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INDIANHEAD BLACK LENTIL: A GREEN MANURE CROP FOR THE BROWN SOIL ZONE?

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INTRODUCTION

The rising cost for N fertilizer, coupled with growing concerns about soil degradation, are stimulating renewed interest in legume green manuring practices. In the semiarid Brown soil zone, the use of biennial and perennial legumes as green manure crops have been shown to be impractical, because yields of the subsequent cash crop are dcpresscd, primarily due to reduced water availability (Power 1990; Green and Bicdcrbeck 1995). However, recent work by Biederbeck et al. (1993) has shown that annual legumes, especially if they are efficient water users and are managed to conserve extra water (e.g., through snowtrapping), may represent a viable option for producers in this region.

The objective of this study was to determine the suitability of using Indianhead black lentil as a green manure fallow substitute when it is grown in a 3-yr rotation with hard red spring wheat in southwestern Saskatchewan.

MATERIALS AND METHODS

In this paper, we examine two of nine crop rotations that were established in 1987 at Swift Current, Saskatchewan, on a Swinton loam, a fallow-wheat-wheat (F-W-W) and a green manure-wheat-wheat (GM-W-W) system. Plots were 15 m x 45 m, arranged in a randomized complete block design with three replicates. All phases of the rotations were present every year and each rotation was cycled on its assigned plots. All plots were managed using minimum and no-tillage practices. Tillage was used only when deemed necessary for proper weed control or seed placement. Plots planted to wheat in 1989, 1992, and 1993 received one preseeding tillage operation; in other years, the wheat was no-till planted. Plots seeded to Indianhead lentil were no-till planted, except in 1988 and 1989 when the secdbed was prepared with one operation of a cultivator with mounted harrow. The wheat and lentil were planted generally between 7 May and 22 May. In 1991, the lentil plots were reseeded on 10 June due to poor germination. Planting was performed with a no-till offset disc drill. Hard red spring wheat was planted at the recommended rate of 67 kg ha^{-1} and lentil at 35 kg ha-‘. The lentil seed was inoculated with an appropriate rizobium culture prior to planting.

Areas planted to wheat received N fertilizer (ammonium nitrate) based on NO,-N levels in the upper 60 cm of soil measured the previous fall (Table 1). The N fertilizer was mid-row banded at the 5 to 7.5 cm depth. Wheat grown on fallow and stubble also received P fertilizer (monomammonium phosphate) applied with the seed at an average rate of 7.4 kg P ha^{-1} during 1988-90 and 9.6 kg P ha^{-1} thereafter. Indianhead lentil rcccivcd only P fertilizer at an average rate of 4.9 kg P ha^{-1}. The wheat received in-crop weed control as required each year; Indianhead lentil received no herbicides.

Table 1. Rates of N fertilizer applied to wheat

Rotation phase”	N fertilizer applied (kg ha-‘)						
	1988	1989	1990	1991	1992	1993	Mean
F-(W)-W	21	13	15	26	40	38	26
GM-(W)-W	27	59	11	37	56	36	38
F-W-(W)	27	42	18	46	63	55	42
GM-W-(W)	27	28	25	32	60	55	38
Mean	26	36	17	35	55	46	36

z In this and subsequent tables and figures, the rotation-phase in parentheses is the one being considered.

Wheat was harvested at full maturity using a conventional, direct cut, header combine. The stubble was cut as high as possible (usually > 30 cm) to enhance over-winter snowtrapping and water conservation. The legume green manure crop was turned down at full bloom (usually between 8 July and 23 July) with a wide V-blade cultivator in 1988 and in other years using a disc. Subsequent weed growth on these areas (if any) was controlled by one operation with the wide V-blade cultivator.

Conventional fallow areas received one spray application in early June using a tank mix of glyphosate plus dicamba and 2,4-D amine. This was followed by one or two tillage operations as required using a wide V-blade cultivator. All plots received 2,4-D ester in the fall to control winter annual broadleaf weeds.

Soil samples were taken prior to commencement of field operations in early spring, at ploughdown of the GM or immediately after wheat harvest, and in mid-October. Subsamples were taken by depth for gravimctric soil water determination, and the remaining soil was air-dried and analyzed for NO_3-N and bicarbonate extractable P.

The data were analyzed as a split plot with rotation-phase as main plot and year as sub-plot (SAS Institute Inc. 1985). Significant differences among treatment means were determined by LSD (Little and Hills 1978). Potential evapotranspiration (PET) for cropped systems was assumed to be 70% of pan evaporation. The lower limit of available water in the soil under wheat was taken as the lowest water content measured under a plot during the study period (i.e., 91 mm in 0- to 120-cm depth). Water deficit was calculated as the available water minus PET, where available water was soil water (O-120 cm) in spring (SpSW) plus growing season (1 May to 3 1 July) precipitation (GSP) minus the lower limit.

RESULTS AND DISCUSSION

Indianhead Black Lentil Production and Water Use

Dry matter production (above ground) of Indianhead lentil by full bloom averaged 2500 kg ha-‘, with yields being lowest in the drought years of 1987 and 1988 (Table 2). This is similar to the dry matter yield reported for Indianhead lentil GM by Biederbeck et al. (1993) at Swift Current over the 1984-90 period, but is lower than that obtained by them for other annual legumes such as chickling vetch and feedpea. Nitrogen concentration of the lentil GM averaged 27.6 g kg^{-1}, and was lowest in 1991 when the lentil plots were reseeded due to poor germination. Nitrogen content of the GM averaged 76.2 kg ha-‘. The lentil used from 82 to 299 mm of water between planting and ploughdown, thus resulting in an average water use efficiency of 13.7 kg ha^{-1} mm-‘. This compares to 15.1 kg ha^{-1} mm^{-1} reported in the earlier study by Biederbeck and Bouman (1994).

Table 2. Yield, N concentration, N content, and water usc efficiency (WUE) of Indianhead black lentil green manurc[z]

Green manure	Year 1987	1988	1989	1990	1991	1992
Yield (kg ha“)	1301	1378	3962	3376	2282	2700
N concentration (g kg-‘)	ND”	30.9	28.1	33.8	19.3	25.7
N content (kg ha-‘)	ND	42	111	114	44	70
Water use (mm)[y]	82	155	268	169	299	181
WUE (kg ha-’ mm^{-1})	15.9	8.9	14.8	20.0	7.6	14.9

z Not determined.

Y Spring soil water was 229, 186, 227, 239, 267, and 235 mm/120 cm depth in 1987, 1988, 1989, 1990, 199 1, and 1992, respcctivcly. Precipitation received from seeding to plough-down of the lentil was 66, 140,205, 116,266, and 143 mm, while soil water at plough-down of the lentil was 213, 171, 164, 186,234, and 197 mm/120 cm in the respective years.

Wheat Grain and Straw Yield

Wheat yields were higher ($P < 0.05$) when the crop was grown on conventional F [F-(W)-W] than on partial-fallow GM [GM-(W)-W] in 4 of the 6 yr (1988, 1990, 1992 and 1993) (Fig. la). However, there was no difference in grain yields of wheat grown on stubble (stubble-wheat) [(F-W-(W)) or GM-W-(W))]. This response was related to the reduction in spring soil water (SpSW) due to use by the GM crop, and was unexpected because growing season precipitation (GSP) was above average in 5 of 6 yr (Table 3).

Table 3. Available water for the two 3-yr rotations

Rotation phase	Year[z]	SpSW (mm/120 cm)	Avail. water[y] (mm/120 cm)	Water deficit[x] (mm)
F-(W)-W	1988	231	283	-477
	1989	230	349	-138
	1990	277	359	-130
	1991	287	498	51
	1992	281	371	-86
	1993	300	394	-86
GM-(W)-W	1988	207	259	-501
	1989	187	296	-191
	1990	215	297	-192
	1991	223	434	-13
	1992	218	308	-149
	1993	238	332	-148
F-W-(W)	1988	188	240	-520
	1989	191	310	-177
	1990	231	313	-176
	1991	260	471	24
	1992	217	307	-150
	1993	214	308	-172
GM-W-(W)	1988	179	231	-529
	1989	198	317	-170
	1990	244	326	-163
	1991	257	468	21
	1992	183	273	-184
	1993	221	315	-165

z GSP = growing season precipitation (1 May to 31 July) was 143, 210, 173, 302, 181, and 185 mm in 1988 to 1993, respectively. PET, was 760, 487, 489, 447, 457, and 480 mm in the respective years.

y Available water = SpSW + GSP - lower limit of available water.

x Water deficit = available water - PET.

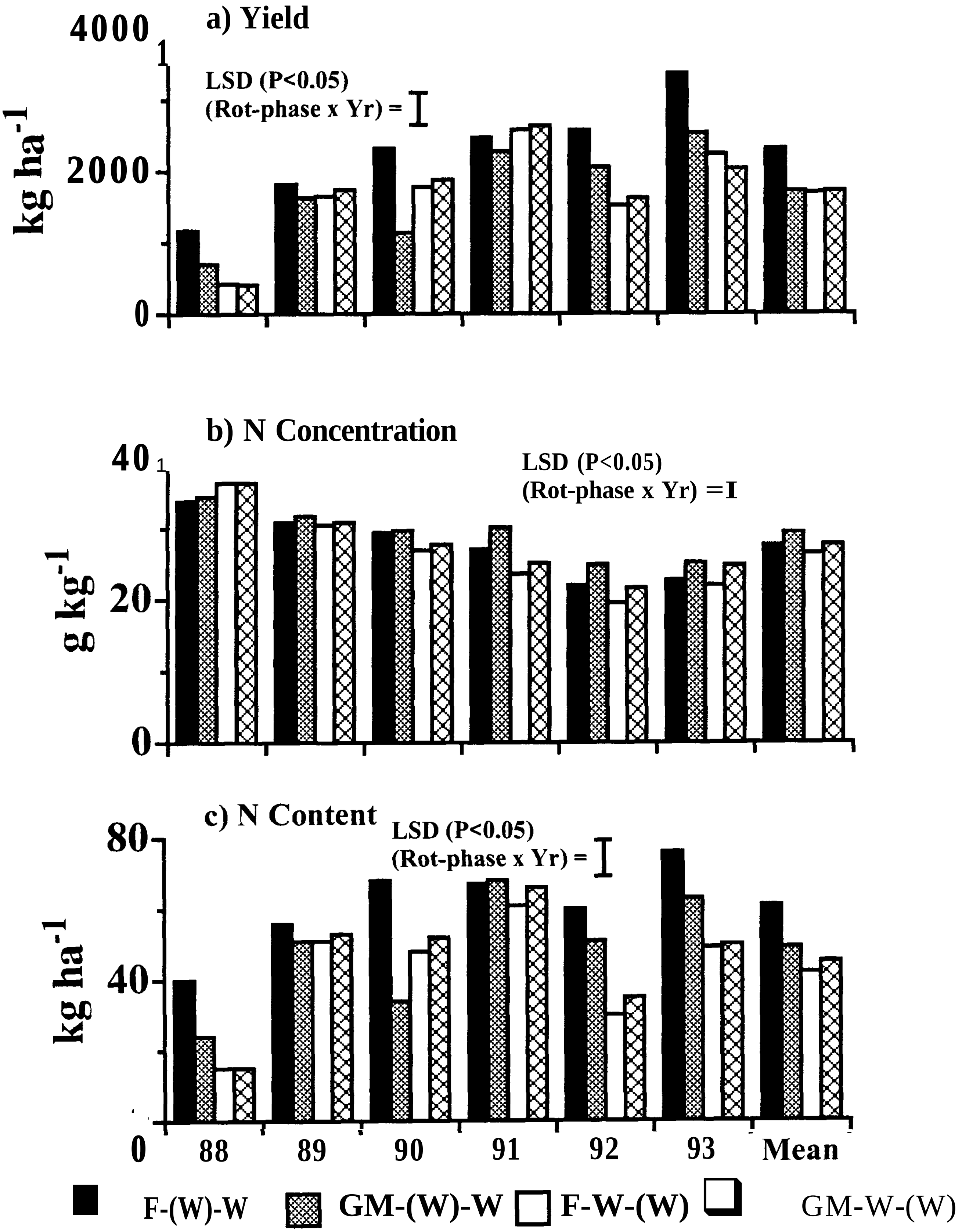

Figure 1. Effect of legume green manure on (a) grain yield, (b) N concentration, and (c) N content (1988 - 1993)

Similar reductions of wheat yields after Indianhead lentil GM, as compared to after F, have been reported in the Dark Brown soil zone at Saskatoon and Qu'Appelle, Saskatchewan (Slinkard and Bicdcrbeck 1987). But, at Scott, Saskatchewan, (also in the Dark Brown soil zone) yields of wheat grown on Indianhead lentil GM were always as high as on F, in particular when the GM was turned down at the bud stage rather than at full bloom (Brandt 1990).

Wheat straw yields, like grain yields, were lower for GM-(W)-W than for F-(W)-W in 3 of 6 yr, but they showed no difference for the stubble-wheat systems (Fig. 2a).

N Concentration of Grain and Straw

In the last 3 yr of the study, N concentration in grain was higher for GM-(W)-W than for F-(W)-W (Fig. 1 b). The same was true for stubble-wheat [GM-W-(W) > F-W-(W)] in 1993. However, there was little difference in grain N concentration between wheat grown on fallow (or partial fallow) and stubble-wheat. The higher grain N concentrations of wheat in the GM system compared to monoculture wheat was partly related to yield dilution (Figs. 1 a and 1 b), and less likely due to any differences in soil available N. For example, there was no difference in NO,-N in 0- to 60-cm depth for the two rotations (data not shown). There was also no effect of rotation phase on NO,-N in the 60- to 90-cm depth (data not shown). Thus, little evidence exists of any preferential increase in soil available N under the GM-containing system, perhaps because: (i) most of the legume N ended up in stable organic N reserves of the surface soil, as found in an earlier study with ^{15}**N-labelled** Indianhead lentil GM (Janzen et al. 1990), and (ii) only two cycles of the rotation (each plot has had GM on it only twice in 6 yr) have been completed. The 6-yr average NO,-N content of the rotation phases were: 42, 43, 74, 56, 44, and 49 kg ha" in the 0- to 60-cm depth for (F)-W-W, (GM)-W-W, F-(W)-W, GM-(W)-W, F-W-(W), and GM-W-(W), respectively; in the 60- to 120-cm depth the respective values were 42, 64, 54, 60, 44, and 68 kg ha-'.

There was generally little consistent effect of rotation or rotation-phase on the N concentration in straw (Fig. 2b). Averaged over years, straw N concentrations were 4.6, 5.5, 4.9, and 5.1 g kg^{-1} for F-(W)-W, GM-(W)-W, F-W-(W), and GM-W-(W), respectively.

As noted for grain yield, which is the main component of grain N content, the latter was greater ($P < 0.05$) for F-(W)-W than for GM-(W)-W in 3 of 6 yr; however, there was no effect of rotation on stubble-wheat grain N content (Fig. 1 c). Although there was no consistent effect of crop rotation on N content of straw, the latter was generally greater for wheat grown on fallow or partial fallow than for stubble-wheat, particularly in the last 3 yr of the study (Fig. 2c).

The above-ground plant N of wheat was greater for F-(W)-W than for GM-(W>W in 1988, 1990 and 1993, and lower in 199 1 (data not shown). However, there was no effect of rotation on above-ground plant N (data not shown). Because of the yield component of N content, above-ground N content was greater for wheat grown on fallow (or partial fallow) than for stubble-wheat. The 6-yr average above-ground plant N content was 79, 68, 54, and 59 kg ha^{-1} for F-(W)-W, GM-(W)-W, F-W-(W), and GM-W-(W), respectively. These above-ground N content results support our earlier observation that, so far, there is no tangible evidence that the two cycles of legume green manure increased the N fertility of the soil compared to the F-W-W system.

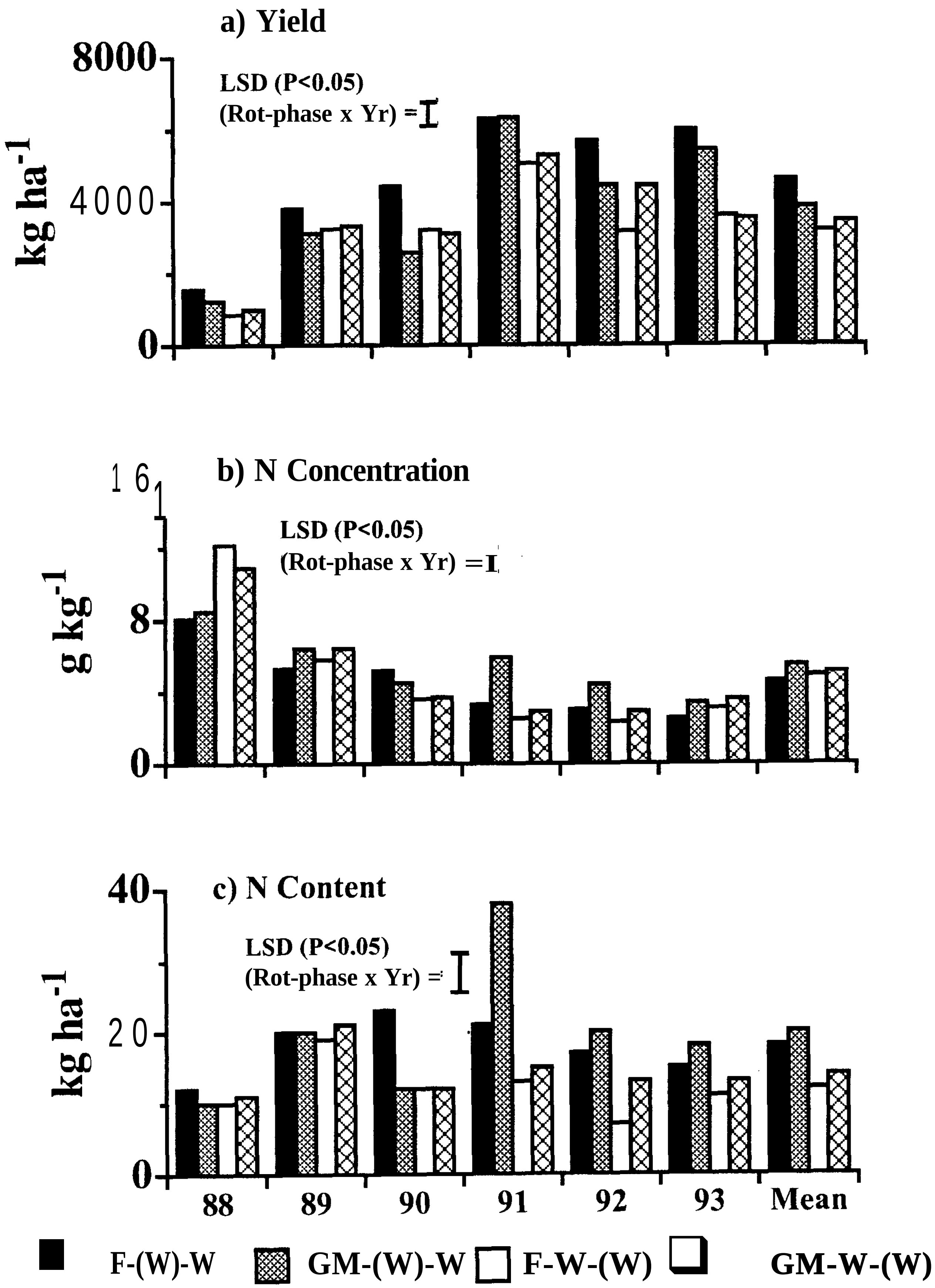

Figure 2. Effect of legume green manure on (a) straw yield, (b) N concentration, and (c) N content (1988 - 1993).

Our results appear to be less encouraging than reports by Biederbeck (1990) who showed that GM-(W) outyielded F-(W) by 12% (averaged over four annual legumes grown during 5 yr at Swift Current). However, in their study they seeded earlier than we did and disced-in the legume no later than the first week of July. We have, since 1993, adopted this management practice, even if it means sacrificing some N_2 fixation, to ensure that there is more likelihood that available soil water will be sufficiently recharged by the following spring to minimize potential yield depression of the subsequent wheat crop in this semiarid environment.

CONCLUSIONS

An Indianhead black lentil green manure-wheat-wheat (GM-W-W) rotation was compared to fallow-wheat-wheat (F-W-W) on a loam soil in the Brown soil zone at Swift Current, Saskatchewan. Results after two cycles (6 yr) of these rotations showed that GM was depressing subsequent yields of wheat grown on partial fallow, compared to wheat grown on conventional fallow in the F-W-W system, although stubble-wheat yields were not affected by rotation. These findings were related to the negative influence of GM on soil water reserves in spring. They were unexpected because, in 5 of the 6 yr, growing season precipitation was above-average for this region. We concluded that, for the annual GM system to be practical in the Brown soil zone, producers must seed the legume as early as possible (i.e., before seeding wheat) and terminate its growth (by soil incorporation or other means) no later than the end of the first week in July, even if this means that the total amount of N_2 fixed will be reduced in some years.

ACKNOWLEDGEMENT

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