THE EFFECTS OF PRIOR CULTIVATION AND CROPPING ON PASTURE PRODUCTIVITY

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ABSTRACT

In two pasture sowings marked differences in productivity occurred between contiguous previously cultivated and virgin sections, and an attempt was made to find the reason for these differences.

Chemical analysis showed that cultivation had resulted in a reduction in the level of a number of elements important in soil fertility, particularly in organic carbon (and nitrogen) at one site. However pot experiments failed to demonstrate that the productivity differences were due to nutrient deficiencies, except possibly nitrogen.

Weeds were not the main cause of the differences in productivity.

Changes in physical conditions were observed and it is suggested that the productivity differential between the cultivated and virgin soils was probably due to physical degradation and reduction in organic matter with cultivation.

The significance of this to the dairy industry in Queensland is briefly discussed.

INTRODUCTION

An important requirement in the development of productive sown pastures is to ensure that any soil nutrient deficiencies are corrected by the application of fertilizers (Davies *et al.* 1964). For many of the virgin major soils in Queensland the nutrient status is known and any nutrient additions necessary can be prescribed. However where these soils have been farmed for some time changes occur. These may involve a change in nutrient status, thus requiring a different fertilizer programme, but also there may be other changes and the problems they cause cannot be solved merely by the addition of nutrients.

In pasture sowings in the Beaudesert district (Site 1) and near Amberley (Site 2) virtual failure occurred where they were made on land that had been cropped for some time previously whereas on adjacent areas of virgin or near-virgin soil, treated in an identical manner, the pastures developed satisfactorily. Establishment was reasonably uniform, although slightly better on the virgin than the cultivated sections but later in the first season mortality of perennials was high on these latter sections and the difference in the pastures on the virgin and cultivated sections was most marked.

In a study of the reasons for the failures on the old cultivations pot studies were undertaken to determine if the failures were due to nutrient deficiencies.

DESCRIPTION AND HISTORY OF THE SITES

Site 1

This was originally hoop pine (*Araucaria cunninghamii*) scrub. The whole area had been cleared for more than 50 years and the cultivated section was first ploughed in the 1920's. The exact cropping and fertilizer history of this section is not known but it was used for lucerne production and annual summer crops of maize or sorghum with an occasional winter crop of field peas. The maize crops were fertilized with a N : P mixture but the amounts of these nutrients applied are not known.

In 1962 the cultivated section was sown with a pasture mixture of green panic (*Panicum maximum* var. *trichoglume*), Siratro (*Macroptilium atropurpureum*), lucerne (*Medicago sativa*) and barrel medic (*M. truncatula*). This was fertilized in 1966 and again in 1967, the total amounts of N: P: K applied being 14, 52 and 11 kg/ha respectively.

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Towards the end of 1967 when the green panic and lucerne had disappeared the whole paddock was uniformly ploughed and cultivated in preparation for sowing. It was sown in February 1968 with a mixture of green panic, Nandi setaria (*Setaria anceps*), Cooper glycine (*Glycine wightii*), Siratro, lucerne, and some temperate species. At sowing the two sections were fertilized with Mo-superphosphate, the virgin section receiving 24 and the cultivated section 48 kg/ha of phosphorus respectively.

The virgin soil was a dark grey/brown clay loam (Gr 3.42). The cultivated soil was lighter in colour at the surface, heavier in texture (light clay) and was less friable. It fitted the category Ug 5.1(6). At a depth of 10 cm the soil was dense and compacted.

Site 2

The original vegetation was forest with ironbark (*Eucalyptus crebra*) the dominant tree species. The whole area was cleared in 1951 and the section designated as cultivated was first cultivated in that year. Cropping was continued until 1967. The so-called virgin section received some cultivation. It commenced in 1954 but was discontinued some years before 1967 because at that date it had reverted to native pasture with perennial grasses predominating. Thus although not strictly virgin it had been cultivated far less than the other section. Two crops of maize followed by one of milo were grown on both sections and they were cropped fairly regularly with either oats or barley which were grazed by dairy cows. No fertilizer was used on either section up to 1967.

In 1967 both sections were uniformly ploughed and cultivated and sown in October with a mixture of Nandi setaria, glycine and lucerne. Mo-superphosphate providing 24 kg/ha of phosphorus was applied at sowing.

The soil originally was a prairie soil (Gn 3.92) derived from basalt with scattered stone throughout the profile. Manganiferous gravel was common in the surface soil. It was not degraded on the cultivated section to any noticeable extent being well structured and friable at the surface. However the depth of dark grey clay above the yellow/grey/brown heavy clay subsurface horizon was slightly less on the old-cultivated than on the "virgin" section where it varied from 15–25 cm.

At both sites establishment and early development of the pastures was satisfactory and only slightly inferior on the cultivated sections but by July 1968 the perennial species on the old cultivation at both sites had declined in density and the surviving plants were small and unproductive.

EXPERIMENTAL

In July 1968 soil samples were collected from both the virgin and cultivated sections of both sites for analysis and pot experiments. For the latter the soils were air-dried, ground where necessary and placed in 15 cm polystyrene nursery pots with polyethylene liners. Pots contained 1200 and 1600 g of soil from Sites 1 & 2 respectively. The test species were established by seeding directly into the soil and were thinned to seven plants per pot. Soil moisture was maintained at pF = 2 by twice-weekly watering.

There were four experiments and each involved four soils (2 sites × 2 periods of cultivation).

Experiment 1

The design was a 2^7 factorial ($\frac{1}{4}$ replicate) (Cochran & Cox 1962, plan 6A. 11) with the following treatments.

1. Phosphorus

Site 1 P_0—nil
P_1—72 kg/ha (750 kg/ha superphosphate applied as $CaH_4(PO_4)_2.H_2O$)

Site 2 P_0—24 kg/ha (250 kg/ha superphosphate applied as $CaH_4(PO_4)_2.H_2O$)
P_1—96 kg/ha (1000 kg/ha superphosphate applied as $CaH_4(PO_4)_2.H_2O$)

For other nutrients the soils from each Site received the same rates of application at two levels, 0 and as follows:

2. Sulphur — 34 kg/ha (Applied as $Na_2SO_4.10H_2O$)
3. Calcium — 2511 kg/ha (2.5 tonnes/ha lime)
4. Potassium — 63 kg/ha (125 kg/ha KCl)
5. Molybdenum — 0.28 kg/ha (Applied as $(NH_4)_6Mo_7O_{24}.4H_2O$)
6. Magnesium — 18 kg/ha (63 kg/ha $MgCO_3$)
7. Trace elements, a mixture of—
   - Boron — 0.75 kg/ha (4.5 kg/ha H_3BO_3)
   - Copper — 2.90 kg/ha (7.8 kg/ha $CuCl_2$. $2H_2O$)
   - Zinc — 3.76 kg/ha (7.8 kg/ha $ZnCl_2$)
   - Manganese — 2.18 kg/ha (7.8 kg/ha $MnCl_2$. $4H_2O$)

Lucerne was the test plant. It was inoculated but not pelleted before sowing. Two harvests were made, (i) 10 weeks, and (ii) 14 weeks after sowing.

Experiment 2

The design was a randomized block, treatments being four rates of nitrogen as follows (i) 0, (ii) 37, (iii) 74 and (iv) 148 kg/ha applied in solution as ammonium nitrate. A basal dressing of nutrients was made to all pots. It consisted of phosphorus at a rate equivalent to 96 kg/ha phosphorus (1 tonne/ha superphosphate) and the other nutrients as applied in Experiment 1. The nitrogen treatments were applied in two equal dressings, three and six weeks after sowing. Prairie grass (*Bromus unioloides*) was used as the test plant.

Experiment 3

This was similar to 2 above except that only two rates of nitrogen, viz, 0 and 74 kg/ha were compared and the test plant was lucerne, seed of which was inoculated before sowing.

Experiment 4

This was in conjunction with Experiment 1. Four pots of each soil from each site were left unweeded and the lucerne and weeds harvested separately at the same time as the first harvest of Experiment 1.

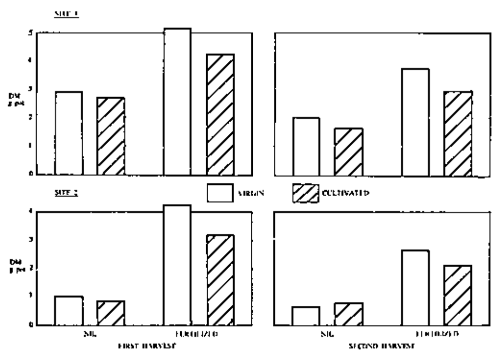

FIGURE 1

Effect on yield of lucerne of applications of nutrients to two soils (virgin & cultivated) at two sites. Results of two harvests. Experiment 1.

TABLE 1

Chemical characteristics and field capacity of virgin and cultivated soils at two sites.

		pH H_2O 1 : 5	NaCl %	C* %	N %	Avail. P† ppm	F.C. pF=2	Exchangeable Cations m. equiv./100 g & (per cent of total)						Base Saturation %
								Total	Ca	Mg	K	Na	H	
Site 1	Virgin	6.2	0.006	4.34	0.459	300	42.8	50.6	24.4 (48)	13.7 (27)	0.70 (2)	0.50 (1)	11.3 (22)	78
	Cultivated	6.4	0.006	1.25	0.153	160	37.3	46.8	21.3 (46)	17.4 (37)	0.36 (1)	0.68 (1)	7.0 (15)	85
Site 2	Virgin	6.0	0.002	2.00	0.172	45	25.6	21.2	6.0 (28)	5.1 (24)	0.29 (1)	0.20 (1)	9.6 (46)	54
	Cultivated	6.0	0.002	1.74	0.147	22	25.3	25.8	7.4 (28)	6.9 (27)	0.19 (1)	0.24 (1)	11.1 (43)	57

* Walkley and Black (1934).
† P soluble in 0.01 N H_2SO_4—Kerr and von Stieglitz (1938).

RESULTS

In Table 1 some characteristics of the surface soils are shown.

The overall effect of the addition of nutrients in Experiment 1 is shown in Figure 1. Without nutrients, yields from the virgin soils were slightly greater than from those that had been cultivated, suggesting only a slight difference in nutrient status of the two soils. With added nutrients the yields were increased markedly, but at both sites the yields attained on the cultivated soils were less than on the virgin suggesting that factors other than nutrients were limiting on the cultivated soils.

A summary of the detailed yield data obtained from the two harvests in Experiment 1 is shown in Table 2. There were no significant soil × single nutrient interactions at Site 1, indicating that soil nutrient status was not responsible for the differences in yield between the two soils.

TABLE 2

Summary of the yields of lucerne from two harvests from virgin and cultivated soils at two sites following a range of nutrient treatments. Experiment 1.

Treatment		Dry matter yield (g/pot)	
		Site 1	Site 2
Soils	— Virgin	3.23***	2.01*
	— Cultivated	2.89	1.88
Harvests	— 1st	3.71***	2.55***
	— 2nd	2.42	1.34
Nutrients	— P_0	2.86‡	1.68
	P_1	3.23***	2.20***
	S_0	2.80	1.95 N.S.
	S_1	3.33***	1.94
	Ca_0	2.86	1.27
	Ca_1	3.26***	2.62***
	K_0	3.09 N.S.	1.88
	K_1	3.04	2.01 N.S.
	Mo_0	3.03	1.84
	Mo_1	3.10 N.S.	2.05**
	Mg_0	3.04	1.95 N.S.
	Mg_1	3.09 N.S.	1.94
	T_0†	2.50	2.00 N.S.
	T_1	2.52 N.S.	1.91
Interactions†*			
	Soils × harvests	***	*
	Soils × Ca	N.S.	**
	Soils × S × K	*	N.S.
	Soils × P × S	*	N.S.
	Harvests × S	***	N.S.
	Harvests × Ca	N.S.	***
	Harvests × Mo	N.S.	**
	P × S	*	N.S.
	Ca × Mo	N.S.	***

Significance of yield increases: *** P = .001; ** P = .01; * P = .05; N.S. = non significant.

† Trace elements.

†* Interactions that were significant at one or both sites.

‡ Phosphorus responses occurred on these Site 1 soils despite a high level of available P (Table 1) as measured by acid extraction. This is further confirmation that this extraction procedure does not give a reliable measure of available P on these soils.

The virgin Site 1 soil gave a 12 percent higher yield than the cultivated soil, but none of the significant yield responses or interactions provided an explanation for the differences in productivity between the two soils.

At Site 2 the virgin soil again gave a higher yield than the cultivated but the difference was less—only about 7 percent. There was a significant soil × calcium interaction but the direction of the effect did not implicate calcium as a limiting factor in the productivity of the cultivated soil; with the addition of calcium the virgin soil yielded more than the cultivated.

In Experiment 2 with the Site 1 soils there was a significant linear ($P = .001$) increase in yield with increasing rates of application of nitrogen (Figure 2). The response of the two soils to the nitrogen applications differed significantly ($P = .001$), the cultivated soil responding more than the virgin. There was a weak nitrogen × soils interaction ($P = .05$), the yield differences between soils tending to be less at the higher rates of nitrogen application.

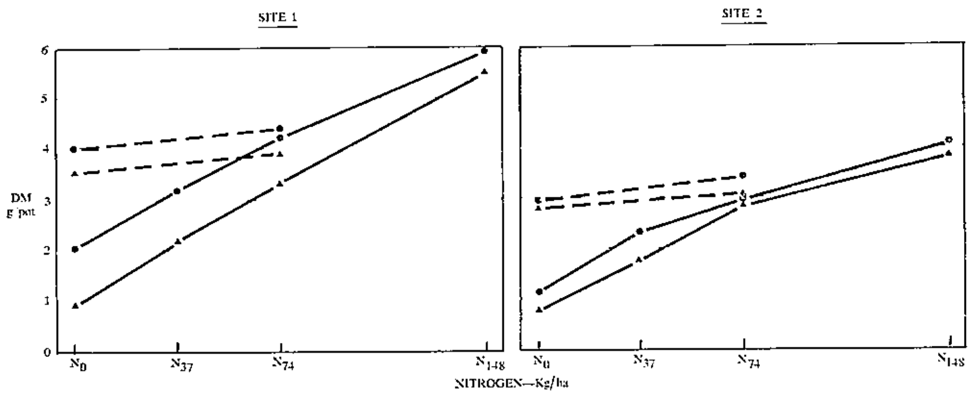

FIGURE 2

Response by prairie grass (full lines) and lucerne (dashed lines) grown on two soils from two sites to different rates of application of nitrogen. Experiments 2 and 3.

O = virgin Δ = cultivated

With the Site 2 soils there was also an increase in yield with increasing rates of nitrogen application with both the linear ($P = .001$) and quadratic ($P = .01$) effects being significant. The response by the cultivated soil was slightly greater ($P = .01$) than that by the virgin.

The overall effect of additions of nitrogen was a higher production of grass dry matter from the virgin soil than from the cultivated soil. The respective yields of dry matter from the virgin and cultivated soils due to nitrogen additions were: Site 1, 4.88 and 3.70 g/pot and Site 2, 3.17 and 2.83 g/pot (differences at both sites significant —$P = .001$).

In Experiment 3 nitrogen application resulted in a slight increase in yield of lucerne (Figure 2), which was significant only on the virgin soil at Site 2. There was no soil × nitrogen interaction at either site. The combined yields from two harvests were significantly greater ($P = .05$) on the virgin soil at both sites.

In Experiment 4, lucerne yields in the presence of weeds tended to be greater on the cultivated than on the virgin soils, but the difference was significant only on Site 2 (Table 3). Weed yields on the other hand tended to be greater on the virgin soils. Weeds reduced the yields of lucerne on the virgin soils but not on the cultivated soils.

TABLE 3

Yields from two soils at two sites of lucerne and weeds growing together compared with yields of lucerne growing without weeds—1st harvest only.

Experiment Number		Dry matter yield (g/pot) Site 1 Virgin Soil	Site 1 Cultivated Soil	Site 1 Diff.	Site 2 Virgin Soil	Site 2 Cultivated Soil	Site 2 Diff.
1	Lucerne	5.03	4.29	***	4.60	3.80	*
4	Lucerne	4.20	4.28	N.S.	2.22	3.22	*
	Weeds	0.97	0.60	*	0.99	0.42	N.S.

Significance of differences: * P = .05; *** P = .001; N.S. = non significant.

DISCUSSION

The results from the pot experiments support the observations at the two field sites that the soils with the history of more cultivation were not as productive as comparable virgin soils.

The lower productivity of the soils that had been cultivated and cropped for the longer period could have been due to a number of factors. Among these are a depletion of available nutrients, deterioration in physical conditions, competition from weeds or death of sown species from disease or other biological factors. The latter were not investigated but it was shown that weeds were unlikely to have been of importance.

The chemical analyses (Table 1) showed some changes in the surface soils due to cultivation. At Site 1 there was a marked reduction in carbon and nitrogen. Available phosphorus was also reduced but was still at a level that should have been adequate. There were also reductions in exchangeable potassium and calcium. At Site 2 the chemical composition was affected less by the differential treatment of the two sections. The level of available phosphorus was halved and there was also a reduction in carbon and nitrogen. Thus cultivation had reduced the level of a number of elements important in soil fertility, but in pot studies even after the addition of nutrients (except nitrogen) a difference in productivity between the soils at both sites still remained, suggesting that nutrient deficiency alone was not responsible for this difference.

However at Site 1, with a longer history of cropping and a greater decline in organic matter (and nitrogen) there was evidence to suggest that a decline in nitrogen level was responsible for differences in productivity of the two soils. In Figure 2, although the yield of grass without nitrogen was significantly greater from the virgin soil ($P = .01$) the differences in yield between virgin and cultivated soils decreased as rate of nitrogen application increased, so that at still higher rates there may have been no difference in yield.

The possibility that soil physical conditions were involved cannot be ruled out. They could have been affected in a manner adverse to plant growth through loss of surface soil by erosion, which although not evident may have occurred, through loss of the bonding action on clay particles by the organic matter as this declined under cultivation, through a direct effect from the shear action and weight of farm implements or through combinations of all these. Physical conditions were not measured, but observations in the field and during potting indicated changes due to cultivation. During preparation of the site for the pasture sowing it was difficult to prepare a satisfactory tilth on the cultivated section. The compacted layer at about 10 cm depth impeded moisture penetration and would probably also have impeded root penetration. With soils collected for potting, that from the cultivated section dried into hard aggregates which had to be mechanically crushed whereas the virgin soil dried into a friable condition. These changes would be expected to affect plant growth adversely. In pot studies their effects would be minimized, yet even with nutrient additions the virgin soil remained more productive than the cultivated.

At Site 2, where the contrast in the amount of cultivation to which the two soils had been subjected was less, a difference in soil physical conditions was not apparent. The soil that had been cultivated more was less productive and here too some factor other than nutrient deficiency was involved because the productivity of the cultivated soil could not be raised to the level of the other soil by nutrient additions.

Normally the organic matter and nitrogen content of the soil could be expected to increase under a legume-based pasture but here on the cultivated soils at both sites the perennial legumes had declined to such a low density and were so lacking in vigour that they were unlikely to produce this effect. The density and vigour of the legumes were unlikely to have been improved appreciably by moderate applications of nitrogen because in Experiment 3, with lucerne as the legume its productivity on the cultivated soils was improved only slightly (9.6 per cent) by addition of 74 kg/ha nitrogen and to a lesser extent than on the virgin soils.

This study examines only some of the factors affecting pasture productivity on old cultivations. Ideally measurements should have been made in the field over several seasons. However it suggests that on soils which appear suited to pasture development there are some situations where successful legume-based pasture sowings cannot be assured even with the addition of nutrients. Such a situation is produced by arable farming. This problem has particular relevance to the dairy industry in Queensland in any plans to increase the proportion of the feed supplied by pastures where it was previously supplied by annual crops. This is because dairy farm pasture sowings are likely to be made on old arable areas. Also, under tropical and sub-tropical climate conditions, soils on these areas are likely to have lost more organic matter than soils which have had similar amounts of arable use in temperate climates.

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