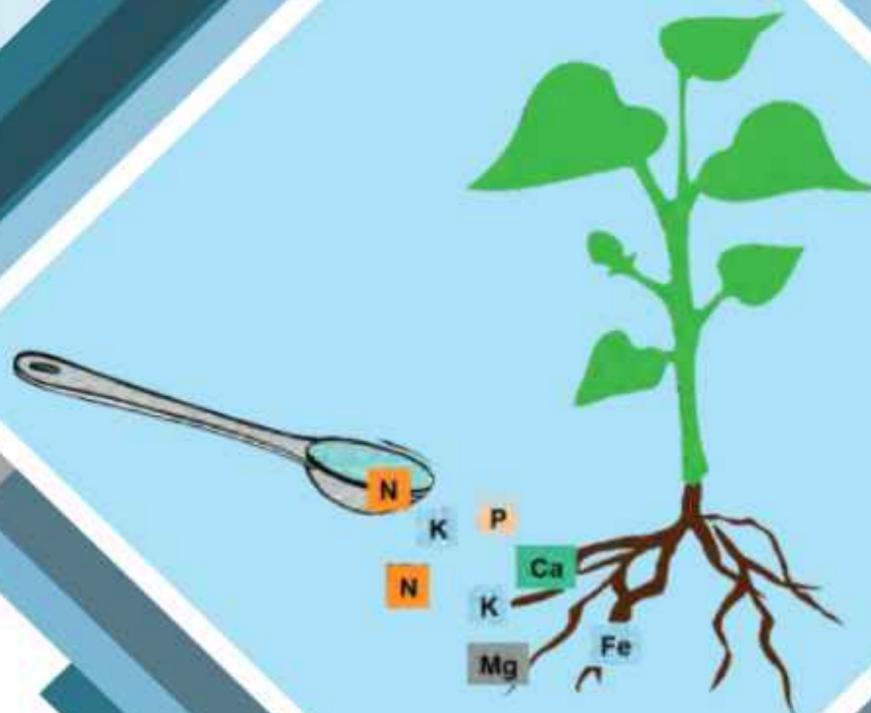


GOVERNMENT OF THE PUNJAB
AGRICULTURE DEPARTMENT

MANUAL

FERTIGATION

UNDER DRIP IRRIGATION SYSTEM



Directorate General Agriculture (Water Management)
Punjab, Lahore



**AGRICULTURE DEPARTMENT
GOVERNMENT OF THE PUNJAB**

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May 2018

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ACRONYMS

A	Area
B	Boron
Ca	Calcium
Chak	Village having a consolidated number
Cl	Chlorine
cm	Centimeter
Cu	Copper
DAG	Day after germination
DAP	Di Ammonium Phosphate
EC	Electrical Conductivity
FAO	Food and Agriculture Organization
Fe	Iron
GOP	Government of Pakistan
GoPb	Government of the Punjab
HA	Hectare
HEIS	High Efficiency Irrigation System
K	Potassium
K ₂ O	Potassium Oxide
Kg	Kilogram
L	Litre
m	Meter
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
MOP	Muriate of Potash
N	Nitrogen
NESPAK	National Engineering Services Pakistan
NH ₃	Ammonia
NH ₄	Ammonium
No ₃	Nitrate
N _p	Nutrient Percentage
OFWM	On-Farm Water Management
P	Phosphorous
P ₂ O ₅	Phosphorous Penta Oxide
PARC	Pakistan Agricultural Research Council
pH	Negative Log of Hydrogen concentration
PIPIP	Punjab Irrigated-Agriculture Productivity Improvement Project
PSC	Project-Implementation Supervision Consultants
Q	Discharge
SOP	Sulfur of Potash
S _p	Solubility Percentage
SSP	Single Super phosphate
Tehsil	Administrative unit that consists of a number of markaz
TNAU	Tamul Nadu Agriculture University
TSP	Triple Super Phosphate
U.C	Union Council - Administrative unit that consists of villages
V	Volume
WB	World Bank
Zn	zinc

PREFACE

To cope with the challenge of water scarcity in agriculture sector, Government of the Punjab with financial assistance of the World Bank has launched a mega project "Punjab Irrigated-Agriculture Productivity Improvement Project (PIPIP)". The main objective is to improve productivity of water use in irrigated agriculture in the Punjab. This will be achieved through increasing delivery efficiency and improving application efficiency by adopting improved high efficiency techniques and technologies, promoting crop diversification / high value crops and effective application of non-water inputs that will translate into greater agricultural output per unit of water used. The major project components include installation of high efficiency irrigation systems on an area of about 120,000 acres, provision of LASER units to farmers and improvement of watercourses.

Under the PIPIP, farmers are switching from flood irrigation to high efficiency irrigation system such as drip system on the basis of its advantages particularly higher fertilizer use efficiency with pressurized irrigation systems which apply fertilizers around the plant roots uniformly and allow for rapid uptake of nutrients by the plants. "Fertigation" is the technique of supplying dissolved fertilizer to crops through an irrigation system. Application of soluble nutrients saves labour, reduces compaction in the field, thereby enhancing productivity. Unluckily, most of the farmers do not have in depth understanding of the soil-plant-water-fertilizer relationships. Farmers are not much clear about the concept of fertigation. They do not have enough information about how much and when to apply the requisite quantity of a fertilizer. It was felt that most of the farmers as well as the project staff is not much clear about the fertigation schedules. On the other hand, proper fertigation schedules are necessary for guidance of the farmers and successful adoption of the drip irrigation. Therefore, a Fertigation Guidelines Manual having sample fertigation schedules for some major crops grown through drip irrigation has been prepared.

The first edition of Fertigation Guidelines Manual has been reviewed by the Technical Manual Development Committee constituted by the Director General Agriculture (Water Management) vide notification No. 21747-59/DGAOFWM/Dev.DS/2-31 dated 09/09/2016. In its meeting on 22/11/2016, the Technical Manual Development Committee made some decisions to improve the manual in the light of comments and suggestions of the committee members. For example, "Fertigation Guidelines Manual" and "Fertigation Schedules for Different Crops under Drip Irrigation in Punjab" may be combined in one manual and additional information contained in "Training Session on Fertigation through Drip Irrigation" may be incorporated to prepare comprehensive guidelines on fertigation under HEIS.

The Fertigation under Drip Irrigation System Manual has been prepared in the light of decisions of the Technical Manual Development Committee plus valuable suggestions of the manual reviewers. The manual has also been improved on the basis of field experience and new information collected from the relevant national and international agencies. The Fertigation under Drip Irrigation System Manual has now sample fertigation schedules of almost all crops,

vegetables and fruits being grown through drip irrigation in the project area. The fertilizer recommendations have been computed on the basis of nutrient uptake / removal for some target yields of crops, vegetables and fruits. The nutrient deficiency symptoms have also been described in the Manual.

The objective of this manual is to provide comprehensive guidelines to the project staff for proper fertigation through HEIS and also transform such information in a simple language in the shape of fertigation schedule to convey the information to the farmers.

1. INTRODUCTION

In Pakistan, farmers have started switching their irrigation over to high efficiency irrigation systems such as drip irrigation and sprinkler irrigation on the basis of their advantages particularly higher fertilizer use efficiency with the help of pressurized irrigation system placed around the plant roots uniformly and allow for rapid uptake of nutrients by the plants. High Efficiency Irrigation System (HEIS) through drip and sprinkler is the most important intervention of the Punjab Irrigated – Agriculture Productivity Improvement Project (PIPIP). The method of supplying dissolved fertilizer to crops through an irrigation system is called as "Fertigation". The technique of fertigation has various advantages over other fertilizer application methods such as:

- Increase in yield by 25-30 percent.
- Saving in fertilizers by 25-30 percent.
- Precise application and uniform distribution of fertilizers.
- Nutrient can be applied as per plant requirements.
- Acidic nature helps in avoiding clogging of drippers: it cleans drip system.
- Minimizes nutrient losses.
- Major & micro nutrients can be applied in one solution with irrigation.
- Fertilizers can be injected as per required concentration.
- Saving in time, labour and energy.
- Light soils can be brought under cultivation.

Drip and sprinkler irrigation provides an efficient method of fertilizer delivery virtually free of cultural constraints that characterize other production systems. Achieving maximum fertigation efficiency requires knowledge of:

- Soil physical and chemical properties
- Water quality data
- Crop nutrient requirements
- Soil nutrient supply
- Fertilizer injection technology
- Crop water requirement
- Irrigation scheduling
- Fertigation scheduling
- Crop and soil monitoring techniques

Soil provides anchorage to the plants on one hand and serves as a medium or reservoir on the other hand through which the plants extract water and with it the nutrients to maintain their life.

An ideal soil must have:

- Desirable texture-loam/clay loam with good water holding capacity
- Suitable structure
- Moderate infiltration rate to timely absorb the water
- Sufficient nutrients level of all the essential elements
- Acceptable level of salts and should be free from salinity and sodicity
- Optimum reaction i.e. pH 6.5-7.5
- Sufficient organic matter i.e. not less than about 3 percent
- Good microbial activity and should be well rich in soil micro-organisms

But it is rarely a case that all the good characteristics of a soil exist together at a farm. Unfortunately, most of the soils are either short or in excess of one or more of the above mentioned parameters because of inherent characteristics and due to lack of proper management. If in the light of soil analysis and plant appearance relevant measures are taken and necessary amendments added, it is possible to bring the soil close to the ideal one and attain the potential yields.

Focus here is being made upon maintaining fertility status of the soil in order to bring the quantitative level of the essential nutrients high enough to readily support the plants growth and development through HEISs with the help of a soil enrichment process called fertigation. Through this process, the plant nutrients are injected into the irrigation water through drip and sprinkler systems in concentrations matching with the plant requirements in such a way that the same precisely reach the area of high root activity. The process itself involves clearance of a number of soil-plant-water-fertilizer relationship concepts and solving of a number of mathematical equations for an expert. With the advancement of the agricultural sciences, it is now easy to determine the requisite quantities of all the essential elements that a particular crop may demand for a desired yield. Against this demand it can also be easily determined that what quantities of these elements are available in the soil.

The objective of this manual is to provide guidelines to the project staff for proper fertigation through HEIS particularly drip and sprinkler irrigation plus transform such information in a simple language in the shape of fertigation schedule to convey to the farmer. It will help the farmers to know that on what date he should apply how much quantity of which fertilizer for how long a duration through drip and sprinkler.

2. PLANT NUTRIENTS

2.1 Essential Plant Nutrients

There are 16 essential plant nutrients as shown in Figure 2.1. Oxygen, hydrogen and carbon are non-mineral essential elements that plants get from air and water. These elements commonly enter a plant body as CO₂ and H₂O. These elements are the building blocks of macromolecules and constitute over 90% of the total dry matter of the plant. Hence these are commonly known as framework elements. The essential mineral nutrients are 13 that are essential for completion of the plant's life cycle and plants get these from soil through soil minerals, soil organic matter and fertilizers. Macro-elements are required in large quantities: nitrogen, phosphorous, potassium, calcium, magnesium and sulphur. Micro-nutrients are required in very low concentration: iron, manganese, zinc, copper, molybdenum, boron and chlorine. For fertigation through HEIS, all of these nutrients should be provided in the hydroponic nutrient solution, in the right concentrations, and in adequate ratios.

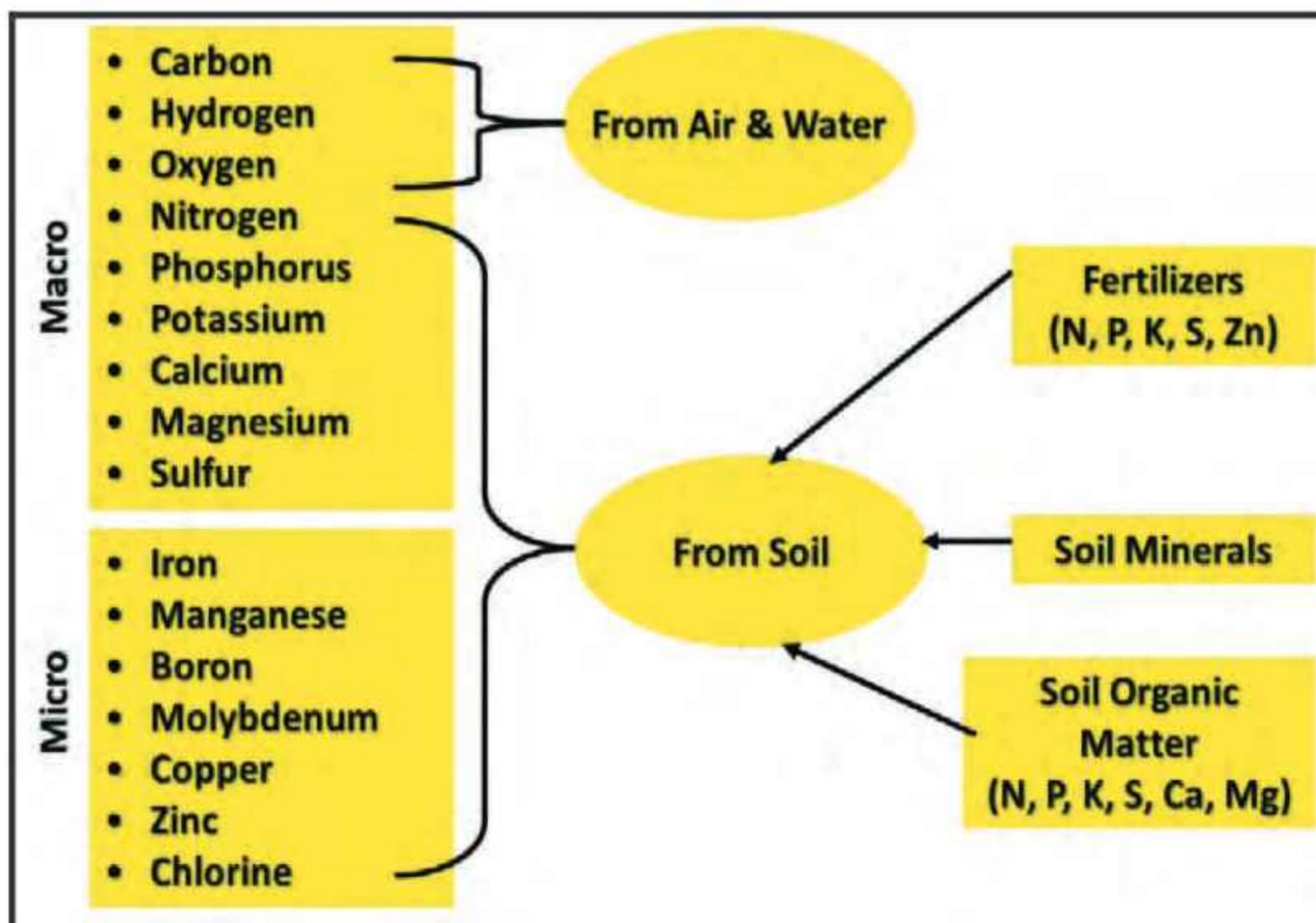


Figure 2.1: Essential Plant Nutrients

According to the law of "limiting factor", if one nutrient is deficient, other nutrients cannot compensate for the deficiency, and the crop may suffer, resulting in decreased quality and/or yield. The salient features of important essential plant nutrients will be discussed in detail in the

next section. It comprises nutrients' role in plant, deficiency symptoms, uptake forms and source fertilizers etc.

2.2 Role and Deficiency Symptoms of Nutrients

All macro and micro nutrients have their specific roles in plant growth. However, nitrogen,

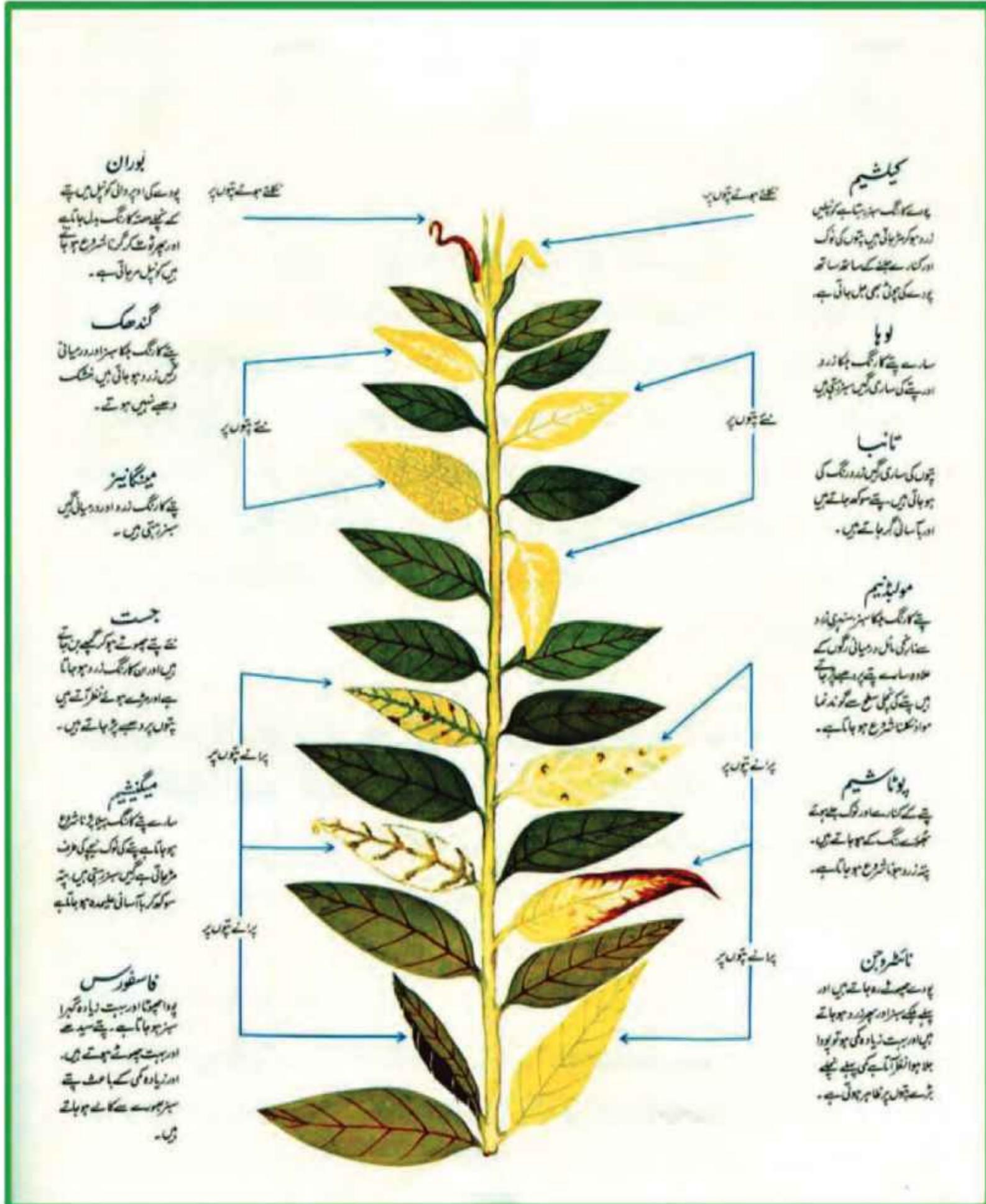


Figure 2.2 Deficiency Symptoms of Plant Nutrients

phosphorous and potassium are mostly deficient in soil and water. These are also called as fertilizer nutrients. These must be provided in the hydroponic nutrient solution using fertilizers. Similarly, all other macro and micro nutrients may be deficient in soil and plants can show different types of deficiency symptoms. The role and deficiency symptoms of different plant nutrients are mostly visible on leaves of the plants as shown in Figure 2.2 and discussed in detail hereinafter.

2.2.1 Nitrogen (N)

Nitrogen is one of the most important essential elements for plants required in comparatively large amounts. Nitrogen is a constituent of amino acids, amides, proteins, enzymes, vitamins, coenzymes and plant hormones. It imparts vigour to the plant and dark green colour to the foliage. Nitrogen is required for cell division and respiration. It delays plant maturity due to which tissues remain succulent in nature. Nitrogen also governs the utilization of phosphorus, potassium and other essential elements. It is a very mobile element. The most important deficiency symptoms include:

- Stunted plant growth due to reduced cell division and dormant lateral buds
- Chlorosis or yellowing of leaves
- Suppressed or late flowering and suppressed yield
- Increase in starch content but decrease in protein content
- Wrinkling of cereal grains
- Purple colouration appears in shoot axis



Nitrogen Deficiency Symptoms

Excess of nitrogen might result in poor root system, soft tissue, delay in harvestable products, low quality yield and higher susceptibility to diseases and pests. Nitrogen is mobile within the plant and, therefore, deficiency symptoms are expressed on older leaves.

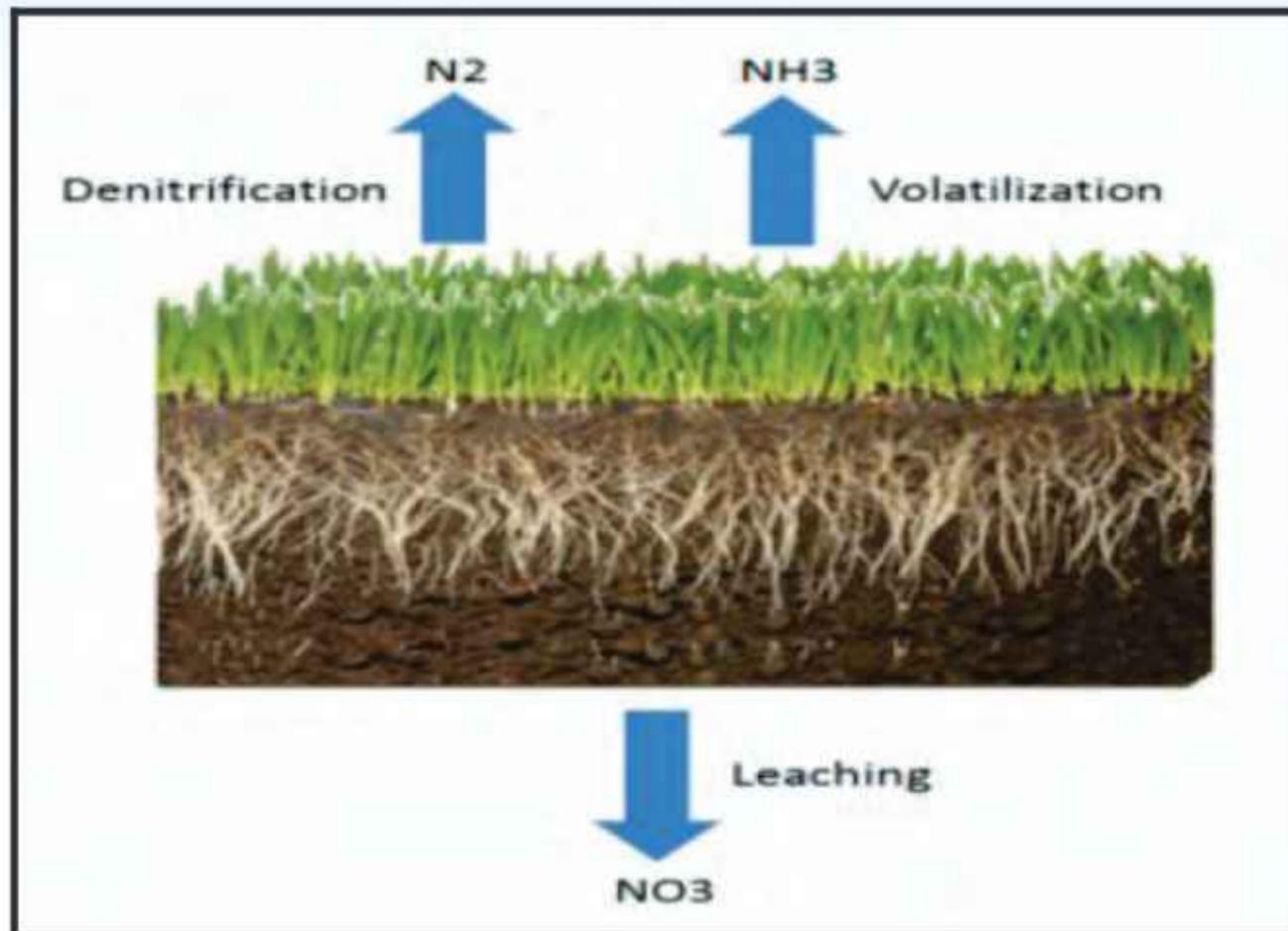
Successful nitrogen management can optimize crop yields and increase profitability while minimizing nitrogen losses to the environment. However, nitrogen management is unique and might be a complex task. Nitrogen behavior is complex and it is determined by many physical, chemical and biological processes. These processes are very much affected by environmental factors.

Natural nitrogen is present mainly in air and soil. The atmospheric nitrogen is a major reservoir of nitrogen, but it is unavailable to most plants. Only legume plants can use atmospheric nitrogen in biological processes that involve bacteria. Small amounts of nitrogen are deposited by rain. Most of the nitrogen in soil is contained in organic matter. The organic matter is relatively stable and it is not directly available to plants. Plants can absorb nitrogen only in its inorganic forms, NO_3 (nitrate) and NH_4 (ammonium). Only about 2-3% of the nitrogen in the organic matter becomes available to plants per year, in a process called "mineralization". This process is influenced by environmental factors, such as temperature, moisture, aeration, and soil pH.

Nitrogen might be lost from the soil and, therefore, become unavailable for plants, in several ways:

1. Leaching – nitrate (NO_3) easily moves downward along with water, as it is not held by soil. As a result, it might be washed out below the root zone, with the flow of water.
2. Volatilization – nitrogen is lost as an ammonia (NH_3) gas. This might happen when fertilizers containing urea are surface-applied.
3. De-nitrification – nitrate-nitrogen (N-NO_3) is converted back, by bacteria, into nitrogen gas, that is lost into the air. This process occurs when the soil is saturated or very wet.

Successful nitrogen management can optimize crop yields and increase profitability while minimizing nitrogen losses to the environment. One of the main challenges in deciding on a nitrogen fertility program is the timing of the application. In fertigation systems, the best practice would be to apply frequent small applications, at rates that meet the crop requirements. In less intensive crops, like cereals and grains, where only a few fertilizer applications are made, timing of nitrogen application is critical. Applying nitrogen too early holds the risk of losing it through leaching, before the crop takes it up, especially if rains are to come. The common approach, in such cases is to split the nitrogen application, where most of the nitrogen fertilizer just before the crop's maximum demand for nitrogen. However, there is a risk of applying the nitrogen fertilizer "too late", if logistic or weather conditions do not allow applying it when planned.



As far application rate of Nitrogen, it goes through the quick and constant changes between its different forms and it is highly mobile in the soil. As a result, testing soil nitrogen gives a reading that is valid only the same moment of testing, and might lead to erroneous recommendations for nitrogen application. Therefore, the common approach is to give nitrogen recommendations based on yield goal and the nitrogen uptake of the crop. Nitrogen credits, due to organic matter in the soil and residues of previous crops, should be also taken into account when making nitrogen fertilizer rate recommendations.

2.2.2 Phosphorous (P)

Phosphorus is an essential macro-element, required for plant nutrition. It participates in metabolic processes such as photosynthesis, energy transfer and synthesis and breakdown of carbohydrates. Phosphorus is found in the soil in organic compounds and in minerals. Nevertheless, the amount of readily available phosphorus is very low compared with the total amount of phosphorus in the soil. Therefore, in many cases phosphorus fertilizers should be applied in order to meet crop requirements. The solubility of phosphorous in soil is low.

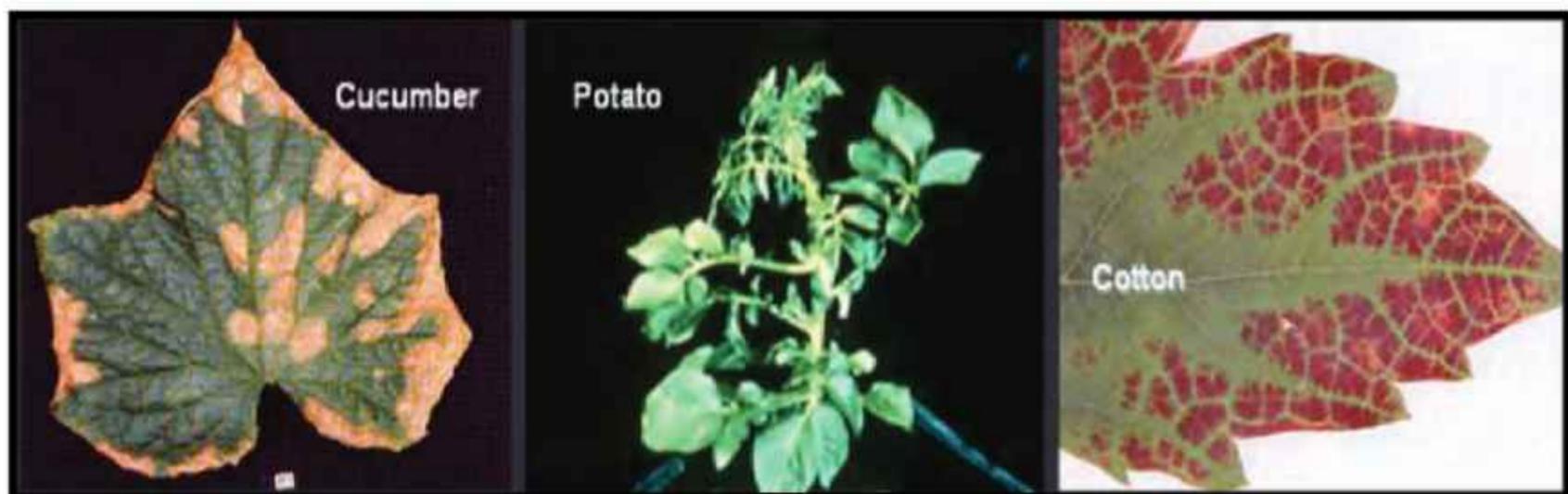
There is equilibrium between solid phase phosphorus in soil and the phosphorus in the soil solution. Plants can only take up phosphorus dissolved in the soil solution, and since most of the soil phosphorus exists in stable chemical compounds, only a small amount of phosphorus is available to the plant at any given time. When plant roots remove phosphorus from the soil solution, some of the phosphorus adsorbed to the solid phase is released into the soil solution in order to maintain equilibrium.

The types of phosphorus compounds that exist in the soil are mostly determined by soil pH and by the type and amount of minerals in the soil. Mineral compounds of phosphorus usually contain aluminum, iron, manganese and calcium. In acidic soils phosphorus tends to react with aluminum, iron and manganese, while in alkaline soils the dominant fixation is with calcium. The optimal pH range for maximum phosphorus availability is 6.0-7.0. In many soils decomposition of organic material and crop residue contributes to available phosphorus in the soil.

Plants take up phosphorus from the soil solution as orthophosphate ion: either HPO_4^{-2} or $\text{H}_2\text{PO}_4^{-1}$. The proportion in which these two forms are absorbed is determined by the soil pH, when at higher soil pH more HPO_4^{-2} is taken up. The mobility of phosphorus in soil is very limited and therefore, plant roots can take up phosphorus only from their immediate surroundings. Since concentration of phosphorus in the soil solution is low, plants use mostly active uptake against the concentration gradient (i.e. concentration of phosphorus is higher in the roots compared with the soil solution).

Symptoms of phosphorus deficiency include:

- Purple or red pigmentation on leaves
- Premature fall of leaves and floral buds
- Delay in seed germination
- Older leaves affected first and become dark brown
- Stunted and slender stem in young plants
- Accumulation of carbohydrates in Glycine max (Soybean)
- Vascular tissues reduce in tomato plants



Phosphorous Deficiency Symptoms

In most plants these symptoms will appear when phosphorus concentration in the leaves is below 0.2%. In case of its excess, phosphorus mostly interferes with uptake of other elements, such as iron, manganese and zinc. Over-fertilization with phosphorus is common and many growers apply unnecessarily high amounts of phosphorus fertilizers, especially when compound NPK fertilizers are used or when irrigation water is acidified using phosphoric acid.

2.2.3 Potassium (K)

Potassium in soil is generally classified into four types:

- Unavailable potassium
- Fixed potassium or slowly available potassium
- Exchangeable potassium or readily available potassium
- Soil solution potassium

The basis for the classification is potassium availability for absorption. Depending on the type of soil and environmental conditions, potassium availability may vary.

Unavailable Potassium – found in crystalline structure of feldspars, clay minerals and micas which are part of the soil. Plants cannot use the potassium in these insoluble forms. However, with time, these minerals eventually break down, and small quantities of potassium are released to the soil solution.

Fixed Potassium – potassium that becomes slowly available to plants over the growing season. Clay minerals have the ability to fix potassium. During wetting and drying of the soil, potassium becomes trapped in-between the mineral layers (clay minerals have a layer structure). Once the soil gets wet, some of the trapped potassium ions are released to the soil solution.

Exchangeable Potassium – is readily available potassium, which plants can easily absorb. This fraction of Potassium is held on the surface of clay particles and organic matter in soil. It is found in equilibrium with the soil solution and is easily released when plants absorb potassium from the soil solution. Exchangeable potassium is measured in most soil testing.

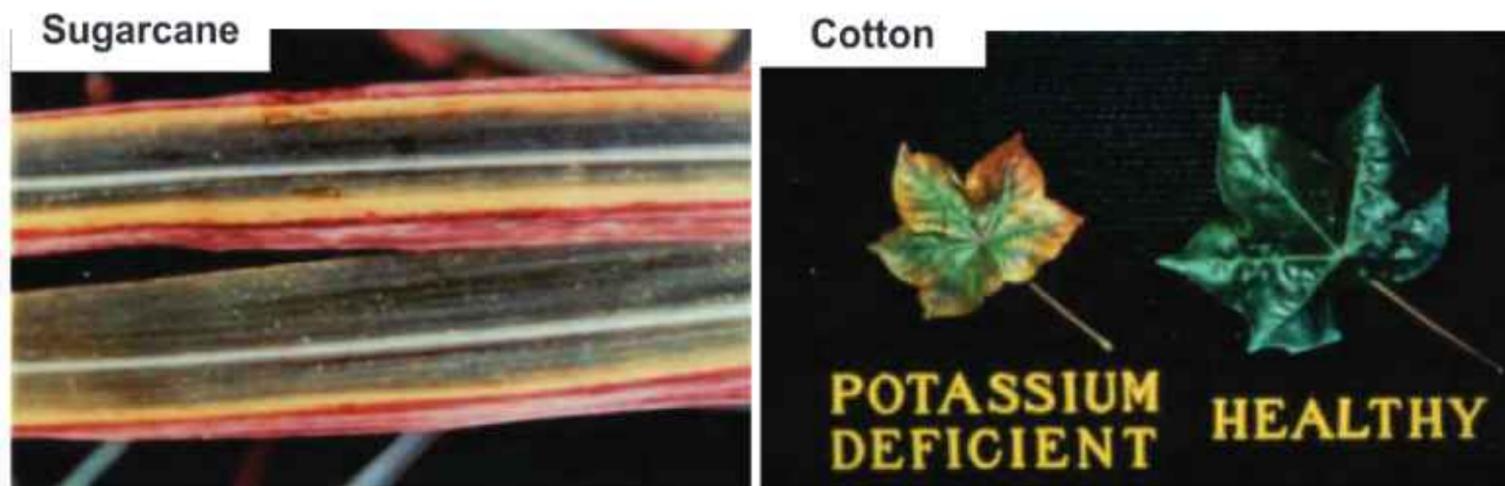
Soil Solution Potassium – potassium dissolved in the soil solution and is readily available to plants. It is the smallest pool of potassium. Testing only potassium in the soil solution does not represent the total amount of potassium available to plants.

Several factors can affect the ability of plant to absorb potassium from soil:

- Oxygen level – oxygen is necessary for proper root function, including uptake of potassium
- Moisture - the more moisture found in the soil, the easier it is for plants to absorb potassium.
- Soil tilling – research has shown that regularly tilled soil allows for better potassium uptake.
- Soil temperature – 60-80 degrees Fahrenheit is the ideal soil temperature range for root activity and most of the physiological processes in plants. The lower the temperature, the slower absorption becomes.

Potassium deficiency symptoms include:

- Brown scorching on leaves
- Curling leaf tips
- Purple spots on the underside of leaves
- Reduced plant growth and root development
- Generally poor quality plant



Potassium Deficiency Symptoms

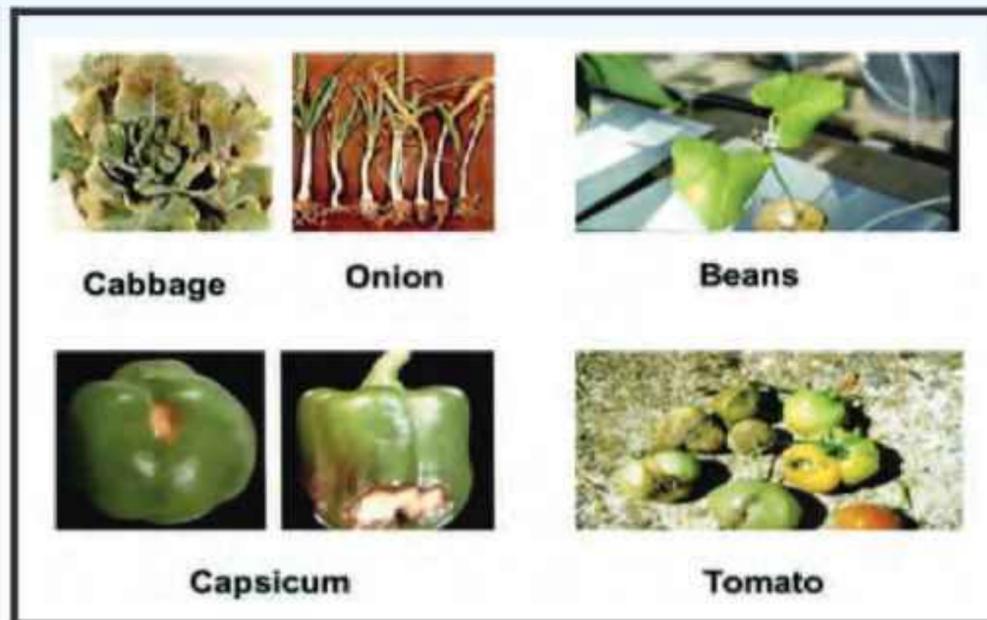
2.2.4 Calcium (Ca)

Calcium is an integral part of cell wall. It promotes root growth and plays an important part in development of buds and flowers. The uptake form of calcium is Ca^{++} and source fertilizers are calcium nitrate, calcium ammonium nitrate and calcium sulphate. The most important functions of this nutrient are:

- Used in synthesis of calcium lactate in middle lamella of cell wall
- Involved in normal functioning of cell membrane
- Used in formation of mitotic spindle
- Serves as a second messenger in action of phytohormones
- Activates certain enzymes like ATPase, kinases and succinate dehydrogenase

Calcium is mostly deficient in sandy soils. Its deficiency symptoms include:

- Stunted growth
- Leaves give very green appearance
- Leaves become crinkled and/or cup shaped
- Terminal buds and growing tips often die
- Chlorosis, downward hooking and deformation in young leaves
- Necrosis of young meristematic regions such as root tips or young leaves



Calcium Deficiency Symptoms

2.2.5 Magnesium (Mg)

Like calcium, magnesium is also available in the soil in form of exchangeable cation. It is absorbed as divalent Mg^{2+} . It is required in leaves. It is withdrawn from ageing leaves and exported to developing seeds. Other most important functions are:

- An essential part of chlorophyll
- Enhances activity of plant enzymes in respiration, photosynthesis and synthesis of DNA and RNA
- Helps in absorption and translocation of phosphorous
- Maintains ribosome structure and chromatin fiber
- Some observations reveal that it helps in formation of oils in the plants

The deficiency symptoms of magnesium have been noted on cotton and citrus especially in light soils. The deficiency symptoms include;

- Interveinal chlorosis (yellowing and then drying) in older leaves
- Upward curling of leaves
- Marginal yellowing along midrib and in cereal along parallel stripes between the veins of leaves
- Necrotic or purple spots on older leaves
- Premature leaf drop.



Magnesium Deficiency Symptoms

2.2.6 Sulphur (S)

In plants sulphur is required in stem, root tips and young leaves. Plants obtain sulphur from soil as divalent sulphate anions (SO_4^{2-}). Atmospheric SO_2 and SO_3 are also absorbed directly. No specific fertilizers but can be obtained from sulphates of Ammonium, Potassium, Zinc, Ferrous, Magnesium and Copper. The most important functions of this nutrient are:

- Essential for formation of chlorophyll in plants
- Constituent of certain Amino Acids such as Cysteine and Methionine
- In leguminous crops, facilitates formation of nodules on roots helping in fixation of nitrogen
- It is essential for stabilizing the structure of protein by formation of disulfide bond (S-S) between two cysteine residues to form a cystine,

The deficiency symptoms of sulphur are similar to those of N except that in case of N deficiency chlorosis is uniform in all leaves but in S it is on young leaves. The common deficiency symptoms of this nutrient include:

- Retarded growth and limited flower production
- Stiff, thin & brittle stems and delayed maturity.
- Chlorosis of younger leaves
- Accumulation of anthocyanin
- Terminal bud growth is inhibited
- Lateral buds develop prematurely



Sulphur Deficiency Symptoms

2.2.7 Zinc (Zn)

The uptake form of zinc is Zn^{++} . The common source fertilizer of zinc is Zinc Sulphate. The most important functions of this nutrient are:

- Essential constituent of certain enzymes and hormones such as indole Acetic Acid
- Enhances flower and seed production
- Promotes absorption of nutrients by the plants

A variety of symptoms appear in the foliage due to zinc deficiency. The most important ones include:

- A typical interveinal chlorosis in terminal young leaves and mottling of leaves
- Rosette growth due to shortened internodes especially in apples
- Height of the plant remains limited
- Brown spots on lower leaves
- Drying of young buds
- Rice crop shows burning appearance from a distance
- Stropping in corn leaves
- Dieback of one-year-old shoots

Note: In citrus Zn deficiency shows irregular and chlorotic leaf spots causing mottle leaf. The area near midrib and lateral veins remain green, the rest of the area becomes very pale yellow. Root growth gets restricted. The symptom may disappear as the season advances. High levels P, Ca and Mg in soil induce zinc deficiency in plants.

Excessive additions of zinc fertilizers or zinc sprays can cause toxicity, which can be cured by addition of lime or by applying super phosphate to soil. Deficiency has been noted in salt affected areas. The deficiency symptoms of micro nutrients have been shown at the end.

2.2.8 Copper (Cu)

The plant uptake of copper is in the form of Cu^+ (Cuprous) and Cu^{++} (Cupric). The source fertilizers are Copper Sulphate and Copper Oxide. Copper is associated with the mechanical strength to cell wall. It is required in oxidation-reduction reactions, photosynthesis, respiration, carbohydrate/nitrogen balance, chlorophyll and vitamin A formation, biosynthesis and ethylene activity in ripening of fruits. Copper proteins have been found in lignifications, anaerobic metabolism, cellular defense mechanism and hormonal metabolism. This nutrient also enhances protein synthesis.

Under field condition it is very difficult to say that the plant is deficient in Cu. Copper deficiency can only be detected through biochemical means. The total copper of the leaves may not limit for Cu deficiency. Deficiency is more pronounced with high proportion of iron and manganese. The most common deficiency symptoms of copper include:

- Length of internodes below normal
- Chlorosis or poor chlorophyll formation in young leaves
- Leaves become narrow and twisted having white tips
- Wilting then death of leaf tips
- Development of gum pockets in stems of citrus, apple, peaches, mango & guava and rupturing of stem bark
- The reduced growth and a change in colour of the foliage
- Twigs become angular in shape and S-shaped more or less drooping with dark green foliage

- In severe Cu deficiency the tips of new shoots look shriveled and finally shed off, followed by sprouting of lower buds.
- The plants show a bushy growth.
- Dieback, gum pockets at nodes of twigs and brown excretions on fruit are common. Fruits have thick peel, lack juice and have insipid taste and rind cracking.
- In severe deficiency twigs remain covered with reddish brown droplets of gum. Fruits may split at the blossom end particularly in citrus fruits

Note: High soil pH normally cause Cu deficiency in fruit plants on these soils. Copper excess cause reduced plant and root growth, with less branching. Rootlets become more thick and abnormal in shape.

2.2.9 Iron (Fe)

Among the micro-nutrients iron is abundantly present in soils. Iron is a constituent of cytochromes and non-haeme iron proteins. It acts as a catalyst in the formation of chlorophyll and co-factor of several enzymes. It helps in various reactions of respiration, photosynthesis and reduction of nitrates and sulphates. It has a role in N₂-fixation also. Plants uptake Iron as Fe⁺⁺ (Ferrous) and Fe⁺⁺⁺(Ferric). The source fertilizer is Ferrous Sulphate and also available in different micro fertilizers in the market.

The most important deficiency symptoms of iron are:

- Interveinal chlorosis of young and terminal leaves which ultimately turn yellow and then white
- In severe cases the fine network of veins is distinctively green and lamina becomes yellow
- Twig die back due to Fe deficiency is most common in citrus
- Acute deficiency causes smelling of leaves and leaf abscission. The Fe-deficiency is difficult to distinguish from Mn-deficiency
- Less fruit formation and that, too, with less juice and small size which later on aborts

Note: Deficiency has been noted to be high in high rainfall areas giving high manganese contents and the areas having alkaline reaction. Excess of iron has rarely been noticed in the fruit plants, this may be due to less solubility of Fe in the soil solution. However, some toxicity has been found in citrus where interveinal areas shows yellow lesions deposited on the leaf surface. High P, Mn, Cu or Zn in soil can cause Iron deficiency.

2.2.10 Manganese (Mn)

Manganese accumulates in leaves more than in seeds. Plants uptake manganese as Mn⁺⁺ and the source fertilizer is Manganese Sulphate and also part of some micro nutrient fertilizers available in the local market. The most important functions of this nutrient are:

- Assists in photosynthetic evolution of O₂, nitrogen metabolism, chlorophyll synthesis and breakdown
- Assists in the activity of some dehydrogenase, decarboxylase, kinase, oxidase, peroxidase, and non-specifically by other divalent cation activated enzymes

- Required for ascorbic acid synthesis
- Mn is involved in the production of amino acids and proteins
- Activates several enzymes essential in growth and development

Manganese deficiency also resembles Fe deficiency, with only difference that the area near the veins remains green in manganese deficiency. The deficiency symptoms of iron appear soon after the leaf is fully expanded and persists for long. The most common symptoms are:

- Necrotic spots in interveinal areas
- The younger leaves show mottled chlorosis with green veins and mesophyll tissue yellow or white this may spread to old leaves.
- Leaves of smaller size and young leaves become chlorotic just like in Zn deficiency, with the only difference that there is no resetting
- With severe deficiency, develops light green to dull pale green splotches between main lateral veins.
- Resinous spots develop on citrus leaves, streaks on wheat leaves, streak and interveinal brown spots on barley, light green strips between dark green veins of sugarcane and development of grey specks in oats

Excess of Mn in soil is due to more solubility of Mn in acidic conditions. Use of acid forming fertilizers and regular sprays of $MnSO_4$ for many years can cause Mn toxicity. The appearance of brown spots on leaves coupled with growth retardation and root decay and finally leaf abscission is the result of Mn toxicity.

2.2.11 Boron (B)

Boron is immobile in plant system. Plants uptake boron as Bo^{--} and source fertilizer is Borax. A few micro nutrient fertilizers in the local market also contain Boron, the functions of boron nutrient are:

- It plays a role in cell division, protein synthesis, carbohydrate metabolism, flower initiation and fruit formation, flowering, pollen germination, pollen tube growth and fruiting
- It helps in the translocation of sugars from leaves to enhance photosynthesis.
- Boron also acts as a catalyst in physiological processes viz, cell division, differentiation and development
- Boron is associated with calcium utilization and in case of their imbalance, terminal growth of plant parts becomes limited
- Promotes seed formation in legumes

The most common nutrient deficiency symptoms of iron include:

- Young leaves show light green colour and older ones become thick, curled and chlorotic
- Curling and then death of short tips causing lateral buds development and producing "witches broom" effect
- Necrotic and cracking spots appear on fruit and fibers
- Reduced flowering and less pollination

- Brown rot of cauliflower, dry rot of sugar beet, heart rot of turnip and corky core of apples
- The terminal buds fail to sprout and twigs show die back.
- Terminal leaves turn necrotic, shed prematurely-resetting and apical meristems turn black.
- Leaves are dark green, boat like, brittle and fall early.
- Fruits show gummy granules in the fruit albedo with hard fruits.
- Seeds fail to develop with deposits around the fruit axis. The skin of citrus fruit becomes hard. In some citrus cultivars fruits may crack.

Note: Boron toxicity in lemon and grapefruits has been reported. In lemons the leaf tips burn and base of this burn is at right angle to the midrib. In grapefruit scattered yellow spots on the upper leaf surface and gummy spots on the lower surface and edge or tip burn is seen. Premature wilting in trees occur inspite of sufficient moisture in the soil.

2.2.12 Molybdenum (Mo)

Plants uptake Molybdenum as MoO_4 (Molybdate) and source fertilizer is Sodium Molybdate. However, this micro nutrient is not short in soils of Pakistan. The common functions of this nutrient are:

- Molybdenum plays an important role in nitrogen metabolism. Without molybdenum nitrate nitrogen can't be transformed into Amino Acids
- It is a constituent of nitrate reductase and xanthine oxidase
- Mo assists in the formation of proteins, starch, amino acids and vitamins
- It helps in the fixation of atmospheric N in legumes
- Enzymes activation has been reported in many plants

Among the most common deficiency symptoms of Molybdenum are:

- Stunted growth similar to nitrogen deficiency. This is attributed to the role of molybdenum in utilization of N by plants
- Edges of leaves show scorching. The leaves become cup shaped and rolled
- Whiptail of cauliflower and appearance of yellow spots in citrus
- The leaf blade may fail to expand in the growing leaves
- Yellow spots develop on the lamina and gum on the lower leaf surface which turns black
- Large interveinal chlorotic spots appear on mature leaves
- The severely affected leaves may fall and tree may become completely defoliated
- In citrus fruits large spots similar to those caused by sun-burn appear
- The yellow patches on leaves coalesce into larger areas, extending all along the leaf margin, leaving the central portion yellowish green

2.2.13 Chlorine (Cl)

Chlorine is the latest element established as essential nutrient for plants and it has been observed to play a key role in oxygen absorption during photosynthesis. Chlorine is involved in the evolution of O_2 in primary reactions of photosynthesis, cell multiplication and turgor production in guard cells. It also helps the plants in maintaining the water level in the cells and

thus creates resistance against drought. Plants uptake this nutrient as Cl^- and the source fertilizer is Ammonium Chloride.

The most common nutrient deficiency symptoms of Chlorine are:

- Wilting and bronzing of leaves and then chlorosis
- Necrotic effects have been noted in tomatoes and barley
- Excessive branching of lateral roots
- Plants show wilting

Note: Excess chlorine results in to stunted growth, burning of tips of leaves and leaf abscission. 40 % of the salts in salt affected soils are in the form of chlorides. Its excess and not shortage is the problem.



Iron in Citrus



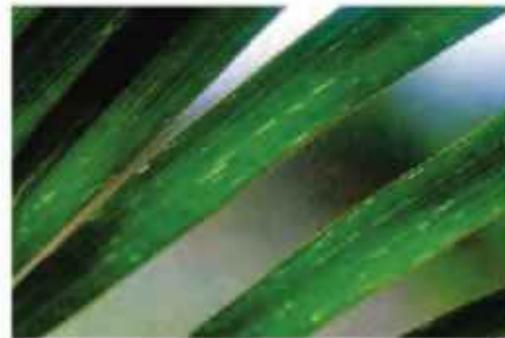
Boron in Tobacco



Mo in Cauliflower



Cu in Corn



Zn in Oil Palm



Mn in Cabbage

Micro Nutrients Deficiency Symptoms

3. NUTRIENT BALANCE

A balanced diet for humans and a balanced provision of nutrients to plants is the call of the day to ensure potential yields. This is very important since shortage of any one of the essential nutrients not only proves to be a limiting factor for desired level of production but it also hinders the absorption of other important nutrients by the plants.

Several nutrients compete with each other over uptake by the plant, so keeping adequate ratios is important for avoiding deficiency. For example, excess of potassium competes with calcium and magnesium absorption. A high iron/manganese ratio can result in manganese deficiency, and high sulfur concentration might decrease the uptake of nitrate.

A number of methods have been recognized through which the level of each essential nutrient may be determined and its balanced deficiency may be detected.

3.1 Detection of Nutrient Deficiency

For detection of nutrient deficiency, there are four methods in practice almost all over the world as per narrated hereunder.

3.1.1 Visual Plant Symptoms

As already discussed under Chapter 2, the symptoms of deficiency of each element, if carefully observed, are quite dependable indicators of their level and requirement of application. But the problem is that by the time these symptoms are observed and then fertilizer application is managed, considerable time stands already elapsed and damage to crop and thus loss in yield stands already occurred. This method should, therefore, be helpful, in fact, for the next year crop. Moreover, the symptoms of two or more elements sometimes intermingle with each other. Their careful differentiation is important particularly when chlorosis (yellowing) and necrosis (dying) of tissue is caused by the factors other than deficiency of elements such as toxicity of salts, damage from herbicides and suffocation of roots.

3.1.2 Soil Analysis

Testing of soil is probably the best tool for detecting the status of each element-both with respect to time as well as quantity. One can assess not only the level of a particular element well before the sowing of a crop but can also calculate that how much quantity of that element is required on acre or hectare basis for the crop going to be sown.

These tests, if run for all the elements, help in development of nutrient balance approach or preparation of proper fertigation schedule for each crop provided its requirement for a particular yield level is known. This fertigation schedule, when carefully maintained, allows the farm manager to avoid the test of each crop every season. Soil tests help in determining other values also such as pH, salinity, sodicity or even toxicity of a particular element and thus prove to be the best guide for proper soil management.

The facility of soil and water testing for agriculture is available almost throughout Pakistan. In Punjab, Soil and Water Testing Laboratories are working under the Soil Fertility Research Institute, Agriculture Department, Government of the Punjab, Lahore. Soil analysis for macro nutrients is being done at district level laboratories but for micro nutrients facility is available at division level. A complete soil analysis provides the soil fertility status including all essential macro and micro nutrients that are used in preparing fertigation schedules for different crops under high efficiency irrigation systems particularly drip irrigation system.

Similarly, the facility of water analysis is also available in the above mentioned Soil and Water Testing Laboratories of Soil Fertility Research Institute of Punjab Agriculture Department. The water analysis results can be used to assess suitability of water for irrigation as well as its role in clogging the drip system. Annex 1 and 2 show sample soil analysis and water analysis reports along with description and limits of various soil and water parameters.

3.1.3 Plant Tissue Analysis

Plant analysis method has an edge over the soil analysis method as it reflects what the plant is actually absorbing from the soil. Soil sampling is often made from the top one foot of soil whereas plants absorb the nutrients from the entire root zone depth. Thus in a way the real representation of the soil nutrient status up to the full root zone depth is made only by the plants and the analysis based on plant tissues reflects the true picture. It also indicates the other counteracting factors. For example, the level of all the essential elements may be up to the mark in a soil but the water table may be so high that the plants may be showing stunted growth or some disease/pest might have attacked the root zone. A combination of analysis techniques may, therefore, prove better. Soil tests and tissue analysis both together will indicate the best picture. It is, however, to be borne in mind as already discussed under plant symptoms method, that by the time tissue culture results are in hand, it might have gone too late to overcome the loss in yield. Care should, therefore, be made in depending only upon plant tissue analysis.

3.1.4 Field Experimentation / Research

Conducting field trials on the farmers' fields or on experimental research farms and observing or analyzing the plant growth as well as yield variations especially in response to the application of

different fertilizers is another dependable method to achieve the objectives under consideration. Moreover, observations and inferring the lessons does well in this context but if certain statistical tools are also adopted and the experimentation is carried out on scientific lines, it always proves better. Here again the results and derivations of the current crop experiment will have to be implemented on the next crop bearing some loss for the current season crop.

3.2 Merit of Maintaining Nutrient Balance

Based on the above discussion, it is advisable that a detailed analysis of all the essential nutrients must be obtained once. This is easily possible through soil fertility laboratories established at divisional and district levels. Then the level of each essential element, if proving deficient, be made up and it should be ensured that highly conducive soil ware house has been developed which will not let the plants suffer because of the shortage or excess of any of the nutrients for ideal growth and development. A few years practice of maintaining this sheet will assist the farm manager to develop a balance record which will prove consistent with the cropping pattern selected/adopted by him without going for the soil tests at the onset of every season and every crop.

3.3 Soil Improvement Practices

The practices such as green manuring, addition of leguminous crops in rotation, adding farm yard manure, running sub-soiler every 4th to 5th year to break the hardpan and managing efficient drainage etc. will certainly lead to develop the soil to exhibit its due potential. It is simply a question of efficient management but without involving heavy expenditures.

4. SALIENT FEATURES OF FERTIGATION

Fertilizers are chemical compounds (liquid or granular) which provide essential plant nutrients to the plants to promote growth. They are either applied through the soil or with irrigation water. **Fertigation** is method of applying fertilizers, soil amendments and other water soluble products required by the plant during its growth stages through drip irrigation system.

4.1 Characteristics of Fertilizers Suitable for Fertigation

- High nutrient content readily available to plants.
- Fully water soluble at field temperature conditions.
- Fast dissolution in irrigation water.
- No clogging of filters and emitters.
- Low content of insolubles (Less than 0.02 percent).
- Minimum content of conditioning agents.
- Compatible with other fertilizers.
- Minimal interaction with irrigation water.
- No drastic changes of water pH ($3.5 < \text{pH} < 9.0$).
- Low corrosives for control head and system

4.2 Suitable Fertilizers for Fertigation

Table 4.1: Suitable Fertilizers for Fertigation

S. No.	Fertilizer	N - P ₂ O ₅ - K ₂ O
1	Urea	46 – 0 – 0
2	Calcium Ammonium Nitrate	26 – 0 – 0
3	Ammonium Sulphate	21 – 0 – 0
4	Calcium Nitrate	16 – 0 – 0
5	Magnesium Sulphate	11 – 0 – 0
6	Potassium Nitrate	13 – 0 – 46
7	Mono Ammonium Phosphate (MAP)	11 – 52 – 0
8	Di Ammonium Phosphate (DAP)*	18 – 46 – 0
9	Potassium Chloride (MOP)	0 – 0 – 60
10	Potassium Nitrate	13 – 0 – 46
11	Potassium Sulphate/Sulphate of Potash (SOP)	0 – 0 – 50
12	Mono Potassium Phosphate (MKP)	0 – 52 – 34
13	Phosphoric Acid	0 – 52 – 0
14	NPK	20 – 20 – 20

Source: Technical Bulletin on Fertigation by National Committee on Plasticulture Applications in Horticulture (NCPAH), Ministry of Agriculture, GOI, New Delhi-110001

* (Di Ammonium Phosphate)

4.3 Micro Nutrient Fertilizers

Micro nutrients are elements which are essential for plant growth and are required in smaller amounts than primary nutrients such as N, P and K. Percent nutrient contents and solubility of micro nutrient fertilizers are shown as in Table 4.2:

Table 4.2: Percent Nutrient Contents and Solubility of Micro Nutrients

Fertilizer	Nutrient	Percent	Solubility (gm / liter)
Solubor	B	20	220
Copper sulphate	Cu	25	320
Iron sulphate	Fe	20	160
Magnesium sulphate	S	10	710
Ammonium molybdate	Mo	54	430
Zinc sulphate	Zn	36	965
Manganese sulphate	Mn	27	1050

Source: Fertilizer Recommendations of Different Crops by Soil Fertility Research Institute, Punjab Agriculture Department, Lahore

4.4 Fertigation Approaches

The most common fertigation approaches are:

1. Quantitative Fertigation
2. Proportional Fertigation

The quantitative approach is commonly used in open fields. The grower first decides how much fertilizer has to be applied per area (e.g. kg/hectare, kg/acre or lbs./acre). This quantity of fertilizer is then delivered through the irrigation water. The proportional approach is mostly used in soil-less media and sandy soils. Here, a defined quantity of fertilizer stock solution is injected into each unit of water flowing through the irrigation system (e.g. l/m³, lbs./gal). Nutrient levels are determined by their concentration in the irrigation water. Most growers who practice

proportional fertigation use units of ppm (parts per million) or mmol/l. Figure 4.1 shows most common fertigation approaches.

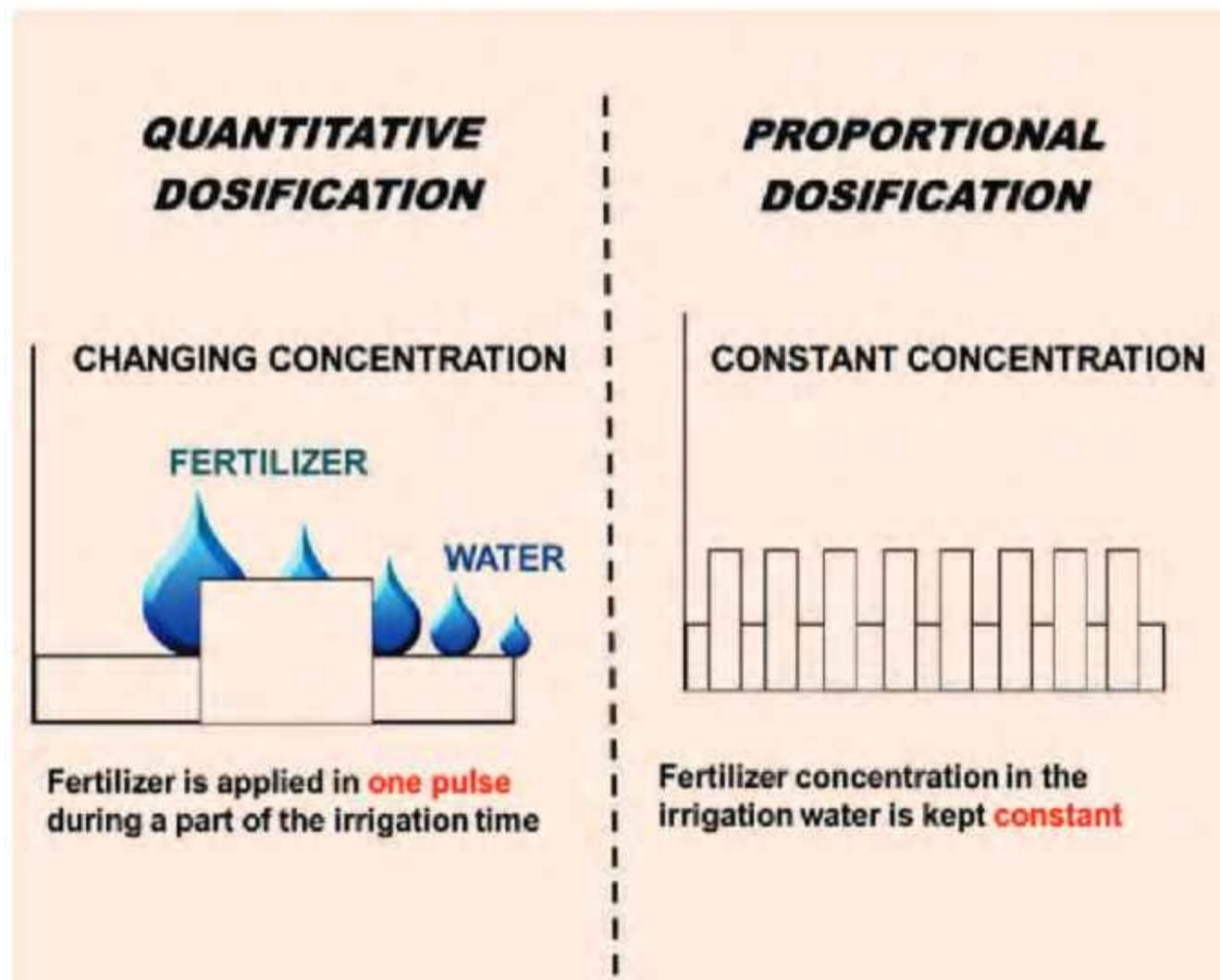


Figure 4.1: Most Common Fertigation Approaches

4.5 Preparation of Fertilizer Stock Solutions for Fertigation

In proportional fertigation, concentrated nutrient solutions are prepared in a number of tanks. The solutions are then injected to the irrigation water at adequate ratios. These concentrated solutions are known as "stock solutions" or "mother solutions".

The advantages of this method are that it reduces the number of times that the nutrient solution has to be prepared, and therefore the grower saves time and labor. It also gives more flexibility in adjusting the salinity of the final nutrient solution and the ratios between nutrients, by enabling the grower to inject different ratios from each stock tank.

In fertigation, knowing the fertilizer amounts that have to be applied is not enough. Other factors must be taken in consideration when preparing fertilizer stock solutions. The main ones are:

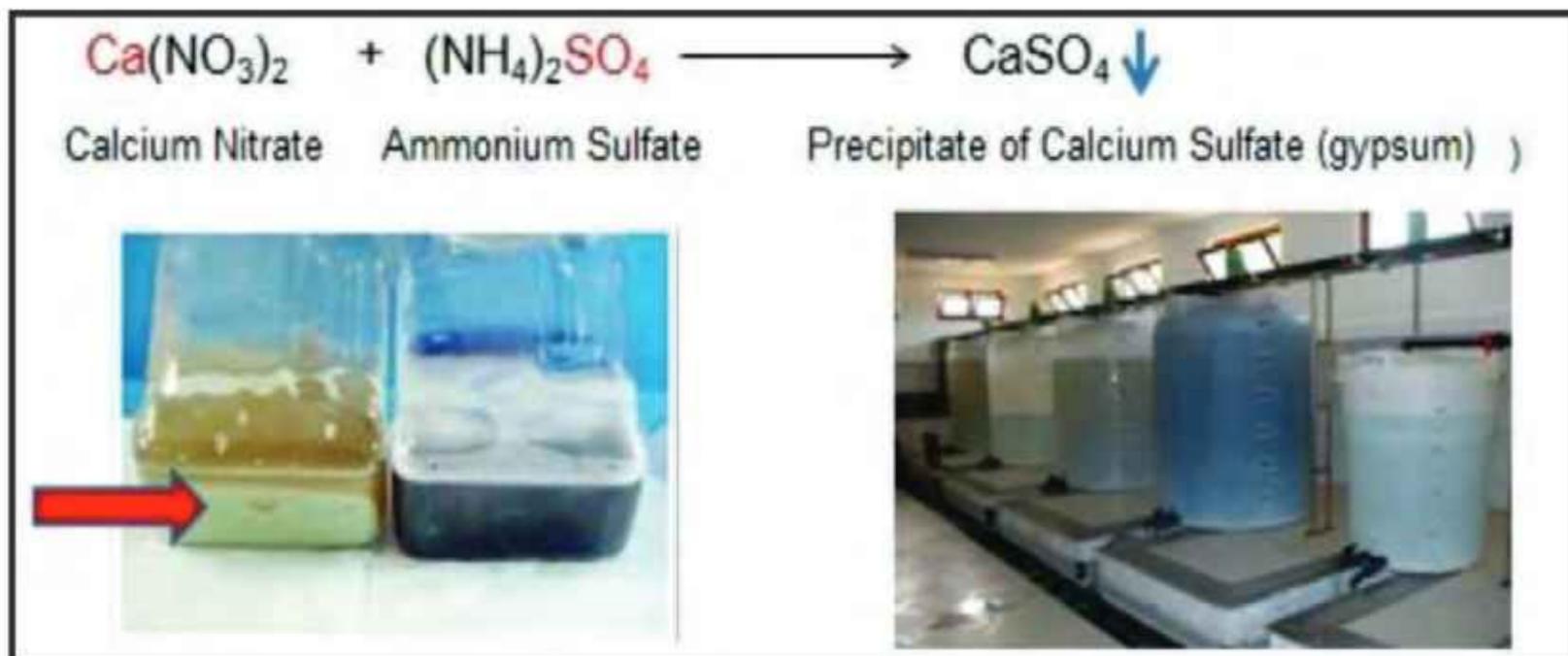
- Fertilizers compatibility.
- Number of stock tanks.
- Fertilizers solubility.

- Injection ratio or injection time.
- Types of fertilizers to be used.
- The use of chelates.
- Interaction of fertilizers with water (endothermic reactions, reactions with elements present in water).

Here, we will concentrate on the first four factors.

4.5.1 Fertilizers compatibility

Some fertilizer materials interact to form insoluble compounds and precipitates. The precipitates tie up the nutrients and make them unavailable to the plant and cause clogging in the irrigation equipment. For example, fertilizers containing calcium must not be mixed with fertilizers containing sulfates or phosphates.



Other similar examples are:

- Calcium nitrate with any phosphates = formation of Ca phosphate precipitate
 $\text{Ca}(\text{NO}_3)_2 + \text{NH}_4\text{H}_2\text{PO}_4 = \text{CaHPO}_4 + \dots$
- Magnesium nitrate with mono-ammonium phosphate = formation of magnesium phosphate precipitate
 $\text{Mg}(\text{NO}_3)_2 + \text{NH}_4\text{H}_2\text{PO}_4 = \text{MgHPO}_4 + \dots$
- Ammonium sulfate with KCl or KNO_3 : formation of K_2SO_4 precipitate
 $(\text{NH}_4)_2\text{SO}_4 + \text{KCl or KNO}_3 = \text{K}_2\text{SO}_4 + \dots$
- Phosphorus with iron = formation of iron phosphates precipitate

To know more about compatibility, use the following chart in Table 4.3.

Table 4.3 Compatibility of Different Fertilizers in Fertigation

Fertilizers	Urea	Ammonium Nitrate	Ammonium Sulphate	Calcium Nitrate	Mono Ammonium Phosphate	Mono Potassium Phosphate	Potassium Nitrate
Urea		C	C	C	C	C	C
Ammonium Nitrate	C		C	C	C	C	C
Ammonium Sulphate	C	C		LC	C	C	LC
Calcium Nitrate	C	C	LC		NC	NC	C
Mono Ammonium Phosphate	C	C	C	NC		C	C
Mono Potassium Phosphate	C	C	C	NC	C		C
Potassium Nitrate	C	C	C	C	C	C	

C = Compatible NC = Not Compatible LC = Low Compatible

Source: SMART Fertilizer Management. 2013. SMART Fertilizer Management Software. 15

4.5.2 Determining the number of tanks required

The types of fertilizers that are being used and their compatibility determine the minimum number of tanks that is required. Incompatible fertilizers must be separated and dissolved in different tanks.

The quality of the irrigation water and the nutrients available in the soil affect the number of stock tanks as well, since they determine which fertilizers should be used. If the source water contains essential nutrients, such as sulfur, calcium and magnesium, at sufficient concentrations, fertilizer containing these elements may not be needed for the fertilizer recipe. Usually, using fertilizers that contain calcium, magnesium or sulfur require using 2-4 stock tanks, due to incompatibility limitations.

For example, assume that the fertilizers that have to be used are Potassium nitrate, Calcium nitrate, MAP and Magnesium sulfate. In this case, a minimum of three tanks is required. Calcium nitrate is incompatible with both MAP and Magnesium sulfate, and Magnesium sulfate is incompatible with MAP. A possible distribution is:

Tank 1 – MAP, Tank 2 – Calcium nitrate + potassium nitrate, Tank 3 – Magnesium sulfate.

4.5.3 The solubility of fertilizers

The solubility of a fertilizer is determined as its maximum amount that can be fully dissolved in a determined volume of water. Exceeding this maximum amount will result in precipitation of the fertilizers in the irrigation system and can be a very serious problem.

The solubility is expressed in units of weight/volume of water. For example: grams/liter or lb./gallon.

The solubility of each fertilizer is dependent on the temperature of the water in which it is being dissolved (Table 4.4). The solubility of most fertilizers increases with the temperature. Therefore, at lower temperatures, the fertilizer stock solutions must be more diluted. At higher temperatures, more concentrated stock solutions can be prepared.

Table 4.4: Solubility of Fertilizers at Different Temperatures

Fertilizer / Temperature (C°)	Solubility (g/l)					
	5	10	20	25	30	40
Potassium nitrate	133	170	209	316	370	458
Ammonium nitrate	1183	1510	1920	.	.	.
Ammonium sulfate	710	730	750	.	.	.
Calcium nitrate	1020	1130	1290	.	.	.
Magnesium Nitrate	680	690	710	720	.	.
Mono Ammonium Phosphate (MAP)	250	295	374	410	464	567
Di Ammonium Phosphate (DAP)	.	.	588	.	.	.
Mono Potassium Phosphate (MKP)	110	180	230	250	300	340
Potassium chloride (MOP)	229	238	255	264	275	-
Potassium sulfate (SOP)	80	90	111	120	-	-
Urea	780	850	1060	1200	-	-

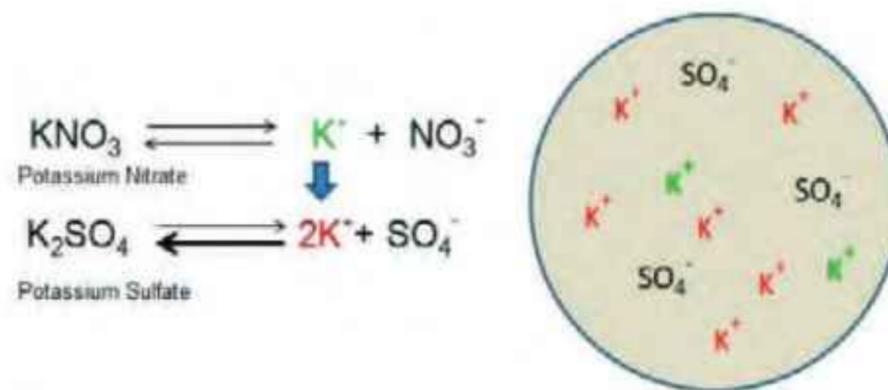
Source: SMART Fertilizer Management. 2013. SMART Fertilizer Management Software. 15 Eshkol Street, Hod Hasharon 45343, Israel Nutrient Source Specifics by International Plant Nutrition Institute (IPNI), Georgia, USA Ref. #17-11040

When you dissolve a fertilizer, you should not exceed its solubility. Otherwise, a precipitate may form and might clog the irrigation system. Moreover, the nutrients you intend to provide through the solution may not be fully available.

For example, according to the data in the table above, the solubility of Potassium Nitrate in 20°C is 209 g/l and the fertilizer contains 38% Potassium. If you attempt to dissolve 300 g/l in the fertilizer stock tank, you will not get 114 g/l of Potassium (38% of 300g), but only 80g. The remaining 34g will precipitate and will not be available.

The solubility is also dependent on other fertilizers in the stock solution. There might be common ion effect - If a certain fertilizer is being dissolved in the same stock tank with another fertilizer that contains a common ion, the solubility of both fertilizers is reduced.

For example, Potassium nitrate and Potassium sulfate are compatible, and can be dissolved in the same stock tank. However, since both contain potassium, their solubility is reduced when mixed together.



When mixing fertilizers, one must be familiar with the solubility data of the fertilizers used, as well as with the chemical reactions that may take place. In order to avoid unwanted precipitates, a common recommendation is to perform a "jar test". In this test, the fertilizers are initially mixed in a jar containing the same water used for irrigation.



Formation of a precipitate Complete dissolution

The fertilizers should be mixed exactly in the same concentration as intended to be used in the stock tanks. If a precipitate forms or if the solution has a "milky" appearance, the test should be repeated with lower concentrations of the fertilizers.

4.5.4 Injection Ratio or Injection Time

The injection ratio is defined as the ratio between the volumes of the fertilizer solution injected and the irrigation water. Therefore, it has units of volume/volume. For example: L/m³, gallon/100 gallon or % (percent).

It can be calculated by the ratio: Injection rate / Irrigation flow rate. Where flow rates of the injection and the irrigation are expressed in units of volume/time. For example, if the injector has a discharge of 200 L/hour and the irrigation flow rate is 40 m³/hour, then the injection ratio is:

200 L/hour / 40 m³/hour = 5 L/m³. This result can also be expressed as 0.5% or a ratio of 1:200.

The minimum injection ratio required is dependent on the solubility of the fertilizers and on the nutrient requirements of the crop. The nutrient requirement of the crop determines the amount of fertilizer to be applied to the field. The solubility of the fertilizer determines the maximum amount that can be dissolved in the tank. If, for example, the solubility of a certain fertilizer is 100 g/L and the required concentration of this fertilizer in the irrigation water is 500 g/m³, the minimum injection ratio will be:

$$500 \text{ g/m}^3 / 100 \text{ g/L} = 5 \text{ l/m}^3$$

A lower injection ratio requires dissolving a higher amount of fertilizer in the tank, in order to reach the same concentration of 500 g/m³ in the irrigation water:

$$\text{Injection ratio } 4 \text{ L/m}^3 = 500 \text{ g/m}^3 / x \text{ g/l}$$

$$X = 500 \text{ g/m}^3 / 4 \text{ L/m}^3 = 125 \text{ g/m}^3, \text{ which exceeds the solubility of the fertilizer.}$$

To convert Injection Ratio to necessary injection time or vice versa, use the following equation:

$$\text{Injection time (min.)} = (F \times D \times IR) / \text{IFR} \text{ where:}$$

$$F = \text{Irrigation flow rate (m}^3/\text{hr.)}$$

$$D = \text{Irrigation duration (min)}$$

$$IR = \text{Injection ratio (L/m}^3)$$

$$\text{IFR} = \text{Injector Flow Rate (L/hr.)}$$

4.6 Dissolving of fertilizer in irrigation water

There are two options to dissolve fertilizers to be used for fertigation. Either each fertilizer is dissolved separately in irrigation water through proper stirring or shaking and then putting the solution in the fertilizer tank or all the requisite fertilizers are dissolved in the irrigation water jointly and then put such solution in the fertilizer tank. However, the most important is to take care of the fertilizers' compatibility.

As far the stirring or shaking, the normal field practice is to put the fertilizer in water and stir with the help of some rod. However, for proper and uniform dissolution of fertilizer with irrigation water, some sort of shakers or stirrers can be operated with the help of some motor or any sort of power available at the system head unit.

Here are a few snaps showing the process of dissolving two fertilizers i.e. Potassium Nitrate and Phosphoric Acid separately through proper mixing / stirring and then putting the solutions in the fertilizer tank followed by stirring again and then start further fertigation process.



4.7 Fertilizer Evaluation for Suitability to Fertigation

Table 4.5: Fertilizer Evaluation for Suitability to Fertigation

Property	NH_4NO_3	$(\text{NH}_4)_2\text{SO}_4$	K_2SO_4	KCl	KNO_3	H_3PO_4	MAP
Solubility	High	Medium	Low	Medium	Medium	High	Medium
Precipitation	Low	High	High	Low	Low	Low	High
Compatibility	Good	Poor	Poor	Medium	Medium	Medium	Good
Corrosion	Medium	Poor	Poor	Poor	Good	Poor	Medium

4.8 Fertigation Equipment's

4.8.1 Ventury Injector

This is very simple and low cost device. A partial vacuum is created in the system which allows suction of the fertilizers into the irrigation system through ventury action. Vacuum is created by diverting a percentage of water flow from the main and pass it through a constriction which increases the velocity of flow thus creating a drop in pressure. When the pressure drops the fertilizer solution is sucked into the ventury through a suction pipe from the tank and from there enters into irrigation stream. The suction rate of ventury is 30 to 120 liters /hour.



4.8.2 Fertilizer Tank

In this system part of irrigation water is diverted from the main line of flow through a tank containing the fertilizer in a fluid or soluble solid form, before returning to the main line, the pressure in the tank and the main line is the same but a slight dip in pressure is



created between the off take and return pipes for the tank by means of a pressure reducing valve. This causes water from main line to flow through the tank causing dilution and flow of the diluted fertilizer into the irrigation stream. With this system the concentration of the fertilizer entering the irrigation water changes continuously with the time, starting at high concentration. As a result, uniformity of fertilizer distribution can be a problem. Fertilizer tanks are available in 90,120 and160 liters capacity.

4.8.3 Fertilizer Injector Pump

These are piston or diaphragm pumps which are driven by the water pressure of the irrigation system and such as the injection rate is proportional to the flow of water in the system. A high degree of control over the fertilizer injection rate is possible, no serious head losses are incurred and operating costs are low. Another advantage is that if the flow of water stops, fertilizer injection also automatically stops. This is perfect equipment for accurate fertigation. Suction rates of pumps vary from 40 lit to 160 liters per hour.



4.9 Points to Remember for Adopting Fertigation

- Fertilizer tank or injection pump may be used to inject the fertilizer
- For precise placement of both water and fertilizer, it is necessary to use pressure compensating drippers or inline drippers instead of micro tubes.
- Daily feeding is most desirable, if not possible to feed alternate day.
- Urea can be combined with WSF for meeting the N requirements.
- Fertigation should be done at the end of irrigation period, run the drip system for 5-6 minutes after the completion of fertigation.
- It is not advisable to use a very concentrated stock solution (generally not more than 10%).
- The fertilizer solution should be compatible with the quality of water into which it is being injected.
- Do not inject fertilizers in combination with pesticides.
- The injection point must be upstream of the filter system so that the filter will remove any un-dissolved fertilizer or precipitate.
- Select fertilizer solutions to help adjust water pH if necessary.
- The time needed to distribute the fertilizer should be less than the time needed to supply enough water to the field.
- Do not over irrigate because this will leach some of the fertilizer out of the root zone.

5. DEVELOPMENT OF FERTIGATION SCHEDULES

For the development of fertigation schedules, attempt has been made to utilize the local information about soil and fertilizer requirements of different crops. Major parameters taken into account include:

1. Fertility status of the soil
2. Nutrient removal by the crop
3. Variety and duration of the crop
4. Target yield of the crop
5. Climatic conditions
6. Specific nutrient requirements for a specific produce

For target yields of different crops, data of different local agencies has been adjusted to have target crop yields under drip irrigation in Pakistan (Table 5.1).

Table 5.1: Target Crop Yields under Drip Irrigation System

Crop	Maunds/Acre	Tons/Acre*
Maize	100	4
Cotton	50	2
Sugarcane	1500	56
Potato	350	13
Bitter Gourd	750	28
Capsicum (Tunnel)	750	28
Tomato (open Field)	450	17
Tomato (Tunnel)	1473	55
Cucumber (Open Field)	400	15
Cucumber (Tunnel)	2143	80
Onion	300	11
Peas	400	15
Pumpkin	600	22
Water Melon	1072	40
Musk Melon	536	20

Source:

1. Hand Book on Tunnel Technology for Off-Season Vegetables Cultivation by Dr. Shahid Niaz, Director, Vegetable Research Institute, Jhang Road, Faisalabad. 2014.
2. Directorate General Agriculture (Extension & A.R.), Punjab
3. Ayub Agriculture Research Institute, Jhang Road, Faisalabad
4. Production Technology of Onion - Agriculture Department, Government of the Punjab.

* 1 Ton (metric), tonne = 26.79 maunds

The fertilizer recommendations for different crops have been computed on the basis of nutrient removal information provided by Nisar Ahmad and Muhammad Rashid (2003) in Training Bulletin Third Edition – FAO and the fertilizer recommendations given by the Soil Fertility Research Institute, Punjab Agriculture Department Lahore as given in Table 5.2.

Table 5.2: Fertilizer Recommendations for Different Crops under Drip Irrigation

Crop	Target Yield (Maunds/Acre)	Nutrient Removal (Kg/Maund of Produce)			Fertilizer Nutrient Recommendation (Kg/Acre)		
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Maize	100	0.75	0.30	0.75	75	30	75
Cotton	50	2.31	0.52	2.24	116	26	112
Sugarcane	1500	0.04	0.02	0.05	60	28	75
Potato	350	0.26	0.05	0.40	91	18	140
Bitter Gourd	750				70	57	50
Capsicum (Tunnel)	750				123	73	75
Tomato (Open Field)	450	0.09	0.03	0.17	41	14	77
Tomato (Tunnel)	1473	0.09	0.03	0.17	133	44	250
Cucumber (Open Field)	400	0.09	0.04	0.11	36	18	44
Cucumber (Tunnel)	2143	0.09	0.04	0.11	193	94	236
Onion	300	0.15	0.06	0.19	45	18	57
Peas	400	0.62	0.20	0.50	248	80	200
Pumpkin	600				36	34	25
Watermelon	1072	0.14	0.04	0.25	150	47	268
Musk Melon	536				64	82	25

Source:

1. Ahmad, N. and M. Rashid. 2003. Fertilizers and Their Use in Pakistan. National Fertilizer Development Centre (NFDC). Training Bulletin Third Edition – FAO
2. Soil Fertility Research Institute (SFRI), Punjab Agriculture Department. 2013. Fertilizer Requirements of Different Crops. www.sfrpunjab.gov.pk

For fruit trees, fertilizer recommendations of Citrus Research Institute Sargodha, Fruit and Vegetable Development Project Lahore, Soil Fertility Research Institute Lahore and data presented by K.N. Tiwari in Better Crops in India. Table 5.3 shows fertilizer requirements of fruit trees. The calculations have been made on the basis of prevailing drip irrigation system and other factors like saving of fertilizer through drip irrigation as compared to surface or flood irrigation system.

Table: 5.3: Fertilizer Requirements of Fruit Plants

Age (Year)	Grams/Plant											
	Citrus			Guava			Mango			Grapes		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
1	100	50	50	60	30	30	120	40	100	60	120	140
2	200	100	100	120	60	60	230	60	100	70	140	160
3	300	150	150	175	85	90	250	60	100	80	160	180
4	400	200	200	230	115	125	450	120	150	120	240	270
5	500	250	250	345	140	220	550	200	200	130	250	300
6	600	300	300	460	173	315	700	250	400	140	260	320
7 to 8	800	400	400	575	200	400	800	290	500	150	280	340
9 to 10 and More	1000	500	500	690	230	500	1020	320	600	160	320	360

Source:

1. Pamphlet on Citrus Fruit written by Dr. Altaf Ur Rehman Khan of Citrus Research Institute, Sargodha and published by Directorate of Agriculture Information, Punjab Agriculture Department, Lahore
2. Soil Fertility Research Institute (SFRI), Punjab Agriculture Department, Thokar Niza Beg, Lahore
3. Fauji Fertilizer Company Limited, Lahore
4. Nutrient Management: Fertigation by Tamal Nado Agriculture University (TNAU), Agritech Portal, Lucknow, India
5. Cultivation of Grapes in Pothohar by Deputy Director Agriculture, Fruit and Vegetables Development Project (Phase-II), Rawalpindi
6. Mango Training Manual by Fruit and Vegetable Development Project, Punjab, 21 Davis Road, Lahore
7. Mango Cultivation with Drip Irrigation - Directorate General Agriculture (Water Management) Punjab, 21 Agha Khan Road, Lahore

The procedure adopted and the assumptions made for preparing fertigation schedules for crops being grown under drip irrigation are summarized as follows:

- The fertigation schedules are in EXCEL Programme and most of the calculations have been made through proper formulas in the Excel Sheets. The procedure has been demonstrated with the help of an example given at the end of this section.
- The target crop yield and nutrient / fertilizer requirement data of various crops is based on information produced by various national agencies such as Punjab Agriculture Department including Agriculture Extension & Adaptive Research, Ayub Agriculture Research Institute (AARI), Soil Fertility Research Institute (SFRI); and National Fertilizer Development Centre (NFDC), Fauji Fertilizer Company and International agencies like Tamil Nadu Agriculture University (TNAU) and NETAFIM.
- The removal of N, P and K nutrients for a target crop yield has been computed on the basis of data produced by the National Fertilizer Development Centre (NFDC) in a publication "Fertilizer and Their Use in Pakistan" written by Dr. Nisar Ahmad and Dr. Muhammad Rashid in 2003 as Training Bulletin Third Edition for FAO.
- The field data collected by the M&E Consultants has revealed that HEIS installation so far under PIPIP have created visible impact in terms of reduction in fertilization use up to 40%. However, to be on safe side the fertilizer saving through fertigation in developing fertigation schedules has been considered 30% and the balance nutrients to be given after saving are calculated accordingly.
- The nutrients in soil have been considered as zero in sample fertigation schedules since most of our soils are deficient in these nutrients. However, the actual nutrient value in the soil analysis report can be converted into kg/acre and put in the EXCEL sheet to account for nutrients in the soil. The conversion of soil nutrient in ppm into kg/acre will be: $\text{ppm} \times 2 = \text{kg/hectare}$ or $\text{kg/hectare} / 2.47 = \text{kg/acre}$.
- Since fertigation starts immediately after sowing, no basal dose has been included while preparing fertigation schedules. However, if someone intends to give some fertilizer as basal dose, provision has been made in the EXCEL SHEET.
- The daily and seasonal nutrient and fertilizer requirements have been calculated for various crops with the help of ratio and ratio days for different crop life stages based on nutrient uptake curves and personal experiences.

- The fertigation schedules are sample guidelines. The recommendations can be adjusted according to the local soil conditions and the availability of fertilizer from the local market. However, the best option would be to use the soluble fertilizers.
- For fruit crops, fertigation schedules have been prepared on the basis of fertilizer recommendations of different national and international research agencies such as Soil Fertility Research Institute (SFRI) Lahore, Citrus Research Institute Sargodha, Fauji Fertilizer Company Ltd Lahore, Fruit and Vegetable Project Lahore, Punjab Agriculture Extension Rawalpindi and TANU, India.
- Attempt has been made to cover different spacings (plant to plant and row to row distances) in the EXCEL Sheets to determine fertigation schedules for fruit crops including high density plantations.

Here is an example to demonstrate preparation of a sample fertigation schedule for maize crop in Table 5.4.

Table 5.4: Example to Demonstrate Preparation of a Sample Fertigation Schedule for Maize Crop

Step # 1: Nutrients Removal from Soil			
Nutrient Removed by One Maund Whole Plant (Kg/Maund)			
N	P₂O₅	K₂O	
0.75	0.30	0.75	
Step # 2: Target Yield			
Target Yield 100 Maunds/Acre			
Step # 3: Total Nutrients Required (Kg/Acre)			
	N	P₂O₅	K₂O
Nutrient Removal for 100 Maunds Yield of Maize	75	30	75
Step # 4: Percent Saving in Fertilizer through Fertigation			
Remaining Nutrients after Fertilizer Saving	53	21	53
Step # 5: Nutrients in the Soil			
Available in the Soil	0	0	0
Step # 6: Nutrients for Fertigation			
Remaining Nutrients to be Applied through Fertigation	53	21	53
Step # 7: Physiological Crop Stages			
Crop Life			Days
Vegetative Phase (1-40 DAG)			40
Flowering Phase (40-60 DAG)			20
Cob Development Phase (60-90 DAG)			30
Grain Development Phase (90-120)			30
Total			120

Step # 8: Ratio and Ratio Days Calculation						
Crop Life	Ratio			Ratio Days		
	N	P₂O₅	K₂O	N	P₂O₅	K₂O
Vegetative Phase (1-40 DAG)	2	1	1	80	40	40
Flowering Phase (40-60 DAG)	3	1	2	60	20	40
Cob Development Phase (60-90 DAG)	2	0	4	60	0	120
Grain Development Phase (90-120)	1	0	2	30	0	60
Total	8	2	9	230	60	260
How to Calculate Nutrient Required (Kg/Acre/Day)?						
Nutrients (Kg/Acre/Day) = $\frac{\text{Total Quantity of Nutrients for Fertigation (Kg/Acre)} \times \text{Ratio Days of Nutrients in the Stage}}{\text{Sum of Ratio Days of the Nutrient} \times \text{No. of Fertigation Days in the Stage}}$						
Step # 9: Nutrients (Kg/Acre/Day)						
Crop Life	Days	Nutrients (Kg/Acre/Day)				
		N	P₂O₅	K₂O		
Vegetative Phase (1-40 DAG)	40	0.457	0.350	0.202		
Flowering Phase (40-60 DAG)	20	0.685	0.350	0.404		
Cob Development Phase (60-90 DAG)	30	0.457	0.000	0.808		
Grain Development Phase (90-120)	30	0.228	0.000	0.404		
Total	120	1.826	0.700	1.817		
Step # 10: Fertilizer (Kg/Acre Day)		Urea	MAP	SOP		
Vegetative Phase (1-40 DAG)	40	0.843	0.574	0.404		
Flowering Phase (40-60 DAG)	20	1.339	0.574	0.808		
Cob Development Phase (60-90 DAG)	30	0.992	0.000	1.615		
Grain Development Phase (90-120)	30	0.496	0.000	0.808		
Total	120	3.670	1.148	3.635		
Step # 11: Fertilizer (Kg/Acre/Season)						
Vegetative Phase (1-40 DAG)	40	33.710	22.951	16.154		
Flowering Phase (40-60 DAG)	20	26.780	11.475	16.154		
Cob Development Phase (60-90 DAG)	30	29.773	0.000	48.462		
Grain Development Phase (90-120)	30	14.887	0.000	24.231		
Total	120	105.150	34.426	105.000		
Total Fertilizer (Kg/Acre)		105	34	105		
Number of Fertilizer Bags / Acre		2.10	0.69	2.10		
Nutrients N:P₂O₅:K₂O (Kg/Acre)		53	21	53		

Annex 4 to 19 show sample fertigation schedules for different crops under drip irrigation. The soft copies of the fertigation schedules in Excel Sheets are being provided with this document in a separate CD so that people could prepare and adjust their fertigation schedules according to their local soil conditions plus basal doses, if required. The simple fertigations schedules for different crops and orchards have been given in Table 5.5 to 5.20.

Table 5.5: Simple Fertigation Schedule of Maize

Crop life	Days	Fertilizer / Acre / Day (Kg)		
		Urea	MAP	SOP
Vegetable Phase (1-40 DAG)	40	0.843	0.574	0.404
Flowering Phase (40-60 DAG)	20	1.339	0.574	0.808
Cob Development Phase (60-90 DAG)	30	0.992	0.000	1.615
Grain Development Phase (90-120 DAG)	30	0.496	0.000	0.808
Total	120			

Table 5.6: Simple Fertigation Schedule of Cotton

Crop Stage	Days	Fertilizer Kg/Acre/Day		
		Urea	MAP	SOP
Vegetative Growth Phase -1 (7-15 DAG)	7	0.461	0.249	0.896
Vegetative Growth Phase- 2 (15-32 DAG)	18	1.287	0.249	0.896
Squares and Flowering (32-57 DAG)	25	1.287	0.249	1.792
Boll Initiation (57-77 DAG)	20	1.963	0.249	0.896
Boll Development Phase -1 (77-107 DAG)	30	1.287	0.249	1.792
Boll Development Phase -2 (107-127 DAG)	20	1.287	0.249	0.896
Initial Boll Maturity (127-142 DAG)	15	0.000	0.000	0.000
Late Boll Maturity (142-167 DAG)	15	0.000	0.000	0.000

Table 5.7 Simple Fertigation Schedule of Sugarcane

Crop Stage	Days	Fertilizer kg/acre/day		
		Urea	MAP	SOP
After germination 7-60 days	53	0.550	0.154	0.213
61 to 105 days	45	0.570	0.077	0.213
106 to 165 days	60	0.177	0.077	0.319
166 to 215 days	50	0.116	0.308	0.532
216 to 275 days	60	0.197	0.000	0.639
Total	268			

Table 5.8 Simple Fertigation Schedule of Potato

Crop Stage	Days	Fertilizer Kg/Acre/Day		
		Urea	MAP	SOP
Establishment	20	0.896	0.435	1.441
Stolonization	18	3.742	0.435	1.441
Beginning of Tuberization	10	2.793	0.435	5.765
Tuber Filling Stage-1	12	1.897	0.000	5.765
Tuber Filling Stage-2	10	0.000	0.000	1.441
Total	70			

Table 5.9: Simple Fertigation Schedule of Bitter Gourd

Crop Stage	Days	Fertilizer (Kg/Acre/Day)		
		Urea	MAP	SOP
Vegetative Growth	25	1.693	0.934	0.651
Vegetative – Flowering	15	1.047	0.934	0.977
Fruit Development - Harvest	30	1.047	0.934	1.302
Total	70			

Table 5.10: Simple Fertigation Schedule of Capsicum (Tunnel)

Crop life	Days	Fertilizer Kg/Acre/Day		
		Urea	MAP	SOP
10 To 30 DAT	20	1.185	1.197	0.389
30 To 50 DAT	20	1.185	1.197	0.778
50 To 80 DAT	30	1.934	1.197	1.167
80 To 120 DAT	40	1.497	0.000	1.167
Total	110			

Table 5.11: Simple Fertigation Schedule of Tomato Open Field

Crop Life	Days	Fertilizer Kg/Acre/Day		
		Urea	MAP	SOP
Establishment Stage	30	0.656	0.062	0.420
Vegetative Stage - Flowering	40	0.424	0.093	0.840
Flowering - Fruit set Stage	40	0.384	0.248	1.260
Fruit set-Harvest Stage	25	0.224	0.000	0.420
Total	135			

Table 5.12: Simple Fertigation Schedule of Tomato Tunnel

Crop Life	Days	Fertilizer Kg/Acre/Day		
		Urea	MAP	SOP
Establishment Stage	30	2.148	0.203	1.375
Vegetative Stage - Flowering	40	1.388	0.304	2.750
Flowering - Fruit set Stage	40	1.256	0.811	4.124
Fruit set-Harvest Stage	25	0.734	0.000	1.375
Total	135			

Table 5.13: Simple Fertigation Schedule of Cucumber Open Field

Crop Life	Days	Fertilizer Kg/Acre/Day		
		Urea	MAP	SOP
Establishment (10 DAG)	10	1.314	0.213	0.587
Vegetative –Flowering	15	0.858	0.213	0.587
Flowering - Fruit set	25	0.802	0.425	1.173
Fruit set-harvest	10	0.346	0.425	1.760
Total	60			

Table 5.14: Simple Fertigation Schedule of Cucumber Tunnel

Crop Life	Days	Fertilizer Kg/Acre/Day		
		Urea	MAP	SOP
Establishment (10 DAG)	10	9.184	1.482	4.074
Vegetative – Flowering	7	5.994	1.482	4.074
Flowering - Fruit set	20	5.607	2.964	8.149
Fruit Set-Harvest	8	2.417	2.964	12.223
Total	45	23.202	8.893	28.520

Table 5.15: Simple Fertigation Schedule of Peas

Crop life	Days	Fertilizer kg/acre/day		
		Urea	MAP	SOP
Initial Stage	20	2.020	0.525	1.600
Development Stage	25	4.039	1.049	3.200
Mid Stage	35	6.059	1.574	4.800
Total	80			

Table 5.16: Simple Fertigation Schedule of Musk Melon

Crop life	Days	Fertilizer kg/acre/day		
		Urea	MAP	SOP
0-14 Days after planting	14	0.524	0.677	0.252
15-28 Days after planting	14	0.786	1.015	0.252
29-56 Days after planting	28	1.048	1.354	0.504
57-78 Days after planting	22	0.786	1.015	0.378
79-93 Days after planting	15	0.524	0.677	0.252
Total	93			

Table 5.17: Simple Fertigation Schedule of Citrus - Fertilizer (Kg/Acre/Day)

	Year 1			Year 2			Year 3 (12 ton/ha)			Year 4 & Above (20 ton/ha)		
	Urea	MAP	SOP	Urea	MAP	SOP	Urea	MAP	SOP	Urea	MAP	SOP
6 m x 6 m (112 Plants)												
February	0.104	0.036	0.019	0.209	0.071	0.037	0.426	0.062	0.154	1.756	0.254	0.634
March	0.033	0.018	0.019	0.067	0.036	0.037	0.139	0.031	0.154	0.574	0.127	0.634
April	0.071	0.018	0.056	0.142	0.036	0.111	0.287	0.031	0.615	1.182	0.127	2.535
May-July	0.033	0.018	0.019	0.067	0.036	0.037	0.139	0.031	0.154	0.574	0.127	0.634
August	0.104	0.036	0.056	0.209	0.071	0.111	0.426	0.062	0.769	1.756	0.254	3.168
September-November	0.033	0.018	0.019	0.067	0.036	0.037	0.139	0.031	0.154	0.574	0.127	0.634
December - January	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 5.18: Simple Fertigation Schedule for Guava Fertilizer (Kg/Acre/Day)

	Year 1			Year 2			Year 3 (15 t/ha)			Year 4 & Above (25 t/ha)		
	Urea	MAP	SOP	Urea	MAP	SOP	Urea	MAP	SOP	Urea	MAP	SOP
6x6 m (112 plants)												
January - February	0.016	0.007	0.007	0.030	0.014	0.014	0.083	0.032	0.095	0.138	0.053	0.159
March-April	0.048	0.014	0.014	0.094	0.028	0.028	0.256	0.064	0.190	0.427	0.106	0.317
May-July	0.016	0.007	0.007	0.030	0.014	0.014	0.083	0.032	0.095	0.138	0.053	0.159
August-September	0.047	0.021	0.035	0.090	0.042	0.070	0.248	0.095	0.476	0.414	0.159	0.793
October-December	0.016	0.007	0.007	0.030	0.014	0.014	0.083	0.032	0.095	0.138	0.053	0.159

Table 5.19: Simple Fertigation Schedule for Mango - Fertilizer (Kg/Acre/Day)

6x6 m (112 plants)	Year 1			Year 2			Year 3			Year 4			Year 5 & Above (20 tons/ha)		
	Urea	MAP	SOP	Urea	MAP	SOP									
June-August	0.051	0.014	0.042	0.098	0.021	0.042	0.107	0.021	0.042	0.192	0.043	0.062	0.255	0.068	0.193
September	0.023	0.014	0.062	0.035	0.021	0.062	0.164	0.021	0.062	0.294	0.043	0.094	0.442	0.045	0.386
October-January	0.025	0.007	0.021	0.049	0.011	0.021	0.054	0.011	0.021	0.096	0.021	0.031	0.085	0.023	0.096
February-May	0.076	0.021	0.062	0.148	0.032	0.062	0.161	0.032	0.062	0.288	0.064	0.094	0.261	0.045	0.289

Table 20: Simple Fertigation Schedule for Grapes - Fertilizer (Kg/Acre/Day)

	Year 1			Year 2			Year 3		
	Urea	MAP	SOP	Urea	MAP	SOP	Urea	MAP	SOP
10x8 ft. (545 plants)									
February - April (Vegetative Growth)	0.149	0.330	0.391	0.173	0.385	0.447	0.198	0.440	0.503
May-July (Vegetative Growth)	0.113	0.165	0.195	0.132	0.193	0.223	0.151	0.220	0.251
August-October (Vegetative Growth)	0.070	0.330	0.586	0.082	0.385	0.670	0.094	0.440	0.754
November-January (Vegetative Growth - Dormant)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10x8 ft. (545 plants)									
	Year 4 & Above (40 tons/ha)			Fertilizer kg/acre/day					
	Urea	MAP	SOP	Urea	MAP	SOP			
February - April (Pruning + Flowering + Fruit Setting)	0.492	0.131	0.747						
May-June (Berry Development)	0.492	0.131	0.374						
July (Berry Development + Harvesting)	0.503	0.088	0.374						
August (Harvesting)	0.515	0.044	1.121						
September - October (Vegetative Growth)	1.345	0.219	1.121						
November-January (No Irrigation and Fertigation)	0.000	0.000	0.000						
Source:	<p>1. Pamphlet on Fertilizer Recommendations for Better Production of Grapes by Soil Fertility Research Institute (SFRI), Punjab Agriculture Department, Thokar Niaz Beg, Lahore</p> <p>2. Pamphlet on Cultivation of Grapes in Pothohar by Deputy Director Agriculture, Fruit and Vegetable Development Project (Phase II), Rawalpindi</p> <p>3. Commercial Cultivation of Grapes by Chaudhary Tanvir Ahmad, EDO Agriculture, Bahawalpur and Shafqat Hussain Bhatti, DDO Agriculture (Extension), Bahawalpur</p> <p>4. Diagnosing Potassium Deficiency and Maximizing Fruit Crop Productivity by K.N. Tiwari Published in Better Crops/Vol. 89 (2005, No. 4)</p>								

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Annexes

1- زمین کی لخت (Soil Texture)

ایک سو گرام مٹی کو پیر کر کے کیلے پانی کی مقدار کو لیتے پیر شدگی کہتے ہیں۔ اسے زمین کی لخت معلوم کرنے کیلئے استعمال کیا جاتا ہے۔ زمین کی لخت کی درجہ بندی حسب ذیل کی جاسکتی ہے۔

لیٹر پیر شدگی	کیلے زمین اور استعمال
19 لیٹر تک	ریشمی زمین
20 سے 30 لیٹر	چنے، گوارا، سرگم، چلی اور باجرا
31 سے 45 لیٹر	ریشمی میرا
46 سے 60 لیٹر	میرا سے درمیانی بخاری میرا
60 سے زیادہ	بخاری میرا یا کچی مٹی

2- مٹی کا تھال (Soil pH)

مٹی کے تھال سے مٹین کی اس خاصیت کا پتہ چتا ہے کہ مٹین میں سو جیو خوراک کی اجزاء چودوں کو کتنی آسانی سے بھرتا سکتے ہیں اس کے علاوہ مٹین (Sodic) کا بھی اندازہ لگایا جاسکتا ہے

مٹی کا تھال	کیلے
7.0 سے 7.5	زمین کی تمام سو جیو خوراک کی تمام سو جیو خوراک کی آسانی بھرتا ہے۔
7.6 سے 8.0	زمین میں سو جیو خوراک کے خوراک عام بھرتا ہے۔ سوائے ذکے اور مگنیز اور بوران کے جن کی دستیابی قدر سے کم ہو جاتی ہے۔
8.1 سے 8.5	مٹاؤر کیرو (شردی) میں فاسفورس کا حصول قدرے مشکل ہوتا ہے لیکن عناصر مٹی کی (اسوائے مٹاؤریم) کی بے حد کمی ہوتی ہے
8.5 سے زیادہ	زمین میں بارہٹ کا مسئلہ پیدا ہو جاتا ہے جس کا تھراک کا مٹیاب کاشت کیلئے ضروری ہے۔

3- برقی موصلیت (Electrical Conductivity)

برقی موصلیت مٹی کی برقی موصلیت کی مقدار کی جاتی ہے۔ زمین میں مٹی کی برقی موصلیت کی مقدار اور لخت کا پودوں کی نشوونما سے گہرا تعلق ہے۔ موصلیت (E.C) اور فصلانگی موزونیت کی درجہ بندی درج ذیل ہے۔

برقی موصلیت	کیلے زمین	فصلانگی اثر
4 سے کم	کلرا مٹی نہیں سمجھی کلرا مٹی	فصلوں کی پیداوار پر کوئی خاص برا اثر نہیں پڑتا۔
4.1 سے 8	درمیانی کلرا مٹی	مٹی، گنا، چلی دار، پتاس، چاول اور کیٹو وغیرہ کی پیداوار متاثر ہوتی ہے۔
8.1 سے 16	بہت کلرا مٹی	صرف مٹیاب برداشت کرنے والی فصلیں مثلاً جو کاشت کی جاسکتی ہیں۔
16 سے زیادہ	بہت زیادہ کلرا مٹی	اکثر فصلانگی کا امین مشکل ہوتا ہے

4- تھال حاصل ذک (Available Zn)

چاول کی کاشت کے علاقے میں چاول کیلے ذک کا استعمال ناگزیر ہے اس کے استعمال کے لئے زمینی درجہ بندی درج ذیل ہے۔

مقدار ذک (مٹی گرام فی کلو گرام) (پاپی ٹی ایم)	ضروریات
1.5 یا اس سے کم	ذک ڈالنے سے نتائج مثبت حاصل ہوں گے
1.5 سے زیادہ	ذک ڈالنے سے مثبت نتائج حاصل ہونے کے امکانات کم ہیں۔

5- جیپسم کی ضروریات (Gypsum Requirement)

یہ جیپسم کی وہ مقدار ہے جو تصور ہارڈ زمینوں میں سوڈیم کو دور کرنے کیلئے درکار ہوتی ہے۔ اس کی اگائی ٹی ایکڑ چھانچے ہے۔ جیپسم ڈالنے کے بعد تقریباً دو فٹ ایکڑ پانی کھڑا کیا جاتا ہے۔

زرخیزی زمین کا معیار

	Poor	Medium	Fertile		Poor	Medium	Fertile
Organic Matter (%)	< 0.86	0.87-1.29	> 1.29	Cu (mg/kg)	< 0.1	0.1-0.2	> 0.2
Available P (mg/kg)	< 7.0	7-21	> 21.0	Fe (mg/kg)	< 2.0	2.0-4.5	> 4.5
Available K (mg/kg)	< 80	80-180	> 180	Mn (mg/kg)	< 0.5	0.5-1.0	> 1.0
Zn (mg/kg)	< 0.5	0.5-1.0	> 1.0	B (mg/kg)	< 0.2	0.2-0.5	0.5-1.0

کھادوں کی سفارشات

Sr #	Crop	Soil Condition	Fertilizer Recommendation (Kg/acre)			Fertilizer Recommendation (Bags / acra)		
			N	P ₂ O ₅	K ₂ O	Urea	DAP	SOP
1	Wheat	Poor	52	46	25	1.5	2.5	1.0
		Medium	46	34	25	1.5	1.5	1.0
		Fertile	32	23	25	1.1	1.0	1.0
2	Rice (Coarse)	After Wheat	57	32	25	2.0	1.5	1.0
		After Legumes	41	32	25	1.25	1.5	1.0
3	Rice (Fine)	After Wheat	69	41	32	2.5	1.75	1.25
		After Legumes	57	41	32	2.0	1.75	1.25
4	Cotton (BT)	Early Sowing	138-116	46	37.50	5.25-4.25	2.0	1.50-2.0
		Medium / Late Sowing	81-104	35	37	3.0-4.0	1.5	1.5
5	Maize	Poor	92	57	37	3.0	2.5	1.5
		Medium	68	46	25	2.25	2.0	1.0
		Fertile						
6	Patato	Poor	123	69	50	4.0	3.0	2.0
		Medium	100	50	50	3.5	2.5	2.0
		Fertile	87	46	37	3.0	2.0	1.5
7	Sugarcane	Poor	120	69	50	5.0	3.0	2.0
		Medium	92	69	50	3.25	2.0	2.0
		Fertile	69	23	25	2.75	1.0	1.0
8	Vegetables	Poor						
		Medium	36	34	25	1.0	1.5	1.0
		Fertile						

Special Remarks

1- حل پذیر نمکیات: (TOTAL SOLUBLE SALTS)

حل پذیر نمکیات کا اندازہ برقی موصلیت (Electrical Conductivity) کے ذریعے لگایا جاسکتا ہے۔ اس کی اکائی مائیکرو سیمنزنی سینٹی میٹر ہوتی ہے اس کو حل پذیر نمکیات میں تبدیل کرنے کے لئے 0.7 ہے ضرب دے کر حاصل ضرب کو حصے دس لاکھ میں (ppm) دکھایا جاسکتا ہے پانی کی موزونیت کی درجہ بندی EG کے حساب سے کی جاتی ہے جو حسب ذیل ہے۔

- (i) 0 سے 1000 مائیکرو سیمنز آب پاشی کے لئے موزوں ہے اور تمام فصلیں کاشت کی جاسکتی ہیں۔
- (ii) 1001 تا 1250 مائیکرو سیمنز اس میں نمکیات کی مقدار درمیانی ہوتی ہے اور نہری پانی میں ملا کر آب پاشی کے لئے استعمال کیا جاسکتا ہے اس پانی کے استعمال کے ساتھ درمیانی نمک برداشت کرنے والی فصلیں مثلاً گندم، چاول، بھئی، جوار، جوی ٹماٹر، آلو، گوبھی، مگاجر، مٹر، پیاز وغیرہ کاشت کی جاسکتی ہے۔
- (iii) 1250 سے زیادہ اس میں نمکیات کی مقدار زیادہ ہے اور آب پاشی کے لئے موزوں نہیں تاہم یہ پانی ریتلی زمینوں یا زیادہ نکاسی آب والی زمینوں میں استعمال ہو سکتا ہے اور اس میں زیادہ نمکیات برداشت کرنے والی فصلیں مثلاً کپاس، جو، رایا، بیٹنگر پالک وغیرہ کاشت ہو سکتی ہے۔

2- سوڈیم کی جذب سطحی نسبت: (SAR)

پانی کی خاصیت سوڈیم اور میگنیشیم + میگنیشیم سے معلوم کی جاتی ہے سوڈیم کی جذب سطحی نسبت کی درجہ بندی مندرجہ ذیل ہیں۔

6 سے کم: سوڈیم سے نفوذ پذیری (Permeability) کا کوئی مسئلہ نہیں۔

6 تا 10: باریک بافت والی زمین مثلاً چکنی اور چکنی میراجن کی فیصد سیرشدگی (Saturation % age) 50 سے زائد ہو میں نفوذ پذیری کا مسئلہ پیدا ہو سکتا ہے۔

10 سے زیادہ: ان زمینوں میں جہاں نامیاتی مادہ کی کمی ہے نفوذ پذیری کا خطرہ ہے لیکن موٹی بافت والی زمینیں (ریتلی یا ریتلی میرا) جن کی فیصد سیرشدگی 20 سے کم ہو میں کم خطرہ ہوتا ہے۔

3- زائد سوڈیم پانی کاربونیٹ: (RESIDUAL SODIUM BICARBONATE)

زائد سوڈیم پانی کاربونیٹ بذریعہ عملی کاربونیٹ تفریق اور بائی کاربونیٹ کی حاصل جمع سے میگنیشیم + میگنیشیم کو منہا کرنے سے حاصل ہوتی ہے اس کی اکائی meq/L ہوتی ہے اور درجہ بندی حسب ذیل ہے۔

1.25 سے کم: پانی آب پاشی کے لئے موزوں ہے۔

1.25 تا 2.5: وہ فصلیں جن میں نمکیات برداشت کرنے کی درمیانی صلاحیت ہو ان کیلئے پانی آب پاشی کے لئے استعمال ہو سکتا ہے۔

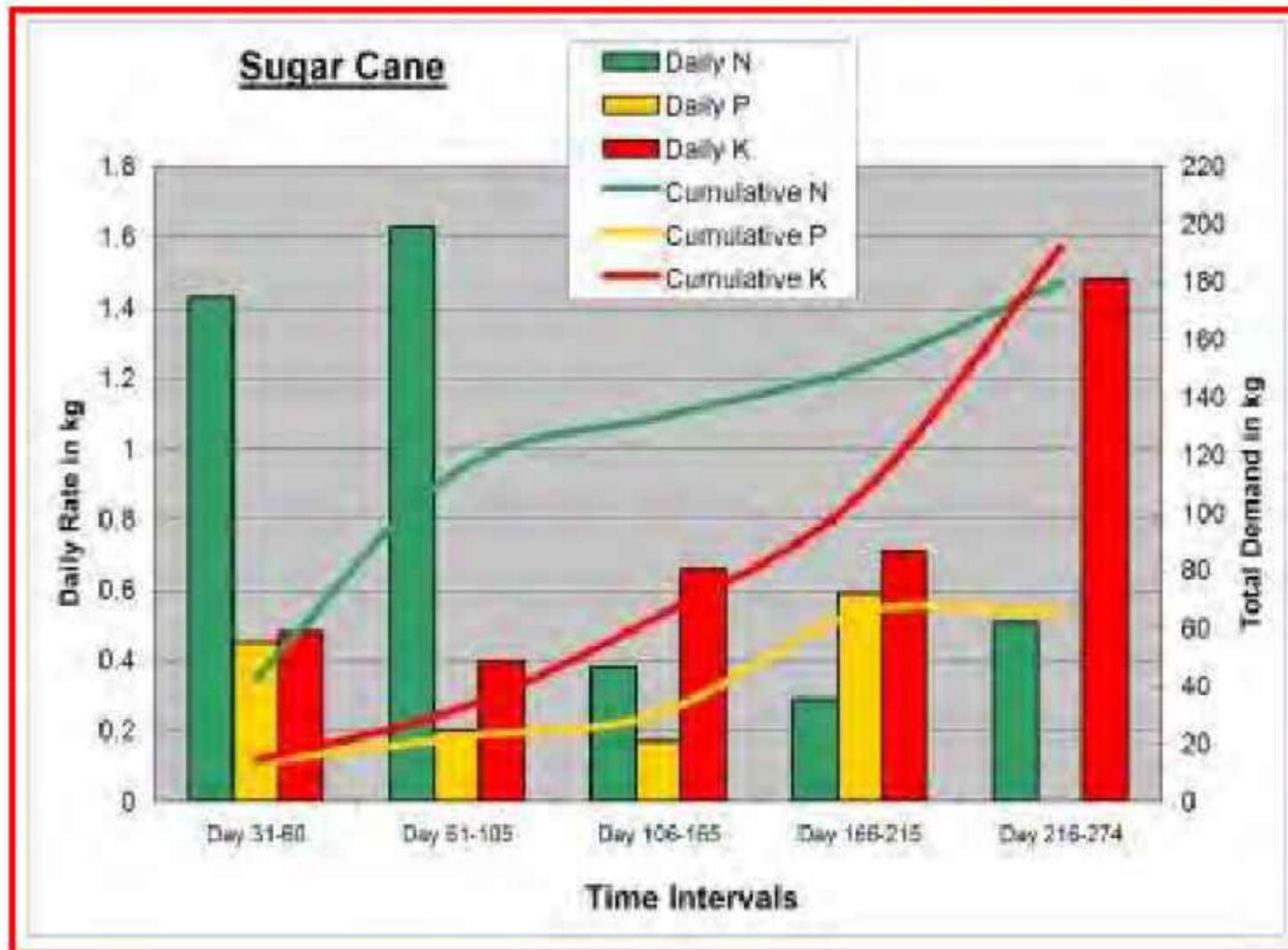
2.5 سے زیادہ: پانی آب پاشی کے لئے موزوں نہیں ہے۔

4- کلورائیڈ: (CHLORIDE)

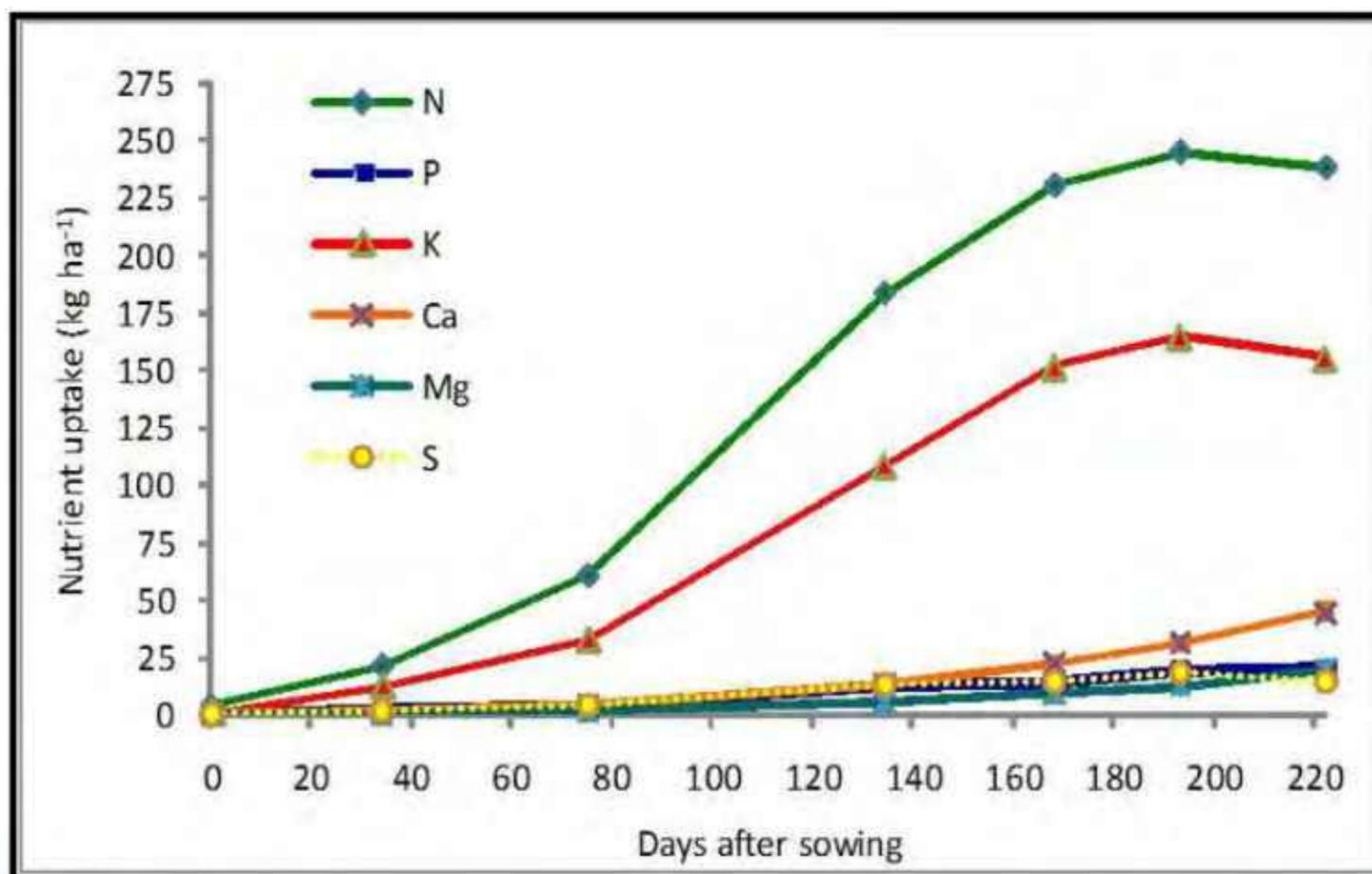
آب پاشی کے لئے اس کی مقدار پانی میں 4.5 me/L سے زیادہ نہیں ہونی چاہیے۔

نوٹ: خیال رہے کہ درجہ بندی کے لئے گوہر خاصیت کا موزوں ہونا ضروری ہے۔ لیکن موزونیت کا زیادہ تر انحصار زمین کی بافت پر ہے یا نہری پانی کے ساتھ ملا کر دینے کی صورت میں ان دونوں کا موزوں تناسب ہے۔

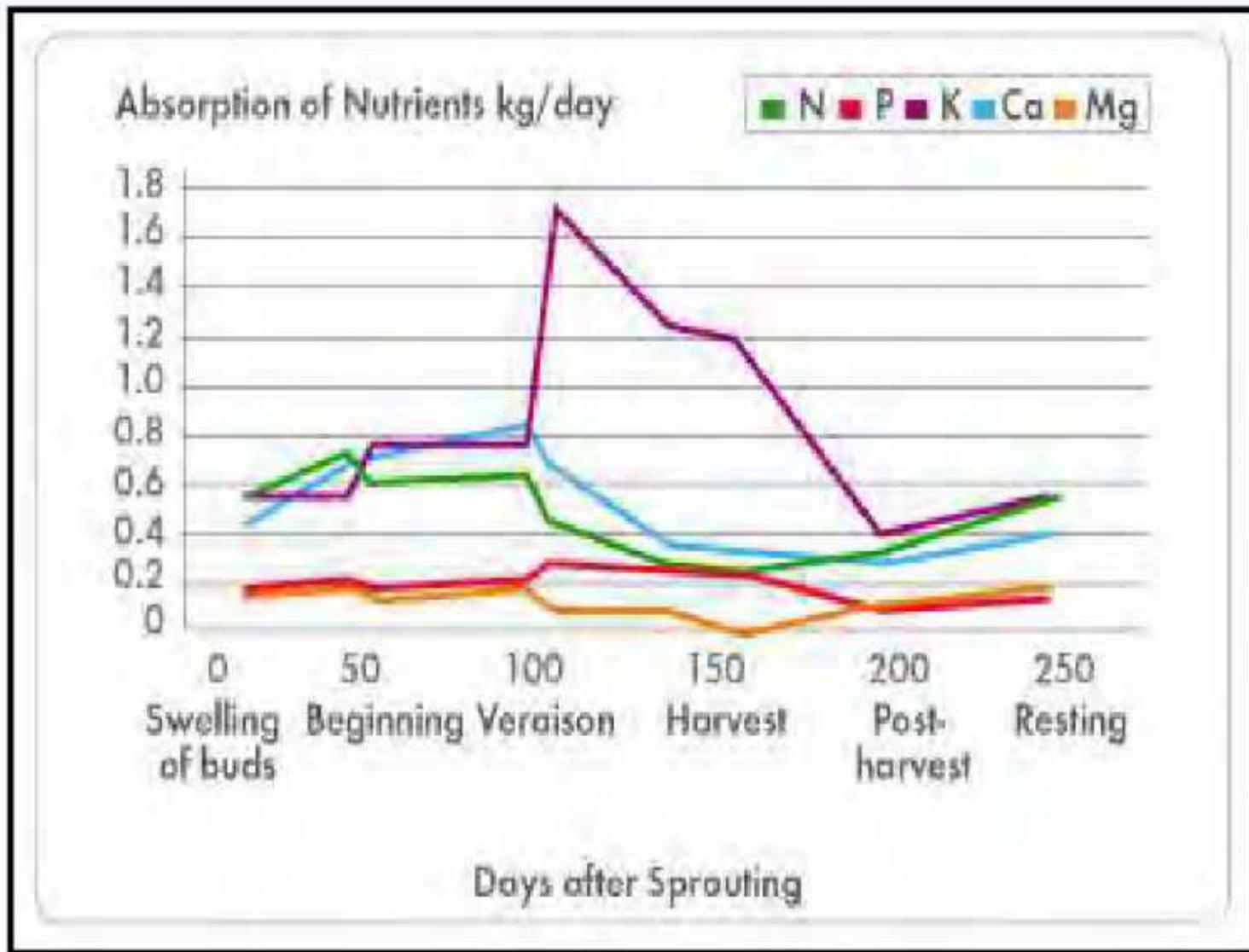
Annex- 3: Nutrient Uptake Curves for Some Crops



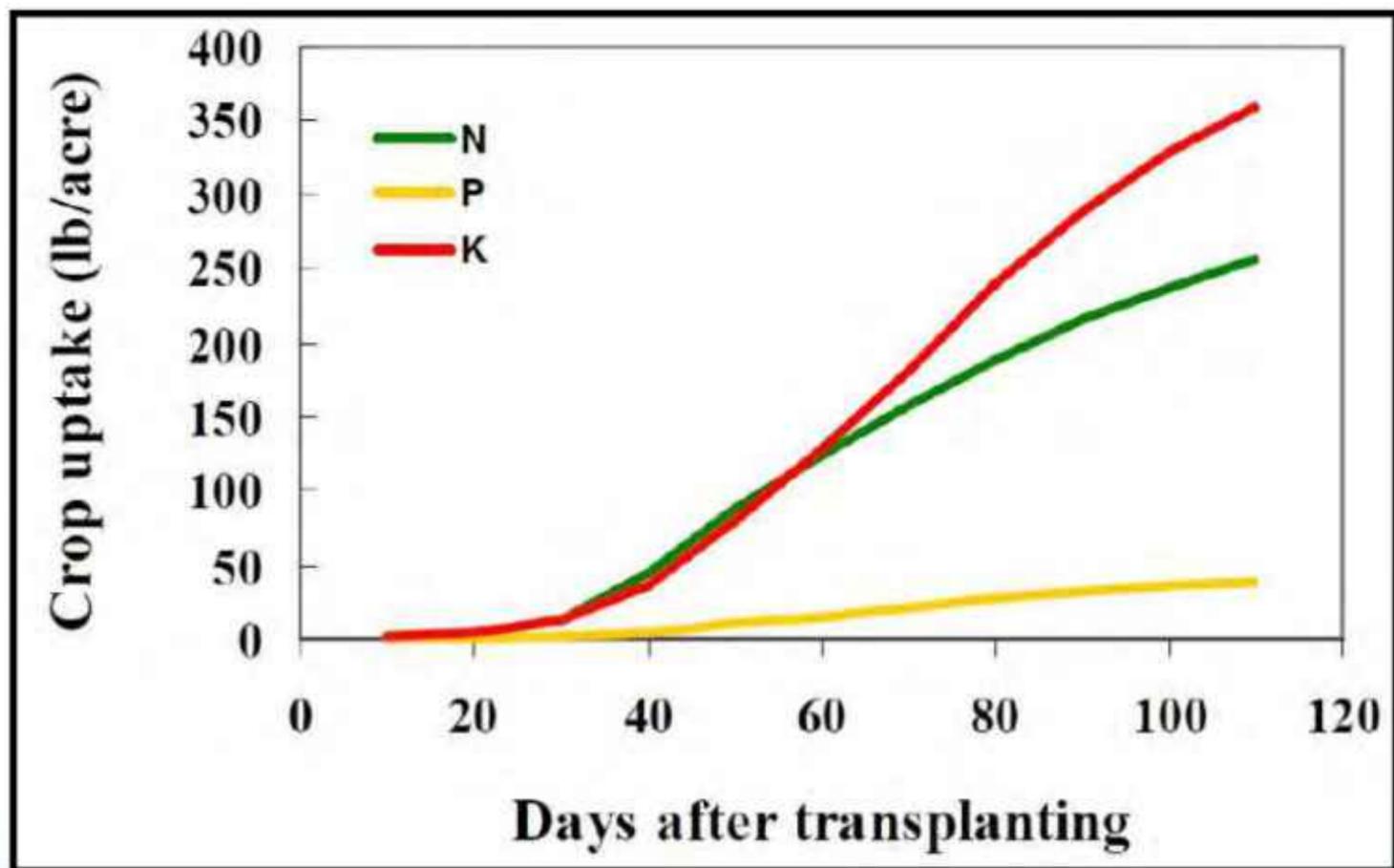
Sugarcane Nutrient Uptake Curve



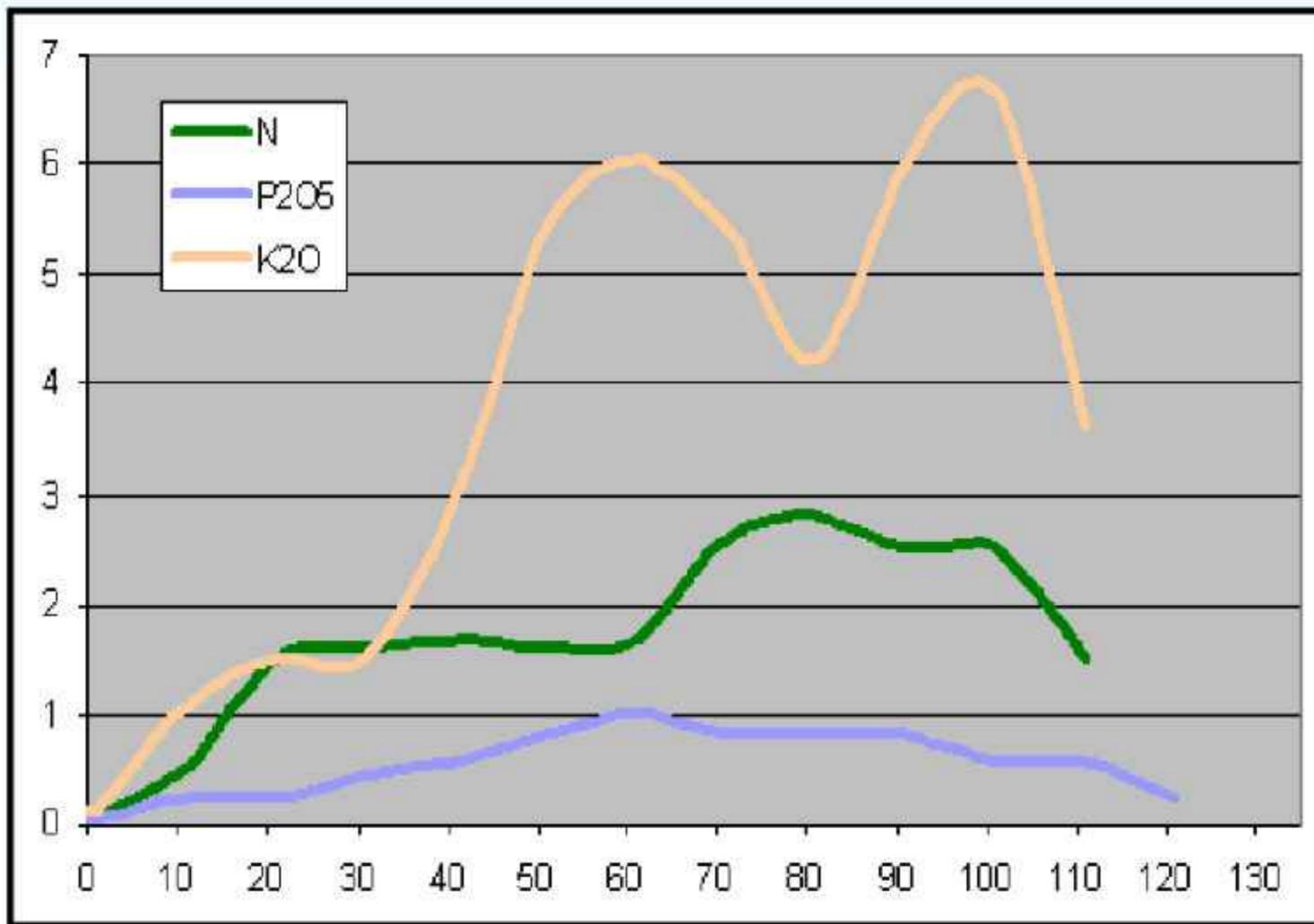
Maize Nutrient Uptake Curve



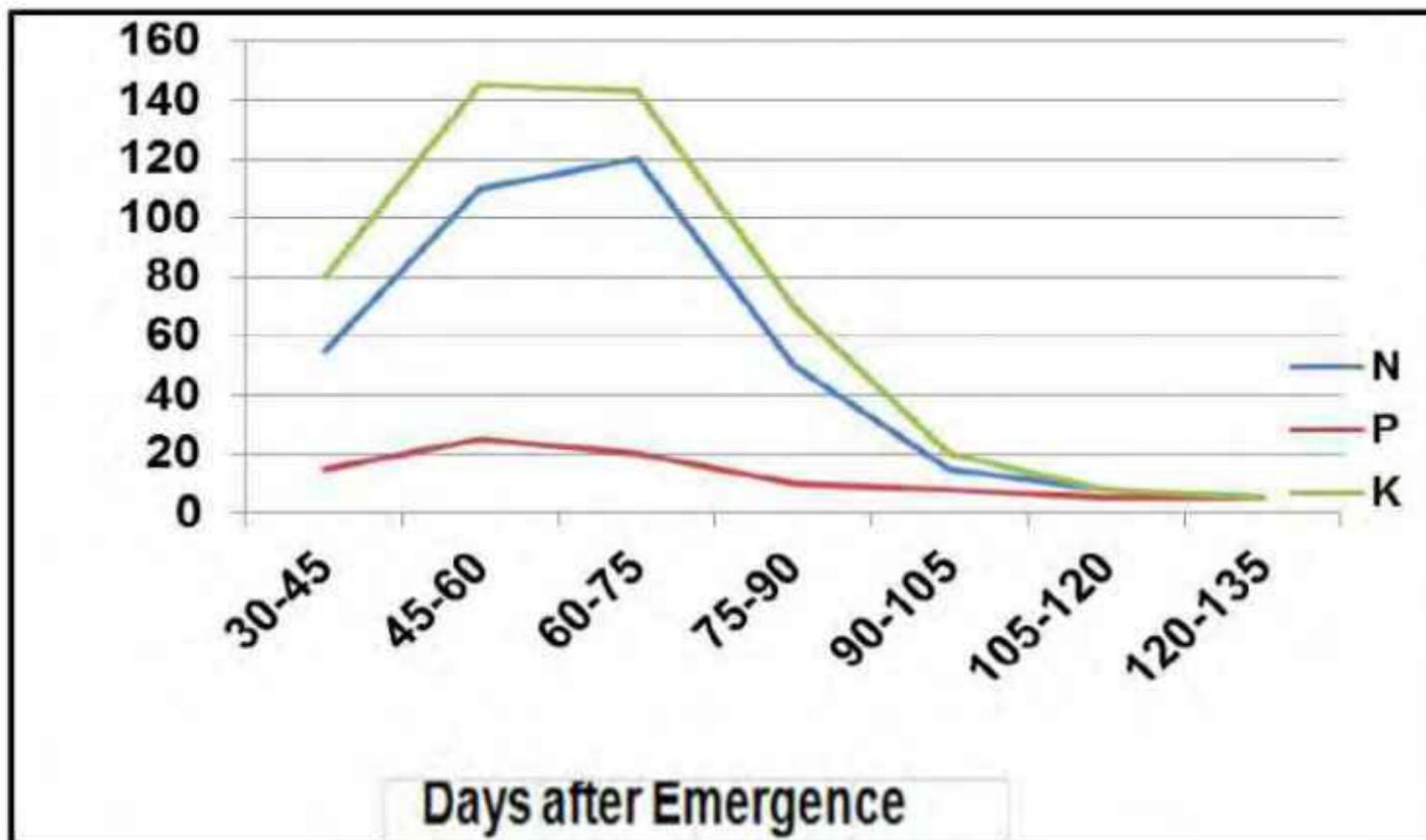
Cotton Nutrient Uptake Curve



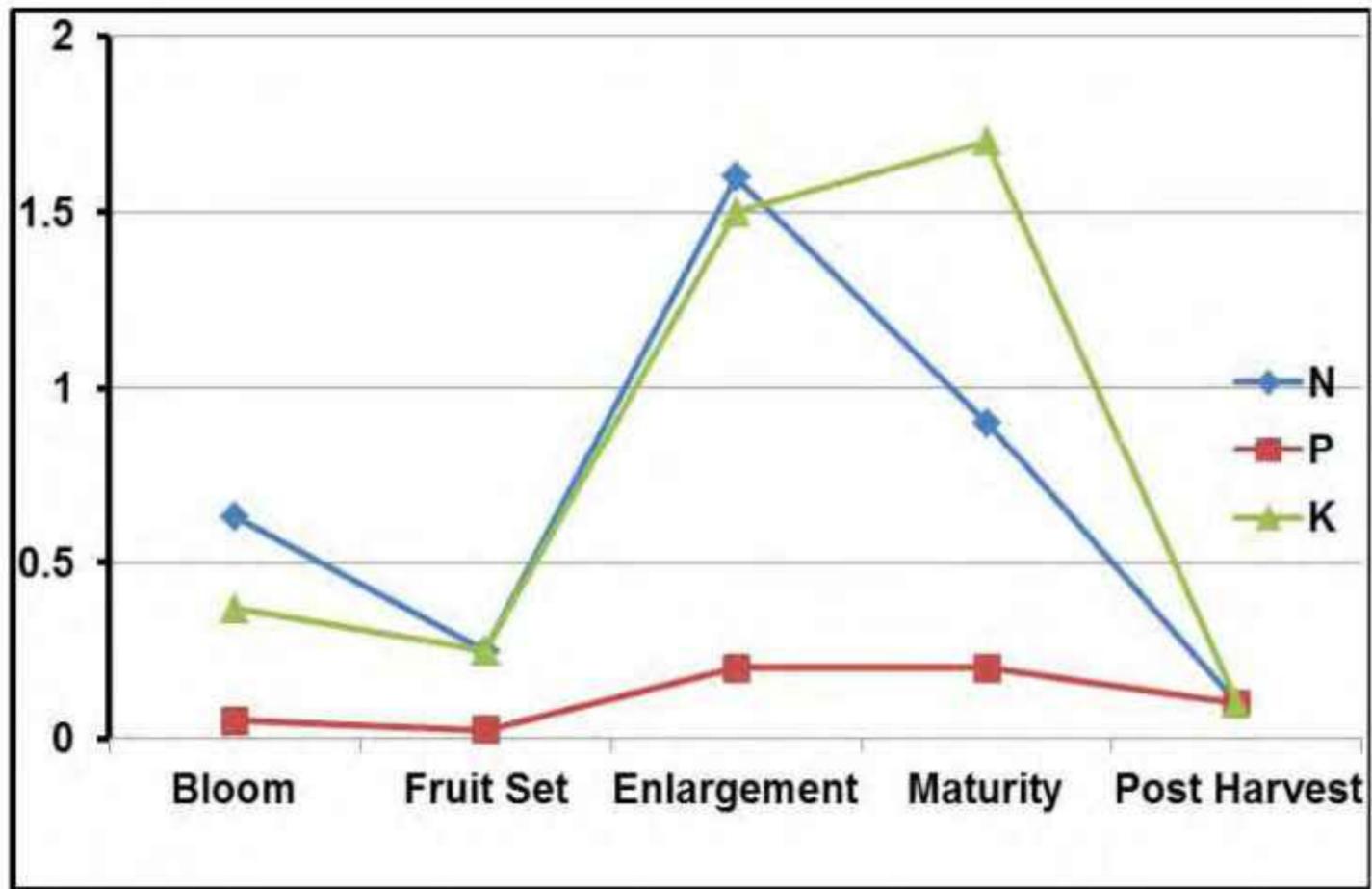
Tomato Nutrient Uptake Curve



Pepper Nutrient Uptake Curve



Potato Nutrient Uptake Curve



Citrus Nutrient Uptake Curve

Annex-4: Sample Fertigation Scheduling for Maize

Particulars		N	P ₂ O ₅	K ₂ O
Nutrients Removal (Kg/Maund of Produce)		0.75	0.30	0.75
		N	P ₂ O ₅	K ₂ O
		(Kg/Acre)	(Kg/Acre)	(Kg/Acre)
Nutrients Removal for 100 Maunds Yield of Maize		75	30	75
Percent Saving in Fertilizer through Fertigation		30	30	30
Remaining Nutrients after Fertilizer Saving		53	21	53
Nutrients Available in Soil		0	0	0
Remaining Nutrients to be Applied through Fertigation		53	21	53
Physiological Crop Stages				
Crop life		Days		
Vegetable Phase (1-40 DAG)		40		
Flowering Phase (40-60 DAG)		20		
Cob Development Phase (60-90 DAG)		30		
Grain Development Phase (90-120 DAG)		30		
Total		120		
Ratio and Ratio Days Calculation				
		Ratio		Ratio Days
Crop life		N	P ₂ O ₅	N
Vegetative Phase (1-40 DAG)		2	1	80
Flowering Phase (40-60 DAG)		3	1	60
Cob Development Phase (60-90 DAG)		2	0	60
Grain Development Phase (90-120 DAG)		1	0	30
Total		8	2	230
			K ₂ O	K ₂ O
Vegetative Phase (1-40 DAG)			1	40
Flowering Phase (40-60 DAG)			2	40
Cob Development Phase (60-90 DAG)			4	120
Grain Development Phase (90-120 DAG)			2	60
Total			9	260
How to Calculate Nutrient (Kg/Acre/Day)?				
Nutrient (kg/Acre/Day) = Total Quantity of Nutrient for fertigation (Kg/Acre) X Ratio Days of Nutrient in the Stage				
Nutrient (Kg/Acre/Day)		Sum of Ratio Days of the Nutrient		No. of Fertigation Days in the Stage
		Days	Nutrients kg/acre/day	Fertilizer kg/acre/day
	Crop life		N	Urea
	Vegetable Phase (1-40 DAG)	40	0.457	0.843
	Flowering Phase (40-60 DAG)	20	0.685	1.339
	Cob Development Phase (60-90 DAG)	30	0.457	0.992
	Grain Development Phase (90-120 DAG)	30	0.228	0.496
	Total	120	1.826	3.670
			P ₂ O ₅	MAP
	Vegetable Phase (1-40 DAG)	40	0.350	0.574
	Flowering Phase (40-60 DAG)	20	0.350	0.574
	Cob Development Phase (60-90 DAG)	30	0.000	0.000
	Grain Development Phase (90-120 DAG)	30	0.000	0.000
	Total	120	0.700	1.148
			K ₂ O	SOP
	Vegetable Phase (1-40 DAG)	40	0.202	0.404
	Flowering Phase (40-60 DAG)	20	0.404	0.808
	Cob Development Phase (60-90 DAG)	30	0.808	1.615
	Grain Development Phase (90-120 DAG)	30	0.404	0.808
	Total	120	1.817	3.635
			Urea	MAP
	Vegetable Phase (1-40 DAG)	40	0.843	22.951
	Flowering Phase (40-60 DAG)	20	1.339	11.475
	Cob Development Phase (60-90 DAG)	30	0.992	0.000
	Grain Development Phase (90-120 DAG)	30	0.496	0.000
	Total	120	3.670	34.426
			SOP	SOP
	Vegetable Phase (1-40 DAG)	40	0.404	16.154
	Flowering Phase (40-60 DAG)	20	0.808	16.154
	Cob Development Phase (60-90 DAG)	30	1.615	48.462
	Grain Development Phase (90-120 DAG)	30	0.808	24.231
	Total	120	3.635	105.000
			Total fertilizer (kg/acre)	105
			Number of fertilizer bags / acre	2.10
			Nutrients N-P ₂ O ₅ -K ₂ O (kg/acre)	53

Annex-5: Sample Fertigation Schedule for Cotton

Particulars							
N	P ₂ O ₅	K ₂ O					
Nutrients Removal (Kg/Maund of Produce)	2.31	0.52	2.24				
N	P ₂ O ₅	K ₂ O					
(Kg/Acre)	(Kg/Acre)	(Kg/Acre)					
Nutrients Removal for 50 Maunds Yield of Cotton	116	26	112				
Percent Saving in Fertilizer through Fertigation	30	30	30				
Remaining Nutrients after Fertilizer Saving	81	18	78				
Nutrients Available in Soil	0	0	0				
Remaining Nutrients to be Applied through Fertigation	81	18	78				
Fertigation							
Crop Stage	Days	Ratio		Ratio Days			
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Vege. Growth Phase -1 (7 - 15DAG)	7	2	1	1	14	7	7
Veg. Growth Phase- 2 (15 - 32DAG)	18	2	1	1	36	18	18
Squares & flowering (32 - 57DAG)	25	2	1	2	50	25	50
Boll initiation (57 - 77DAG)	20	3	1	1	60	20	20
Boll Develop. Phase -1 (77 - 107DAG)	30	2	1	2	60	30	60
Boll Develop. Phase -2 (107 - 127DAG)	20	2	1	1	40	20	20
Initial Boll Maturity (127 - 142DAG)	15	0	0	0	0	0	0
Late Boll Maturity (142 - 167DAG)	15	0	0	0	0	0	0
	150	13	6	8	260	120	175
Nutrient (kg/Acre/Day= Total Quantity of Nutrient for fertigation (Kg/Acre)X Ratio Days of Nutrient in the Stage							
Sum of Ratio Days of the Nutrient							
Frequency & Dose							
Crop Stage	Days	Nutrients kg/acre/day			Fertilizer kg/acre/day		
		N	P ₂ O ₅	K ₂ O	Urea	MAP	SOP
Vege. Growth Phase -1 (7 - 15DAG)	7	0.242	0.152	0.448	0.461	0.249	0.896
Veg. Growth Phase- 2 (15 - 32DAG)	18	0.622	0.152	0.448	1.287	0.249	0.896
Squares & flowering (32 - 57DAG)	25	0.622	0.152	0.896	1.287	0.249	1.792
Boll initiation (57 - 77DAG)	20	0.933	0.152	0.448	1.963	0.249	0.896
Boll Develop. Phase -1 (77 - 107DAG)	30	0.622	0.152	0.896	1.287	0.249	1.792
Boll Develop. Phase -2 (107 - 127DAG)	20	0.622	0.152	0.448	1.287	0.249	0.896
Initial Boll Maturity (127 - 142DAG)	15	0.000	0.000	0.000	0.000	0.000	0.000
Late Boll Maturity (142 - 167DAG)	15	0.000	0.000	0.000	0.000	0.000	0.000
		Total fertilizer kg/acre			Total fertilizer kg/acre/growth stage		
		162			162		
		Nutrients NPK in kg/acre			Nutrients NPK in kg/acre		
		78			78		
		Total number of bags/acre			Total number of bags/acre		
		3.24			3.24		

Annex-6: Sample Fertigation Schedule for Sugarcane

Recommendation	Particulars	N	P ₂ O ₅	K ₂ O
Nutrients Removal (Kg/Maund of Produce)		0.04	0.02	0.05
		N	P ₂ O ₅	K ₂ O
	(Kg/Acre)	(Kg/Acre)	(Kg/Acre)	(Kg/Acre)
Nutrients Removal for 1500 Maunds Yield of Sugarcane	60	28	75	
Percent Saving in Fertilizer through Fertigation	30	30	30	
Remaining Nutrients after Fertilizer Saving	42	19	53	
Nutrients Available in the Soil	0	0	0	
Remaining Nutrients to be Applied through Fertigation	42	19	53	

Physiological Crop Stage	Days	Ratio			Ratio Days		
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
After germination 7-60 days	53	3	1	1	159	53	53
61 to 105 days	45	3	0.5	1	135	23	45
106 to 165 days	60	1	0.5	1.5	60	30	90
166 to 215 days	50	1	2	2.5	50	100	125
216 to 275 days	60	1	0	3	60	0	180
Total	268	9	4	9	464	206	493

Nutrient (kg/Acre/Day = Total Quantity of Nutrient for fertigation (Kg/Acre) X Ratio Days of Nutrient in the Stage / Sum of Ratio Days of the Nutrient

Fertigation Frequency & dose	Crop Stage	Days	Nutrients kg/acre/day			Fertilizer kg/acre/day			Fertilizer kg/acre/growth stage		
			N	P ₂ O ₅	K ₂ O	Urea	MAP	SOP	Urea	MAP	SOP
After germination 7-60 days		53	0.272	0.094	0.106	0.550	0.154	0.213	29.157	8.168	11.288
61 to 105 days		45	0.272	0.047	0.106	0.570	0.077	0.213	25.660	3.468	9.584
106 to 165 days		60	0.091	0.047	0.160	0.177	0.077	0.319	10.600	4.624	19.168
166 to 215 days		50	0.091	0.188	0.266	0.116	0.308	0.532	5.818	15.412	26.623
216 to 275 days		60	0.091	0.000	0.319	0.197	0.000	0.639	11.807	0.000	38.337
Total		268	0.815	0.376	0.958	1.610	0.616	1.917	83.042	31.672	105.000
			Total fertilizer kg/acre						83	32	105
			Nutrients NPK (kg/acre)						42	19	53
			Total number of bags/acre						1.66	0.63	2.10

Annex-7: Sample Fertigation Schedule for Potato

Recommendation		N	P ₂ O ₅	K ₂ O
Particulars				
Nutrients Removal (Kg/Maund of Produce)		0.26	0.05	0.40
		N	P ₂ O ₅	K ₂ O
		(Kg/Acre)	(Kg/Acre)	(Kg/Acre)
Nutrients Removal for 350 Maunds Yield of Potato		91	18	140
Percent Saving in Fertilizer through Fertigation		30	30	30
Remaining Nutrients after Fertilizer Saving		64	13	98
Nutrients Available in Soil		0	0	0
Remaining Nutrients to be Applied through Fertigation		64	13	98
Fertigation		Ratio		
Crop Stage	Days	Ratio		
		N	P ₂ O ₅	K ₂ O
Establishment	20	1	1	20
Stolonization	18	4	1	18
Beginning of Tuberization	10	3	1	40
Tuber Filling Stage-1	12	2	0	48
Tuber Filling Stage-2	10	0	0	10
Total	70	10	3	136
Nutrient (kg/Acre/Day = Total Quantity of Nutrient for fertigation (Kg/Acre) X Ratio Days of Nutrient in the Stage		No. of Fertigation Days in the Stage		
Frequency & Dose		Fertilizer kg/acre/day		
Crop Stage	Days	Fertilizer kg/acre/day		
		N	P ₂ O ₅	K ₂ O
Establishment	20	0.436	0.265	0.721
Stolonization	18	1.745	0.265	0.721
Beginning of Tuberization	10	1.309	0.265	2.882
Tuber Filling Stage-1	12	0.873	0.000	2.882
Tuber Filling Stage-2	10	0.000	0.000	0.721
Total	70			
		Total fertilizer kg/acre	136	21
		Nutrients NPK (kg/acre)	64	13
		Total number of bags/acre	2.72	0.42
		Fertilizer kg/acre/growth stage	Urea	SOP
			17.925	8.702
			67.351	7.832
			27.932	4.351
			22.764	0.000
			0.000	0.000
			136	21
			64	13
			2.72	0.42
			28.824	25.941
			57.647	69.176
			14.412	196
			98	3.92

* Source: Ahmad, N. and M. Rashid. 2003. Fertilizers and Their Use in Pakistan. National Fertilizer Development Centre (NFDC), Islamabad. Training Bulletin Third Edition - FAO

Note:

1. The sample fertigation schedule is a guideline. It can be slightly changed or adjusted according to the prevailing soil and other conditions.
2. Since fertigation starts from the very beginning, basal fertilizer dose has been ignored. However, if farmer intends to apply basal dose at the time of land preparation it is not prohibited.

Annex-8: Sample Fertigation Schedule for Bitter Ground

Particulars	N			P ₂ O ₅			K ₂ O		
	(Kg/Acre)								
Recommendation by Soil Fertility Research Institute	70			57			50		
Percent Saving in Fertilizer through Fertigation	30			30			30		
Remaining Nutrients after Fertilizer Saving	49			40			35		
Nutrients Available in Soil	0			0			0		
Remaining Nutrients to be Applied through Fertigation	49			40			35		

Crop Life	Days	Ratio			Ratio Days		
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Vegetative Growth	25	3	1	1	75	25	25
Vegetative - Flowering	15	2	1	2	30	15	23
Fruit Development - Harvest	30	2	1	2	60	30	60
TOTAL	70	7	3	5	165	70	108

Crop Stage	Days	Nutrients (Kg/Acre/Day)			Fertilizer (Kg/Acre/Day)			Fertilizer (Kg/Acre/Season)		
		N	P ₂ O ₅	K ₂ O	Urea	MAP	SOP	Urea	MAP	SOP
Vegetative Growth	25	0.891	0.570	0.326	1.693	0.934	0.651	42.3	23.4	16.3
Vegetative - Flowering	15	0.594	0.570	0.488	1.047	0.934	0.977	15.7	14.0	14.7
Fruit Development - Harvest	30	0.594	0.570	0.651	1.047	0.934	1.302	31.4	28.0	39.1
Total	70	2.079	1.710	1.465	3.788	2.803	2.930	89.458	65.410	70.000
					Total fertilizer kg/acre			89	65	70
					Nutrients NPK (kg/acre)			49	40	35
					Total number of bags/acre			0.98	0.80	0.70

Nutrient (kg/Acre/Day = Total Quantity of Nutrient for fertigation (Kg/Acre) X Ratio Days of Nutrient in the Stage

Sum of Ratio Days of the Nutrient

No. of Fertigation Days in the Stage

Annex-10: Sample Fertigation Schedule for Tamato Through Open Field

Recommendation	N	P ₂ O ₅	K ₂ O
Nutrients Removal (Kg/Maund of Mroduce)	0.09	0.03	0.17
	N (Kg/Acre)	P ₂ O ₅ (Kg/Acre)	K ₂ O (Kg/Acre)
Nutrients Removal for 450 Maunds of Tomato	41	14	77
Percent Saving in Fertillier through Fertigation	30	30	30
Remaining Nutrients after Fertilizer Saving	28	9	54
Nutrients Available in Soil	0	0	0
Remaining Nutrients to be Applied through Fertigation	28	9	54

Fertigation

Nutrient (kg/Acre/Day= Total Quantity of Nutrient for fertigation (Kg/Acre)X Ratio Days of Nutrient in the Stage
Sum of Ratio Days of the Nutrient **No. of Fertigation Days in the Stage**

Crop Life	Days	Ratios			Ratio Days		
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Establishment Stage	30	3.0	0.2	1.0	90	6	30
Vegetative Stage - Flowering	40	2.0	0.3	2.0	80	12	80
Flowering - Fruitset Stage	40	2.0	0.8	3.0	80	32	120
Fruitset-Harvest Stage	25	1.0	0.0	1.0	25	0	25
Total	135	8	1	7	275	50	255

Crop Life	Days	Nutrients Kg/Acre/Day			Fertilizer kg/acre/day			Fertilizer kg/acre/Season		
		N	P ₂ O ₅	K ₂ O	Urea	MAP	SOP	Urea	MAP	SOP
Establishment Stage	30	0.309	0.038	0.210	0.656	0.062	0.420	19.685	1.859	12.600
Vegetative Stage - Flowering	40	0.206	0.057	0.420	0.424	0.093	0.840	16.959	3.718	33.600
Flowering - Fruitset Stage	40	0.206	0.151	0.630	0.384	0.248	1.260	15.342	9.915	50.400
Fruitset-Harvest Stage	25	0.103	0.000	0.210	0.224	0.000	0.420	5.603	0.000	10.500
Total	135	0.825	0.246	1.470	1.584	0.534	2.940	57.589	15.492	107.100
		Total fertilizer (kg/acre)						58	15	107
		Fertilizer bags/acre						1.15	0.31	2.14
		Nutrients NPK (kg/acre)						28	9	54

Annex-11: Sample Fertigation Schedule for Tamato Through Tunnel

Recommendation	N	P ₂ O ₅	K ₂ O
Nutrients Removal (Kg/Maund of Mroduce)	0.09	0.03	0.17
	N (Kg/Acre)	P₂O₅ (Kg/Acre)	K₂O (Kg/Acre)
Nutrients Removal for 1473 Maunds of Tomato	133	44	250
Percent Saving in Fertilier through Fertigation	30	30	30
Remaining Nutrients after Fertilizer Saving	93	31	175
Nutrients Available in Soil	0	0	0
Remaining Nutrients to be Applied through Fertigation	93	31	175
Fertigation			

Crop Life	Days	Ratios			Ratio Days		
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Establishment Stage	30	3.0	0.2	1.0	90	6	30
Vegetative Stage - Flowering	40	2.0	0.3	2.0	80	12	80
Flowering - Fruitset Stage	40	2.0	0.8	3.0	80	32	120
Fruitset-Harvest Stage	25	1.0	0.0	1.0	25	0	25
Total	135	8	1	7	275	50	255

Crop Life	Days	Nutrients Kg/Acre/Day			Fertilizer kg/acre/day			Fertilizer kg/acre/Season		
		N	P ₂ O ₅	K ₂ O	Urea	MAP	SOP	Urea	MAP	SOP
Establishment Stage	30	1.012	0.124	0.687	2.148	0.203	1.375	64.436	6.085	41.244
Vegetative Stage - Flowering	40	0.675	0.186	1.375	1.368	0.304	2.750	55.512	12.170	109.984
Flowering - Fruitset Stage	40	0.675	0.495	2.062	1.256	0.811	4.124	50.221	32.454	164.976
Fruitset-Harvest Stage	25	0.337	0.000	0.687	0.734	0.000	1.375	18.340	0.000	34.370
Total	135	2.700	0.804	4.812	5.185	1.748	9.624	188.508	50.710	350.574
		Total fertilizer (kg/acre)			189			51		
		Fertilizer bags/acre			3.77			1.01		
		Nutrients NPK (kg/acre)			93			31		

Nutrient (kg/Acre/Day= Total Quantity of Nutrient for fertigation (Kg/Acre)X Ratio Days of Nutrient in the Stage
Sum of Ratio Days of the Nutrient **No. of Fertigation Days in the Stage**

Annex-12: Fertigation Schedule for Cucumber (Open Field)										
Recommendation	N	P ₂ O ₅	K ₂ O							
Nutrients Removal (Kg/Maund of Produce)	0.09	0.04	0.11							
	Kg/Acre									
Nutrients Removal for 400 Maunds of Cucumber	36	18	44							
Percent Saving in Fertilizer through Fertigation	30	30	30							
Remaining Nutrients after Fertilier Saving	25	12	31							
Nutrients Availale in Soil	0	0	0							
Remaining Nutrients to be Applied through Fertigation	25	12	31							
Fertigation										
Nutrient (kg/Acre/Day= Total Quantity of Nutrient for fertigation (Kg/Acre)X Ratio Days of Nutrient in the Stage										
Sum of Ratio Days of the Nutrient			No. of Fertigation Days in the Stage							
Crop Life	Days	Ratios			Ratio Days					
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O			
Establishment (10 DAG)	10	3	1	1	30	10	10			
Vegetative - -Flowering	15	2	1	1	30	15	15			
Flowering- - fruitset	25	2	2	2	50	50	50			
Fruitset-harvest	10	1	2	3	10	20	30			
Total	60	8	6	7	120	95	105			
Crop Life	Days	Nurients Kg/Acre/Day			Fertilizer kg/acre/day			Fertilizer kg/acre/Season		
		N	P ₂ O ₅	K ₂ O	Urea	MAP	SOP	Urea	MAP	SOP
Establishment (10 DAG)	10	0.630	0.130	0.293	1.314	0.213	0.587	13.141	2.126	5.867
Vegetative - -Flowering	15	0.420	0.130	0.293	0.858	0.213	0.587	12.864	3.189	8.800
Flowering- - fruitset	25	0.420	0.259	0.587	0.802	0.425	1.173	20.053	10.630	29.333
Fruitset-harvest	10	0.210	0.259	0.880	0.346	0.425	1.760	3.456	4.252	17.600
Total	60	1.680	0.778	2.053	3.319	1.276	4.107	49.514	20.197	61.600
		Total fertilizer (kg/acre)						50	20	62
		Fertilizer bags/acre						0.99	0.40	1.23
		Nutrients NPK (kg/acre)						25	12	31

Annex-13: Fertigation Schedule for Cucumber (Tunnel)

Recommendation	N	P ₂ O ₅	K ₂ O
Nutrients Removal (Kg/Maund of Produce)	0.09	0.04	0.11
	Kg/Acre		
Nutrients Removal for 2143 Maunds of Cucumber	193	94	236
Percent Saving in Fertilizer through Fertigation	30	30	30
Remaining Nutrients after Fertilizer Saving	135	66	165
Nutrients Available in Soil	0	0	0
Remaining Nutrients to be Applied through Fertigation	135	66	165

Fertigation

Nutrient (kg/Acre/Day= Total Quantity of Nutrient for fertigation (Kg/Acre)X Ratio Days of Nutrient in the Stage	
Sum of Ratio Days of the Nutrient	No. of Fertigation Days in the Stage

Crop Life	Days	Ratios			Ratio Days			
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	
Establishment (10 DAG)	10	3	1	1	30	10	10	
Vegetative - -Flowering	7	2	1	1	14	7	7	
Flowering- - fruitset	20	2	2	2	40	40	40	
Fruitset-harvest	8	1	2	3	8	16	24	
Total	45	8	6	7	92	73	81	
Crop Life		Nutrients Kg/Acre/Day			Fertilizer kg/acre/day			
Days	N	P ₂ O ₅	K ₂ O	Urea	MAP	SOP	Fertilizer kg/acre/Season	
Establishment (10 DAG)	4.402	0.904	2.037	9.184	1.482	4.074	91.839	
Vegetative - -Flowering	2.935	0.904	2.037	5.994	1.482	4.074	41.956	
Flowering- - fruitset	2.935	1.808	4.074	5.607	2.964	8.149	112.141	
Fruitset-harvest	1.467	1.808	6.112	2.417	2.964	12.223	19.335	
Total	11.740	5.425	14.260	23.202	8.893	28.520	265.271	
				Total fertilizer (kg/acre)			265	330
				Fertilizer bags/acre			5.31	6.60
				Nutrients NPK (kg/acre)			135	66
							135	165

ANNEX-14: SAMPLE FERTIGATION SCHEDULE FOR PEAS

Recommendation	N	P ₂ O ₅	K ₂ O
Nutrient Removal (Kg/Maund of Produce)	0.62	0.20	0.50
	Kg/Acre		
Nutrient Removal for 400 Maunds of Peas	248	80	200
Percent Saving in Fertilizer through Fertigation	30	30	30
Remaining Nutrients after Fertilizer Saving	174	56	140
Nutrients Available in Soil	0	0	0
Remaining Nutrients to be Applied through Fertigation	174	56	140

Fertigation

Crop Life	Days	Ratio			Ratio Days		
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Initial Stage	20	1	1	1	20	20	20
Development Stage	25	2	2	2	50	50	50
Mid Stage	35	3	3	3	105	105	105
Total	80	6	6	6	175	175	175

Nutrient (kg/Acre/Day) = Total Quantity of Nutrient for fertigation (Kg/Acre) X Ratio Days of Nutrient in the Stage

Sum of Ratio Days of the Nutrient

No. of Fertigation Days in the Stage

Crop life	Days	Nutrient kg/acre/day			Fertilizer (kg/acre/day)			Fertilizer kg/acre/Season			
		N	P ₂ O ₅	K ₂ O	Urea	MAP	SOP	Urea	MAP	SOP	
Initial Stage	20	0.992	0.320	0.800	2.020	0.525	1.600	40.393	10.492	32.000	
Development Stage	25	1.984	0.640	1.600	4.039	1.049	3.200	100.984	26.230	80.000	
Mid Stage	35	2.976	0.960	2.400	6.059	1.574	4.800	212.066	55.082	168.000	
Total	80.000	5.952	1.920	4.800	12.118	3.148	9.600	353.443	91.803	280.000	
		Total fertilizer (kg/acre)			353				92	280	
		Fertilizer bags/acre			7.07				1.84	5.60	
		Nutrients NPK (kg/acre)			174				56	140	

Annex-15: Sample Fertigation Schedule for Melon

Recommendation	Kg/Acre		
	N	P ₂ O ₅	K ₂ O
Recommendation by Soil Fertility Research Institute	64	82	25
Percent Saving in Fertilizer through Fertigation	30	30	30
Remaining Nutrients after Fertilizer Saving	45	57	18
Nutrients available in Soil	0	0	0
Remaining Nutrients to be Applied through Fertigation	45	57	18
Physiological Crop Stages			
Crop life	Days		
0-14 Days after planting	14		
15-28 Days after planting	14		
29-56 Days after planting	28		
57-78 Days after planting	22		
79-93 Days after planting	15		
Total	93		

Ratio and Ratio Days Calculation	Ratio			Ratio Days		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Crop life	1	1	1	14	14	14
0-14 Days after planting	1.5	1.5	1.5	21	21	21
15-28 Days after planting	2	2	2	56	56	56
29-56 Days after planting	1.5	1.5	1.5	33	33	33
57-78 Days after planting	1	1	1	15	15	15
79-93 Days after planting	7	7	7	139	139	139
Total						

How to Calculate Nutrient (Kg/Acre/Day)?	Nutrient (kg/Acre/Day) = Total Quantity of Nutrient for fertigation (Kg/Acre) X Ratio Days of Nutrient in the Stage / Sum of Ratio Days of the Nutrient					
	Days	N	P ₂ O ₅	K ₂ O	Urea	MAP
Crop life	93	2.256	2.891	0.818	3.668	4.739
0-14 Days after planting	14	0.322	0.413	0.126	0.524	0.677
15-28 Days after planting	14	0.483	0.619	0.126	0.786	1.015
29-56 Days after planting	28	0.645	0.826	0.252	1.048	1.354
57-78 Days after planting	22	0.483	0.619	0.189	0.786	1.015
79-93 Days after planting	15	0.322	0.413	0.126	0.524	0.677
Total						
				Total fertilizer (kg/acre)	73	94
				Fertilizer bags/acre	1.46	1.88
				Nutrients NPK (kg/acre)	45	57
					Urea	MAP
					7.337	9.478
					11.005	14.216
					29.347	37.910
					17.294	22.340
					7.861	10.154
					72.844	94.098
					1.637	33.237
					0.252	3.525
					0.252	3.525
					0.504	14.101
					0.378	8.309
					0.252	3.777

		2nd Year						
Plant to Plant Spacing (m)	6							
Row to Row Spacing (m)	6							
Number of Plants / Acre	112							
Particulars		Grams/Plant						
Total plant nutrients required		N	P ₂ O ₅	K ₂ O				
Percent saving in fertilizer through fertigation		200	100	100				
Nutrients required after fertilizer saving		30	30	30				
Nutrients available in soil		140	70	70				
Remaining nutrients through fertigation		0	0	0				
Total quantity of nutrients (kg/acre)		140	70	70				
		16	8	8				
		Ratio		Ratio Days				
Crop life	Days	N	P₂O₅	K₂O	N	P₂O₅	K₂O	
February	28	3	2	1	84	56	28	
March	31	1	1	1	31	31	31	
April	30	2	1	3	60	30	90	
May-July	92	1	1	1	92	92	92	
August	31	3	2	3	93	62	93	
September-November	91	1	1	1	91	91	91	
December - January	62	0	0	0	0	0	0	
Total	365	11	8	10	451	362	425	
How to Calculate Nutrient (Kg/Acre/Day)?								
Nutrient (kg/Acre/Day) = Total Quantity of Nutrient for fertigation (Kg/Acre) X Ratio Days of Nutrient in the Stage								
Sum of Ratio Days of the Nutrient		No. of Fertigation Days in the Stage						
		Nutrients kg/acre/day		Nutrient kg/acre/season				
Crop life	Days	N	P₂O₅	K₂O	N	P₂O₅	K₂O	
February	28	0.105	0.043	0.019	2.931	1.217	0.518	
March	31	0.035	0.022	0.019	1.082	0.674	0.574	
April	30	0.070	0.022	0.056	2.094	0.652	1.666	
May-July	92	0.035	0.022	0.019	3.210	2.000	1.703	
August	31	0.105	0.043	0.056	3.245	1.348	1.722	
September-November	91	0.035	0.022	0.019	3.176	1.978	1.665	
December - January	62	0.000	0.000	0.000	0.000	0.000	0.000	
Total	365	0.384	0.174	0.185	15.738	7.869	7.869	
		Fertilizer kg/acre/day		Fertilizer kg/acre/season				
Crop life	Days	Urea	MAP	SOP	Urea	MAP	SOP	
February	28	0.209	0.071	0.037	5.852	1.996	1.037	
March	31	0.067	0.036	0.037	2.064	1.105	1.148	
April	30	0.142	0.036	0.111	4.273	1.069	3.333	
May-July	92	0.067	0.036	0.037	6.124	3.279	3.407	
August	31	0.209	0.071	0.111	6.479	2.209	3.444	
September-November	91	0.067	0.036	0.037	6.057	3.243	3.370	
December - January	62	0.000	0.000	0.000	0.000	0.000	0.000	
Total	365	0.760	0.285	0.370	30.848	12.900	15.738	
		Fertilizer/Plant (Grams)		Fertilizer/Plant (Grams)				
		N	P₂O₅	K₂O	N	P₂O₅	K₂O	
		140	70	70	140	70	70	

		3rd Year		Nutrient Removal (Kg/ton) ²	
		N	P ₂ O ₅	K ₂ O	
Plant to Plant Spacing (m)	6				
Row to Row Spacing (m)	6				
Number of Plants / Acre	112	9.0	2.0	11.7	
Target Yield (tons/ha) - 3 year old plant	12	Kg/acre			
Particulars		N	P ₂ O ₅	K ₂ O	
Nutrients required for target yield		44	10	57	
Percent saving in fertilizer through fertigation		30	30	30	
Nutrients required after fertilizer saving		31	7	40	
Nutrients available in soil		0	0	0	
Remaining nutrients through fertigation		31	7	40	
Nutrients required in grams/plant		272	60	354	
		Ratio			
		Ratio Days			
Crop life	Days	N	P₂O₅	K₂O	N
February	28	3	2	1	84
March	31	1	1	1	31
April	30	2	1	4	60
May-July	92	1	1	1	92
August	31	3	2	5	93
September-November	91	1	1	1	91
December - January	62	0	0	0	0
Total	365	11	8	13	451
		Nutrient kg/acre/season			
		K ₂ O			
		P ₂ O ₅			
		N			
		K ₂ O			
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		4th Year & Above			Nutrient Removal (Kg/ton) ¹		
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Plant to Plant Spacing (m)	6						
Row to Row Spacing (m)	6						
Number of Plants / Acre	112	9.0	2.0	11.7			
Target Yield (tons/ha)	20	Kg/acre					
Particulars		N	P ₂ O ₅	K ₂ O			
Nutrients required for target yield		180	40	234			
Percent saving in fertilizer through fertigation		30	30	30			
Nutrients required after fertilizer saving		126	28	164			
Nutrients available in soil		0	0	0			
Remaining nutrients through fertigation		126	28	164			
Nutrients required in grams/plant		1121	249	1457			
		Ratio			Ratio Days		
Crop life	Days	N	P₂O₅	K₂O	N	P₂O₅	K₂O
February	28	3	2	1	84	56	28
March	31	1	1	1	31	31	31
April	30	2	1	4	60	30	120
May-July	92	1	1	1	92	92	92
August	31	3	2	5	93	62	155
September-November	91	1	1	1	91	91	91
December - January	62	0	0	0	0	0	0
Total	365	11	8	13	451	362	517
Nutrient (kg/Acre/Day=Total Quantity of Nutrient for fertigation (Kg/Acre)X Ratio Days of Nutrient in the Stage							
Sum of Ratio Days of the Nutrient		No. of Fertigation Days in the Stage					
Crop life	Days	Nutrients kg/acre/day		Nutrient kg/acre/season			
February	28	0.838	0.155	23.468	4.331	8.871	
March	31	0.279	0.077	8.661	2.398	9.822	
April	30	0.559	0.077	16.763	2.320	38.019	
May-July	92	0.279	0.077	25.703	7.116	29.148	
August	31	0.838	0.155	25.982	4.796	49.108	
September-November	91	0.279	0.077	25.424	7.039	28.831	
December - January	62	0.000	0.000	0.000	0.000	0.000	
Total	365	3.073	0.619	126.000	28.000	163.800	
		Fertilizer kg/acre/day		Fertilizer kg/acre/season			
Crop life	Days	Urea	MAP	Urea	MAP	SOP	
February	28	1.756	0.254	49.165	7.101	17.742	
March	31	0.574	0.127	17.802	3.931	19.643	
April	30	1.182	0.127	35.448	3.804	76.039	
May-July	92	0.574	0.127	52.833	11.666	58.296	
August	31	1.756	0.254	54.432	7.862	98.217	
September-November	91	0.574	0.127	52.258	11.539	57.663	
December - January	62	0.000	0.000	0.000	0.000	0.000	
Total	365	6.416	1.014	261.939	45.902	327.600	
		Fertilizer/Plant (Grams)		Fertilizer/Plant (Grams)			
				N	P₂O₅	K₂O	
				1121	249	1457	
Source:							
1. Pamphlet on Citrus Fruit by Dr. Altaf Ur Rehman published in 2011-12 by Directorate of Agriculture Information, 21-Sir Agha Khan Soyum Road, Lahore							
2. Diagnosing Potassium Deficiency and Maximizing Fruit Crop Productivity by K.N. Tiwari Published in Better Crops/Vol. 89 (2005, No. 4)							
Note: The sample fertigation schedule is a guideline and necessary change can be made on the basis of the prevailing soil and climatic conditions.							

Plant to Plant Spacing (m)	6	3rd Year	Nutrient Removal (Kg/ton) ¹		
Row to Row Spacing (m)	6		N	P ₂ O ₅	K ₂ O
Number of Plants / Acre	112		6.0	2.5	7.5
Target Yield (tons/ha) - 3 year old plant	15		Kg/acre		
Particulars	N	P ₂ O ₅	K ₂ O		
Nutrients required for target yield	36	15	46		
Percent saving in fertilizer through fertigation	30	30	30		
Nutrients required after fertilizer saving	25	11	32		
Nutrients available in soil	0	0	0		
Remaining nutrients through fertigation	25	11	32		
Nutrients required in grams/plant	227	94	283		
Crop life	Days	N	P ₂ O ₅	K ₂ O	Ratio Days
January - February	59	1	1	1	59
March-April	61	3	2	2	122
May-July	92	1	1	1	92
August-September	61	3	3	5	183
October-December	92	1	1	1	92
Total	365	9	8	10	670
How to Calculate Nutrient (Kg/Acre/Day)?					
Nutrient (kg/Acre/Day = Total Quantity of Nutrient for fertigation (Kg/Acre) X Ratio Days of Nutrient in the Stage					
Sum of Ratio Days of the Nutrient					
Crop life	Days	N	P ₂ O ₅	K ₂ O	Nutrient kg/acre/season
January - February	59	0.042	0.019	0.048	2.470
March-April	61	0.126	0.039	0.095	7.661
May-July	92	0.042	0.019	0.048	3.852
August-September	61	0.126	0.058	0.238	7.661
October-December	92	0.042	0.019	0.048	3.852
Total	365	0.377	0.155	0.476	25.496
Crop life	Days	Urea	MAP	SOP	Fertilizer kg/acre/season
January - February	59	0.083	0.032	0.095	4.881
March-April	61	0.256	0.064	0.190	15.644
May-July	92	0.083	0.032	0.095	7.610
August-September	61	0.248	0.095	0.476	15.138
October-December	92	0.083	0.032	0.095	7.610
Total	365	0.753	0.254	0.951	50.882
Fertilizer/Plant (Grams)					
					453
Nutrient/Plant (Grams)					
					227
					94
					283

		4th Year & Above			Nutrient Removal (Kg/ton) ¹		
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Plant to Plant Spacing (m)	6						
Row to Row Spacing (m)	6						
Number of Plants / Acre	112	6.0	2.5	7.5			
Target Yield (tons/ha) - 2 year old plant	25	Kg/acre					
Particulars		N	P ₂ O ₅	K ₂ O			
Nutrients required for target yield		61	25	76			
Percent saving in fertilizer through fertigation		30	30	30			
Nutrients required after fertilizer saving		42	18	53			
Nutrients available in soil		0	0	0			
Remaining nutrients through fertigation		42	18	53			
Nutrients required in grams/plant		379	158	474			
		Ratio					
		Ratio Days					
Crop life	Days	N	P₂O₅	K₂O	N	P₂O₅	K₂O
January - February	59	1	1	1	59	59	59
March-April	61	3	2	2	183	122	122
May-July	92	1	1	1	92	92	92
August-September	61	3	3	5	183	183	305
October-December	92	1	1	1	92	92	92
Total	365	9	8	10	609	548	670
How to Calculate Nutrient (Kg/Acre/Day)?							
Nutrient (kg/Acre/Day)= Total Quantity of Nutrient for fertigation (Kg/Acre) X Ratio Days of Nutrient in the Stage							
Sum of Ratio Days of the Nutrient		No. of Fertigation Days in the Stage					
		Nutrient kg/acre/season					
Crop life	Days	N	P₂O₅	K₂O	N	P₂O₅	K₂O
January - February	59	0.070	0.032	0.079	4.117	1.906	4.677
March-April	61	0.209	0.065	0.159	12.769	3.942	9.672
May-July	92	0.070	0.032	0.079	6.419	2.972	7.294
August-September	61	0.209	0.097	0.396	12.769	5.913	24.180
October-December	92	0.070	0.032	0.079	6.419	2.972	7.294
Total	365	0.628	0.258	0.793	42.493	17.705	53.116
		Fertilizer kg/acre/season					
Crop life	Days	Urea	MAP	SOP	Urea	MAP	SOP
January - February	59	0.138	0.053	0.159	8.134	3.125	9.355
March-April	61	0.427	0.106	0.317	26.073	6.462	19.344
May-July	92	0.138	0.053	0.159	12.684	4.873	14.587
August-September	61	0.414	0.159	0.793	25.230	9.693	48.359
October-December	92	0.138	0.053	0.159	12.684	4.873	14.587
Total	365	1.255	0.424	1.586	84.804	29.025	106.232
		Fertilizer/Plant (Grams)					
		Nutrient/Plant (Grams)					
Source:							
1. Pamphlet on Fertilizer Recommendation for Better Production of Guava by Soil Fertility Research Institute, Punjab Agriculture Department, Thokar Niaz Beg, Multan Road, Lahore							
2. Pamphlet on Guava by Fauji Fertilizer Company Ltd. Lahore Trade Centre, Shah Rahay Awan-i-Tajarat., Lahore							
3. Pamphlet on Production Technology of Guava by Fruit Research Station, Ayub Agriculture Research Institute, Jhang Road							
4. Diagnosing Potassium Deficiency and Maximizing Fruit Crop Productivity by K.N. Tiwari Published in Better Crops/Vol. 89 (2005, No. 4)							
Note: The sample fertigation schedule is a guideline and necessary change can be made on the basis of the prevailing soil and climatic conditions.							

		5th Year & Above					
Plant to Plant Spacing (m)	6	Nutrient Removal (Kg/ton) ³					
Row to Row Spacing (m)	6	N	P ₂ O ₅	K ₂ O			
Number of Plants / Acre	112	6.7	1.7	6.7			
Target Yield (tons/ha) - 4 and above years old plant	20	Kg/acre					
Particulars							
Nutrients required for target yield		N	P ₂ O ₅	K ₂ O			
Percent saving in fertilizer through fertigation		54	14	54			
Nutrients required after fertilizer saving		30	30	30			
Nutrients available in soil		38	10	38			
Remaining nutrients through fertigation		0	0	0			
Nutrients required in grams/plant		38	10	38			
		338	86	338			
Ratio							
Crop life	Days	N	P₂O₅	K₂O	N	P₂O₅	K₂O
June-August	92	3	3	2	276	276	184
September	30	5	2	4	150	60	120
October-January	123	1	1	1	123	123	123
February-May	120	3	2	3	360	240	360
Total	365	12	8	10	909	699	787
How to Calculate Nutrient (Kg/Acre/Day)?							
Nutrient (kg/Acre/Day = Total Quantity of Nutrient for fertigation (Kg/Acre) X Ratio Days of Nutrient in the Stage							
Sum of Ratio Days of the Nutrient							
No. of Fertigation Days in the Stage							
Nutrient kg/acre/season							
Crop life	Days	N	P₂O₅	K₂O	N	P₂O₅	K₂O
June-August	92	0.125	0.041	0.096	11.526	3.803	8.875
September	30	0.209	0.028	0.193	6.264	0.827	5.788
October-January	123	0.042	0.014	0.048	5.137	1.695	5.933
February-May	120	0.125	0.028	0.145	15.034	3.307	17.364
Total	365	0.501	0.110	0.482	37.960	9.632	37.960
Fertilizer kg/acre/day							
Crop life	Days	Urea	MAP	SOP	Urea	MAP	SOP
June-August	92	0.255	0.068	0.193	23.430	6.235	17.750
September	30	0.442	0.045	0.386	13.264	1.355	11.576
October-January	123	0.085	0.023	0.096	10.442	2.778	11.866
February-May	120	0.261	0.045	0.289	31.268	5.421	34.729
Total	365	1.042	0.181	0.965	78.403	15.790	75.921
Fertilizer/Plant (Grams)							
Nutrient/Plant (Grams)							
		697	140	675	338	86	338
Source:							

1. Pamphlet on Cultivatio of Mango under Drip Irrigation by Directorate General Agriculture (Water Management) Punjab, 21 Agha Khan (Davis) Road, Lahore

2. Diagnosing Potassium Deficiency and Maximizing Fruit Crop Productivity By K.N. Tiwari published in Better Crops/Vol. 89 (2005, No. 4)

FERTIGATION SCHEDULE FOR YOUNG NON BEARING GRAPES - SECOND YEAR									
Plant Spacing (Ft)	8								
Row Spacing (Ft)	10								
Number of Plants / Acre	545								
Recommended Dose		Grams/Plant							
		N	P₂O₅	K₂O					
Total Nutrients to be Applied		70	140	160					
Percent saving in fertilizer through fertigation		30	30	30					
Nutrients required after fertilizer saving		49	98	112					
Nutrients Available from Soil		0	0	0					
Nutrients to be Applied through Fertigation		49	98	112					
Nutrients to be Applied through Fertigation (Kg/Acre)		27	53	61					
		Ratio			Ratio Days				
		N	P₂O₅	K₂O	N	P₂O₅	K₂O		
Crop life	Days	N	P₂O₅	K₂O	N	P₂O₅	K₂O		
February - April (Vegetative Growth)	89	3	2	2	267	178	178		
May-July (Vegetative Growth)	92	2	1	1	184	92	92		
August-October (Vegetative Growth)	92	2	2	3	184	184	276		
November-January (Vegetative Growth - Dormant)	92	0	0	0	0	0	0		
Total	365	7	5	6	635	454	546		
How to Calculate Nutrient (Kg/Acre/Day)?									
Nutrient (kg/Acre/Day= Total Quantity of Nutrient for fertigation (Kg/Acre) X Ratio Days of Nutrient in the Stage									
		Sum of Ratio Days of the Nutrient			No. of Fertigation Days in the Stage				
		Nutrients / Acre / Day (kg)			Nutrients / Acre / Season (kg)				
Crop life	Days	N	P₂O₅	K₂O	N	P₂O₅	K₂O		
February - April (Vegetative Growth)	89	0.126	0.235	0.223	11.218	20.921	19.881		
May-July (Vegetative Growth)	92	0.084	0.118	0.112	7.731	10.813	10.276		
August-October (Vegetative Growth)	92	0.084	0.235	0.335	7.731	21.626	30.827		
November-January (Vegetative Growth - Dormant)	92	0.000	0.000	0.000	0.000	0.000	0.000		
Total	365	0.294	0.588	0.670	26.681	53.361	60.984		
		Fertilizer / Acre / Day (kg)			Fertilizer / Acre / Season (kg)				
Crop life	Days	Urea	MAP	SOP	Urea	MAP	SOP		
February - April (Vegetative Growth)	89	0.173	0.385	0.447	15.441	34.297	39.762		
May-July (Vegetative Growth)	92	0.132	0.193	0.223	12.182	17.727	20.551		
August-October (Vegetative Growth)	92	0.082	0.385	0.670	7.558	35.453	61.654		
November-January (Vegetative Growth - Dormant)	92	0.000	0.000	0.000	0.000	0.000	0.000		
Total	365	0.388	0.963	1.340	35.181	87.477	121.968		
		Fertilizer/Plant (Grams)			Fertilizer / Acre / Season (kg)				
		Nutrient/Plant (Grams)			Nutrient / Acre / Season (kg)				
		65			161				
		49			98				

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LASER Land Leveling



Watercourse Improvement



Sprinkler Irrigation



Drip Irrigation



Storage Pond



Solar Coupled HEIS



Training/Human Resource Development



Soil Moisture Meter

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