The economics of cultivation vs. herbicides vs. mulch control and cultivation under different tillage systems

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Summary The effects of weed control system and tillage system and their interactions on okra and wheat yields were investigated. Weed control systems were chemical herbicides only (CH), chemical herbicides and mechanical cultivation (CHMC), mulch control and mechanical cultivation (MMC), and mechanical cultivation only (MC). Tillage systems were blade ploughing as primary tillage followed by disc harrow as secondary tillage, disk ploughing as primary tillage followed by rotary tiller as secondary tillage, and no tillage. The average okra and wheat yields for three years for each of the four weed management systems under the three tillage systems were analysed and reported. Based on results from field tests, it was found that weed control method affected okra and wheat yields. MMC gave the highest okra and wheat yields. It was found that no tillage produced higher yields than blade and disk tillage systems. Percentage increases in yield between 4% to 32% were obtained with no tillage treatments compared to the other two tillage systems. The results of this analysis showed that MC with no tillage practice was the alternative with the lowest machinery investment and total machinery and labour costs per hectare per year, followed by blade tillage and finally disk tillage.
Keywords Weed control, tillage system, chemical herbicides, mechanical cultivation, plastic mulch.

INTRODUCTION

The control of weeds has always been one of the greatest time – and labour – consuming operations in the production of crops. In addition to requiring extensive control measures, weeds share crop plants available nutrients and water, often serve as hosts to insects and other pests, and create equipment problems, especially in harvesting and processing of certain crops.

In the early growth stages of some crops, implements such as the duck foot cultivator can be operated directly between the rows to uproot small weed seedlings. Chemical herbicides are widely used for weed control at various stages of crop planting and growth. Crop quality and yields have been improved and the use of chemical herbicides has greatly reduced labour requirements for weed control.

Properly timed cultivation can control early germinating, annual broadleaf and grass weeds (Callihan and Bellinder 1993) and may be less expensive than using herbicides for weed control (Chitsaz and Nelson 1983). Furthermore, cultivation may aerate and improve structure of some soils, especially those high in silt and very fine sand (Chitsaz and Nelson 1983). Good weed control usually involves a combination of the available methods plus timeliness and good farming. Abu-Hamdeh and Abu-Qudais (2001) investigated the effects of four weed management systems and other factors on *Pisum sativum* (pea) and *Lactuca sativa* (lettuce) yields. They found that mechanical cultivation between the rows and using plastic mulch to cover the rows gave the highest pea and lettuce yields.

The adoption of conservation-tillage production systems is increasing in the world because of savings in time and economic inputs and for soil conservation considerations. As tillage is decreased, weed control can become a limiting factor in crop production (Buhler 1992, Worsham and Lewis 1985). Changes in tillage practices can affect weed population dynamics, including weed seed distribution and abundance in the soil seedbank (Mulugeta and Stoltenberg 1997).

The objectives of this work were (1) to compare the economics and effectiveness of four systems of weed control under repeated three different three tillage systems in two crops; *Abelmoschus esculentus* (okra) and *Triticum aestivum* (wheat); and (2) to compare the effect of weed control on yields, in kg ha^{-1}, of *Abelmoschus esculentus* (okra) and *Triticum aestivum* (wheat).

MATERIALS AND METHODS

Experimental design This research study was conducted on a sandy loam soil (55% sand, 23% silt, 22% clay). The experiments were repeated three times in two years with two replicates each time and average results were reported. Each experiment consisted of twelve combinations of weed control and tillage systems. Each test plot was 5 m wide and 9 m long. The field had not been cultivated or cropped for years prior to this study. All experimental areas received primary tillage and secondary tillage followed by bed preparation as usually practised by local farmers in the region.

All plots were planted with *Abelmoschus esculentus* (okra) and *Triticum aestivum* (wheat) with all rows of each plot being harvested for yield. Machines and chemical costs for each crop were estimated. Analysis of yield data was accomplished using the MINITAB computer package.

Field operations All tillage operations were conducted in November as soon as field conditions permitted. The primary tillage operations consisted of disk ploughing 20 cm deep using a semi mounted four-bottom disk plough fitted with 60 cm diameter blades and blade ploughing at a depth of 20 cm using a 200 cm implement with seven V-blade shanks. The secondary tillage operations consisted of rotary tiller in the plots that received disk primary tillage using a 230 cm wide powered tiller equipped with 10 blade–rotors on a 22 cm spacing. The plots received blade primary tillage were secondary tilled using a 237 cm wide mounted tandem disc harrow fitted with 41 mm diameter blades at 20 cm spacing.

The okra was hand-planted at 58,000 seeds ha^{-1} without fertiliser or insecticide at a row spacing of 50 cm. Next, wheat was planted in rows spaced 50 cm apart using a 300 cm wide seed drill and the seeding rate was 110 kg ha^{-1}.

Herbicide spraying was carried out as planned in the experimental design, however each chemically treated plot was treated with the same chemicals even if infestations occurred in only a few plots. Fluazifop-P-butyl (Fusilladed Super), an experimental herbicide that contains 0.125 kg of fluazifop-P-butyl per litre, was applied later in the growing season of each year to control *Echinochloa crus-galli* (barnyard grass). The average weather conditions were temperature 16°C, wind at 7 km h^{-1}, relative humidity 69%. The same experimental herbicide was applied another time early in spring of each year to control this weed. Mechanical cultivation at a depth of approximately 10 cm was carried out twice using a 205 cm wide duck foot chisel cultivator with five curved shanks, 23.4 cm wide tines in the mechanical weed control treatments. All tillage and weed control (chemical and/or mechanical) operations were performed by an 80 kW (two-wheel drive) Kubota M8030 tractor weighing 5 tonnes.

The amount of okra and wheat collected from each test plot were weighed separately for yield comparisons and analysis. The ANOVA was used at a probability level of 5% to examine if there is any significant effects for weed control system and/or tillage system on crop yield.

Economic comparisons Costs of all field operations were calculated in US dollars during the growing season. The analysis of the four weed control systems in terms of plastic mulch cost and in terms of net cost of machinery investment and annual fixed, operating and total machinery and labour costs for tillage and weed control was performed. Chemical costs were actual costs and the machine costs were estimated from standard fixed cost and repair cost data (Bowers 1992), assuming maximum machine life. Machine costs were based on current list prices of machinery. Fuel was estimated at \$0.15 L^{-1} and lubrication costs were assumed to be 10% of fuel costs. Labour was valued at \$5.00 h^{-1}. Work rates in hectares per hour for any machine or equipment were calculated by accurate reading and recording of time periods and travel speeds to accomplish all field operations. The economic analysis was performed using the equations in Bowers (1992).

RESULTS AND DISCUSSION

Crop yields Table 1 shows the average yield for three years under different treatment combinations for okra and wheat. Least square means of crops yield for each treatment combination were statistically analysed to determine crop response, in terms of yield, to the management parameters. The ANOVA test was used for the statistical analysis. Both the main effects and interaction effects between the two management parameters on crop yield are summarised in Table 2 for okra and wheat. The most significant main effects of weed control and tillage system are discussed individually.

Effect of weed management The ANOVA test showed that there was a significant difference in okra and wheat yields between the factors investigated (Table 2). Average okra and wheat yields are different for different weed control methods under the same tillage system. MMC consistently gives higher yields of okra than other weed control methods under all tillage systems. Plastic mulch saves moisture, prevents evaporation, and suppresses weeds growth. CH treatments in the disk-ploughed plots generally gives the second highest okra yield. This is because of the uniform and complete coverage of chemicals across the rows and inter-row weeds. Yield for the CHMC method is slightly higher than yield of the MC under disk ploughing. This is because of treating the inter-row weeds in the case of the CHMC method. This is similar to the results obtained under blade ploughing. It seems that MMC constitutes the best weed control method for okra. CHMC in wheat did improve yields over MC alone (Table 1).

Effect of tillage system Overall, the yield of okra and wheat crops in the no tillage plots are higher than in the disk and blade tillage plots (Table 1). Average okra yield in the no tillage treatment is 10% higher than in the disk-ploughed plots and 29% higher than in the blade-ploughed plots. The differences in yield between

Table 1. Mean okra and wheat yields in kg ha^{-1} by type of weed control system for the three tillage systems.

	Yield of okra (kg ha^{-1})			Yield of wheat (kg ha^{-1})		
Weed control system	Disk ploughing	Blade ploughing	No tillage	Disk ploughing	Blade ploughing	No tillage
MC	762.4	599.9	791.7	6586.2	5740.7	7179.9
CH	1124.3	879.1	1247.3	10,873.6	10,460.5	11,846.9
CHMC	782.9	643.6	948.5	7599.2	6700.8	8601.5
MMC	1349.2	1054.9	1496.7	13,592.0	13,075.7	14,808.7
Overall average	1004.7	794.4	1121.1	9662.8	8994.4	10,609.3

Table 2. Analysis of variance of okra and wheat yields.

	Okra		Wheat	
Source	*F*	P-value	*F*	P-value
Weed	31.72	0.001		0.000
Tillage	12.33	0.004	56.72	0.000
Weed by tillage	11.98	0.004	64.54	0.000

Table 3. Calculated machine and chemical total costs per hectare for okra.

	System cost, \$ ha^{-1}											
	Mechanical cultivation only			Chemical herbicides only			Cultivation plus banded herbicides			Cultivation plus mulch		
Operation and input	Disk	Blade	No tillage	Disk	Blade	No tillage	Disk	Blade	No tillage	Disk	Blade	No tillage
Primary tillage	176.85	163.43	–	176.85	163.43	–	176.85	163.43	–	176.85	163.43	–
Secondary tillage	198.64	123.42	–	198.64	123.42	–	198.64	123.42	–	198.64	123.42	–
Weeding	123.10	124.85	126.10	–	–	–	125.99	127.00	125.01	125.01	124.98	125.34
Spraying	–	–	–	273.35	272.80	273.11	386.88	385.86	385.56	–	–	–
Chemicals	–	–	–	438.30	438.30	438.30	218.61	218.61	218.61	–	–	–
Mulching	–	–	–	–	–	–	–	–	–	792.75	792.75	792.75
Total	498.59	411.70	126.10	1087.14	997.95	711.41	1106.97	1018.32	729.18	1293.25	1204.58	918.09

disk-ploughed and blade-ploughed plots are small. The same trend is seen for wheat yields (Table 1). Hence, in addition of being a viable economic alternative, no tillage gives higher yields than other tillage systems. Tillage treatments are expected to affect soil response and crop yield. Tillage and vehicle traffic change the equivalent diameters of soil macropores, i.e. change soil porosity. Macropore continuity is probably more important than volume or number in determining fluid flow. For example, Douglas *et al.* (1980) showed that although the volume of macropores was greater in ploughed soil than in no tillage soil, infiltration of a tracer solution was slower in the ploughed soil because of limited pore continuity. Also, there is a good soil-seed contact for germination and moisture conservation with no tillage.

Economic analysis The calculated machine and chemical costs for okra are shown in Table 3 and those for wheat in Table 4. The results for okra show that MC consistently has the lowest total costs per hectare per year under all tillage systems used in this study but with lower yields in comparison with other control systems because of the inter-row weeds. CH always has the second lowest costs per hectare followed by CHMC, and finally MMC has the highest costs per hectare. Under blade ploughing for okra, MC has an annual machinery and labour cost advantage of over \$586 ha^{-1} compared with CH, almost \$606 ha^{-1} compared with CHMC, and \$792 ha^{-1} compared with MMC (Table 3). Less equipment and materials are necessary in MC than in other weed control systems. These differences between MC and other weed control

Table 4. Calculated machine and chemical total costs per hectare for wheat.

Operation and input	System cost, $ ha^{-1}											
	Mechanical cultivation only			Chemical herbicides only			Cultivation plus banded herbicides			Cultivation plus mulch		
	Disk	Blade	No tillage	Disk	Blade	No tillage	Disk	Blade	No tillage	Disk	Blade	No tillage
Primary tillage	176.85	163.43	–	176.85	163.43	–	176.85	163.43	–	176.85	163.43	–
Secondary tillage	198.64	123.42	–	198.64	123.42	–	198.64	123.42	–	198.64	123.42	–
Weeding	126.20	126.10	124.99	–	–	–	124.13	126.83	128.26	123.98	125.73	125.09
Spraying	–	–	–	272.61	272.10	274.64	386.20	385.61	385.97	–	–	–
Chemicals	–	–	–	438.30	438.30	438.30	218.61	218.61	218.61	–	–	–
Mulching	–	–	–	–	–	–	–	–	–	792.75	792.75	792.75
Planting	225.81	227.72	227.63	225.42	228.39	226.62	227.27	227.39	227.12	226.53	227.13	227.01
Harvesting	450.00	451.31	452.24	451.27	452.23	450.77	452.52	451.73	454.44	452.32	453.98	454.03
Total	1177.50	1091.98	804.86	1763.09	1677.87	1390.33	1784.22	1697.02	1414.40	1971.07	1886.44	1598.88

methods under blade ploughing are less than the differences obtained with no tillage and disk ploughing. The only exception is the difference between the total costs of MC and total costs of CH that was almost the same under all tillage systems. Since no tillage is cheaper than ploughing because less equipment is necessary, it has the lowest total costs for all weed controls compared to other tillage systems, followed by the blade ploughing treatment and then by the disk ploughing treatment. MC under no tillage has total annual costs of $126 ha^{-1} while it was $411 ha^{-1} under blade ploughing and $498 ha^{-1} under the disk ploughing treatment.

The cost analysis for wheat shows that MC consistently has the lowest total costs per hectare per year under all tillage systems used in this study, followed by CH, then CHMC and finally MMC which has the highest costs per hectare (Table 4). The results of this analysis show that MC with no tillage is the alternative with the lowest machinery investment and total machinery and labour costs per hectare per year, followed by blade ploughing and finally disk ploughing. Hence, this comparison shows no tillage to be a viable economical alternative for Jordan farms.

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