*Queensland Journal of Agricultural and Animal Sciences* Vol. 41 (1), 1-12 (1984)
Published by the Queensland Department of Primary Industries 

# Effect of pasture on subsequent wheat crops on a black earth soil of the Darling Downs. I. The overall experiment

**J. W. Littler**


## Summary

Over the 11 year period 1958 to 1968, a rotation experiment was conducted in which wheat monoculture was compared with a rotation involving 4 years of pasture, followed by wheat. Comparisons were possible among crops of wheat 1, 2, 3 and 4 years from the pasture phase and following continuous wheat crops.

Wheat after pasture was superior to wheat after continuous wheat with respect to dry matter yields, grain yields and degree of wild oat infestation.

The pasture phase did not effect improvement in test weight of the subsequent wheat crops and in some years a reduction occurred. No significant reduction in the incidence of root rot diseases occurred and measured soil structure improvement was of short duration only.

Adequate replenishment of soil moisture to a depth of at least 90 cm occurred during the fallow period between ploughing of the pasture and sowing of the wheat crop.


## INTRODUCTION

The practice of including a pasture in a cropping system, especially if one of the components is a legume, is regarded as sound agronomy (Russell 1961).

Gardner and Robertson (1954) concluded that a rotation involving lucerne improved the yields of succeeding crops, due mainly to the increase in available soil nitrogen. Hedlin, Smith and Leclaire (1957) showed that there was also a higher level of grain protein for wheat crops following lucerne.

An 11 year experiment conducted in the Wimmera, Victoria (Sims, Rooney and Tuohey 1964), showed that higher wheat yields and higher grain protein contents resulted from a rotation involving a medic pasture than from one involving natural pasture (non-medic).

Among other references cited in the literature supporting the beneficial effect of a legume on subsequent wheat crops were Horner (1960), Duley (1960), Taylor (1965) and Jooste (1967).

The author in 1956 surveyed four farms on the Darling Downs where lucerne-wheat rotations had been practised. These farmers had obtained variable results from the rotations and it was apparent that information available at that time concerning pasture-wheat rotations on the black earth soils of the Darling Downs was inconclusive. The experiment described here was, therefore, planned to provide comparative data and was begun at Jondaryan in 1958.

## MATERIALS AND METHODS

The soil type at the experimental site was a self-mulching Waco black earth (Beckmann and Thompson 1960). Certain chemical and physical characteristics of the soil are shown in Table 1. Originally the trial site comprised grassland, typical of the Darling Downs plains country. This grassland was first ploughed in 1898 and was then intermittently cropped and grazed until 1936 when annual cropping to cereals began. In 1956 the crop was canary seed and in 1957 wheat.

**Table 1. Some chemical and physical characteristics of the soil on the experimental site**

| Total N % | Organic* % | pH 1/2.5 $H_2O$ | TEC m.e. % | Clay % | P† ppm | Repl. K m.e. % |
|---|---|---|---|---|---|---|
| 0.132 | 1.22 | 8.3 | 80 | 78 | 46 | 3.04 |

* Walkley and Black (1934).
† Colwell (1963).

The land use sequences over the period 1958 to 1968 for the nine experimental treatments are shown in Table 2. Originally the experiment was designed for an 8 year period to permit a comparison in the eighth year of 1st, 2nd, 3rd and 4th crops of wheat following pasture with continuus wheat. The experiment was then continued for three further years to obtain a total of four such comparisons.

**Table 2. Key to treatments**

| Treatment number | Year | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 |
| 1 | W | W | W | W | P | P | P | P | $W_1$ | $W_2$ | $W_3$ |
| 2 | P | $W_1$ | $W_2$ | $W_3$ | $W_4$ | P | P | P | P | $W_1$ | $W_2$ |
| 3 | P | P | $W_1$ | $W_2$ | $W_3$ | $W_4$ | P | P | P | P | $W_1$ |
| 4 | P | P | P | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_7$ | $W_8$ |
| 5 | P | P | P | P | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ | $W_7$ |
| 6 | W | P | P | P | P | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ | $W_6$ |
| 7 | W | W | P | P | P | P | $W_1$ | $W_2$ | $W_3$ | $W_4$ | $W_5$ |
| 8 | W | W | W | P | P | P | P | $W_1$ | $W_2$ | $W_3$ | $W_4$ |
| 9 | W | W | W | W | W | W | W | W | W | W | W |

W=Continuous wheat $W_1$=First wheat crop following pasture $W_2$=Second wheat crop (etc.) P=Pasture.

The experiment comprised thirty-six parallel plots (Figure 1), individually fenced, each of 0.053 ha. In 1967, plots were subdivided into 4 subplots to permit a comparison with a range of nitrogen fertiliser rates (0, 33.6, 69.3 and 100.9 kg/ha N).

The wheat plots (cv. Spica) were sown each year using a commercial combine, at the rate of 50 kg/ha. Sowing date each year was determined by the occurrence of planting rains which varied from May to mid August. The plots were harvested with a commercial header. A 2 kg sample of grain was taken from each plot at harvest for quality assessment.

Apart from grain yields other quantitative data recorded were head heights, number of heads, 1000 grain weights, grain test weights (kg/ha), dry matter yield and mottling percentage.

For the pasture phase a mixture of grass and legume was sown to combine the probable beneficial physical effect of grass with the nitrogen contribution of the legume. The mixture selected was perennial prairie grass (*Bromus unioloides*) and lucerne (*Medicago sativa*, cv. Hunter River). The sowing rates were 17 and 5 kg/ha respectively.

Pasture sowings were made annually from 1958 to 1964 in appropriate plots from March to August, but usually in April. Ploughing out of the relevant pasture plots was carried out each year in the period September-October; this allowed a sufficient time under fallow for soil moisture replenishment over the summer rainfall period before sowing wheat.

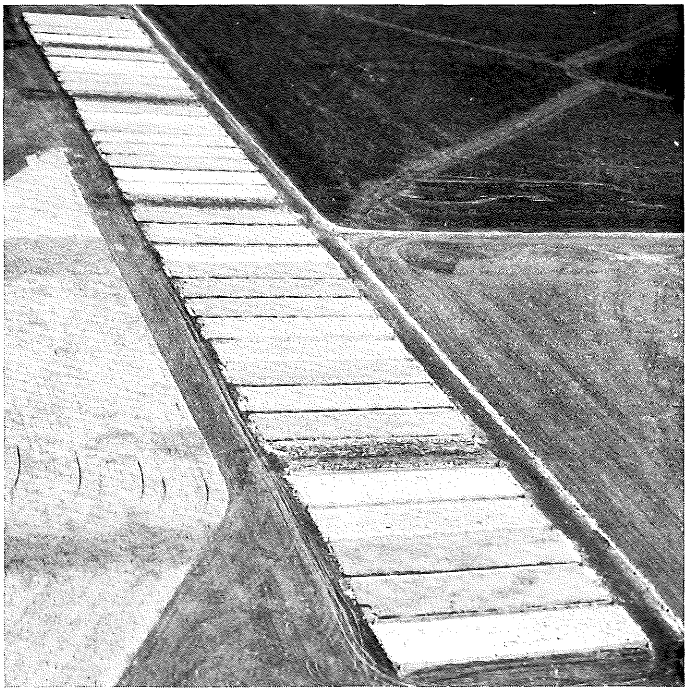

Figure 1. Aerial view of trial showing the 36 plots, October 1963.

The pasture growth was removed as required by grazing with sheep to a height of about 5 cm over periods of 1 to 2 days duration. There were usually four grazings per year between February and December, but good seasonal conditions in 1964 permitted six grazings. The experiment was first grazed on 9 August 1958 and the final grazing was completed on 17 November 1966.

Composite sampling for soil moisture was carried out at the end of the fallow period each year to the depth of the wetting front, often about 90 cm. In 1966, 1967 and 1968, however, individual plots were sampled. Bulk density assessments were carried out at 7.5 cm increments to a depth of 30 cm on each plot in 1962 and 1964. In addition, samples for soil nitrogen, pH and organic carbon determinations were taken at various times during the experiment, and results of these are discussed by Whitehouse and Littler (1984).

Wild oat plants (*Avena ludoviciana* and *A. fatua*) were rogued as a management practice from all wheat plots at the time of anthesis of the wheat plants during the period 1963 to 1966. Counts of the wild oat plants rogued were kept during the period 1964 to 1966 inclusive.

In the 1967 season, two quadrats (each 0.84 $m^2$) of wheat plants were pulled per subplot at the soft dough stage for an estimate of dry matter. At the same time the roots were retained for a visual rating of root rot diseases. In 1968, one quadrat only per subplot was taken.

Rainfall registrations were recorded for the 11 year period of the experiment and monthly totals are shown in Figure 2. Also, average monthly rainfalls are presented for Pittsworth, the closest rainfall recording station some 25 km from the trial site.

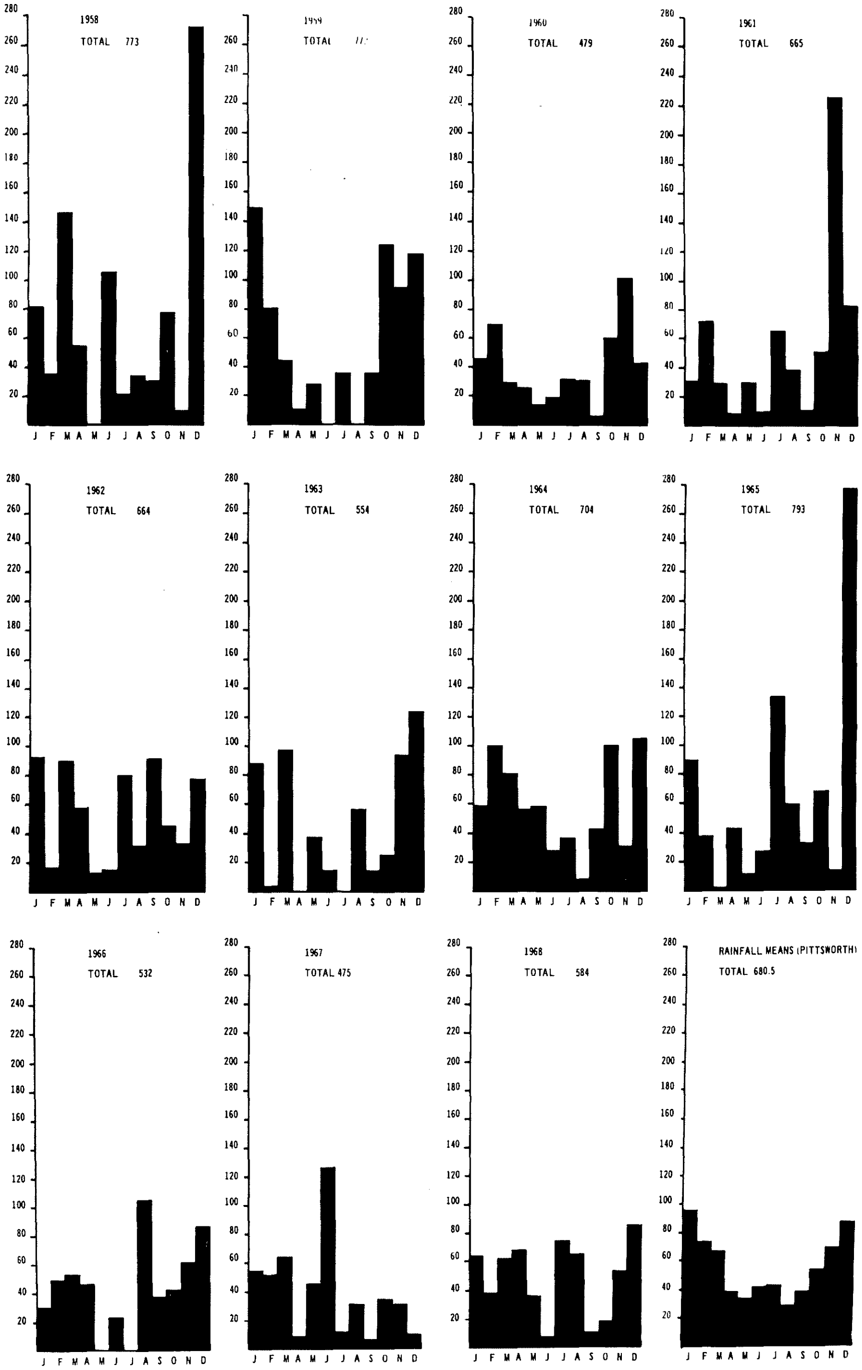


Figure 2. Rainfall (mm) at the trial site 1958-1968 and monthly means for Pittsworth.

# RESULTS

## Wheat yield data

Grain yields, grain protein and test weights: Table 3 sets out wheat yields for each of the eleven seasons, Table 4 the grain protein percentages and Table 5 the test weights.

The grain yield data indicate that the first crop of wheat after pasture generally had the highest yield, the mean grain yields being 31% greater than control; the highest increase was 55% in 1962 while the seventh wheat crop in 1967 was still significantly better than control. The grain yield potential of 1968 was far from being realised, due to the abnormally hot, dry conditions in spring.

Grain protein percentages for the control treatment were generally lower than all the treatments which had included pasture. It is interesting to note that treatment differences in grain protein showed up in 1959, before those of grain yield in 1960.

**Table 3. Wheat grain yields for all years of the experiment (kg/ha)**

| Treatment | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1128 | 2395 | 1308 | 727 | P | P | P | P | 2479 | 2035 | 1886 |
| 2 | P | 2540 | 1351 | 790 | 917 | P | P | P | P | 2316 | 1354 |
| 3 | P | P | 1652 | 926 | 966 | 2252 | P | P | P | P | 1635 |
| 4 | P | P | P | 1028 | 1082 | 2289 | 2176 | 1706 | 2354 | 2099 | 1531 |
| 5 | P | P | P | P | 1081 | 2303 | 2131 | 1751 | 2198 | 2235 | 1592 |
| 6 | 1151 | P | P | P | P | 2602 | 2233 | 1728 | 2190 | 2018 | 1699 |
| 7 | 1091 | 2655 | P | P | P | P | 2202 | 1728 | 2343 | 2074 | 1662 |
| 8 | 1066 | 2500 | 1379 | P | P | P | P | 1945 | 2420 | 2226 | 1669 |
| 9 | 1135 | 2442 | 1283 | 699 | 698 | 1780 | 1501 | 1553 | 1754 | 1695 | 1578 |
| l.s.d. | | | | | | | | | | | |
| 5% | n.s. | Note 2 | | | 147 | 336 | 277 | 186 | 169 | 211 | 176 |
| 1% | Note 1 | | | | 207 | 471 | 388 | 256 | 231 | 283 | 235 |

1. 1958 uniformity test satisfactory.

2. Means and l.s.d. for treatments in the same year of wheat as continuous wheat (control) before 1962:

| Year | Year of wheat | | | | | l.s.d. | |
|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | | 5% | 1% |
| 1959 | 2540 | 2498 | | | Not significant | | |
| 1960 | 1652 | 1341 | 1323 | | Between 1st and 2nd | 291 | 404 |
| | | | | | Tests involving 3rd | 238 | 330 |
| 1961 | 1028 | 926 | 790 | 713 | Between 1st, 2nd and 3rd | 196 | 274 |
| | | | | | Tests involving 4th | 169 | 238 |

Grain test weights; treatment differences were generally small, and favoured control.

Table 6 was constructed from data selected from Tables 3, 4 and 5 in order to demonstrate certain treatment effects. A comparison of wheat yields, grain protein percentages and test weights for control and five treatments of different periods of the time following 3 or 4 years of pasture is shown. The 3 year period under pasture was included because its effectiveness in increasing soil nitrogen was known to be similar to that of the 4 year period (M.J. Whitehouse, pers. comm.).

**Table 4. Wheat grain protein (%) for all years of the experiment (at 13.5% moisture)**

| Treatment | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11.51 | 10.94 | 13.11 | 15.33 | | | | | 13.97 | 12.48 | 14.42 |
| 2 | | 12.43 | 14.19 | 15.90 | 13.05 | | | | | 13.68 | 15.56 |
| 3 | | | 14.93 | 16.30 | 12.88 | 12.20 | | | | | 17.21 |
| 4 | | | | 17.33 | 12.88 | 12.48 | 13.91 | 16.02 | 12.03 | 12.08 | 13.22 |
| 5 | | | | | 13.40 | 12.77 | 13.68 | 16.19 | 12.03 | 11.97 | 13.62 |
| 6 | 11.63 | | | | | 14.42 | 13.97 | 16.36 | 12.26 | 12.03 | 13.28 |
| 7 | 11.86 | 11.06 | | | | | 13.68 | 16.30 | 11.97 | 12.14 | 13.79 |
| 8 | 11.80 | 10.83 | 13.97 | | | | | 17.50 | 12.60 | 12.20 | 14.36 |
| 9 | 11.74 | 11.12 | 13.79 | 15.05 | 12.94 | 11.29 | 13.22 | 13.68 | 10.26 | 10.77 | 11.91 |
| l.s.d. | | | | | | | | | | | |
| 5% | n.s. | Note 2 | | | n.s. | 0.51 | n.s. | 0.80 | 0.57 | 0.34 | 0.68 |
| 1% | Note 1 | | | | | 0.74 | | 1.14 | 0.80 | 0.51 | 0.91 |

1. 1958 uniformity test satisfactory
2. Means and l.s.d. for treatments in the same year of wheat as continuous wheat (control):

| Year | Year of wheat | | | | | l.s.d. | |
|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | | 5% | 1% |
| 1959 | 12.43 | 11.00 | | | Between 1st and 2nd | 0.40 | 0.57 |
| 1960 | 14.93 | 14.19 | 13.62 | | Between 1st and 2nd | 1.25 | 1.71 |
| | | | | | Tests involving 3rd | 1.03 | 1.43 |
| 1961 | 17.33 | 16.30 | 15.90 | 15.22 | Between 1st, 2nd, 3rd | 0.57 | 0.74 |
| | | | | | Tests involving 4th | 0.46 | 0.68 |

**Table 5. Wheat grain test weights for all years of the experiment (kg/hL)**

| Treatment | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 77.3 | 70.2 | | | | | 79.9 | 80.1 | 79.0 |
| 2 | 78.2 | 68.9 | 77.0 | | | | | 79.6 | 75.8 |
| 3 | 78.2 | 69.8 | 76.5 | 79.5 | | | | | 75.1 |
| 4 | | 69.1 | 76.8 | 80.1 | 73.2 | 70.9 | 81.2 | 80.3 | 78.5 |
| 5 | | | 77.3 | 79.5 | 73.3 | 71.2 | 80.8 | 80.3 | 78.8 |
| 6 | | | | 79.2 | 72.7 | 70.5 | 80.8 | 80.3 | 80.0 |
| 7 | | | | | 73.9 | 69.4 | 80.6 | 80.7 | 78.6 |
| 8 | 76.9 | | | | | 67.7 | 80.6 | 79.9 | 78.5 |
| 9 | 77.9 | 70.4 | 75.8 | 79.2 | 69.8 | 74.1 | 82.1 | 81.3 | 81.1 |
| l.s.d. | | | | | | | | | |
| 5% | Note 1 | Note 1 | n.s. | | n.s. | 2.2 | 0.9 | 0.7 | 1.5 |
| 1% | | | | | | 3.1 | 1.3 | 0.9 | 2.0 |

1958 and 1959 test weights not available.
1. Means and l.s.d. for treatments in the same year of wheat as continuous wheat (control):

| Year | Year of wheat | | | | |
|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | |
| 1960 | 78.2 | 78.2 | 77.3 | | No significant differences |
| 1961 | 69.1 | 69.8 | 68.9 | 70.3 | No significant differences |

**Table 6. Grain yield, protein and test weight for 1965-68**

| Years following pasture | 1965 Yield kg/ha | 1965 GP % | 1965 TW kg/hL | 1966 Yield kg/ha | 1966 GP % | 1966 TW kg/hL | 1976 Yield kg/ha | 1976 GP % | 1976 TW kg/hL | 1968 Yield kg/ha | 1968 GP % | 1968 TW kg/hL | Means 4 years Yield kg/ha | Means 4 years GP % | Means 4 years TW kg/hL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| First $W_1$ | 1945 | 17.45 | 67.7 | 2479 | 13.97 | 79.9 | 2316 | 13.68 | 79.6 | 1635 | 17.21 | 75.1 | 2094 | 15.58 | 75.6 |
| Second $W_2$ | 1728 | 16.30 | 69.4 | 2420 | 12.60 | 80.6 | 2035 | 12.48 | 80.1 | 1354 | 15.56 | 75.8 | 1884 | 14.24 | 76.5 |
| Third $W_3$ | 1728 | 16.36 | 70.5 | 2343 | 11.97 | 80.6 | 2226 | 12.20 | 79.9 | 1886 | 14.42 | 79.0 | 2046 | 13.74 | 77.5 |
| Fourth $W_4$ | 1751 | 16.19 | 71.2 | 2190 | 12.26 | 80.8 | 2074 | 12.14 | 80.7 | 1669 | 14.36 | 78.5 | 1921 | 13.74 | 77.8 |
| Fifth $W_5$ | 1706 | 16.02 | 70.9 | 2198 | 12.03 | 80.8 | 2018 | 12.03 | 80.3 | 1662 | 13.79 | 78.6 | 1896 | 13.47 | 77.7 |
| Control W | 1553 | 13.68 | 74.1 | 1754 | 10.26 | 82.1 | 1695 | 10.77 | 81.3 | 1578 | 11.91 | 81.1 | 1645 | 11.66 | 79.6 |
| l.s.d. | | | | | | | | | | | | | | | |
| 5% | 186 | 0.80 | 2.2 | 169 | 0.57 | 0.9 | 211 | 0.34 | 0.7 | 176 | 0.68 | 1.5 | | | |
| 1% | 256 | 1.14 | 3.1 | 231 | 0.80 | 1.3 | 283 | 0.51 | 0.9 | 235 | 0.91 | 2.0 | | | |

Seasons: 1965, 1966, 1976, 1968

**Table 7. Baking quality results (composite samples, 1967)**

| Treatment number | Code | Flour yield % | Maltose mg per 10 g flour | Water absorption % | Extensibility at 135 min cm | Maximum resistance at 135 min EU† | Loaf volume cm³ | Baking score |
|---|---|---|---|---|---|---|---|---|
| 1 | $W_2$ | 76.9 | 1.66 | 58.7 | 21.5 | 485 | $770^{20}$* | 35 |
| 2 | $W_1$ | 76.2 | 1.26 | 59.7 | 20.8 | 540 | $800^{30}$ | 37 |
| 4 | $W_7$ | 76.5 | 1.82 | 58.7 | 20.7 | 515 | $725^{20}$ | 33 |
| 5 | $W_6$ | 76.1 | 1.76 | 59.0 | 21.4 | 520 | $750^{20}$ | 34 |
| 6 | $W_5$ | 76.4 | 1.82 | 59.0 | 22.2 | 500 | $700^{20}$ | 31 |
| 7 | $W_4$ | 76.3 | 1.82 | 59.0 | 21.0 | 495 | $725^{20}$ | 33 |
| 8 | $W_3$ | 76.1 | 1.71 | 59.3 | 23.0 | 530 | $735^{20}$ | 33 |
| 9 | W | 77.5 | 1.88 | 57.0 | 20.3 | 440 | $690^{20}$ | 32 |

* Optimum bromate concentration.
†Extensograph units.

### Wheat quality

Aspects of wheat quality which were considered included grain protein and baking quality.

Grain protein contents of the various treatments are presented in Tables 4 and 6. In the three seasons 1966, 1967 and 1968 the presence of mottled grain was restricted virtually to the continuous wheat plots, the percentages being 33, 21 and 22 respectively. All other treatments yielded nil, or, at most, 1% mottled grain.

Baking quality data for 1967 are presented in Table 7. These show the highest quality in the first and second wheat crops, with the lowest in the control treatment. These data are representative of the treatment pattern for six of the eight seasons in which quality was assessed. In the other two seasons the baking quality of grain for all treatments was similar. The best season for baking quality was 1961 when even wheat from the control treatment produced grain of high baking quality.

### Soil bulk densities

Bulk density determinations on samples at four depth intervals for the years 1962 and 1964 are shown in Table 8. These values have been adjusted by co-variance for soil moisture percentage because the soil is of a cracking clay type.

In both years differences between treatments were detected in the 7.5 to 15.0, and 15.0 to 22.5 cm layers. In the 22.5 to 30 cm layer differences were detected in 1964 but not in 1962. In this latter year, however, there was a trend similar to the variation in 1964. It should be noted that, in these three soil layers, the pasture phase improved soil structure as indicated by the lower bulk density figures. This improvement was, however, lost after 1 year cropping to wheat.

In the surface soil (0 to 7.5 cm) differences between treatments were detectable in 1962 but not in 1964 when there was a trend similar to the variation in 1962. In both seasons, the lowest soil bulk densities were in the continuous wheat and the first two wheat crops after pasture.

### Grazing

In this experiment the emphasis was on the cropping phase. Nevertheless, grazing records of the pasture phases of the rotation were kept. The number of grazings for the duration of the trial depended on treatment and ranged from 9 to 16. The average carrying capacity was 13.4 sheep/ha on a year round basis.

While a lucerne-perennial prairie pasture mixture was sown, this normally had reverted to a pure lucerne stand within 18 months.

### Wild oats

Wild oat plants were rogued from the wheat plots each year and in the 3 years, 1964 to 1966, the number of plants were counted. The mean number of wild oat plants/ha in the wheat treatment were 84 in $W_1$, 352 in $W_2$, 1698 in $W_3$, 3152 in $W_4$, 6167 in $W_5$, 7411 in $W_6$ and 11 607 in continuous wheat.

## DISCUSSION

During the course of the experiment, there were five years which were free from adverse seasonal conditions such as heat waves, frost and hail. The best season for wheat was 1959 while the worst was the last season, 1968, when dry weather, accompanied by heat waves late in the crop growth, scorched the wheat plants. The two best years for pasture were 1958 and 1964, while the worst was 1963.

This experiment demonstrated some of the benefits to subsequent wheat crops which can be attributed to a pasture phase in crop rotations on the heavy clay soils of the Darling Downs. These included yield increases, principally in the first and second crops

**Table 8. Soil bulk densities ($g/cm_3$)**

| 1962 | | | | | | 1964 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | | Depth intervals (cm) | | | | Treatment | | Depth intervals (cm) | | | |
| Number | Code | 0–7.5 | 7.5–15.0 | 15.0–22.5 | 22.5–30.0 | Number | Code | 0–7.5 | 7.5–15.0 | 15.0–22.5 | 22.5–30.0 |
| 2 | $1PW_4$ | 0.70 | 0.94 | 0.99 | 0.98 | 4 | $3PW_4$ | 0.83 | 0.98 | 0.99 | 0.98 |
| 4 | $3PW_2$ | 0.66 | 0.93 | 0.97 | 0.96 | 5 | $4PW_3$ | 0.80 | 0.99 | 0.98 | 0.99 |
| †9 | W | 0.62 | 0.90 | 0.98 | 1.00 | 9 | W | 0.74 | 0.96 | 0.99 | 0.98 |
| †1 | $4WP_1$ | (0.62) | (0.90) | (0.98) | (1.00) | 3 | $4WP_1$ | 0.75 | 0.98 | 0.97 | 0.99 |
| 3 | $2PW_3$ | 0.70 | 0.85 | 0.96 | 0.99 | 6 | $4PW_2$ | 0.73 | 0.98 | 0.97 | 0.97 |
| 5 | $4PW_1$ | 0.64 | 0.79 | 0.90 | 0.94 | 7 | $4PW_1$ | 0.74 | 0.92 | 0.95 | 0.97 |
| 8 | $3WP_2$ | 0.75 | 0.91 | 0.82 | 0.66 | 2 | $4WP_2$ | 0.83 | 0.78 | 0.77 | 0.86 |
| 7 | $2WP_3$ | 0.75 | 0.84 | 0.83 | 0.72 | 8 | $3WP_4$ | 0.82 | 0.77 | 0.78 | 0.85 |
| 6 | $1WP_4$ | 0.72 | 0.80 | 0.70 | 0.67 | 1 | $4WP_3$ | 0.80 | 0.73 | 0.77 | 0.78 |
| Means | | 0.69 | 0.87 | 0.90 | 0.88 | Means | | 0.78 | 0.90 | 0.91 | 0.93 |
| l.s.d. 5% | | 0.07 | 0.07 | 0.07 | 0.10 | l.s.d. 5% | | 0.10 | 0.09 | 0.06 | 0.07 |
| 1% | | 1.10 | 0.09 | 0.10 | 0.13 | 1% | | 0.14 | 0.12 | 0.09 | 0.09 |
| *F* value for adjusted treatments | | * | ** | * | n.s. | *F* value for adjusted treatments | | n.s. | ** | ** | ** |

†At time of sampling the pasture phase of treatment 1 had not been planted. Both treatments were identical and data have been analysed as one.

**Table 9. Grain yield components and plant weight**

| Treatment | 1963 | | 1966 | | | | | 1967 | | | | | 1968 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Crop | A | Crop | A | B | C | D | Crop | A | B | C | D | Crop | A | B | C | D |
| 1 | P | .. | $W_1$ | 4180 | 22.7 | 26.1 | 105.97 | $W_2$ | 3391 | 40.5 | 14.8 | 76.17 | $W_3$ | 3371 | 39.8 | 14.1 | 84.84 |
| 2 | P | .. | P | .. | .. | .. | .. | $W_1$ | 4030 | 37.9 | 15.2 | 79.76 | $W_2$ | 3270 | 37.1 | 11.2 | 77.72 |
| 3 | $W_4$ | 3086 | P | .. | .. | .. | .. | P | .. | .. | .. | .. | $W_1$ | 3962 | 37.9 | 11.0 | 89.54 |
| 4 | $W_3$ | 3157 | $W_6$ | 3354 | 27.6 | 25.4 | 96.82 | $W_7$ | 3355 | 40.4 | 15.5 | 80.47 | $W_8$ | 2989 | 42.5 | 12.0 | 82.17 |
| 5 | $W_2$ | 3238 | $W_5$ | 3276 | 26.3 | 25.5 | 95.17 | $W_6$ | 3115 | 40.1 | 17.9 | 77.93 | $W_7$ | 3170 | 38.9 | 12.9 | 83.82 |
| 6 | $W_1$ | 3750 | $W_4$ | 3300 | 26.0 | 25.5 | 93.85 | $W_5$ | 3436 | 40.2 | 14.6 | 76.84 | $W_6$ | 3168 | 41.0 | 13.1 | 82.85 |
| 7 | P | .. | $W_3$ | 3301 | 27.4 | 25.9 | 94.67 | $W_4$ | 3500 | 40.2 | 14.7 | 76.45 | $W_5$ | 3106 | 39.6 | 13.5 | 83.62 |
| 8 | P | .. | $W_2$ | 3649 | 26.6 | 24.9 | 96.44 | $W_3$ | 3731 | 39.7 | 15.0 | 81.08 | $W_4$ | 3000 | 38.1 | 14.6 | 81.84 |
| 9 | W | 2759 | W | 2546 | 30.8 | 22.4 | 87.81 | W | 2675 | 42.3 | 15.0 | 74.30 | W | 2305 | 44.4 | 15.4 | 79.93 |
| l.s.d. 5% | | 316 | | 323 | | 1.8 | 3.38 | | 384 | 1.6 | | 5.11 | | 358 | 4.2 | | 3.03 |
| 1% | | 443 | | 442 | | 2.5 | 4.62 | | 515 | 2.2 | | 6.89 | | 478 | 5.6 | | 4.05 |

A=thousand heads per hectare; B=1000 grain weight (g); C=grains per head; D=plant height at maturity (cm).

(25 to 55%) but detectable up to the seventh crop, associated increases in number of heads per hectare (Table 9), higher grain protein (Tables 4 and 6), better baking quality (Table 7) and a reduction in the level of wild oat infestation.

In this experiment quadrats were cut for dry matter determination in two years only, 1967 and 1968. The potential grain yield, as indicated by dry matter yield at anthesis, is not always achieved. This non-achievement of potential was particularly evident in the 1968 season due to harsh finishing conditions of the weather. At anthesis, the $W_1$ treatment showed a 64% superiority over continuous wheat but there was no significant difference between the subsequent grain yields.

Rixon (1972) also obtained superior yields and higher grain protein in wheat following perennial pasture, especially with white clover included.

Grain mottling, a symptom of low grain protein and poor baking quality, was virtually restricted to the control treatment. This confirms previous work by Littler (1963) and is in agreement with the findings of Lipsett (1963).

Visual responses in the wheat plots following pasture were apparent at an early stage, about 8 weeks after sowing. Wheat plants in these plots were darker green and taller (Table 9), with broader leaves and more tillers than those in the continuous wheat plots. These visual responses, together with higher grain yields and increased grain protein, suggest that the period under pasture contributed increased available soil nitrogen to subsequent wheat crops. This is in agreement with the claim of Tucker, Cox and Eck (1971) who concluded that the principal effect of lucerne on subsequent wheat yields was to supply nitrogen. The soil nitrogen changes measured in this experiment are discussed by Whitehouse and Littler (1984).

The reduction in wild oat infestations achieved with the pasture phase is similar to that recorded by Dadd (1957). If roguing the wild oat plants from the wheat plots had not been undertaken each year as a weed control measure on the co-operator's property, the wild oat populations would have built up to much higher levels, especially in the control plots. This would almost certainly have resulted in greater yield differences between control and the early wheat crops after pasture than were actually recorded.

It should be noted that the soil bulk densities in the surface layer (0 to 7.5 cm) were lowest in the continuous wheat, $W_1$ and $W_2$ treatments whereas, in the three deeper soil layers (7.5 to 30.0 cm), the $P_2$, $P_3$ and $P_4$ treatments exhibited the lowest soil bulk densities. This apparent anomaly is difficult to explain and serves to emphasise the structural strength of this Waco soil generally.

The failure to achieve a stable improvement in soil bulk density measurement below the surface layer following lucerne is in agreement with the findings of Tucker *et al.* (1971). If, however, the grass component in this experiment had persisted for the full pasture term, the effect on soil structure may have been more pronounced.

The main disease involved in the assessment made in 1967 was crown rot (*Fusarium graminearum*). The visual rating of tiller leaves as means of the four nitrogen subtreatments revealed no significant differences between treatments. The range in mean infection of plants was from 9.2% for continuous wheat to 30.3% for $W_3$.

The pasture phase in the rotation had no beneficial effects on root rot incidence or grain test weight (Table 5).

Wheat and other winter crops in Queensland depend on a buffering store of soil moisture at planting for consistent successful production (Fitzpatrick and Nix 1969). In this experiment, soil moisture determinations just before sowing wheat indicated that replenishment of moisture during the fallow period was as great in the rotation plots as in the continuous wheat plots to a depth of at least 90 cm. Available soil moistures at planting averaged over 7 years were calculated at 178 mm and 172 mm for the first wheat crop after pasture plots and the continuous wheat plots respectively. In contrast to experimental results obtained by Tucker *et al.* (1971), the grain yield of the first crop following pasture was not exceeded by that in any other treatment, indicating that soil moisture stress relative to treatments was not a significant factor. Even though lucerne is known to dry out soil to a depth of about 5.5 m (Hobbs 1953), lucerne in this experiment did not adversely affect the availability of soil moisture to the first following wheat crop. This confirms that the early ploughing out of such pastures about September ensures adequate replenishment of soil moisture.

One benefit not appraised in this experiment is the soil conservation aspect since the site was on plains country where a severe soil erosion hazard does not exist. In other situations, such as steeper slopes and soils more erosion prone, the desire to stabilise the farming system and ensure minimum erosion of soil could override the economic consideration which varies according to the cost/price structure.

## ACKNOWLEDGEMENTS

The author thanks Mr H.H. Tod for his valued and ready co-operation during the course of the experiment located on his property at Jondaryan.

The assistance of Mr G.B. Wildermuth, Plant Pathology Branch, the late Mr P.B. McGovern and Miss E.A. Goward, Biometry Branch and Mr D.P. Law, Agricultural Chemistry Branch is gratefully acknowledged.

## References

Beckman, G.C. and Thompson, C.H. (1960), *Soil and land use in the Kurrawa area, Darling Downs, Queensland*, CSIRO Soil and Land Use Series No. 37.

Colwell, I.D. (1963), The estimation of fertiliser requirements on wheat in southern New South Wales by soil analysis, *Australian Journal of Experimental Agriculture and Animal Husbandry* **3**, 190.

Dadd, C.V. (1957), A review of wild oats, *Field Crop Abstracts* **10**, 66.

Duley, F.L. (1960), *Yield in different cropping systems and fertiliser tests under stubble mulching and ploughing in Eastern Nebraska*, Nebraska Agricultural Experiment Station Research Bulletin No. 190.

Fitzpatrick, I.A. and Nix, H.A. (1969), A model for simulating soil water regime in alternating fallow-crop systems, *Agricultural Meteorology* **6**, 303-19.

Gardner, R. and Robertson, D.W. (1954), *The beneficial effects from alfalfa in a crop rotation*, Colorado Agricultural and Mechanical College, Technical Bulletin No. 51.

Hedlin, R.A., Smith, R.E. and Leclaire, F.P. (1957), Effect of crop residues and fertiliser treatments on the yield and protein content of wheat, *Canadian Journal of Soil Science* **37**, 34-40.

Hobbs, J.A. (1953), Replenishment of soil moisture supply, following the growth of alfalfa, *Agronomy Journal* **45**, 490-92.

Horner, G.M. (1960), Effect of cropping systems on erosion, run-off and wheat yields, *Agronomy Journal* **52**, 342-44.

Jooste, W. (1967), For better wheat crops in the Swartland, *Farming in South Africa* **48**(6), 7-9.

Lipsett, J. (1963), Factors affecting the occurrence of mottling in Wheat, *Australian Journal of Agricultural Research* **14**, 303-14.

Littler, J.W. (1963), Effect of time and rate of application of urea to wheat, *Queensland Journal of Agricultural Science* **20**, 323-44.

Rixon, A.J. (1972), Yield and quality of four wheat crops subsequent to annual and perennial irrigated pastures, *Australian Journal of Agricultural Research* **23**, 561-71.

Russell, E.W. (1961), *Soil Conditions and Plant Growth*, 9th edition, Longmans, London.

Sims, H.J., Rooney, D.R. and Tuohey, C.L. (1964), Wimmera crop rotation trials, *Journal of Agriculture, Victoria*, 527-31.

Taylor, A.C. (1965), Wheat crop surveys in southern New South Wales. I. Some factors influencing grain protein, *Australian Journal of Experimental Agriculture and Animal Husbandry* **5**, 487-90.

Tucker, B.B., Cox, M.B. and Eck, H.V. (1971), Effect of rotations, tillage methods and N fertilisation on winter wheat production, *Agronomy Journal* **63**, 699-702.

Walkley, A. and Black, I.A. (1934), An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method, *Soil Science* **37**, 29-38.

Whitehouse, M.J. and Littler, J.W. (1984), Effect of pasture on subsequent wheat crops on a black earth soil of the Darling Downs. II. Organic C, nitrogen and pH changes, *Queensland Journal of Agricultural and Animal Sciences* **41**, 13-20.

(Received for publication 5 February 1980)

Mr Littler (now retired) was formerly an officer of Agriculture Branch, Queensland Department of Primary Industries. Correspondence should be addressed to the Director, Agriculture Branch, Department of Primary Industries, GPO Box 46, Brisbane, Q. 4001.