Yield of Continuous Spring Wheat with Several Combinations of Stubble, Weed Control and Fertility Management

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ABSTRACT

Studies to evaluate stubble management, weed control and fertility treatments applied in combination in a continuous spring wheat (*Triticum aestivum* L.) rotation were conducted over a seven year period (1983-89) at Scott, Lashburn and Loon Lake and over a four year period (1983-86) at Kindersley and Mervin. Leaving stubble standing overwinter at either a normal swathing height or with strips of taller stubble as snowtraps gave yields equal to or significantly greater than fall tillage. Use of herbicides for control of broadleaved and grassy weeds generally increased yield as did application of nitrogen and phosphate fertilizers. Yields were increased from 910 to 1970 at Scott; 1300 to 2450 at Lashburn; 940 to 1600 at Loon Lake; 1150 to 2420 at Kindersley and from 1920 to 2920 at Mervin where herbicides and fertilizers were applied in combination with tall stubble compared with no herbicide or fertilizer application. The occurrence and nature of interactions between factors suggest a need to conduct more studies to evaluate interactions of cropping system components. In developing sustainable crop production systems it is likely that improved efficiencies will arise from development and manipulation of entire cropping systems rather than individual components.

INTRODUCTION

Traditional crop rotations on the Canadian prairies are based on frequent summerfallowing (Brandt and Kirkland 1986). In the drier portions of the Brown soil zone, a crop-fallow rotation is normally followed ,with summerfallow practiced every 3 to 4 years on dark Brown and thin Black soils and every 4 to 6 years on the moister Black and Gray soils (Henry, 1984). Summerfallow has been shown to play a prominent role in soil erosion and organic matter loss (Mc Gill et al, 1981). Extended or continuously cropped rotations have been proposed as an alternative to summerfallow. Because spring wheat is widely adapted and its production technology is well developed, it is expected to play a major role in such rotations.

Continuous cropping to wheat has been evaluated in some long-term crop rotation and management studies. Early results suggested that this practice was not viable because of poor weed control, inadequate moisture, poor fertility or inability to adequately manage crop residues (Austenson et al 1970, Smika, 1970). In more recent years with improved weed control, higher levels of applied fertility and more suitable tillage and seeding equipment, continuous wheat yield relative to summerfallow yield has improved substantially (Brandt and Kirkland 1986, Zentner et al 1987). Despite these developments, economic returns only favored continuous wheat when prices were abnormally high (Zentner et al 1988). Further, the degree of income variability from year to year was much greater with continuous wheat than with wheat on fallow.

Improving economic performance of extended rotations involves some combination of increased returns and/or decreased production costs. Most studies have been conducted by varying one input or production practice while holding all others constant. Such studies provide valid data but tend to ignore possible interactions between inputs or practices. These studies were undertaken to evaluate a number of stubble management, weed control and fertility treatments applied in combination in a continuous wheat rotation. One of the main objectives was to determine the occurrence and nature of interactions between practices, and how they might be utilized to enhance production efficiency. Such data should prove highly valuable in developing efficient, sustainable, extended cropping systems.

This paper is a report and discussion of the yield data collected over a 4 to 8 year period at 5 locations covering all the major soil zones of the Canadian prairie region.

MATERIALS AND METHODS

In 1982 a continuous wheat rotation study was initiated at 5 locations in West-Central and Northwestern Saskatchewan. The locations represented a wide range of soil and climatic conditions (Table 1) ranging from the relatively dry area near Kindersley to the moist northern fringe of the agricultural zone at Loon Lake. All the major soil zones were represented with 4 sites on loam to clay loam soils and one on a heavy clay soil.

Table 1. Location and Soil Characteristics for Sites where Continuous Wheat Management Studies were conducted.

Location	Soil zone	Soil type	Ann. Precip (mm)*
Kindersley	Brown	Sceptre heavy clay	320*
Scott	Dark Brown	Elstow Loam	355
Lashburn	Thin Black	Waseca Loam	449
Mervin	Degraded Black	Whitewood Loam	422
Loon Lake	Grey	Loon River Loam	428

The experimental design utilized a split-split plot arrangement of treatments with four replications. Stubble treatments were applied to main plots; weed control practices to sub plots; fertility levels to sub-sub plots. At Scott, a sub-sub plot size of 3.6 m x 12 m was utilized, while sub plots and main plots consisted of 3 and 12 such sub-sub plots respectively. At other locations, the sub-sub plot size was 1.8 m x 6 m with sub plots and main plots reduced correspondingly. Factors and levels tested were as outlined in table 2. Because Avadex/2,4-D herbicide treatment was used only with fall tillage and Hoegrass-Buctril M only with the standing stubble treatments, treatment combinations with these herbicides were excluded from the analysis.

All herbicide treatments were applied post emergent to the crop and weeds using a plot sprayer applying a total volume of 100 l/ha and operating at 275 kPa. For herbicide treatments two and four, Hoegrass was applied first followed by either Glean

Table 2. Factor level descriptions for treatments used in continuous wheat studies.

FACTOR	LEVEL
Stubble management	1. fall tillage, cultivated following harvest 2. normal height stubble 3. tall stubble, snowtrap stips
Herbicide treatment	1. untreated 2. Hoegrass (0.70 kg/ha) and Glean (0.02kg/ha) separate application 3. Hoegrass (0.70 kg/ha/ Torch (0.35 kg/ha) tank mix
Fertility levels	1. 0-nitrogen, 0-phosphate 2. 40 kg nitrogen/ha - broadcast (83-86) banded (86-90) 20 kg phospahte/ha - seed placed 3. 80 kg nitrogen/ha - broadcast (83-86) banded (86-90) 40 kg phosphate/ha - seed placed

or Buctril M at no less than five day intervals. For treatment three Hoegrass and Torch were applied simultaneously as a tank mixture. Weed counts at all locations were taken from a one m area of each plot in mid July to correspond to the results obtained in the Saskatchewan weed survey (Thomas, 1980).

Preseeding tillage treatments varied somewhat depending on conditions at each location from year to year. However, the same preseeding tillage was performed on all treatments at any one location. Generally 1 or 2 operations with a cultivator and harrows was required, followed by seeding with a double disc press drill. Nitrogen fertilizer was broadcast prior to preseeding tillage from 1983-86 and was banded from 1987-89. Phosphate was seed placed.

Grain yields were determined at full ripeness by direct combining a 1.2 m wide strip the length of each plot using a small plot combine. The grain was cleaned, weighed and sub samples retained for kernel weight, volume weight and protein determinations. Protein analyses were performed utilizing a semi-micro Kjeldahl procedure or a near infra red reflectance analyser.

The sites at Kindersley, Scott and Lashburn were located on open fields without trees, hedgerows or other wind barriers within 100 m. The Mervin location had trees on three sides within 100 m and was open only to the north while the Loon Lake location was open on three sides with trees within 100 m to the west of the test site.

RESULTS

Statistical analyses of the yield data at each location indicated that in most cases main treatment effects (years, stubble treatment, herbicide treatment, fertilizer treatment) had a significant impact on yield at all locations (table 3). In addition a number of interactions were significant. Some interactions were significant at all locations while others were not.

Fall tillage resulted in lower yield than tall stubble at Scott, Kindersley and Lashburn, while the short stubble treatment exceeded yield from fall tillage at Scott, Lashburn and

Table 3. Results of statistical analysis of yield data for continuous wheat studies at five locations in Saskatchewan.

Source of variation	Scott 1983-90	Kindersley 1983-86	Lashburn 1983-89	Mervin 1983-86	Loon Lake 1983-89
Years (Yr)	**	**	**	**	**
Stubble (St)	**	*	**	*	ns
Yr x St	ns	ns	**	ns	**
Herbicide (Hb)	**	**	**	**	**
Yr x Hb	**	**	**	**	**
St x Hb	**	ns	**	ns	ns
Yr x St x Hb	ns	ns	ns	ns	ns
Fertility (Ft)	**	**	**	**	**
Yr x Ft	**	**	**	**	**
St x Ft	*	ns	**	**	ns
Yr x St x Ft	ns	ns	*	ns	ns
Hb x Ft	**	**	ns	ns	**
Yr x Hb x Ft	**	ns	ns	ns	**
St x Hb x Ft	ns	ns	**	ns	**
Yr x St x Hb x Ft	ns	ns	ns	ns	ns

* and ** denote significance at P=0.05 and 0.01. ns - not significant.

Table 4. Summary of main treatment effects on yield (kg/ha) of wheat in a continuous wheat rotation.

			location		
	Scott 1983-90	Kindersley 1983-86	Lashburn 1983-89	Mervin 1983-86	Loon Lake 1983-89
Stubble treatment*					
- Fall tillage	1411	1857	1824	2639	1226
- Short stubble	1553	1871	1939	2738	1234
- Tall stubble	1524	2019	1933	2503	1274
LSD P=0.05	67	105	59	119	50
Herbicide treatment					
-check	1085	1573	1721	2408	952
-Hoegrass-Glean	1703	2123	1997	2711	1490
-Hoegrass-Torch	1701	2051	2035	2752	1335
LSD P=0.05	43	75	39	79	34
Fertilizer treatment					
-check	1160	1449	1420	2086	1092
-40N-20P	1638	2072	2089	2804	1328
-80N-40P	1691	2226	2187	2981	1357
LSD P=0.05	29	47	29	53	21

*Tabulated means are for 9 herbicide x fertilizer combinations per year for each stubble treatment; 9 stubble x fertilizer conditions per year for each herbicide treatment; and 9 stubble x herbicide combinations per year for each fertilizer treatment.

Mervin (table 4). At Mervin, tall stubble gave yields that were significantly lower than for fall tillage while stubble treatment did not have a significant impact on yield at Loon Lake.

Hoegrass - Glean or Hoegrass - Torch increased yield over the unsprayed check at all locations, and occasionally significant differences between the two herbicides were noted.

Application of fertilizer increased yield over the unfertilized check treatment at all locations and there was a general tendency for the higher application rate to provide higher yields.

While the main treatment effects provided a general overview of their impact on yield, interactions between them provided a more comprehensive understanding of how these yield effects were achieved.

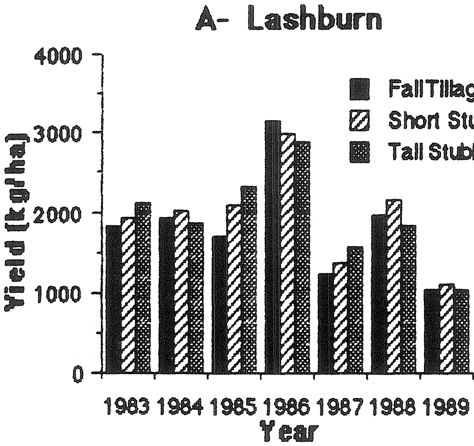
The year x stubble interaction was significant at Lashburn and at Loon Lake. At Lashburn, stubble treatment responses were quite variable from year to year (fig 1-A) but generally either short or tall stubble resulted in higher yield than fall tillage and there was no apparent trend for any treatment to change relative to the others over time. At Loon Lake, yields with short or tall stubble generally equalled or exceeded yield with fall tillage from 1983-85 but generally yielded less than for fall tillage from 1986-89 (fig 1-B). This change over time may have been related to leaf diseases (septoria leaf and glume blotches and possibly tan spot) which increased to epidemic proportions at this site from 1987-89. It is possible that fall tillage reduced the amount of innoculum coming from infected crop residues although no apparent differences in degree of infection between stubble treatments were noted. There did not appear to be any indication that stubble treatment responses could be explained on the basis of either overwinter or growing season precipitation (table 5). Snow depth and soil moisture measurements were not made at any site except Scott where soil moisture levels, spring and fall were determined.

The year x herbicide interaction was significant at all sites. In general, year x herbicide interactions reflected changes in weed populations over time.

At Scott (fig 2-A), the impact of herbicides on yield was relatively small in early years of the study because weed populations were low, but yield responses increased in latter years (except 1988) due to higher weed populations. During 1989 and 1990, Hoegrass - Glean resulted in higher yield than Hoegrass - Torch. Green foxtail numbers were lower for the Hoegrass - Glean treatment than for Hoegrass - Torch in those 2 year likely due to residual activity of Glean on green foxtail.

At Kindersley reduced yield with Hoegrass - Torch in 1986 was due to a flush of broadleaf weeds after herbicide application (fig 2-B). The Glean component of the Hoegrass - Glean treatment provided sufficient soil residual activity to control these weeds.

At Lashburn, yield responses to the herbicide treatments tended to increase over time, corresponding with an increase in weed populations over time (fig 2-C). A somewhat similar response was noted at Mervin (fig 2-D) and at Loon Lake (fig 2-E). In addition at Loon Lake, Hoegrass - Glean provided higher yields than Hoegrass Torch from 1987-89. This occurred because of the greater activity of Glean on corn spurry, a weed that had become a serious problem at that time. Torch was very ineffective on corn spurry.



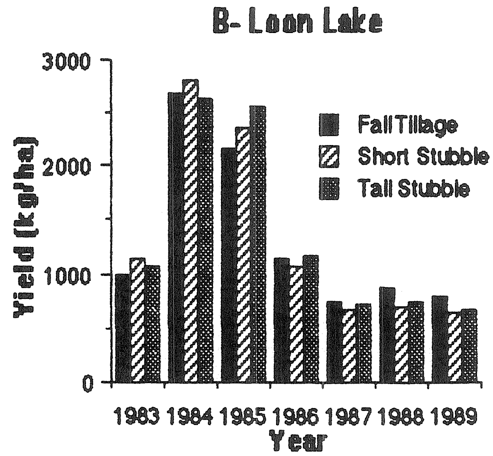


Figure 1. Stubble treatment responses of wheat grown continuously during 1983-89 at ; A- Lashburn, B - Loon Lake

At Scott and Lashburn, the stubble treatment x herbicide interaction was significant. At both locations, the response to herbicides was negligible with fall tillage but was significant where short or tall stubble were used (fig 3-A and 3-B).

Responses to fertilizers varied considerably from year to year at all locations (fig 4-A to E). Year to year variations were likely related to moisture conditions as well as levels of available nutrients before fertilizer application. At Scott for example in the extreme drought year 1984, fertilizer applications decreased yield while increasing yield in all other years. In general the 40 N - 20 P205 application rate increased yield over the check treatment in almost all years at all locations. The higher rate of fertilizer did not result in a consistant further increase in yield and sometimes reduced yield compared with the 40 N - 20 P205 rate. The stubble x fertilizer interaction was significant at three locations. At Scott and at Lashburn, yields were similar for the unfertilized check for all stubble treatments, but the response to the 40 N - 20 P205 rate was much higher with standing or tall stubble than with fall tillage. Standing or tall stubble at Scott and tall stubble at Lashburn resulted in a further yield increase with the 80N - 40 P205 rate. (fig 5A & B).

While the stubble x fertility interaction was significant at Lashburn, the three way interaction of years x stubble x fertility was also significant at that location. While in most years, yield enhancement by the highest fertilizer rate was less for fall tillage than for standing or tall stubble, in 1986 it was equal to responses with standing or tall stubble (table 6). In addition, while the highest rate of fertility typically enhanced yield over the lower rate with standing or tall stubble, yield enhancement did not occur in all years with both stubble treatments (eg. 1984,1988).

The herbicide x fertility interaction was significant at Scott, Kindersley and Loon Lake. At Scott, where herbicides were not used, application of fertilizer increased yield but the highest rate depressed yield compared to the lower rate while yields were not depressed by the higher rate where Hoegrass plus Glean or Torch were applied (fig 6-A). At Kindersley, application of the highest rate of fertilizer enhanced yield over the lower rate where herbicides were applied but not where herbicides were not used (fig 6-B). Responses to fertility were similar for the check and Hoegrass - Glean treatments

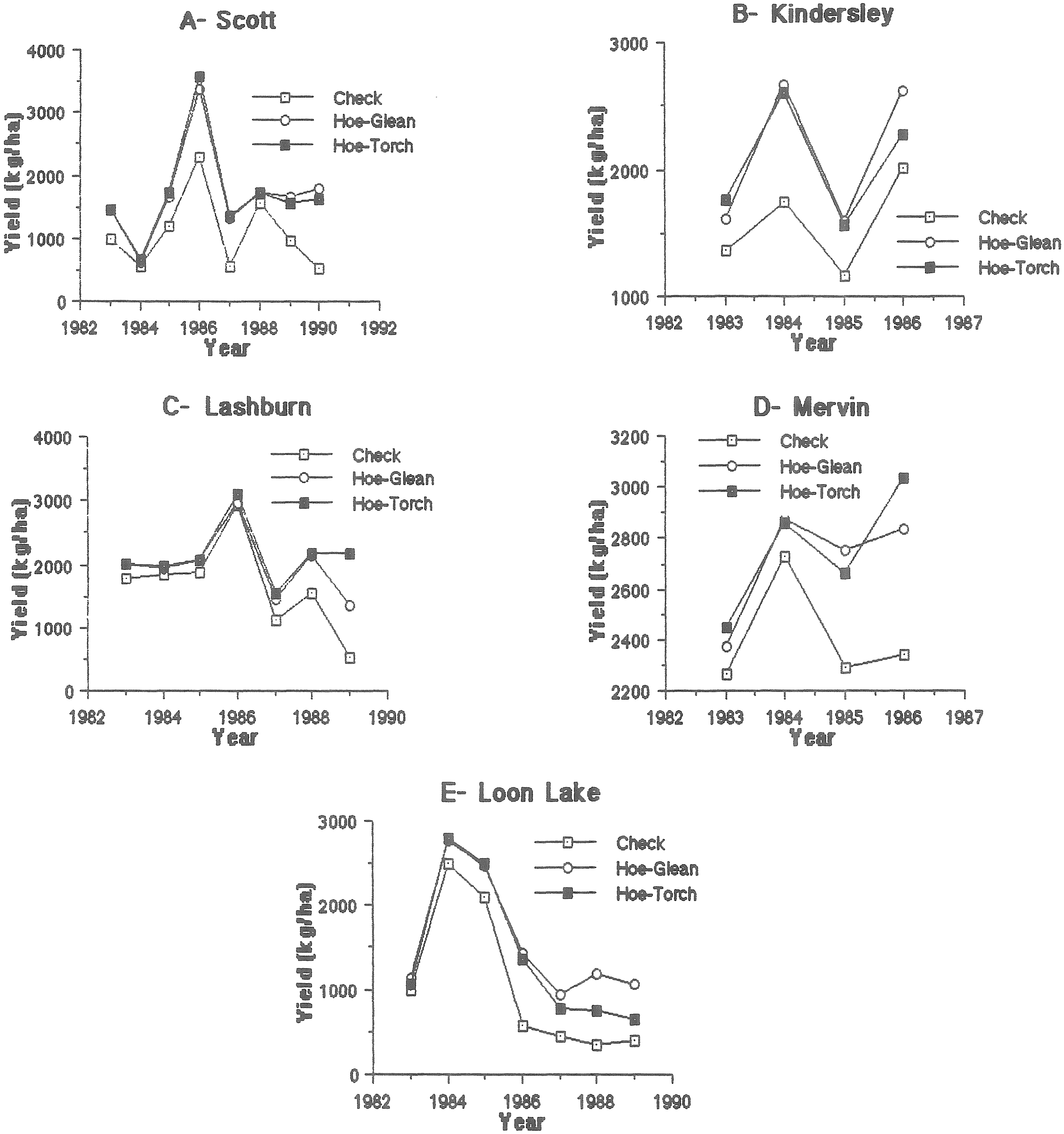
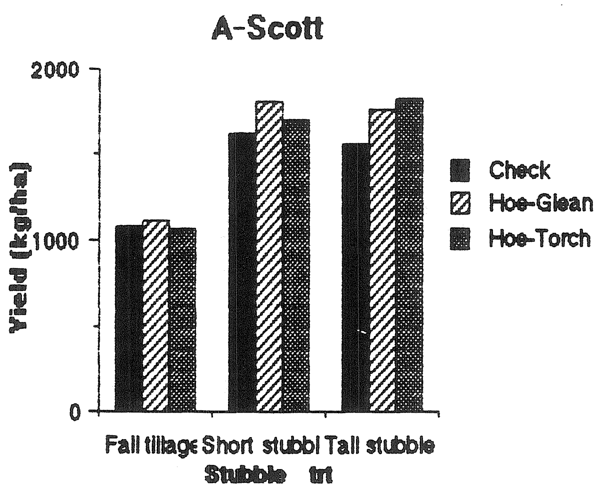


Figure 2. Yield of continuous wheat with 3 herbicide treatments at; A- Scott 1983-90, B- Kindersley 1983-86, C- Lashburn 1983-89, D- Mervin 1983-86 and E- Loon Lake 1983-89.



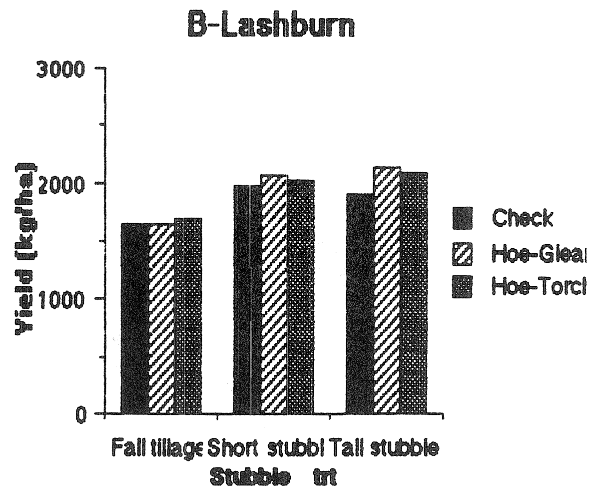


Figure 3. Yield of continuous wheat with 3 stubble and 3 herbicide traetments at; A-Scott (1983-90 avg) and B- Lashburn (1983-89avg).

Table 5. Precipitation (mm) at five locations in West Central and Northwestern Saskatchewan for seven 12 month periods.

Location	1982 -83	1983 -84	1984 -85	1985 -86	1986 -87	1987 -88	1988 -89	Long term mean
			Overwinter precipitation (1 Sept - 30 April)					
Scott	195	172	270	130	157	84	116	153
Lashburn	113	160	191	98	201	114	87	190
Loon Lake	122	248	256	178	180	126	107	174
Kindersley	138	121	184	113	—	—	—	137
			Growing season precipitation (1May - 31 Aug)					
Scott	182	173	178	241	308	247	231	200
Lashburn	219	203	168	352	324	385	265	259
Loon Lake	187	228	228	293	259	378	179	254
Kindersley	226	163	118	197	—	—	—	183
			12 month total precipitation (1 Sept - 31 Aug)					
Scott	377	343	448	371	465	331	347	353
Lashburn	332	363	359	450	525	499	452	449
Loon Lake	303	476	486	471	439	504	353	428
Kindersley	364	284	302	310	—	—	—	320

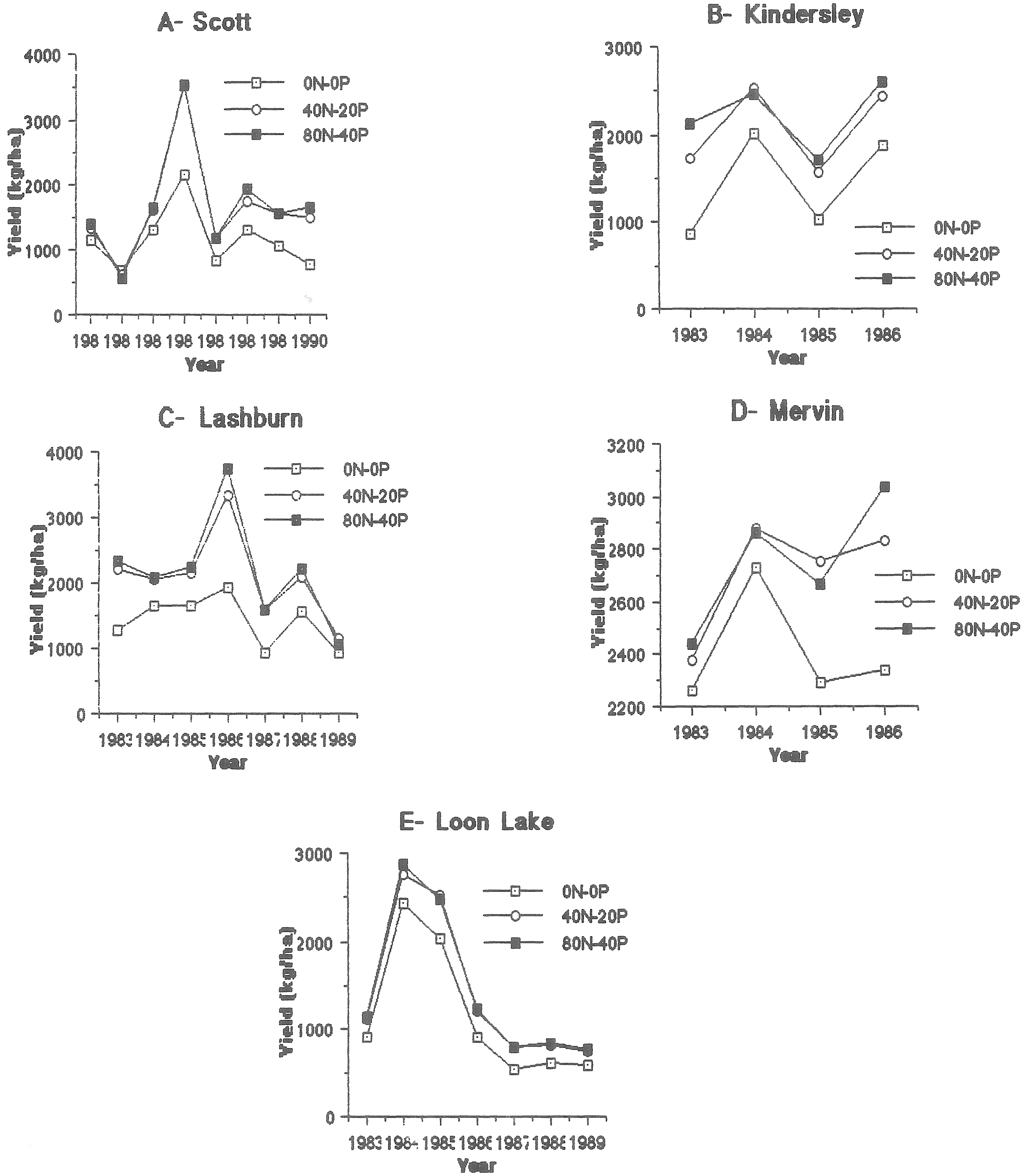


Figure 4. Yield of continuous wheat with 3 fertilizer treatments

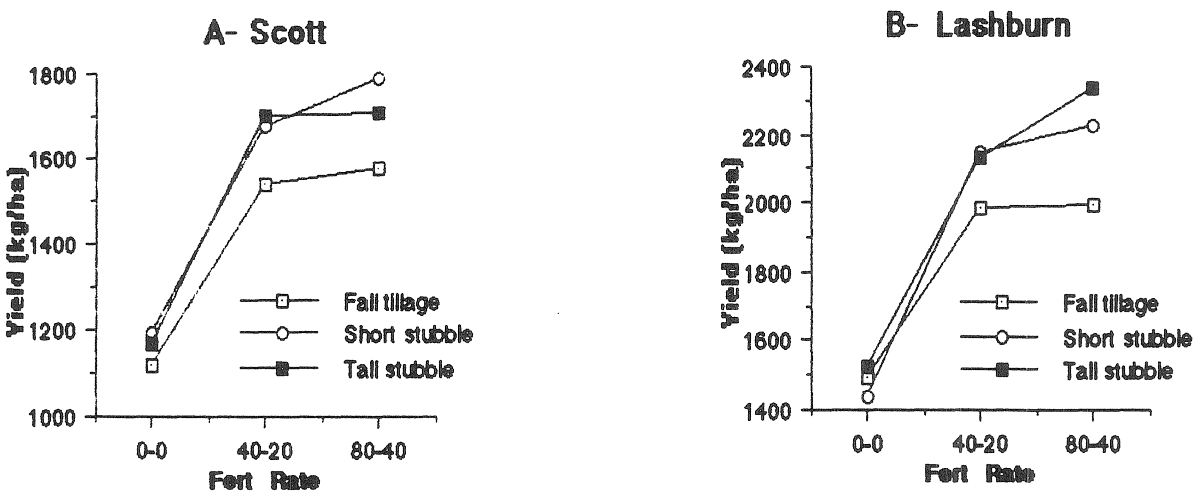


Figure 5.Yield of continuous wheat with 3 stubble and 3 fertility treatments at; A- Scott (1983-90 avg) and B- Lashburn (1983-89 avg).

Table 6. Yield (kg/ha) of wheat grown continuously with 3 stubble, 8 and 3 fertilizer treatments at Lashburn 1983-89.

Stubble treatment	N (kg/ha)	P205 (kg/ha)	1983	1984	1985	1986	1987	1988	1989
Fall tillage	0	0	1340	1760	1580	2210	980	1720	990
	40	20	1990	2040	1790	3570	1390	2120	1060
	80	40	1980	2030	1820	3810	1410	2180	950
Short stubble	0	0	1220	1630	1750	1970	940	1760	1070
	40	20	2250	2150	2250	3340	1560	2330	1210
	80	40	2330	2120	2230	3740	1600	2390	1130
Tall stubble	0	0	1310	1540	1810	1770	930	1310	860
	40	20	2380	1960	2450	3270	1970	1970	1230
	80	40	2600	2070	2700	3730	1890	2330	1120

at Loon Lake, but where Hoegrass - Torch was applied the fertilizer check and 40 N - 20 P205 fertilizer rates gave yields lower than corresponding yields for Hoegrass - Glean, but much of the difference disappeared where the 80N - 40 P205 rate was applied (fig 6-C). Reduced yield with Hoegrass Torch was related to poorer corn spurry control than with Hoegrass - Glean. It is possible that higher fertility may have enhanced the ability of the crop to compete with this weed species which has a short stature and is not as competitive as some other species.

The significant year x herbicide x fertilizer interaction at Scott indicated that while there was a general tendency for yields to increase as the rate of applied fertilizer increased where herbicides were applied but not where herbicide were not used, there was also considerable year to year variation. On at least two occasions, the higher rate of

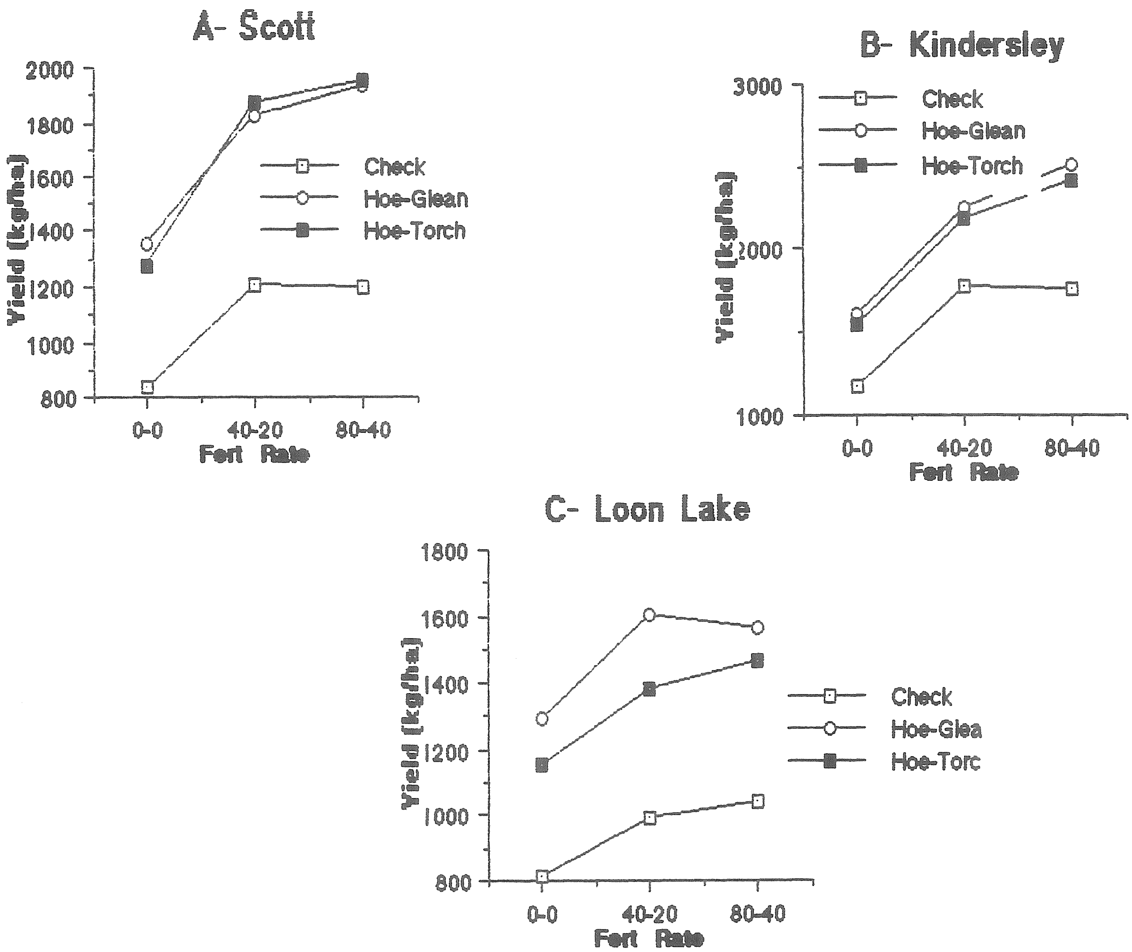


Figure 6. Yield of continuous wheat with 3 herbicide and 3 fertilizer treatments at; A-Scott (1983-90 avg) B- Kindersley (1983-86 avg) and C- Loon Lake (1983-89 avg).

fertilizer did not enhance yield over the 40 N - 20 P205 rate regardless of whether herbicides were applied or not (table 7). A somewhat similar variation from year to year in the herbicide/fertilizer responses occurred at Loon Lake.

The significant stubble treatment x herbicide x fertilizer interaction at Lashburn was related to the yield decrease to the high rate of fertilizer where fall tillage and no herbicide were used while the high rate of fertilizer generally provided the highest yield wehre it was used in combination with short or tall stubble plus herbicides (table 8). At Loon Lake the same significant 3 way interaction was not as clear, but it did appear that yields with the 40 N - 20 P205 rate combined with Hoegrass - Glean plus short or tall stubble exceeded yields for the same rate of fertilizer with other tretatment combinations were lower. Other fertilizer rates did not provide a similar response.

Table 7. Yield (kg/ha) of continuous wheat with 3 herbicides and 3 fertilizer treatments at Scott, 1983-90 and Loon Lake 1983-89.

Herbicide treatment	N (kg/ha)	P205 (kg/ha)	1983	1984	1985	1986	1987	1988	1989	1990
at Scott, 1983-90										
Check	0	0	960	610	1050	1380	570	1280	660	250
	40	20	1040	610	1320	2660	610	1660	1100	720
	80	40	1000	490	1240	2770	500	1770	1160	660
Hoe-Glean	0	0	1260	700	1440	2600	1000	1340	1330	1210
	40	20	1490	610	1740	3680	1460	1820	1820	1960
	80	40	1590	490	1770	3820	1540	2040	1850	2240
Hoe-Torch	0	0	1210	700	1410	2460	970	1350	1180	920
	40	20	1490	610	1780	4210	1510	1810	1750	1820
	80	40	1630	570	1960	4030	1570	2040	1710	2080
at Loon Lake, 1983-89										
Check	0	0	790	2210	1800	500	350	320	370	
	40	20	1120	2580	2250	560	480	380	390	
	80	40	1090	2740	2260	620	500	390	470	
Hoe-Glean	0	0	1030	2530	2170	1120	710	980	900	
	40	20	1210	2970	2680	1600	1060	1280	1120	
	80	40	1170	2860	2560	1580	1020	1270	1150	
Hoe-Torch	0	0	960	2600	2160	1110	570	560	480	
	40	20	1030	2760	2680	1490	830	780	740	
	80	40	1200	3030	2640	1520	890	890	700	

To provide an overview of responses to management practices, some additional summarizing of data was done. Because standing stubble, either short or tall, typically resulted in increased yield they were averaged for each location. Similarly Hoegrass-Gleam and Hoegrass-Torch were averaged as were the 40 N - 20 P205 and 80 N - 40 P205 fertilizer rates.

Standing stubble without herbicides or fertilizer applied gave a mixed response compared with fall tillage without herbicides or fertilizers (table 9), ranging from increases at some locations and decreases at other. Where herbicides or fertilizers were applied alone along with fall tillage yields were enhanced but the greatest yield enhancement occurred with standing stubble plus herbicides and fertilizer.

Based on yields obtained with single management factors (table 9), yield responses to standing stubble, herbicides and fertilizers used alone or in combination were determined (table 10). In all cases, when averaged over a location the yield response to standing stubble with herbicides and fertilizers exceeded the sum of their individual responses. This enhancement of yield over 30 location years provides strong evidence that many management practices are inter-related and that to obtain optimum response to any one management practice requires optimum levels of other complimenting management practices.

Table 8. Yield (k/ha) of continuous wheat with 3 stubble, 3 herbicide and 3 fertilizer treatments at Lashburn and Loon Lake, 1983-89 avg.

Herbicide treatment	N (kg/ha)	P205 (kg/ha)	Fall tillage	Short stubble	Tall Stubble
LASHBURN					
Check	0	0	1300	1210	1100
	40	20	1840	1900	1870
	80	40	1770	1800	2120
Hoe-Glean	0	0	1580	1530	1430
	40	20	2090	2210	2200
	80	40	2110	2410	2410
Hoe-Torch	0	0	1610	1580	1440
	40	20	1960	2330	2340
	80	40	2090	2480	2480
LOON LAKE					
Check	0	0	940	910	870
	40	20	1090	1150	1090
	80	40	1150	1100	1200
Hoe-Glean	0	0	1360	1290	1400
	40	20	1650	1720	1740
	80	40	1640	1640	1690
Hoe Torch	0	0	1170	1250	1200
	40	20	1500	1400	1530
	80	40	1540	1570	1550

Table 9. Summary of yields (kg/ha) of continuous wheat with and without standing stubble, herbicides and fertilizer alone and in combination at 5 locations in west-central and northwestern Saskatchewan.

	Location				
Treatment Combination*	Scott 1983-90	Kindersley 1983-86	Lashburn 1983-89	Mervin 1983-86	Loon Lake 1983-89
F.T.-no herbic-no fert.	830	1150	1300	1920	940
S.S.-no herbic-no fert.	850	1190	1170	1860	890
F.T.-Herbic-no fert	1260	1550	1590	2230	1260
F.T.-no heric-Fert	1190	1760	1840	2580	1120
S.S.-Herbic-Fert	1950	2390	2390	2980	1610

*F.T. = fall tillage; ss = standing stubble (mean of short and tall stubble); Herbic = mean of Hoegrass-Glean and Hoegrass-Torch; Fert = mean of 40N-20P and 80N-40P.

Table 10. Summary of yield responses (kg/ha) of continuous wheat to standing stubble, herbicides and fertilizers alone and in combination at 5 locations in west-central and Northwestern Saskatchewan.

	Location				
Response to	Scott 1983-90	Kindersley 1983-86	Lashburn 1983-89	Mervin 1983-86	Loon Lake 1983-89
1. Standing stubble only	20	40	-130	-60	-50
2. Herbicides only	430	400	290	310	320
3. Fertilizers only	360	610	540	660	180
4. 1+2+3	810	1050	700	910	450
5. Actual combined response	1120	1240	1090	1060	670
6. Increase (5-4)	310	190	390	150	220

SUMMARY

- Yield responses to standing stubble were seldom observed unless weeds were adequately controlled and adequate fertility applied.

- Yield was normally increased by applying herbicides or fertilizers alone except under low weed populations or severe drought conditions.

- Yield responses to standing stubble, herbicides and fertilizers used in combination typically exceeded the totals for each used alone.

- Results suggest that to achieve optimum response to one management practice other crop requirements need to be met.

- To improve production efficiency (reduced unit cost of production), interdisciplinary research should be emphasized.

Studies of individual components of the cropping system provide useful information on how they function. However, multiple component studies such as this provide a much more comprehensive understanding of how they interact with one another. The occurrence and nature of interactions in these studies suggest a need for comprehensive multifactor studies in the future. Such studies will take on added importance in the development of sustainable production systems where reducing external inputs and making highly efficient use of resources is critical. In more sustainable systems it is likely that efficiencies will result from development and manipulation of entire production systems than from individual components.

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