Laws of Fertilizer Application

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Laws of fertilizer application

The basic principles of agronomy is to increase the profitability of crop production without deteriorating soil fertility and food quality. Keeping these views in mind several laws have been formulated for judicious application of fertilizers. These laws are:

1) Law of restitution of elements removed by harvesting
2) Law of restitution of available elements that have disappeared
3) Law of minimum
4) Law of maximum
5) Law of the priority of biological quality

1. Law of restitution of elements removed by harvesting

This law has been studied and formulated in France by Boussingault and in Great Britain by Lawes Gilbert. In general terms this basic law can be expressed as: "It is essential, if the soil is not to be exhausted, that all the fertilizing elements removed from it during the harvest should be returned."

To be more precise: If the soil is not to be exhausted, all the nutritive elements that harvests/remove must be returned, namely the four basic elements: nitrogen, phosphorus, potassium and calcium (N, P, K and Ca).

Table 1. removal of nutrients by some major cereals

Crops	Grain yield (t ha^{-1})	Nutrient removal (kg ha^{-1})		
		N	P_2O_5	K_2O
Rice (indica)	2.80	82	23	123
Wheat (dwarf)	2.24	59	29	67
Maize	2.69	114	47	105

Explanation:

Crop growth is simply the incorporation of food elements from soil into the plant body. Soil may be assumed as the reservoir of plant nutrients. As a consequence, upon harvesting of crops nutrients are removed from the soils and the soil becomes infertile. In such case, if the soil fertility to be maintained the fertilizing elements removed through harvest must be returned.

The law of restitution formulated above includes only the making good of nutritive elements removed by harvest. But some other elements that were available in the soils are disappeared because of the antagonistic nature of the applied nutritive elements. Therefore, if the soil fertility is to be maintained one must restore the elements removed by harvest, elements leached by rainfall and also by disappearance. So, the new law of restitution is worded by Andre Voisin (1965).

2. Law of restitution of available elements that have disappeared

When the soil is a regular recipient of fertilizers, the fertilizing elements may upset existing mineral balance and may cause certain available elements to 'disappear'. It was first noticed by Andre Voisin (1965) and he enunciated this law. This law states that: "It is essential, if the soil is not to be exhausted, that it should have restored to it the available elements that disappeared as the result of application of the four common fertilizers (N, P, K and Ca)".

Explanation:

To ensure proper growth and development it is essential to ensure all of the required plant nutrients in balanced amount. Imbalances supply of nutrition as well as changes in soil pH alter the availability of plant nutrients. Excess of any nutrients may disturb the availability of other nutrients.

For example, excess application of N makes the Cu to be disappeared from soil which results in Cu deficiency in crops. Excessive application of P results in unavailability of Zn. Likewise, excessive K led to unavailability of Ca, Mg and B which retard normal growth and development of crop.

3. Law of minimum

In 1828, the German botanist, Carl Sprengel, developed one of the principles of agriculture, later popularised by Justus von Liebig, a German chemist. This principle is known as "Liebig's Law of the Minimum". Justus von Liebig, generally credited as the "father of the fertilizer industry". According to Liebig, "If one crop nutrient is missing or deficient, plant growth will be poor, even if the other elements are abundant". More simply, "Harvested yields are proportional to the minimum amount of fertilizing elements present in the soil relative to the plants needs".

Liebig's Law suggests that plant growth is controlled, not by the total amount of nutrients or resources available, but by the availability of the scarcest resource. Simplistically, water can be seen as one of those resources and we know that it doesn't matter how many other resources there are in the soil for our crops, without any water those crops will not grow well. Liebig's Law is often described as being like a wooden barrel with different length staves, where each stave represents a different resource. The amount of water able to be held in the barrel (an analogy for plant growth) is quite obviously determined by the length of the shortest stave (the availability of the scarcest resource).

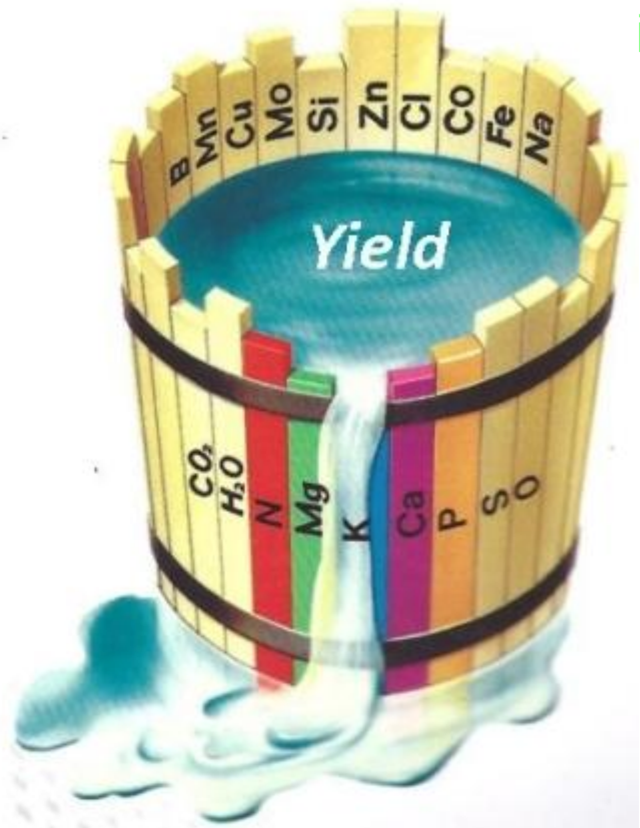

Fig. 1 Leibig's 'Wooden Cup Model'

The law of the minimum rarely applied quantitatively, and so it was left only with its qualitative aspect, with the result that the law today is most often expressed as follows:

"Insufficiency of an available element in soil reduces the effectiveness of other elements, and consequently lowers harvest yields".

Explanation:

Growth and yield of crop pants is determined by the presence of the element which is at minimum level. Suppose, a soil is fertilized with N, P and K but Mg and other elements are present in below optimum level. Here Mg will limit the growth and yield of the crop.

Liebig's Law was used to support the development of the fertiliser industry, to replace soil nutrient deficiencies with inorganic chemicals. But nowadays we know that applying ever-increasing chemicals to our soil is not achieving satisfactory returns. It doesn't take a lot of thought to realise that this is because the nutrients concerned are no longer the limiting resource factor. We know that the excessive application of inorganic chemicals has had deleterious impacts on soil biota and that the availability of the appropriate soil food web is often the prime constraint on crop growth.

4. Law of maximum

From both the theoretical and practical standpoints, however, emphasis should be laid on the fact that excess, like insufficiency of an element limits yield. With this in mind Andre Voisin have formulated a new "Law of maximum" which can be expressed as: "Excess of an available element in the soil reduces the effectiveness of other elements and consequently lowers the harvest yield obtained".

Explanation:

If any of the fertilizer element remain in soil in excessive amount it may retard the availability of other nutrients. In addition the excessive accumulation of any nutrients may exhibit toxicity in plants and as a result growth and yield may be decreased drastically. In such case balanced use of all essential nutrient elemnts is necessary to ensure an optimum harvest.

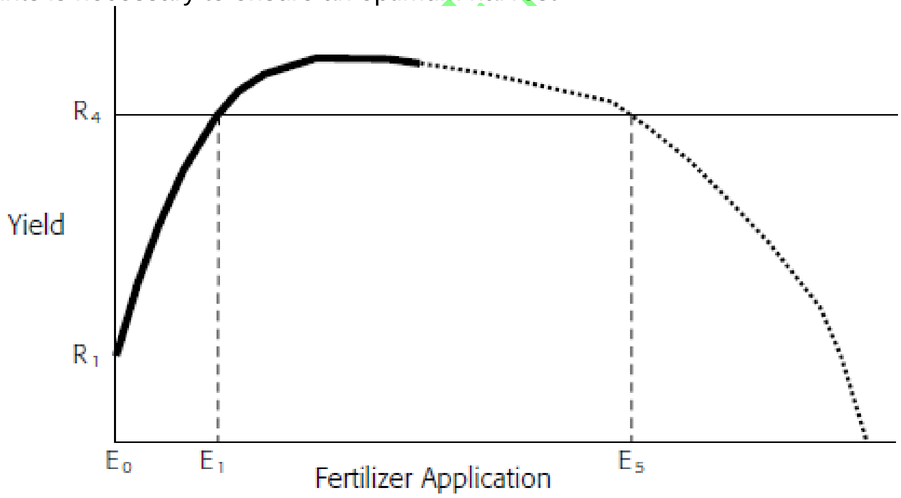

Fig. 2 fertilizer and yield response in ryegrass

Figure 2 demonstrates the Law of Maximum where E is fertilizer application and R the yield. Most fertilizer research and extension only shows the thick line, however the whole curve reveals the reality of fertilizer excesses.

The curve shows how yields quadruple (R4) compared to not spreading fertilizer at all (R1). However, the farmer can achieve R4 in two ways: with a normal dressing (E1) or one that is five times greater (E5). The graph shows how production reaches a ceiling between these dressings and then falls. Larger fertilizer applications do not necessarily produce higher yields because the excess tends to reduce the effectiveness of other elements and the ability of plants to grow and ripen.

Sometimes farmers continue applying high rates of fertilizer because of their original experiences. If a limiting element in the soil is addressed with an amount between E1 and E5, for example, the farmer sees a huge response in yield and thinks the same amount should be applied each year, without realizing an excess is building in the soil. Voisin's insight demonstrates why farmers need to monitor the environment to prevent excess nutrients building up, and increasingly farmers are now doing so through soil and herbage tests, measuring brix and sap, and so on.

The Law of Maximum is Voisin's fourth law of fertilizer application; that excesses of an available element in the soil reduce the effectiveness of other elements as well as harvest yield. The laws of minimum and maximum work alongside each other, as the excess of one element causes the disappearance of one or more other elements, and vice versa. This imbalance reduces crop yield.

5. Law of biological quality

Biological quality represents the sum of the individual factors present in the plant that contribute towards maintaining normal metabolism in the organism of the living being consuming that plant. The preliminary formulation of the law can be worded as: "Fertilizer application must primarily improve biological quality, or at least never impair it, while increasing yield as much as possible:. Yield must never be obtained at the expense of biological quality. The final formulation of the law will therefore be "The primary aim of fertilizer application must be to improve biological quality, which takes priority over yield".

It has been observed that excessive application of lime disturbs manganese metabolism and consequently the reproductive function in grazing animals. In Brussels Sprout, excessive application of Mn may reduce the content of ascorbic acid (Vitamin C) (Fig. 3) .

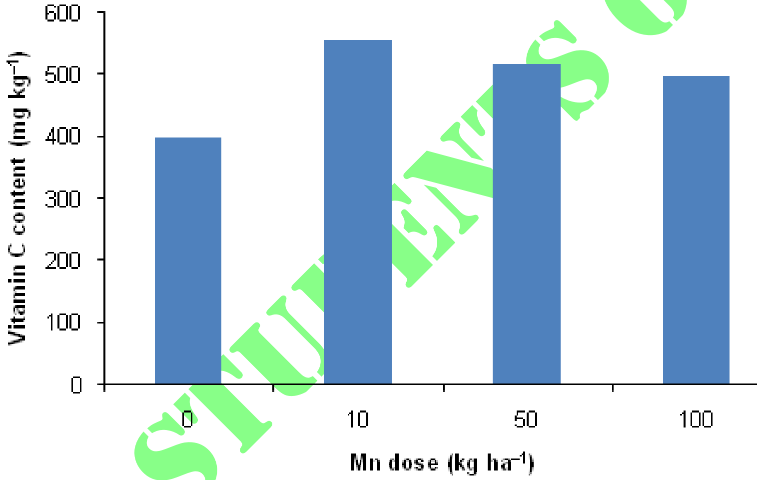

Fig. Vitamin C content in Brussels sprout as influenced by manganese

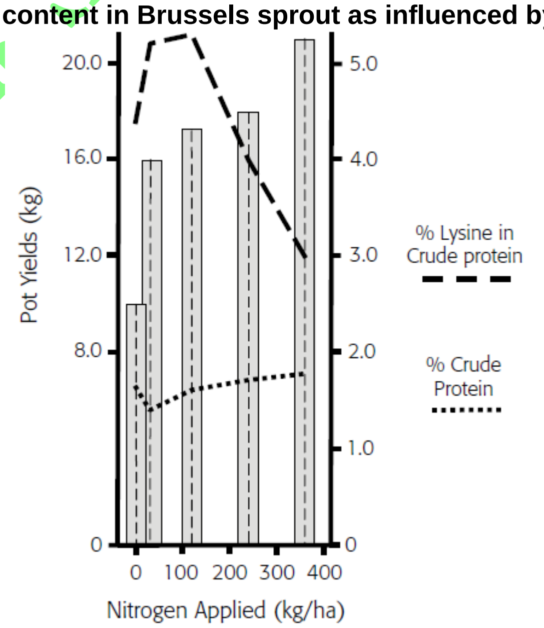

Fig. 4 Biological quality of white cabbage as influenced by N fertilizer

For example, Figure 4 highlights the relationship between fertilizer rate, yield and biological quality. It shows white cabbage yield and crude protein increase with the nitrogen fertilizer rate. However, as the proportion of the essential amino acid lysine in the crude protein declines (reflecting the Law of Maximum), the cabbage loses nutritional value and integrity. The maximum yield does not coincide with the highest biological value of the crude protein, and therefore the produce is inferior.