'Living soil' seminar

Department of Agriculture, Western Australia

Follow this and additional works at: http://researchlibrary.agric.wa.gov.au/misc_pbns

Part of the Agricultural Science Commons, Agriculture Commons, Botany Commons, and the Other Plant Sciences Commons

Recommended Citation

Department of Agriculture, Western Australia. (1992), 'Living soil' seminar. Department of Agriculture and Food, Western Australia, Perth. Report 7/92.

This report is brought to you for free and open access by Research Library. It has been accepted for inclusion in Miscellaneous Publications by an authorized administrator of Research Library. For more information, please contact jennifer.heathcote@agric.wa.gov.au, sandra.papenfus@agric.wa.gov.au.
'LIVING SOIL' SEMINAR

Proceedings of seminar held at Katanning on 18th September 1991
Organised by: G.J. Parlevliet

GREAT SOUTHERN AGRICULTURAL RESEARCH INSTITUTE,
KATANNING
'LIVING SOIL' SEMINAR

Sponsored by:

Australian Institute of Agricultural Scientists
Broomehill Land Conservation District
Department of Agriculture

Proceedings of seminar held at Katanning on 18th September 1991
Compiled by: G.J. Parlevliet

Great Southern Agricultural Research Institute - Katanning

Material in this booklet cannot be quoted without first contacting the author.
INTRODUCTION

Gerry Parlevliet, Broadacre Organic Specialist
Department of Agriculture, Katanning

I organised the seminar to provide an opportunity for farmers and those involved in the agricultural service industry, to focus on what happens in the soil.

Most seminars and field days refer to production orientated topics, but generally don’t pay attention to the sub surface problems.

This seminar reflects the interest that I have detected amongst farmers in knowing more about the things that influence plant growth and a genuine concern about the environment.

The speakers today include scientists, extension people and farmers. The mix provides a balanced view of the issues. These include soil profiles, soil acidification, soil microbiology, effect of rotation on organic matter, nitrogen cycling and the practical approach to farmers.

Sponsorship from Broomehill Land Conservation District and the Australian Institute of Agricultural Scientists to fund this forum on sustainable agriculture also indicate the co-operative approach to improving Western Australian agriculture.

The seminar is being chaired by Angus Woithe, chairman of the Broomehill LCD

I would like to thank Rosalee McAuliffe for her assistance in the organisation of the seminar and the production of these proceedings.
- CONTENTS -

SOILS OF THE GREAT SOUTHERN REGION:
- Heather Percy, Research, Department of Agriculture

SOIL MICROFLORA AND THEIR IMPORTANCE TO AGRICULTURE
- Dr Lyn Abbott, University of Western Australia

SOIL ACIDITY - ITS SIGNIFICANCE ON THE AGRICULTURAL SYSTEM
- Fionnuala Frost, Acidity Adviser,
  Department of Agriculture, Northam
- Tony Clark, Adviser,
  Department of Agriculture, Katanning

ROTATIONS:
- Ian Rowland, Research Officer, Department of Agriculture

NUTRIENT CYCLING FROM ORGANIC MATTER
- Ian Fillery, Scientist, CSIRO
- Paper not available for these proceedings

FARMERS DEVELOPING THE SOIL:
A Case Study - Danny Bignell, Broomehill
A Case Study - Graeme Smith, Broomehill
Effect of Bio-Dynamics on Our Soils - John Benn, Boscobel

CONCLUDING COMMENT:
- Kevin Goss, Acting Director of Division of Resource Management

ADDITIONAL PAPERS:
Earthworms for Farmer's Soils - C.A. Parker, University of W.A.
SOILS OF THE GREAT SOUTHERN REGION

Heather Percy, G.S.A.R.L, Katanning

Introduction

The aim of this talk was to give a brief overview of local soils and to set the scene for the rest of the "Living Soils" seminar.

For simplicity I placed the varied soils types found in the Great Southern into four broad groups:

- deep sands
- gravels
- duplex soils (sand over clay)
- loams and clays

The main features of the broad groups and variability within each group were discussed with the aid of slides. However before showing the slides the broad groups were put into context in terms of their position in the landscape.

Soils and the Landscape

The diagram below shows an idealized cross-section down a hillslope.
On the uplands (upper slopes and ridges) are often found remnants of the ancient lateritic soil profile which was formed when the climate in this area was tropical. It is on the remains of the ancient sands and gravels that modern soils have formed. These are generally the deep sands and gravel soils.

The uplands form a source of material which is moved downslope after erosion. This deposited material is known as colluvium. The soils on the valley slopes are varied but are generally the duplex types, loams and clays. They may be formed on colluvium but may also form on bedrock or on the clay which forms when the bedrock break downs (or weathers).

Clays, loams and duplex soils are also the most common soils on drainage lines and broad river flats. These soils are formed on alluvium, material which has been deposited by rivers and streams. Areas of deep sands may also be found in dunes close to rivers or on the north-eastern sides of lakes.

**Local Soils**

Thirteen slides of soil profiles were shown at the seminar. They were taken from four publications (see reference list). The main points covered are summarised below. A common feature on all slides is the shallow depth of topsoil which is generally only 10 cm deep. This is the layer where organic matter has accumulated and where most of the nutrients are stored and turned over by micro-organisms.

**Deep Sands:**

- Sand layers deeper than 60 cm (2 feet);
- Generally formed on remnant sandplain but also formed on colluvium, alluvium, wind-blown (aeolian) sand and on bedrock;
- Vegetation ranges from heath, mallee, Christmas tree, banksia, sheoak and includes some Eucalypts such as wandoo and marri or red gum;
- Deep sands are generally:
  - prone to wind erosion and require high inputs of fertilizers as nutrients leach rapidly,
  - generally have high groundwater recharge and may have problems of water repellency, water erosion and acidification;
- Productivity of deep sands varies with clay content, size of sand grains (coarse sand retains less than fine sand) and colour of sand (generally white sand is poorer than yellow sand);
- The yellow colour is due to the presence of iron oxides which retain some nutrients;
- Some deep sands contain ironstone nodules (gravel). This may help retain water and phosphorus.

**Gravels:**

- Soils with more than 50-70% gravel throughout or below a sandy topsoil;
- Generally 50-70cm of sandy gravel over clay profile;
- The gravel is usually iron-rich nodules (ironstone gravel) which may be formed in the current soil or may be derived from ancient soils;
- Generally found on upper slopes and ridges;
- Gravels are formed on remnant gravel or colluvium;
- Vegetation varies from west to east with rainfall and includes jarrah, wandoo, powderbark wandoo, mallee, health and dryandra (parrot bush);
- Gravels are usually very productive for annual subclover pasture, cereals and lupins (providing soils is well drained) given sufficient fertilizers. Problems arise where massive hard layers of gravel (ironstone rock) are exposed at the surface or occur at shallow depth. Other management/land conservation issues include water erosion, wind erosion and groundwater recharge. Acidification may also be a problem on these soil types;

- Variability of gravels includes:
  - shallow depth to ironstone,
  - layers of sand over gravel,
  - size of gravel and how loose or cemented the gravel is may influence the ease with which plant roots can grow.

**Duplex Soil:**

- These are soils with layers of sand or sandy loam over clay;
- May be subdivided into deep and shallow duplex.
- **Deep duplex** soils have 30-60 cm (1-2 feet) of sand over clay. They are generally found on valley slopes and are usually formed on colluvium or weathered rock. The vegetation cover includes wandoo, marri (red gum), sheoak, jam and mallee. Management problems include wind erosion, water erosion, waterlogging, groundwater recharge and possible acidification. The soil type varies with the parent material, for example the subsoil maybe alkaline if this soil is located near a dolerite outcrop (dyke);
- **Shallow duplex** soils have layers of sand 10-30cm deep over clay. They are usually found on lower valley slopes and valley floors and are formed on alluvium, colluvium, clay and weathered rock. The vegetation on shallow duplex soil ranges from wandoo, mallee, york gum, morrell and salmon gum. The main land management problem on this soil is waterlogging and salinity with flooding and wind erosion also hazards. The main variability relates to the depth of clay and the pH of the clay sub soil. If the shallow layers of sand are removed by erosion to expose the clay sub soil, then these soils become very unproductive. Another problem occurs when the clay sub soil is brought to the surface during cultivation. The makes the soil’s surface hardsetting.

**Clays and Loams**

- Have the highest clay content and grade into the shallow duplex. Some clays and loams have a thin layer of sand (< 10cm) over clay but this group also includes soils which have a gradual increase in clay content with depth. Clays and loams may be found on valley floors where they are formed on alluvium, on valley slopes where they are formed on clay, colluvium or on bedrock;

- Vegetation includes moort, mallee, york gum, salmon gum, morrell;

- These soils generally have a high potential productivity but this is often reduced because of structure decline, salinity, waterlogging, flooding and erosion. Some soils are often difficult to cultivate and are known locally as "Sunday soils."

- Variability: - colour is the main variation in this group of soils which includes "grey clays" and "red clays". The colour reflects the parent material of the soil with the red colours associated with dolerite, gabbro and "greenstone" rock types. The last slide was of a "morrell" soil which IS found to be east and south east of salt lakes. The clay content gradually increases with depth from a loam to medium clay in this soil and the sub soil is alkaline and saline. Care must be taken to avoid the topsoil being lost to expose the unproductive saline subsoils.
References

For more detailed information please refer to the following publications available from your local Department of Agriculture District Office.


SOIL MICROFLORA AND THEIR IMPORTANCE TO AGRICULTURE

Lyn Abbott

Soil Science and Plant Nutrition, School of Agriculture,
University of Western Australia, Nedlands 6009

Soils contain a wide diversity of microorganisms and small animals which are important for maintaining a suitable environment for the growth of plants (Paul and Clark 1989). These organisms play roles in processes that affect the physical, chemical and biological conditions of soil and are therefore essential to sustainable agriculture systems (Lynch 1983).

The biology of soil is complex. Indeed, most organisms make their contribution during interactions with other organisms, including plants. This needs to be considered as I briefly describe the biological processes that are important to the development and maintenance of ideal soil conditions for the growth of crops and pastures. Another important point is that as soil conditions change such as with wetting and drying cycles or with the implementation of various agricultural practices, there will be significant effects on the microorganisms and soil animals. Their benefits may be enhanced or reduced as a result.

The major beneficial microbiological processes in soil are:

i) nutrient cycling (e.g. the degradation of organic matter to inorganic nutrients that can be taken up by plants);
ii) symbiotic nitrogen fixation (e.g. in association with legumes);
iii) the enhancement of nutrient uptake into plants by mycorrhizal fungi;
iv) the degradation of pesticides;
v) the biological control of plant pathogens and
vi) the development of suitable soil structure for plants.

For some of these processes, specific organisms are involved, but for others, a wide range of microorganisms can be involved. For example, during the degradation of organic matter in soil, many species of microorganisms and soil animals participate either simultaneously or in succession. In contrast, the bacteria involved in symbiotic nitrogen fixation by subterranean clover are highly specific.

The cycling of nutrients from organic matter in soil is an essential process enabling the release of nutrients into a form suitable for plants to take up (Haynes 1986a). A heterogeneous group of fungi, bacteria and soil animals are involved in this degradation. Initially, soluble compounds are released from the material. If they are organic, they may be converted either into inorganic forms or into other organic forms by microbial processes. The remaining plant organic material gradually becomes broken down by microorganisms. Carbon present in specific components, such as cellulose and lignin, is released by the activity of microorganisms which possess the appropriate enzymes. A succession of species of fungi and bacteria are involved (Harper and Lynch 1985). The rate of degradation depends on the chemical bonding of the organic matter. The microbial breakdown is driven by the availability of carbon in the organic matter, because it is required for the growth of the microorganisms.

Simultaneously, other elements are released (e.g. nitrogen, phosphorus and sulphur) which are either used by the microorganisms or released into the soil where they may be absorbed by plants.

The degradation of organic matter can lead to a net release of nitrogen into soil and this is generally the case for legume residues which contain a relatively high concentration of nitrogen (Leeper 1964). Alternatively, there may be a net loss of nitrogen from the soil during degrada-
tion if sufficient nitrogen for the growth of the microorganisms is not present in the residues (Jansson and Persson 1982). The latter usually applies for wheat straw.

An example of a microbial process that involves the conversion of one inorganic form of nitrogen (NH$_4^+$) to another (NO$_3^-$), is nitrification (Haynes 1986b). For this to occur, two specific groups of microorganisms are required, and these are generally both present in soil. One group converts NH$_4^+$ to NO$_2^-$ and the other group converts NO$_2^-$ to NO$_3^+$. Nitrogen fixation is a process that can be carried out by relatively few species of microorganisms. It may occur in symbiotic association with plants such as legumes (Beringer 1982), or by free-living bacteria present in soil or on root surfaces (Roper 1983). Symbiotic nitrogen fixation provides nitrogen directly to the plant. Specific strains of bacteria are required for particular legumes. For example, bacteria that nodulate subterranean clover will not nodulate lupins (Trinick 1982).

A common group of fungi that occurs in soil comprises vesicular arbuscular mycorrhizal fungi. These fungi form a symbiotic association with roots of most species of agricultural plants (Abbott and Robson 1982, 1991). The hyphae of the fungi colonize the inner part of the root and obtain carbon. The hyphae also spread in the soil surrounding the root and act as an extension to the root system, providing a means for the plant to explore a greater volume of soil. This is most important for nutrients such as phosphorus that move slowly through soil. Mycorrhizal plants are efficient at obtaining phosphorus from phosphate-deficient soils. Mycorrhizal hyphae are also very important contributors to the formation and maintenance of stable soil aggregates.

Certain groups of soil fungi and bacteria produce enzymes that are responsible for the breakdown of agricultural pesticides in soil (Torsø, 1980). Some substances (eg. many herbicides) are degraded rapidly whereas others (eg. organochlorides) have chemical structures that are not easily attacked by enzymes. Microbial degradation is the main process for degradation of pesticides in soil. The length of time that pesticides remain effective is related to their susceptibility to degradation by soil microorganisms. Within soil there are organisms which influence the growth of other organisms either directly, such as by predation, or indirectly by changing the environment so that it is no longer suitable for the growth of another organism. In such cases where the affected organisms is a plant pathogen, the outcome of the interaction may lead to biological control of a disease (Campbell 1985). This process may occur naturally, or could be enhanced by altering the soil conditions to suit the antagonist of the pathogen.

Microbial processes that enhance soil structure can occur simultaneously during the degradation of organic matter, in association with the formation of mycorrhizas or through direct actions of soil animals such as earthworms. As organic matter is degraded, certain bacteria and fungi produce polysaccharide gums which stick soil particles together. Fungal hyphae also physically bind soil particles (Tisdall and Oades 1979, Lynch and Bragg 1985). These processes also occur in association with roots via wefts of mycorrhizal hyphae that radiate in soil around the roots. In addition, roots generally enhance the abundance of microorganisms in their vicinity. This occurs because an abundance of soluble carbon compounds is released continually from roots and is a ready source of carbon for many microorganisms.

In general, the greater the quantity of organic matter in soil, the greater the total biomass of microorganisms. Most microorganisms are relatively short-lived, and can be degraded more rapidly than plant organic matter primarily because of differences in the structure of their cell walls. The biomass of microorganisms in soil represents an important pool of potential nutrients for plants.
This brief outline of the major microbiological processes in soils is intended simply as an introduction. The biology of soil is complex and ever-changing. Many of the species of organisms present cannot easily be either extracted from soil, grown in artificial media or named. The interactions among organisms and between them and plants and the physical and chemical components of soil are largely undescribed. What is known however, is that soil microorganisms and soil animals play a crucial role in the maintenance of soil in a condition suitable for sustainable agricultural production. By understanding the way that agricultural practices alter this biological component of soil fertility, practices can be used that conserve and enhance the functioning of this essential biological resource.


SOIL ACIDITY - ITS SIGNIFICANCE ON THE AGRICULTURAL SYSTEM

Fionnuala Frost, Department of Agriculture, Northam and
Tony Clark, Department of Agriculture, Katanning

Introduction

Soil pH is a measure of the power or concentration of hydrogen in the soil. Technically an acid soil is one where the soil pH is less than 5.0. The major agricultural crop and pasture species all have varying tolerances to soil pH, in fact many require pH values of between 5.0 and 6.0 to achieve their potential. It is when plants are grown out of their pH range that acidity becomes a problem. For example medics are far more intolerant to acidity than subclover varieties, barley and some wheat varieties, namely Aroona, Cranbrook, and Wilgoyne, are less tolerant to acidity than most wheat varieties and lupins. Figure 1 describes the appropriate pH range for most agricultural crop and pasture species.

Figure 1:

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>pH (Calcium Chloride)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truncatula medics</td>
<td>3.8, 4, 4.2, 4.4, 4.6, 4.8, 5, 5.2, 5.4, 5.6, 5.8</td>
</tr>
<tr>
<td>Polymorpha medics</td>
<td>3.8, 4, 4.2, 4.4, 4.6, 4.8, 5, 5.2, 5.4, 5.6, 5.8</td>
</tr>
<tr>
<td>Murex medics</td>
<td>3.8, 4, 4.2, 4.4, 4.6, 4.8, 5, 5.2, 5.4, 5.6, 5.8</td>
</tr>
<tr>
<td>Sub. clover (peas)</td>
<td>3.8, 4, 4.2, 4.4, 4.6, 4.8, 5, 5.2, 5.4, 5.6, 5.8</td>
</tr>
<tr>
<td>Serradella, lupins</td>
<td>3.8, 4, 4.2, 4.4, 4.6, 4.8, 5, 5.2, 5.4, 5.6, 5.8</td>
</tr>
<tr>
<td>Barley, Sensitive wheats</td>
<td>3.8, 4, 4.2, 4.4, 4.6, 4.8, 5, 5.2, 5.4, 5.6, 5.8</td>
</tr>
<tr>
<td>Tolerant wheats</td>
<td>3.8, 4, 4.2, 4.4, 4.6, 4.8, 5, 5.2, 5.4, 5.6, 5.8</td>
</tr>
<tr>
<td>Oats, triticale</td>
<td>3.8, 4, 4.2, 4.4, 4.6, 4.8, 5, 5.2, 5.4, 5.6, 5.8</td>
</tr>
<tr>
<td>Cereal rye</td>
<td>3.8, 4, 4.2, 4.4, 4.6, 4.8, 5, 5.2, 5.4, 5.6, 5.8</td>
</tr>
</tbody>
</table>

Truncatula medics - for example Cyprus
Polymorpha medics - for example Serena, Circle Valley, Santiago
Murex medics - for example Zodiac
Sub. clover - all varieties
Peas - rough guide only, little data available.
Serradella, lupins - rough guide only
Barley - all current commercial varieties
Sensitive wheats - Aroona, Cranbrook, Wilgoyne
Tolerant wheats - all other current commercial varieties
Oats, triticale, cereal rye - rough guide only

Soil pH values below the critical ranges indicate a high risk of severe plant growth problems.

It is not soil pH itself that adversely affects plant growth and development, it is the effect that pH has on nutrient availability and the activity of rhizobia and other micro-organisms in the soil. Table 1 lists the effect pH has on the availability of some nutrients and soil organisms.
Table 1: Soil acidity has two types of effects on plant growth.

1. Some effects can only be overcome by liming:
   Aluminium toxicity
   Manganese toxicity
   Nodulation failure

2. Some effects can be overcome by lime or by fertilizers:
   Molybdenum deficiency
   Nitrogen deficiency
   Phosphorus deficiency
   Calcium deficiency
   Magnesium deficiency

N.B. Be careful of overliming, as this can induce Take-all or split seed in lupins.

How do agricultural soils acidify?

Soil acidification is a naturally occurring process, however the rate of acidification under bushland is much slower than that under an agricultural system. (Fig 2).

Farming increases soil acidification by increasing two processes that produce acidity as a side effect.

Figure 2:

_Clearing and agricultural development has caused acidification of the soil_
Nitrogen Cycle

Most of the nitrogen that accumulates in W.A. results from nitrogen fixation by legumes. It is not nitrogen fixation itself that is acidifying but when the plant dies and breaks down in the soil, the nitrogen that was converted to a form usable by cereals is converted to nitrate and acid is produced. The process is known as the Nitrogen Cycle. (Fig 3). The conversion of organic nitrogen to nitrate releases hydrogen ions (H\(^+\)) into the soil. The resulting acid may be taken up by the nitrate if the nitrate is taken up by the plant or by soil organisms, however, if the nitrate is leached out of that soil layer then the accumulated acidity will persist since there is no source for the H\(^+\) to attach itself to.

Fig 3.

The process of acidification

Nitrogen fertilisers have variable effects on the acidification of the soil. The nitrogen in Agran, Agran and Urea is the same as the nitrogen fixed by legumes, therefore if the nitrate is allowed to leach, the free hydrogen ions will accumulate and consequently acidify the soil. The phosphate in D.A.P. has a neutralising effect on soils that have a pH less than 6.0. This means that it balances some of the acidity produced by the nitrogen base in the fertiliser.

Nutrient uptake

The removal of produce from a paddock can be thought of as the equivalent of removing lime. When plants take up nutrients they excrete acidity from their roots. This is to balance the electrical charges in the plant. Plants take up more positively charged elements such as calcium, potassium and magnesium. The positively charged hydrogen (H\(^+\)), is then excreted by the roots to balance the charges in the plants cells. The net result is that the plant becomes alkaline and the soil acid. Because most plants are either harvested or eaten, there is little of this alkaline plant material returned to the soil to decompose into organic matter. So again, there is a net accumulation of acidity in the soil. The legumes excrete more H\(^+\) into the soil than cereals. (Table 2.)
Leguminous hay acidifies the soil rapidly.

Table 2: Typical amounts of alkalinity accumulated by a range of species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Plant parts</th>
<th>Alkalinity (kg lime per tonne plant dry matter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub clover</td>
<td>Whole tops</td>
<td>40</td>
</tr>
<tr>
<td>Lucerne</td>
<td>Whole tops</td>
<td>60</td>
</tr>
<tr>
<td>Lupin</td>
<td>Whole tops</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Grain</td>
<td>20</td>
</tr>
<tr>
<td>Ryegrass</td>
<td>Whole tops</td>
<td>40</td>
</tr>
<tr>
<td>Cereals</td>
<td>Whole tops</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Grain</td>
<td>5</td>
</tr>
</tbody>
</table>

Acidity in Katanning

It is important to understand and know why some soils are more at risk to acidity than others. The initial soil pH is one factor to consider. Soil pH less that 4.5 (CaCl₂) is considered low and pH greater than 6.0(CaCl₂) is high. The buffering capacity of the soil, that is the soils ability to resist a change in pH is also an important factor. The lower the clay content, the faster the rate of acidification. Sands and loamy sands will acidify faster than loams and clay. By categorising the soils in the Katanning region by pH and buffering capacity an approximately area of the current and future area of risk of soil acidity may be estimated. In the Katanning advisory district, approximately 18.9% of the area of 290,000 ha may have an immediate risk of soil acidity. 49% of the area, that is 751,000 ha may be at risk of soil acidification in the next 10-20 years. A break down of the area at risk as well as the pertinent soil types is given in Table 3.

Table 3: Area at risk of acidity in the Katanning Advisory District.

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Area (1000ha)</th>
<th>% area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1. (acid now)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yellow sandplain</td>
<td>290.5 (S)</td>
<td>19</td>
</tr>
<tr>
<td>Class 2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sand/gravel</td>
<td>751 (T)</td>
<td>49</td>
</tr>
<tr>
<td>yellow sandplain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>gravel</td>
<td>120 (S)</td>
<td>8</td>
</tr>
<tr>
<td>sand/clay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 3.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fresh colluvial sand (river)</td>
<td>46 (T)</td>
<td>8</td>
</tr>
<tr>
<td>red brown earth</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N.B.: Please note that the area affected represents all soil types in each category.

(T) surface soil (0-10cm)
(S) subsurface soil (15-30cm)
Management

There are two broad options for W.A. farmers to use when managing soil acidity. They are:

1. Reduce the rate of acidification by improving the utilisation of nitrate. Options include;
   * growing perennial pastures
   * strategic timing of nitrogen application so most is taken up by the crop
   * stubble retention (retaining and allowing alkaline material to decompose in the paddock)
   * feeding hay on the paddocks the hay was cut from
   * early time of sowing to maximise the growing season and the use of fertilisers.

2. Liming

Lime is a neutralising ameliorant and, like European farmers, West Australian farmers will one day have to adopt a liming programme on the farm. The rate of lime applied depends on the initial soil pH and the quality of the lime. Lime quality is assessed by the neutralising value (N.V.) and the fineness of the lime. A high quality lime will have a N.V. of 75% or better and 90% of the product you receive will pass through a 0.6mm sieve. If you do apply lime, leave a test strip to monitor the response. When determining the rate to apply it is very important not to overlime the soil as this will reduce the availability of manganese and may induce split seed in lupin crops. Take-all is suppressed by acid soils and overliming will cause any take-all fungus to become active and therefore reduce cereal yields, particularly if the grasses have not been controlled. Lime applied is more effective when incorporated into the soil.

Both these strategies are important for the farmer to consider. However, most important of all is to soil test regularly and monitor the rate of acidification on the key soil types. Whilst it was discussed that the medium soils will not acidify rapidly, they may acidify sufficient to reduce the production of medic pastures since medics are acid sensitive. Sandplain soils that are supporting productive lupin wheat rotations or are hay paddocks, are obvious targets for monitoring.
"A central component of almost all sustainable farming systems is the rotation of crops."

This quote is from an article on Sustainable Agriculture in the June 1990 issue of Scientific American. Farmers in America are being urged to adopt farming techniques which Western Australian farmers have generally used since the 1950s when the widespread use of pasture legumes began.

Rotations may be defined as "the growing of crops and/or pastures in a fixed sequence with the aim of maximising the long-term productivity and profitability of the farm." This is usually done by rotating the legumes (pastures and crop) with non-legumes (mostly cereal crops). In the Western Australian wheatbelt pasture legumes are mainly subterranean clover (Trifolium subterraneum) sown on the acid to neutral soils; barrel medic (Medicago truncatula) on the alkaline heavy red clay loams; strand medic (M. littoralis) on neutral to alkaline sandy soils; spineless burr medic (M. polymorpha) on slightly acid to neutral heavy grey clays, loams and sandy loams also on neutral to alkaline heavy red soils; yellow serradella (Ornithopus compressus) on highly acid deep sands. The main crop legumes are the narrow-leaf lupin (Lupinus angustifolius) grown on acid to neutral deep sands and sandy loams; and field peas (Pisum sativum) grown on neutral to alkaline clay loams and loams. The opposite to rotation is continuous mono-species cropping which with cereals is considered exploitive of the environment and eventually detrimental to profitability. The benefits of rotation versus continuous cereal cropping (or fallow/crop) are due to the effects of a legume on the following factors:

- livestock production
- soil nutrition
- soil moisture
- soil structure
- disease incidence
- pest incidence
- weed incidence

Before discussing these benefits a few disadvantages of legumes should be mentioned. Legumes can provide too much nitrogen which can lead to a following cereal crop with too much leaf material which can "hay off" prematurely, however, this is more a problem on heavier soils in the drier wheatbelt. Another problem with legumes (pasture and quite likely crop also) is a significant drop in soil pH which can increase soil acidity and lead to reduced production of both legumes and the non-legumes. It has also been shown that increases in organic matter from legume pastures and crops can give an increase in water repellency of sandy surfaced soils, which can cause problems with germination of future crops and pastures and may increase the risk of water erosion. Shallow rooted annual pastures have also been shown to increase the amount of water entering recharge areas of watertables, which may lead to waterlogging and salinity further down the catchment.

**Livestock Production**

The introduction of legumes into pastures has increased livestock production through the quantity and quality of the legumes themselves and through the effect of improved fertility on the production of other pasture plants. A further advantage of the annual legume pasture is their production of large quantities of seed. This lies on the surface or in the top 2 or 3 cm of soil and represents a substantial feed reserve for the dry summer period.
Similarly the lupin stubbles have proven to give valuable summer grazing provided care is taken to minimize the risk of lupinosis by grazing early and/or remove sheep after summer rain.

The above increase in wool and meat production and inclusion of crop legumes has given both increases in farm income and reduced income variability.

**Soil Nutrition**

The most important feature of legumes is that they can use nitrogen from the air to produced their own protein. This is called "nitrogen fixation" and is achieved by the successful combination of the plant and a bacteria called Rhizobium in nodules on the legume’s roots. In a pasture phase this nitrogen can build up in the soil to provide nitrogen for future non-legume crops. However, there are many losses from such a pasture system and the net result of how much does a year of pasture contribute, is very complex. See Figure 1 for the change in soil nitrogen at Wongan Hills. This pasture based on sub. clover increased soil nitrogen by about 60 kg N/ha. This is total organic nitrogen much of which is not immediately available to a following cereal and consists mainly of microbial matter. Usually 3% or less of the organic nitrogen is mineralised annually.

![Figure 1: Changes in total soil nitrogen following years of pasture and years of wheat at Wongan Hills, Western Australia (Rowland, unpub. data)](image)

In a legume crop phase (such as lupins) the main effect on soil nitrogen may be because the lupins (compared to a cereal) do not use any of the soil nitrogen, thus giving a "N saving" rather than a net increase. This is more likely if harvesting efficiency has been greatly improved so that all the seed is removed. This seed is high in nitrogen, 2-2.5 times that in wheat.
Another important aspect of soil nutrition that can be greatly improved by legumes, mainly pastures, is that of increases in organic matter. This is particularly important on the inherently infertile sandplain soils where legume pasture, with superphosphate applied, can lead to increases in residual phosphorus and soil organic matter, which leads to increased amounts of available phosphorus, sulphur and nitrogen; increased cation exchange capacity of the soil with accompanying increases in the amounts of potassium and magnesium.

**Soil Moisture**

Increases in soil organic matter, as mentioned above, should lead to improvement in the moisture holding capacity of poorly textured sandplain soils. It is possible that under pasture there may be more moisture left further down the profile because of the relatively shallow roots of the pasture legumes. This moisture would be available to a following cereal crop. This is not the case with the lupins which are a deep rooting plant and have been shown to remove water from deep in the profile.

**Soil Structure**

Improvement in soil structure (as measured by water stable aggregates) have been measured under legume based pastures. The longer the length of pasture the greater the increase, with a rapid drop when cultivated for cropping (see Figure 2). Such improvements were on better quality soils than the sandplain soils, whether there would be similar improvements is not known. It would be unlikely to occur under short rotations of one year legume pasture:one year cereal or a lupin:wheat rotation.

![Figure 2: Changes in water-stable aggregation of soil (0-7.5 centimetres) under differing rotations since clearing — Wongan loamy sand (adapted from Stoneman 1973)](image-url)
Traffic pans have been shown to develop in sandplain soils which are continuously cropped. These soil layers of high bulk density appear about 20 cm under the surface and are due to machinery movement. Lupins with their deep rooting ability may act as a "biological plough" and help fracture the hardpan.

**Effect on Following Cereal Crop**

Many trials have shown the extra yield gained by including legumes (mainly sub. clover) in the pasture phase of a rotation. One such trial at Wongan Hills (see Figure 3) showed that two years of sub. clover based pasture could lift yield by almost one tonne/ha compared to crops without pasture. Further years of pasture only increased yields slightly, however successive cropping decreased yields.

![Graph showing wheat yields](image)

*Figure 3: Mean wheat-yields of four successive crops grown after various lengths of subterranean clover-based pasture at Wongan Hills, Western Australia (Rowland, unpub. data)*
Use of grain lupins in rotation with wheat has shown that yield of wheat grown after a lupin crop is nearly 70% better than a wheat on wheat rotation. This result is the mean of 45 site x years for trials where:

- wheat on wheat - 0.76 tonnes/ha
- wheat on lupins - 1.29 tonnes/ha.

These yields are without added nitrogen fertilizer. Similarly growing field peas before wheat has increased wheat yields by about 0.5 tonnes per ha when compared to continuous wheat on heavier loam soils.

**Effect of Wheat on Subsequent Crop/pasture**

For lupins grown on sandplain soils the retention of the wheat stubble is essential for control of wind erosion in the following lupin crop. The cereal stubble, with minimum disturbance seedling, helps protect developing lupin plants from sand blasting. Good control of broad leaved weeds in the cereal crop can help reduce the density of these weeds for the following lupins. Root diseases affecting a lupin crop are less prevalent after a cereal crop than after pasture ley. Further, the presence of cereal stubble has been shown to help reduce the incidence of brown leaf spot by cutting down the spread of the spores by raindrops hitting the soil. Cereals also use up the nitrogen built up under a pasture phase. This nitrogen, if unused, would encourage the growth of grasses and other weeds in the lupin crop.

Pasture based on annual legumes (sub. clover or medics) need to build up a bank of seed in the soil which will persist through "false breaks" (early germination/s which are followed by death of the young seedlings, due to the soil drying out) a phenomenon which is very common on the sandplain soils. The legume seed must also be capable of persisting through the cropping phase of a rotation. In order to persist like this, the legume must be capable of setting a high proportion of hard seed which will not germinate even when the soil is wet. In general, the medics have a higher proportion of hard seeds than the sub. clovers and are better able to persist on soils suited to them.

**Duration of Crops and Pastures in the Rotation**

The integration of animals and legumes pastures and crops into dryland cereal-farming in the wheatbelt of Western Australia has produced a stable low-input agriculture which permits a range of cropping and animal enterprise options. The question of how much crop and how much pasture, what kind of livestock and how many are of significance. The profitability of each enterprise becomes a critical factor in deciding on allocation of resources between the crop and the animal. If returns for animal products are high compared to that from cereals, then the proportion of the farm in pasture would increase, whereas the cropped area would increase if livestock returns are low and/or that from crops are high.

A recent change in farming systems has been for intensive crop-crop rotations to be carried out on suitable soils of a farm. These have been based on grain lupins and wheat on good sandplain soils with use of field peas and wheat on loamy soils. However, it is essential that soil fertility is monitored under these system because, at best, they only maintain soil fertility. Even with use of minimum tillage, essential for lupin: wheat on sandplain soils, there is still a decline in soil structure, even if substantially less in many cases. These intensive systems also require a high degree of management input, often need considerable capital investment, and are more dependent on favourable climatic and marketing conditions than a mixed farming enterprise.
Further Reading

Pastures:


Lemon, J. Clover re-establishment in medium rainfall areas. Farmnote No. 78/89.


Lupins:


Field Peas:


Soil Acidity:


Water Repellent Soils:


Water Use:

NUTRIENT CYCLING FROM ORGANIC MATTER
Ian Fillery, Scientist, CSIRO

PAPER NOT AVAILABLE FOR THESE PROCEEDINGS
FARMERS DEVELOPING THE SOIL - A CASE STUDY

Danny Bignell, farmer, Broomehill

I am pleased to be able to assist the Broomehill Land Conservation District and Department of Agriculture with today's seminar.

I will outline what we are doing and why in our situation.

I have tried many different systems of soil, pasture and cropping management.

For the last 12 years we have been cropping 50-55% of arable hectares of which

- 50% to wheat
- 33% to legumes
- 17% to barley, oats, canola (oats for sheep feed).

All the cropped country is continually cropped, some of it for up to 20 years without a break and without any major problems, the last 12 years in a lupin rotation.

In most soils we have a 2 year cereal and 1 legume, but on heavy grey clays we extend this to 3 year cereal and 1 legume of peas.

For 3 years in varying seasons we tried to grow faba beans on this soil type but finished up renaming them failure beans.

The main problem was the soil pH being too low in parts of paddocks and if you can not get a reasonably even growth of legume over the entire area then there is a problem maintaining good yields on the following crops.

On some of the much lighter soils we use a 1 year lupin 1 year cereal system, these soils may have a tendency to blow if stubble is removed.

We used to be on a 1 crop then 3 year pasture and changed to a 2 year in 3 year out rotation. Then again changed to continually cropping the poorer country with a legume rotation and running sheep on the better feed paddocks which as a general rule would have been the best cropping paddocks.

On our earlier systems 1.4 to 1.6 tonne/hectare or 7 to 8 bags wheat to the acre was considered a good average.

The later system inputs are much higher but the returns are almost double with wheat average 2.6 to 2.7 tonne/hectare - 12.5, 13 bags.

Averages:

- Barley 2.6 15-16 bags
- Oats 2.7 20 bags
- Peas 1.4 to 1.5 average

We could now most likely achieve much better results on our earlier system with the chemical weed control that we know today but not so to the sheep enterprise.
On crop pasture rotation it takes 3 years of pasture after a good crop to reach 80% of its potential then you turn around and wipe the pasture out again in the spring to stop seed set, then after one crop of cereal it is 3 years again to get back to near potential.

In my area the sheep enterprise is equally as important as the cropping enterprise, it is a matter of getting the ratio of livestock to cereals correct to your particular farm and just as importantly your particular preference and expertise plus make maximum Net dollars.

We are finding the lupins are doing a great job in opening up soils by getting their tap root well down and incorporating more bulk of usable lupin stubble in the soil.

In trials we did 2 years ago deep ripping the soil prior to sowing lupins gave a dramatic increase in plant vigour and pod set.

Thus this season we have deep ripped 2/3 of the area sown to lupins but with the very wet July this year it would be too early to say whether it has been an advantage or disadvantage. I have the feeling the end result will be very much positive as root growth on ripped against unripped soil is a definite positive.

Not a great number of farmers have grown lupins (the soil renovators) in the past mainly because the earlier varieties had a similar toxicity to York Road poison, later varieties are much less of a problem but on the other hand are also a little more finicky to grow and much shorter to try to harvest.

These soil renovators (lupins) are often not a very paying crop, they don’t like it too wet (in other words your drainage must be right) and even then they will still suffer, most insects seem to love them, then in the late spring they are subject to yellow bean or cucumber virus. Then again in the summer they work for the wool corporation by reducing your sheep numbers in one foul hit if great care is not taken.

In our case we eat the stubbles out as early and quickly as possible to avoid toxicity then remove the stock after a rain as the rain, even if only 5-10mm, seems to put a crust on the soil and along with a little foliage will hold the soil together.

On the positive side lupin or peas are a tool to grow good crops, renovate poorer paddocks, improve soil structure and to increase your sheep carrying capacity by 25-30% through much thicker and better pastures not being destroyed to grow one cereal crop.

Lupin yields we have achieved are nothing fancy, the worst average being .93 t/ha and the best average 1.6 t/ha. We are always improving our preparation and sowing method and in doing so gradually improving yields, plus reducing crop failure risk.

Hopefully the agro ploughing of the soil beforehand will prove to be a real winner, far more so than deep banding of fertilizer perhaps as I have not seen a deep banding of fertilizer trial that could not have been confused with a deep ripping effect on old land.

If the season starts off wet without proper drainage and control of water in a wetter winter the potential yield of a crop can be almost halved. The initial cost of banks and drains can be recouped in the first year if it happens to be a wet one.

Those traditional areas that are too wet to grow anything all of a sudden become very productive when drained correctly thus the soil stops collapsing to any further degree and starts to get some life back into it with the subsequent extra root growth.

Likewise with areas on the sides of slopes where a dyke comes to the surface if the water can be
drained off then all the country below becomes much more productive and less likely to go saline. This is nearly always the case down the slope from gravel hills and ridges.

Then we get to the all time problem of stubble, in this area because we have a little longer growing season crops tend to grow taller than average wheat belt region which in itself creates an even bigger problem.

If you have got the system right and growing good crops plus utilizing the major part of your stubble as stock feed, then you will not get a tyned implement through the stubble to seed next years crop.

If it is ungrazed there is more of a chance as the standing stubble will feed through better.

In our case we built our own seeding machine which attaches to any air seeder box and sows through any thickness stubble while still retaining a reasonable even sowing depth. The front ploughing discs are a normal heavy duty cultitrasch configuration then another row of sowing discs with an independent depth control, then behind that again is a set of Walker rotary harrows which flick the stubble back on the surface of the soil.

Rollers behind do seem to improve germination, weeds and all especially when the moisture is a little light on.

All our country with exception of new paddocks is seeded with one pass and only when the soil is damp enough. The majority of our farm 2/3, is white gum country which if worked dry will become very powdery thus water repellent even with the stubble left there.

Fresh paddocks brought into the system are worked once then seeded as it is almost impossible to attain a correct sowing depth with one pass on country that has not been worked annually.

All lupin, peas, barley, oats and canola are sown direct into stubbles without any problem.

Wheat is sown direct into lupin stubble but where a second wheat crop in succession is grown the stubble is burnt or removed.

If burnt it is done after the break of the season and used as the first weed kill, so between that and heavy grazing of stubbles we generally manage to sow 25-30% of our programme with no Knockdown.

From experience, if we sow wheat into anything over a remaining 5-6 bag wheat stubble it reduces the potential yield by a considerable amount. It would appear to be more like a problem of toxins produced in the straw affecting the new plants rather than a utilization of extra nitrogen to break down straw.

Probably about 2/3 of potential is all that can be expected, on the other hand barley, oats and canola don't seem to be affected to the same degree and again it is essential to have as much stubble as possible there for lupin establishment (on the top not buried) for control of brown spot.

In summing up most sustainable development of the soil can be done profitably with a normal working programme. With

Correct drainage;
Tillage timing;
Retain as much stubble as possible;
Stocking care.
FARMERS DEVELOPING THE SOIL - A CASE STUDY

Graeme Smith, Broomehill

Farm Details
358mm rainfall, 260mm usable.
Cropped most of 5-7 years.
High rates of Glean.
Phosphate levels 20-25 ppm.
Nitrogen levels 3-5, very low.

Soil types:  Mallee clay  6.0-6.5 pH
             Grey clay     6.2-6.8 pH
             Red loam       7.0-10.00 pH
             Whitegum Sand  5.2-6.0 pH

Pasture options to fit into a system. (Looked at)
1. Clover and crop every 3 years.
2. Clover and crop year in, year out.
3. Continuous cropping rotation ie. wheat - peas and have continuous clover paddocks.
4. Medic year in, year out.

The option we went for was the medic system. Reasons:
1. High levels of feed in the non crop year.
   Present wool yield last year - 29.6 kg/ha over year in pasture area.
2. With the spraying out of grass in non crop year. Low V.M. levels in wool.
3. Lambs can be carried through summer and only shorn in Feb-Mar. Top wool prices.
4. With no grass in pasture, seeding can start on very first rain - yield increase.
5. With 400-700 medic plants/m² nitrogen levels as high as 40-60 unit/ha and we are talking organic nitrogen.
6. Increased organic matter.
7. No stubble to handle, no stubble to burn.
8. Large long tap roots to break up hard pans and increase earth worm numbers.
9. High value of summer feed.
10. Reduced risks of wind erosion.
11. Medic stand more prostrate, allowing more feed/bite; higher weight gain of sheep.
12. Nitrogen tied up in stubble and increase organic carbon development.

Types tried:
1. Seeded with small seed box on cultitrash.
2. Worked up, spread, vicron and harrowed.
3. Combine tyne scratched over top.
4. Air seeder with scarifier behind.

Most success: Worked up, spread and harrowed.

Combined:
Barley/Medic
Oats/Medic
Medic -
Dalyup:  sm
Nungarin:  mid
Dwallanup:  long
Circle valley:  large
EFFECT OF BIO-DYNAMICS ON OUR SOILS
John Benn, Farmer, Kojonup

1. 500 Spray is applied in late Autumn after the break of the season. This creates microbial and worm activity and helps to structure the soil.

2. Our old farm has had 6 applications of 500 spray with good results in soil structure and deep root penetration - down 12 inches plus. The effect on light soil was apparent in the first year, with colour and root growth holding the soil together. This also resulted in good water penetration and less run off.

3. Controlled grazing is also a must in the BD programme with a rotation time of no more than 3 weeks. This also helps with worm control in stock.

4. Cultivating is done with tyned machines which have a shattering chiselling affect on the soil and not a troweling finish.

Working speed must also be kept down. Deep ripping is for badly compacted and clay soils. A special type of ripper has been developed to lift and break the soil as it works.
CONCLUDING COMMENT

K. Goss, Acting Director, Division of Resource Management

I take this opportunity to conclude with a brief statement on the relevance of this Seminar to the long term challenge of sustainable agriculture.

Sustainable agriculture is an expression both you and I will hear often in the future.

Currently, we have the Ecologically Sustainable Development exercise sponsored by the Prime Minister, across nine areas including agriculture. As we see in the news, it is hotly debated among various interest groups and I do not see resolutions occurring quickly. It is a policy exercise "a world away."

On the other hand, the organisers of today also set out to give direction to sustainable agriculture, in a more meaningful and relevant way. The Seminar brought together knowledge from two sources - science and practice. This partnership of the farmer and scientist is crucial to achieving sustainable agriculture.

We can not afford each to go his or her own way. Scientific research and development without farm-scale testing can lead us down "blind alleys." Farmer experiences, in the absence of scientific explanations, lack credibility and will remain in the hands of few farmers. For instance, I thought this morning's session on soil microflora was particularly informative, and relevant to some farm responses being reported.

Sustainable agriculture to my mind involves another partnership - achieving the dual benefits of conservation and production. We can develop farming systems to increase both simultaneously. You were given some prospects for this today.

I congratulate the Broomehill LCDC and the Australian Institute of Agricultural Science for sponsoring this Seminar. This epitomises the partnership between science and practice. I also acknowledge the support given by the Katanning Office of the Department of Agriculture.

I trust you found the day as informative as I did, and offered you directions in achieving sustainable agriculture.
EARTH WORMS FOR FARMER'S SOILS

C.A. Parker, University of Western Australia

Introduction

Some 12 or 13 years ago, Dr Ian Abbott and I were comparing the soil fauna under native vegetation with adjacent farm soils. The virgin soils had a rich and varied population of soil animals larger than 2 mm, the adjacent farm soils had none except for a few subterranean termites. Later we discovered two species of earthworms near farm homesteads and along fence lines. One species is an active worm grandly named Aporrectodea trapezoides (At) (European origin) and Microscolex dubius (Md) from South America.

Later, Mr Tom McCredie, still an undergraduate student and I, assessed the biomass of the earthworm A.t. on the University's farm at Allandale near Woorooloo. The soil had not been disturbed for several years because it was cut off by a little creek. The pasture was only about 50% clover with weeds predominating. The biomass of the earthworms was around 800 kg/ha which is high compared to British figures. These earthworms aestivate (sleep) over the summer between approx. 25-40 cm below the surface. The soil was honeycombed with their burrows.

Western Farmers funded us for most of our research until recently, with substantial help from I.C.I. and 'Town and Country' in the early stages. This funding made it possible to do some long term field work.

Mr McCredie and I chose two different soil types near Dangin on the farms of the Johnston family and Mr Lester Strickland. The two species of earthworms were collected from the Darling Scarp because it had been a late season in the wheatbelt. Our first upset was that earthworms appear to dislike being shifted to different soil types. They left the plots, and we lost a year's results. From then on we have collected them from nearby fencelines; but we "fence them in" just in case!

Results

The two species A. trapezoides and M. dubious can significantly improve the macroporosity of soils and water flow in grey (hardsetting) sandy loams or brown sandy loams at Dangin. A naturally occurring population of A. trapezoides in soil beneath a wheat crop in December 1990 significantly increase sorptivity and rate of water flow as compared with adjacent soil with no earthworms.

P.S. Earthworms were examined for weedicide damage, but we found none. Indeed, some farmers have reported that they flourish after the weeds are killed.

C.A. Parker
17 Sept 1991