



LEADERS IN BIOLOGY AND MINERAL FERTILISERS

Innovation through Research & Development

Hi Everyone,

Western Mineral Fertilisers is an innovative, progressive company focussed on developing & delivering sustainable & cutting-edge approaches to meet the challenges of the rapidly changing agricultural system. In this newsletter we present a summary of a sample of the extensive research results from the many independent trials conducted over the past 5 years. The trial data shows that Western Mineral Fertiliser mineral and biological programs are not only resulting on average best yield and \$ return per ha, they are also showing measurable positive changes in the soil. These can assist in increasing soil fertility both chemically & biologically, which along with the obvious benefits, will also help in the long-term viability of our soils.

The research also confirms that **the results** are achieved on the Western Mineral Fertilisers mineral and biological program with managed Nitrogen inputs, without all the side added products. This not only keeps the program **simple** but also **minimises the input costs**.

Fertiliser pricing and general farm inputs costs are certainly a serious issue, unfortunately the cost of Phosphate, Potassium and Nitrogen have affected our pricing which has seen some big increases through the 07/08 season. The only consolation is the higher the price the acid fertilisers become, the greater the price difference between **us & them**; for example a standard MAP type product has gone from \$750± to \$1,400± from October 2007 to June 2008, an increase of 90% where our NPK Crop Plus has gone from \$630± to \$950± in the same period, a 45% increase.

This season saw an exponential growth in the demand for our product - where orders very nearly filled the season production by November 2007; this was on top of the company doubling its manufacturing output. Even though the '09 year production will again increase significantly we strongly urge farmers to book their requirements as early as possible. Demand will again outstrip supply.

Handling - the Western Mineral Fertiliser products are designed to flow through precision and air seeders. There is however a higher dust load in the product than with acid fertilisers. We do apologise for any inconvenience this may have caused and want to make it clear that addressing this issue is a major priority of the company. The nature of



On farm trial site - Bindoon

the product (low moisture content and where micro-fine powders are used; in conjunction with constraints preventing the use of commercial dust polymers - due to their negative affect on beneficial biology) has made finding a solution more difficult. The good news is we are currently trialling 2 new biologically based polymers and in conjunction with some changes in our manufacturing process should make noticeable differences in product dust levels. Please be aware when using our products to keep to a minimum excessive product handling (particularly avoid over auguring), and monitor areas where dust can build up in your seeding equipment, such as metering wheels.

In summary, the overall field and trial results show the success of our standard mineral/biological program. Not only do they on average out return conventional acid fertiliser programs dollar for dollar, but also will start addressing serious soil health issues, while reducing reliance on high chemical inputs and escalating farm input costs.

Stephen Frost
Managing Director

Visit us at DOWERIN and NEWDEGATE

Meet with our Technical staff, on hand to discuss:

- Latest Microbe & Soil Nutrition Technology
- Our Mineral / Biological Programs
 - Ideal for Cropping and Grazing
- Silicate based compound Mineral Fertilisers
- Our Beneficial Microbe Seed Dressings
- Excellent on-Farm Yield Results
- Research Trial Results

‘Soil Health is more than simply applying Lime to an acid soil’

A Brief Review by Paul Storer, Microbiologist, BSc, MSc.

Soil health and **soil quality** are terms often used to describe the soil's ability to support plant growth without harming the environment or becoming degraded. **Soil quality** is defined by the interactions of a soil's *measurable* chemical, physical, and biological properties. **Soil health** is defined as the capacity of soil to function as a living, dynamic organism that responds (either positively or negatively) to the way it is managed and maintained – the soil varies from being in a ‘fit’ and ‘healthy’ condition to an ‘unfit’ and ‘poor’ one. The natural balance of the soil is disturbed when the soil is used to produce crops – particularly when only small amounts of plant material / organic matter are retained or reincorporated. **Soil health** is all about utilizing farming practices that encourage the cycling of organic matter, increasing mineral nutrient status, multiplying beneficial biological / microbiological activity and improving water infiltration – leading to improving soil structure, which also improves crop root health (1, 2).

The **Rhizosphere** is the zone of soil immediately surrounding a



plant root that is directly influenced by root secretions and associated soil microorganisms. The **rhizosphere** plays a critical role in the nutrition and general health of plants (3);

with the majority of a plants nutrient cycling and disease suppression occurring immediately adjacent to the roots (4). The **rhizosphere** is an area of intense biological and chemical activity teeming with bacteria and fungi that feed on sloughed-off plant cells and root exudates (including amino acids, organic acids, carbohydrates, sugars, vitamins, mucilage, and proteins). In addition, the bacteria and fungi influence root morphology, nutrient bio-availability and uptake, plant growth factors, metabolic changes and the growth of the entire plant (5, 6, 7).

So, plant roots can affect soil micro-organisms, and soil micro-organisms can, in turn, effect plant growth.

Michelle Watt (CSIRO Plant Industry) describes **the rhizosphere as the next big frontier in farming**. She maintains that roots are the best way to influence soil biology to enhance farming systems. The emphasis is on selection of cereals with bigger, fast-growing roots that access more nutrients and water, and that form interactions with soil organisms beneficial to plant growth. Roots are the largest component of the soil biology, including the living roots of the crop and the dead roots from previous crops. Roots are the source of almost all the below-ground carbon that feeds organisms such as bacteria, fungi, protzoa, nematodes, ants and termites. Roots create soil spaces for future roots and organisms, and aggregate soil particles with their root hairs and special glues. The size of the soil spaces influence water movement and its availability to the crop (8).

The health and the mineral balance of our agricultural soils are in decline. This decline is partially due to the fact that the importance of beneficial soil biology has largely been ignored, and that farming practices have mined the soil of more minerals than have been replaced by conventional fertiliser's.

Conventional soluble fertilisers usually provide the three main plant macro-nutrients (nitrogen, phosphorus, and potassium). Some conventional fertilisers *may* provide secondary plant nutrients (calcium, sulfur, magnesium); and *occasionally* even some trace elements (or micronutrients) which also have a role in plant nutrition (such as: boron, manganese, iron, zinc, copper and molybdenum). In addition, these conventional fertiliser programs tend to be very acidic and have high salt indexes – factors that can create more detrimental problems in the soil than they solve (eg acidification, activation of Aluminium toxicity, nutrient tie-up

and antagonism between nutrients, selection against beneficial micro-organisms, etc). Hardly any conventional fertiliser programs address and / or include biology! **Simply applying lime alone is not going to have a major affect on Soil Health!**

In addition, climate change is now being felt in WA – a combination of natural variability and a trend due to the enhanced greenhouse effect; plus stratospheric ozone depletion may also be causing a southward shift of the westerlies & associated rainfall systems (9). Not only has the average rainfall decreased in *recent times*, with prolonged drought periods, but the actual rainfall patterns have also changed significantly (now tends to be more summer rain than before, & less winter rain in the critical months of May, June & July).

Western Mineral Fertilisers and Soil Health:

Western Mineral Fertilisers Mineral and Microbe programs are designed to help remineralise depleted nutrients, restoring mineral balance to the soil, and to grow larger roots to increase organic matter levels. In addition, by increasing the root system and ultimately the area for colonization by beneficial microbes (such as Mycorrhizal fungi), the crop may have better access to soil moisture during periods of mid-winter water-stress / drought. It may also access additional nutrition later in the growing season (10, 11, 12, 13).

Remineralisation involves the addition of mineral fertilisers of ore-based origin. The “Mineral” fertilisers can contain up to 65 different minerals including the major plant nutrient – Silicon (for more info – see [Minerals in Nutrition Tech Sheet](#) on the WMF website). Release of nutrients from these mineral fertilisers can be accelerated by beneficial micro-organisms & biological activity (14, 15, 16).

In dryland agriculture, farmers can respond to many of the direct effects of climate change, deal with changes in weather patterns; & the challenges of mineral & biologically depleted soils by adjusting their practices. A Mineral/Microbe program that encourages larger roots systems & increases farmer \$ returns while restoring the soil asset - is an important place to start.

REFERENCES:

- Romig, D.E., M.J. Garlynd, R.F. Harris, and K. McSweeney (1995). How farmers assess soil health and quality. *Journal of Soil and Water Conservation*. 50:229-236.
- Doran, J.W., M. Sarrantonio, and M.A. Liebig (1996). Soil health and sustainability. *Advances in Agronomy*. 56. pp 1-54.
- Curl, E. A. and B. Truelove (1986). *The Rhizosphere*. (p. 1-8, Introduction; p.140-166, Microbial Interactions; p. 167-190, Rhizosphere in Relation to Plant Nutrition and Growth). Springer-Verlag, New York.
- Azcon-Aguilar, C. and J.M. Barea (1996). Arbuscular mycorrhizas and biological control of soil-borne plant pathogens - An overview of the mechanisms involved. *Mycorrhiza* 6:457-464.
- Morgan, J. A. W., G. D. Bending and P. J. White (2005). Biological costs and benefits to plant-microbe interactions in the rhizosphere *Journal of Experimental Botany*, Vol. 56, No. 417, pp. 1729-1739.
- Atkins, C.A.; P.J Storer, E.B. Young (1991). Translocation of nitrogen and expression of nodule-specific uricase (nodulin-35) in *Robinia pseudoacacia*. *Physiologia Plantarum* Vol. 83(3) p. 483-491.
- Gogala, N. (1991) Regulation of mycorrhizal infection by hormonal factors produced by hosts & fungi. *Cellular & Molecular Life Sci*, V 47, 4, pp331-340.
- Watt, M. (2008). Your Soils – Your Future. Proc 2008 State Soil Health Forum.
- Pittock B. (2003). Climate Change - An Australian Guide to the Science and Potential Impacts, Australian Greenhouse Office.
- Augé, R.M., A.J.W. Stodola, R.C. Ebel, & X. Duan. (1995). Leaf elongation and water relations of mycorrhizal sorghum in response to partial soil drying: two *Glomus* species at varying P fertilization. *J. Expt. Bot.* 46:297-307.
- Blackwell, P., S. Shea, P. Storer, Z. Solaiman, M. Kerkmans, and I. Stanley (2007). Improving wheat production with deep banded Oil Mallee Charcoal in WA, Proc. International Agrichar Initiative Conference Terrigal NSW.
- Duan X, D.S. Neuman, J.M. Reiber, C.D. Green, A.M. Saxton, & R.M. Augé (1996). Mycorrhizal influence on hydraulic & hormonal factors implicated in the control of stomatal conductance during drought. *J. Exp. Bot.* 47:1541-50.
- Kothari S.K., H.Marschner, E. George (1990). Effect of VA Mycorrhizal fungi and rhizosphere microorganisms on root and shoot morphology, growth and water relations in maize. *New Phytol.* 116 pp 303-311.
- Clark R.B., S.K. Zeto (2000). Mineral acquisition by arbuscular mycorrhizal plants. *J. Plant Nutr.* 23 pp 867-902.
- Cooper K.M., P.B. Tinker (1978). Translocation and transfer of nutrients in vesicular-arbuscular mycorrhizas. *New Phytol.* 81 pp 43-52.
- Cui M.Y., M.M. Caldwell (1996). Facilitation of plant phosphate acquisition by arbuscular mycorrhizas from enriched soil patches. 1. Roots and hyphae exploiting the same soil volume. *New Phytol.* 133 pp 453-460.

Summary of Research Trials (in this newsletter)

Western Mineral Fertilisers (WMF) has a progressive approach to R & D. Numerous independent & on-farm trials are conducted across WA in varying soil types and climatic conditions (from the adverse conditions in the North East, to the highly fertile areas and more consistent rainfall regions in the Southern wheatbelt). These trials are designed to enhance our understanding of, and develop and possibly improve WMF's mineral / microbe programs - thereby keeping WMF at the innovative cutting-edge of agriculture.

MAXIMIZING YIELD POTENTIAL UNDER NON-RAIN LIMITING CONDITIONS

A proprietary microbial **bio stimulant** product is being marketed in WA. The product purported feeds and increases the population of beneficial micro-organisms in the soil. This trial was set up to examine whether the bio stimulant product enhanced a **WMF mineral fertiliser** program as compared to a **conventional DAP** fertiliser program.

The wheat trial was conducted at Katanning in 2007 – rainfall was not limiting, and adequate post emergent N (60kg/ha urea) was applied. **This preliminary trial showed that there was no net advantage in adding the bio stimulant to the WMF program, and that in fact, there was a cost penalty of between \$59 to \$175 per ha (2.9% to 8.1%). Not only were the standard WMF programs cheaper to implement, but they significantly out performed the DAP programs...** see Page 4:

FERTILISER COMPARISON TRIAL

A proprietary liquid row support treatment (calcium and molasses, biological liquid and phosphorus) is being marketed in WA. The liquid treatment is purported to increase availability of soil nutrients, enhance root development and also displace sodium. This trial was set up to examine whether the liquid row support treatment enhanced a **WMF mineral fertiliser** program; and also compared a **conventional MAP/MOP** fertiliser program.

The wheat trial was conducted on a Ravensthorpe farm by the RAIN group in 2007. Parameters such as germination rates and crop vigour (*above ground* biomass assessed at various developmental stages) ultimately showed no significant differences between any of the treatments. Unfortunately *below ground* root growth and vigour was not assessed (root development is a key component of the early development of crops on the mineral program) – above ground monitoring does not take this into account. The **standard WMF mineral fertiliser** program *biologically out performed* the **Mineral+Liquid** row support program for **Fungal:Bacterial Ratio, Microbial Biomass & % Root colonisation by VA Mycorrhiza**. The mineral fertiliser packages produced a significantly higher level of Mycorrhizal (VAM) colonisation than the conventional fertilisers.

Bottom line - the **standard WMF Mineral** fertiliser package yielded 1.952t/ha, the **Mineral + Liquid** support package 1.718t/ha, followed by the **Conventional** 1.686t/ha. According to the 2007 AWB Pool matrix, **there was a cost penalty for applying the Liquid support of about \$84.00 per ha...** see Page 5:

MINERALISING THE PLANT

Plants can lack proper nutrition (minerals) due to poor root systems (caused by factors such as chemical root pruning, aluminium in the soil, poor Phosphorus availability, poor soil structure, and lack of biological activity).

This wheat trial was conducted in 2006 at Mt Madden, to evaluate root development, nutrient uptake and production. The **WMF mineral / biological** program showed significantly increased **root to shoot ratios** and **root surface areas**, as well as higher Phosphorus, Calcium and Potassium uptake in comparison with the conventional fertiliser. **Based on the golden rewards system of the AWB the mineral treatment returned \$171.92 per hectare more than the conventional system...** see Page 6:

REHABILITATION-PASTURE RE-ESTABLISHMENT

The nutritional quality of pasture, forage and diet plays a major role in the health and reproductive performance of animals. Micro or trace mineral deficiencies are associated with soil deficiencies or UN-availability (due to lock-up in the soil matrix).

This pasture trial was conducted at Capel in 2004 using a combination of WMF beneficial microbes and "Natural" based mineral fertiliser (*not a standard pasture program*) compared to a conventional High Analysis program - to assess possible improvements in soil properties, pasture establishment and in ameliorating hard setting soils. Results of the Mineral/Microbe program showed improved mineral levels and an increase in dry matter (less moisture), improved production (based on dry weight) and better pasture species composition (less weeds). **The High Analysis program contained high moisture content** (more potential for scouring), **less dry matter, more fragile plants, which would result in lower feed value...** see Page 8:

FUTURE DIRECTIONS IN AGRICULTURE

WMF has made a long term commitment to the future of agriculture, and to improving our programs for our customers. One of the many exciting and novel areas of innovation that is being actively researched at this time is in the use of **Bio-Char** as a possible soil ameliorant to complement the mineral / microbe programs - and to potentially improve *Soil Health*. These are the preliminary stages of research, however it should be noted that the programs with Bio-Char are in their infancy, *and are not commercially available at this stage*. The following research reports are published here to demonstrate the potential for Bio-Char.

CAN BIOCHAR HELP DRIVE BIOLOGICAL FARMING?

Biochar (charcoal) has been reported to encourage microbial activity in soil and increase mycorrhizal colonisation of crops. Various trials have been conducted (wheat and pasture) to determine the possible net benefits of employing wood Biochar in combination with mineral fertiliser and beneficial microbes, compared to soluble fertiliser.

Preliminary results show Biochar is effective at encouraging mycorrhizal colonisation of wheat (even two years after being applied to soil), and trends show yield increases in low phosphorus status soils. Early growth of tropical perennial grasses on deep white sand have also been improved by a mix of biochar and WMF product, compared to conventional DAP use... see Page 11:

USE OF BIOCHAR, MINERAL FERTILISERS AND MICROBES FOR SUSTAINABLE CROP PRODUCTION

A glasshouse pot trial was carried out in soil from a site used for a previous biochar field experiment. A WMF Mineral fertiliser + microbes treatment was used and the effects of adding three types of wood biochar was compared. The plants were either well-watered (80% of field capacity) or subject to drought stress (40% of field capacity) and grown through to ear emergence.

The results showed that wood biochar enabled improved shoot and root growth in well-watered conditions and better Mycorrhizal root colonisation in drought stress. Plant biomass was not increased by biochars in drought conditions. **All biochars increased Mycorrhizal root colonisation when added with the mineral fertiliser including microbes...** see Page 12:

There are many new "stand alone" Biological products coming onto the market – ask for the independent scientific research and data that validates any claims made.

IF YOU ARE USING WMF MINERALS and MICROBES - AND YOU PLAN TO USE ANY OTHER SEED DRESSING TREATMENTS – CONTACT WMF OFFICE AND CHECK FOR COMPATABILITY.



FERTILISER COMPARISON TRIAL

CROPPING – Ravensthorpe Region

Summary of data (see RAIN 2007 Yearbook for full report).

AIM:

To compare the crop growth and soil health effects of conventional granular fertilisers (MAP + MOP), granular mineral fertilisers (mineral NPK and microbial seed dressing) and mineral fertilisers with liquid row support (mineral NPK, calcium and molasses, biological liquid and phosphorus).

TREATMENTS:

This trial was conducted at Andrew Chambers' farm, 25km NE of Ravensthorpe. Wyalkatchem wheat (*Triticum aestivum*) @ 75kg/ha was seeded on 24 May 2007 using a plot seeder with knife points and press wheels, and a row width of 22cm.

Treatment	Components	Rate	Timing
1. Conventional	Agflow Extra	60kg/ha	Banded
	MOP	20kg/ha	Banded
	Urea	50kg/ha	Top dressed
2. Mineral	NPK Crop Plus	80kg/ha	Banded
	Hort Blend microbes	500g/t seed	Seed dress
	Liquid N	25L/ha	Sprayed
	Urea	27.5kg/ha	Top dressed 11 WAS
3. Mineral+Liquid	NPK Crop Plus	50kg/ha	Top dressed
	TC16	15L/ha	Banded
	Calsap	5L/ha	Banded
	Liquid N	25kg/ha	Banded
	Phosphorus	1kg/ha	Banded
	Urea	30kg/ha	Top dressed 11 WAS

RESULTS AND DISCUSSION:

When crop vigour was rated at 12 DA-S; Treatment 3 (mineral fertiliser plus liquid row support) was best performing, although it was not significantly better than Treatment 1 (the conventional fertiliser package). Early crop vigour (above ground biomass) was found to be lowest for Treatment 2 (which may be due to the microbial seed dressing slowing germination); however by the time the crop vigour was reassessed at 50 DA-S, there was no significant difference between any treatments.

Table 1. Results for Crop Vigour (1-9) at 12 & 50 DA-S, Crop Plant Counts (plants/m in row) at 50 DA-S, and Crop Head Counts (heads/m in row) at 159 DA-S:

Treatment	12 DA-S	50 DA-S		159 DA-S
	Vigour	Plant Counts	Vigour	Head Counts
1. Conventional	7.3 ab	42.4 a	7.7	23.5
2. Mineral	7.0 b	37.1 b	7.0	22.9
3. Mineral+Liquid	8.0 a	43.0 a	6.7	25.1
LSD (P=.05)	0.8	3.7	NSD	NSD
CV	4.5	4.0	7.4	12.7

Means followed by same letter do not significantly differ (P=.05, LSD)
Crop Vigour (scale 1-9 - where 1= Very poor; 9= Excellent crop vigour)

Plant counts at 50 DA-S also suggested that the seed dressing may have had an effect on plant germination, with Treatment 2 showing lower crop density than other treatments - despite this the crop was able to compensate for this, and when crop head counts occurred at 159 DA-S there was no significant difference between any of the three treatments.

Splitting Nitrogen application in Treatments 2 and 3 may have improved Nitrogen use efficiency and N uptake in these treatments, when compared with a single IBS application used in Treatment 1, both which can affect crop yield. This would also place Treatment 1 at a relative disadvantage and thus the yield response observed may be a response to the late applied Nitrogen fertiliser (urea top-dressed at 11 WAS).

Table 2. Results for Fungal : Bacterial Ratio, Microbial Biomass (g/kg soil) & % Root Colonisation by VA Mycorrhiza:

Treatment	F:B Ratio	Microbial Biomass	% VAM Root Colonisation
1. Conventional	3.02	9.18	3.10 b
2. Mineral	1.91	14.14	11.23 a
3. Mineral+Liquid	1.72	11.56	8.80 a
LSD (P=.05)	NSD	NSD	4.39
CV	36.69	21.46	21.91

Means followed by same letter do not significantly differ (P=.05, LSD)

Table 3. Results for Grain Yield (t/ha) at 191 DA-S:

Treatment	Yield	Protein	Moisture	Spec Wt	Screens
1. Conventional	1.686	9.7	10.2	78.5	8.5
2. Mineral	1.952	11.0	10.2	76.5	7.3
3. Mineral+Liq	1.718	10.7	10.2	78.9	7.9
LSD (P=.05)	NSD	NSD	NSD	NSD	NSD
CV	8.050	5.6	0.0	3.4	6.5

CONCLUSIONS:

The Mineral + Liquid package showed highest early above ground vigour and plant emergence, although it was not significantly better than conventional fertilisers. Early crop vigour and emergence was worse for the alternative Mineral fertiliser package – however plants in this treatment were able to compensate, and later crop vigour and head counts showed no significant differences between any of the treatments.

There was no significant difference between treatments for Fungal/Bacterial Biomass ratios or Total Microbial Biomass, however both of the alternative mineral fertiliser packages produced a significantly higher level of Mycorrhizal (VAM) colonisation than the conventional fertilisers. Despite this, VAM colonisation was relatively low in all treatments.

The Mineral fertiliser package (Treatment 2) was found to be the highest yielding treatment at 1.9t/ha, although this was not significantly more than the Mineral + Liquid package at 1.7t/ha.

This plot size trial was a duplication of a farmer size Alternative Fertiliser trial at Owen Brownley's, and was undertaken to demonstrate the effect of the alternative fertilisers on various soils and under different farmer practices. Although this report indicates no statistically significant differences in yield, using the 2007 AWB Pool matrix, the difference in net return between treatments was approximately \$84.00 per ha (Table 4). RAIN plans to repeat similar treatments across the Shire in 2008.

Table 4. Gross Return Comparison:

Treatment	Average Yield	Fertiliser Cost	Increments Decrements	Net Return	\$ Difference
1. Conventional	1.69	\$65.68	-\$7.00	\$433.32	-\$84.72
2. Mineral	1.95	\$69.66	\$2.00	\$518.04	0
3. Mineral+Liq	1.72	\$79.27	-\$2.50	\$433.73	-\$84.31

Acknowledgements:

This information has been produced by the Ravensthorpe Agricultural Initiative Network (RAIN) with funding provided by South Coast NRM Inc., through the Australian and State governments, for the project "Soil Health and Precision Agriculture" (Project ID 043057). Intellectual property including all copyright belongs to the State of Western Australia.



MINERALISING THE PLANT

By H.F. De Wet (MSc Soil Chemistry)

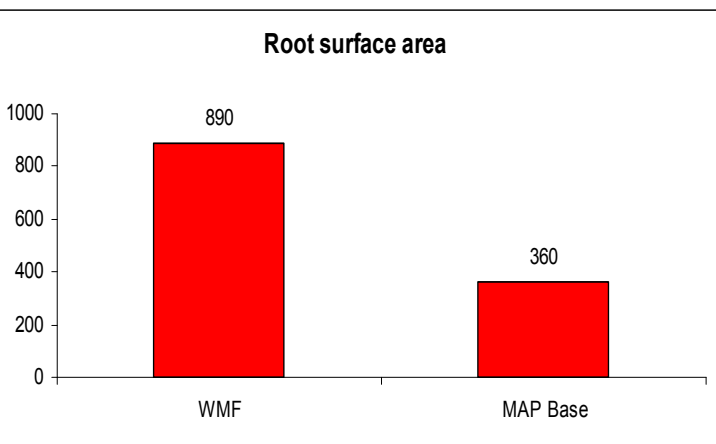
Conditioning the soil is very important if you want to utilise maximum of what the soil has got to offer in the way of nutrition. A highly mineralised plant will give more resistance to fungal and insect attacks. Also a plant rich in minerals will have a higher resistance to frost.

The excessive use of chemicals to try and control disease, and high rates of wipe-out with frost over the last couple of years was the motivation for Owen Brownley (Lake King) to look at an "alternative" way to successfully grow a crop.

One of the main reasons for the plants lacking proper nutrition (minerals) is a poor root system. The lack of roots could be due to several reasons like chemical residue pruning roots, high levels of aluminium in the soil, poor soil structure resulting in anaerobic conditions, poor Phosphorus availability (related to high level of Aluminium) and lack of biological activity.

A replicated trial was conducted in the 2006 growing season to evaluate root development, nutrient uptake and production on the property of Owen Brownley - comparing a Mineral / Microbe program with a conventional MAP base fertiliser program. The availability of nutrients is related to soil acidity. In general macro-nutrients are more available in lower acid conditions while micro-nutrients, except Molybdenum, are readily available when the pH drops. One of the concerns is the acidification in the root zone caused by the nitrification process of ammonium-N (source of Nitrogen in MAP). Studies show that this process leads to the mobilising of Aluminium. The higher concentration of Aluminium could be responsible for Phosphorus fixation, making the P efficiency very low. In contrast the mineral fertiliser is Silicate-based and non-acidifying. Silicate is highly negatively charged and has an affinity to react with Aluminium. Due to the Silicate forming a complex with Aluminium (alumino-silicate), more Phosphorus is available for plant uptake.

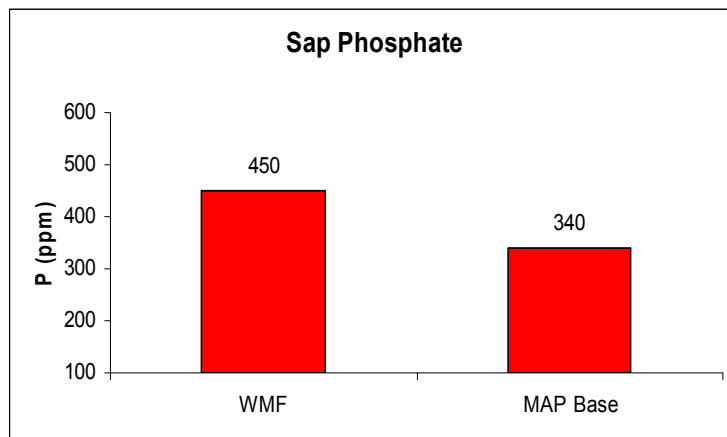
Data collected from the trial showed a higher root to shoot ratio where the mineral fertiliser had been used in comparison with the conventional fertiliser. This is confirmed by a bigger root surface area on the mineral fertiliser plants.



Average root surface area.

The bigger root systems in relation to the rest of the plant could be due to a few reasons; one may be the higher Phosphorus availability in the plants that were seeded with the mineral product.

Work has been done to show that plants have to seek out Phosphorus much more than nutrients like Nitrogen, Potassium, Calcium and Magnesium. A good healthy root structure is therefore essential for adequate uptake of P. One of the most important roles of Phosphorus is its involvements with ATP. This is one of the energy molecules used to power the plants chemical



processes.

Not only Phosphorus was significantly higher in the mineral / biological program, but also Calcium and Potassium uptake. Calcium is responsible for the structural integrity and stability of plant tissue and together with other substances regulates inward and outward movement processes in plant cells and tissues. These processes are important in managing plant stress like disease, insects, lack of moisture and frost. Potassium is important in the maintenance of water pressure inside the plant. With adequate K levels, cells remain turgid, one of the physical requirements for growing a proper crop. Like Phosphorus, Potassium is involved in both the accumulation and utilisation of energy.

Owen is very excited about the long term benefits of having a bigger root system, contributing to the organic fraction of the soil hence improving soil biological activity. Also the fact that the potential is there to reduce inputs due to the more effective way supplying nutrition.

Although there was no substantial frost event during the 2006 season to evaluate these different programs the mineral fertiliser treatment result in a higher grain yield and quality. **Based on the golden rewards system of the AWB the mineral treatment returned \$171.92 per hectare more than the conventional system.**



Owen Brownley at the Lake King trial site

CROPPING – Grain Quality

At different stages of grain development, various environmental factors, *such as frost*, can affect yield. Generally, frost can cause empty florets & severely pinched grains (which are likely to be screened out due to small size) - resulting in reduced tonnage & adversely affected grain quality. The poor quality can lead to downgrading of harvested grain to ‘feed wheat’. Most of these low quality grains will not be able to be used as seed for the following year - due to poor germination and low vigour.

WHEAT HEAD SIZES, SEED FILLING & GRAIN WT:

The following data is the result of Grain Mapping vs Floret position of 100 wheat head samples comparing Conventional and WMF Mineral Fertiliser / Microbe / Seed treatment Programs:



Arrino Wheat
harvested
2nd Dec 05
(Narembeen)



Number of samples = 100	WMF	Conventional
Av. Length Wheat Head	87mm	79mm
Av. Number Grains per Head	36 seeds @5.91g	30 seeds @3.9g
Av. Weight of Grains:	0.164g/seed	0.130g/seed

CONCLUSION - WMF Mineral Microbe Programs:

The significant difference found between the Conventional and Mineral/Microbe/Seed treatment programs in Grain Quality is reflected across the WMF Trial sites and “on-farm”. These Results included:

- Consistently Higher grain numbers (Av. up 20%)
- Consistently Higher grain weight (Av. 26% higher hectolitre wt)
- Considerably less shrivelled grain and screenings
- Considerably less Frost effects.

PASTURE - INTRODUCTION:

Silicate minerals have the potential to be utilized in the rehabilitation of soil¹ (particularly in mine site reclamation). Mineral ores are relative slow to weather². Micro-organisms such as mycorrhizal fungi have the ability to selectively acquire nutrients^{3,4,5,6,7} (e.g. inorganic P, K, iron & silicon) for host plant species by colonizing & biologically weathering mineral ores, as found in Silicate based mineral fertilisers. Silicate minerals also show potential as soil ameliorants – such as liming agents, increasing ion exchange capacity; water holding capacity; organic carbon storage and turnover; and coarse pore volume in clayey soils^{8,9,10,11}.

The objectives of part of this project was to assess possible improvements in soil properties through the addition of silicate mineral fertilisers and enhancing microbial activity in ameliorating hard setting soils and pasture establishment.

AMELIORATION OF HARD SETTING SOILS

This trial was conducted in the winter of 2004 to evaluate the addition of amendments in influencing hardsetting subsoils, following mineral sand mining east of Capel, WA. The subsoil in this area was returned to the mine void during the summer period of 1999/2000. Approximately 500mm of subsoil originating from this area was spread over the underlying clayey overburden. By 2001/2002 this subsoil had hardset to a depth of 300-400mm, becoming friable during winter rains, & hardset again from October 2002 to April 2003. *Hardsetting observed in this reconstructed subsurface limits the effectiveness of rehabilitation plants due to a combination of limited soil moisture availability & impeded root penetration. This is reflected in limited pasture growth at this site.*

Prior to trial establishment, four trenches were installed for description & base line sampling. Soils characterised by an upper 200-300mm sandy topsoil (organic carbon concentrations of approximately 2.1%, average clay 3.86±0.94% & silt contents 2.06±0.27%). Average bulk density values are 1.44±0.18 g/cm³ & stable micro- & macrostructure. The topsoil is acidic, with low electrical conductivity values. Base saturation & exchangeable acidity however indicates that base cations occupy the exchange complex. The subsoil by comparison has higher average clay contents (6.46±3.37%) & higher bulk density values (1.77±0.08 g/cm³). Although the microstructure is stable, the macrostructure is highly unstable. A higher exchangeable aluminium & exchange acidity, with corresponding lower base saturation occurred in the subsoil.

In part of the trial, one hectare plots, each with four 2,500 m² subplots were established each with separate treatments. Treatments including silicate mineral fertilisers (insoluble P, no N) and were applied in June 2004.

Pasture species including clover & ryegrass were established during the 2004 growing season. Following seeding, the pasture was allowed to grow without additional inputs and cattle were excluded from the trial. The topsoil (0-100mm) and plant material were harvested in the first week of October 2004. The herbage was then incorporated into the soil to increase organic matter and water holding capacity within the topsoil. Soil samples were analysed for a range of nutrient and chemical properties while herbage material was collected for production calculations.

Four treatments were applied to this part of the trial:

- **Treatment 1 (Control):** Control plots (no treatment);
- **Treatment 2 (WMF):** Western Mineral Fertilisers “Natural” (no N, no water soluble P) Silicate-based mineral fertiliser (200kg/ha) & WMF Microbes (20L/ha);
- **Treatment 3 (WMF x2):** “Natural” (no N, no water soluble P) Silicate-based mineral fertiliser (400kg/ha) & microbes (20L/ha);
- **Treatment 4 (HiAn - High Analysis District Practice):** high P, K and N fertiliser.

PASTURE - PRELIMINARY RESULTS:

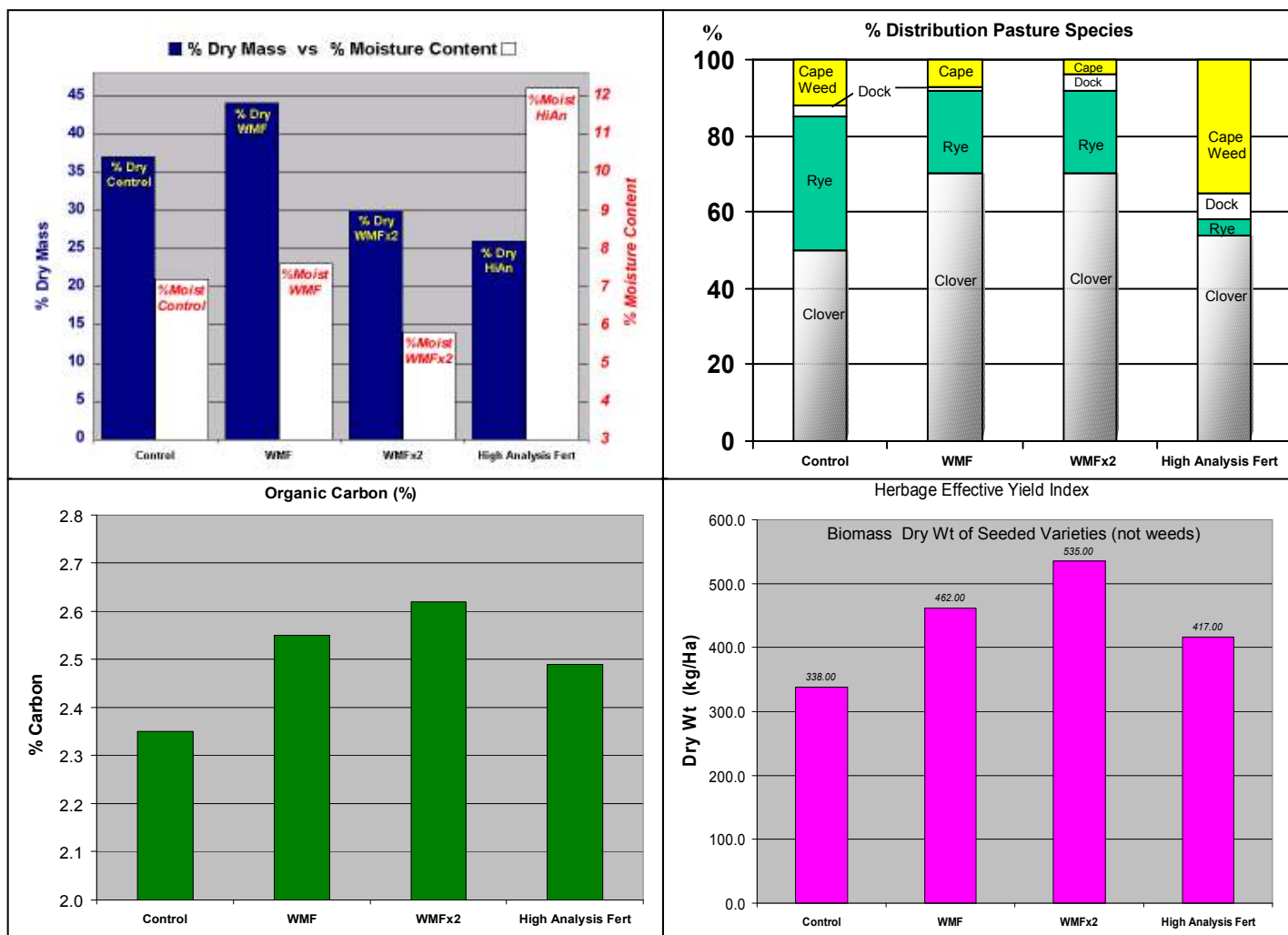
Data was collected (October 2004). Although trends were difficult to ascertain, the following was identified :

- mean organic carbon percentages were higher than the pre-trial for all treatments, although significant differences were observed between Control and WMF, WMF_{x2} and HiAn;
- mean pH (water) values were higher than pre-trial with significant differences for WMF and WMF_{x2};
- mean pH (CaCl₂) values generally lower than pre-trial values although significant increase observed for WMF_{x2};
- mean nitrate levels were lower than pre-trial values, although no significant values were observed. This reflects the (no N) status of the Natural WMF fertiliser. HiAn?
- mean ammonium levels were lower for control, WMF_{x2} and HiAn, and elevated for WMF (perhaps indicating greater microbial activity in this treatment);
- significant increases were observed for Colwell *soluble* P concentrations for WMF_{x2} (contains no water soluble P!) and HiAn. Total P values are yet to be ascertained;
- mean trace element concentrations were generally lower than pre-trial values except for WMF_{x2};
- Manganese concentrations were significantly lower than pre-trial for all treatments except WMF;
- mean exchangeable cations & exchangeable bases showed no significant differences compared to pre-trial concentrations except for exchangeable potassium & magnesium which was significantly higher for WMF;
- Ca/Mg ratios were significantly lower for WMF – indicating a better calcium and magnesium balance.
- % Moisture Content was significantly elevated in HiAn, and subsequently % Dry Matter was significantly lower in this high N treatment.

Pasture Trial September '04



The distribution of pasture species indicate that clover dominates the pasture with ryegrass having a greater percentage in the control and WMF treatments. Capeweed (*Arctotheca calendula*) and Dock (*Rumex* species) also appear in a greater percentage in the **High Analysis District Practice** treatments.



PASTURE - CONCLUSION:

The preliminary results from this pasture trial indicate that there is increased dry matter in pasture, improved production (based on dry weight) and better pasture species composition (& less weeds) when using a combination of WMF beneficial microbes and “Natural” Silicate based mineral fertiliser. This “Natural” fertiliser used specifically for this trial contains no soluble Nitrogen; & Phosphorous only as insoluble P (usually WMF’s general pasture program – uses a combination of some N, soluble & insoluble P). Data indicates good conversion of the insoluble P to bio-available P. The mineral levels (eg soluble P, exchangeable potassium & magnesium, Ca:Mg ratio etc) also show signs of becoming better balanced and more available to the plants. The HiAn treatment contained high analysis N- leading to rapid cell elongation, high moisture content, less dry matter, more fragile plants, which would result in lower feed value, resulting in more feeding time, higher energy out put = poorer weight gain in animals.

References:

1. Harley, A.D. (2002) — *The evaluation & improvement of silicate mineral fertilisers*, PhD Thesis. University of Western Australia. pp144.
2. Bolland, M.D.A. and M.J. Baker (2000) — *Powdered granite is not an effective fertilizer for clover and wheat in sandy soils from Western Australia*. Nutrient Cycling in Agroecosystems, **56** 59-68.
3. Jongmans, A.G., et al. (1997) — *Rock eating fungi*. Nature, **389** 682-683.
4. Jakobsen, I., C. Gazey, and I.K. Abbott (2001) — *Phosphate transport by communities of arbuscular mycorrhizal fungi in intact soil cores*. New Phytologist, **149** 95-103.
5. Landeweert, R., et al. (2001) — *Linking plants to rocks: ectomycorrhizal fungi mobilize nutrients from minerals*. Trends in Ecol & Evol, **16** 248-254.
6. Rogers, J.R. and P.C. Bennett (2004) — *Mineral stimulation of subsurface microorganisms: release of limiting nutrients from silicates*. Chemical Geology, **203** 91-108.
7. Coroneos, C., P. Hinsinger, and R.J. Gilkes (1996) — *Granite powder as a source of potassium for plants - a glasshouse bioassay comparing two pasture species*. Fertilizer Research, **45** 143-152.
8. Gillman, G.P. (1980) — *The effect of crushed basalt scoria on the cation exchange properties of a highly weathered soil*. Soil Sci. Society America Journal, **44** 465-468.
9. Hinsinger, P., M.D.A. Bolland, and R.J. Gilkes (1996) — *Silicate rock powder: effect on selected chemical properties of a range of soils from Western Australia and on plant growth as assessed in a glasshouse experiment*. Fertilizer Research, **45** 69-79.
10. Coventry, R.J., et al. (2001) — *Rejuvenating soils with Minplus™: A rock dust and soil conditioner to improve the productivity of acidic, highly weathered soils*. Canberra, ACT: Rural Industries Research & Development Corporation. 151 pp.
11. Hildebrand, E.E. and H. Schack-Kirchner (2000) — *Initial effects of lime and rock powder application on soil solution chemistry in a dystic cambisol*. Nutrient Cycling in Agroecosystems, **56** 69-78.

MINERALS FOR PLANT AND ANIMAL NUTRITION = FEED QUALITY

Even though the bulk of our 2005 trials were conducted in Cropping, we have also been getting tremendous results in both *hay* and general *pasture*. In 2005, we launched our new Pasture products which have seen a massive increase in *Dry Matter yields*, without compromising *feed quality*.

Remineralising pasture improves pasture quality, constantly resulting in:

- Greater Dry Matter/Wet Wt comparison,
- Increased stock weight gain per hectare,
- Higher reproductive performance in both cattle and sheep,
- Overall better animal health, and replaces the need for lick blocks and mineral supplements,
- Gives pasture a high tolerance to drought and insect stress.

Gingjin - Hay 2005

WINJARDIE OATS

Fertiliser:

- at seeding – NP Crop Mineral 110kg/ha + Sulphate of Ammonia.

Serpentine - Jutland Park



Guy and Pat with Cooper King, the proud product of Jutland's first Imported embryo from Leachman Cattle Company, Montana, USA.

Jutland Park is owned and operated by Pat and Guy Jellicoe. They have won numerous awards, including 9x Red Angus Champion awards from the Perth Royal Show and back-to-back Cattle Bonanza Awards. "Last year we had to wean earlier because of the phenomenal growth, which we put down to the better pastures which were fertilised with products from Western Mineral Fertilisers. We feel that this has been very beneficial to our herd." Guy said.

MINERAL NUTRITION IN ANIMALS

The nutritional quality of pasture, forage and diet plays a major role in the health and reproductive performance of animals. Mineral nutrition is a significant component in the management of any animal. Micro or trace mineral deficiencies are associated with soil deficiencies or UN-availability (due to lock-up in the soil matrix).

Certain minerals can act antagonistically against the absorption of other minerals. Bio-availability of one mineral is influenced by the concentration of other minerals in the diet. For example - calcium interacts directly with phosphorus and Vitamin D. If calcium levels are extremely high, phosphorus availability can be reduced. Intricate macro and micro mineral interactions can also arise - high levels of calcium can reduce the absorption of phosphorus, magnesium, manganese, zinc, iron, cobalt and iodine. On the other hand, high levels of phosphorus and magnesium reduces calcium absorption. High levels of sulfur or molybdenum can hinder copper absorption. While analysis of the feed may show a sufficient copper concentration, because of this antagonism, an animal may actually be copper deficient.

Animals require multiple different minerals. The amount and combination of minerals required will vary depending on the age, weight, health, species and type and level of production of the animal. For example, young animals absorb minerals such as Calcium more efficiently than older animals, but they have higher mineral requirements. Mineral uptake is best achieved from the diet when in a Bio-available form.

For further information, refer to WMF Mineral Fact Sheet :

Visit our web site - www.wmf1.com

Head Office Tenterden WA

Ph: (08)-9851-7222

CAN BIOCHAR HELP DRIVE BIOLOGICAL FARMING?

by Dr. Paul Blackwell, Department of Agriculture and Food WA.

CHARCOAL IS BIOCHAR

Email: PBlackwell@agric.wa.gov.au

Charcoal has been around ever since lightning & volcanic activity lit the first fires among the primal forests. We humans found it very valuable for making the first crude steel and it has been used ever since for reducing metal ores to metal, as well as providing smokeless fuel for indoor cooking. Charcoal is the remnant of wood cooked in oxygen free conditions (a process called pyrolysis). Any organic material (animal waste, feathers, crop residues & bones, as well as woody material) can be pyrolysed to a form of charcoal; or biochar, which is the new term.

BIOCHAR IS AMAZING STUFF!

The carbon rings which form most of biochar are very stable, only graphite and diamond are more stable forms. So it is a good material for carbon trading.

In the current, vital, discussions about the fight against global warming Pyrolysis power stations are one of the few options to extract CO₂ from the atmosphere, in the form of biochar, and make electrical power or fuel. We all need to promote pyrolysis more instead of burning biomass, because pyrolysis does not produce harmful emissions such as dioxin and nitrous oxide.

Biochar is also quite alkaline, so it is capable of helping correct acidity in some soils.

The surfaces in the biochar are very reactive and can adsorb many forms of inorganic and organic substances. This is exemplified in 'activated carbon' which is biochar treated with superheated steam to drive off the more labile materials in exchange surfaces of the biochar.

Thus in plant nutrition it can provide extra nutrient exchange capacity to soil, especially sandy soil. The material is very porous, so can hold much water, but the amount of char to supply a crop with all the water it needs would be very high.

The pores and spaces in biochar (see Figures 1 and 2) are a great home for soil microbes; they find refuge from their predators, and stored water and nutrition in the pores.

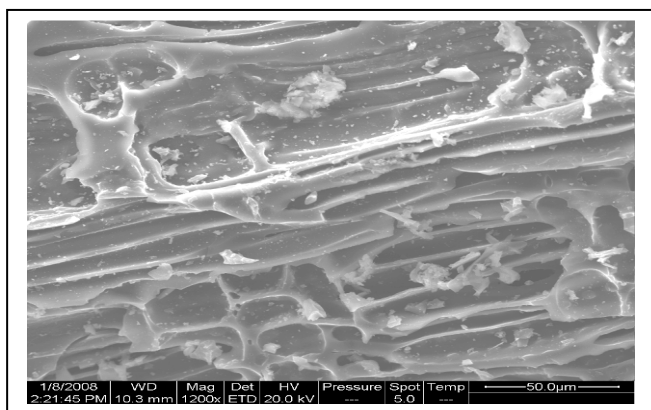


Figure 1. Scanning electron microscope (SEM) picture of charcoal from jarrah wood. The holes are relic shapes of the xylem & phloem vessels in the wood.

HOW BIOCHAR BENEFITS BENEFICIAL SOIL BIOLOGY

Japanese scientists have spent many years studying the benefits of biochar for soil microbiology, especially soil symbiotic fungi. Makago Ogawa and his colleagues have acquired much knowledge about how biochar can help agriculture in Asia. Figure 3 is from one of their reports. Ogawa reports that symbiotic mycorrhizal fungi will freely sporulate in the pores of biochar. This helps them to persist in soil and enables biochar to be a very effective carrier of beneficial biology into new environments.

Figure 2. SEM picture of biochar from wheat chaff. The holes are smaller and the fabric lighter.

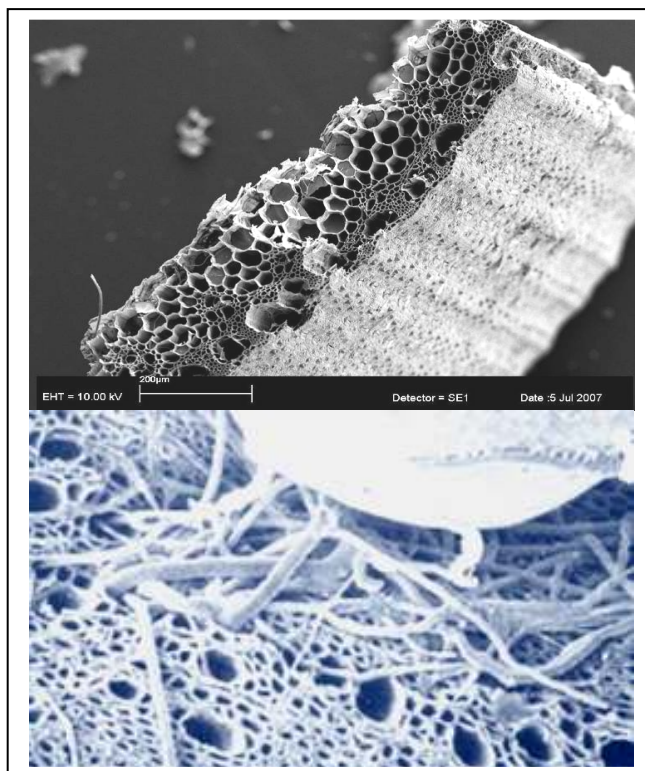


Figure 3. SEM picture of mycorrhizal fungi exploring biochar. From Ogawa (1994).

RESEARCH PROGRESS AND THE FUTURE

Research into potential benefits of biochar for agriculture in WA started in 2005 and is still under way. The results so far have confirmed biochar is very effective at encouraging mycorrhizal fungal colonisation of wheat in sandy soils with low phosphorous status, even two years after being applied. In the limited studies so far, grain yields can increase when biochar is added with fertiliser, when background P is low and soluble fertiliser rates are lowered (see papers: http://www.iaiconference.org/images/Blackwell-Improving_Wheat_Production_with_Mallee_Charcoal.pdf and http://www.oilmallee.com.au/pdf/Improving_wheat_prod.pdf). With Western Mineral Fertilisers product we have also seen evidence of biochar reducing the need for as much fertiliser application to achieve the same yield. Many more experiments are needed to be confident about what is happening and why with this complex material.

Early growth of tropical perennial grasses on deep white sand have also been improved by a mix of biochar and WMF product, compared to conventional DAP use; this is in a small pilot experiment at Dongara. We are planning a larger experiment to understand better what is happening in these circumstances. We are pleased that WMF is supporting this research.

A new avenue we are investigating is the possibility that activity of the beneficial microbiology of WMF may be improved by incorporating biochar in the fertiliser prill. We have made some prills which include biochar, and are testing them with a small scale field experiment using peas, the new prill designs and the presence or absence of rock phosphate.

A general concept in the research is that biochar will help the activity of the beneficial soil biology and it will use the rock phosphate as a long term source of P for symbiotic nutrition of the crops and pastures it is hosted by.

We will keep you updated with the research progress and hope it will lead to more efficient use of soil biology and fertiliser inputs to help agriculture in the future.

FUTURE DIRECTIONS IN AGRICULTURE

USE OF BIOCHAR, MINERAL FERTILISERS AND MICROBES FOR SUSTAINABLE CROP PRODUCTION

¹ Solaiman, M. Z., ² Blackwell, P., ³ Storer, P., & ¹ Abbott, L. K.

¹ The University of Western Australia, ² Department of Agriculture and Food WA; ³ Western Mineral Fertilisers.

Soils of Western Australia are generally deficient in essential nutrients because they are ancient and deeply weathered. Thus, farmers of WA have to rely largely on chemical fertilisers to grow crops efficiently. But any perturbations in nutrient status, such as removals by crops and loss by leaching, or problems with root growth and function, can cause nutrient deficiency and yield losses. Understanding the cycle of nutrients including immobilisation of nutrients by microbes, addition by organic carbon and the amount of nutrient loss is essential for nutrient budgeting and fertilisation for the following season.

Biochar, pyrolysed biomass from plant or animal sources, has potential beneficial effects on soil microorganisms & may reduce some negative effects of agriculture on the environment in WA. There are prospects of future biochar supply from pyrolysis based power generation; one of the few power technologies able to be carbon negative by sequestering atmospheric carbon into biochar.

Table 1. Growth, mycorrhizal colonisation and shoot P uptake of clover

Treatment	Microbial activity ($\mu\text{g CO}_2/\text{g soil/h}$)	Myc colonisation (%)	Total root length (m/plant)	Colonised root length (m/plant)	Shoot DW mg/plant	Root DW mg/plant	Shoot P conc. (%)	Shoot P ($\mu\text{g/plant}$)
Control (bulk soil)	0.29	5.8	2.9	0.2	98.5	57.2	0.21	70.50
Char 0 WMF100	0.38	17.5	7.0	1.2	166.0	114.8	0.29	157.90
Char 0 MAP 30	0.36	7.1	4.0	0.3	98.3	73.7	0.19	63.34
Char 1.5 WMF100	0.42	20.6	6.0	1.2	124.0	97.2	0.22	91.76
Char 3.0 WMF100	0.58	31.4	8.3	2.6	160.0	108.5	0.26	143.52
Char 3.0 MAP 30	0.53	18.9	9.8	1.9	142.0	151.0	0.27	125.55
Char 6.0 WMF100	0.77	35.1	9.3	3.3	176.7	120.2	0.29	177.18
Char 6.0 MAP 30	0.65	38.0	6.9	2.6	175.5	79.8	0.32	184.27
LSD (P<0.05)	0.07	8.2	3.1	1.4	50.0	41.4	0.07	80.00
P level	<0.001	<0.001	0.009	0.004	0.032	0.025	0.034	0.05

Char (biochar) rate in tonne per ha; Western Mineral Fertilisers (WMF) and Monoammonium phosphate (MAP) rate in kg/ha

Potential benefits of biochar to agriculture & environment include a habitat for soil microbes with protection against microbial predators, additional nutrient supply to plants in environments with a poor capacity to retain soil nutrients, protection from plant pathogens, provision of additional water supply to plants in environments and circumstances with inadequate soil moisture supply, and improved capacity of very sandy soils to intercept leachable nutrients and reduce eutrophication risk. Maintaining an appropriate level of soil organic carbon and biological cycling of nutrients is crucial to the success of any soil management in this environment by adding biochar & slow release mineral fertilisers.

The residual effect of biochar and mineral fertiliser was evaluated by mycorrhizal bioassay under glasshouse conditions (see Figure 1). Soil samples were taken after a year of drought from the site of a previous field trial from Pindar, WA. The biochar was applied in the field trial 22 months earlier, followed by one reasonable growing season in 2005 and one fallow drought year in 2006. The presence of biochar from the 2005 incorporation encouraged microbial respiration and microbial biomass; **especially after use of mineral fertiliser inoculated with a mixture of beneficial microbes** (Table 1). Soil from plots inoculated with beneficial microbes showed more mycorrhizal colonisation in clover roots where biochar was present. Shoot phosphorus concentration and uptake were also higher where biochar was present. This suggests that the survival of mycorrhizal fungi and microbiological activity through drought periods can be enhanced by deep-banded biochar application even after a drought year.

There is an increasing interest in evaluation of biochar for agricultural & environmental benefit, especially through increase of

activity of beneficial microbes. The choice of available biochar sources is partly driven by this characteristic of beneficial microbial habitat, especially for arbuscular mycorrhizal fungi (AMF).

For such an evaluation, a pot trial was carried out in a sandy clay loam soil from a site used for a previous biochar field experiment. A microbial fertiliser was used (a mixture of rock minerals and inoculated beneficial microbes) and the effects of adding three types of biochar compared at a rate of 1.5 t/ha uniformly mixed. The plants were either well-watered (80% of field capacity) or subject to drought stress (40% of field capacity) and grown through to ear emergence.

The results showed that the fresh biochar from wood (jarrah feedstock, at 600°C for 24 h from Simcoa Ltd Bunbury) enabled most shoot growth in well-watered conditions and most root colonisation in drought stress (Table 2). All biochars increased root colonisation by AMF when added with the mineral fertiliser including microbes. Aged jarrah biochar (ex Wundowie foundry and produced in earlier decade by the same process as at Simcoa Ltd) provided the most colonisation in well-watered conditions. Plant biomass was not increased by wood biochars in drought conditions, perhaps there was a competition for carbon in the restricted pot environment. The results generally encourage the use of fresh wood biochar for field experiments in dry land conditions, especially to encourage AMF colonisation in drought environments.

Table 2. Effect of biochar & microbes on mycorrhizal colonisation & plant biomass

Treatment	Myc colon. (%)	Shoot DW (g/pot)	Root DW (g/pot)	Total DW (g/pot)
Drought (40% FC)				
Control	19	1.9	1.7	3.6
WMF	22	3.0	2.2	5.2
WMF+M	28	2.9	2.2	5.1
WMF+M+OMC	32	3.3	3.1	6.4
WMF+M+WC	36	2.7	3.2	5.9
WMF+M+SC	41	2.4	2.7	5.1
Well watered (80% FC)				
Control	20	2.4	4.3	6.7
WMF	25	3.6	4.9	8.5
WMF+M	33	3.9	4.8	8.7
WMF+M+OMC	39	3.9	4.3	8.2
WMF+M+WC	34	3.9	4.1	8.0
WMF+M+SC	40	4.4	5.2	9.6
LSD (P<0.05)				
Treatment	2.5	0.4	1.0	1.0
Water regimes	1.4	0.2	0.6	0.6

WMF= Western Mineral Fertilisers; M= microbes; OMC= Oil mallee charcoal, WC= Wood charcoal, FC=Field Capacity; DW=dry weight



Figure 1: Mycorrhizal bioassays using subterranean clover in the glasshouse.