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The Canon of Potato Science: 27. Hydroponics

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What is it?

Plants commonly grow in soil. The soil environment provides nutrients, water, oxygen and mechanical support to the below-ground plant parts. *Hydroponics* is a soilless cultivation method in which plants are grown on a nutrient solution. The word *hydroponics* results from the Greek words "*hydros*" meaning "water" and "*ponos*" meaning "labour", or the Latin "*ponere*" meaning "put in".

Hydroponic systems differ in:

- whether plants are cultivated on nutrient solution alone or on nutrient solution in combination with a solid material (often called "substrate");
- the type of solid material used;
- the way by which the nutrient solution is supplied to the plants; and
- the frequency at which the nutrients in the solution are replenished, the pH adjusted, or the solution is renewed or recycled.

The nutrient solutions used for potato contain all important macro- and micronutrients: N (as NO_3^- and NH_4^+), P, K, S, Ca, Na, Mg, Fe (usually as chelate), Mn, Zn, B, Cu and Mo.

Solution culture systems are hydroponic systems in which plants are grown on nutrient solution alone, with the root systems emerged in the solution. The nutrient solution can be static, in which case it should be aerated to avoid lack of oxygen when the root system is completely immersed in the solution. The nutrient solution can also flow continuously alongside the (lower) roots. An example of this type is the nutrient film technique (NFT) in which a shallow stream (film) of nutrient solution floats continuously in a gutter along the roots. A special culture system is *aeroponics*, in which the "below-ground" plant parts are suspended in the air and (usually) intermittently misted with nutrient solution by sprayers. This provides a

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good supply of oxygen to the roots, stolons and tubers of potato plants growing in such systems. In the above-mentioned systems, plants have to be anchored because there is no solid material in the hydroponic system that provides support to the plants.

Other hydroponic systems contain solid materials in combination with a nutrient solution. Common solid materials used in hydroponics are rockwool, perlite, vermiculite, gravel, pumice, expanded clay pebbles, and mixtures of these. Also sand and organic materials as coconut fibre are used in hydroponics, but the difference with cultivation in soil media is smaller in those cases. The solid materials used in hydroponics differ in water holding capacity, drainage, aeration, pH, bulk density and CEC (cation exchange capacity). In hydroponic systems with solid materials, the nutrient solution is commonly supplied by ebb and flow (flood and drain) irrigation systems from below, by drip irrigation (fertigation) per plant or pot, or simply on top by hand and watering can. The latter is less suitable for it increases the humidity in the leaf environment, thus increasing the risk of disease spread and reducing transpiration, and leads to salt accumulation when not succeeded by supplies of water without nutrients.

Hydroponic systems are regarded to be cleaner than soil-based cultivation systems, with fewer or no soil-based diseases and pests. They also have the advantages that the supply of nutrients can be more stable than in soil, and can be adjusted very rapidly to the need in specific phases. Hydroponic systems can – depending on the system – also be more efficient in water use, nutrient use and show no leaching.

Because the growth of stolons and tubers is best in darkness, it is important in hydroponic potato production to exclude light from penetrating deep in the culture environment.

Why is it Important in Potato Science?

Roots, stolons and tubers are difficult to study while they grow in the soil. A huge advantage of especially the hydroponic systems without solid materials is that the stolon and tuber environment can be accessed and observed during plant growth, and sequential measurements can be taken on the same stolons and tubers. Hydroponic systems are therefore extremely important for studies on the timing and dynamics of stolon and tuber formation. Tuberization in potato, however, is sensitive to the density of the substrate, and results obtained in hydroponics are not directly transferable to the situation in the field. The use of easily removable solid materials in the hydroponic system circumvents this to some extent. When root zone inspection is needed, the solid material can be removed. This disturbs the system, however, and increases the risk of damage.

Solution culture systems and aeroponic systems also offer the possibility of removing or manipulating the below-ground parts easily, e.g., in studies on effects of stolon or tuber removal, or locally adding nutrients, growth regulators or any other substances or treatments.

Finally, hydroponic systems are very suitable for studying effects of nutrients, pH or other components in the nutrient solution, both on short term and long term.

Why is it Important for the Potato Industry?

Hydroponic systems firstly are important in the production of high quality potato seed. Hydroponic systems offer the possibility to produce minitubers on *in vitro* produced plantlets − or cuttings from these plantlets − under relatively disease-free conditions *"in vivo"*. Antagonists or other beneficial micro-organisms could be added optionally in this phase. Soilless cultivation will also facilitate easier import and export of the tubers produced. An additional advantage of hydroponic systems without solid material is that minitubers can be harvested repeatedly. Minitubers then are removed from the plants once they have grown to a certain minimum size. This leads to initiation of new (extra) tubers and allows tubers that are still too small to grow to harvestable sizes. These tubers can be harvested in a later harvest. Compared to conventional systems in which tubers are only harvested once, the total number of minitubers of a minimum size is greatly increased and thereby also the multiplication rate. In addition, the size distribution of the harvested tubers is very uniform. Only the solution culture and aeroponic systems allow frequent harvesting. Several successful systems have been established, e.g., in South Korea.

Hydroponic systems also are considered for production of table potatoes. This concerns for example the production of "Gourmet" potatoes in systems allowing repeated harvesting. Young, small sized, freshly harvested tubers for use in restaurants can be produced year-round in such systems. Hydroponic production can be part of completely closed production systems, in which use of resources and environmental pollution are minimum. NASA-funded research has investigated the production of table potatoes on hydroponics under completely controlled conditions to be included in life support systems for space bases. When table potatoes are produced in hydroponic systems, excluding light from penetrating the stolon- and tuber environment is especially important, because light stimulates the production of glycoalkaloids, which can be toxic to humans at high levels of concentration and intake.

Scientific Developments

Scientific developments can be expected both in research using hydroponic systems as a tool for accessing the stolon and tuber environment and in the development of the hydroponic systems themselves.

The systems will increase our understanding of the relation between morphological characteristics of stems and stolons on the one hand and stolon growth, tuber growth and tuber hierarchy on the other hand. They will also allow further progress in understanding the effects of removing above-ground (shoot tips) or below-ground (tubers) plant parts and the timing of removal on stolon and tuber initiation and growth.

Further studies on the nutrient effects, pH and electrical conductivity (EC) of the nutrient solution and the timing of applications of the solution will lead to optimization of the nutrient solution and its supply for different phases of crop growth; knowledge on how to respond to prevailing weather conditions or climatic factors in general; to possibilities of delaying, enhancing and synchronizing tuber initiation; to balancing canopy growth and below-ground growth, e.g., for prolonged production or inducing senescence; and to improvement of tuber quality. The latter concerns the dormancy, storability, and vigour of the seed tubers produced in hydroponics and the keepability and sensoric quality of the table potatoes produced in hydroponics.

Also a general optimization of technical aspects and production technology of hydroponic production is still needed. Hydroponics is potentially very promising and potential yields are high, but systems are still less robust and more delicate than soil-based systems and it is still difficult to realize the higher yield levels.

Further Reading

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