**A diagnostic approach to cropping systems research: two sites at South Stirling, WA.**

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**Abstract**

Average crop yields in Western Australia have improved markedly in recent years but are still only about two-thirds of those expected on the basis of seasonal rainfall. There may be more than one reason for the performance of paddocks that consistently yield below expectations. This project uses soil physical, chemical and biological tests, plant analyses and farmer experience to diagnose possible limiting factors and follows an experimental approach to test combinations of treatments that might improve yields.

Two paddocks in the South Stirling area were selected by their owners because of difficulties in management and lower performance of both grain yields and pasture growth. The first site (M and R Easton) was loamy sand overlying gravel and clay at about 50 cm. It had been prone to wind erosion, was moderately non-wetting and had low pH and available K in the 10-20 cm horizon despite past surface application of both lime and K fertilizer. The second site (N and L Shearer) was a sandy loam overlying a sodic clay at about 30 cm. The soil above the clay was extremely compacted and the paddock was prone to waterlogging.

In 2004 the sites received only 233 mm of rain during the season. At the Easton site canola yields were significantly increased by either treatment with 100 t/ha clay or 40 kg/ha of K applied at 20 cm depth or 2.5 t/ha of lime placed at 20 cm depth. There were no further yield increases with combined treatments. Similarly at the Shearer site only raised beds alone or deep ripping (to 25 cm) alone increased yields. We attributed the lack of additional responses to the fact that the best yields were already close to the seasonal potential.

In 2005 all sowings not on raised beds were destroyed by torrential rains after sowing in late May. Subsequently the barley was re-sown in July. However, the only significant yield increases at the Easton site were to N fertilizer applied tactically after waterlogging events and at the Shearer site to tactical N and to raised beds.

Some key soil parameters were improved by the treatments at both sites. The options for improved management will be assessed after a further 3 years.

**Keywords**

yield, gypsum, lime, ripping, claying, raised beds.

**Introduction**

Average yields of all grain crops produced in Western Australia have improved markedly in recent years but are still only about two-thirds of those expected on the basis of seasonal rainfall (calculated by the methods described by Tenant 2000). There may be more than one reason for the performance of paddocks that consistently yield below expectations and there is a need to establish by objective means which are the factors most limiting yield, and what are the consequences of applying one, or more than one remedial measure at the same time. This project uses soil physical, chemical and biological tests, plant analyses and farmer experience to diagnose possible deficiencies and follows an experimental approach to test combinations of treatments that might improve yields. The aim of the work is to assess the efficacy of methods used to overcome the diagnosed limiting factors so that farmers have choices to economically lift grain yields to the levels set by the seasonal rainfall each season.

## Materials and methods

Two paddocks in the South Stirling area (approx. 34$^0$S, 118$^0$ E, 525 mm average annual rainfall) were selected by their owners because of difficulties in management and lower performance. The first site (M and R Easton) was loamy sand overlying gravel and clay at ~35 cm and clay at ~75 cm (Chromosol). It had been prone to wind erosion, had previously failed to support a lucerne crop, and was generally unproductive (yields less than achieved with similar management on other paddocks). The second site (N and L Shearer) was a grey, shallow, sandy duplex, gravelly (Sodosol) with sandy loam overlying a sodic clay at about 30 cm. The paddock was prone to waterlogging and had supported only mediocre yields. Yields at both sites had been only about half of those expected by the farmers.

The soils were tested (20 samples/site) at three depths (approx. 0-10, 10-20 and 20-30 cm according to the soil horizons) for nutrients, pH (0.01M $CaCl_2$), water repellence (Molarity of Ethanol Drop test, King 1981), dispersion and slaking, electrical conductivity, CEC, soil organisms (Predicta B? test) and penetrometer resistance (Table 1). Slotted tubes were inserted into each plot in the experiments to a depth of 80 cm and the water levels recorded at weekly intervals during each season. Plant measurements during the season (plant numbers, biomass, anthesis dates, yield components) were taken on 2, 2m rows in each plot. Mechanical harvest was from the inside 6 of 8 rows in each plot after trimming to 20m length. Results were analysed after spatial adjustment (Genstat ?) and all significances quoted are at the 5% level of probability.

The first site (Easton) was moderately non-wetting and had low pH and available K (Table 1) in the 10-20 cm horizon despite past application of both lime and K fertilizer. All combinations of +/- 100 t/ha of clay applied to the surface, +/- 2.5 t/ha of lime at 20 cm depth and +/- 50 kg/ha of K applied at 20 cm depth were used as treatments.

The soil above the clay at the second site (Shearer) was extremely compacted and the clay was sodic. Treatment combinations of +/- deep ripping to 25 cm, +/- 2.5 t/ha of gypsum and +/- raised beds were used. Some key diagnostic test results are shown in Table 1 from samples taken in 2003 before implementing the experiments.

**Table 1. Key diagnostic test results from samples taken in 2003 [numbers in bold were deemed to be limiting and important for determination of treatments (Moore 1998)].**

| Measurement | Soil Depth | Site 1 – Easton | Site 2 - Shearer |
|---|---|---|---|
| pH ($CaCl_2$) | A1 | 4.8 | 4.9 |
| | A2 | **4.6** | 4.9 |
| | B2 | 6.0 | 5.9 |
| K (mg/kg) | A1 | 77 | 87 |
| | A2 | **29** | 48 |
| | B2 | 40 | 220 |

| | | | |
|---|---|---|---|
| CEC (me%) | A1 | **3.7** | 4.5 |
| | A2 | **1.1** | **0.8** |
| | B2 | **3.0** | 9.0 |
| Exch. Na (me%) | A1 | 0.08 | 0.27 |
| | A2 | 0.03 | 0.04 |
| | B2 | 0.95 | **1.54** |
| MED (non-wetting) | A1 | 1.6 | 2.3 |
| Penetrometer Resistance of limiting layer | | 1,988 | **>4,000** |
| Clover tissue S% | | 0.28 | **0.19** |

In 2005 the plots at both sites were split to compare the 'farmer' strategy of applying N in two doses split between sowing and tillering with three doses applied after observed waterlogging events in the plots. All plots (except for those sown onto raised beds at the second site) needed to be re-sown (in the first week of July) due to heavy rain after sowing in late May. Canola was sown at 5 kg seed/ha in 2004 and barley at 80 kg seed/ha in 2005 (at both sites).

**Results and discussion**

In 2004 the sites received only 233 mm of rain during the season. At the Easton site canola yields were significantly increased compared to the nil treatment by either the clay treatment or the K treatment or the lime treatment, but there were no further yield increases with combined treatments. Similarly at the Shearer site only raised beds alone or deep ripping alone increased yields compared to the untreated plots (Table 2). We attributed the lack of additional responses to the fact that the best yields were already close to the seasonal potential.

**Table 2. Grain yield of canola in 2004. [Numbers in bold were significantly different from the Nil treatment]**

| Site 1 – Easton | | Site 2 - Shearer | |
|---|---|---|---|
| Treatment | Yield (t/ha) | Treatment | Yield (t/ha) |
| Nil | 1.64 | Nil | 2.07 |
| Clay (100 t/ha) | **1.82** | Deep Rip to 25cm | **2.27** |

| | | | |
|---|---|---|---|
| Deep K (50 kg/ha) | **1.86** | Raised beds | **2.26** |
| Deep Lime (2.5 t/ha) | **2.01** | Gypsum (2.5 t/ha) | 2.14 |
| C + L | **1.91** | DR + RB | 2.15 |
| C + K | 1.78 | DR + G | **2.33** |
| K + L | 1.67 | RB + G | 2.13 |
| C + K + L | **1.83** | DR + RB + G | **2.25** |
| lsd | 0.17 | lsd | 0.16 |

In 2005 there was a full profile of water stored at sowing and a further 60 mm of rain fell immediately after sowing followed by 23 rain days in June (a total of 130 mm rainfall). The total of stored water plus rainfall was about 450 mm for the raised bed plots that survived and about 290 mm for those re-sown in July. Plant numbers (57 plants/$m^2$) on the raised beds were only about half of the number targeted. The only significant yield increase at the Easton site (sown in July) was to N fertilizer applied tactically after each waterlogging event and at the Shearer site to raised beds and to tactical N on the raised beds (Table 3). Tactical N application was associated with reduced kernel size at both sites, possibly contributing to the relatively small response to applied N.

**Table 3. Grain yield and kernel weight of barley in 2005.**

| Site 1 – Easton | | | Site 2 – Shearer | | |
|---|---|---|---|---|---|
| Treatment | Grain yield (t/ha) | Kernel weight (mg) | Treatment | Grain yield* (t/ha) | Kernel weight* (mg) |
| Nil | 3.53 | 46.2 | Nil | 3.62 | 37.8 |
| Tactical N** | 4.32 | 40.2 | Tactical N*** | 3.96 | 37.2 |
| | | | Raised beds | 4.58 | 40.8 |
| | | | N + RB | 4.26 | 35.7 |
| lsd | 0.27 | 0.1 | lsd | 0.41 | 0.2 |

* Data from hand samples, ** 70kg/ha in 3 doses, *** 60kg/ha N in 2 doses

Some of the soil parameters as measured in 2005 were changed by the treatments. At the first site (Easton) the pH in the 10-20 cm depth was increased significantly from 4.79 to 5.64 and the aluminium was significantly decreased from 4.0 to 2.38 mg/kg. Similarly the soil K test increased significantly in the

10-20 and 20-30 cm depths by the deep K treatment. The CEC values were also significantly increased by various treatment combinations (Table 4).

At the Shearer site in 2005 the EC values were increased significantly, especially by various combinations of gypsum, deep ripping and raised beds (Table 5). This raises the possibility that some soil amendments involving radical movements of soil may exacerbate salinity even though the values recorded were less than those likely to reduce plant growth. In this experiment the application of gypsum reduced the accumulation of sodium in the 0-10 cm depth that was associated with the deep ripping plus raised beds treatment.

**Table 4. CEC (me%) at three depths at Site 1 in 2005.**

| Treatment | 0-10 cm | 10-20 cm | 20-30 cm |
|---|---|---|---|
| Nil | 3.63 | 1.50 | 2.25 |
| Clay (100 t/ha) | **4.50** | **2.50** | 2.12 |
| Deep Lime (2.5 t/ha) | 4.38 | **2.38** | 2.12 |
| Clay + Lime | 4.12 | **2.12** | 1.75 |
| Lsd | 0.82 | 0.62 | ns |

**Table 5. Electrical conductivity and exchangeable sodium at 0-10 cm depth at Site 2 in 2005. [Numbers in bold were significantly different from the Nil treatment]**

| Treatment | EC (ms/m) | Exchangeable Na (mg/kg) |
|---|---|---|
| Nil | 6.8 | 0.088 |
| Gypsum (2.5 t/ha) | 14.5 | 0.070 |
| Deep rip (25 cm) | 10.8 | 0.085 |
| Raised beds | 8.0 | 0.103 |
| Gypsum + deep rip | 16.5 | 0.068 |
| Gypsum + raised beds | **36.5** | 0.083 |
| Deep rip + raised beds | **19.7** | **0.145** |

| | | |
|---|---|---|
| G + DR + RB | 16.5 | 0.085 |
| lsd | 10.3 | 0.022 |

**Conclusions**

As might be expected the responses to the treatments were highly dependent on the rainfall in two contrasting seasons. Given this unusual range of seasons it is probably sensible to obtain data on yields, costs and likely profits over at least one more season before making conclusions about optimum combinations of practices. However, the efficiency of use of rainfall (seasonal rain plus estimated soil storage less losses, (Tennant 2000) of the highest-yielding treatments was in the range 16 - 21 kg/ha/mm, or close to the potential. Most of the measured soil properties were improved. This gives us some optimism that applying treatments according to soil and plant diagnostic tests and farmer experience can be successful in identifying options for improved management that may ultimately lead to increased profits and soil health.

**References**

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