- **A New Agricultural Revolution**: another look at how plants protect themselves against pests and diseases.

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Inspired by Chaboussou

- Book photo, 1985

And that in turn by Jose Lutzenberger. The theme of this work is Chaboussou's theory of ***Trophobiosis***, that the susceptibility of crops to pests and diseases is depends on their nutritional states, and that the modern fertilisers and pesticides are a cause of increased proliferation of pest and disease organisms.

There were of course several agric revolutions. I will start by putting this new one into the context of the older ones.

Ancient agric revolution – almost always eventually destroyed environment – effort was trying to overcome limitations or constraints of nature. Domesticated a limited variety of plants and animals, omitting one – Homo sapiens!

Manuring and Composting was soon discovered, but few farming systems survived for long. The Chinese farmed for 4 millenia, but at the cost of their forests. Most others collapsed

- Space photo: Fertile crescent, origin of European farming

Europe was well placed with moist deep soils, requiring better ploughing but surviving, until the population grew.

Enter Malthus – can improvement outpace population growth? His assumption was soon, in the short term at least, proved wrong. Farm output could also increase, per acre.

Start of a new, partly hidden revolution with Liebig

- Liebig portrait

His work was descended directly from the scientific and social revolutions of the time. Prior to the French revolution, came a complete re-think on the nature of chemistry. The example of the discovery of oxygen was used by Thomas Kuhn in the 1960's. Lavoisier, after he met Priestley but before he was beheaded, changed the scientific approach to burning and hence to much of chemistry. This was not just the discovery of a new gas but a shift of understanding, a paradigm shift.

Liebig studied in Paris for 2 years and returned with a new enthusiasm for the new chemistry. L's finding that plants thrive on soluble salts in effect domesticated the means of nutrition, going far beyond the domestication of just the species. His discovery caused a deeper revolution and mind-shift than is usually recognised.

- Book photo Liebig

Leibig's work stimulated the start of Rothamsted experimental station, 1843, by Lawes who had inherited the property and Gilbert whom he employed to farm.

- The modern buildings
- Arial photo: the Broadbalk wheat trials

Chilean saltpetre was then one of the major sources of nitrogen compounds for farming and for making of explosives. Trials of many nutritional methods continued here and in Germany and other places. About 70k tons of Chilean nitrate is still exported to USA each year. But at the outbreak of WW!, Germany especially suffered a shortage, partly due to the blockade of war. Enter Fritz Haber.

- Haber
- Machine

Haber's work gave the boost to mineral fertilisation. From now on, it was no longer necessary to grow crops in soil, to fertilise the soil with wastes and compost. Now, 40% of all food is grown with H-B fixed nitrogen, 4/5th of all the protein of the next generation will be of HB nitrogen. The throughput of nitrogen in the biosphere has been doubled.

- Fertilised to death, paper from Nature describing effects of excess nitrogen on forests.

This is a much appreciated but not very visible revolution has changed the face of farming and made possible the huge scales of monoculture production.

It made possible the **Green Revolution**, which at least some of its proponents claim could not be done under organic conditions. Short-stemmed rice and wheat, which could stand the very high nitrogen inputs, increased yields per acre enormously. But there are several costs, one of which is increased pests and diseases, demanding more pesticides, fungicides, etc.

- Rice Blast
- All this was the **Nitrogen Revolution.** This and the associated development of many chemically manufactured fertilisers also stimulated the developments of new pesticides, especially from nerve gases after the Second World War. Note how both wars led to these agricultural revolutions, confirmed in UK by the 1947 Agriculture Act, which in effect gave the agro-chemical industry its remit for many decades to now. At the time that Chaboussou was working, this is how the pesticide industry in France publicised their products:
- Three pics of herbicides and insecticides.

These show an appreciation of the beauty of nature – wild flowers, insect – and the attitude to total domination

- Cartoon. The narrow view of agro-chemicals

That was one side of scientific research, stemming from the new understanding of chemistry and leading to the direct refutation of Malthus's idea. Underlying this progress is the world-view that new scientific understanding can overcome the constraints of nature – Nature can be Conquered.

We must turn then to a parallel path of scientific discovery, that led to critic of the above progress.

In 1882 Franciszek Kamienski, (1851-1912) discovered fungi growing in close contact, apparently symbiotically, with plant roots; he named them mycorrhizal fungi. He and German biologists (???) realised that these fungi exchanged nutrition with the plant. We now understand that mycorrizha release bound nutrients in the soil and feed them directly into the roots, in return for carbohydrates made by the plant.

- Mycorrhizal photos

It is now known that most, 70-90% of all plants are associated with such fungi for their growth. It is even probable that plant life on land was made possible by such symbiosis.

"the mycorrhizal condition represents the most abundant type of symbiosis in the world" (Smith & Douglas, Symbiosis).

Even around and soon after WW1, Albert Howard in India understood the value of soils containing much humus, and developed the Indoore composting methods. He understood that soil humus was vital for mycorrhiza, and so for plant nutrition.

- Howards book: An Agricultural Testament

The downside of artificial fertlisers was becoming apparent in the degradation of oils. FH King in studying China had warned of this.

Quote from Howard.

“The slow poisoning of the life of the soil by artificial manures is one of the greatest calamities which has befallen agriculture and mankind. The responsibility for this disaster must be shared equally by the disciples of Liebig and by the economic system under which we are living.”

His oxen, fed on healthy grazing, did not contract F&M D even when rubbing nosed with infected cattle. McCarrison met him in India, and extended Howard’s ideas of plant and animal health to humans.

Here was the beginning of a different **revolution** from the technical industrialisation of farming, on grounds of health of soil, crops, animals including humans. It differs since it deals with how plants actually take up their nutrients, not with how they could if the opportunities are presented.

The process is much more complex than the take-up of soluble nutrients like nitrogen. The soil symbiotic fungi are only a simple indicator that there is greater complexity among the millions of species in the soil. For example, a recent paper in Nature described rice Blight, caused by a fungus that is very similar to mycorrhiza.

- Rice, seedling blight

But this fungus has a bacterium living in it that secretes a poison that is the cause of trouble. It is highly likely that mycorrhiza also often harbour other bugs, which if they are benign or even positively useful, we would not know about.

Thus, mycorrhiza are not just a straight new fad like nitrate fertiliser, but a new approach of which we know as yet little – a new attitude rather than just another discovery.

This difference in attitude, renders these two lines of scientific progress more or less incompatible. They are also technically incompatible, in that soluble fertilisers inhibit the growth of mycorrhiza, both directly and by slowly causing the loss of humus.

- Soil carbon over time, in conventional and various organic regimes.

Thus the choice between these two scientific approaches to agricultural progress cannot be made on scientific grounds alone; they depend on attitudes about how to harness nature's resources. I suggest elsewhere, that there are indeed at least two sciences.

Stress that this was not just opposition, but bringing thorough scientific observation to the service of farming, just as Liebig had done but leading into other directions. No-one has yet demonstrated that supplying the known chemical nutrients, not requiring soil at all, can lead to food that is as healthy for animals as that grown on a rich soil. The onus, put in contemporary terms, is not on the organic movement to demonstrate health, but on the agro-industry.

[Split lecture here, 2nd part]

Now enter the main subject of this talk, Chaboussou. After much encouragement by Lutzenberger, of whom more later, Ch's book was recently translated

- Chab. Engl

His work immediately followed Howard. Even in France, the work has been largely disregarded all these years.

He asserts that the very pesticides that are used to control pests and diseases, actually stimulate increased multiplication of the insects, fungi, bacteria and viruses and so exacerbate the problems. This is not an easy notion to accept.

Chaboussou's argument is that most pest and disease organisms depend for their growth on free amino acids and reducing sugars in solution in the plant's cell sap. These soluble organic supplies increase under many conditions, including soluble nitrogen, stress, age, and other nutritional states. Most agrochemicals for different reasons increase the availability of these nutrients in the plant, and so allow pest and disease organisms to multiply.

He reviewed innumerable studies stretching over nearly 50 years, which together, in his own words:

"have established a fundamental fact: namely, that the relationships between plant and parasite are primarily nutritional in nature. We have given the name *Trophobiosis* to this theory.*"*

For example, heavy applications of soluble nitrogen fertilisers increase the cellular amounts of nitrate, ammonia and amino acids faster than they can be used for the synthesis of protein.

- See diagram.

Similarly herbicides, even in recommended concentrations, inevitably affect the crop plant somewhat (perhaps not visibly), the main effect being a temporary reduction in protein synthesis - the most sensitive of metabolic processes. Some agro-poisons may even cause some degradation of protein. Spraying with almost any pesticide or fungicide has the same effect. These reductions in the rate of protein synthesis result in temporary accumulation of amino acids. Therefore, while the immediate attack by a pest may be reduced by a pesticide, the susceptibility of the crop is increased: when offered soluble free nutrients, pests grow better and multiply faster. In this sense therefore, agro-chemicals and -poisons *cause* pests and diseases.

Chaboussou worked at the French National Institute for Agricultural Research (INRA). In this book he describes some of his and colleagues work, and reviews the period from the 1930's to 1985 with over 400 references, mostly from the 1960's to 80's. Whether dealing with viruses, bacteria, fungi or insects, the same general principles emerge – that treatments that are liable to stop protein synthesis or stimulate protein hydrolysis, allow the pests to multiply.

There is extensive coverage of the micro-nutrients, which have profound effects on the physiology of the plant and on protein and carbohydrate metabolism. Improvements in husbandry are indicated, woven into the whole argument.

Modern organic farmers will see this work as a scientific underpinning of what has been learnt empirically over the years. Chaboussou however links his studies to organic farming in only one small section. The research stands on its own, and one might hope that it can serve a spread of improved methods of husbandry.

Chaboussou's findings contrast sharply with common assumptions about why pesticides sometimes result in increases in pests – namely that the poison has destroyed the natural enemies of the pest. His explanation is that, however benign the pesticide may be, it still affects the plant and changes its nutritional balance.

- Ratios in relation to resistance of Piricularia ; (blast) “enrichment of tissues in amino acids”. Showing especially how Mn and Cu are deficient in diseased plants.
- Atrazine and dwarf mosaic virus: atrazine is still commonly used for growing maze, and here clearly increased incidence of disease.
- Red spider in vines, in relation to amines. Effects of grafting are crucial, extensive studies. The higher the amount of amino and amide nitrogen in the cell sap in relation to ammonium nitrogen, the more the aphid proliferates.
- Cartoon, illustrates it all!

Finding that “pests actually increased their biotic potential when fed on leaves treated with the suspect chemical”. So-called resistance to the chemical, which so often arises quickly, was not resistance but stimulation of reproduction through nutrition.

This aspect has too often been neglected.

For example, a Royal Society Symposium on the Biological Control of Pests and Diseases (1987) made no mention of the physiological or biochemical state of the plant as a factor in susceptibility to pests and disease.

- Royal Soc biological control contents page.

When various agro-chemicals fail in their function, this is usually ascribed to accumulated resistance to the chemical by in the pest, or to killing off of natural predators. Chaboussou shows how the altered nutritional state of the plant offers another and often better explanation.

Indeed some papers in the Royal Society Symposium could be interpreted in this way. It remains the case that the idea that plants practice their own "*Integrated Pest Management"* dependant on their physiological health, is not part of modern thinking. That is why *Trophobiosis* provides a way forward which is nothing less than "an agronomic revolution."

With so many interacting factors that affect a plant, including its nutrition, the amounts and ratios of all the nutrients, major and micro, and the impacts of the many chemical control agents, and other conditions such as stress, drought, ageing, this study is dealing in essence with complex interacting systems, like a whole eco-system. This is difficult to present in the linear text of a book, and so it is not surprising that the original French edition is in many ways badly laid out. Much of this has been improved in the English edition.

This book is for every farmer who wishes to study the underlying biology of his farming, and for every agricultural college and research institute as a backbone text for their teaching and research.

It is clear nevertheless that much more research is needed to establish the scope and validity of Chaboussou's interpretations. Whatever the technical details, it is now obvious that close attention to the physiological and biochemical states of crop plants must become a vital part of agricultural practice. Such an approach constitutes a new *biotechnology* in a true meaning of this term. There is much to be done; Chaboussou has provided a powerful basis.

It was Lutzenberger, who met Chaboussou, who has promoted his work, and interpreted some of his own work in this light.

- Lutz, gesticulating against a local agrochem firm, "I don't care whether their new 'cide is as nutritious as mothers' milk or as pure as water, the question is whether you need it. You don't."
- Lutz's Gaia Corner farm near Porto Allegre, Brazil
- First stage of preparation of health-promoting "Humoflor"; this shows treatment effluent from a cellulose plant in Porte Allegre
- Anaerobic digestion of the effluent for 6 months in deep pits
- Drying of the digest, aerobically . This is the base of Humoflor.
- Lutz spraying. Humoflor is used as a soil additive or sprayed as here on cactuses. Ants feeding on aphids on the underside of the leaves, become disturbed within an hour, and aphids then fall off. Lutz interprets the effect in terms of better nutritional control in the plant, which starves the aphids.
- Bottle of Humoflor, (in current packaging style)
- Humoflor, made commercially in Porto Allegre, used eg in orchid houses, to enable cultivation free from pesticides. Does this act as a health promoter which maintains the nutritional state of the plant such that it becomes resistant to pests? That would link empirical findings here with Chaboussou's *trophobiosis.*

We tried at Lothian Trees & Timber (with a grant from Waste Resources Action Program) to prepare similar anaerobic sawdust digests.

- Here is the effect on Courgettes, sprayed at 2 week interval on the left and not on the right of white line. The former appear healthier as judged by darker green leaves.

Conclusion: if indeed most of the major currently used agrochemicals sensitise plants to pests and diseases, this inhibits the plants own protective mechanisms. The two revolutions I have described therefore are inevitably incompatible, both technically and philosophically.