1.2 Availability of N to Plants from Legume and Fertilizer Sources: Which is Greater?

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INTRODUCTION

Several methods are available to determine plant recovery of N from various sources. N balance methods are based on the difference in total N uptake between amended and unamended treatments. With this method the observed recoveries of applied green manure N ranged from 0 to 149%, with most values between 20 and 60%. Another method more common in field studies has been to compare N response following legumes to that following a non-legume. This type of study showed that N from legume green manures was from 16 to 92% and as effective as fertilizer N. Problems with these methods include poor precision, requirement of a N deficient soil, and responses due to factors other than N, such as changes in soil physical structure, incidence of disease or weeds, or release of growth-promoting or inhibiting substances. A direct and generally more accurate method of determining recovery of added N involves adding a N source enriched in the heavier N isotope, ^{15}N, and then determining how much of the added ^{15}N is taken up by a subsequent crop. This method to showed that 26.5% of N from soybean residue was taken up by the following crop in a pot study.

The objectives of our study were to determine how much and when N from fertilizer, lentil green manure, lentil straw or wheat straw was taken up by a subsequent crop, and to compare surface placement and incorporation of residues on recovery of fertilizer and residue N. The ^{15}N balance method was used to meet this objective.

MATERIALS AND METHODS

Production of ^{15}N-enriched and unenriched residues was carried out in 1988. Microplots (0.5 m^2 by 20 cm depth) were installed in field plots containing spring-seeded Neepawa wheat and Laird lentil and late-July-seeded Indianhead lentil. Fertilizer N enriched in ^{15}N (10 to 17 atom % ^{15}N excess) was applied to microplots three or four times during the growing season; total fertilizer added was equivalent to 6.0 and 10.5 g m^{-2} for late-seeded and spring-seeded microplots, respectively. Similar rates of unenriched fertilizer N were applied to a square meter area in the same plot. Early-seeded microplots were harvested on Aug. 29 and the late-seeded microplot was harvested on Sept. 23. Residues were air-dried, ground with a Wiley mill to pass a 2 mm screen, and then analyzed for N concentration and ^{15}N abundance (Table 1.2.1).

Table 1.2.1 N and ^{15}N content of residues used.

	Green manure	Lentil straw	Wheat straw
% N	4.05	1.29	0.94
C/N ratio	10.4	32.6	44.7
Atom % ^{15}N excess	2.665	3.440	4.043

The experimental site was located at the Saskatchewan Irrigation Research Center at Outlook in an area in which unfertilized wheat had been grown in 1988. The soil was a Bradwell sandy loam, pH 7.8, 1.6% C, 0.16%N, mineral N and P of 6.7 and 8.2 $\mu g\ g^{-1}$ in the 0-10 cm depth and 7.7 and 2.4 $\mu g\ g^{-1}$ in the 10-30 cm depth, respectively. Microplots of PVC pipe, 10 cm in diameter by 40 cm in length, were pressed into the ground with hydraulic force in a grid pattern (approximately 0.4 m by 0.4 m). Soil compaction during installation of the microplots was minimal.

^{15}N-enriched and unenriched residues of the Indianhead lentil green manure (G), Laird lentil straw (L), and Neepawa wheat straw (W) were surface-placed and incorporated (2.5 to 7.5 cm) on Oct. 5, 1988. A treatment with no added residue (NR) was also included. The following spring (May 8, 1989) microplots containing ^{15}N-enriched residue were amended with 24 mg of unenriched NH_4^+-N (ammonium sulfate; equivalent to 3.0 mg N m^{-2}) while microplots containing unenriched residue were amended with 24 mg N of ^{15}N-enriched NH_4^+-N (9.67 atom % ^{15}N excess). Four seeds of wheat were then planted in each microplot; after two weeks these were thinned to two wheat plants microplot^{-1}. The microplots were rain-fed except for an additional 5 cm added between weeks 6 and 10 weeks when rainfall was negligible. Three microplots of each treatment were removed from the field at the time of planting (^{15}N-enriched microplots only), and at 6, 10 and 13 weeks after planting, which coincided with emergence of the fifth leaf, culm elongation, and maturity, respectively.

Microplots were brought back intact to Saskatoon. Wheat tops were first removed and placed in a forced-air oven at 50°C. The soil was removed in three depths: 0-10 cm, 10-25 cm, and 25-40 cm. Soil samples were well mixed and analyzed for total and mineral N. Subsamples for total N were dried at 60°C and then ground with a mortar and pestle. Wheat tops were finely ground with a cyclone mill. Grain and straw were analyzed separately at the final sampling date. Total soil and wheat N was determined by micro-Kjeldahl analysis modified to include nitrate and nitrite forms. Mineral N was determined by steam distillation with MgO and Devarda alloy of extracts obtained by shaking soil with 2 M KCl for 1 hour. ^{15}N analysis was carried out by converting NH_4^+ to N_2 by LiBrOH. and determining the ^{15}N:^{14}N ratio with a VG Micromass 602E isotope ratio mass spectrometer. The proportion of N derived from fertilizer (Ndff) or residue (Ndfr) was calculated as atom % ^{15}N excess of N in wheat or soil pool divided by the atom % ^{15}N excess of N added as fertilizer or residue.

RESULTS AND DISCUSSION

Total N in the tops of wheat was not significantly affected by type or placement of residue at any of the sampling dates (Figure 1.2.1), indicating that N was probably not limiting in this experiment. This was likely because during early growth added fertilizer N could likely meet N requirements while during later growth N from below the microplots could likely meet N requirements.

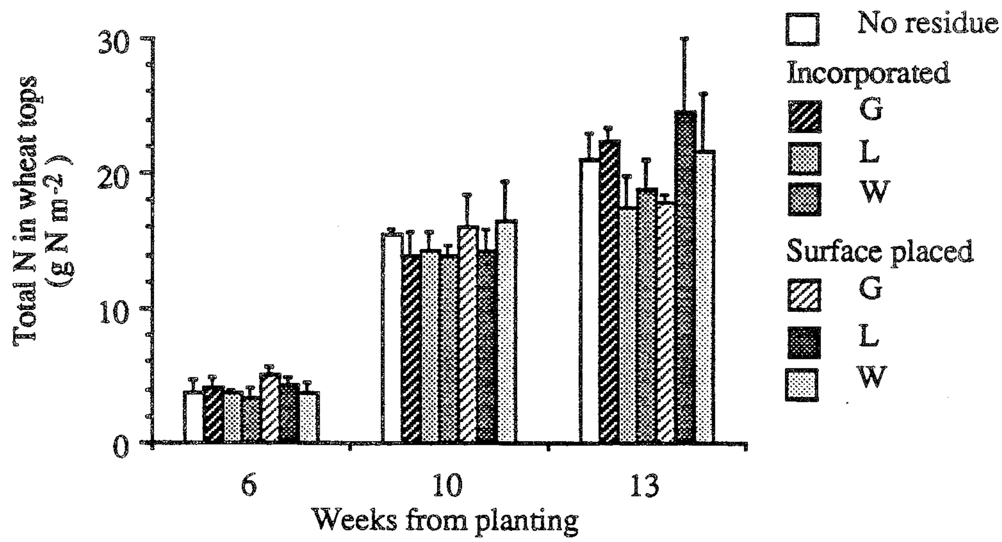

Figure 1.2.1 N accumulation of N in wheat tops at 6, 10 and 13 weeks after planting in each treatment. Error bars are standard deviations.

Recoveries of fertilizer ^{15}N in the tops of wheat was similar following G, surface-placed W, surface-placed L and NR; maximum recoveries of approximately 34% were obtained by the final sampling date (Figure 1.2.2). These recoveries are somewhat low due to losses of approximately 30% between 0 and 6 weeks (Figure 1.2.3). Within 16 days of planting 9 cm of rain had been received at the experimental site, and thus losses

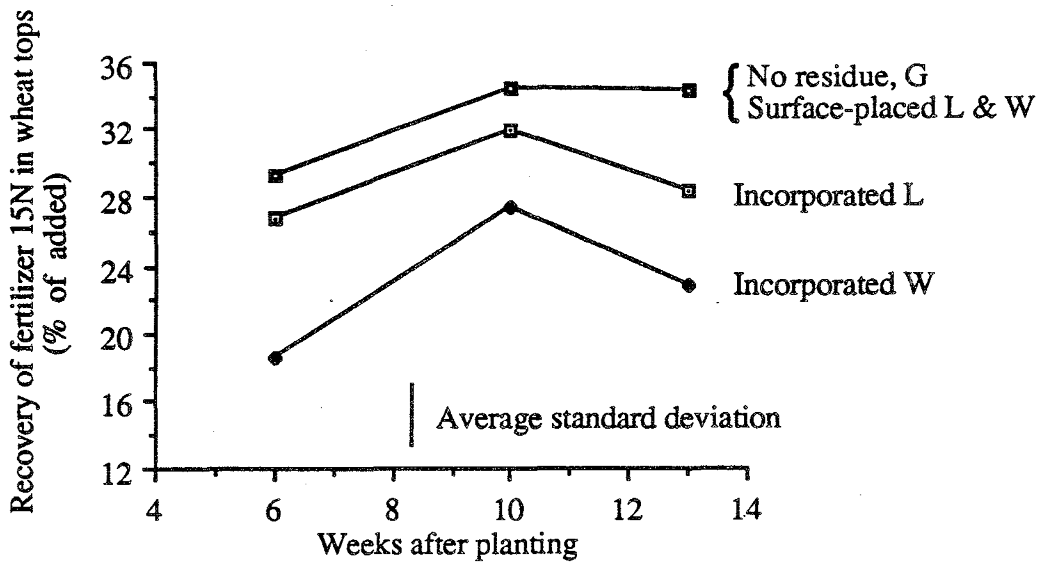

Figure 1.2.2 Recovery of fertilizer ^{15}N in wheat tops at 6, 10 and 13 weeks after planting.

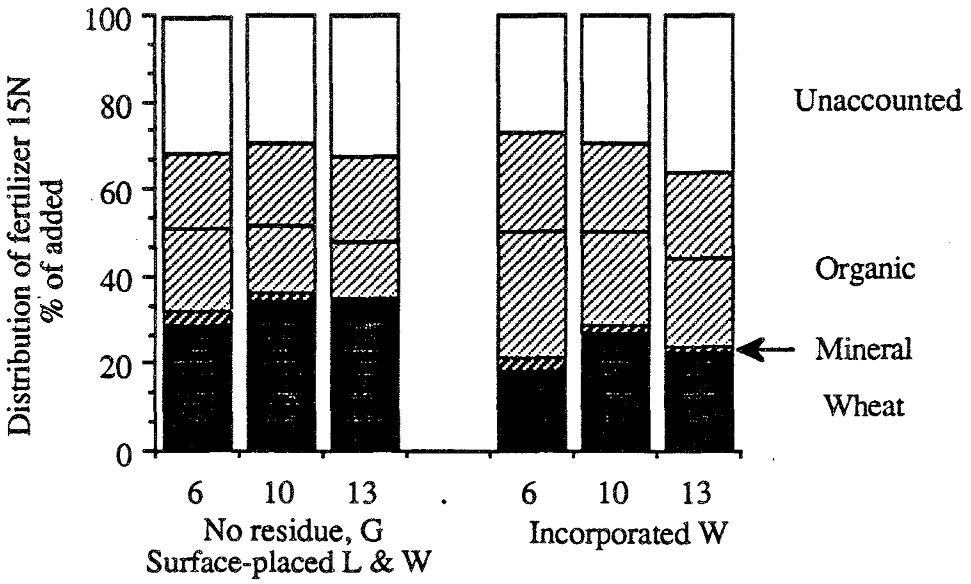

Figure 1.2.3 Distribution of fertilizer ^{15}N at 6, 10 and 13 weeks after planting.

likely occurred through denitrification and/or leaching. Recovery was slightly reduced by incorporation of L and significantly reduced by incorporation of W due to immobilization of fertilizer ^{15}N (Figures 1.2.2 and 1.2.3); losses of fertilizer ^{15}N were similar to that of the other treatments (Figure 1.2.3). Reduced immobilization of fertilizer ^{15}N due to surface placement of residues with a high C/N ratio has also been observed in other studies (Smith and Sharpley, 1990), and can be attributed to reduced microbial growth and to spatial separation of fertilizer ^{15}N from the decomposing residue.

Recoveries of residue ^{15}N in the tops of wheat were always lower than that of fertilizer ^{15}N: a maximum recovery of 19% was obtained from incorporated G at the final sampling date (Figure 1.2.4). Less residue ^{15}N was recovered from surface-placed G than from incorporated G because of greater losses of ^{15}N from surface-placed G (Figures 1.2.4 and 1.2.5). Losses of ^{15}N from surface-placed G may be due to volatilization of N

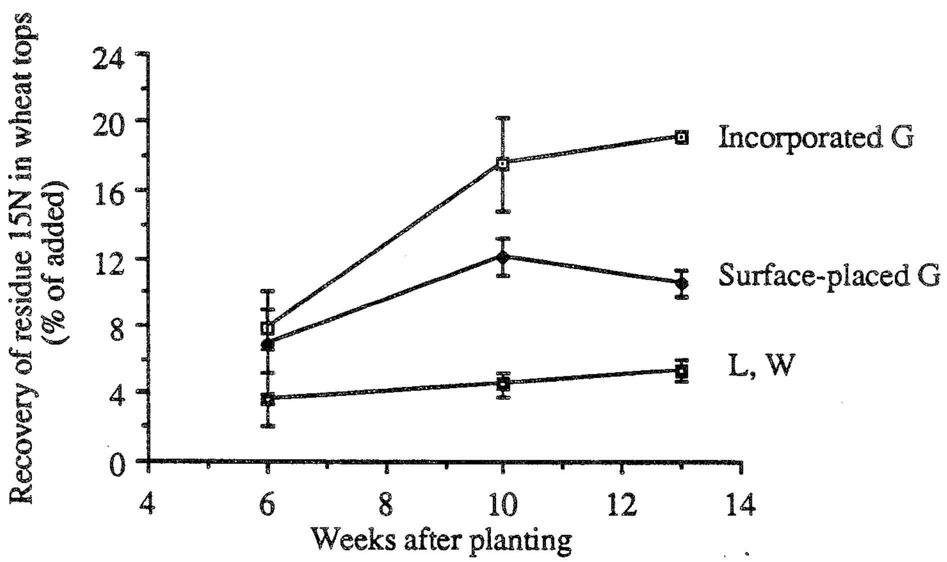

Figure 1.2.4 Recovery of residue ^{15}N in wheat tops at 6, 10 and 13 weeks after planting.

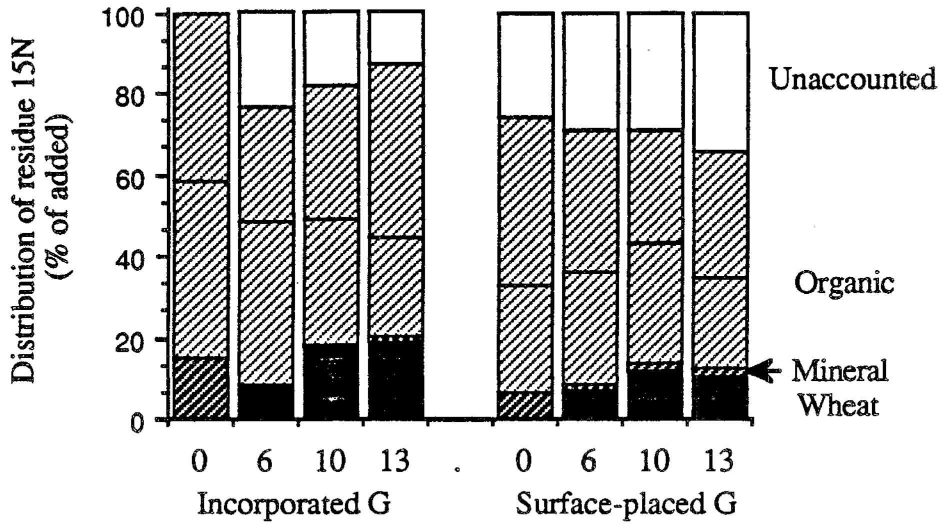

Figure 1.2.5 Distribution of residue ^{15}N in G treatments at 0, 6, 10 and 13 weeks after planting.

during decomposition or to leaching during spring runoff. Increased NH_3 evolution after alfalfa was cut has been observed and losses of green manure N due to volatilization of approximately 20% have been observed. The data suggests that losses from incorporated G were most likely due to leaching: losses occurred between 0 and 6 weeks after planting, 15% of added ^{15}N was present in mineral form in the 10-40 cm depths at the time of planting, and part of the ^{15}N lost by 6 weeks after planting was recovered by wheat plants after 6 weeks. Recovery of residue ^{15}N from surface-placed and incorporated L and W was similar; a maximum recovery of 5.8 % in wheat tops was obtained for these residues. Surface placement of W and L did not affect recovery of ^{15}N in wheat but increased unaccounted ^{15}N from 0 to 10%, again most likely due to volatilization of ^{15}N. The low recovery of ^{15}N from these residue can be attributed to their wide C:N ratio:microorganisms breaking down these residues would require any N present for their own growth (Figure 1.2.6).

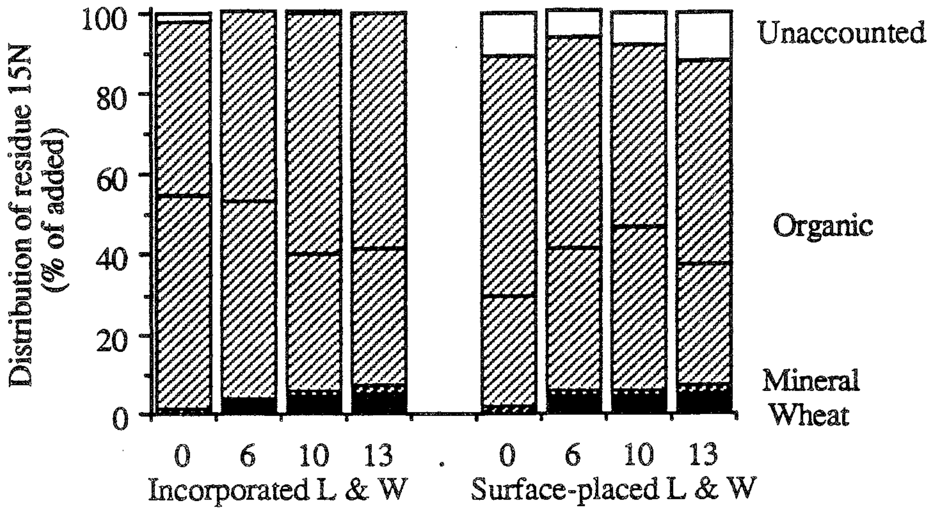

Figure 1.2.6 Distribution of residue ^{15}N in L and W treatments at 0, 6, 10 and 13 weeks after planting.

Although only 20% of N in wheat tops was accumulated by 6 weeks, close to 85% of fertilizer ^{15}N and approximately 60% of residue ^{15}N was accumulated by this time. The main reason for poor synchronization between N and ^{15}N uptake is that N from both fertilizer or residues is most readily available to soil microoganisms initially and quickly becomes stabilized in more resistant forms.

The recoveries of residue ^{15}N from G were similar to those obtained from other studies using ^{15}N balance for residues with a high N concentration (Table 1.2.2). In general, less N from plant residues was accumulated by a growing crop than was or could be expected from fertilizer. However, ^{15}N recoveries may underestimate the total amount of N released, especially with added residues, because it does not account for increased net mineralization of native N. Higher but often variable estimates of N recovery based on differences in N uptake or N response may often be real and due to the interaction of added residue with native soil N.

Table 1.2.2 Reported recoveries by a subsequent crop of ^{15}N from ^{15}N-enriched legume residues.

Authors	Country	Residue type	% Recovered
Bremer and Van Kessel	Canada	Lentil	11, 19
Ladd et al. (1981, 1983, 1986)	Australia	Alfalfa	11 - 25
Muller and Sundman (1988)	Finland	Field Bean, Clover	18 - 24
Harris and Hesterman (1990)	U.S.A.	Alfalfa	17 - 25

CONCLUSIONS

(1) Maximum recoveries of fertilizer ^{15}N were 34% by the final sampling date.

(2) The proportion of residue ^{15}N recovered in wheat tops at the final sampling dates was 19% and 11% from incorporated and surface-placed G, respectively, and 5.4 and 5.3% from L and W, respectively.

(3) Surface placement of residues reduced immobilization of fertilizer N but increased losses of residue N.

(4) Comparisons of N availability based on recovery of ^{15}N may be misleading because ^{15}N recovery does not account for changes in mineralization of native N, which is likely to be affected unequally by the addition of different N sources.