

XYLEM & PHLOEM

The Law of Limiting Factors

I have been meaning to write this article for some time and finally got around to it over the last Christmas break! It should be useful to both general vegetable growers and exhibitors as it will cover the factors that could be limiting the yield of your crop or the size of the individual vegetables which can matter with some exhibits, especially in giant vegetable classes. If you look at figures from various vegetable growers both professional and amateur, they show that crop yields vary widely, and many growers are well below the top yields. This is owing to various factors which I will look at in this article.

The Law of Limiting Factors was first proposed by a British scientist called Frederick Frost Blackmann (also spelt Blackman) in 1905 and states "that the rate of a physiological process will be limited by the factor which is in the shortest supply". This is not to be confused with another British scientist's (Justus Von Liebig) law the Law of the Minimum this states that the plants yield is limited by the most limited nutrient. So basically, you need to know which nutrient is the most lacking your soil / growing media as that is the one which will limit the growth of your crops. There is no point in applying loads of NPK if magnesium is low as it is the magnesium which will be the main factor in controlling the growth.

Plants grow fastest when they are at their preferred equilibrium of inputs, in other words when everything is perfect for growing. The factors covered by the law of limiting factors are light, water, gases, nutrients, and temperature; there are some others that can have an effect like the plant's genes, pest and diseases, humidity and time. We will look at these factors individually and what growers can do to achieve the best results and highest yields.

Light

There are two light factors which are light intensity and duration, a third factor is the light wavelength, but this is difficult to control outdoors. If growing indoors and supplementary lighting is used then ensure that blue and orange red are the main wavelengths, this can be done by using LED lights programmed to the correct wavelengths.

Looking at light intensity this is how bright / intense the light is, on a dull day in the winter the light intensity is well below

that of a sunny day in the summer and it is likely very little plant growth will occur even if the temperature is sufficient. The higher the intensity of light the greater the photosynthesis rate and the more carbohydrates produced resulting in more growth.

What can be done to improve light intensity? In greenhouses and polytunnels ensure the glass and polythene is clean, clean at least once a year using hot water with some detergent in to remove the dirt. Clean between the glass panes at the joints and both inside and outside, it is surprising how dirty the inside can get! Prune back any plants close by to allow light into the structure, don't stack junk adjacent to them and if any walls paint them white each year to reflect light. Research has also shown that if the floor is covered with white polythene, it reflects light back up to the leaves, using silver foil also works if it can be fixed to walls and floors.

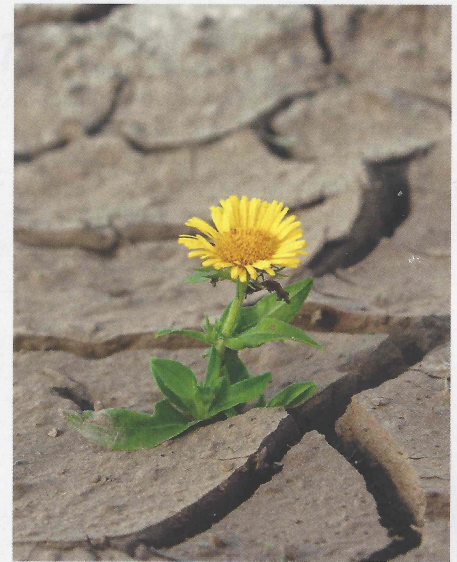
Outdoors try to avoid growing in the shade of trees or hedges or choose crops that will tolerate lower light levels like rhubarb, salad leaves, spinach, chard, radish will produce good crops even in lower light; comfrey and green manures will also grow. If hedges are tall, can they be reduced in height and possible width giving more growing room. Trees can often have the lower branches pruned back to the trunk to allow light to pass below the crown to the crops, or possible thin the crown to allow more light through. If the shade is from building short of demolishing them there is little that can be done other than paint the walls white of fix aluminium foil to them. If possible grow taller crops

like runner beans on the northern side of the plot so they do not shade other crops (tough on the neighbouring plot!).

As the season progresses so does the light duration with longer days in the summer and shorter in the winter; there is little we can do about this other than using supplementary lighting indoors and ensuring plants get maximum light outdoors and are grown in open unshaded areas.

Water

This is the next limiting factor and was a major problem in 2022 with the drought conditions in many parts of the country. If a plant starts to get short of water it shuts the stomata on the underside of the leaves to reduce transpiration, when it does this



photosynthesis stops so the plant stops growing therefore no growth. This happens well before the plant starts to wilt so the grower may not notice it at first. One other problem that occurs at this time is the plant is becoming stressed and this makes it more prone to pest and disease attack.

What can the grower do? Firstly, ensure the growing media / soil never becomes too dry, water regularly giving a good soaking on each occasion. Never just wet the surface, check the water is penetrating down into the soil to the roots. Wetting the surface encourages surface rooting which are then damaged by high temperatures and dry soil and soon die. Water in the evenings or early morning as less will evaporate then. Plants growing in greenhouses, polytunnels, cold frames, under cloches and in containers will need watering daily during the summer and every couple of days in the spring / autumn. Plants growing in the soil outdoors may need watering 2 to 3 times a week during dry periods and again soak the soil to a good depth. After watering it can pay to use a trowel to dig a small hole to check how deep the water has penetrated.

Plants growing outdoors or in borders indoors should be mulched to help conserve the moisture and if organic mulches are used can help to insulate the soil from really high temperatures. Organic mulches should be applied at a minimum depth of 5cm and if possible, up to 10cm deep. When digging add as much organic matter to the soil as possible as this will hold both water and nutrients for the plant. If a no-digger spread a good depth of organic matter over the soil in the winter so it is incorporated by soil organisms by the summer.

Before moving onto the next factor, I should mention that too much water is equally bad for the plant and will restrict the growth of plants or even kill them. The plants are not killed by the water but a lack of oxygen which neatly brings me to the next factor!

Gases

The two main gases a plant requires are oxygen and carbon dioxide, although a number of plants like the legumes make use of nitrogen from the atmosphere for growth. The aerial parts of the plant can usually get sufficient oxygen especially as they release it from the leaves as a by-product of photosynthesis. Carbon dioxide is not usually a problem outdoors especially with the effects of climate change and increased levels of CO₂ in the atmosphere. But indoors it can be a limiting factor on warm sunny days from the spring to early autumn, a greenhouse full of plants can soon deplete the atmosphere of CO₂ and once this happens the plant cannot photosynthesise owing to insufficient CO₂. On sunny days it is important to open the ventilators and if necessary, the door to allow in fresh air with more CO₂. If you have a gas heater the CO₂ from this can be used by the plants for growth.

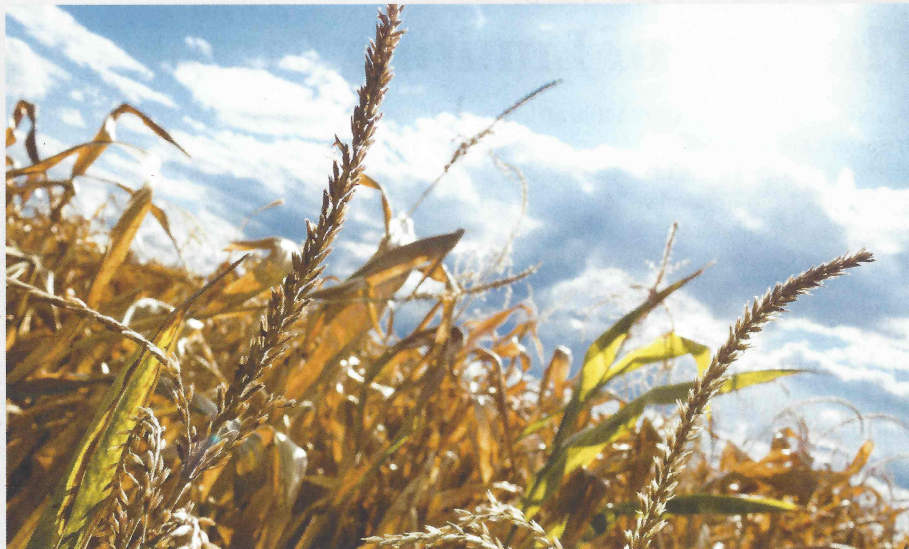
Many people forget that the gases oxygen and carbon dioxide can affect root growth in the soil, low levels of oxygen will reduce or even stop root respiration and therefore root and plant growth. Low oxygen can be caused by over wet or waterlogged soil, compaction or capped soils. Ensure the soil is never too wet, avoid walking or driving over the soil adjacent to plants and aerate the soil if there is any compaction. I might add at this stage one of my concerns of no-dig is the soil could become compacted over time.

As the roots respire (to grow) they give off CO₂, if this builds up in the soil it will reduce or stunt root growth which will then affect plant growth. It is important to prevent this happening by avoiding compacting the soil and breaking any caps that form on the surface. Keep the soil open by adding organic matter and break any compaction by cultivation.

One other gas I have not mentioned is ethanol which is produced by plant roots if the soil is waterlogged for more than a couple days in the summer, this gas will kill the roots relatively quickly resulting in plant death. Improve the drainage so the water gets away quickly, if your plot is on a wet site consider using raised beds.

Nutrients

Most plants require 17 nutrients to grow well, the main three are carbon, oxygen and hydrogen which are obtained from the atmosphere and water. Next are the six macro nutrients of nitrogen, phosphorous, potassium, calcium, sulphur and magnesium, nitrogen is the most important by far. Finally, there are the micronutrients of iron, manganese, copper, boron, zinc, molybdenum, are the ones most widely quoted but some plants seem to require chlorine, sodium, cobalt, and silicon there use in the plant is still being studied. All of these nutrients need to be available to the plant in the required amounts and this



will vary depending on the plant species. Plants grown for leaves like lettuce, cabbage, Brussels sprouts etc will need more nitrogen than plants grown for fruits like tomatoes, cucumbers, apples, and pears. Some plants have a requirement for certain micronutrients and this needs to be available or the plant will show deficiency symptoms which will limit growth. It is important to feed the soil with organic matter and or fertilisers to ensure crops are never short of nutrients. Plants grown in containers will need regular liquid feeds and or top dressing.

Temperature

I should possible have covered this earlier as it is a fairly major limiting factor, if the temperature is too low very few plants will grow especially if it is less than 3°C, some tender crops will be killed at this temperature. As the temperature increases so does the growth rate up to just over 30°C when enzymes in the plant start to be denatured and plant growth stops. The hardy vegetables like peas, broad beans, chard, winter cabbage etc. will start growing at 5 to 7°C; the plants from warmer climates like runner and French beans need 15 to 20°C to grow reasonably well and will grow better at 23°C. crops like cucumber, melons and tomatoes are happy at 25 to 27°C but will grow fine at slightly lower temperatures.

In the winter heating greenhouses and polytunnels is prohibitively expensive these days but its still possible to use small propagators to raise plants and then move them to lower temperatures. Using hotbeds is an old-fashioned method of heating if you have source of fresh manure.

To avoid too high temperatures indoors open the ventilators and doors on warm sunny days, damp down by spraying water on the floor and benches etc. and shade if necessary. Remember shading will reduce the light level so therefore will affect the growth rate so only use as a last resort. Blinds are the best shades as they can be raised or lowered as required.

Outdoors the temperature can be improved by using fleece, cloches (glass or polythene), or frames, if a windy site use windbreaks to reduce the wind which will help maintain a reasonable temperature.

Humidity

This can be a limiting factor but there is little that can be done outdoors, and it will not often be a problem. Indoors too high humidity will reduce transpiration as the atmosphere is already full of moisture, so this will limit growth as it slows down photosynthesis a little. Too low humidity will increase transpiration and that will increase the plants need for water, if the atmosphere is too dry damp down the greenhouse floors and leave some trays of water to evaporate to add to the humidity.

The above are the main factors that limit growth covered by the Law of Limiting Factors, the next two will limit growth but are not part of the law of limiting factors. Pests and diseases especially if they build up will reduce growth rate and some will kill the plant if not controlled. Most will stunt the growth if not prevented or controlled promptly. The aim should be to prevent infection using various cultural methods like barriers (fleece, insect mesh, collars, netting etc.), reduce humidity, time of sowing to avoid the problem etc or as a last resort using chemicals.

The other factor are the plants genes, if the plant has been bred for size or yield it is likely to be high yielding or good size or both; but if bred for flavour or colour and is naturally small in size it is unlikely to become a high yielder as its not in the genes. Carrot Paris Market is a round carrot is not going to produce a stump root like Sweet Candle or long root like Chantenay red Cored it has not got the necessary genes!

To ensure you achieve the best yield, size and quality for the kitchen or exhibiting ensure all the factors that can limit growth are kept to a minimum and the plants reach their full potential.

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