Long-Term Response of Spring Wheat to N and P Fertilization in Southwestern Saskatchewan

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INTRODUCTION

- Available water is the most limiting factor influencing crop production in the semiarid prairie. Nitrogen is the second most limiting factor.
- Declining soil quality, combined with the movement to extended crop rotations, have increased producers' reliance on inorganic fertilizers.
- Highly variable growing season precipitation, combined with high evaporation demands, make crop production and fertilization risky ventures.

OBJECTIVE

- To discuss the long-term (42 years) impact of N and P fertilizers on crop production, grain quality, water use efficiency, and economic returns for spring wheat grown on fallow and stubble on a medium texture soil in southwestern Saskatchewan.

MATERIALS AND METHODS

- The experiment was initiated in 1967 on a Swinton loam involving 12 crop rotation-fertility treatments, of which three Fallow-Wheat-Wheat (F-W-W) and two Continuous Wheat (Cont W) systems were selected for evaluation.
- The F-W-W cropping systems were fertilized based on soil test criteria with recommended rates of N and P, with N only, and with P only fertilizer, while the Cont W systems received recommended rates of N and P, or P only fertilizer. Rates of N fertilizer applied were increased substantially beginning in 1991 in response to a change in the fertilizer recommendation guidelines adopted by the Saskatchewan Soil Testing Laboratory (Table 1). Plots designated to receive P fertilizer had 9.6 kg P ha^{-1} applied with the seed each year.
- All phases of each rotation were present every year and each rotation was cycled on its assigned plots. Plots were 10 m by 40 m in size, arranged in a randomized complete block design with three replicates.
- Stubble mulch tillage was used. Plots received 2,4-D each fall for control of winter annual weeds.

- Grain protein concentration (%N x 5.7) was corrected to a constant 14% moisture basis. Water use (WU) was calculated as the difference between spring and harvest soil water (0-120 cm depth) plus growing season (May 1 to August 31) precipitation. Water use efficiency (WUE) was calculated as grain yield / water use.
- The economic benefits from fertilization used the 2010 expected costs for N ($0.95 kg^{-1}) and P_2O_5 ($0.70 kg^{-1}). Net earnings (above the cost of fertilizer) were calculated at a base wheat price of $175 t^{-1}, and with price adjustments for grain protein concentrations. The latter analysis used the 2009-2010 protein price schedule established by the Canadian Wheat Board.
- All data were subjected to ANOVA for split-plot designs with rotation-phase as main plot and year as sub-plot. LSDs were calculated and used to test for significant differences among treatment means ($P<0.05$).

Table 1. Average N (kg ha^{-1}) fertilizer applied to wheat grown on fallow and stubble by period

Wheat grown on	1967-1990	1991-2008[1]
Fallow	7	28
Stubble	16-30	40-54

[1] The recommendation guidelines for N used by the Saskatchewan Soil Testing Laboratory were changed in 1990.

RESULTS AND DISCUSSION

Weather Conditions

- Growing season (May 1 to August 31) precipitation (GSP) was highly variable over the 42-year study period (Fig. 1), conditions typical of this semiarid region. The long-term (124-yr) mean GSP at Swift Current is 212 mm.
- During the first 24 years (1967-1990), GSP averaged 178 mm or 16% lower than the long-term mean, and it was less than 80% of normal in 12 of 24 years.
- In contrast, during the latter 18-year period (1991-2008), GSP averaged 250 mm and was near average to above average in 13 of 18 years.
- Thus, 1967-1990 represents a relatively dry period, while 1991-2008 represents a period of generally favorable growing conditions.

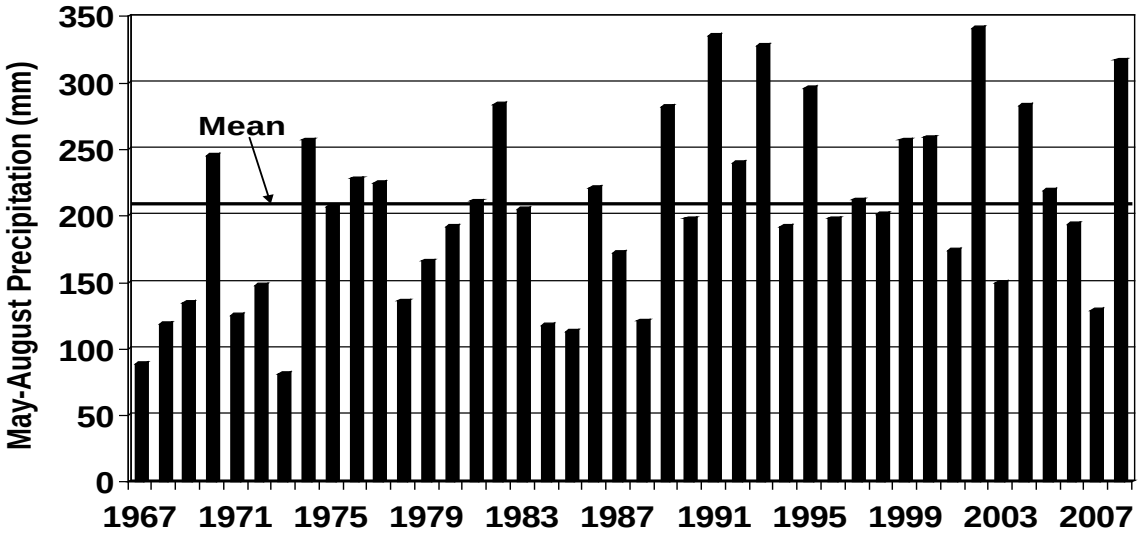

Fig. 1 Growing season precipitation at Swift Current

Response of Wheat Grown on Fallow to N and P Fertilization

- Application of N and P fertilizer, compared to P fertilizer alone (i.e., the effect of adding N), increased yields of fallow-wheat by an average 107 kg ha^{-1} (or about 5%). During the dry 1967-1990 period, the addition of N fertilizer increased fallow-wheat yields by an average of only 32 kg ha^{-1}, but during the 1991-2008 period, when N rates were higher and GSP was more favorable, the yield increase averaged 208 kg ha^{-1}. Thus overall, the addition of recommended rates of N fertilizer to wheat grown on fallow produced significant ($P<0.05$) yield increases (>80 kg ha^{-1}) in 19 of 42 years, had little influence ($P>0.05$) on grain yield in 18 years, and resulted in significantly lower yields in the remaining 5 years (Fig. 2).

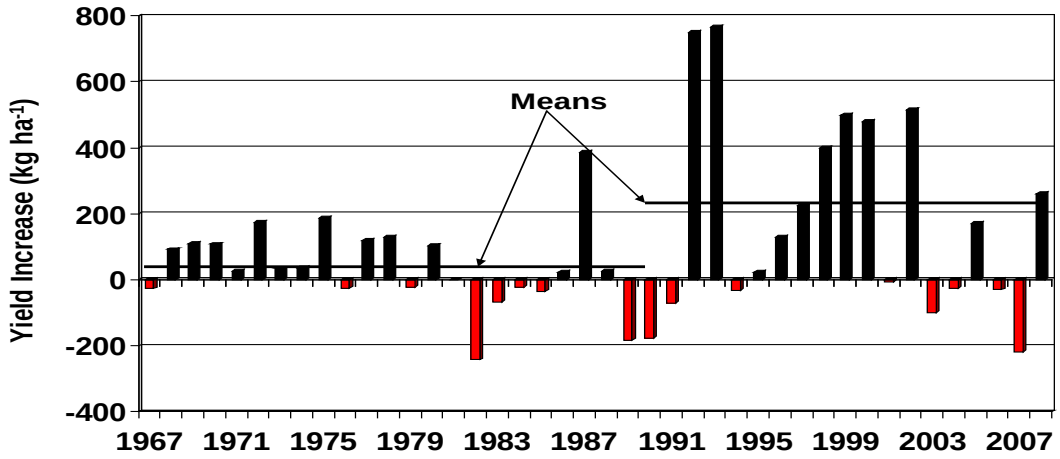

Fig. 2 Yield response of fallow-wheat to the addition of N fertilizer

- In contrast to N, the addition of P fertilizer increased fallow-wheat yields by an average of 337 kg ha^{-1} (or about 17%), reflecting that summerfallowing encourages the mineralization of N from soil organic matter but does little for the buildup of soil P. During the first 24 years, the yield increase averaged 199 kg ha^{-1}, while in the latter 18 years the yield increase averaged 522 kg ha^{-1}. Overall, the yield increases from P fertilizer application were significant in 33 of 42 years (Fig. 3).

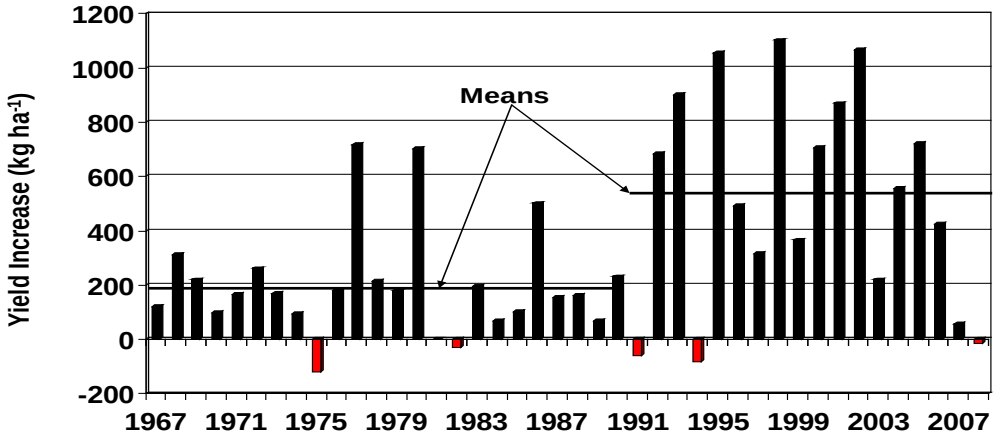

Fig. 3 Yield response of fallow-wheat to the addition of P fertilizer

- Grain protein concentration in fallow-wheat during the 1967-1990 period was largely unaffected by the low recommended rates of N fertilizer applied and the dry growing conditions, but during the 1991-2008 period when N rates and GSP were higher, the

protein content of wheat was consistently and significantly increased by an average of 1.7 percentage points (Fig. 4). The addition of P fertilizer also had little influence on grain protein content in the earlier period, but in the later period grain protein content was reduced by an average of 0.6 percentage points due to yield dilution (Fig. 5).

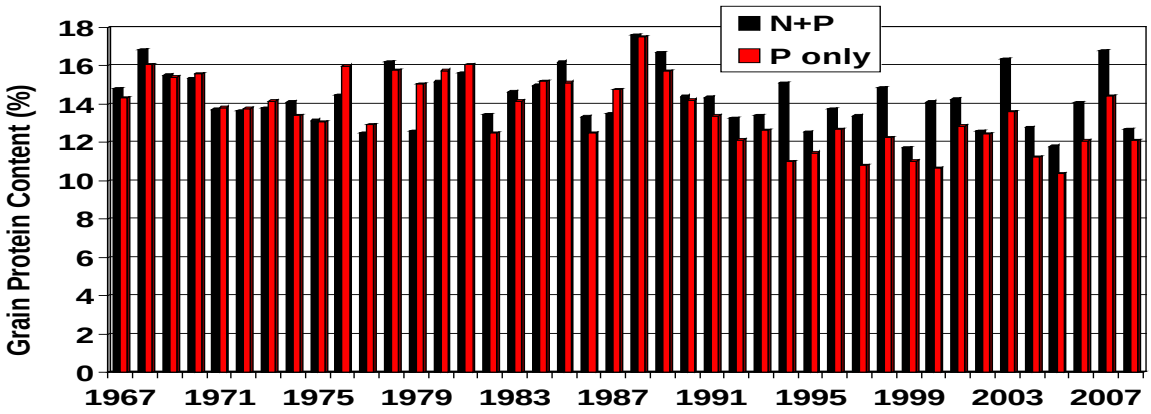

Fig. 4 Grain protein response of fallow-wheat to the addition of N fertilizer

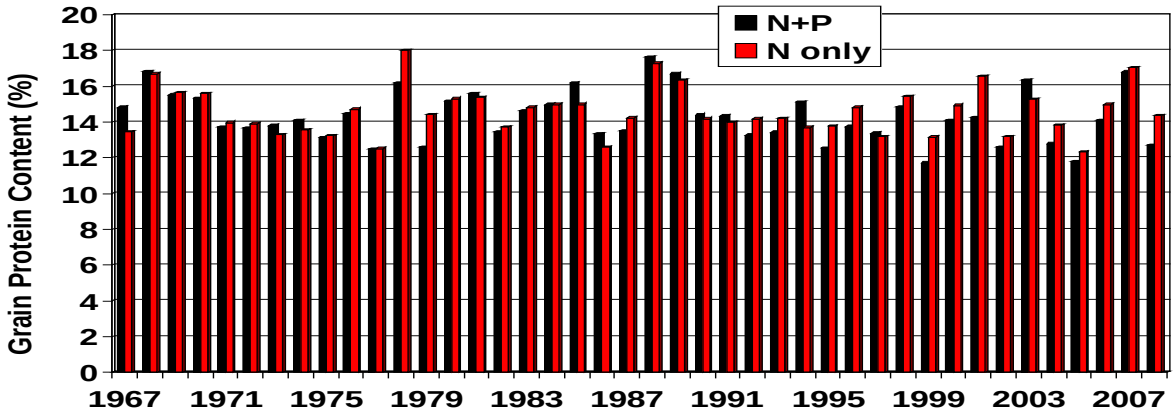

Fig. 5 Grain protein response of fallow-wheat to the addition of P fertilizer

- Soil water in the 120-cm depth in spring after summerfallow averaged 250 mm, and at harvest of the wheat crop it averaged 151 mm. Soil water conservation and water

remaining in the soil at harvest were unaffected by fertilizer treatment (data not shown). Water use by fallow-wheat averaged about 302 mm for all fertilizer treatments.

- Water use efficiency for fallow-wheat averaged 6.64 kg ha^{-1} mm^{-1} when recommended rates of N and P fertilizer were applied, compared to 6.50 kg ha^{-1} mm^{-1} when P only fertilizer was applied (not significantly different), and 5.88 kg ha^{-1} mm^{-1} when N only was applied (significantly lower).
- Average annual net earnings (above the cost of fertilizer) were increased by \$7.70 ha^{-1} at the base price for wheat by the addition of recommended rates of N fertilizer, while the addition of recommended rates of P fertilizer increased annual net earnings by \$40.53 ha^{-1}. When wheat price was adjusted for grain protein content, annual net earning were increased to \$26.35 with the addition of N fertilizer and to \$43.24 ha^{-1} with the addition of P fertilizer, indicating that proper fertilization improves farm income through enhancing of both grain yield and grain quality. The addition of N fertilizer to fallow-wheat produced significant economic gains (>\$13 ha^{-1}) in 9 of 24 years during the drier 1967-1990 period and in 15 of 18 years during the wetter 1991-2008 period (Fig. 6). While the addition of P fertilizer to fallow-wheat produced significant economic gains in 11 of 24 years during the dry period, and in 14 of 18 years during the wetter period (Fig. 7).

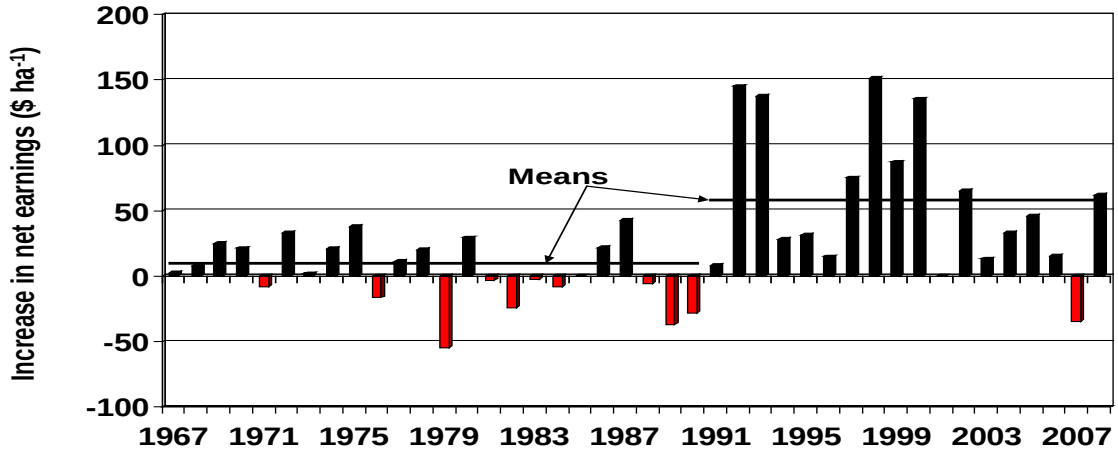

Fig. 6 Economic benefit of applying N fertilizer to fallow-wheat

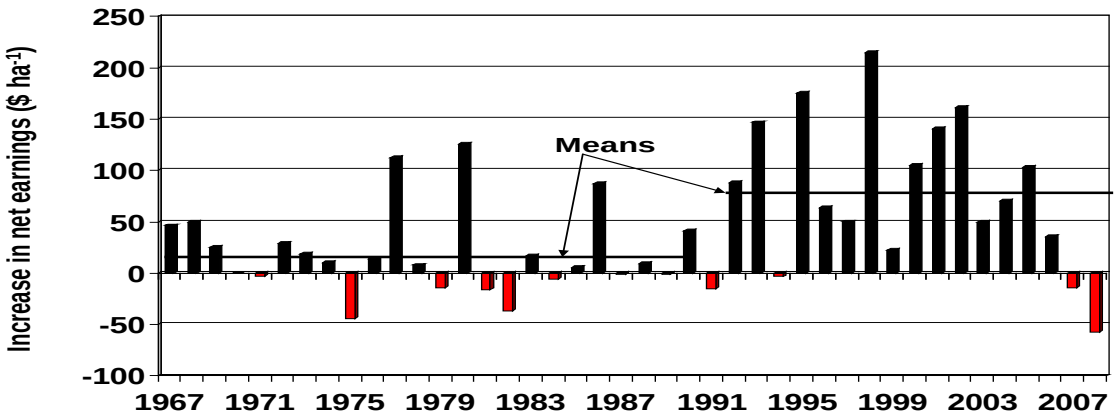

Fig. 7 Economic benefit of applying P fertilizer to fallow-wheat

Response of Wheat Grown on Stubble to N and P Fertilization

- The application of N and P, compared to P fertilizer alone, increased stubble-wheat yields by an average 423 kg ha^{-1} (or by 34%) in the F-W-W rotation and by 452 kg ha^{-1} (or by 38%) in the Cont W rotation, about 4 times the yield response obtained from the addition of N fertilizer to fallow-wheat because available soil N is typically less limiting on fallow. During the first 24 years, the yield increase from N fertilizer averaged only 82 kg ha^{-1} in F-W-W and 165 kg ha^{-1} in the Cont W, but in the wetter latter 18-year period with higher N rates the respective yield increases averaged 879 and 834 kg ha^{-1}, reflecting the typically positive N x water interaction. The yield increases from the addition of N fertilizer were significant (> 80 kg ha^{-1}) in 28 of 42 years for F-W-W (Fig. 8) and in 34 of 42 years for Cont W (Fig. 9).

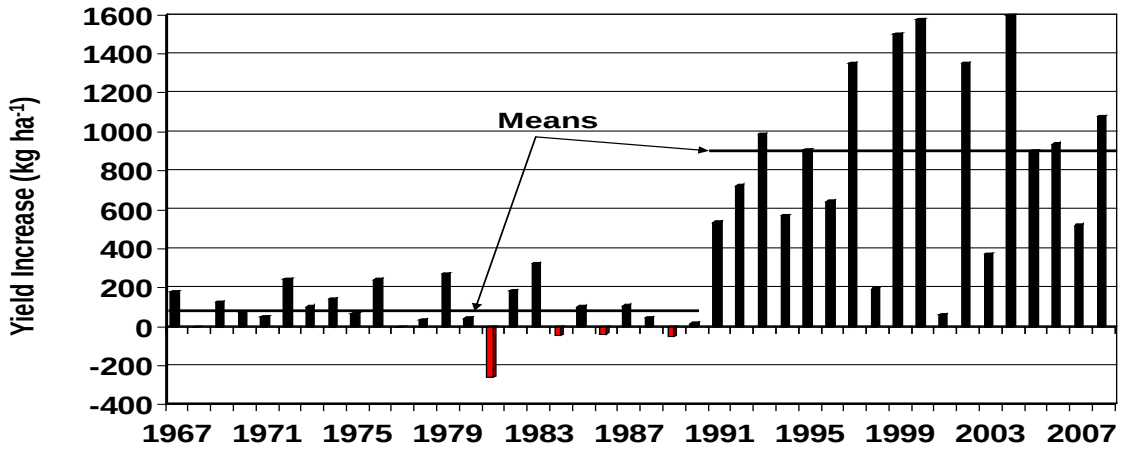

Fig. 8 Yield response of stubble-wheat to N fertilizer – F-W-W rotation

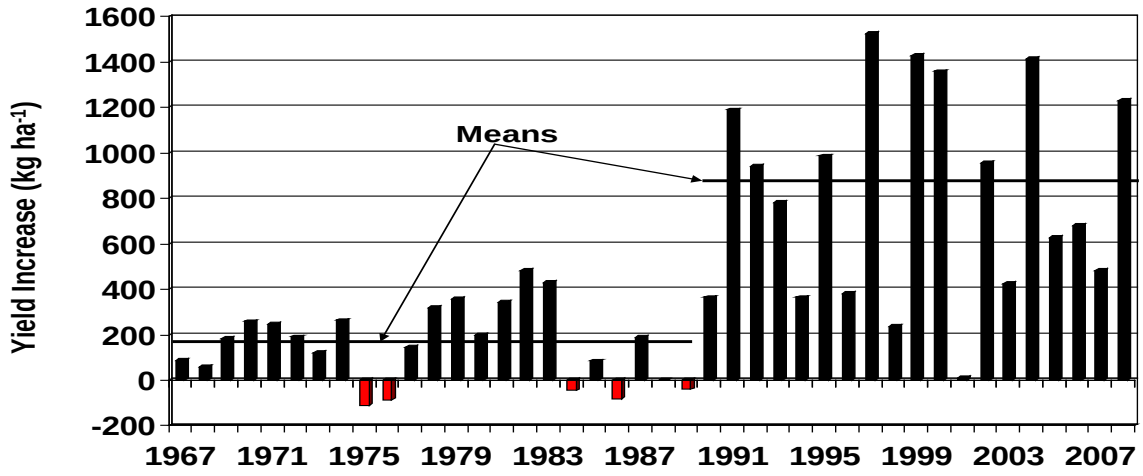

Fig 9. Yield response of stubble-wheat to N fertilizer – Cont W rotation

- The addition of P fertilizer to stubble-wheat in the F-W-W rotation increased average grain yields by 179 kg ha^{-1} (or by 12%), with the yield increase averaging 130 kg ha^{-1} during the drier period and 244 kg ha $^{-1}$ during the wetter period. The yield increases from P fertilizer were significant in 24 of 42 years (Fig. 10).

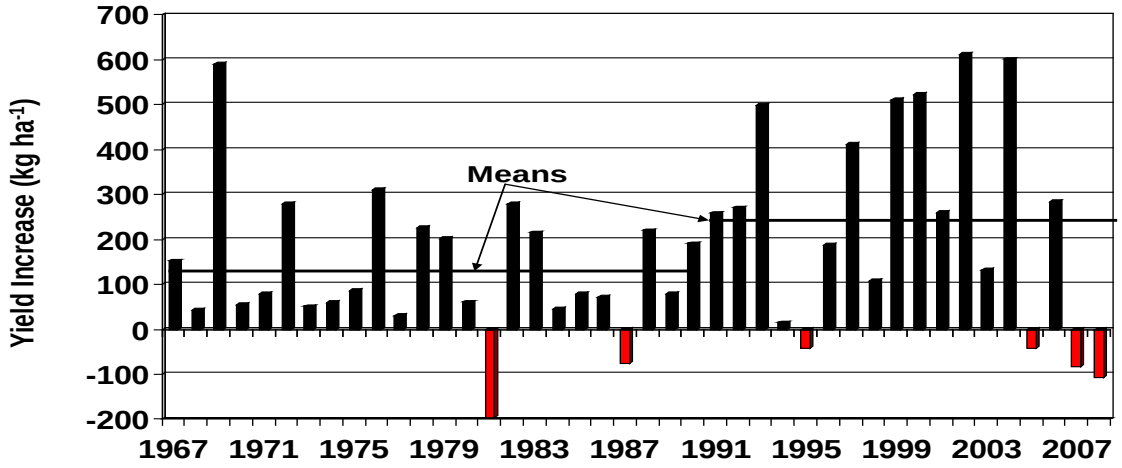

Fig. 10 Yield response of stubble-wheat to P fertilizer – F-W-W rotation

- The average protein content of stubble-wheat grown with recommended rates of N and P fertilizers was 14.0% in the F-W-W rotation (Fig. 11) and 13.7% in Cont W (Fig. 12), compared to 12.8% and 11.9% (both significantly lower) when N fertilizer was not applied. As for fallow-wheat, applying P fertilizer to stubble-wheat increased grain protein content by 0.9 percentage points in the early period, but decreased it by nearly 1.0 percentage point in the later period due to yield dilution (data not shown).

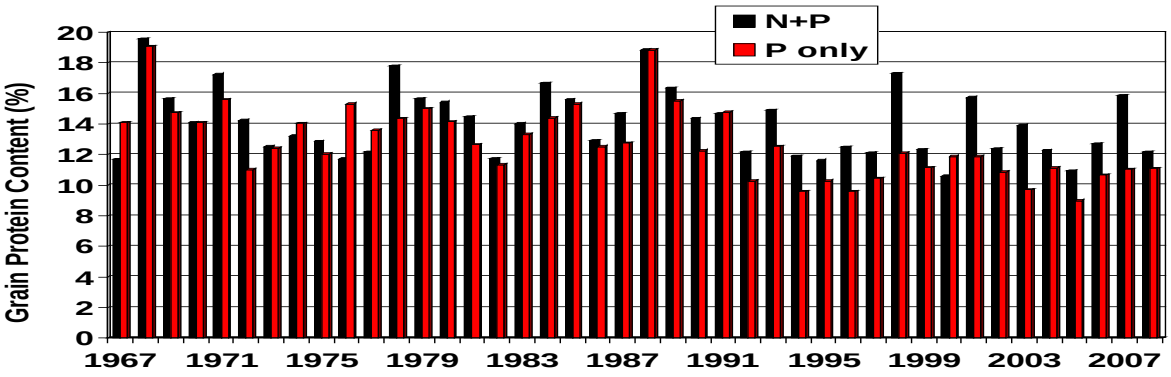

Fig. 11 Grain protein response of stubble-wheat to N fertilizer – F-W-W rotation

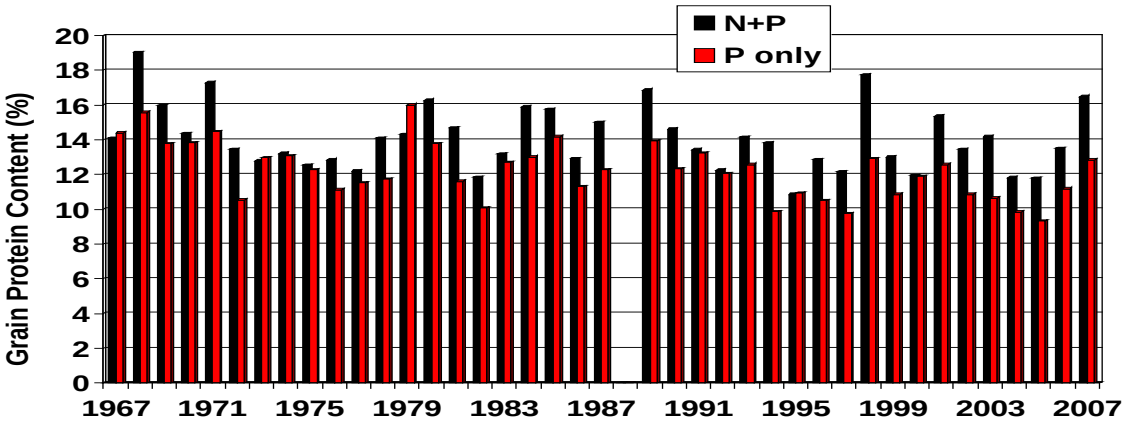

Fig. 12 Grain protein response of stubble-wheat to N fertilizer – Cont W rotation

- Soil water in the 120-cm depth in spring in stubble-wheat averaged 208 mm, and it too was unaffected by fertilizer treatment (data not shown). At harvest soil water averaged 151 mm in the N fertilized systems, with about 12 mm more soil water was left at harvest in the systems that received no N. Water use by stubble-wheat averaged 262 mm for the N fertilized systems and 249 mm in those systems receiving only P fertilizer.
- Water use efficiency for wheat grown on stubble averaged 5.45 kg ha^{-1} mm^{-1} when N and P fertilizer were applied, compared to 4.89 kg ha^{-1} mm^{-1} when P alone was applied and 4.29 kg ha^{-1} mm^{-1} when N alone was applied (both significantly lower).
- Net earnings from the addition of N fertilizer to stubble-wheat at the base price averaged \$42.67 ha^{-1} in the F-W-W rotation and \$48.61 ha^{-1} in the Cont W rotation. When the protein price premiums were included, net earnings from N fertilization increased to \$57.59 and \$74.30 ha^{-1} for the respective rotations. The economic gains from N fertilization of stubble-wheat in the F-W-W rotation were significant in 10 of 24 years during the dry period and in 17 of 18 years during the wetter period (Fig. 13). By comparison, the addition of N fertilizer to Cont W generated significant economic gains in 16 of 24 years and in 17 of 18 years in the respective periods (Fig. 14).
- In contrast, the net earning from the addition of P fertilizer to stubble-wheat in the F-W-W rotation averaged less than \$4.00 ha^{-1}, and was little affected by the inclusion of protein price premiums for wheat. Significant positive economic benefits from P fertilization of stubble-wheat were earned in only 13 of 42 years (Fig. 15).

CONCLUSIONS

- Our findings show the importance of applying recommended rates of N and P fertilizers to wheat grown on fallow and stubble to optimize crop production in this semiarid region.
- The responses to N and P fertilizer varied considerably from year to year and were highly dependent on available water. Applying N fertilizer to fallow-wheat produced

significant yield increases about 50% of the time, while applying P fertilizer produced significant yield increases about 80% of the time. For stubble-wheat, applying N fertilizer produced significant yield increases in about 70% of the time under the F-W-W rotation, and in nearly 80% of the time under Cont W. Applying P fertilizer to stubble-wheat produced significant yield increases about 60% of the time.

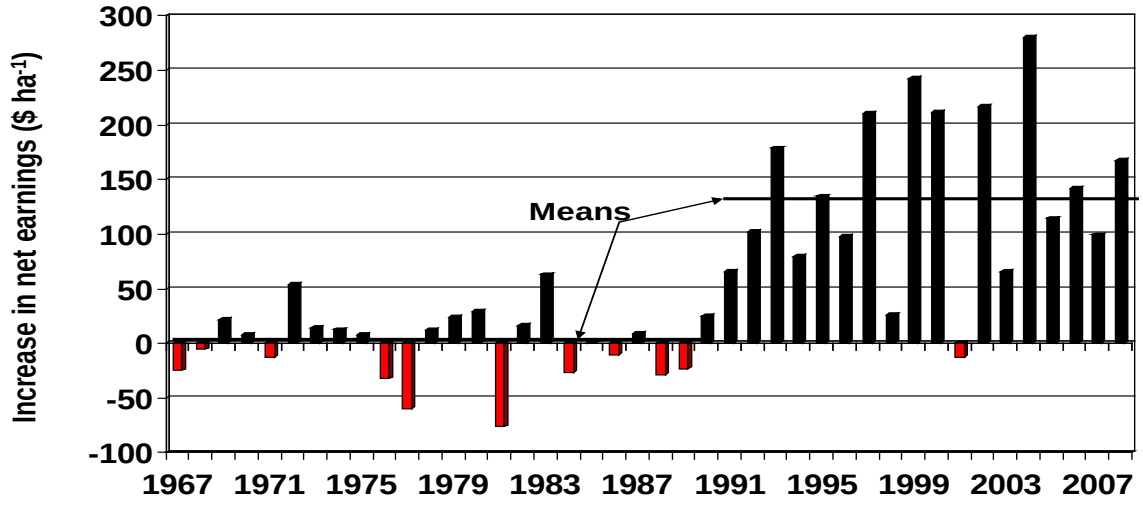

Fig. 13 Economic benefit of applying N fertilizer to stubble-wheat – F-W-W rotation

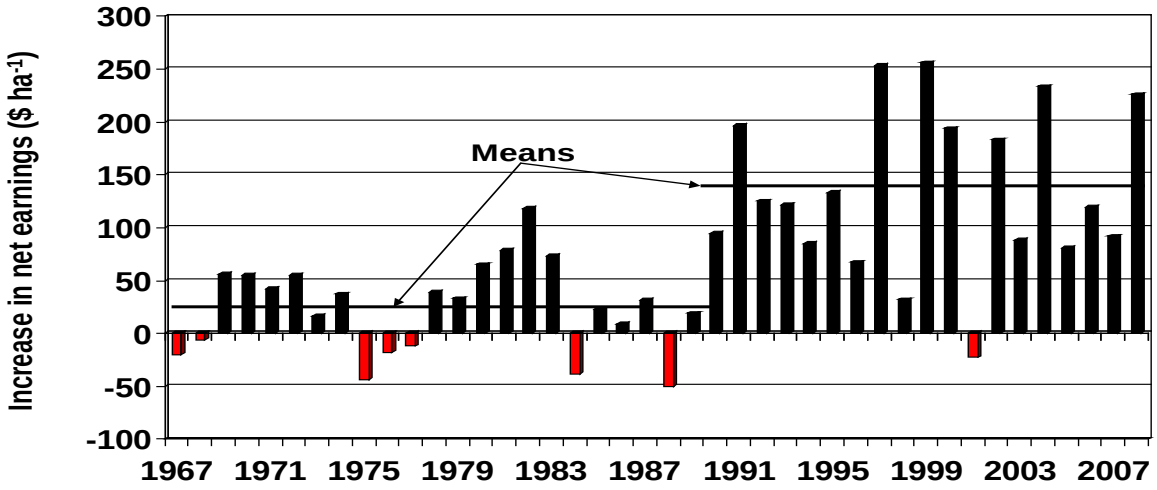

Fig. 14 Economic benefit of applying N fertilizer to stubble-wheat – Cont W rotation

- Producers growing wheat on fallow or on stubble should expect to at least recover the added cost of the N fertilizer in about 8.5 of 10 years, with significant economic gains being earned in about 6 of 10 years for fallow-wheat and in about 7.5 of 10 years for stubble-wheat. Applying recommended rates of P fertilizer to fallow-wheat will produce yield increases large enough to recover the fertilizer cost in 8.3 of 10 years, with significant economic gains in 6 of 10 years. Applying P fertilizer to stubble wheat will recover the cost of fertilizer in 7.0 of 10 years, with significant economic gains in about 3 of 10 years.
- Although the 1967-1990 period was drier than 1991-2008, our data suggest that the recommendation guidelines for N fertilizer used during the earlier period may have been too conservative for maximum economic returns (at least under present day prices and costs). Further, that the annual blanket rate of P fertilizer applied to stubble-wheat may have been too high in most years for the available moisture conditions and the gradual accumulation of soil P that resulted.

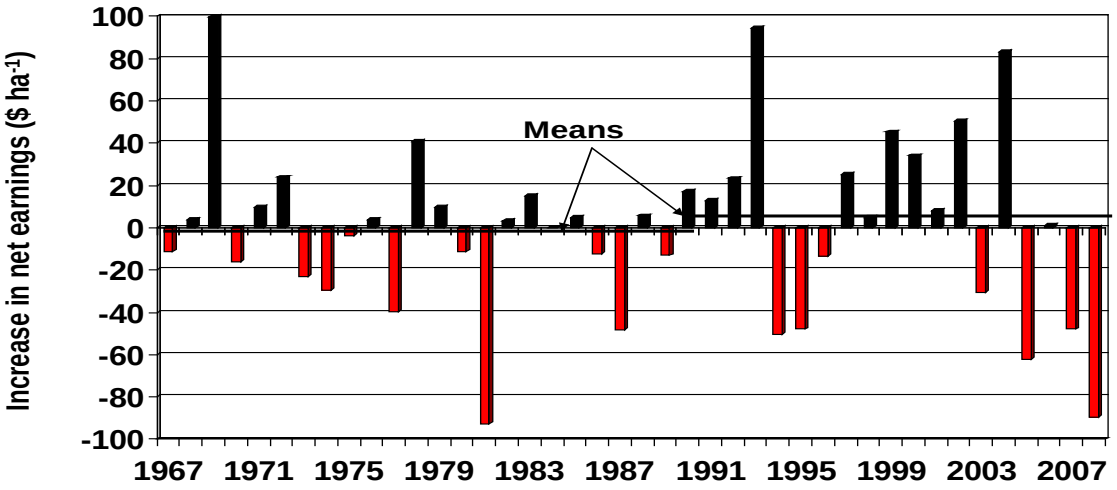

Fig. 15 Economic benefit of applying P fertilizer to stubble-wheat – F-W-W rotation

- Nevertheless, under current economic conditions producers should expect an additional \$14 to \$28 ha^{-1} of net earnings from long-term application of recommended rates of N and P fertilizers when using a F-W-W rotation and an additional \$74 ha^{-1} when using a Cont W rotation.