YIELD TRENDS OF WHEAT - IMPACT OF FERTILIZATION AND LEGUME

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ABSTRACT

A long-term (34-yr) crop rotation experiment being conducted at Indian Head, Saskatchewan, on a thin Black Chernozem with heavy clay texture, was used to assess the influence of fertilizer (N and P), sweetclover green manure, and alfalfa-bromegrass hay on yield trends of hard red spring wheat grown on wheat stubble in rotations of varying cropping intensity. When no fertilizer was applied, yields of wheat grown on wheat stubble trended downwards for fallow-wheat-wheat, presumably due to increased soil erosion and declining fertility. Yield trends remained generally constant for unfertilized continuous wheat, perhaps because of less soil erosion. The inclusion of green manure in an unfertilized green manure-wheat-wheat rotation increased the yields of wheat grown on stubble compared to unfertilized fallow-wheat-wheat, but the yield trends were still negative. We speculated that this was because legumes do not provide any P to the system. The unfertilized fallow-wheat-wheat-hay-hay-hay system maintained stubble wheat yields at a generally constant level due to low soil erosion and because the hay-containing system markedly increased N-supplying power of the soil. The addition of N and P fertilizer at rates based on soil tests resulted in a positive divergence in yield trends of fallow-wheat-wheat and continuous wheat systems. We suggest that legumes require added P if they are to sustain crop production in a manner similar to that provided by responsible use of fertilizers.

INTRODUCTION

Proponents of organic farming and low-input agriculture allege that inorganic fertilizers degrade the soil. They recommend use of legumes to supply nitrogen (N), and the use of crop rotations and tillage to reduce incidence of pests and weeds. While there is little doubt about the efficacy of these practices, there is some question whether inorganic fertilizers are harmful if they are applied based on proper soil test criteria (Potash and Phosphate Institute Scientists, 1989). For example, Campbell et al. (1991a, b) demonstrated that when spring wheat was grown annually on a thin Black Chernozem at Indian Head, Saskatchewan, where fertilizer was applied at rates based on soil tests, soil quality (e.g., organic matter, microbial biomass, and N supplying power) was maintained as effectively as when legume green manure, or hay crops, were included in the rotations.

Legumes do not supply any phosphorus (P) to the soil (Saskatchewan Agriculture, Soils and Crops Branch, 1986). Therefore, one might expect any system that relies solely on legumes for maintaining soil fertility, to eventually become impoverished and yields will suffer.

The objective of this study was to demonstrate the long-term consequences of withholding fertilizer N and P on wheat yields, and to determine if inclusion of legume-green manures, or hay crops in rotations can maintain wheat yields.

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MATERIALS AND METHODS
General Description of Rotations

This rotation experiment has been described in detail elsewhere (Zentner, et al., 1987; Campbell et al., 1991a,b). The crop rotation experiment at Indian Head, Saskatchewan, involves 14 cropping systems, we examined six (Table 1). The experiment was established in 1958 on land that had previously been cropped to fallow-spring wheat (F-W) or F-W-W from the 1890's. The experimental area is situated on Indian Head heavy clay, a thin Black Chernozemic soil with pH of the 0 to 0.5 ft depth being 7.5 (dilute $CaCl_2$). Organic N (kjeldahl) and the initial potential rate of N mineralization (Campbell et al., 1991b) are shown in Table 1.

The plots, each 14.8 x 110 ft, with ample roadways, were organized in a randomized block design with four replicates. All phases of each rotation were present each year. All cultural and tillage operations are performed with field-sized equipment using the generally recommended methods for the region, (Zentner et al., 1987). The plots were seeded with a double disc press drill at the recommended rates of 115 lb/ac for spring wheat, 10 lb/ac for sweetclover, 12 lb/ac for bromegrass, and 6 lb/ac for alfalfa. Forage crops were established by underseeding the preceding cereal crop.

Rates of N and P fertilizer applied to rotations designated to receive fertilizer varied over the study period (Zentner et al., 1987). During 1958 to 1977, fertilizer N as ammonium nitrate-phosphate (23-23-0), and P as monoammonium phosphate (11-48-0) were applied according to rotation specifications and the generally recommended rates for this region. Since 1978, N as ammonium nitrate (34-0-0), and P as (11-48-0), were applied based on soil test levels of N and P determined the previous fall. During the period 1958 to 1977, the average annual rates of N and P applied to wheat grown on fallow were 5 and 10 lb/ac, respectively; for wheat grown on stubble it was 20 and 7.5 lb/ac, respectively. During the period 1978 to 1991, the respective rates of N and P for wheat grown on fallow were 9 and 7 lb/ac and for wheat grown on stubble 68 and 7.5 lb/ac.

Table 1. Crop rotations sampled and selected characteristics of the top 0.5 ft of soil.

Rotation† sequence	N and P fertilizer	Organic N‡ (t/ac)	Initial potential rate of N mineralization‡ (lb/ac/wk)
F-(W)-W	No	1.32	25.2
F-(W)-W	Yes	1.45	33.5
GM-(W)-W	No	1.50	39.3
(F)-(W)-W-H-H-(H)	No	1.55	43.4
Cont (W)	No	1.41	32.2
Cont (W)	Yes	1.54	49.4

†F = fallow, W = hard red spring wheat, GM = sweetclover green manure, H = alfalfa-bromegrass cut for hay, Cont = annual cropping. Phases in parenthesis were the ones on which organic characteristics were measured, but stubble-wheat were the phases discussed in this paper.

‡Organic N and initial potential rate of N mineralization measured in 1987 (Campbell et al., 1991b).

Annual crops were swathed at the full-ripe stage (usually in early September) with yield determinations made by threshing the grain from the entire plot with a conventional combine. The straw was redistributed on the plots by a paddle-type straw spreader attachment on the combine. Forage plots were cut at full-bloom (usually late June to early July), field-dried, baled and the hay removed. The crowns after the third hay crop, and the green manure crop were soil-incorporated by rototilling in mid-June.

Herbicides were applied as required for in-crop weed control using recommended methods and rates (Zentner et al., 1987). Herbicide was rarely applied to the forage plots. Weed control on summerfallow areas was achieved by mechanical tillage. An average of 5 operations (range 4 to 6) with a heavy-duty cultivator were required. In some years, a rodweeder replaced one or more cultivation operations, and in the early years of the study a disc was also used.

Precipitation data were collected at a meteorological site located about 0.5 miles from the test site.

Five-year running means of grain yields were calculated for each cropping system so as to minimize the influences of annual variability in weather. Regression analysis was used to determine the time trends in yields with years as the independent variable.

RESULTS AND DISCUSSION

Wheat on Fallow

Yield trends for wheat grown on fallow or partial fallow showed the positive influence of fertilizers and legumes, but there was no consistent divergence in the trends with time (data not shown). Similar results were reported by Freyman et al. (1981) for a long-term study conducted at Lethbridge, Alberta. They suggested that the lack of marked fertilizer effects was because N and P mineralization during the fallow periods was sufficient to cover up any shortfalls due to the apparent gradual depletion in soil fertility.

Effect of Fertilizers on Yields of Wheat Grown on Stubble

As found by Freyman et al. (1981) in Alberta, the influence of N and P fertilizers on yields of wheat grown on stubble was positive and significant (average yield increase of 13.2 bu/ac) (Figures 1 and 2). Yields increased at a rate of 0.45 to 0.49 bu/ac/yr for fertilized wheat grown on stubble. The widening difference between the unfertilized and fertilized systems was partly due to the major increase in N rate after 1978. However, the downward trend in check yields also suggests that the unfertilized system may be showing evidence of a gradual degradation of the inherent soil fertility. This yield decline was more apparent in F-W-(W) (i.e., decline of 0.41 bu/ac/yr) (Figure 2) than in the Cont (W) (i.e. decline of 0.16 bu/ac/yr)(Figure 1). This difference in rate of decline in yields probably reflects the greater incidence of erosion and the lower quantity of residues being returned to the soil in the F-W-W system (Greer, 1989). Evidence of the degradation in fertility status of the soil was also seen in the lower organic matter and N-supplying power of unfertilized F-W-W system compared to unfertilized Cont W (Table 1) (Campbell et al., 1991b). The downward trends in yields of check treatments were not related to precipitation because, with the exception of the first decade, precipitation was generally above average (Figure 3).

Effect of Legumes on Stubble-Wheat Yields

Legume (sweetclover) green manure, increased yields of wheat grown on stubble, compared to unfertilized F-W-(W), by an average of 5.2 bu/ac (Figure 2), likely as a result of N fixation. Evidence of N fixation was seen in the 56% higher N-supplying power of the soil that included green manure, compared to the unfertilized F-W-W rotation (Table 1). Even so, the yield trends of wheat grown

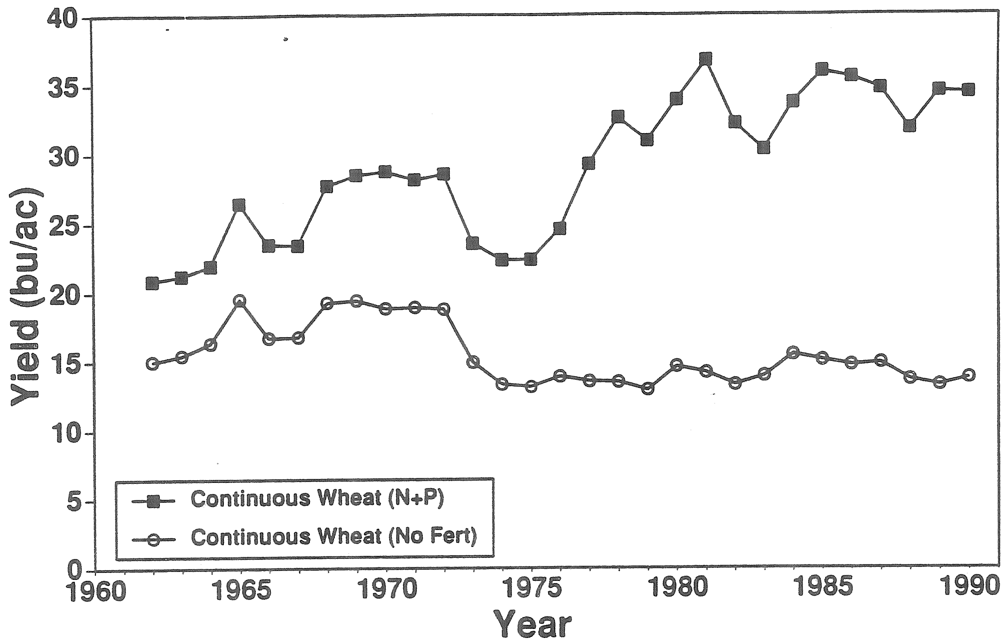

Figure 1. Yield trends of continuously grown hard red spring wheat at Indian Head, Saskatchewan, as influenced by N and P fertilizer (the points are 5-yr running means).

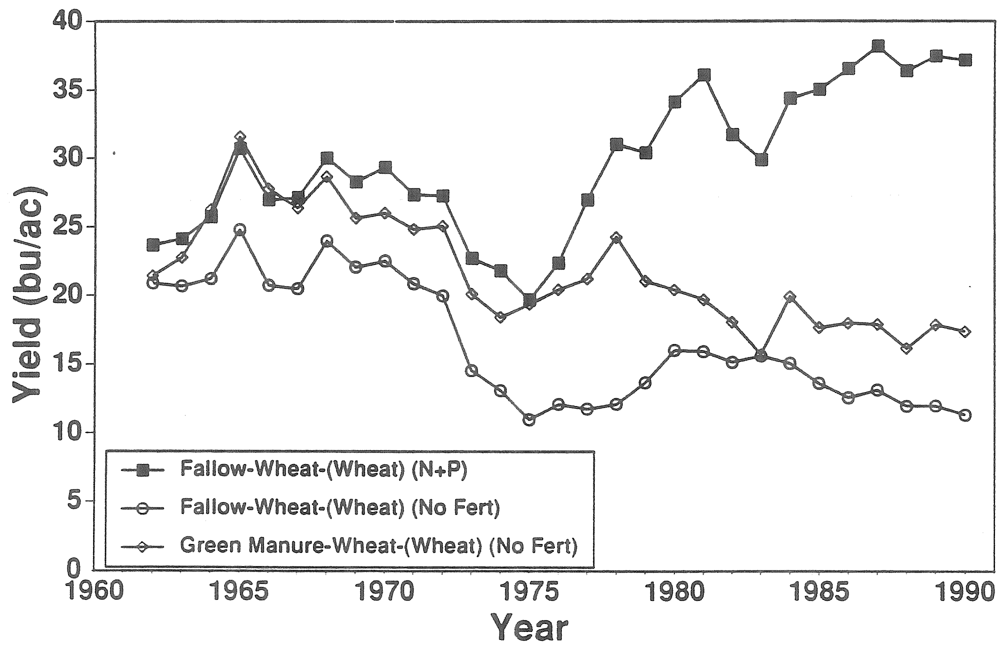

Figure 2. Yield trends of hard red spring wheat grown on stubble in a fallow-wheat-wheat rotation at Indian Head, Saskatchewan, showing the influence of sweetclover green manure and of N + P fertilizer. (The points are 5-yr running means).

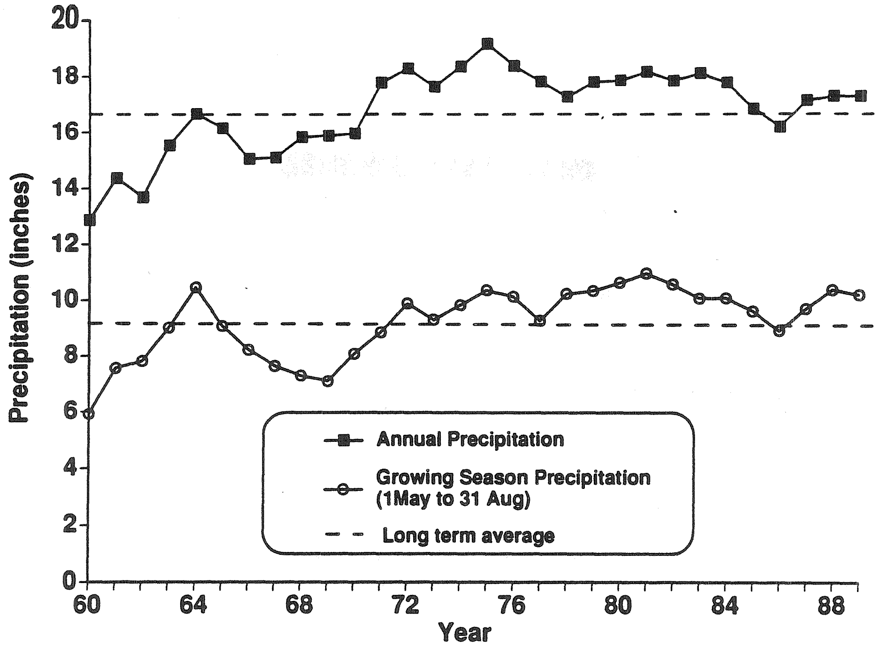

Figure 3. Five-yr running mean annual- and growing season-precipitation compared to the long-term (90-yr) averages.

on stubble in this green manure system was downwards like that of unfertilized F-W-(W) (i.e., decline of 0.39 bu/ac/yr). This was probably due to the fact that legumes do not supply phosphorus, which is required for efficient crop production. The lower yields in the GM-W(W) compared to the fertilized F-W-(W) system was likely due to both N and P; we were unable to estimate the relative contribution of each nutrient because we did not measure the actual contribution of N from the green manure. Nevertheless, one can say that when F-W-(W) is fertilized based on soil tests, yield trends were superior to those for wheat grown on stubble in a sweetclover GM-W-W system that did not receive any fertilizer, suggesting that the latter system may not be sustainable in the long-term.

The unfertilized F-W-W-H-H-H system maintained higher yields of wheat grown on stubble than those of fertilized F-W-(W) up to 1978, a period when the latter system was likely underfertilized for this particular soil (Figure 4). This yield difference was partly because of much less erosion in the hay-containing system (Greer, 1989), and partly because the hay has greatly increased the N-supplying power of this soil (Table 1). Thus, in contrast to the green manure system, and even though the hay would not have provided extra P to the system, the large increase in N-supplying power of the soil has prevented the yield of stubble wheat in the 6-yr rotation from trending downwards over the years. However, even with the marked benefit in available N due to the hay, this 6-yr rotation was eventually less productive than F-W-W that was fertilized using soil test criteria.

CONCLUSIONS

Long-term (34-yr) trends in grain yield of hard red spring wheat, grown on stubble in various crop rotations on a heavy-textured Udic Haploboroll, at Indian Head, Saskatchewan, clearly showed that for crop production to be maintained: (i) adequate N and P fertilization must be provided; (ii) the practice of summerfallowing must be minimized; and (iii) legumes, although they provide extra N, will not sustain production for extended periods, probably because they supply no P. Proponents of Low Input Sustainable Agriculture (LISA) should take particular note of these findings.

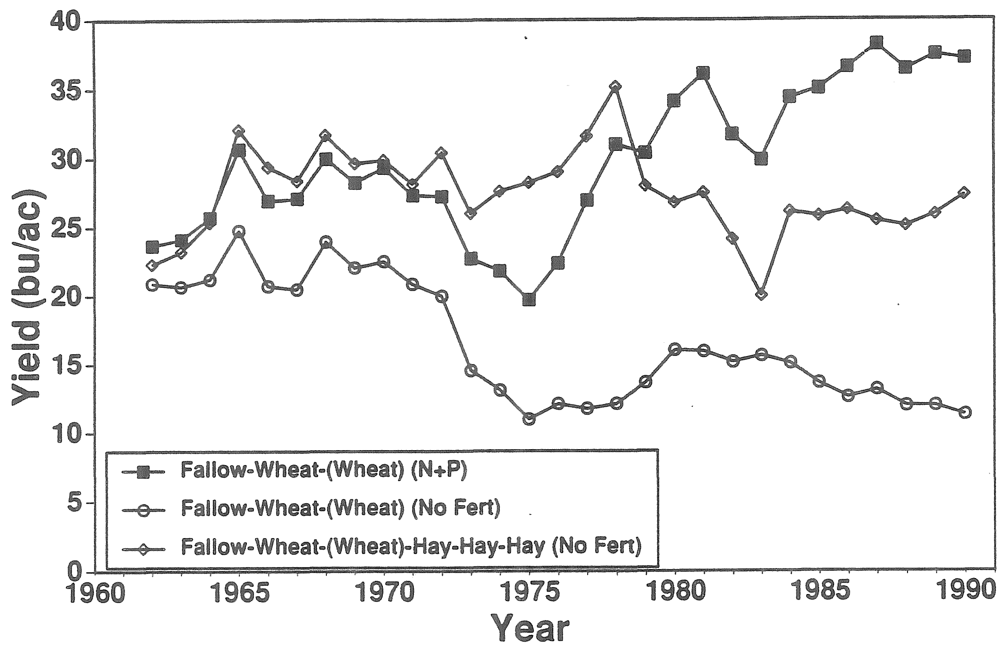

Figure 4. Yield trends of hard red spring wheat grown on wheat stubble in an unfertilized fallow-wheat-wheat-hay-hay-hay rotation at Indian Head, Saskatchewan, compared to N and P fertilized and unfertilized fallow-wheat-wheat systems. (The points are 5-yr running means).

REFERENCES

Campbell, C.A., V.O. Biederbeck, R.P. Zentner, and G.P. Lafond. 1991a. Effect of crop rotations and cultural practices on soil organic matter, microbial biomass and respiration in a thin Black Chernozem. Can. J. Soil Sci. 71: 363-376.

Campbell, C.A., G.P. Lafond, A.J. Leyshon, R.P. Zentner, and H.H. Janzen. 1991b. Effect of cropping practices on the initial potential rate of N mineralization in a thin Black Chernozem. Can. J. Soil Sci. 71: 43-53.

Freyman, S., C.J. Palmer, E.H. Hobbs, J.F. Dormaar, G.B. Schaalje, and J.R. Moyer. 1981. Yield trends on long-term dryland wheat rotations at Lethbridge. Can. J. Plant Sci. 61: 609-619.

Greer, K.J. 1989. Evaluating the soil quality of long-term crop rotations at Indian Head. MSc. Thesis. University of Saskatchewan, Saskatoon, SK.

Potash and Phosphate Institute Scientists. 1989. A review of the National Research Council Report on Alternative Agriculture (20 pp). Potash and Phosphate Institute, Atlanta, GA.

Saskatchewan Agriculture, Soils and Crops Branch. 1986. Soil improvement with legumes. Bull. M10-86-02. Regina, SK.

Zentner, R.P., E.D. Spratt, H. Reisdorf, and C.A. Campbell. 1987. Effect of crop rotation and N and P fertilizer on yields of spring wheat grown on a Black Chernozemic clay. Can. J. Plant Sci. 67: 965-982.