# FACT OR FICTION? HOW DO I KNOW WHO IS TELLING THE TRUTH?


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## Summary

- Farmers are bombarded daily by people selling advice and products
- Science is a tool that allows us to determine the effect of a treatment, compared to what difference could occur just by chance
- Science is a well defined process, developed over the last 600 years. It culminates in a scientific paper presenting the results of the experiment following a review by world experts
- If the claims for a product have not been published in a scientific paper, you cannot afford to believe them
- To tell fact from fiction:
- ask for the data behind the claims
- ask for the scientific paper
- ask where the research was undertaken
- If it sounds too good to be true, it probably is
- If in doubt, ask a scientist


> "There is nothing so tragic as a beautiful theory destroyed by an ugly fact"
>
> Thomas Huxley, 1825–1895

## Introduction

Farmers are bombarded daily by people selling advice and products. Farming newspapers are full of advertisements, advertorials and infomercials for animal health remedies, dietary minerals, supplementary feeds, fertilisers, soil conditioners and management techniques aimed at improving pasture and milksolids (MS) production per hectare. The claims made often conflict with scientific advice, and are sometimes bewildering (e.g. a new ryegrass variety that produces 33 tonne DM). How did we get to this state of affairs and what can be done about it?

The prevailing policy attitude for a deregulated economy dictates that choice (of, or between products and services) is essential. Modern economic and political theory assumes that this will result in the most efficient use of resources. In this environment farmers who fail to make good choices will be replaced by more effective decision makers (i.e. the equivalent of natural selection in the consumer environment).

For these reasons the principle of *Caveat emptor* – let the buyer beware – prevails in the market place. In this paper we assert that if the farmer is to beware he must first be aware. To be a survivor in this environment you must be able to tell fact from fiction; what will make you a dollar and what will lose you a dollar. The only way to ensure such success is through an understanding of science, otherwise you are just gambling – and the stakes are high!

Above all else consumers need to appreciate that most people – product manufacturers, salespeople, technical reps, and even scientists – have an agenda. Knowing something about the scientific method will enable you to see through possible agendas and hence determine which advice is true, which advice is exaggerated, and which is false.

## Political correctness – the enemy of truth

"Political correctness is driving machismo underground and recalling effeminacy from exile".

Mason Cooley, 1927-

The modern philosophical current of political correctness makes sorting fact from fiction difficult. At the heart of political correctness is the belief that all systems of thought, all cultures, and all beliefs are equal in value. To assume otherwise is politically incorrect.

Political correctness has extended to impose limits on viewpoints and public discussion, to avoid potentially controversial debate. Therefore all "truths" must be given equal weighting. An example of this is the acceptance of alternative medicines, such as homeopathy, as equal to antibiotics in curing mastitis. Definitive studies have shown that homeopathy is no better than doing nothing, whereas antibiotics will cure approximately 60 to 80% more cows than doing nothing. Considering we have a duty to care for our cows, should we not expect a consumer watchdog, such as the Consumers Institute, to stop homeopaths plying their trade until they prove that their products work? In a rational world, we would. In the current climate of political correctness we must treat them with the same respect as we do our visiting veterinarian with his scientifically proven cures.

## Science and society

"Even if the open windows of science at first make us shiver after the cosy indoor warmth of traditional humanising myths, in the end the fresh air brings vigour, and the great spaces have a splendour of their own".

Bertrand Russell, 1872-1970

The scientific process emerged out of the Dark Ages approximately 600 years ago when people began to challenge the authority and power of the church, and questioned the idea that the only truth was that which could be revealed through prayer. These enlightened thinkers picked up concepts and ideas from pre-Christian Greek thinkers, who believed that truth could be revealed by logic, reason and experimentation. So began the Age of Enlightenment, sometimes referred to as the Age of Reason or Modernism (Table 1).

The authority of the Church was not, however, easily relinquished. Copernicus was the first to challenge the religious belief ("truth") that the earth was at the centre of the universe. However, it was just his opinion that the earlier views of Ptolemy about an "earth-centred universe" were wrong, and that the earth in fact revolved around the sun. He took no measurements, although in his defence reasonable telescopes were not invented until 60 years after his death. For fear of excommunication, *or worse*, his ideas were not published until after his death. The fear of debate was similar to what we find today.

Following the invention of the telescope, Galileo (who further improved this invention) took measurements which led him to conclude that Copernicus was correct in his hypothesis. This was an even greater threat to the establishment (Church). It is more difficult to argue with a man that has facts. Instead they silenced him. This is similar to a technique used today by the environmental movement to silence anyone who questions their motives or "facts". They use their power to impugn such a scientist's reputation, claiming that he/she does not care for nature.

Silencing Galileo did not stop the progress of science, and over time the Church's authority on this matter was overwhelmed by the evidence – the religious dogma which was once believed to be the 'truth' had to yield to the 'truth' as revealed by science. Today there is so much evidence supporting Copernicus' theory that we are all comfortable with the fact that the earth revolves around the sun. There are many more examples of this, such as the shape of the earth (flat or round), gravity, evolution, and even substitution rate of supplements for pasture. All of these ideas were at one time disputed, but with scientific facts gathered during the age of modernism, they have become accepted as fact.

**Table 1:** The concept of truth as it has changed through time

| | **Define "Truth"** | **Authority** | **Attitude** | **Example** |
|---|---|---|---|---|
| Dark Ages | Truth can only be found through prayer | Church | Thou shalt obey the laws of God | • Pray for a good harvest<br>• Your cows died because you sinned |
| Age of Reason | The truth as revealed by reason, logic and experiment | Science | I do not care for opinion. What are the facts | • Nitrogen fertiliser results in more pasture<br>• Liquid fertilisers are ineffective<br>• Calcium supplements prevent milk fever |
| Age of Non-reason (Post-modernism) | If you believe it is true, then it is | Individual | Science is the source of global misery. We must find a new truth | • Homeopathy prevents mastitis, because I believe it does<br>• Organic farming is better for the environment, because it must be |

However, we have entered what is referred to as the Age of Post-modernism, where political correctness is of utmost importance, and where debate is frowned upon for fear that the facts will interfere with a person's right to believe what they wish. Because of political correctness, science and the scientific method have become devalued. Examples are numerous: homeopathy vs. antibiotics, liquid and "organic" fertilisers vs. inorganic fertilisers, vaccines vs. natural immunity, or fluoridated vs. non-fluoridated water. Another frightening example is the recent policy that schools in many developed countries should be given the choice as to whether they teach Creationism or Darwinism; two centuries of compelling research evidence re-challenged by the Book of Genesis!

## The fear of science

“Science confers power to everyone who takes the trouble to learn it”

Carl Sagan, 1934-1996

“Science has made us gods even before we are worthy of being men”.

Jean Rostand, 1894-1977

Political correctness suggests that there are multiple valid “truths, and if you do not agree with the scientific truth you should find another truth. This truth is no longer objective or rational, but subjective and irrational. It is in this context that societies are seriously considering things like “alternative medicines” over cures that have been scientifically tested and proven.

People feel lost; so they must “find themselves”. Facts do not matter to the post-modernist: if it feels good to you, or you are in ‘touch’ with yourself, that is all that is important. The tolerance of such idiocy has resulted in the widespread use of homeopathy and other non-proven “cures” for ailments, the proliferation of organic agriculture through the developed world, the dismissal of new technologies which could improve the life of paralytics - if not cure them entirely (stem cell research), the ignoring of food production techniques that could end the misery of one billion people that remain starving, and so forth. Although the scientific evidence refutes many of these public policies it does not matter; facts are set aside by the thought that we are better to be in harmony with “Mother Nature” – as if such a fallacy were ever true.

It is in this modern context that science faces its biggest challenge and that must be met by helping the layperson to understand science and its benefits to society. Ironically, it is only the success of science in the last 50 years that has stabilised food production and given people the luxury of worrying about anything other than where their next meal was to come from.

## What is science?

“Facts are not science - as the dictionary is not literature”

Martin H. Fischer 1879-1962

“No one should approach the temple of science with the soul of a money changer”.

Thomas Browne, 1605-1682

Science is a tool. A logical objective process for testing ideas, and thereby reaching a conclusion. If that conclusion stands the test of time we can say we have found “a *truth*. The people who have been trained to use this tool are called scientists. This does not make them infallible. Take away their training and scientists are first and foremost humans, with all the implied strengths and weaknesses. Therefore, they can, and do make mistakes. However, the process of science, when used properly and openly should always be self correcting.

The science process normally begins with a formal question - an hypothesis. These questions arise because there is a problem that needs solving. For example:

- What effect does product A have on pasture or animal production?
- Is product A better than product B?
- Does product C improve conception?

The possible questions are endless. Having clarified and defined the question, an experiment (or sometimes a series of experiments) is designed to answer the question (test the hypothesis). In agriculture this involves measuring some properties of animals, plants or soils (e.g. milksolids production, blood mineral concentration, pasture production, soil Olsen P). The variable being measured will depend on the question being asked.

The data collected are then analysed using complex mathematical techniques, otherwise known as statistics. This is done to ensure that any difference seen is due to the treatment imposed and is unlikely to be due to chance.

The next part of the process is the review of the research by experts working in the same area of science. Provided this review process does not show serious flaws in either the experimental design, the analysis of the data, or the interpretation of the results, the results are then published in a peer-reviewed scientific journal. This publication of results in a scientific journal is extremely important. It is science's quality control. It is also important because when the results are published it should be possible for another scientist to repeat exactly the same experiment. If the repeated experiment gives the same result then more confidence can be placed in the result. However, if their results are different then that becomes a reason for further investigation before accepting the results. An important test for good science is: are the results repeatable?

Experiments can be undertaken in a laboratory, a glasshouse, on a research farm, or on a commercial farm. Whenever experiments occur, the science protocol must be followed precisely to remove the potential for personal bias (giving one treatment preference over another). Failing to do this increases the risk of generating a false result.

## Difficulties in science

"Science is the great antidote to the poison of enthusiasm and superstition".

Adam Smith, 1723-1790

One of the difficulties in science is the natural variability in everything we measure. For example, two cows of the same breeding worth that calved the same day in the same herd will be producing different amounts of milk on any given day; yet they are both treated the same, offered the same access to pasture, supplement and water, and are milked at the same time. Similarly paddocks side by side produce different amounts of pasture, and there can even be significant variation within a paddock due to fertility gradients, uneven distribution of dung and urine, changes in topsoil depth, or a multitude of other reasons. This type of variation is not an error in measurement, but is biological and therefore is important in our measures. There is little that can be done about it, other than to understand it, measure it, and above all account for it in planning, designing an experiment, and when interpreting the results. Knowledge of this biological variation allows us to determine the odds of the measured difference occurring just by chance.

Not to account for background variation is a grave mistake. Taking a simple example: we want to test whether an animal health remedy (Product A) has an effect on milksolids production. We choose two cows and we treat one with Product A. The other gets no treatment; it is our control. Production is measured over time and the treated cow produces more MS. How do we know that this difference is due to Product A and not simply due to the inherent biological differences between the two cows? The same problem arises in pasture production experiments because no two plots of ground produce the same amount of pasture.

## Using science to determine the truth

"Scientific principles and laws do not lie on the surface of nature. They are hidden, and must be wrested from nature by an active and elaborate technique of inquiry".

John Dewey, 1859-1952

Table 2 shows a number of easy tests to determine the quality of science. To overcome the problem of natural variation, the experiment must be repeated more than once (i.e. we need more cows). The allocation of these cows to treatment must be completely random. Otherwise we could be biasing the results by selecting good milk producers in one treatment and poor milk producers in the other. Thus, as part of any experiment, treatments are replicated on several cows (or several herds of cows; or several paddocks if the treatment is a fertiliser), and replicates (cows, herds, paddocks) are randomly allocated to treatment or control groups. We then proceed with the experiment, taking the appropriate measurements while following a precisely defined protocol.

If after taking into account this inherent variability the average production for the treated animals is higher than the untreated control animals we can conclude that Product A increases MS production. Scientists will say the effect is statistically significant. For this reason another measure of good science quality is that the results are presented together with a measure of the biological variation for that particular experiment. This is normally expressed as a standard deviation, a coefficient of variation or the least significant difference. These numbers are our way of determining whether the difference is real. If these numbers are not presented then you should be suspicious.

**Table 2:** Simple tests of science quality

| **Issue** | **Question** |
|---|---|
| Trial Design | • How were the measurements made - where is the experimental protocol?<br>• How many replicates per treatment were used?<br>• Were the treatments randomised? |
| Trial Data | • Where is the experimental data?<br>• Is all the data presented?<br>• Have bits of the data been selected?<br>• Are there appropriate measurements of the biological variability?<br>• Are the data 'honestly' presented? |
| Repeatability | • Are there other similar experiments?<br>• Are the results between experiments consistent? |
| Publication | • Are the results published?<br>• Are the results published in a peer review journal? |
| Credibility | • Who did the research?<br>• What is the reputation of the researcher or organization?<br>• Are they independent of the company selling the product? |

The last, and arguably the most important test of science quality is whether or not the experiment is published in the scientific literature. This is the quality control process for science and is vital in determining whether you can trust the results. The process is as follows: the experiment is written in the form of a report, containing an Introduction (why was the experiment conducted?), Methods (how was the experiment carried out), Results (including a measure of the biological variability), and Discussion (what conclusion can be drawn from the data). A draft of the paper is sent to the editor of a scientific journal, and the editor sends the paper to a number of qualified assessors (generally 2 or 3). These are fellow scientists working in the same field. Their task is to assess the quality of the work. Was the experiment properly conducted? Are the results properly reported? Are the conclusions consistent with the data? In short, their job is to pick it apart. If fault is found, the editor will decide not to publish or give the authors the chance to defend and/or correct their work.

## Science in a politically correct world?

"The notion of political correctness declares certain topics, certain expressions, even certain gestures, off-limits. What began as a crusade for civility has soured into a cause of conflict and even censorship".

George Bush, 1924-

Science is an iterative process; it proceeds cautiously and tentatively, reworking past observations, making new observations, and all along refining its hypotheses. Once results are published in a scientific journal, all other interested scientists will read, scrutinise and criticise the work. They may even attempt to repeat the experiment, adding to or building upon the previous studies. It was this iterative process (repetition of trials) that led Isaac Newton to say "*if I have seen farther it is by standing on the shoulders of giants*". This process which is at the core of science – hypothesis, experiment, publication, peer review, modified or new hypotheses, experiment, publication, peer review, etc. goes on forever. The 'truth' is thereby endlessly refined.

Note that science's quality assurance system (peer-review publication) demands openness – the right and the imperative to publish. Regrettably, in our post-modern world where the debate and critical evaluation of another's work are discouraged, this process by which we generate the truth is being eroded. Science has become increasingly profit driven, turning scientists into salesmen, and making them dependant on commercial donors who can be very protective about publishing results; particularly if the results reflect badly on the company's product.

"Any doctrine or program that claims the merit of going against common sense has presumption in its favour – a major discovery is at hand. Where earlier the proponent was declared a charlatan, now he is the bearer of the desirable news and enlightenment".

Jaques Barzun, 1907-

The quotation above highlights one of the trends in the post-modernist world. There are now products in the market place which are justified to farmers on the basis that they are developed as a result of a new way of thinking. This is an echo of the politically correct notion that science has got it wrong, and my product (animal health remedy, fertiliser, soil conditioner, etc.) will improve your productivity and save you money, even though I cannot prove it. Alternative medicines use such a philosophy. Often such tricksters prey on a farmer's innate desire to have healthy cows or a "healthy soil". Their proposition can be easy to accept, because the media bombards people with exaggerated and often false reports about the negative effect of modern technology: the effect of fertilisers on soil health and the environment, pesticides on human health, and in particular cancer, or the effect of antibiotics on the proliferation of "superbugs". The trickster plays on these fears.

## The misuse of science - pseudoscience and tricksters

"The only antidote for pseudoscience is science itself"

Carl Sagan, 1934-1996

### *Conjuring results*

The only way to truly tell science from pseudoscience is to ask where has the information been published. Science will be published in a recognised scientific journal; pseudoscience can not be (in theory). Publication of results in a scientific journal ensures that the way in which the work was carried out, the analysis of the data, and the interpretation of the results are all done correctly. It is science's quality control. If a science paper can not be provided you should be suspicious. However, in the absence of scientific data the 'effective' salesman has other tools that you should be aware of:

- Anecdotal evidence or the use of a farmer's name that you know
- Their own experiments
- Experimental evidence from abroad (after all, that must be better than NZ research)

Anecdotal "evidence" is something to be very wary of. For example, how often have you heard salesmen say that they have several farmers using Product X with great results – higher milk production, lower SCC, no milk fever, no grass staggers, cows are happier, and all because the farmer used Product X. Another favourite is name dropping; Joe Bloggs (a very successful farmer in your region) used the product and look at him.

Unfortunately, there are two problems with this type of evidence. Firstly, you are unlikely to rubbish Joe Bloggs, especially if you know him. Modern day political correctness demands that you do no such thing. As important, it is possible that Joe did use Product X, and that he had a great season. However, this does not prove that Product X was the cause: How many other practices were changed at the same time? Was it climatically a good season (spring 2004 vs. spring 2005)?

Be wary of anecdotal evidence that does not have science results to back it up, and more especially if science results refute the claims made. For example, years of research both here in New Zealand and around the world suggest you will get 1 kg MS from 15 litres molasses (7.5 g MS/MJ ME; 11.5 MJ ME/kg DM molasses; molasses = 75% DM). Yet if you were told that Joe Bloggs was getting 1 kg MS from 10 litres of molasses, who would you believe?

Many salesmen will claim to have done their own "experiments" on their product. They may even print nice glossy graphs in farming magazines. In these situations, the word experiment is generally misused to suggest it was a scientific study. Salesmen will often drop comments like "we did experiments on Product Y and found …" into the conversation. What they are calling an experiment may be good science, but is often no more than observing that a farmer used Product Y one season, and some things were different to the season before:

- Joe Bloggs applied Product Y on one half of a paddock and swears it grew more grass.
- Joe fed 1 kg grain/cow/day during lactation and his empty rate is 3% lower than it was last year.

Such comparisons are not scientific experiments. Again they are little more than anecdotal evidence, and it is impossible to separate the effects of treatment from the background variation.

By asking for the data or the peer-reviewed publication supporting the product, you should be able to decide quickly whether the claims made are true or bogus. We are not saying that scientific projects that have not been published in a recognised science journal have not been done correctly. However, such projects have not been assessed for quality or accuracy of either methods, data analysis or interpretation. There has been no quality control; you are merely receiving someone's opinion.

### *Using data that is not appropriate for pasture-based systems*

Although not having research results from experiments undertaken in New Zealand, sales people may have research evidence from overseas. This is certainly better than not having evidence, but the effect of this product under our pasture-based system may not be the same, and results should be viewed cautiously. If this company is serious about marketing their product in New Zealand, then they must do the research (in the manner outlined earlier) to determine if they can achieve the same effect. Only then should you trust their results. Otherwise, you are their guinea pig!

### *Manufacturing a "fact" through inductive reasoning*

One way to misuse science is through inductive reasoning; by stringing facts together to create another "fact". Examples of this are provided in Table 3.

**Table 3:** Examples of false inductive reasoning

| **Inductive logic** | **Flaw** |
|---|---|
| • SuperP is made from acid (true)<br>• Acid is bad for soils (true)<br>• Therefore SuperP is bad (false) | Measurements show that the amount of residual acid in SuperP is very small and that soil pH does not decline even where SuperP has been applied for 50 years. |
| • Manganese is essential for fertility (true)<br>• Product A contains Manganese (true)<br>• Therefore Product A will improve fertility (false) | Pasture generally contain surplus manganese, so supplementation will not improve animal production or reproduction. |
| • Nutrients are good for soils (true)<br>• Product B contains 50 elements (true)<br>• Therefore it must be good for soils (false) | Science has shown that pasture plants need only 16 elements (nutrients). Adding other nutrients will have no effect on pasture production. |
| • Cows require sugar (true)<br>• There is more sugar in a total mixed ration (TMR) than grass (true)<br>• TMR cows produce more milk than grass-fed cows (true)<br>• Therefore, I should supplement my cows with sugar or starch (false) | Cows absorb less than 10% of the sugar they are fed, instead producing sugar in their liver.<br>Supplementing cows with sugar or starch will only be beneficial if it increases energy intake or if the diet is deficient in protein. |
| • Organic matter is good for soils (true)<br>• Product C contains organic matter (true)<br>• Therefore this product will be beneficial (false) | Many products contain organic matter, but the amount present when the product is used as recommended are trivial in relation to the amounts already present in soils. |
| • Dairy meal contains 13 MJ ME/ kg DM (true)<br>• 13 MJ ME = 0.2 kg MS (true)<br>• Therefore, giving cows 1 kg DM dairy meal will increase production by 0.2 kg MS (false) | When a cow eats a supplement, she refuses pasture. This is known as substitution and it results in smaller milk production responses to supplements than would be predicted in theory. A kg DM of dairy meal will increase milk production by 0.1 kg MS on average. |

Some commercial companies may often use "charlatan" scientists who have a knowledge of biochemistry and biological systems to present a logical reason for why their products work. To assess the validity of the claims, we refer you to the earlier questions: Where are the data? Where is the scientific paper? Where was the research undertaken?

### *Using exaggerated graphs*

It is very easy to make a small difference look large through manipulating the shape or the scale of graphs. Figure 1 shows three graphs, each depicting the same data – the effect of Product A on milksolids production. However, Graph A shows little if any effect of Product A, Graph B depicts quite a substantial effect, and the effect of Product A on milk production in Graph C is quite staggering.

This effect is achieved quite easily through exaggerating the scale of the vertical axis. In Graph A, the scale is from 0 to 2.5 kg MS/cow, giving a clear and honest portrayal of the effect of Product A. In Graph B, the scale has been shrunk, depicting milksolids yield between 1.3 and 2.1 kg MS/cow and thereby exaggerating the effect of product A, to make its effect on MS appear larger than it is. A further marketing ploy can be to remove the scale (as done here), leaving the reader clueless about the actual difference in milksolids production as a result of Product A, but planting the thought that the effect is large. Graph C further exaggerates the scale (1.82 to 2.05 kg MS/cow) by focussing in on the period of greatest effect. All of these graphs are a correct depiction of the effect of product A on milk production. However, they tell very different stories.

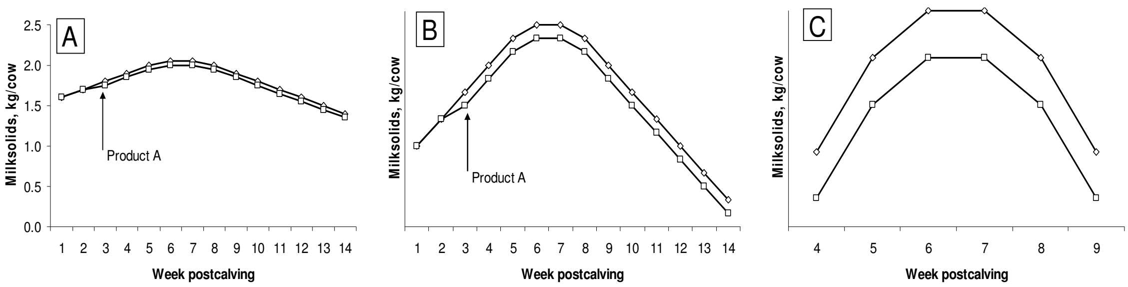


**Figure 1:** Effect of supplementing cows with product A on subsequent milk production

Figure 2 shows another interesting marketing ploy. Both graphs show the effect of 5 fertiliser products on pasture production. Identical data is used in both graphs, the scale is the same in both graphs, however, the vertical and horizontal axes are interchanged. The human brain is trained to associate increased height in a graph with increased gain, in this case more pasture. In Graph B, it appears that fertiliser E is absolutely fantastic, beating all other competitors easily. However, Graph A shows a different story. Fertiliser E produces no more pasture than either C or D, and only a small amount more than A and B. There is nothing wrong with the data presented in these graphs, but the message is different.

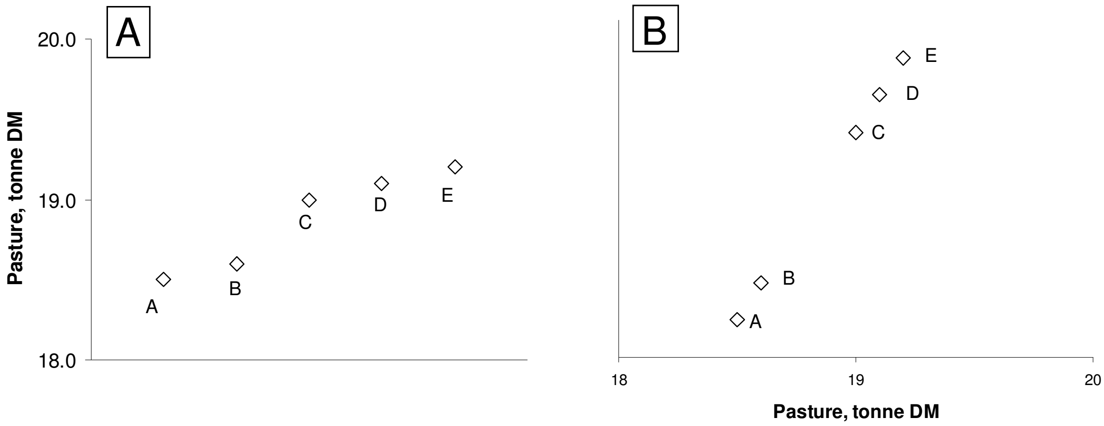


**Figure 2:** Effect of different fertiliser treatments on pasture production

## Conclusion

So what can you do?

"All scientific truth is conditioned by the state of knowledge at the time of its announcement".

William Osler, 1849-1919

Although the biological systems we work with are complex, there has been considerable research over the last fifty years into factors affecting these systems, and the responses to external stimuli, such as fertilisers and animal supplements. These responses have been published and allow us to predict, with reasonable accuracy, the response to particular fertilisers and supplements under a range of conditions. Responses greater than these, although possible under certain circumstances (poor initial fertility in the case of fertilisers, a hungry cow in the case of supplements), are unlikely in most cases. If in doubt about the validity of the claims, ask the three questions already outlined:

- Where are your data?
- Is it published (and if so can I have a copy of the paper)?
- Where was the research undertaken?

These questions will allow you to separate the muck from the magic, and to make a more qualified decision on the validity of the claims of all products. Most tricksters will fail these tests, although some (the experienced trickster) will offer scientific references, which have little to do with the claims they are making.

If in doubt, seek out the help of a scientist. Most dislike pseudoscience and would be delighted to help you. Finally remember:

“If it sounds too good to be true. It probably is”.