Hydroponics Agriculture: Its Status, Scope and Limitations

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Hydroponics (Greek words '*hydro*' water and '*ponos*' labour) is a method of growing plants using mineral nutrient solutions without soil. It is also called as "controlled environment agriculture" (CEA) since raising plants hydroponically requires control of environmental factors such as light intensity and duration, temperature, humidity, pH of the solution/medium and mineral nutrients.

1. Historical background of hydroponics

The study of crop nutrition began thousands of years ago. According to the ancient history, various experiments were undertaken by Theophrastus (372-287 B.C.) while several writings of Dioscorides on botany dated from the first century A.D. are still in existence (Douglas & James, 1975). The classic work on growing terrestrial plants without soil was published by Sir Francis Bacon in 1627, the book named '*Sylva Sylvarum*'. After Bacon's work, water culture became a popular research technique. In 1699, John Woodward published his water culture experiments with spearmint. He observed that plants grew better in less pure water sources than plants in distilled water. Experiments of German botanists, Julius von Sachs and Wilhelm Knop (1859-65) resulted in a development of the technique of soilless cultivation. It was Professor William Frederick Gericke (1937), who finally introduced the term *hydroponics* and wrote the book named '*Complete Guide to Soilless Gardening*'. Two other plant nutritionists, Dennis R. Hoagland and Daniel I. Arnon, at the University of California wrote a classic in 1938 in agricultural bulletin, *The Water Culture Method for Growing Plants without Soil*. These two researchers developed several formulas for mineral nutrient solutions, known as Hoagland solutions. Modified Hoagland solutions are still used today.

One of the early successes of hydroponics occurred in 1930s on Wake Island where it was used to grow vegetables for the passengers of Pan American Airlines. Since the inception of hydroponics, research to refine the methodology has continued. In the late 1960s researchers at the Glasshouse Crops Research Institute (GCRI), Littlehampton, England developed the nutrient film technique along with a number of subsequent refinements (Graves, 1983). This research gave rise to the hydroponic systems used today. Jensen and Collins (1985) published a complete review of hydroponics highlighting many new cultural systems developed in Europe and the United States. In recent decades, NASA has done extensive hydroponic research for their 'Controlled Ecological Life Support System' (CELSS). Hydroponics intended to take place on Mars are using LED lighting to grow in different color spectrum with much less heat.

2. Techniques of hydroponic or controlled environment agriculture

There are primarily two types of hydroponics *viz.* i) solution culture and ii) medium culture. In solution culture, there is no solid medium for the roots to support, just the nutrient solution while the medium culture has a solid medium for the roots and is named for the type of medium being used, e.g. sand culture, gravel culture or rockwool culture.

2.1 Solution culture: There are three main methods of growing plants in solution culture:

2.1.1 Static solution culture

In static solution culture, plants are grown in containers of nutrient solution, such as glass Mason jars (typically in-home applications), plastic buckets, tubs or tanks. The solution may or may not be aerated but usually gentle aeration is required. In case of unaerated solution, the level of solution is kept low so that enough roots are above the solution to get adequate oxygen. A hole is made in the lid of the reservoir for each plant. The lid can be of styrofoam (thermocol) or any other material sufficient to support the weight of shoots. There can be one to many plants per reservoir. Reservoir size can be increased as plant size increases. Aeration can be provided by an aquarium pump, aquarium tubing and aquarium valves. Clear containers are covered with aluminium foil, carbon paper, black plastic or other material to exclude light in order to eliminate the formation of algae. The nutrient solution is either changed on a schedule or when the concentration drops below a certain level as determined with an electrical conductivity meter. Whenever the solution is depleted below a certain level, fresh nutrient solution is added. In raft solution culture, plants are placed in a sheet of buoyant plastic that is floated on the surface of the nutrient solution. That way, the solution level never drops below the roots.

2.1.2 Continuous flow solution culture

The nutrient solution constantly flows past the roots in continuous flow culture. The main advantage of this method is that it is much easier to automate than the static solution culture since sampling and adjustments to the temperature and nutrient concentrations can be made in a large storage tank that serves potentially thousands of plants. One of the popular methods is the nutrient film technique (NFT) in which a very shallow stream of water containing all the dissolved nutrients required for plant growth, is re-circulated past the bare roots of plants in a watertight gully, known as channels. The depths of re-circulating stream remains very shallow, little more than a film of water, and therefore called 'nutrient film'. This ensures that the thick root mat in the bottom of the channel, although moist, is in the air and that there is an abundant supply of oxygen to the roots of the plants. For proper design of NFT system, it is required that it should have right channel slope, flow rate and channel length. The main advantage of the NFT system over other forms of hydroponics is that the plant roots are exposed to adequate supplies of water, oxygen and nutrients. The result of these advantages is that higher yields of high quality produce are obtained over an extended period of cropping. A downside of NFT is that it has a very little buffering against interruptions in the flow e.g. power outages, but overall, it is probably one of the more productive techniques.

The same design characteristics apply to all conventional NFT systems. It is recommended that slopes of 1:30 to 1:40 are used along the channels. This allows for minor irregularities in the surface but, even with these slopes, ponding and waterlogging may occur. The flow rates for each gully should be 1L/minute. The flow rate may be 0.5L/min at planting, while upper limit of 2L/min appears to be the maximum. Flow rates beyond these extremes are often associated with nutritional problems. The channel length should not exceed 10-15 meters otherwise depressed growth rates of plants will occur.

2.1.3 Aeroponics

In this system, roots are suspended in air in a closed chamber and are saturated with fine drops, in the form of a mist or aerosol of nutrient solution intermittently. In this method no substrate is required. Plants are grown with their roots suspended in a deep air or growth chamber with the roots periodically wetted with fine mist of atomized nutrients. Main advantage of aeroponics is the excellent aeration.

Aeroponic techniques have proved very successful for propagation, but have yet to prove themselves on a commercial scale. Aeroponics is also widely used in laboratory studies of plant physiology. Aeroponic techniques have been given special attention from NASA since a mist is easier to handle in a zero gravity environment than a liquid.

2.2 Medium Culture

In this method, there are two main variations for each media, i.e., sub-irrigation and top irrigation. For all techniques, most hydroponic reservoirs are now built of plastic but other materials have been used including concrete, glass, metal and wood. The containers should be such that it excludes light to prevent algae growth in the nutrient solution.

2.2.1 Passive sub-irrigation

This method of culture is also known as passive hydroponics or semi-hydroponics. In this method, plants are grown in an inert porous medium that transports water and fertilizer to the roots by capillary action from a separate reservoir as necessary, reducing labor and providing a constant supply of water to the roots. It is a very simple method in which a pot is kept in a shallow solution of fertilizer and water or on a capillary mat saturated with nutrient solution. The media (expanded clay and coconut husk) that contain more air space than traditional potting mixes deliver increased oxygen to the roots. Epiphytic plants such as orchids and bromeliads, whose roots are exposed to the air in nature can be grown using this method of hydroponics. Additional advantages of passive hydroponics are the reduction of root rot and the additional ambient humidity provided through evaporation.

2.2.2 Flood and drain sub-irrigation

In this method, a tray is kept on the reservoir of nutrient solution and is either filled with growing medium, i.e., clay granules or any other media and planted directly, or pots filled with media. A timer is used to cause the pump fill the upper tray with nutrient solution at regular intervals, after which the solution drains back down into the reservoir. This keeps the medium regularly flushed with nutrients and air.

2.2.3 Top irrigation

In Top irrigation method, nutrient solution is periodically applied to the surface of the media. This operation may be done manually once per day in large containers of some media, such as sand or gravel. Usually it is automated with a pump, timer and drip irrigation tubing to deliver nutrient solution as frequently as 5 to 10 minutes every hour.

2.2.4 Deep water culture

In deep water culture, the plant roots are suspended in a solution of nutrient rich, oxygenated water. In traditional methods, large plastic buckets and large containers are used with the plant contained in a net-pot or thick thermocol sheet suspended from the centre of the lid and the roots suspended in the nutrient solution.

3. Media

One of the most important decisions a hydroponic farmer has to make is the type of medium he should use. Different media are appropriate for different growing techniques.

3.1 Diahydro

Diahydro is a natural sedimentary rock medium that consists of the fossilized remains of diatoms. Diahydro is extremely high in Silica (87-94%), an essential component for the growth of plants and strengthening of cell walls.

3.2 Expanded clay

It is made by baking the clay pellets and known under the trade name of 'Hydroton' or LECA (light expanded clay aggregate). Hydroton or expanded clay pellets are suitable for hydroponic systems in which all nutrients are carefully controlled in water solution. The clay pellets are inert, pH neutral and do not contain any nutrient value. The clay is formed into round pellets and fired at high temperatures (1200°C) in rotary klins. This makes the clay to pop-up and become porous. The main advantage of hydroton is it is light in weight and does not compact over time. This is an ecologically sustainable and re-usable growing medium because of its ability to be cleaned and sterilized by washing in solutions of white vinegar, chlorine bleach or hydrogen peroxide and rinsing completely. But there is an opinion that clay pebbles are best not re-used even when they are cleaned due to root growth which may enter the medium. Breaking open a clay pebble after a crop has been grown will reveal this growth.

3.3 Rock wool

Rock wool, also called mineral wool is the most widely used media in hydroponics. It is an inert substrate for both free drainage and re-circulating systems. It is produced by aerosolization of molten mineral compounds which results in a fibrous medium accessible to capillary action that is not degraded by microbiological activity.

3.4 Coir

Coco peat, also known as coir or coco, is the leftover material after the fibres have been removed from the outermost shell of the coconut. Coir is a 100% natural growing medium.

3.5 Perlite

Perlite is made from volcanic rock after being superheated into very lightweight expanded glass pebbles. It is used either loose or in plastic sleeves immersed in water. It is also used in potting soil mixes to decrease soil density and facilitates drainage. Perlite generally holds more air and less water. If not contained, it can float if flood and drain feeding is used. It is a fusion of granite, obsidian, pumice and basalt. This volcanic rock is naturally fused at high temperatures undergoing what is called "Fusionic Metamorphosis".

3.6 Vermiculite

Like perlite, vermiculite is another mineral that has been superheated until it has expanded into light pebbles. Vermiculite holds more water than perlite and has a natural "wicking" property that can draw water and nutrients in a passive hydroponic system. If too much water and not enough air surround the plant roots, it is possible to gradually lower the medium's water-retention capability by mixing in increasing quantities of perlite.

3.7 Sand

Sand is the cheapest and easily available medium. However, the main disadvantages of using sand are that it is heavy, it does not always drain well and it must be sterilized between use.

3.8 Gravel/Quartz

Quartz or gravel of size <2mm can be used as a medium after washing it with dilute acid and properly rinsing with water. Indeed, plants growing in a typical traditional gravel filter bed, with water circulated using electric power head pumps, are in effect being grown using gravel hydroponics. Although it is heavy but it has advantages such as it is inexpensive, easy to keep clean, drains well and won't become waterlogged.

3.9 Brick shards

Brick shards have similar properties as that of gravel. But they have the added disadvantages of possibly altering the pH and require extra cleaning before re-use.

4. Nutrient solution

Plant nutrients used in hydroponics are dissolved in water and are mostly in inorganic and ionic forms. All the 17 elements *viz.* C, H, O, N, P, K, S, Mg, Ca, Fe, Mn, Cu, Zn, B, Cl, Mo and Ni essential for plant growth are supplied using different chemical combinations. Primary dissolved cations are Ca^{2+}, Mg^{2+} and K^+ and the major nutrient anions in the solution are NO_3^-, SO_4^{2-} and $H_2PO_4^-$. Though numerous 'recipes' for hydroponic solutions are available but all combinations of chemicals reach to a similar total final compositions.

Commonly used composition of nutrient solution, also called Hoagland solution, is given in Table 1. Chelating agents are used to keep Fe soluble. Many variations of the nutrient solutions used by Arnon and Hoagland have been named as 'modified Hoagland solutions' and are widely used. Variation of different mixes throughout the plant life cycle further optimizes its nutritional value. pH of the nutrient solution should range between 5.6 to 5.8. Once the plants are grown, it will change the composition of nutrient solution upon contact by depleting specific nutrients more rapidly than others, removing water from the solution, and altering the pH by excretion of either acidity or alkalinity. Care is required not to allow salt concentrations to become too high, nutrients to become too depleted, or pH to change far from the desired value.

5. Scope of hydroponics/ controlled environment agriculture

Growing crops in hydroponics under protected cultivation can be considered the most complex production system available today. In terms of farming systems, Ruthenberg (1980) classified hydroponic cultivation as a "high input – high output – high risk" system. In fact, the available techniques to date require considerable specialisation with sophisticated management and know-how as well as high financial inputs to realise expected production potential, otherwise the crop failures can be disastrous. Before going for a large scale hydroponic system, the growers should be much more critical in regard to site selection, structures, the growing system, pest control and markets.

5.1 Site selection

One of the important environmental factors depending on which site selection for CEA should be done is light intensity and duration rather than locating close to a population centre. Highest light levels are especially important if the greenhouse vegetables have to be grown during the winter, when tomato and cucumber prices are at their highest. Generally, a 1% decrease in light reduces yield by 1%. A greenhouse in a high light region can produce more than 500 tons of winter tomatoes per ha per year. Producing such yields in northern latitudes is only possible if the crops are grown through the summer period, when market prices are at their lowest.

Another important factor is temperature. For example, if tomatoes are selected as the crop to be grown year-round, low elevations must be avoided. Because it would be difficult to maintain desirable temperatures in the greenhouse during summers even with fan and pad cooling since the evaporative cooling is usually ineffective due to high ambient humidity. Given the high cost of fan and pad equipment, future hydroponic growers should select sites at specific elevations that have summer temperatures which do not require evaporative cooling, therefore sparing the costs of such cooling equipment. At the same time, an elevation should be selected that is not too high in order to avoid high heating costs in winter. As an alternative to fan and pad cooling a high-pressure fog system can be used. Recent experiences have proven this method of cooling desirable if the feed water is absolutely free of any un-dissolved or dissolved solids. If evaporative cooling systems are used, locating the greenhouse in a region of low outdoor humidity is important.

Important consideration for site selection is that the site should be free of insects that might be vectors for severe viral diseases. Growing in regions where there are mild winters normally increases the incidence of insects and diseases due to the continued life cycle of the pest. Selecting a site that is not already a major producer of vegetable crops is also advisable for economic returns purpose.

5.2 Energy and water

There are many choices available for energy sources such as natural gas, propane, fuel oil and electricity. Earlier hydroponic growers did not consider cost differences between the types of energy used in CEA. Many used natural gas and fuel oil. Coal was also used but air pollution standards and regulations made the use of this fuel prohibitively expensive.

Water quality is one of the major concerns for hydroponics. Plant growth is affected by the interaction of the dissolved chemical elements in the water supply, the chemical properties of the growing medium to which the water is applied, and the fertility program employed. Therefore, in selecting a greenhouse site, a grower must be aware of several chemical properties of water that might cause problems for greenhouse crops: pH, alkalinity, soluble salts, calcium, magnesium, boron, fluoride, chloride, sulphates, sodium, carbonate, and iron. The cleaner the water, the greater the opportunity to achieve maximum yields.

5.3 Structures and environmental control

Today the European glass structures are commonly being built for vegetable production in the south-western part of the United States and are very different from the polyethylene /fibreglass houses used in hydroponic production between 1965 and 1990. To achieve a more uniform growing environment without rapid temperature fluctuations, more total volume of space is being allotted within a greenhouse. The types of polyethylene sheet films retard the loss of infrared heat. These films are reported to reduce 20% of the heat loss from a greenhouse and are used commonly. Other glazing materials, such as fibreglass, polyvinyl chloride, have proven either inconvenient or much more expensive than polyethylene. Newer materials, such as polycarbonates and acrylics have become much more common, but their popularity has been offset by high costs.

Greenhouses are expensive and controlling the environment within a greenhouse requires considerable energy. Whatever be the source of energy, it should be conserved once it is in the greenhouse. In regions of cold winter weather, thermal curtains of porous polyester can be installed to reduce night heat loss by as much as 57%.

Within a greenhouse, computers can operate hundreds of devices such as vents, heaters, fans, hot water mixing valves, irrigation valves, curtains, lights, etc. by utilizing dozens of input parameters, such as outside and inside temperatures, humidity, outside wind direction and velocity, carbon dioxide levels and even the time of day or night. A computer can keep track of all relevant information such as temperature, humidity, CO_2, and light levels. Such a data acquisition system enables the grower to gain a comprehensive understanding of all factors affecting the quality and timeliness of the product.

5.4 Selection of growing systems

While there are many types of growing systems, the two most popular growing media today are rockwool and perlite but in India, coco-peat along with perlite is most commonly used. The irrigation system can be activated more than 30 times per day depending upon the temperature. At University of Arizona, excellent tomato crops were grown in a container no bigger than 956 cm^3 and maximum yields were 12.8 kg of tomatoes per plant over a period of 6-months.

In order to reduce media cost and maximize control over mineral nutrition, pH, aeration and root diseases, little root volume should be provided. High salt levels are maintained in the root systems where the E.C. of feed solution approach 3.5 and the drain water at an E.C. of 4.5 to 5.0. In future, systems designed should be closed, with no drainage which will prevent any loss of mineral elements and the contamination of groundwater.

5.5 Pest control

White flies, leaf miners, pin worms, nematodes, *Cladosporium* leaf mold and viruses, as well as root diseases such as *Pythium* root rot and bacterial wilt are commonly reported in hydroponics/CEA. To prevent many of these problems, the drain solution is often sterilized (Runia, 1995) using heat treatment, ozone and ultraviolet radiation. To control pests, integrated pest management (IPM) is of particular interest. Crop production requires both the identification of possible crop disease and insect problems, and the ability to properly integrate disease and insect prevention and control practices into a total management plan.

6. Status of hydroponics

6.1 International status

The area under hydroponics/CEA began to expand significantly in Europe and Asia during 1950s and 1960s, and large hydroponic systems were developed in the deserts of California, Arizona, Abu Dhabi, and Iran (1970) (Fontes, 1973; Jensen and Teran, 1971). In these desert locations, the advantages of the technology were augmented by the duration and interest of solar radiation, which maximized photosynthetic production.

At present, the largest commercial hydroponics facility in the world is “Eurofresh” Farms in Wilcox, Arizona, which has sold 125 million pounds of tomatoes in 2005. Eurofresh has 318 acres (1.29 km^2) under glass and represents about a third of the commercial hydroponic greenhouse area in the United States. Eurofresh does not consider its tomatoes organic, but they are pesticide-free. They are grown in rockwool with top irrigation.

Almost 20 years have passed since the last real commercial interest in hydroponics, but today there is renewed interest among growers to establish CEA/hydroponics systems. In the last four years, nearly 40 ha of greenhouses have been built in Colorado, Nevada, and Arizona. Many more hectares are planned, not only in the Southwest, but in Mexico too. The future for hydroponics appears more positive today than any time over the last 50 years.

6.2 National status

Hydroponics did not reach India until 1946. The first research studies were started at the Government of Bengal’s Experimental Farm at Kalimpong in the Darjeeling district. Initially a number of problems were faced but later on after a careful appraisal of salient problems, during 1946-47, the Bengal System of hydroponics was developed representing the efforts to meet Indian requirements. Last year (2008), about seven farmers in south Gujarat have adopted this technology for growing different varieties of exotic hybrid tea roses by Mr. Kumar Patel of ‘Best Roses’. He currently produces 10 million rose stems worth about Rs 5 crore, all of which is flown to overseas flower markets in Japan, New Zealand and Europe. It is now planned to double the production to 20 million rose stems by installing the hydroponics system on 12 hectares in Kuched village of Navsari district. Localised experiments have also shown that other exotic crops like strawberry, green garlic and tomatoes can also be grown using this imported technology. A Pune-based turnkey consultants, Flora Consult, which had helped ‘Best Roses’ set up the system three years ago, is now helping a vitrified-tile industry to set up a cluster of seven projects of exotic hybrid tea roses in Varawav village near Idar, Sabarkantha district of North Gujarat. Another giant ‘Landmark Agrotech’ project is the second big hydroponics project in Gujarat and is currently under implementation.

In India, several tracts of wastelands having poor quality soil but plenty of water can be brought under hydroponics. All that will be needed is to create an impervious surface at the bottom and bunds to hold water. The technology used for polythene lining of canals can come in handy for creating large hydroponic farms to grow food crops, vegetables and other plants.

7. Advantages of hydroponics over conventional agriculture

Today, hydroponics is an established branch of agronomical science. Progress has been rapid and results obtained in various countries have proved it to be thoroughly practical and to have very definite advantages over conventional methods of agriculture/horticulture. The two chief merits of the soilless cultivation of plants are, first, much higher crop yields, and secondly, the fact that hydroponics can be used in places where ordinary agriculture or gardening is impossible. Besides these, there are other advantages listed below:

- Less space is required to produce same amount of crop as compared to that grown in the field.
- Less growing time is required. Growth of plant is faster as there is no mechanical impediment to the roots and all the nutrient elements are available to the plant in plenty. Further, to increase plant growth, lighting systems such as metal halide or high pressure sodium lamps are used to lengthen the day or to supplement natural sunshine.
- Labour and garden maintenance is reduced as the intercultural operation is often absent or is very less, fertilization and irrigation is automated and no hard manual work is required.
- Water conservation is the biggest advantage. Hydroponics saves an incredible amount of water since it uses as little as $1/20^{th}$ the amount as a regular farm would to produce the same amount of food. Waterlogging never occurs.
- Saves money by recycling nutrients and water. In case of closed system of hydroponics such NFT, the nutrient is recycled thereby preventing loss of nutrient elements and preventing soil pollution. Large amounts of water can be recycled not used by the plant, after being aerated and eliminating anoxic conditions.
- Pest and disease problems can be controlled easily while weed is practically non-existent.
- Plants grown hydroponically avoids soil borne pests.
- More control over the plants rooting environment as the root zone's temperature, humidity, darkness, etc. can be easily manipulated.
- Higher yields can be obtained since the number of plants per unit is higher compared to conventional agriculture and produce can be obtained over an extended period of cropping (Table 2)
- Higher returns. Some plants can be raised out of season which can fetch higher income to the farmers.
- Excellent quality of produce with no dirt or smell.
- A hydroponic farmer in Virginia developed a Ca and K enriched head of lettuce claimed that their hydroponic lettuce uses 90% less water than traditional soil farming.
- Besides being a commercially useful technique, hydroponics is also a standard technique to be used in biological research and teaching.

8. Limitations of hydroponics/CEA

Though there are many merits of hydroponics over conventional agriculture, there are some limitations too:

- Higher set up cost
- Growers require skill and knowledge to maintain optimum production in commercial applications
- Because each plant in a hydroponics system is sharing the exact same nutrient, diseases and pests can easily affect each plant.
- Plants react quicker to changes in the environment, however, if this change is for the worst, plants will quickly react to it; showing signs of deficiency or trouble.
- Hot weather and limited oxygenation may limit production and can result in loss of crops

As with most things, it is important to understand the advantages and disadvantages of hydroponics. This will allow one to make informed decisions on what application is "right" for his individual requirements. This technology allows for growing where no one has grown before, be it underground, or above, in space or under the oceans this technology will allow humanity to live where humanity chooses. If used for our own survival, hydroponics is and will be a major part of our collective future (Winterborne 2005).

Table 1 : Composition of nutrient solution for hydroponic culture (maize)

Chemical	Final Concentration (mM)	Molecular wt.	g/L (200x stock; use 5 ml/L
Macronutrients KNO_3	1.25	101.11	**25.28**
$Ca(NO_3)_2$	1.5	236.16	**70.85**
$MgSO_4$	0.75	246.47	**36.97**
KH_2PO_4	0.5	136.09	**13.61**
NH_4Cl	1	53.50	**53.50**
Micronutrients			**g/L (1000x stock; use 5 ml/L)**
H_3BO_3	0.00005	61.83	**3.0915**
MnCl	0.00001	198	**1.9800**
$ZnSO_4$	0.000002	288	**0.5760**
$CuSO_4$	0.0000015	250	**0.3750**
$NH_4Mo_7O_{24}$	0.000000075	1236	**0.0927**
Fe-EDTA	0.000074	367	**27.1580**

pH should be adjusted between 5.6 to 5.8

Table 2 : Hydroponic averages compared with ordinary soil yields (Douglas and James 1975)

Name of crop	Bengal		United States	
	Hydroponic equivalent per acre	**Agricultural average per acre**	**Hydroponic equivalent per acre**	**Agricultural average per acre**
Wheat	8,000 lb.	5,600 lb.		
Oats	3,000 lb.	1,850 lb.		
Rice	12,000 lb.	750-900 lb.		
Maize	8,000 lb.	1,500 lb.		
Soya beans	1,500 lb.	600 lb.		
Potatoes	70 tons	8 tons	62.5 tons	6-10 tons
Beetroot	20,000 lb.	9,500 lb.		
Cabbage	18,000 lb.	13,000 lb.		
Peas	140,000 lb.	25,000 lb.		
Tomatoes	180 tons	5-10 tons	300 tons in Florida	5-10 tons for unstaked field plants; 50 tons for greenhouse cultured crops
Cauliflower	30,000 lb.	15-35,000 lb.		
French beans	42,000 lb of pods			
Lettuce	21,000 lb.	9,000 lb.		
Lady's finger	19,000 lb.	5-10,000 lb.		
Cucumber	28,000 lb.	7,000 lb.		

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