Economics of Integrated Crop Management Systems in the Dark Brown Soil Zone

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Introduction

Low commodity prices, rising input costs, and increasing concerns about environmental degradation are encouraging producers in western Canada to consider alternative soil tillage and weed management methods that conserve resource inputs. However, little is known about the economic merits of these management changes. This study determines the effects of six integrated soil, cultural, and weed management practices on production costs, economic returns, and riskiness for a Wheat (**W**)-Canola (**C**)-Barley (**B**)-Pea (**P**) rotation in the Dark Brown soil zone of Saskatchewan.

Materials and Methods

<u>Experimental Data</u>

Field trials were conducted from 1997 through 2000 on a clay soil (with soil organic matter at 4.5% and pH of 7.2) at Saskatoon and on a clay-loam soil (with soil organic matter at 4.5% and pH of 7.0) at Watrous. Each W-C-B-P rotation was operated using six integrated management systems: i) High Herbicide / Zero till (**HH/ZT**),

ii) Medium Herbicide / Zero Till (**MH/ZT**),
iii) Low Herbicide / Zero Till (**LH/ZT**),
iv) Low Herbicide / Low Till (**LH/LT**),
v) Medium Herbicide / Medium Till (**MH/MT**), and
vi) No Herbicide / High Till (**NH/HT**).

Within these systems there were differences in seeding rates, fall weed control, pre-seeding weed control, in-crop herbicide rate, and seeding date (Table1). In addition, half of each plot received fungicide (i.e., Quadris) each year applied at flagleaf for wheat and barley, at 2 to 5 leaf stage for canola, and at flowering for pea; the other half was left untreated.

Recommended rates of fertilizer N, P, and S were applied (N and S were banded, while P was seed placed) to all crops based on soil tests. At Saskatoon, wheat received an average of 64, 27, and 7 kg ha^{-1} of N, P_2O_5, and S, respectively. Canola received 88, 24, 14; malt barley 59, 27, 7; and pea received 17, 23, and 7 kg ha^{-1} of the respective nutrients. At Watrous, the respective fertilizer rates were 47, 24, 0 for wheat; 66, 22, 0 for canola; 50, 24, 0 for barley; and 9, 20, 0 for pea. At Saskatoon, all crops were planted using a Versatile hoe drill (at 20 cm row spacing and a 5 cm seed row spread) with on row packing. While at Watrous, a Fabro direct seed drill was used equipped with disc openers (at 20 cm spacings) in 1997, and thereafter with knife openers (at 25 cm spacing).

Each crop was grown every year, and each management system was cycled on its assigned plots. In 1998 at Saskatoon, the canola plots failed to establish due to very dry surface soil moisture conditions. At Watrous, the crops experienced hail damage in 1999 (moderate damage) and 2000 (light damage). The experimental design was a slit-split plot with four replicates. Crop types were main plots, management systems were sub-plots, and fungicide treatments were sub-sub-plots. The plot size was 4 m by 20 m.

Economic Analyses

The economic performance of the twelve integrated crop management systems at the Saskatoon and Watrous sites was determined annually using methods described by Zentner et al. (1996). Each system was evaluated in regard to costs of production, gross return, net return, breakeven conditions, and riskiness. Net return was defined as the income remaining after paying for all cash costs (seed, fertilizer, pesticides, fuel, oil, repairs, crop insurance, miscellaneous items, land taxes, and interest), ownership costs for machinery and grain storage, and for labor. Riskiness was assessed using expected value-variance analysis (Anderson et al. 1977) to compare the distributions of net returns from each treatment. All purchased inputs and machine operations were valued and held constant at their year 2000 cost levels (Saskatchewan Agriculture and Food 2000; University of Saskatchewan 2000) (Table 2). No allowance was made for interest costs associated with land equity, or for differences in management requirements among the cropping systems. The research plot data were extrapolated to the farm-level using a 907 ha representative farm with a typical complement of machinery and labor supply for each treatment. Participation in the Canada/Saskatchewan Crop Insurance Program was assumed to be at the 70% yield coverage for all crops. Premium rates and payout criteria for each crop in Risk Area #18 (Saskatoon) and #15 (Watrous) of Saskatchewan were assumed (Saskatchewan Crop Insurance Corporation 2000). The farm-gate prices for (top grade) grains were taken at their respective 10-year (1990/1991 to 1999/2000) mean values (net of rail transportation and elevator handling costs), namely \$144 t^{-1} (protein content < 12%) (SD = 30 t^{-1}) for spring wheat, \$323 t^{-1} (SD = 61 t^{-1}) for canola, \$140 t^{-1} (SD = 30 t^{-1}) for malt barley, and \$176 t^{-1} (SD = 24 t^{-1}) for field pea. All grain prices were adjusted in accordance with the specific grades (or whether the barley met the standards for malt) obtained for each treatment, replicate, and year. The 10-year historical (1990/91 to 1999/2000) price discounts for lower grades of each grain were assumed. In addition, the price for spring wheat was adjusted in accordance with the 1999/2000 price schedule for grain protein content as established by the Canadian Wheat Board (Canadian Wheat Board 2000). The performance of each cropping system was also evaluated for a range of product prices (representing one standard deviation lower than the respective mean or base prices, to one standard deviation higher than the respective mean values) to test the sensitivity of the findings to changes in these price conditions. The economic performance results were expressed on a per hectare basis for the complete cropping systems, and for individual crops within the rotations. Data collected over the 1997 to 2000 period were used in the analyses.

All economic data were subjected to analysis of variance for split-plot designs (SAS Institute, Inc., 1985); the analyses was conducted separately for each location and for the fungicide versus no fungicide application treatments. Sources of variation were partitioned as follows: years, replicates within years (Error A), cropping system, cropping system x year, and cropping system x year x replicates within years (residual error). In cases where data were analyzed annually, the sources of variation were cropping system and replicates. Significant differences among treatment means were determined using LSD ($P<0.10$) (Little and Hills 1978).

Results and Discussion

Production Costs and Breakeven Conditions

Total costs for the complete cropping systems (Table 3) were typically higher at Saskatoon than at Watrous (\$35 ha^{-1} more), reflecting the higher rates of fertilizers applied and the greater number of tillage operations for weed control, residue management, and seedbed preparation required at the Saskatoon site. Total costs were also significantly ($P<0.10$) influenced by management method and whether the treatments received in-crop fungicide application (Table 3). At Saskatoon, total costs averaged \$310 ha^{-1} for the no-fungicide treatments and \$374 ha^{-1} for those that received a blanket application of fungicide applied at flagleaf for wheat and barley, at 2 to 5 leaf stage for canola, and at flowering for pea. Similarly, at Watrous, total costs averaged \$275 ha^{-1} and \$339 ha^{-1} for the no-fungicide and fungicide treatments, respectively. The higher cost for these latter treatments (i.e., \$64 ha^{-1} more) reflects the added cost of the Quadris fungicide and its application, plus the additional costs associated with harvesting, transportation, and storage of the higher grain yields obtained with fungicide application, especially for barley, wheat and, to a lesser extent, pea (Sapsford et al. 2002).

Total costs were highest for the HH/ZT treatment and typically lowest for NH/HT (avg. \$377 ha^{-1} vs \$308 ha^{-1} at Saskatoon, and \$339 ha^{-1} vs \$287 ha^{-1} at Watrous, respectively). At Saskatoon, total costs for the medium-herbicide treatments (MH/ZT and MH/LT) were similar and ranked second highest (about \$27 ha^{-1} less than for HH/ZT), while total costs for the low-herbicide treatments (LH/ZT and LH/LT) ranked third highest (about \$45 ha^{-1} less than for HH/ZT). At Watrous there was generally little difference in total costs among the medium- herbicide and low-herbicide treatments (about \$36 ha^{-1} less than for HH/ZT). Typically treatments that used zero tillage management practices required lower expenditures for machinery operation (i.e., fuel and oil, machine repair, and machine overhead) and labor, but higher expenditures for herbicides compared to those that used mechanical tillage management practices (Table 3). These results are similar to those reported in most other studies that compared zero- and conventional-tillage management practices (Smith et al. 1996; Zentner et al. 1996, 2002). Cash outlays were highest for fertilizer and chemical inputs, and together they represented from 24 to 46% of the total costs for most cropping systems. Machinery overhead (depreciation and investment) averaged 19 to 24% of the total costs of each cropping system.

The total cost of producing individual crops within each cropping system (Tables 4 and 5) were highest for pea (avg. \$415 ha^{-1} at Saskatoon and \$359 ha^{-1} at Watrous for the no-fungicide treatments), intermediate for canola (avg. \$301 ha^{-1} at Saskatoon and \$276 ha^{-1} at Watrous for these same no-fungicide treatments) and lowest for wheat (avg. \$267 ha^{-1} and \$244 ha^{-1}) and barley (avg. \$256 ha^{-1} and \$221 ha^{-1} at the respective locations). The effect of method of management on the production costs for the individual crops generally displayed similar tends to those reported for the complete cropping systems (i.e., typically HH/ZT > NH/HT, with relatively small differences among MH/ZT, MH/LT, LH/ZT, and LH/LT).

The average cost per unit of grain produced is shown for the individual crops in Table 4 and Table 5. These values, in effect, represent the 'breakeven grain prices' that are required to recover production costs. The average cost of producing wheat ranged from \$97 t^{-1} to \$139 t^{-1} at Saskatoon and from \$115 t^{-1} to \$160 t^{-1} at Watrous. The unit cost of producing wheat was highest for the NH/HT system and generally similar for the other management treatments at Saskatoon. In contrast, at Watrous the unit cost of producing wheat was highest for the HH/ZT, LH/ZT, and LH/LT systems, and lowest for NH/HT, MH/ZT, and MH/ZT. Similarly, the unit cost of producing canola ranged from \$202 to 461 t^{-1} at Saskatoon (excludes 1998) and from \$250 to \$440 t^{-1} at Watrous, with the unit costs typically being highest for the MH/MT and/or NH/HT treatments, and lowest for LH/ZT. The cost per unit of barley produced ranged from \$64 to \$100 t^{-1} at Saskatoon and from \$101 to \$127 t^{-1} at Watrous. At Saskatoon, the lowest unit cost method of producing barley was with LH/ZT, while the highest unit cost management method was NH/HT. At Watrous, the unit cost of producing barley was generally similar among the various management systems when no fungicide was applied; however, when in-crop fungicide was applied unit production costs were lowest for MH/MT. For pea, the unit costs ranged from \$130 to \$167 t^{-1} at Saskatoon and from \$140 to \$174 t^{-1} at Watrous, with HH/ZT and MH/MT being the lowest unit cost production methods (among the no-fungicide treatments) at Saskatoon, and HH/ZT and LH/LT being the lowest unit cost production methods at Watrous. These results not only reflect differences in the cost per unit of land area among the various management methods, but also the effects of the management methods on grain yields (Sapsford et al. 2002).

Similarly, the breakeven yields [i.e., the yield required to generate sufficient revenue (at the base product prices) to recover production costs] for each crop and management method are shown in Table 4 and Table 5. In most cases, these breakeven yields are lower than the actual yields obtained for each management system (Sapsford et al. 2002), which bodes well for the potential of earning positive net returns.

<u>Gross Returns</u>

The 4-year mean gross returns (i.e., value of the grain produced at base grain prices, adjusted for grain quality) for the complete cropping systems are shown in Table 3. As with total production costs, gross returns were generally highest for HH/ZT (avg. \$525 ha^{-1} at Saskatoon and \$386 ha^{-1} at Watrous) and lowest for NH/HT (avg. \$379 ha^{-1} and \$319 ha^{-1} at these respective locations); however, at Watrous gross returns for MH/ZT and MH/MT also ranked among the highest revenue earning systems when in-crop fungicide was used. On average, the application of in-crop fungicide increased gross returns by \$21 ha^{-1} at Saskatoon and by \$16 ha^{-1} at Watrous. These incremental returns from fungicide application are less than the additional costs (avg. \$64 ha^{-1}) associated with its application, signalling that at the current cost level of Quadris and the base grain price levels, blanket applications of in-crop fungicide would not be not profitable at either study location.

Gross returns for individual crops within the cropping systems (Tables 4 and 5) displayed similar patterns as for grain yields (Sapsford et al. 2002). Gross returns were generally highest for HH/ZT or MH/ZT, and lowest for NH/HT management of most crops. The application of in-crop fungicide increased gross returns from wheat production by \$38 ha^{-1} at Saskatoon and by

$21 ha^{-1} at Watrous. Similarly, fungicide application increased gross returns from canola production by $5 ha^{-1} and $13 ha^{-1}, barley by $23 ha^{-1} and $10 ha^{-1}, and pea by $19 ha^{-1} and $20 ha^{-1} at the Saskatoon and Watrous sites, respectively. These increased gross returns directly reflect the enhanced crop yields and/or grain quality improvements obtained from the application of the Quadris fungicide, and they represent the maximum prices that could be paid for the fungicide in order to just break even when applying it as a 'blanket application'. Perhaps a more cost effective and profitable approach to in-crop fungicide application is one that is based on a needs assessment for the individual crops and years (e.g., presence of disease spores, weather conditions) and the fungicide then applied as required.

Net Returns

Net returns (at base grain prices) for the complete cropping systems averaged $159 ha^{-1} and $80 ha^{-1} for the no-fungicide treatments at Saskatoon and Watrous, respectively (Table 3). These net return values include the significant payouts from the all-risk crop insurance program, reflecting the failure of canola plots to properly establish in 1998 at Saskatoon due to the very dry soil moisture conditions, and the crop damage suffered from hail at Watrous in 1999 (moderate damage) and 2000 (light damage). Overall, the blanket application of in-crop fungicide was not profitable at either location, with net returns averaging $30 to $70 ha^{-1} lower than for the comparable no-fungicide treatments. At Saskatoon, net returns (for the no-fungicide treatments) were highest (and similar) for the zero-till managed systems (HH/ZT, MH/ZT, and LH/ZT), and lowest for NH/HT. At Watrous, the most profitable cropping systems were LH/LT and MH/ZT, and the least profitable systems were NH/HT, LH/ZT, and HH/ZT.

On an annual basis, net returns at Saskatoon were highest in 1999 (Figure 1), a year with cool and wet growing season conditions which resulted in the highest recorded grain yields. Under these favorable growing conditions, HH/ZT was the most profitable management method (no-fungicide treatments only). This was followed by MH/ZT which ranked second highest, and then by LH/ZT and MH/MT. In the relatively dry years of 1998 and 2000, the HH/ZT, MH/ZT and LH/ZT systems generally performed best, reflecting the improved soil moisture conditions with zero tillage management. In all years except 1997, the NH/HT system, and to a lesser extent LH/LT, provided the lowest net return, reflecting in part the difficulty of adequately controlling weeds when relying primarily on tillage alone.

At Watrous, net returns were highest in 1998, a year with high spring soil moisture reserves and normal growing season precipitation (Figure 2). The most profitable management methods in 1998 were MH/ZT, HH/ZT, and MH/MT (no-fungicide treatments only). Net returns for all cropping systems tended to be low (or negative) in 1999 and 2000 reflecting the crop damage from hail, and the fact that the all-risk crop insurance option selected for the economic analysis provided coverage at the 70% yield guarantee level (which also masks the effects of the management treatments). In 1997, a year when moisture conditions were favorable in spring but were relatively dry in the latter part of the growing season, net returns were highest for LH/LT and lowest for HH/ZT, MH/ZT, and MH/MT.

The most profitable crops at Saskatoon were the cereal grains (Table 4), while at Watrous the most profitable crops were the pulses (Table 5). The net returns for the individual crops at Saskatoon (no-fungicide treatments only) averaged \$212 ha^{-1} for wheat, \$105 ha^{-1} for canola, \$191 ha^{-1} for barley, and \$129 ha^{-1} for pea. At Watrous the 4-year average net returns for these same crops were \$69 ha^{-1}, \$80 ha^{-1}, \$79 ha^{-1}, and \$91 ha^{-1}. As with the complete cropping systems, the net returns for the individual crops at Saskatoon were, in most instances, highest when managed using zero tillage practices. In contrast, at Watrous there was little consistency in the most profitable management method for individual crops.

Effect of Changes in Grain Prices on Net Returns

Changes in grain prices had a major impact on the absolute level of net returns earned, but had relatively little impact on the rankings of net returns for the various cropping systems (Table 6). These results reflect the rather small impacts of the different management methods on grain yields and quality. At Saskatoon, the HH/ZT, MH/ZT, and LH/ZT management methods provided the highest and NH/HT provided the lowest net return under all grain price scenarios when no fungicide was applied. When the treatments included in-crop fungicide, the most profitable methods were HH/ZT and LH/ZT when prices for all grains together, and for individual crops, were high (i.e., one standard deviation above the mean grain prices), while at low grain prices LH/ZT was typically the most profitable management system. At Watrous, the best systems were MH/ZT and LH/LT under high and low grain price scenarios when no in-crop fungicide was applied, and typically MH/ZT and MH/MT under all grain price scenarios when blanket applications of fungicide were used.

Riskiness of Cropping Systems

When choosing among cropping systems, producers are often faced with a trade-off between increases in annual net returns and increases in income variability (or riskiness). As producers become increasingly risk averse (i.e., do not like to gamble), they tend to prefer cropping systems that display lower income variability (Zentner et al. 1996). Under the limited duration of this study (only 4 years), annual income variability (as measured by the coefficient of variation, Table 3) at the Saskatoon site was highest for the NH/HT system, and lowest for LH/ZT (no-fungicide treatments) and LH/LT (fungicide treatments).

At Watrous, income variability was highest for the HH/ZT and LH/ZT systems when no in-crop fungicide was used, and highest for the NH/ZT and LH/LT systems when fungicide was applied. The management systems that displayed the lowest income variability were LH/LT (no-fungicide) and MH/ZT (fungicide).

Based on assessment of the risk-return tradeoffs, producers who are risk averse would choose LH/ZT management from among the no-fungicide cropping systems at Saskatoon, and either LH/ZT or LH/LT management from among the fungicide treatments. This is because these cropping systems provide higher average annual net returns and the same or lower income variability compared to the others, or they provide lower average net returns but also lower risk.

Similarly, at Watrous, risk averse producers would choose LH/LT from among the no-fungicide treatments, and MH/ZT from among the fungicide treatments.

Conclusions

The results of the economic analysis support the use of the LH/ZT management method at Saskatoon and the LH/LT management method at Watrous when using a 4-year wheat-canola-barley-pea crop rotation. These cropping systems provided the highest net return and displayed the lowest income variability, despite not being the lowest cost production systems. The least profitable management method was typically NH/HT, in part because of the lower grain yields resulting from increased competition with weeds. Changes in grain prices had little impact on the most profitable cropping systems because the different management methods had only a small or no impact on grain yields or grain quality. The use of blanket applications of in-crop fungicide was not profitable for any management system at either test site, despite the positive yield responses of barley, wheat and pea to fungicide application. The maximum breakeven price that could be paid for the fungicide (i.e., its maximum economic value) under this method of application was estimated at about 25% to 33% of its current market cost.

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Table 1. Summary of management system variables.

	Seeding Rate				Fall				Burn Off				Incrop				Seeding Date			
	W	C	B	P	W	C	B	P	W	C	B	P	W	C	B	P	W	C	B	P
HH/ZT	1	1	1	1	2,4-D	2,4-D	2,4-D	2,4-D	yes	yes	yes	yes	yes	yes	yes	yes	mid	mid	early	early
MH/ZT	1	1	1	1	2,4-D	no	2,4-D	no	no	yes	no	yes	(2/3)	(2/3)	(1/2)	yes	early	mid	early	early
LH/ZT	1.5	1.5	1.5	1.3	2,4-D	no	2,4-D	no	no	yes	no	yes	(2/3)	no	no	yes	early	late	early	early
LH/LT	1.5	1	1.5	1	till	no	till	till	no	till	no	no	(2/3)	(2/3)	no	yes	early	mid	early	early
MH/MT	1	1	1	1	till	till	till	till	till	yes	till	yes	(2/3)	(2/3)	(1/2)	yes	mid	mid	early	early
NH/HT	1.5	1.5	1	1.3	till	till	till	till	till	till	till	till	p-e till	no	p-e till	p-e till	mid	late	early	early

Table 2. Summary of selected input costs and economic parameters

Input item	Cost				Units	
Fuel						
Diesel	0.61				$\$\ L^{-1}$	
Gasoline	0.65				$\$\ L^{-1}$	
Fertilizer						
N	0.59				$\$\ kg^{-1}$	
P_2O_5	0.71				$\$\ kg^{-1}$	
S	0.58				$\$\ kg^{-1}$	
Chemicals[1]						
2,4-D Ester 700	7.40				$\$\ L^{-1}$	
2,4-D Amine 600	6.15				$\$\ L^{-1}$	
Achieve Dg	157.70				$\$\ kg^{-1}$	
Achieve Extra Gold	54.75				$\$\ L^{-1}$	
Assure II	82.50				$\$\ L^{-1}$	
Attain	13.24				$\$\ L^{-1}$	
Basagran	29.05				$\$\ L^{-1}$	
Buctril M	15.95				$\$\ L^{-1}$	
Curtail	14.38				$\$\ L^{-1}$	
Dyvel	10.35				$\$\ L^{-1}$	
Furadan	33.40				$\$\ L^{-1}$	
Liberty	17.00				$\$\ L^{-1}$	
Lontrel	137.08				$\$\ L^{-1}$	
Loresban 4E	15.62				$\$\ L^{-1}$	
MCPA Ester	7.15				$\$\ L^{-1}$	
Muster	1.99				$\$\ g^{-1}$	
Odessey	1.51				$\$\ g^{-1}$	
Poast Ultra	80.51				$\$\ L^{-1}$	
Pursuit	260.44				$\$\ L^{-1}$	
Quadris	94.75				$\$\ L^{-1}$	
Refine Extras Toss & Go	0.70				$\$\ kg^{-1}$	
Round-Up	8.99				$\$\ L^{-1}$	
Round-Up Transorb	9.79				$\$\ L^{-1}$	
Sencor 500	43.06				$\$\ L^{-1}$	
Tropotox	11.50				$\$\ L^{-1}$	
Labor	9.00				$\$\ hr^{-1}$	
Interest	10.00				%	
Crop Insurance Premiums and Yield Guarantees	Saskatoon		Watrous			
Spring Wheat	2.94	1512	2.52	1346	$\$\ ha^{-1}$	$kg\ ha^{-1}$
Canola	3.88	863	3.76	756	$\$\ ha^{-1}$	$kg\ ha^{-1}$
Barley	3.66	1910	3.31	1735	$\$\ ha^{-1}$	$kg\ ha^{-1}$
Pea	3.95	1385	4.35	1302	$\$\ ha^{-1}$	$kg\ ha^{-1}$
Machine Operations	Cash Costs & Labor		Fixed Cost			
Heavy duty cultivator	5.40		4.93		$\$\ ha^{-1}$	
Field cultivator	5.05		4.50		$\$\ ha^{-1}$	
Heavy duty cultivator & harrow	6.12		5.42		$\$\ ha^{-1}$	
Tine harrow	2.82		2.44		$\$\ ha^{-1}$	
Sprayer	2.59		4.31		$\$\ ha^{-1}$	
Haul water	0.51		0.63		$\$\ ha^{-1}$	
Swath	6.21		14.92		$\$\ ha^{-1}$	
Grain transportation	2.72		2.42		$\$\ t^{-1}$	
Zero-till seeder	8.51		14.01		$\$\ ha^{-1}$	
Conventional hoedrill	8.18		12.26		$\$\ ha^{-1}$	
Combine	74.75		121.20		$\$\ hr^{-1}$	

[1] Costs for all herbicides are per L or kg of product.

Table 3. Production costs and economic returns ($ ha^{-1}) for integrated crop management systems at Saskatoon and Watrous for the base price assumptions (1997-2000)[1].

Location	Fungicide Application	Cost/Return Item	Integrated crop management system: HH/ZT	MH/ZT	LH/ZT	LH/LT	MH/MT	NH/HT
Saskatoon	No	Seed	38.19	37.77	46.48	41.48	37.77	47.98
		Fertilizer	56.46	56.46	56.46	56.46	56.46	56.46
		Chemicals	74.95	64.29	47.28	47.23	50.28	16.11
		Fuel & Oil	17.02	15.60	14.88	15.93	19.31	20.09
		Repairs	25.37	23.23	22.20	21.16	24.49	21.74
		Insurance	3.61	3.61	3.61	3.61	3.61	3.61
		Other[2]	26.42	25.78	25.70	24.69	25.42	23.63
		Interest	12.28	12.15	10.67	10.48	11.06	9.76
		Labor	10.02	8.98	8.41	8.05	9.64	8.85
		Machine Overhead	81.08	74.01	70.34	66.49	70.90	68.04
		Total Cost	345.40_a	321.88_b	306.03_c	295.58_c	314.94_b	276.27_d
		Gross Return	514.90_a	490.82_b	479.97_b	413.53_d	459.80_c	364.89_e
		Payout (Crop Insurance)	12.17	14.39	12.52	15.59	16.84	19.92
		Net Return (w/payout)	181.67_a	183.33_a	186.46_a	133.54_c	161.70_b	108.54_d
		CV(%)	75	62	44	50	59	97
Saskatoon	Yes	Seed	38.19	37.77	46.48	41.48	37.77	47.98
		Fertilizer	56.46	56.46	56.46	56.46	56.46	56.46
		Chemicals	124.10	113.44	96.43	96.38	99.47	65.26
		Fuel & Oil	18.40	16.89	16.27	17.20	20.94	21.45
		Repairs	27.38	25.11	24.24	22.96	26.93	23.74
		Insurance	3.61	3.61	3.61	3.61	3.61	3.61
		Other[2]	27.09	26.25	26.33	25.09	26.30	24.18
		Interest	15.26	15.04	13.32	13.10	13.77	12.40
		Labor	11.07	9.97	9.47	9.02	10.84	9.89
		Machine Overhead	87.86	80.42	77.21	72.82	84.45	74.80
		Total Cost	409.42_a	384.96_b	369.82_c	358.12_c	380.54_b	339.77_d
		Gross Return	536.24_a	494.86_b	505.00_b	428.66_c	495.05_b	391.57_d
		Payout (Crop Insurance)	12.06	14.18	11.76	14.17	16.43	17.95
		Net Return (w/payout)	138.88_{ab}	124.08_b	146.94_a	84.71_c	130.94_b	69.75_d
		CV(%)	102	78	47	39	84	145
Watrous	No	Seed	38.69	38.43	53.93	42.89	38.43	53.93
		Fertilizer	43.29	43.29	43.29	43.29	43.29	43.29
		Chemicals	76.36	52.56	42.50	42.93	47.99	18.49
		Fuel & Oil	14.51	13.36	12.31	15.06	17.38	18.11
		Repairs	21.14	19.46	17.91	19.10	20.99	19.40
		Insurance	3.49	3.49	3.49	3.49	3.49	3.49
		Other[2]	23.49	23.20	22.82	22.87	23.02	22.43
		Interest	11.22	10.23	10.25	9.95	10.24	9.32
		Labor	8.44	7.54	6.74	7.27	8.32	7.81
		Machine Overhead	67.02	61.23	55.97	58.74	64.89	59.14
		Total Cost	307.65_a	272.78_b	269.21_{bc}	265.59_{bc}	278.04_b	255.41_c
		Gross Return	380.37_a	357.55_b	338.27_c	350.75_b	350.56_b	315.33_d
		Payout (Crop Insurance)	2.22	4.39	5.14	5.34	6.21	10.36
		Net Return (w/payout)	74.94_{bc}	89.16_{ab}	74.20_{bc}	90.50_a	78.73_b	70.28_{bc}
		CV(%)	131	109	134	96	118	119

Watrous	Yes	Seed	38.69	38.43	53.93	42.89	38.43	53.93
		Fertilizer	43.29	43.29	43.29	43.29	43.29	43.29
		Chemicals	126.10	102.30	92.25	92.68	98.52	68.23
		Fuel & Oil	15.67	14.69	13.96	16.21	18.88	19.48
		Repairs	22.77	21.23	20.42	20.73	23.20	21.37
		Insurance	3.49	3.49	3.49	3.49	3.49	3.49
		Other[2]	23.79	23.48	23.52	23.06	23.63	22.87
		Interest	14.09	12.93	13.05	12.63	13.04	12.05
		Labor	9.36	8.51	7.94	8.19	9.45	8.85
		Machine Overhead	72.83	67.44	64.23	64.56	72.32	65.91
		Total Cost	370.08_{a}	335.79_{b}	336.08_{bc}	327.73_{bc}	344.25_{b}	319.47_{c}
		Gross Return	390.72_{a}	383.87_{a}	365.87_{b}	344.33_{c}	382.70_{a}	323.37_{d}
		Payout (Crop Insurance)	2.07	4.47	3.17	3.53	3.31	7.45
		Net Return (w/payout)	22.71_{bc}	52.55_{a}	32.96_{b}	20.13_{c}	41.76_{ab}	11.35_{d}
		CV(%)	364	118	252	414	175	445

1 Means within a row followed by the same letter are not significantly different at P<0.10.

2 Other includes land taxes and miscellaneous costs.

Table 4. Production costs and economic returns for individual crops and management methods at Saskatoon (1997-2000).

Crop	Management System	Fungicide Application	Fertilizer	Chemicals	Machine Operation	Labor	Total Cost	Average Cost	Breakeven Yield	Gross Return	Net Return
			($ ha^{-1})					($ t^{-1})	(kg $ha^{-1)}$	($ ha^{-1})	
Wheat	HH/ZT	No	61.08	60.00	104.43	9.39	296.32	99.94	1712	544.35	248.04
	MH/ZT	No	61.08	43.92	90.94	]8.00	263.04	98.92	1505	492.46	230.23
	LH/ZT	No	61.08	44.42	92.51	8.14	273.76	98.19	1611	497.22	223.46
	LH/LT	No	61.08	35.33	89.63	7.73	259.91	103.35	1469	472.37	212.53
	MH/MT	No	61.08	30.93	103.38	9.02	263.34	97.06	1595	473.80	210.45
	NH/HT	No	61.08	18.76	95.34	8.46	247.72	118.10	1440	390.40	146.39
	LSD (P<0.10)						8			28	25
	HH/ZT	Yes	61.08	107.38	114.03	10.41	357.65	115.16	2162	556.03	198.98
	MH/ZT	Yes	61.08	91.30	106.36	9.56	331.85	109.64	1914	570.90	239.04
	LH/ZT	Yes	61.08	91.80	102.51	9.21	335.38	113.59	1952	528.90	193.52
	LH/LT	Yes	61.08	82.70	98.34	8.67	319.82	122.95	1788	495.49	175.67
	MH/MT	Yes	61.08	78.31	115.78	10.30	328.14	110.06	1959	529.02	200.87
	NH/HT	Yes	61.08	66.14	105.90	9.58	310.07	139.43	1816	416.96	110.91
	LSD (P<0.10)						9			33	28
Canola	HH/ZT	No	77.26	102.72	103.54	7.66	366.64	249.56[1]	1135[1]	444.00	126.05
	MH/ZT	No	77.26	79.46	91.41	6.50	326.33	296.08	1010	397.58	127.98
	LH/ZT	No	77.26	32.35	79.44	5.35	264.70	201.83	819	352.69	138.09
	LH/LT	No	77.26	48.63	76.18	5.15	275.30	347.12	852	288.92	75.89
	MH/MT	No	77.26	74.50	95.82	6.98	325.72	418.67	1008	359.26	100.92
	NH/HT	No	77.26	11.82	86.37	6.13	249.85	307.61	773	242.36	61.11
	LSD (P<0.10)						9			34	28
	HH/ZT	Yes	77.26	138.25	110.92	8.41	412.46	276.71[1]	1277[1]	462.55	98.35
	MH/ZT	Yes	77.26	114.99	95.70	7.02	368.43	371.62	1140	386.92	75.21
	LH/ZT	Yes	77.26	67.88	84.46	5.93	307.67	239.77	952	348.95	88.31
	LH/LT	Yes	77.26	84.16	83.46	5.89	321.01	333.80	994	306.54	42.23
	MH/MT	Yes	77.26	110.16	100.60	7.66	368.90	460.87	1142	369.77	66.60
	NH/HT	Yes	77.26	47.36	91.62	6.72	293.09	357.69	907	240.66	10.44
	LSD (P<0.10)						9			33	29
Barley	HH/ZT	No	57.48	48.98	114.80	10.51	291.11	75.19	2646	481.01	189.90
	MH/ZT	No	57.48	26.04	105.30	9.45	256.12	66.65	2078	512.14	256.02
	LH/ZT	No	57.48	17.54	97.24	8.56	245.86	63.57	1997	505.92	260.06
	LH/LT	No	57.48	12.04	94.54	8.18	235.71	66.19	2358	383.14	147.44
	MH/MT	No	57.48	22.87	114.76	10.25	262.14	73.98	2302	441.90	179.76
	NH/HT	No	57.48	12.04	104.82	9.46	245.97	85.83	2449	349.18	110.59
	LSD (P<0.10)						9			33	29
	HH/ZT	Yes	57.48	96.36	130.27	12.05	360.10	84.04	3270	538.66	178.56
	MH/ZT	Yes	57.48	73.38	112.46	10.25	313.97	83.15	2896	443.41	129.44
	LH/ZT	Yes	57.48	64.91	111.79	10.06	313.66	73.55	2548	559.21	245.55
	LH/LT	Yes	57.48	59.42	104.24	9.23	296.98	80.81	3030	378.41	81.43
	MH/MT	Yes	57.48	70.24	129.35	11.76	330.00	86.04	2977	482.82	152.82
	NH/HT	Yes	57.48	59.42	116.86	10.72	310.39	100.35	2829	409.31	103.82
	LSD (P<0.10)						9			25	19
Pea	HH/ZT	No	30.01	88.11	171.13	12.54	427.54	131.54	2431	590.23	162.69
	MH/ZT	No	30.01	107.78	163.75	11.95	442.01	145.27	2513	561.08	119.08
	LH/ZT	No	30.01	94.81	160.46	11.57	439.71	149.32	2500	564.04	124.34
	LH/LT	No	30.01	92.92	153.80	11.14	411.19	144.78	2338	509.66	98.48
	MH/MT	No	30.01	72.84	168.86	12.33	408.57	129.73	2323	564.24	155.67
	NH/HT	No	30.01	21.80	152.97	11.36	361.51	140.47	2055	477.61	116.10
	LSD (P<0.10)						18			34	24

HH/ZT	Yes	30.01	154.43	179.31	13.41	507.41	158.31	2885	587.14	79.74
MH/ZT	Yes	30.01	174.11	175.16	13.06	525.59	167.18	2988	578.20	52.61
LH/ZT	Yes	30.01	161.13	172.10	12.68	522.53	167.20	2971	582.96	60.43
LH/LT	Yes	30.01	159.24	165.86	12.28	494.61	166.83	2812	534.18	39.57
MH/MT	Yes	30.01	139.16	183.54	13.66	495.06	148.03	2814	598.59	103.52
NH/HT	Yes	30.01	88.12	165.60	12.55	445.48	165.34	2533	499.34	53.85
LSD (P<0.10)						16			30	22

[1] Excludes 1998.

Table 5. Production costs and economic returns for individual crops and management methods at Watrous (1997-2000).

Crop	Management System	Fungicide Application	Fertilizer	Chemicals	Machine Operation	Labor	Total Cost	Average Cost	Breakeven Yield	Gross Return	Net Return
			------------------------($ ha^{-1})------------------------					($ t^{-1})	(kg ha^{-1})	-------($ ha^{-1})--------	
Wheat	HH/ZT	No	44.84	80.80	86.48	7.82	277.00	133.12	1866	331.53	55.18
	MH/ZT	No	44.84	49.60	78.86	6.90	235.60	115.80	1632	314.13	79.46
	LH/ZT	No	44.84	48.67	73.33	6.36	238.42	140.95	1801	279.86	47.99
	LH/LT	No	44.84	47.47	78.64	6.74	242.97	136.04	1785	290.71	51.91
	MH/MT	No	44.84	43.36	94.64	8.20	246.76	116.03	1646	346.72	101.09
	NH/HT	No	44.84	22.25	85.77	7.53	224.79	115.35	1493	301.40	76.61
	LSD (P<0.10)						9			26	21
	HH/ZT	Yes	44.84	128.18	99.31	9.07	342.32	141.24	2601	343.70	1.38
	MH/ZT	Yes	44.84	96.97	89.81	8.05	298.47	134.30	2056	346.82	48.35
	LH/ZT	Yes	44.84	96.04	86.81	7.74	304.67	140.14	2549	295.54	-9.13
	LH/LT	Yes	44.84	94.84	87.42	7.69	302.97	160.64	2426	278.98	-21.54
	MH/MT	Yes	44.84	90.73	105.23	9.32	309.16	135.19	2062	372.56	64.33
	NH/HT	Yes	44.84	69.62	98.86	8.88	290.51	128.88	1906	352.91	62.40
	LSD (P<0.10)						9			30	25
Canola	HH/ZT	No	61.95	118.81	90.31	7.17	353.36	275.74	1094	431.50	78.14
	MH/ZT	No	61.95	59.54	77.89	6.06	275.41	269.62	852	365.27	95.61
	LH/ZT	No	61.95	30.69	65.34	4.72	251.55	250.29	779	349.12	100.54
	LH/LT	No	61.95	45.42	74.34	5.58	256.17	261.21	793	334.18	82.53
	MH/MT	No	61.95	57.14	81.11	6.35	276.10	407.81	855	329.81	70.34
	NH/HT	No	61.95	15.91	70.58	5.23	241.04	379.93	746	266.94	55.09
	LSD (P<0.10)						10			40	31
	HH/ZT	Yes	61.95	166.19	98.63	8.05	412.62	326.94	1277	441.80	31.31
	MH/ZT	Yes	61.95	106.91	86.24	6.78	334.21	349.85	1034	353.96	29.26
	LH/ZT	Yes	61.95	78.06	73.73	5.61	310.88	307.24	962	360.02	54.08
	LH/LT	Yes	61.95	92.80	84.42	6.59	317.56	296.68	983	361.23	45.93
	MH/MT	Yes	61.95	104.51	92.27	7.45	338.80	341.59	1049	367.19	36.90
	NH/HT	Yes	61.95	63.28	78.49	6.09	299.79	440.16	928	273.40	-2.66
	LSD (P<0.10)						9			38	30
Barley	HH/ZT	No	46.69	46.10	90.87	8.25	249.88	110.33	2433	292.87	57.24
	MH/ZT	No	46.69	26.16	84.50	7.56	215.63	101.80	2145	289.11	84.35
	LH/ZT	No	46.69	26.52	76.04	6.63	213.85	107.04	2139	276.58	73.77
	LH/LT	No	46.69	18.70	80.49	6.89	210.78	105.79	1888	325.11	127.01
	MH/MT	No	46.69	19.67	94.92	8.32	219.84	103.05	2189	278.28	65.54
	NH/HT	No	46.69	12.04	90.32	8.12	214.88	104.14	2140	267.73	65.10
	LSD (P<0.10)						9			21	15
	HH/ZT	Yes	46.69	93.47	98.72	9.12	302.67	127.17	2762	320.00	23.12
	MH/ZT	Yes	46.69	73.53	91.32	8.33	273.03	124.70	2211	346.39	81.72
	LH/ZT	Yes	46.69	73.90	83.98	7.51	272.74	125.62	2509	302.50	37.52
	LH/LT	Yes	46.69	66.08	87.91	7.72	268.97	125.42	2705	280.13	20.58
	MH/MT	Yes	46.69	67.05	106.21	9.52	283.24	114.73	2595	324.20	44.68
	NH/HT	Yes	46.69	59.42	97.43	8.92	272.66	123.12	3029	218.77	-47.82
	LSD (P<0.10)						10			23	16
Pea	HH/ZT	No	19.69	59.72	143.00	10.52	356.28	143.92	2025	465.56	109.28
	MH/ZT	No	19.69	74.94	134.92	9.65	364.47	145.63	2072	461.68	97.22
	LH/ZT	No	19.69	64.14	130.02	9.24	372.98	152.11	2120	447.53	74.55
	LH/LT	No	19.69	60.14	138.14	9.88	352.48	140.16	2004	453.01	100.53
	MH/MT	No	19.69	71.81	142.37	10.41	369.44	150.96	2100	447.45	78.01
	NH/HT	No	19.69	23.76	139.95	10.36	340.93	148.62	1938	425.25	84.31
	LSD (P<0.10)						9			33	24

HH/ZT	Yes	19.69	116.57	148.44	11.21	422.73	175.32	2403	457.39	35.05
MH/ZT	Yes	19.69	131.79	146.11	10.87	437.45	164.56	2487	488.31	50.86
LH/ZT	Yes	19.69	120.99	149.91	10.92	455.99	162.73	2592	505.42	49.43
LH/LT	Yes	19.69	116.99	146.26	10.75	421.43	168.92	2396	456.97	35.53
MH/MT	Yes	19.69	131.79	153.87	11.51	445.71	174.07	2534	466.95	21.23
NH/HT	Yes	19.69	80.61	152.25	11.53	414.87	167.97	2359	448.39	33.52
LSD (P<0.10)						12			46	34

Table 6. Effect of changes in grain price on net returns ($\$$ ha^{-1}) for the integrated crop management systems at Saskatoon and Watrous (1997-2000).

Location	Management System	Fungicide Application	Base Prices[1]	Low Prices[2]	High Prices[3]	Low Wheat[4]	High Wheat[5]	Low Canola[6]	High Canola[7]	Low Barley[8]	High Barley[9]	Low Pea[10]	High Pea[11]
Saskatoon	HH/ZT	No	182	87	276	158	205	161	203	152	211	161	202
	MH/ZT	No	183	94	272	162	204	164	202	154	213	164	203
	LH/ZT	No	187	99	274	165	208	170	203	157	216	167	206
	LH/LT	No	134	56	211	114	154	120	147	108	160	116	151
	MH/MT	No	162	76	247	140	184	145	179	135	189	142	181
	NH/HT	No	109	40	177	92	126	97	120	85	132	92	125
	LSD (P<0.10)		12	10	15	12	12	11	13	12	13	11	13
	HH/ZT	Yes	139	38	240	113	164	117	160	106	172	119	159
	MH/ZT	Yes	124	33	216	100	148	106	142	95	153	104	144
	LH/ZT	Yes	147	55	239	124	170	130	163	114	180	127	167
	LH/LT	Yes	85	5	165	64	105	70	99	58	111	66	103
	MH/MT	Yes	131	39	223	107	155	113	149	101	161	110	152
	NH/HT	Yes	70	-3	142	51	88	58	81	44	95	53	87
	LSD (P<0.10)		12	9	14	11	13	11	13	12	12	11	12
Watrous	HH/ZT	No	75	3	147	58	92	54	95	56	94	59	91
	MH/ZT	No	89	21	158	73	106	72	106	70	108	73	105
	LH/ZT	No	74	9	139	60	89	58	91	56	92	59	90
	LH/LT	No	91	25	156	76	105	75	106	71	110	75	106
	MH/MT	No	79	12	145	62	96	63	94	61	97	63	94
	NH/HT	No	70	10	130	55	86	58	83	53	88	56	85
	LSD (P<0.10)		10	8	13	10	11	10	12	10	11	10	11
	HH/ZT	Yes	23	-52	98	4	41	2	44	3	42	7	38
	MH/ZT	Yes	53	-18	124	35	71	36	69	33	72	36	69
	LH/ZT	Yes	33	-37	103	16	50	16	50	14	52	16	50
	LH/LT	Yes	20	-46	87	5	35	3	37	1	39	4	36
	MH/MT	Yes	42	-30	114	23	60	24	59	22	62	26	58
	NH/HT	Yes	11	-52	74	-6	29	-2	24	-6	28	-4	27
	LSD (P<0.10)		13	11	16	13	14	12	14	13	13	12	14

[1] Base prices: wheat = $\$144\ t^{-1}$, canola = $\$323\ t^{-1}$, barley = $\$140\ t^{-1}$, and pea = $\$176\ t^{-1}$.
[2] Low prices: wheat = $\$114\ t^{-1}$, canola = $\$262\ t^{-1}$, barley = $\$110\ t^{-1}$, and pea = $\$152\ t^{-1}$.
[3] High prices: wheat = $\$174\ t^{-1}$, canola = $\$384\ t^{-1}$, barley = $\$170\ t^{-1}$, and pea = $\$200\ t^{-1}$.
[4] Low wheat: wheat = $\$114\ t^{-1}$, all other grains held at base prices.
[5] High wheat: wheat = $\$174\ t^{-1}$, all other grains held at base prices.
[6] Low canola: canola = $\$262\ t^{-1}$, all other grains held at base prices.
[7] High canola: canola = $\$384\ t^{-1}$, all other grains held at base prices.
[8] Low barley: barley = $\$110\ t^{-1}$, all other grains held at base prices.
[9] High barley: barley = $\$170\ t^{-1}$, all other grains held at base prices.
[10] Low pea: Pea = $\$152\ t^{-1}$, all other grains held at base prices.
[11] High pea: Pea = $\$200\ t^{-1}$, all other grains held at base prices.

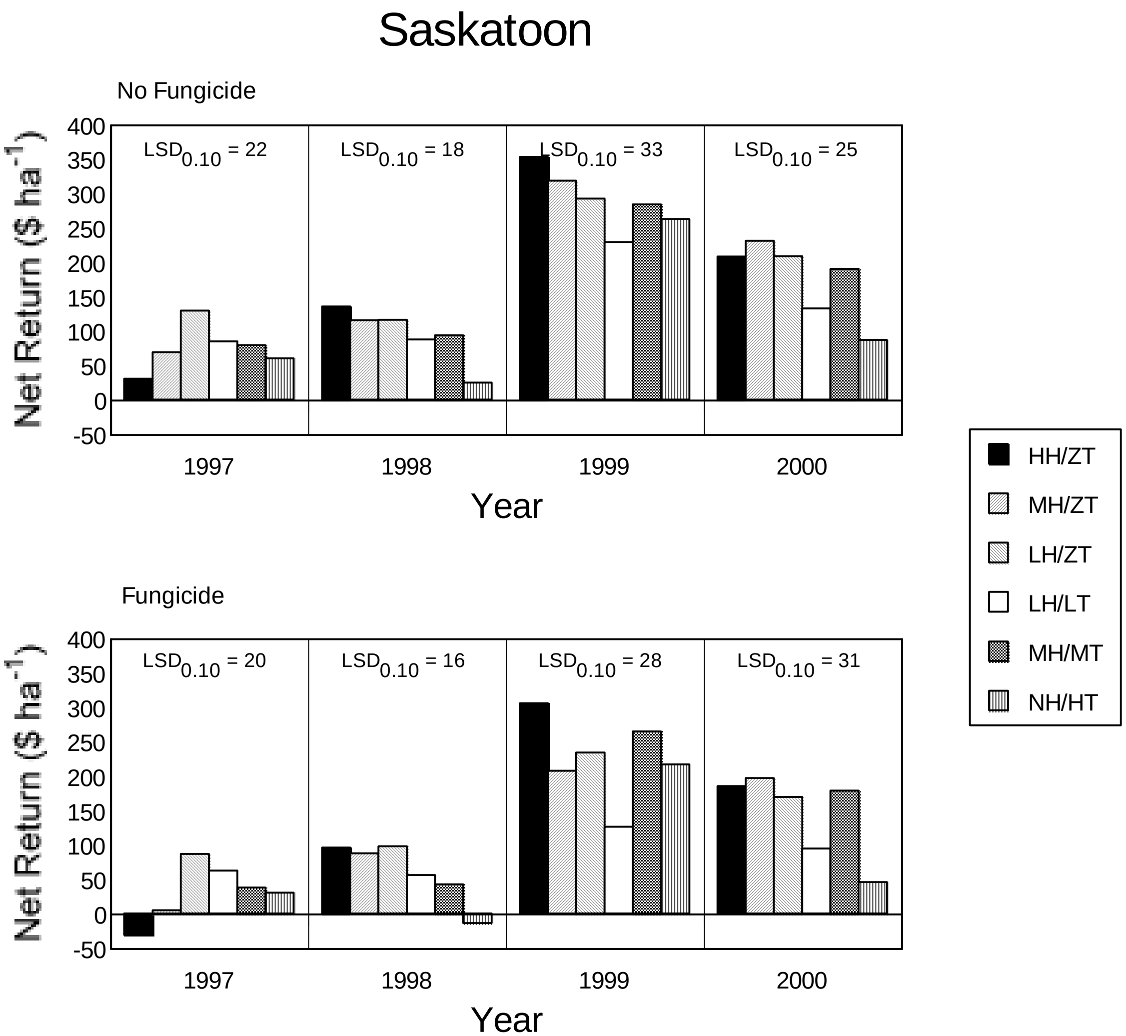

Figure 1. Annual net returns for integrated crop management systems at Saskatoon.

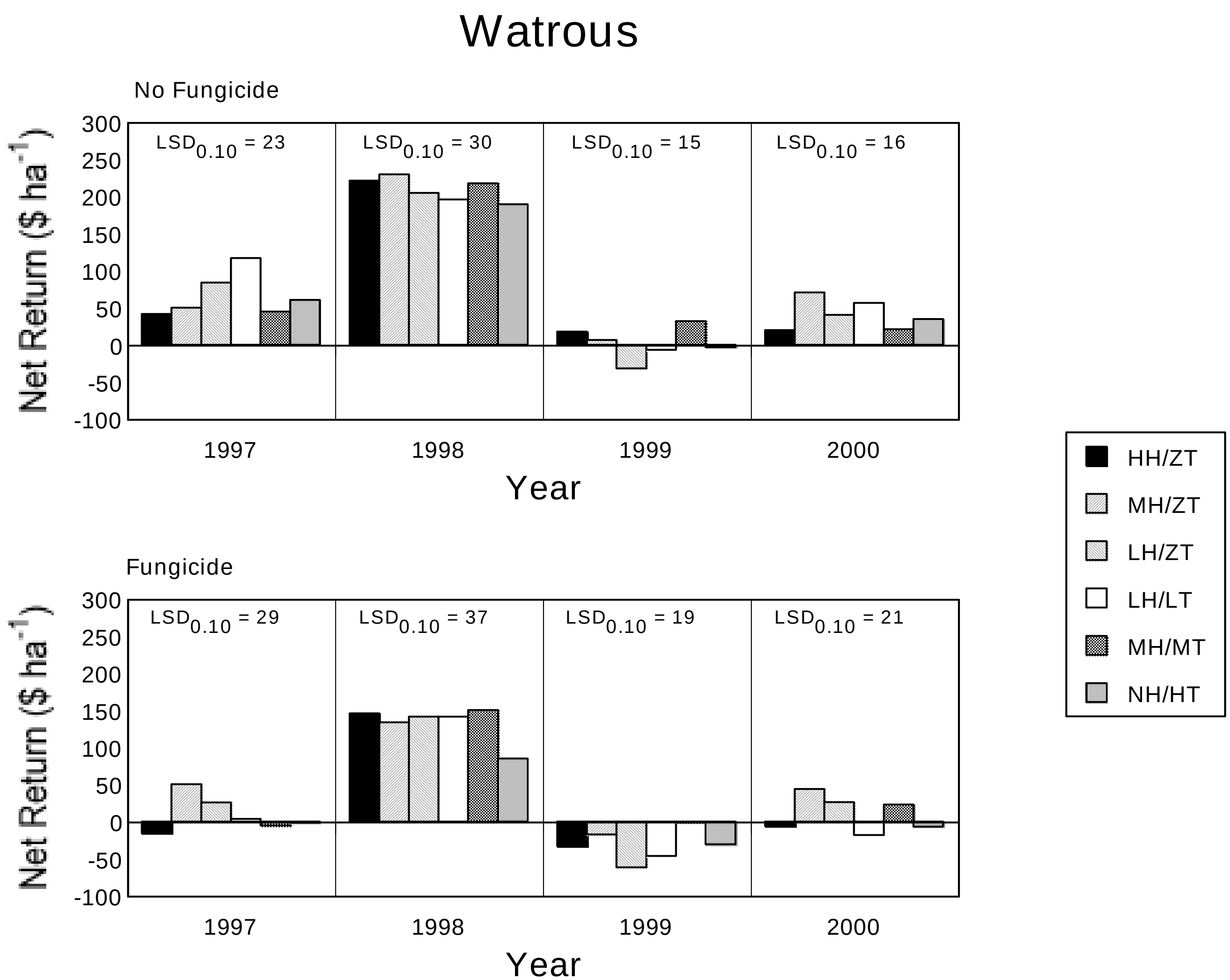

Figure 2. Annual net returns for integrated crop management systems at Watrous.