EFFECT OF CROP ROTATIONS ON POTENTIALLY MINERALIZABLE N AND AMINO COMPOUNDS IN A BLACK CHERNOZEM AT INDIAN HEAD.

C.A. Campbell*, M. Schnitzer, A.J. Leyshon,
G. LaFond, R.P. Zentner, F. Selles

ABSTRACT

The effect (i) of fertilization on fallow-wheat (F-W), F-W-W, and continuous wheat; (ii) of baling straw on F-W-W (fertilized); (iii) of including sweetclover as green manure (GM) in F-W-W (unfertilized); and (iv) of including bromegrass-alfalfa cut for hay (H) in a 6-yr mixed rotation (F-W-W-H-H-H), on soil organic matter nitrogen (N) characteristics was determined in the top 15 cm of a thin Black Chernozem at Indian Head Saskatchewan after 30 years of treatments. Treatment effects were apparent from analysis of kjeldahl N, amino N released during hydrolysis with 6M HCl, and with potentially mineralizable N (N_o) and its rate constant (k). However, the "potential rate of mineralization" (N_o X k) proved to be the most powerful tool in segregating treatment effects. The relative molar distribution (RMD) of amino acids showed significant increases in aspartic acid and decreases in arginine and leucine, but these differences were mainly related to the influence of the 6-yr and fertilized continuous wheat being different from the shorter or unfertilized systems. It was concluded that fertilizers are as effective as legume green manure or grass-alfalfa in increasing soil organic matter and improving its quality (N supplying power) in this medium fertility soil where moisture is rarely limiting to crop production. Secondly, it was suggested that the parameter N_o X k could be a powerful tool for scientists to use in assessing soil quality. Finally, we estimated that the F-W and F-W-W rotations, especially when not fertilized or when straw was baled, had continued to cause losses in total N ; that fertilized F-W-W and unfertilized continuous wheat was maintaining the organic N, while the legume-containing and fertilized continuous wheat systems had increased the organic matter compared to the level at the start of the experiment (i.e., following many years of conventionally tilled F-W & F-W-W).

INTRODUCTION

The influence of rotation length and fertilizers (Biederbeck et al 1984; Janzen 1987a,b) and legumes in mixed cereal-legume systems (Janzen 1987b, Khan 1971; Poyser et al 1957) on soil organic matter content and soil quality parameters such as potentially mineralizable N (Biederbeck et al 1984; Janzen 1987b) and amino compounds (Khan 1971) have been investigated to a limited extent in Western Canada. In most of these studies, soil organic matter contents and quality were shown to be improved by the use of fertilizer, and extending the rotation length. However, while some benefits were credited to legumes in the Black soil zone (Poyser et al 1957; Khan 1971), Janzen (1987b) concluded that, in the Dark Brown soil zone, "inclusion of perennial forages in spring wheat rotations for the purpose of enhancing soil fertility and organic matter levels was not justified".

The practice of baling and removing straw for feed or other purposes is common in the Black soil zone, but no studies have been carried out to determine how the practice influences soil organic matter, except for current studies reported by Greer and Anderson (1989) and Campbell et al. (1989) at the 1989 Soils and Crops Workshop.

An ongoing crop rotation study, initiated in 1958 on a Black Chermozem at Indian Head Saskatchewan, provided an ideal opportunity to determine how fertilizers, rotation length, green manure, intermediate length cereal-forage (legume-grass) systems and straw baling influence soil organic matter. At these meetings last year, Campbell et al (1989) reported on the effect of these systems on total soil organic matter. In the present paper we discuss the influence of the same treatments on the hydrolyzable amino compounds and some mineralizable nitrogen parameters.

MATERIALS AND METHODS

The 0-to 7.5 and 7.5 to 15-cm depths of replicates 1 to 4 of each rotation phase specified in Table 1 were sampled in early June 1987 after 30 years of the rotation treatments.

Table 1. Rotations[+] sampled at Indian Head in early June 1987.

No.	Rotation phase[‡] sampled	N	P
1	(F)-W	no	no
2	(F)-W (fertilized)	yes	yes
3	(F)-W-W	no	no
4	(F)-W-W (fertilized)	yes	yes
5	(F)-W-W (fertilized, straw baled)	yes	yes
6	(GM)-W-W	no	no
7	GM-(W)-W	no	no
8	(F)-W-W-H-H-H	no	no
9	F-W-W-(H)-H-H	no	no
10	Continuous W	no	no
11	Continuous W (fertilized)	yes	yes

[+] F = fallow; W = spring wheat; GM = sweetclover turned under for green manure; H = bromegrass-alfalfa cut for hay.
[‡] The phase in parenthesis was the one sampled.

The average annual rates of fertilizer applied to treatments that were designated to receive fertilizer are shown in Table 2.

Table 2. Average annual rates of fertilizers applied

INDIAN HEAD	FERTILIZER RATES N	FERTILIZER RATES P_2O_5
	- kg ha^{-1} -	
1960-77 (Gen. Rec.)		
Wheat on fallow	6	27
Wheat on stubble	24	21
Since 1978 (Soil Test)		
Wheat on fallow	5	22
Wheat on stubble	82	25

Total N in each depth sampled was determined by kjeldahl digestion. Potential mineralizable N (N_o) and rate constants (k) were determined by long-term (up to 16 weeks) incubation at 35°C with periodic leaching (Standford and Smith 1972). A soil property called the "potential rate of mineralization" was calculated as the product of N_o and k. Amino acids and amino sugars were determined in the hydrolysates of soil hydrolysed with 6M HCl (Schnitzer and Hindle 1981). In all three analyses air-dried soil was used.

Since there was no treatment effect on bulk densities, the average densities of 0.95 g cm^{-3} and 1.22 g cm^{-3} for the 0- to 7.5- and 7.5- to 15-cm depths, respectively, were used to convert concentrations to kg ha^{-1} for each parameter in each depth. Values for 0- to 15-cm depth were derived either by arithmetic summation where amounts (eg, kg ha^{-1}) were involved, or by weighted average where concentrations (e.g., % N) were involved. The rate constant (k) for the 0- to 15- cm depth was calculated for each treatment replicate as follows: [N_o X k (0- to 7.5-cm) + N_o X k (7.5- to 15-cm)] ÷ [N_o (0- to 7.5-cm) + N_o (7.5- to 15-cm)], where N_o was in kg ha^{-1} and k = wk^{-1}. In this paper, only the values for the 0- to 15-cm depth are presented except in a few instances.

Analysis of variance was carried out on the 11 rotation treatments and single degree of freedom linear contasts (SAS Institute Inc. 1985) used to make 21 appropriate comparisons of treatment means. Unless specified otherwise, significance was assumed to be P = 0.10 or less.

RESULTS AND DISCUSSION

Total Soil Nitrogen

Since this facet was discussed last year (Campbell et al 1989), we will only present a summary of our findings here to facilitate the reader. It was found (Table 3) that:

1) Tillage was the main factor causing loss of organic nitrogen.
2) Soil organic nitrogen increased with rotation length.
3) Fertilizing according to soil test lead to increase in soil organic N in direct proportion to rotation length.
4) Sweet clover used for green manure in the 3-yr rotation with spring wheat increased organic nitrogen to the same extent as where fertilizers were applied to wheat at rates based on soil test.
5) In contrast to the findings of Janzen (1987b) in the Dark Brown Soil at Lethbridge, Alta., the 6-yr F-W-W-H-H-H rotation increased organic N more than did unfertilized continuous wheat. Even though there was one year of fallow every 6 years, the organic N content of the mixed rotation was similar to that of fertilized continuous wheat.

Table 3. ROTATION EFFECTS ON TOTAL N, AMINO COMPOUNDS, AND POTENTIAL MINERALIZABLE N PARAMETERS IN INDIAN HEAD SOILS (0- to 15-cm depth).

	(F)-W NO FERT	(F)-W FERT	(F)-W-W NO FERT	(F)-W-W FERT	(F)-W-W STRAW REMOVED	(GM)-W-W	GM-(W)-W	(F)-W-W -H-H-H	F-W-W- (H)-H-H	CONT W NO FERT	CONT W FERT
N CONC. (%)	0.181	0.187	0.182	0.199	0.188	0.207	0.205	0.213	0.226	0.195	0.213
TOTAL N (kg ha^{-1})	2944	3044	2966	3243	3067	3372	3343	3475	3678	3168	3464
TOTAL AMINO COMPOUNDS (kg ha^{-1})	1020	1041	1015	1124	1048	1152	1150	1274	1251	1104	1219
N_o (kg ha^{-1})	253	230	248	235	213	269	301	345	333	247	332
K (wk^{-1})	0.097	0.139	0.144	0.160	0.150	0.164	0.151	0.141	0.141	0.146	0.167
N_ok (kg ha^{-1} wk^{-1})	24.39	32.03	27.57	37.29	31.29	43.40	44.54	48.33	47.02	34.91	52.92
TOTAL AA / TOTAL N	0.301	0.303	0.302	0.305	0.305	0.299	0.303	0.326	0.302	0.305	0.318
TOTAL AS / TOTAL N	0.045	0.040	0.041	0.041	0.038	0.042	0.042	0.045	0.040	0.045	0.039
TOTAL AC / TOTAL N	0.346	0.344	0.343	0.346	0.344	0.341	0.345	0.371	0.342	0.349	0.357
N_o / TOTAL N	0.087	0.077	0.083	0.073	0.070	0.079	0.091	0.102	0.091	0.080	0.098
N_oK / TOTAL N	0.008	0.011	0.009	0.012	0.011	0.013	0.013	0.014	0.013	0.011	0.015

6) Removal of straw by baling in 18 of 27 years in F-W-W (feritilized) system resulted in a 5% decrease in soil organic N (although this difference was not significant at P>0.10)
7) In the two legume-containing systems where we sampled more than one phase of each rotation, there was no significant difference (P>0.10) due to phase.

One important point that was not discussed last year is how have these treatments affected the N concentration in the surface soil since the experiment was started. Although no values are available for the N concentrations in the surface 15 cm at the start of the experiment we have estimated by graphical extrapolation of data from Shutt (1925) and Biederbeck et al (1980) that the initial % N in the 0- to 15-cm depth would have been about 0.195%. For example, Shutt (1925) reports values of 0.375, 0.254 and 0.223 for the 0 to 20 cm depth of this soil in 1884 (Virgin), 1905 and 1922 after 21 and 38 years fallow-wheat systems, respectively. Biederbeck et al (1980) for a nearby straw burning study recorded values of 0.20% for the 0- to 2.5-cm of the fallow-wheat chopped straw check plots in 1977 and our unpublished data show the value for the 0- to 15-cm depth for this treatment was about 0.195%

The N concentrations in the 0- to 15-cm depth (Table 3) show that the fertilized F-W-W and unfertilized continuous wheat systems have maintained the organic N, the F-W and F-W-W (unfertilized and baled straw) systems have depleted organic N further, while legume containing and fertilized continuous wheat systems have increased the N concentration.

<u>Amino Acids and Amino Sugars - Absolute Quantities</u>

The amount of amino acids in the acid hydrolysate of the top 15 cm of the Indian Head soil ranged between 880 and 1120 kg ha^{-1} while the amount of amino sugars ranged between 120 and 160 kg ha^{-1} (Table 4). Thus the amino acids (AA) constituted 30-33% and amino sugar (AS) 4-4.5% of the total N in the soil (Table 3). These proportions are within the range of values reported for 31 Canadian surface soils (Kowalenko 1978).

The response of amino acids, and generally amino sugars, to the rotational treatments mimicked the response of total N. Except for the S-containing amino acids, all groups of amino acids responded to rotational treatments in a similar manner on an absolute basis (Table 4). This is not surprising since, as shown above, about 40% of the soil N was hydrolyzable amino N. A correlation between total hydrolyzable amino compounds N (AC = AA + AS) and total soil N for the 0 to 15 cm depth was highly significant (R^2 = 0.93**). However, if AC-N was normalized for total N (i.e., AC-N/Total N) and this ratio was then related to total soil N, the relationship was poor and not significant (Table 5). This suggests that the harsh acid hydrolysis treatment was not very effective in isolating N constituents of a very active nature. Campbell et al (1967) in fact obtained a mean residence time for the carbon in this acid hydrolyzate of about 50 years indicating a fraction of medium stability. These results also suggest that though we can use the amino compounds to detect absolute changes in the soil organic matter as a result of cultural treatments, it was no more effective in this respect than the more easily determined kjeldahl N. When linear contrast was used to determine the effect of treatments on the amino N/N ratio, only the fallow phase of the 6-yr rotation consistently differed from the other treatments; the sample taken early in the first hay crop (after 2 years wheat) did not differ from the other treatments. This suggests that the amino compounds in grass-alfalfa differs from those under wheat.

Another way of determining whether the cultural treatments had influenced the quality of the amino compounds in the soil is to determine if any changes in the relative molar distribution (RMD) of the amino acids-N had occurred. Stevenson (1956) showed evidence that long-time cultivation of the Morrow plots at the University of Illinois had significantly increased the proportion of the amino acid material in the basic form. Yamashita and Akiya (1963) reported similar findings in Japan. However, a 30-year rotation in Ohio (Young and Mortensen 1958) and a 40 yr study in Alberta, Canada (Khan 1971) showed no such effects. Nor did Campbell et al (1986) find any effects on RMD of the Indian Head soil when either P fertilizer or manure was applied once every three years over a 30 to 40 yr period.

In the present study the RMD responses were similar for the two soil depths, consequently only data for the 7.5 to 15 cm depth are shown (Table 6). The average RMD for the four groups of amino acids were 28%, 10%, 60% and 1% for the acidic, basic, neutral, and sulfur-containing groups, respectively. Values quoted for cool temperate soils by Sowden et al (1977) were lower for acidic (20%) and for neutral (50%) and higher for basic (24%)

than our values. The main difference in values for the acidic groups was the much higher proportion of aspartic acid we obtained (17%) compared to 12% reported by Sowden et al (1977) who also reported much higher proportions of the basic amino acid arginine (10%) and lysine (7.6%) than we found.

Linear contrasts showed that in both depths there were consistent treatment effects on the RMD of 3 amino acids, namely aspartic acid, arginine and leucine. The systems that increased the total organic N the most (i.e., fertilized continuous wheat and the 6-yr mixed cereal-forage rotation) generally increased the RMD of arginine and leucine compared to the RMD obtained for the 2- and 3-yr rotations or unfertilized continuous wheat. Conversely, the RMD of aspartic acid was reduced by the treatments that tended to increase total organic N. The differences for aspartic acid and leucine (Table 6) may be related to the differences noted earlier between soils that had just grown cereals versus those that had grown forages.

Thus, the RMD results do show some small evidence of qualitative changes in the soil organic matter due to some of the rotational treatments, but these changes were not confined to any specific amino acid group. Stevenson (1982) suggest that very long periods of differential management are required for changes in amino acid quality to become evident in soils.

Mineralizable N

On the Canadian Prairies, the potentially mineralizable N (N_o), a capacity factor, has been shown to reflect changes in soil N supplying power (Campbell & Souster 1982; Biederbeck et al 1984; Janzen 1987a,b) resulting from cultural and crop management practices. Thus, it was not surprising to find that this parameter, like total N and amino compounds-N, also significantly reflected some of the rotational and other cultural treatments (Table 3). Generally, the effects on N_o were more often significant for the 0- to 7.5- than for the 7.5- to 15-cm depth (data not shown). Linear contrast analysis revealed differences due to green manuring and the use of the 6-yr mixed rotation relative to the 2- and 3-yr monoculture wheat systems. As

Table 4. ROTATION EFFECTS ON AMINO ACID GROUPS AND AMINO SUGARS IN INDIAN HEAD SOILS (0-15 cm)

AMINO ACID GROUPS	(F)-W NO FERT	(F)-W FERT	(F)-W-W NO FERT	(F)-W-W FERT	(F)-W-W STRAW REMOVED	(GM)-W-W	GM-(W)-W	(F)-W-W -H-H-H	F-W-W- (H)-H-H	CONT W NO FERT	CONT W FERT
	kg ha^{-1}										
ACIDIC	217	224	220	242	229	243	241	261	258	234	258
BASIC	196	205	200	222	210	231	226	253	251	216	247
NEUTRAL	461	478	462	513	482	525	531	591	583	502	569
SULFUR	10.6	11.5	11.0	12.0	10.7	11.1	11.5	12.1	12.6	11.7	11.8
TOTAL (AA)	885	918	893	989	931	1010	1010	1117	1105	964	1086
TOTAL (AS)	135	123	121	134	117	142	140	156	146	140	134

Table 5. REGRESSIONS, COEFFICIENT OF DETERMINATION (R^2) AND SIGNIFICANCE OF RELATIONSHIPS BETWEEN SOME N PARAMETERS (0-15 cm depth)

Variable (Y)	Variable (x)		
	Total Amino Acids (AA)	Total Amino Compounds (AC)+	Total N
N_o	$Y = -856 + 0.49\ x$ $R^2 = 0.77$**	$Y = -927 + 0.45x$ $R^2 = 0.79$**	$Y = -260 + 0.16x$ $R^2 = 0.70$**
N_o X k	$Y = -268 + 0.106x$ $R^2 = 0.91$**	$Y = -273 + 0.095x$ $R^2 = 0.88$**	$Y = -80 + 0.037x$ $R^2 = 0.87$**
AC	ND	ND	$Y = -91 + 0.37x$ $R^2 = 0.93$**
N_o/N	ND	ND	$Y = 0.007 + 2.4 \times 10^{-5}x$ $R^2 = 0.34$*
N_o X k/N	ND	ND	$Y = -0.013 + 7.7\ 10^{-6}x$ $R^2 = 0.75$**
AC/N	ND	ND	$Y = 0.32 + 9 \times 10^{-6}x$ $R^2 = 0.08^{ns}$

+ AC = Hydrolyzed amino acids plus amino sugars (amino compounds)
ND = not determined; * = significant at $P<0.05$; ** = significant at $P<0.01$;
ns = not significant

Table 6. ROTATION EFFECTS ON RELATIVE MOLAR DISTRIBUTION (RMD)± OF AMINO ACID AND GROUPS IN INDIAN HEAD SOILS (7.5-15 cm)

AMINO ACIDS	(F)-W NO FERT	(F)-W FERT	(F)-W-W NO FERT	(F)-W-W FERT	(F)-W-W STRAW REMOVED	(GM)-W-W	GM-(W)-W	(F)-W-W -H-H-H	F-W-W- (H)-H-H FERT	CONT W NO	CONT W FERT	MEAN
	%											
ACIDIC												
ASPARTIC+	18.5	18.2	18.6	18.5	18.7	17.9	17.7	17.4	17.5	18.5	17.9	18.1
GLUTAMIC	10.3	10.2	10.3	10.4	10.5	10.4	10.3	10.3	10.3	10.3	10.5	10.3
TOTAL ACIDIC	28.8	28.3	28.9	28.9	29.2	28.3	28.0	27.7	27.8	28.8	28.4	28.4
BASIC												
HISTIDINE	1.3	1.3	1.2	1.3	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3
LYSINE	5.5	5.5	5.6	5.4	5.6	5.5	5.4	5.4	5.4	5.5	5.5	5.5
ARGININE+	2.8	2.8	2.8	2.8	2.9	3.0	2.8	2.9	3.0	2.8	3.0	2.9
TOTAL BASIC	9.6	9.6	9.6	9.5	9.7	9.8	9.5	9.6	9.7	9.6	9.8	9.7
NEUTRAL												
THREONINE	6.4	6.6	6.7	6.7	6.7	6.8	6.6	6.6	6.7	6.8	6.7	6.7
SERINE	5.6	5.7	5.7	5.6	5.6	5.8	5.7	5.7	5.8	5.4	5.9	5.7
PROLINE	6.1	6.5	5.8	5.8	7.1	5.6	6.6	6.4	6.3	6.4	6.0	6.2
GLYCINE	15.1	15.2	15.0	15.1	15.2	15.1	14.9	14.6	14.9	14.9	15.0	15.0
ALANINE	10.7	10.7	10.5	10.8	10.9	10.7	10.7	10.7	10.7	10.7	10.8	10.7
VALINE	5.3	4.7	5.3	5.3	3.8	5.4	5.7	5.8	5.1	5.0	5.6	5.2
ISOLEUCINE	2.8	3.1	3.0	2.8	2.9	2.8	2.8	2.9	2.9	2.8	2.9	2.9
LEUCINE+	4.9	4.9	4.9	4.9	4.9	5.0	4.9	5.1	5.1	4.9	5.2	5.0
TYROSINE	0.7	0.7	0.6	0.7	0.6	0.8	0.8	0.8	0.9	0.8	0.6	0.7
PHENYLALANINE	2.6	2.5	2.5	2.5	2.2	2.7	2.5	2.7	2.7	2.5	1.8	2.5
TOTAL NEUTRAL	60.2	60.6	60.0	60.1	59.9	60.6	61.1	61.4	61.3	60.2	60.5	60.5
SULFUR CONTAINING												
METHIONINE	1.4	1.5	1.5	1.4	1.3	1.3	1.4	1.3	1.3	1.4	1.4	1.4
CYSTINE	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL SULFUR	1.4	1.5	1.5	1.4	1.3	1.3	1.4	1.3	1.3	1.4	1.4	1.4

± RMD = (amino acid N: total amino acid N) X 100.

+ Amino acids showing consistent significant treatment effects on RMD in both depths.

well, fertilized continuous wheat had higher N_o than all treatments except the fallow phase of the 6-yr mixed rotation. In contrast to the findings of Janzen (1987b) in the Dark Brown soil zone, N_o in the fallow phase of this unfertilized 6-yr mixed cereal-forage rotation exceeded not only that of the unfertilized but also of the fertilized continuous wheat system. Obviously this difference in results is related to the more favourable soil moisture conditions normally prevalent in the Thin Black soil thereby enhancing the forage biomass production without being detrimental to cereal production in this system (Zentner et al 1987). On the other hand in the Dark Brown soil at Lethbridge the converse was true (Janzen 1987b). We were unable to detect significant differences ($P>0.10$) in N_o due to fertilizer or rotation length in the 2-yr and 3-yr wheat rotations.

The k values were generally higher than those reported for soils in the drier regions of the prairies (Table 3) but values as high have been reported for some Gray Luvisols and Black soils in Saskatchewan (Campbell et al 1984). For k, significant treatment differences were more often apparent in the 7.5 to 15 cm depth than in the 0 to 7.5 cm depth (data not shown). Again, like N_o, though we were able to use k values to differentiate between some of the treatment effects, these results were less consistent than for total N or for AC-N. Janzen (1987b) found no effect of rotation treatments on k at Lethbridge.

The calculation of N_o and k is done by computer iteration (Campbell et al 1984; 1988); consequently, N_o and k are not exclusively independent. In fact, correlation analysis showed a weak but significant inverse relationship ($r = -0.5^{**}$) between N_o and k in the 0- to 7.5-cm depth of this soil but not for the 7.5 to 15 cm depth. In order to counteract the anomalies presented by this situation we decided to calculate a new parameter that we called the "potential rate of mineralization" by multiplying N_o X k (i.e., N_ok, Table 3). This factor proved to be much more effective than all other parameters tested in segregating the effect of all treatments. Linear contrast analysis showed significant effects of fertilizer at all rotation lengths; significant increase in N_ok due to green manure, due to the 6-yr mixed rotation, and due to rotation length. There was a strong tendency for baling straw to reduce N_ok but the effect was not significant as $P>0.10$. There was no effect of rotation phase sampled, and no difference between the 6-yr rotation and fertilized continuous wheat, but the mixed rotation had much greater $N_o k$ than unfertilized continuous wheat.

In contrast to results obtained with ratios of total AC-N/N and N_o/N, which were not completely adequate in isolating all treatment effects (as assessed by contrast analysis), $N_o k/N$ still proved effective in this respect (Table 3). As well, although N_o/N was significantly correlated to N (R^2 = 0.34*), $N_o k/N$ was much more closely associated with N (R^2 = 0.75**) (Table 5). This indicates that the latter parameter may be a very worthwhile tool for use in assessing changes in soil quality due to cultural practices.

The results also confirmed the findings of Campbell and Souster (1982) and Janzen (1987b) that changes in mineralizable N due to cultivation or crop management are much greater than changes in total N (or, as shown in this paper, amino acids).

Finally, McGill et al (1988) has hypothesized that when a soil's cultural management is modified, the active fraction of the organic matter (which he assessed to be proportional to N_o/N) would change faster than would total N and also reach a new equilibrium faster both in degrading and aggrading conditions. But in degrading systems (eg., due to the breaking of virgin land - Campbell and Souster 1982) the relationship of N_o/N vs N would be negative (McGill 1988) while for aggrading systems it would be positive. No experimental evidence to support the latter half of this hypothesis was presented by McGill et al; however, our results (Table 5) appear to provide evidence in support of the expected behaviour for aggrading systems [i.e., $N_o/N = 0.007 + 5.9 \times 10^{-6} N$ (R^2 = 0.34*)].

CONCLUSIONS

The results of this study have demonstrated the benefits of fertilizers, green manures, grass-legume forages, and longer rotations of monoculture wheat in increasing soil N, amino compounds, and the potential N supplying power of the soil. It has provided a useful new tool in the form of $N_o k$ for use by scientists wishing to assess soil organic matter quality changes, a tool that is much more sensitive than either kjeldahl or amino N. It has demonstrated that, under conditions of adequate moisture, the fertility benefits from including 3 years of brome-alfalfa in a 6-yr rotation with 2 yr of wheat and even 1 yr of fallow, will still result in significantly greater quantities and better quality of soil organic N than will unfertilized continuous wheat. However, in contrast to erroneous view points of proponents of organic farming and LISA, fertilizers used responsibly, especially with continuous cropping, will be just as effective in maintaining organic matter quantity and quality as do legumes. Evidence that baling straw will reduce soil N was consistent though not significant and in any event the decrease after 30 years was not great in quantity nor quality.

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