 days before sowing. No herbicide was used because of the unavailability of a herbicide which was compatible to all components in the mixtures. Immediately before sowing, seed was treated with methiocarb (3 g methiocarb/kg seed) to deter birds from damaging germinating seed. The crop was sown on 11 October, 1984 with a 'Stanhay' precision seeder 5 cm deep in 15 cm rows. The plots were 1.5 m by 16 m. Irrigation was given when the gravimetric level of soil moisture fell to 14% on a dry weight basis.

Dry matter (DM) yield was determined from a 0.2 m^2 quadrat. Each quadrat contained 2 rows each of oats and legume and was taken from the central 6 rows of each plot at 60, 87 and 105 days after sowing (DAS). A final harvest for DM yield was taken at 120 DAS by cutting two 0.2 m^2 quadrats from each plot. Each sample was separated into oats, legume and weeds and then dried to a constant weight in a forced draught oven.

RESULTS

Weekly rainfall and the timing of irrigation are shown in Figure 1. The season was warmer and drier than the long term average. Mean monthly rainfall during the experimental period was below the normal long term average.

Total dry matter production

Differences in the trend of dry matter production for the sole and the intercrops became clear after 60 days from sowing (Figure 2). Total dry matter (TDM) production by both of the intercrop combinations out-yielded oats alone at all stages of growth. The intercrop combination of oat/lupin was best at 87 and 120 days after sowing (DAS) and produced 5920 and 9500 kg TDM/ha compared with 5070 and 6380 kg TDM/ha respectively by oats alone. This was an increase in yield of 14 and 33% due to intercrop over the sole crop oats.

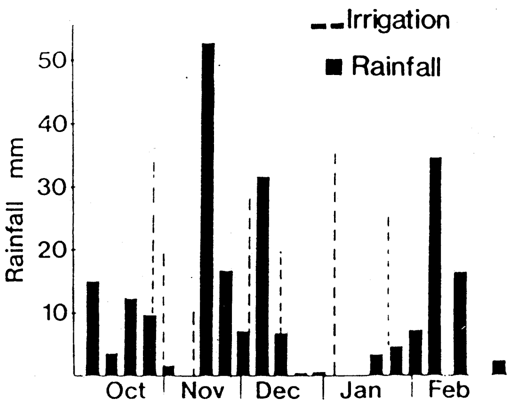

Figure 1: Weekly distribution of rainfall and irrigation events from Oct. 1984 — Feb. 1985.

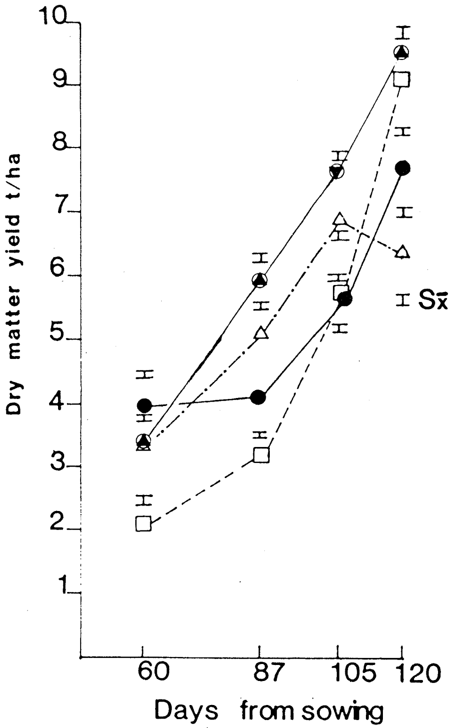

Figure 2: Dry matter accumulation in sole and intercrops (▲—▲ best intercrop yield, △—△ oat yield, ●—● pea yield, □—□ lupin yield).

The oat/pea combination produced best at 105 DAS and gave 10% TDM yield increase over sole crop oat by producing 7640 kg DM/ha against 6840 kg DM/ha. In the early stage, peas in sole crop produced more DM yield (3910 kg/ha) than the best intercrop yield (3400 kg/ha). After that, DM production of the peas did not exceed those of the intercrops. Similarly, yield of oats or lupins alone never exceeded the best intercrop DM yield.

Growth of legume species

There was no significant difference in the contribution to the TDM by the two legume species in the early stage of growth when they were grown in mixture with oats. However, the pea plus oat mixture produced about 10% higher ($P < 0.001$) TDM yield (7430 kg/ha) than the lupin plus oat combination TDM yield (6720 kg/ha) at 105 DAS (Figure 3). The latter combination produced significantly ($P < 0.001$) higher TDM (9500 kg/ha) yield than the peas and oat TDM yield (6970 kg/ha) at 120 DAS.

In the component yield of legumes, peas had greater ($P < 0.001$) contribution up to 105 DAS than the lupins, after which the latter surpassed the contribution of peas (Figure 3).

Effect of legumes on oat yield

The DM yield of oats, as a component in the mixture, was greatly enhanced by the legume association compared with the DM yield of oats grown alone (Figure 4).

Oats produced more dry matter with lupins than with peas and the DM yield was increased by 18% in the early and late growth stage. On the other hand oats produced 11% more DM in association with peas at 105 DAS. Thus in the intercrop combination, it can be seen that oat yield was considerably increased above the 'expected' value (i.e. the level that would have been achieved if the legume row had produced exactly the same competition as the oat row) by the legume association. The expected intercrop yield of oats has been calculated on the basis of achieved sole crop yield when 50% of oats in mixture would produce 50% yields of sole crop. Hence a marked increase in oat yield is observed at all the growth stages in both of the combinations of intercropping over the expected crop yield (Figure 4).

Effect of legume population

The effect of plant population on TDM production varied between oats and legumes. There was no significant effect of oat population in the mixture on TDM at any growth stage. However, legume population made significant differences in TDM yield and legume component yields (Figure 5).

The high legume population made a significant (P< 0.001) difference in the legume component yield throughout the experiment (Figure 5). TDM was significantly (P< 0.05) increased from 5300 to 5810 kg TDM/ha and from 6850 to 7300 kg TDM/ha by the high population at 87 and 105 DAS respectively but it had no significant effect at the early and later growth stages.

Growth of weeds in the mixture

The growth of weeds and their dry matter accumulation varied with oat/lupin and oat/peas combination in the intercropping situation (Table 1). The lupin/oat combination favoured higher weed DM accumulation than the oat/pea combination.

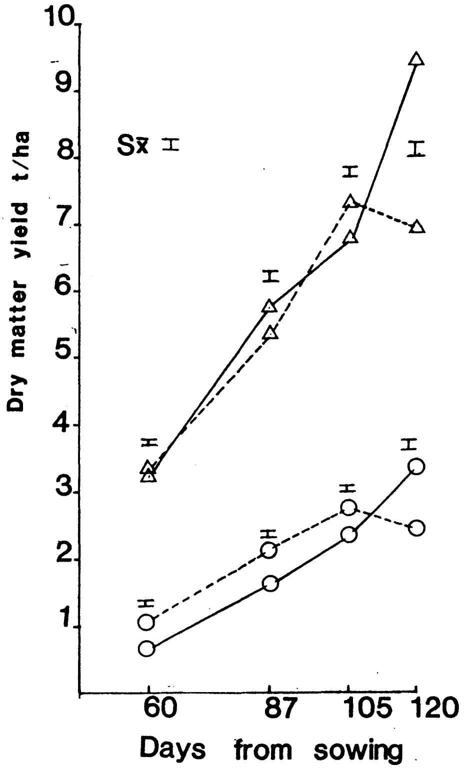

Figure 3: Effect of legume species on total and component dry matter accumulation (△ total yield, ○ legume yield, —— lupins, ---peas).

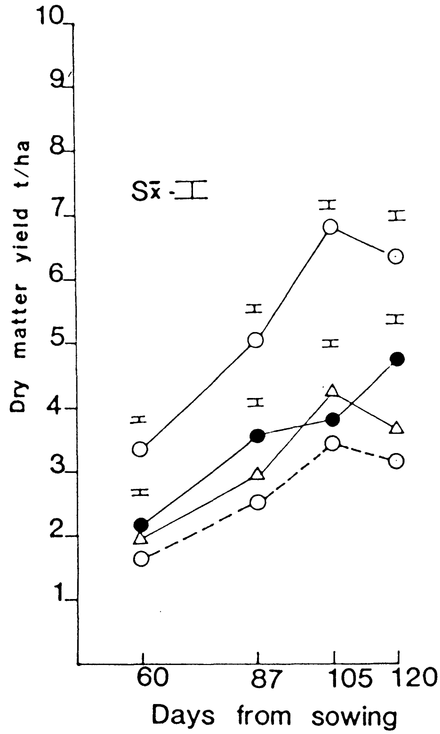

Figure 4: Dry matter accumulation in oats (○—○ oat-sole, ● — ● oat with lupins, △ — △ oat with peas, ○ --- ○ oat intercrop expected).

DISCUSSION

The total dry matter yield obtained compares favourably with the yields of other summer forages in New Zealand particularly in Canterbury (O'Connor *et al.*, 1968; Mortlock, 1975). Thus oat/legume mixtures may provide a basis to develop new forage cropping systems.

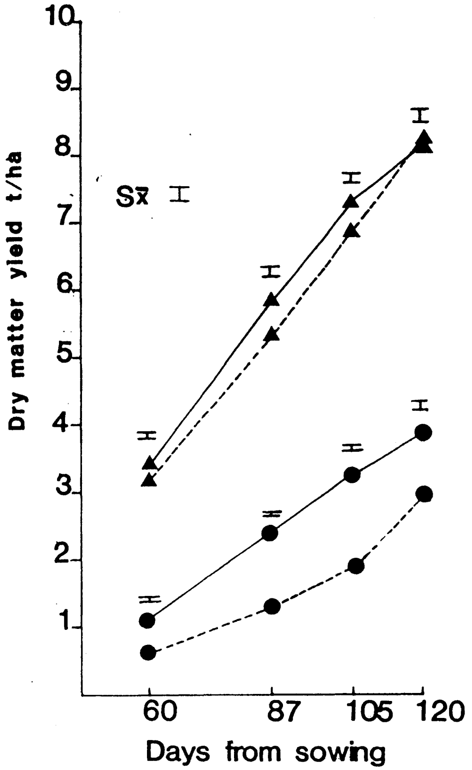

Figure 5: Effect of legume population on total and component dry matter accumulation (▲ total yield, ● legume yield, --- low legume, —— high legume).

As has been emphasised by Willey (1979), to accurately assess the possible yield advantages from a given intercrop combination, the maximum intercropping productivity should be compared with the maximum sole crop productivity. Experimentally, this means comparing a range of sole crop and intercrop treatments to identify the combinations required for maximum productivity. The experiment reported here was an initial attempt at this and the main objective was to obtain an indication of suitable intercrop combinations. It is observed in this experiment that the oat/lupins mixture was the best combination for intercropping in terms of total dry matter yield for a prolonged period of time.

Oats and the legumes both in the sole and intercrop situation differed markedly in their dry matter production, presumably due to the differences in their growth rate and the timing of these differences. Therefore, the trend of dry matter production in the intercrops seem consistent with the results summarized by Willey (1979) and as observed by Clarke and Francis (1985), namely that intercrop yield increases as component crop resource demand differs in time and space. Moreover, the sharp decline in the dry matter production in sole oats after 105 days did not occur in the oat/lupin intercrop (Figure 4). Thus it appears that oat senescence in the mixture was probably delayed and that resulted in more dry matter accumulation by oats. Consequently, the intercrop TDM was higher than that of oat alone and, from 60 days onward, it was also higher than the sole legume crops. Oats seemed to be more competitive than the legumes and thus made a greater contribution to the total intercrop DM yield than its sole crop yield potential would indicate (Figure 4).

TABLE 1: Dry matter accumulation by weeds in oat/legume mixtures (kg/ha).

	Days after sowing			
	60	76	105	120
Oat/lupins	360	530	500	750
Oat/peas	300	310	360	340
C.V.%	60	59	62	32
SE mean	40	50	60	40

Pea yield exceeded that of oats and lupin sole crops up to 50 DAS. Subsequently oats surpassed the peas and continued to do so up to 105 days after sowing following which their yield declined sharply. Peas and lupins however continued to produce DM up to 120 DAS. Oats assimilate little dry matter after the late milk stage. On the other hand, the legumes being indeterminate, continue to assimilate dry matter if environmental conditions are favourable (Hodgson, 1956).

The difference between the two legumes was that the peas suppressed weeds more than the lupins (Table 1) probably because of their early canopy closure. Dry matter accumulation in lupins during vegetative growth is often slow until the onset of flowering (Herbert and Hill, 1978). This is probably another reason why lupins had a delayed 'pick up' in DM accumulation and were less competitive. Thus the slower growing legumes suffered in the competition from oats and had reduced DM accumulation in the mixture, while oats exploited the available growth resources in the presence of adequate soil moisture, which might have also delayed its decline in DM accumulation. The absence of a significant effect of oat population on TDM production might be due to the plasticity of this species. Oats overcame the lower than optimum plant population by a large increase in tillering or through a reduction in tillering at high plant populations and thus maximised the use of growth resources. On the other hand the high legume population in the mixture favoured both TDM yield and increased legume yield. Hodgson (1956) observed that a mixture containing a high proportion of legumes (e.g. peas) tended to increase total yield. In our situation high legume population increased TDM yield through a substantial legume yield increase.

CONCLUSION

This experiment indicates that a substantial yield increase in terms of total dry matter yield can be obtained by intercropping oats and legumes. Lupins in the combination had shown greater contribution in the increase of total dry matter yield over a prolonged period of time. However, the selection of legume species for the intercrop combination will depend on the time and season of feed demand. Integration of legumes with a cereal forage may not only reduce inputs like nitrogen but will also improve feed value.

ACKNOWLEDGEMENTS

The New Zealand Ministry of Foreign Affairs for awarding a scholarship and the Government of Bangladesh for granting study leave to M.T. Hassan; Lincoln College Research Committee for providing funds; Dr M. Hussain, Mr A.G. Kausar, Mr G. Meijer, D. Heffer, D. Jack, D. Fowler and Field Service Centre Staff for technical assistance.

REFERENCES

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

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

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.

Burt, E.W., 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 N.Z. 11:* 45-50.

Clark, E.A., Francis, C.A. 1985. Transgressive yielding in Bean:Maize; interference in time and space. *Field Crops Research 11:* 37-53.

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

Donald, C.M. 1963. Competition among crop and pasture plants. *Advances in Agronomy 15:* 1-118.

Eagles, H.A., Lewis, T.D., Holland, R., Haslemore, R.M. 1979. Quality and quantity of forage from winter oats in the Manawatu, *N.Z. Journal of Experimental Agriculture 7:* 337-341.

Herbert, S.J., Hill, G.D. 1978. Plant population and irrigation studies on lupins. I. Growth analysis of *Lupinus angustifolius* cv. "WAU11B". *N.Z. Journal of Agricultural Research 21:* 467-474.

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.

Hughes, K.A., Haslemore, R.M. 1981. Winter oats: changes in nutritive value during development of the crop. *Proceedings Agronomy Society of N.Z. 11:* 41-44.

Janson, C.G., Knight, T.L. 1980. Legumes for winter greenfeed production in South Island arable cropping systems. *Proceedings Agronomy Society of N.Z. 10:* 63-65.

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 and yield in dry peas. *Agronomy Journal 71:* 348-351.

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

Mortlock, C.T. 1975. An assessment of some forage crops in South Canterbury. *Proceedings Agronomy Society of N.Z. 5:* 17-19.

O'Connor, K.F., Vartha, E.W., Belcher, R.A., Coulter, J.D. 1968. Seasonal and annual variation in pasture production in Canterbury and North Otago. *Proceedings N.Z. Grasslands Association 30:* 50-53.

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

Rickard, D.S. 1968. Climate, Pasture Production and Irrigation. *Proceedings N.Z. Grasslands Association 30:* 81-92.

Risk, S.G. 1966. Atmospheric Nitrogen fixation by legumes under Egyptian condition. *Journal of Microbiology of U.A.R. 1:* 33-45.

Taylor, A.O., Hughes, K.A. 1979. Effect of locality and sowing date on seasonal rate of dry matter accumulation of cereal forages. *Proceedings Agronomy Society of N.Z. 9:* 105-108.

Trenbath, B.R. 1976. Plant interactions in mixed crop communities. In "Multiple Cropping" Symposium American Society of Agronomy.

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

Willey, R.W. 1979. Intercropping — its importance and research needs. Part 1. Competition and yield advantages. *Field Crop Abstracts 32:* 1-10.

Willey, R.W. 1985. Evaluation and presentation of intercropping advantages. *Experimental Agriculture 21:* 119-133.