QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES
DIVISION OF PLANT INDUSTRY BULLETIN No. 857

Effects of chemical and mechanical management of fallow land on soil moisture accumulation and yield of wheat

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Summary

The effects of chemical weed control and conventional cultivation on fallow land were investigated over 4 years at a fixed site on alluvial clay soil in central Queensland. The mean yield of wheat grain following chemical weed control was 3 193 kg ha^{-1}, an increase of about 7% over the yield following cultivation. The increase in yield was significant in 3 years but the profile soil moisture content at planting time was significantly greater in only one of those years. There was no yield response to the addition of nitrogen fertilizer.

1. Introduction

Wheat is grown in Queensland as a winter crop, usually being sown in May or June and harvested during the following October or November. The rainfall has a seasonal distribution with the heaviest falls during the summer months, therefore the crop depends for much of its requirements on moisture stored in the subsoil during the summer fallow period (George 1949; Clydesdale and Miles 1950; Gill *et al.* 1970). Efficient storage of moisture requires suppression of weed growth which is traditionally achieved by cultivation.

The implements commonly used to control weeds in fallows bury the residue from the previous crop and this may result in reduced infiltration and increased evaporation of moisture (Jacks *et al.* 1955). Water drains to the subsoil through the cracks which develop on drying in some types of clay soil and cultivation may restrict this process by sealing the cracks at the surface (Bott and Douglas 1975).

Several authors including Pearce (1977) and Rowell *et al.* (1977) have recorded the successful substitution of herbicides for cultivation to control weeds in fallows and in studies involving soil moisture determinations, the practice generally showed better storage of moisture than conventional methods (Barnes *et al.* 1955; Unger 1977).

In the Callide and Dawson valleys of central Queensland the quantity of rainfall during the fallow period is sometimes too low to allow sufficient storage of moisture in the soil to grow a wheat crop (Gill *et al.* 1970). Were the efficiency of moisture storage to be improved by the substitution of chemical weed control for cultivation of fallow land, wheat production might become more reliable.

The purpose of the experiment reported here was to compare the effects of chemical weed control and conventional cultivation of fallow land on soil moisture accumulation and yield of grain under a system of wheat monoculture.

2. Methods

The experiment was located at Biloela Research Station, latitude 24°22′S, longitude 150°31′E on a very dark greyish-brown cracking clay alluvial soil classified as Ug 5.15 (Northcote 1965). The area grew wheat during the winter before commencement of the experiment.

The experimental design was a 2 x 2 factorial with two fallow management treatments (conventional cultivation and chemical weed control) and two levels of nitrogen applied to the wheat crops (nil, and nitrogen as urea at 30 kg N ha^{-1}). Greenwood *et al.* (1970) showed that a crop grown after chemical fallow may be affected by nitrogen deficiency. The plots measured 24 m x 8 m and there were five replicates. The experiment was repeated at the same site and with the same design for 4 consecutive years. Throughout this paper a designated year refers to the wheat crop of that year and the preceding fallow period. The dates of planting and harvest in each year together with the rainfall received during the fallow and crop periods are given in table 1.

Conventional cultivation consisted of an initial ploughing to a depth of 20 cm using a reversible disc plough followed by sufficient working with disc or tine implements to control weeds and develop a seedbed. Chemical control of weeds in the fallow was achieved mainly by spraying with paraquat or a mixture of paraquat and diquat. On some occasions amitrole, MSMA, 2,4-D and 2,2-DPA were also used. Compaction of the sprayed plots was avoided by mounting the spray boom to one side of a vehicle and driving along the edges of the plots or by using a hand-held boom. Weeds which were not controlled by herbicides were removed by hand. The implements used for fallow tillage in 'cultivation' treatments and the herbicide applications for fallow weed control in 'no cultivation' treatments are listed in Appendices 1 and 2 respectively.

Table 1. Rainfall during fallow and crop periods

Crop year	Preceding harvest	Plant	Harvest	Rainfall (mm)		
				Fallow	Crop	Total
1972 ..	2 Nov 71	17 May 72	6 Oct 72	482	48	530
1973 ..	6 Oct 72	15 Jun 73	22 Oct 73	544	161	705
1974 ..	22 Oct 73	31 May 74	11 Nov 74	782	270	1 052
1975 ..	11 Nov 74	26 Jun 75	5 Nov 75	573	264	837

Table 2. **Effect of fallow management on soil moisture content (mm of water) at start and finish of fallow period**

Depth of sampling (cm)	Fallow management	1972		1973		1974		1975	
		Start	Finish	Start	Finish	Start	Finish	Start	Finish
0—20 ..	Cultivation	60.2	58.1	25.0	68.6*	33.5	75.5	54.0	69.6*
	No cultivation	61.4	58.7	25.5	64.3*	35.3	75.3	53.6	67.6*
20—40 ..	Cultivation	54.0	72.1	41.7	74.6	45.0**	81.3	68.1	76.3**
	No cultivation	56.0	72.1	42.9	74.6	48.3**	82.2	68.7	73.8**
40—60 ..	Cultivation	50.1	72.8	45.1	67.7**	44.8	78.1	69.7	74.5
	No cultivation	50.7	73.5	45.6	75.5**	45.8	78.2	68.7	73.1
60—80 ..	Cultivation	46.9**	66.7	42.0	50.1**	40.6	68.4	59.0	66.3
	No cultivation	44.4**	65.3	41.3	67.7**	39.9	68.8	59.8	65.0
80—100 ..	Cultivation	40.4	58.5	38.1**	39.4**	38.5	62.5	48.9	60.0
	No cultivation	39.3	60.6	36.0**	59.4**	38.6	61.4	50.3	58.9
100—120 ..	Cultivation	44.1	57.1*	41.0	41.7**	43.9	61.9	49.3	60.7
	No cultivation	43.7	59.5*	40.4	57.8**	41.6	61.2	48.3	59.3
120—140 ..	Cultivation	46.5	54.2**	40.2	37.7**	40.9	58.3	48.3	58.8
	No cultivation	46.0	59.5**	41.2	52.6**	44.6	59.3	44.7	59.2
Entire profile ..	Cultivation	342.3	439.5	273.1	379.6**	287.2	485.8	397.3	466.1
	No cultivation	341.4	449.1	272.9	451.8**	295.4	486.4	397.7	456.9

Means within pairs followed by * or ** differ significantly at the 5% and 1% levels respectively.

The soil was sampled to a depth of 140 cm for moisture determination at the beginning and end of each fallow period. Either hand-operated auger samplers or power-driven core samplers, each 5 cm in diameter, were used. Two sampling positions were selected at random in each plot on each occasion. The soil from each sampling position was divided into 20 cm increments and dried at 100°C for 48 h to determine gravimetric moisture content. This was converted to a volumetric basis using bulk densities calculated from the maximum gravimetric moisture content, using a procedure developed for cracking clay soils by Shaw and Yule (1978).

Urea was distributed on the soil surface in the nitrogen treated plots shortly before planting, using a cultivator drill. This equipment was also drawn over the plots which did not receive nitrogen, without operating, to achieve similar soil compaction by the wheels of tractor and drill.

Wheat seed was planted in the first 2 years using a small linkage cultivator drill with spring release tines. This machine tended to become clogged by crop residue in the chemically fallowed plots and in the remaining years the experimental area was cultivated after the fallowing periods to allow a conventional spring tine cultivator drill to be used. The wheat variety 'Timgalen' was planted at a seed rate of 50 kg ha^{-1}.

The yield of grain from a sample area measuring 20 m x 1.8 m in each plot was determined using a small combine harvester. In 1975 there was severe lodging and this was rated visually shortly before harvest on a scale of 0 (upright) to 10 (fully lodged).

Table 3. Effect of fallow management on increase in soil moisture content (mm of water) during the fallow periods

Depth of sampling (cm)	Fallow management	1972	1973	1974	1975
0–20 . .	Cultivation	−2.2	43.8	42.0	15.6
	No cultivation	−2.7	38.7	40.0	13.9
20–40 . .	Cultivation	18.1	32.9	36.2	8.2
	No cultivation	16.1	31.7	34.0	5.1
40–60 . .	Cultivation	22.7	22.6 **	33.3	4.9
	No cultivation	22.8	29.9 **	32.3	4.3
60–80 . .	Cultivation	19.8	8.1 **	27.7	7.2
	No cultivation	20.9	26.4 **	28.8	5.3
80–100 . .	Cultivation	18.1 *	1.3 **	24.0	11.1
	No cultivation	21.4 *	23.4 **	22.8	8.6
100–120 . .	Cultivation	13.0	0.7 **	18.0	11.4
	No cultivation	15.8	17.4 **	19.6	11.0
120–140 . .	Cultivation	7.6 *	−2.6 **	17.3	10.5
	No cultivation	13.5 *	11.4 **	14.7	13.8
Entire profile	Cultivation	97.2	107.6 **	198.6	68.8
	No cultivation	107.7	178.9 **	192.3	57.8

Means within pairs followed by * or ** differ significantly at the 5 % and 1 % levels respectively.

Table 4. Effects of fallow management and nitrogen on grain yield (kg ha^{-1})

Treatments	1972	1973	1974	1975	Mean
Cultivation ..	2 919 *	1 644 **	4 636	2 725 **	2 988 **
No cultivation	3 071 *	1 825 **	4 832	3 044 **	3 193 **
No nitrogen ..	3 017	1 703	4 765	2 915	3 100
Nitrogen ..	2 973	1 765	4 702	2 856	3 080

Means within pairs followed by * or ** differ significantly at the 5 % and 1 % levels respectively.

Table 5. Effects of fallow management and nitrogen on weight of 1 000 grains (g)

Treatments	1973	1974	1975	Mean
Cultivation	28.0	33.5	23.4 **	28.3 *
No cultivation ..	28.1	33.8	26.2 **	29.4 *
No nitrogen	28.2	33.7	25.2 *	29.0
Nitrogen	27.8	33.6	24.4 *	28.6

Means within pairs followed by * or ** differ significantly at the 5 % and 1 % levels respectively.

Table 6. Effects of fallow management and nitrogen on lodging (1975 crop)

Treatments	Lodging rating (0 = upright, 10 = fully lodged)
Cultivation ..	9.6 **
No cultivation ..	5.8 **
No nitrogen ..	7.0
Nitrogen	8.4

Means within pairs followed by ** differ significantly at the 1 % level.

3. Results and discussion

Volumetric soil water profiles for the start and finish of each fallow period are given in table 2, and in table 3 these data are expressed as increases in soil moisture content. Grain yields are given in table 4. Weights of 1 000 grains and lodging ratings for the years they were recorded are set out in tables 5 and 6 respectively.

Chemical fallow was superior to cultivation in terms of grain yields in 1972 ($P < 0.05$) and in 1973 and 1975 ($P < 0.01$). The increased yield was associated with significantly higher weight of 1 000 grains in 1975 although severe lodging in the cultivated plots may have reduced grain size.

The increased moisture storage in the profile following chemical fallow in 1973 ($P < 0.01$) was mainly at depth and could be related to soil cracking at the start of the fallow period. Since soil moisture content was unaffected by fallow management in 1974 and 1975, and the 1972 differences were at two depths only, factors other than stored soil moisture caused the yield differences. Pearce (1977) refers to an increase in soil organic matter and improved soil structure following chemical fallow.

Also, the persistence of residue from the preceding crop following chemical fallow management may have contributed to higher yields by improving moisture infiltration during the growing period. However, this does not explain the higher yields recorded in 1972 and 1975 since in the former there was little rainfall during the crop period (table 1) and in the latter crop residue was largely buried by disc cultivation shortly before planting.

The main effects of nitrogen on crop yield and the interactions between nitrogen and cultivation were not significant. Significance of the nitrogen main effects on weight of 1 000 grains in 1975 appears to be associated with lodging as was the cultivation main effect. Significant differences in lodging between the cultivation treatments in 1975 might be explained by increased availability of soil nitrogen following conventional fallow management but are not reflected in grain yield. However, if the 1975 yields are adjusted for variations in weight of 1 000 grains they are similar, which suggests that some factor was affecting the trend towards higher yield following chemical fallow.

It has been demonstrated under the conditions of this experiment that it is practicable to replace cultivation of fallows with chemical weed control provided that equipment is available to plant through undisturbed crop residues. If such equipment is not available it is necessary to cultivate the ground at the end of the fallow to allow conventional planting equipment to be used.

Chemical weed control gave a yield increase of about 200 kg ha^{-1} but whether this increase would justify a change in fallow management practice would depend on current economic factors. There could be other benefits and repeating the experiment on the same site for 4 consecutive years might have been expected to result in some progressive change in soil condition which would be reflected in grain yield. The results suggest no such development.

Appendix 1

Implements used for Fallow Tillage in ' Cultivation ' Treatments

Crop year	Date	Implement
1972 ..	11 Nov 71	Reversible disc plough
	2 Dec 71	Peg tooth harrow
	3 Dec 71	Tined cultivator
	9 Dec 71	Disc harrow
	22 Dec 71	Scarifier
	7 Jan 72	Chisel plough
	21 Jan 72	Disc cultivator
	11 Feb 72	Scarifier
1973 ..	16 Nov 72	Reversible disc plough
	4 Dec 72	Disc cultivator
	23 Jan 73	Scarifier
	27 Feb 73	Scarifier
	22 Apr 73	Disc cultivator
1974 ..	16 Nov 73	Reversible disc plough
	22 Jan 74	Scarifier
	7 Feb 74	Scarifier
	8 Apr 74	Disc cultivator (also in ' no cultivation ' treatments)
1975 ..	17 Dec 74	Reversible disc plough
	30 Jan 75	Disc cultivator
	6 Mar 75	Scarifier
	14 Apr 75	Disc cultivator (also in ' no cultivation ' treatments)
	25 May 75	Spring tine cultivator drill
	24 Jun 75	Peg tooth harrow (also in ' no cultivation ' treatments)

Appendix 2

Herbicide Applications for Fallow Weed Control in ' No Cultivation ' Treatments

Crop year	Date	Herbicide	Rate a.i. (kg ha^{-1})
1972	17 Nov 71	paraquat	0.6
	2 Dec 71	*paraquat + diquat	0.3 + 0.3
	7 Dec 71	amitrole	2.5
	17 Dec 71	paraquat	0.6
	22 Dec 71	paraquat	0.6
	29 Dec 71	paraquat	0.6
	13 Jan 72	*paraquat + MSMA	0.3 + 2.2
	24 Jan 72	MSMA	2.2
	28 Jan 72	*paraquat + MSMA	0.5 + 1.4
	11 Feb 72	*paraquat + MSMA	0.3 + 2.9
	4 Apr 72	*paraquat + MSMA	0.4 + 1.2
1973	8 Nov 72	†paraquat	0.3
	16 Nov 72	*paraquat + 2, 4–D (amine)	0.4 + 0.9
	5 Dec 72	paraquat	0.3
	1 Mar 73	paraquat + MSMA	0.2 + 1.9
1974	15 Nov 73	†paraquat	0.5
	22 Jan 74	*paraquat + diquat	0.2 + 0.2
	27 Feb 74	*paraquat + diquat	0.3 + 0.1
1975	19 Dec 74	paraquat + diquat	0.2 + 0.2
	7 Jan 75	paraquat + 2, 2–DPA	0.4 + 3.8
	8 Feb 75	paraquat + diquat	0.2 + 0.2
	11 Mar 75	paraquat + diquat	0.2 + 0.2

* Tank mix.

† Also applied in ' cultivation ' treatments.

4. Acknowledgements

The authors gratefully acknowledge the advice of Mr R. Mayer and the late Dr Jocelyn A. Tommerup on statistical treatment of the results and the assistance of Mr R. Shaw in the determination of volumetric soil water profiles.

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(Received for publication 2 December 1980)

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