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FERTIGATION SCHEDULING FOR HORTICULTURAL CROPS

Centre for Protected Cultivation Technology
Indian Agricultural Research Institute
New Delhi- 110012

ICAR

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Indian Farmers Fertiliser Cooperative Limited
IFFCO SADAN, C-1, District Centre, Saket Place, Saket,
New Delhi-110017

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M. Hasan[1], Balraj Singh[1], M. C. Singh[1], A. K. Singh[1],
S. V. Kaore[2], Tarunendu[2], Naved Sabir[3]
and B. S. Tomar[4]

[1] Centre for Protected Cultivation Technology, IARI
[2] Indian Farmers Fertiliser Cooperative Limited
[3] National Centre for Integrated Pest Management, ICAR
[4] Division of Seed Science, IARI

भाकृअनुप
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भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली-110012 (भारत)
INDIAN AGRICULTURAL RESEARCH INSTITUTE
(A UNIVERSITY UNDER SECTION 3 OF UGC ACT, 1956)
NEW DELHI-110012 (INDIA)

हरि शंकर गुप्त, पीएच.डी (आई आई टी), एफ.एन.ए.ए.एस
निदेशक

H.S. Gupta, Ph.D. (IIT KGP), FNAAS
Director

Phones : (Off.) 011-2573 3367, 2584 3375
(Res.) 011-2584 6774, 2573 3973
Fax : +91-11-2584 6420
E-mail (off.): director@iari.res.in
personal : hsgupta@lycos.com

FOREWORD

Water is one of the most important and critical inputs for agricultural production system. The demand for food grains, vegetables, fruits and flowers is increasing day by day because of the increasing population. The total geographical area of our country is 2.3% of the world area, which supports 17% of the total world population. The total fresh water resource of the country is only 4% of the world's fresh water resources and agriculture consumes about 80% of the total water resources of the country. Irrigated agriculture provides a crop water productivity of about 2.5 t/ha with an overall irrigation efficiency of about 30% compared to the world's average crop water productivity of 4 t/ha. In this scenario, it is imperative to improve the country's crop water productivity as well as irrigation efficiency. The food habits of the people are changing throughout the world with greater demands for quality fruits and vegetables as dietary supplements. This calls for more viable and efficient technological options such as drip irrigation and fertigation. They provide several advantages in the context of crop agronomy as well as water and energy conservation. Drip irrigation and fertigation have potential to achieve the desired level of 4 t/ha of crop water productivity and simultaneously maintain an irrigation efficiency of more than 80%. It would help in producing high value nutritional crops in open fields and under protected conditions. The total coverage of micro-irrigation in the Xth Plan was only about 2.0 million hectare. The task force on micro-irrigation (2004) has indicated a potential of 69 million hectare for our country. Hence, there is a tremendous potential to increase the coverage of drip irrigation to cover more crops across new areas.

Indian Farmers Fertiliser Cooperative Limited (IFFCO) has indigenously developed a 100-per cent water soluble fertilizer, urea phosphate (17:44:0) and other water soluble fertilisers, which are useful for drip fertigation. This publication summarises the work done at CPCT, IARI, New Delhi related to drip fertigation scheduling for different horticultural crops and provides valuable information to the farmers in a user-friendly form. I compliment the CPCT team of IARI, and IFFCO for their efforts in bringing out this publication, which will be extremely useful for the farmers, professionals, academicians, policy makers and scientists working in the area of water management and drip fertigation of horticultural crops.

(H.S. GUPTA)

New Delhi
August 31, 2010

इंडियन फारमर्स फर्टिलाइजर कोआपरेटिव लिमिटेड
इफको सदन, सी-1, डिस्ट्रिक्ट सेन्टर, साकेत प्लेस, नई दिल्ली-110017

INDIAN FARMERS FERTILISER COOPERATIVE LIMITED
IFFCO Sadan, C-1, Distt. Centre, Saket Place, New Delhi-110017

अरविंद राय
विपणन निदेशक

ARABINDA ROY
Marketing Director

PREFACE

Ensuring food security to over 1.2 billion people from available resources on a sustainable basis is a gigantic task. Increased urbanisation has put pressure on land for agriculture. With the growth of urban middle class, dietary habits of people are changing. This is particularly predominant in case of fruits and vegetables, where their preference for the quality of produce throughout the year is distinct. As a result, the demand for fruits and vegetables is increasing. These crops are cultivated mostly under conventional irrigation system, where water requirement is very high. Availability of water for use in agriculture is becoming scarce, which in turn affects crop productivity. Supply of balanced and integrated use of inputs in fruits and vegetables is a prerequisite for their quality produce. Fertigation is the answer to increase the productivity of horticultural crops through increase in water and fertiliser use efficiency with minimum impact on environment. Indian Farmers Fertiliser Cooperative Limited have indigenously developed 100% water soluble fertiliser urea phosphate (17:44:0) and in the process of developing other products which would be suitable for drip irrigation. The information on fertigation scheduling in horticultural crops is highly important for the farmers for increasing the yield.

I am happy that Indian Agricultural Research Institute, New Delhi and Indian Farmers Fertiliser Cooperative Limited, New Delhi has appropriately thought to address the issue of fertigation scheduling for horticultural crops in the form of this booklet for the benefit of farmers. The contents of the publication are very much relevant in today's context. I compliment the scientists of Centre for Protected Cultivation Technology, IARI, New Delhi who have painstakingly developed the fertigation scheduling for horticultural crops. The publication, I am sure, will be useful to the farmers and those who are associated with fertigation technology for different crops in the country.

New Delhi
September 3, 2010

(A. Roy)
Marketing Director

• फोन कार्यालय : 011-42592602
011-26542802
• तार : इफको नई दिल्ली
• फैक्स : 011-40593002
• ई-मेल : aroy@iffco.nic.in
• वेबसाइट : www.iffco.nic.in

• Phone Off. : 011-42592602
011-26542802
• Gram : IFFCO New Delhi
• Fax : 011-40593002
• e-mail : aroy@iffco.nic.in
• Website : www.iffco.nic.in

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Management of water and nutrients is critical for crop productivity enhancement, particularly in horticultural crops. Over a period of time scientists have developed fertigation technology which increases water and nutrient use efficiency in these crops. Understanding of fertigation scheduling for horticultural crops during crop growth stages is important from the point of view of application of water and nutrients as it has direct impact on yield and quality of produce.

Since last over one decade, Centre for Protected Cultivation Technology (CPCT), IARI, New Delhi has conducted number of experiments on fertigation scheduling for horticultural crops both under open field and protected condition. The results are encouraging. There is a need to disseminate and also create awareness about fertigation scheduling for high value crops at farmers level. Indian Farmers Fertiliser Cooperative Limited is working for the benefit of farmers and cooperatives through various promotional programmes, besides production and marketing of fertilisers in the country.

The guidance and encouragement received from Dr. H.S. Gupta, Director, IARI, New Delhi and Mr. A. Roy, Marketing Director, IFFCO, New Delhi in bringing out joint publication on "Fertigation Scheduling for Horticultural Crops" is gratefully acknowledged. The assistance received from NAIP for conducting research work related to fertigation scheduling for horticultural crops under the project "Protected Cultivation of High Value Vegetables and Cut Flowers - A Value Chain Approach" through CPCT is acknowledged. Since last one decade, scientists at CPCT, IARI, New Delhi have been working on the aspect of fertigation for horticultural crops, their painstaking effort in investigation of various aspects of fertigation is sincerely acknowledged.

The publication provides information on fertigation scheduling for horticultural crops for the benefit of farmers and those who are associated with fertigation technology. Their comments / suggestions will help in crystallising views in application of fertigation technology in high value crops.

New Delhi **Authors**
September 7, 2010

FERTIGATION SCHEDULING FOR HORTICULTURAL CROPS

Introduction

Water is an essential natural resource for sustaining life and environment. It is imperative that it is utilised with maximum possible efficiency. Agriculture sector is the major user of water resources and the demand is increasing to produce more per unit area and time. The decades of sixties and seventies saw the accelerated development of agriculture in India through the intensive use of high yielding varieties, fertilisers, water, and mechanization. The input-based agriculture led to manifold increase in foodgrains production during the last four decades. But the technology based on predominant use of water and fertilisers resulted in a paradoxical situation in which soils in the parts of northern plains turned saline, whereas in some other parts including South India, the water table lowered due to excessive pumping. This situation affected agricultural productivity to a point of stagnation. In the eighties, general awareness and consensus emerged on the efficiency and judicious use of water. It was then that the drip irrigation gained momentum and also popularity with its inherent advantages, like, water saving and use in problem soils. Various research institutes conducted experiments on drip system and extended the technology to the farmers. The government also provided support through subsidies on installation of drip irrigation systems in various crops with thrust on horticultural crops. By the end of 2006, about 2 million hectare of area was brought under micro irrigation in India. The task force has estimated the potential of micro irrigation as 69 million hectare, which should be achieved by the Year 2025. It signifies the importance of drip fertigation for our country. The major states having maximum coverage area of drip fertigation are Maharashtra, Gujarat, Rajasthan, Karnataka, Andhra Pradesh and Tamil Nadu, whereas it is expanding very rapidly in some states like Madhya Pradesh, Chhattisgarh and Jharkhand.

Drip fertigation is taken up under two conditions i.e. open field where fruits, vegetables, cotton and sugarcane are mostly grown and other is protected cultivation where vegetables and flowers are grown under protected structures like greenhouse, net house, shade net and nursery. Of late farmers are also growing crops like sunflower, groundnut, and maize in a limited way under drip fertigation. Protected cultivation technology provides the option for round the year production by combating biotic and abiotic stress. The crop water requirement under protected cultivation is less than in open field condition and there is precise requirement of nutrients and micro nutrients. Drip irrigation and fertigation under protected cultivation provides efficient use of water and nutrient and increases the yield and improve quality of the produce. Fertigation scheduling refers to timely application of water and nutrients as per crop stages through drip fertigation. It is the most important aspects of drip fertigation to know exactly the quantity of water and fertilisers to be applied through drip fertigation on daily and monthly basis for different horticultural crops. This information needs to be made available to the farmers in user friendly form. Very complex mathematical formulae and models are available to calculate the fertigation scheduling for different horticultural crops. Therefore, an attempt has been made to compile all the data related to the fertigation scheduling works done during the last ten years for various horticultural crops grown in open field and protected cultivation at Centre for Protected Cultivation Technology (CPCT), IARI New Delhi. Indian Farmers Fertiliser Cooperative Limited (IFFCO) has indigenously developed 100% water soluble fertiliser urea phosphate (17:44:0) which is suitable for drip fertigation for different horticultural crops. An attempt has been made to prepare crop wise monthly fertigation scheduling in a very user friendly way for different horticultural crops.

Drip Irrigation System

Drip irrigation is the best available technology for the efficient use of water for growing horticultural crops in large scale on sustainable basis. Drip irrigation is a low labour intensive and highly efficient system of irrigation, which is also amenable to use in difficult situations and problematic soils, even with poor quality water. Irrigation water savings ranging from 36-79% can be affected by adopting a suitable drip irrigation system. Drip irrigation or low volume irrigation is designed to supply filtered water directly to the root zone of the plant so as to maintain the soil moisture near to field capacity level for most of the time, which is found to be ideal for efficient growing of horticultural crops. This is due to the fact that at this level the plant gets ideal mixture of water and air for its development. The device that delivers the water to the plant is called dripper. Water is frequently applied to the soil through emitter placed along a water delivery lateral line placed near the plant row. The principle of drip irrigation is to irrigate the root zone of the plant rather than the soil and getting minimal wetted soil surface. This is the reason for getting very high water application efficiency (90-95%) through drip irrigation. The area between the crop row is not irrigated therefore more area of land can be irrigated with the same amount of water. Thus, water saving and production per unit of water is very high in drip irrigation.

Drip Irrigation System Network

The layout of drip irrigation system network is shown in Fig 1. It consists of 4 units as described below.

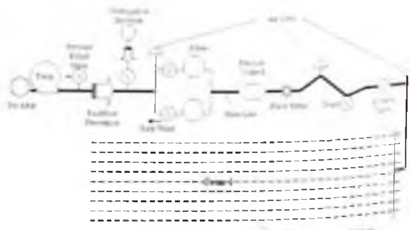


Fig.1: Layout of Drip Irrigation System

a) **Pumping unit** : It takes water from the source and supplies pressurized water to the control head. Pumps used in the drip irrigation system are similar to those used in other irrigation method and include centrifugal, submersible and turbine pumps. These pumps can be driven either by an electric motor or an internal combustion engine. An efficiently designed irrigation system has a pumping capacity closely matched to the system demand.

b) **Control head** : It serves as the irrigation system policeman, regulating flow pressure and filtration. It is also the place for chemical injection. Manifold, water meter and pressure gauge is must for control head. It includes the different types of valves, filters and hydraulic regulating components. Filtration is the single most critical area in irrigation system. It includes the primary and secondary filtration. Several different types of filter can be used to capture and remove contaminants from the irrigation water.

- – Gravity filter
- – Wire screens
- – Sand separator
- – Screen filter
- – Gravel filter

c) **Pipe network** : Water is delivered from the control head and filter to the lateral lines in the field through the main and sub main pipelines. Main line is mostly of PVC material. Sub main can be of either PVC or polythene. Rigid PVC and polyethylene are typical material used because of their low cost and chemical resistant qualities. In the pressurized irrigation system network most of the main and sub main pipes are buried under the ground and are controlled by various types of control valves. Main and sub-main pipe lines are usually rigid PVC and HDPE pipes with pressure rating of about 10 and 6 kg/cm^2, respectively. Lateral pipes are of HDPE or LDPE ranging from 10 mm to 20 mm diameters, which are spread over the field in a specified layout. Designed to carry water at about 2-3 kg/cm^2, these pipes are provided with point-source emitters or drippers spaced along it. The lateral lines supply water to the emitter or dripper from sub main. Usually this is placed on the ground. It is made of polyethylene pipes. The diameter varies from 12-25 mm. The pressure in the lateral line varies from 2-3 kg/cm^2 depending upon the lateral length and dripper characteristics.

d) **Dripper** : This is a device designed to dissipate the hydraulic pressure and to discharge a small uniform flow of water, drop by drop, at the given place. The dripper capacity varies from 2-10 liter per hour. Its working pressure is about one bar. Some of the common types of dripper used are.

- – In-line dripper
- – On-line dripper
- – Pressure compensating dripper
- – Button type dripper

Important accessories related to drip irrigation system network :

a) **Hydraulic connections** : It is used to connect different types of pipes as per the configurations required in the field like tee joint, elbow, bend, connector etc.

b) **Fertiliser applicators** : These are used to inject fertiliser, systemic insecticides/algaecides, acids and other liquid materials into the water being supplied through drip system. They are of 3 types, namely, fertiliser tank, venturi injector and fertiliser injector (Fig. 2).

i) **Fertiliser tank** : A metallic tank is provided at the head of the drip irrigation system for applying fertilisers in solution along with the irrigation water. The tank is connected to the main irrigation line by means of a bypass line. Some of the irrigation water is diverted from main irrigation line in to the tank. This bypass flow is created by the pressure difference between the entry and exit points of the tank. This application method is simple in construction and operation with low requirement of electricity. However, the application of fertiliser during the fertigation schedule is not constant. Therefore, it does not permit a precise control over the fertiliser concentration.

ii) **Venturi injector** : It consists of a built-in converging section, throat and diverging section. A suction effect is created at the converging section due to high velocity, which allows the entry of the liquid fertiliser in to the system. This system is simple in operation and a fairly uniform fertiliser concentration can be maintained in the irrigation water.

iii) **Fertiliser injector** : This is operated either with electricity or with water. It draws fertiliser solution from a tank and pumps it under pressure in to the irrigation system. It provides a precision control on the fertiliser application. However, it is expensive and needs skilled operation.

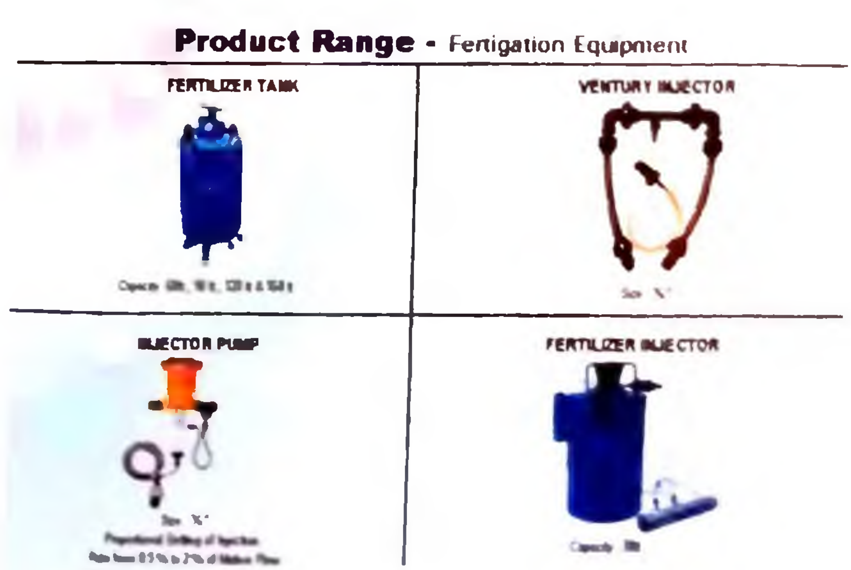


Fig. 2: A Range of Fertiliser Applicators through Fertigation

c) **Pressure/flow regulators** : These are control valves that are actuated either manually or electro-hydraulically to regulate flow and pressure in the drip system.

d) **Controllers** : These automatic – mostly micro-processor based – devices are used to provide stop/start signals to pump and valves/regulators. The actuating signal may either be time or volume based. In more advanced technological modes, these gadgets are controlled by soil moisture sensors placed in the plant root zone.

Different components of automation of drip irrigation system are illustrated in Fig. 3.

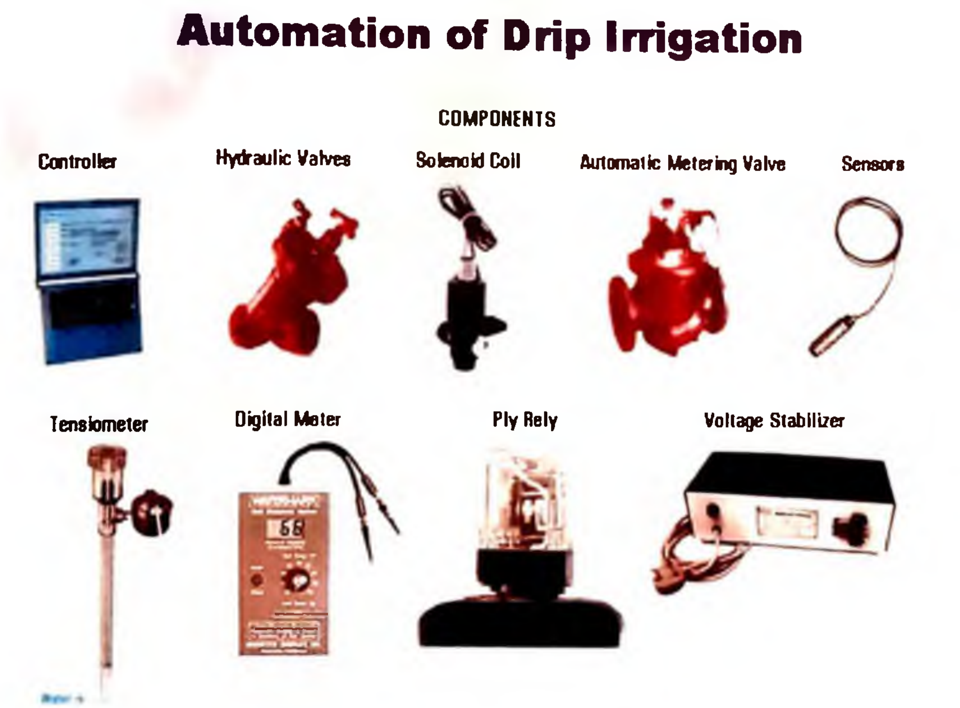


Fig. 3: Different Components of Automation of Drip Irrigation System

The following guidelines help in the planning and design of drip irrigation system.

- Work out the number of connectors needed when planning the drip irrigation system
- Plants in sunny areas usually require more water due to higher evaporation rates. Plants in shaded areas will require less water due to lower evaporation rates
- Soil types affects the water requirements for different areas of farm. For example, gardens with heavy clay soil may need more water pressure

- Select drip emitters according to the plants' water requirements
- Consider the places where there is need of joints and connectors
- Rain switches and soil moisture sensors are highly recommended especially in areas with high rainfall
- Lay the piping above ground before digging. A 10 cm deep trench should be adequate, although sandy soil may require a slightly deeper trench to hold the piping in place
- To make it easier to connect joints, heat the end of piping to soften to make it more flexible
- Make sure drip emitters are installed above ground so that they do not become clogged by dirt

Types of Irrigation Systems

A distinction is made between the two principal micro-irrigation methods, namely, the sprayer or micro-sprinkler, and the drip irrigation system. Sprayers and micro-sprinklers spray the water through the atmosphere and are designed principally to wet a specific volume of soil around individual trees in an orchard. Drip irrigation, on the other hand, represents a point source of water, and wets a specific volume of soil by direct application of water to the root zone of the plant. The type of drip emitter from the point of view of its discharge and the distribution of the emitters throughout the plot (distances along the drip lateral and between the drip laterals) is dependent on the soil texture and the crop. The drip system is suitable for irrigation of row crops and orchards.

Broadly, the drip irrigation system is of two types; Low Pressure Drip Irrigation System and Pressurised Drip Irrigation System.

Low Pressure Drip Irrigation System : It requires comparatively less pressure than normal pressurised drip irrigation system (Fig.4). It is suitable for small land holdings, green houses, nursery and hilly areas. This system does not require regular supply of electrical energy and the hydraulic head of about 2m is sufficient for irrigating an area of 500 m^2. This system has very high irrigation efficiency (>90%) and is easy to install, operate and maintain. Low Pressure Drip Irrigation System consists of following components:

i) 500 litre water tank
ii) 32 mm diameter LDPE main pipe line of about 30 m

iii) One inch 120 mesh/130 micron disc / screen filter
iv) Tank connectors
V) 500 m length lateral pipe of 12 mm diameter fitted with in-line dripper of 1.0 Lph discharge capacity

Fertigation becomes very easy in Low Pressure Drip Irrigation System as no additional pump or any other device is required in this system. The same tank can be used for mixing of water and water soluble fertilisers.

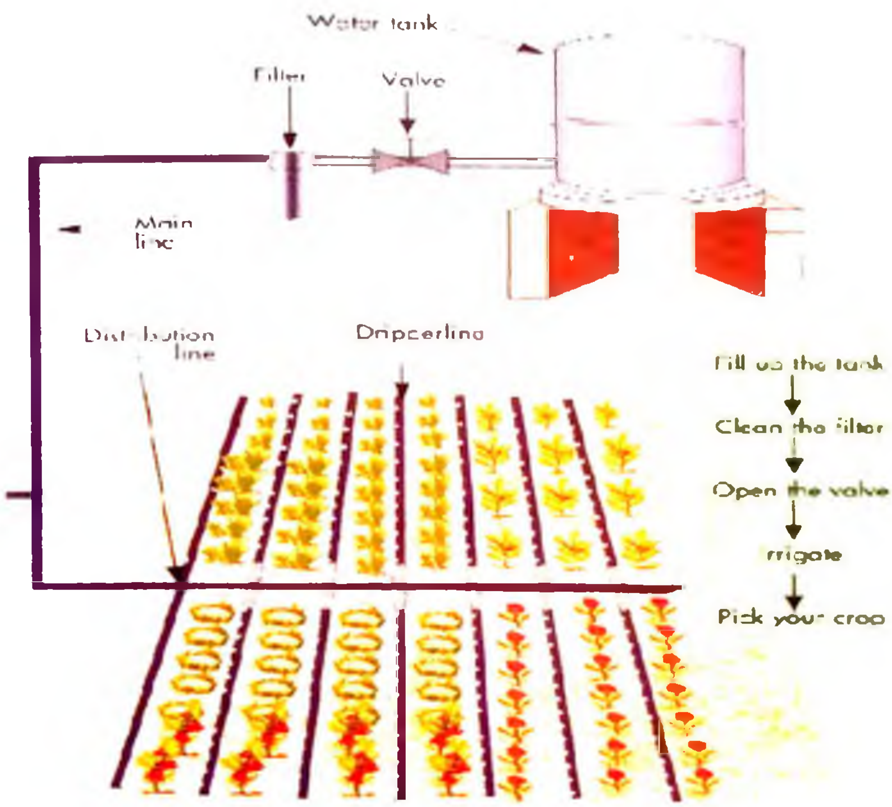


Fig. 4: Low Pressure Drip Irrigation System

Pressurised Drip Irrigation System : It requires pressure and energy for its working. Mostly, this energy is in the form of electrical energy to operate pumps and generate pressure for working of the Pressurised Drip Irrigation System. This system is commonly used in orchards, open fields, big green houses for different horticultural crops.

Reservoir and Pumping station

Primary Filtration Station and Water Supply System

Irrigation Control Unit for Open Field Cultivation

Calculation of Crop Water Requirement (CWR)

Water is the most critical input under drip irrigation system. Knowledge about calculation of water requirement during crop growth period will help to increase water use efficiency both under open field and protected condition. Important terminology related to drip irrigation system is as under :

Pan evaporation : It is evaporation of water from open surface and is recorded at meteorological station on daily basis and expressed in mm/day. Under protected cultivation open field pan evaporation is multiplied by a conversion factor of 0.45 to know the actual evaporation inside protected structures.

Pan factor : It is the factor (0.8) taken to compensate the actual measurement of pan evaporimeter.

Evapotranspiration : It is water loss through transpiration from plants canopy and evaporation from soil surface and expressed in mm/day.

Crop factor : It is a ratio between actual and potential evapotranspiration. It varies as per crop growth stages.

Crop water requirement for open field and protected cultivation can be calculated by using the following formula. Here ET is in mm/day

Crop water requirement (m^3/day/ha) = ET * 10 * 0.5 for open field cultivation

Crop water requirement (m^3/day/1000 m^2) = ET * 1 * 0.5 for protected cultivation

Where, ET (mm/day) = Pan evaporation * Kc (where Kc = crop coefficient)

AVSM (Available soil moisture) or MAD (Management allowable deficit) = 50 % = 0.5

Maintenance of Drip Irrigation and Fertigation

The usual life of drip irrigation system is said to be of 7-10 years. It can be achieved only by regular maintenance of different components of drip irrigation system. The drip irrigation system can become non operational or ineffective if its components are not maintained regularly. Most of the maintenance jobs can be done very easily without any extra expenditure. Maintenance of some of the key components of drip irrigation system is described below :

Filtration : Filters should be checked and flushed on a regular basis. Disc filters and screen filters are secondary filters commonly used in drip irrigation system. Gravel filter is the primary filter used at the pumping head. 120-150 mesh filters should be used in drip irrigation system.

Drippers : Drippers really do not need any kind of regular maintenance. There are models which come apart and can be cleaned. The life of drippers varies from 6-8 years.

Controllers : Controllers need protection from direct rains and uninterrupted regular power supply. Some arrangements should be there to regulate the supply.

Valves : Valves can be affected by debris in the water which could collect over a period of time. This can be fixed by disassembling the valve and cleaning it. There are some very small parts and all of them are needed to make the valve work correctly.

Flow of water : Place a water flow meter between the solenoid valve at each zone and record its discharge daily. This provides a clear indication of how much water is applied to each zone. Records of water flow can be used to detect deviations from the standard flow of the system, which may be caused by leaks or by clogged lines. The actual amount of water applied recorded on the meter can be compared with the estimated crop water use (crop evapotranspiration) to help assure efficient water management.

Standard Maintenance

- Add chlorine or other chemicals to the drip line periodically to kill bacteria and algae. Acid might also be needed to dissolve calcium carbonates
- Filters must be managed and changed as needed. Even with filtration, however, drip tape must be flushed regularly. The frequency of flushing depends on the amount and kinds of sedimentation in the tape
- Other management factors: Root intrusion needs to be controlled for some crops. Rodents must be controlled, especially where drip tape is buried

Safety Devices

- An interlock to stop the fertiliser pump
- A check valve to prevent back flow of the fertiliser from the fertiliser tank to the irrigation line following shut down
- Flow sensor to assure system shut down in case of flow ceases in injection line
- A bleed valve to relieve the pressure in the injection line when disconnecting
- A strainer to prevent foreign materials

Quality Control of Drip Fertigation

All the components used under drip fertigation should be BIS certified so that it should work smoothly throughout its life. List of BIS Standards for different components of drip fertigation are as follows :

1. Polyethylene pipes for Irrigation – Laterals (IS 12786: 1989)
2. Emitters (IS 13487: 1992)
3. Emitting pipes system (IS 12785: 1994)
4. Strainer type filters (IS 12785: 1994)
5. Irrigation equipment rotating sprinkler Part II, Test method for uniformity of distribution (1st revision) (amendment 1) (IS 12232 (Part II) – 1995.
6. Irrigation equipment rotating sprinkler Part I, Design and Operational requirements (1st revision) (S 12232 (Part-I) – 1996.
7. Polyethylene micro tubes for drip irrigation system (IS 14482: 1997)
8. Fertiliser and Chemicals Injection system Part I Venturi Injector (IS 14483 (Part I) 1997

9. Micro sprayers (IS 14605 : 1998)
10. Media filters (IS 14606: 1998)
11. Hydro cyclone separators (IS 14743: 1999)
12. PVC pipes for water supply (IS 4985 – 1999)
13. Irrigation equipment sprinkler pipes specifications Part I Polyethylene pipes (IS 14151: 1999)
14. Irrigation equipment sprinkler pipes specifications Part II Quick couples Polyethylene pipes {IS 14151 (Part II) 1999}

Fertigation for Open Field and Protected Cultivation Technology

Fertigation is the process in which fertilisers can be applied through the system with the irrigation water directly to the region where most of the plant roots develop. It is done with the aid of special fertiliser apparatus (injectors) installed at the head control unit of the system, before the filter. The element most commonly applied is nitrogen. However, application of phosphorous, potassium and other micro-nutrients are common for different horticultural crops. Fertigation is a necessity in drip irrigation. The main objectives of fertigation are :

- Uniform and timely application of fertilisers
- Water and nutrient saving
- Optimising yield
- Quality improvement
- Minimising pollution

The rational for fertigation are as under :

- Irrigation and fertilisers are the most important management factors through which farmers control plant development and yield
- Water and fertilisers have important synergism which is very well used in fertigation
- Timely application of water and fertilisers can be controlled through fertigation

Principles of Fertigation

It is to feed the plant in appropriate time, quantity and location. These can be controlled through fertigation. The plant yield and the quality depend on all these three factors.

Advantages of Fertigation

- Amount and concentration of nutrient can be adjusted according to the stage of development and climatic considerations
- Deeper penetration of nutrients into the soil
- Avoiding ammonia volatilizing from soil surface
- Application restricted to the wetted area where the active roots are concentrated
- Reduced time fluctuation in nutrient concentrations
- Crop foliage is kept dry, thus retarding the development of plant pathogens and avoiding leaf burn
- Allows fertilisation in the rainy season when the soil is in wet

condition without stepping on it and destroying the structure
- Convenient use of fertilisers
- Remote control operation
- Convenience in saving manpower
- Low losses in transportation and storage
- The system may be used for additional applications

Factors Controlling Nutrient Uptake under Fertigation
- Water and nutrient distribution in soil under drip fertigation
- Quantity considerations
- Intensity considerations (concentration)
- Uptake fluxes: nutrient concentration at root surface

Factors Affecting Fertilisers Composition
- Plant characteristics
- Soil characteristics
- Irrigation water quality
- Growing place

Chemicals and Biological Considerations in Selecting Fertilizers for Fertigation
- Fertilizers solubility and compatibility
- Solution pH and NH_4/NO_3 ratio
- Nutrients mobility and chemistry in soils
- Salinity of the irrigation water

Requirement for Fertilisers Used in Fertigation
- 100% water soluble
- Quick dissolution
- High nutrient content
- Lack of toxic materials
- Low price
- Easy availability

Fertigation Solution EC and pH
EC (Electrical Conductivity) and pH are the two important indices of fertigation. They represent the whole quality and characteristics of fertilisers and water. It varies for different plants and soils. Some important facts related to pH are as under :
- Alkaline pH may cause precipitation of Ca and Mg carbonates and phosphates
- High soil pH reduces Zn, P and Fe availability to plants
- Ammonia raises the solution pH and urea increases soil pH upon hydrolysis
- Acids (nitric, phosphoric) may be used to reduce the irrigation solution pH

Methods of Application of Fertilisers

- Fertiliser tank (available in 60, 90 , 120 litre etc)
- Venturi device(head loss/ vacuum operated)
- Dosatron (costly and most effective)
- Fertiliser pumps or injectors(hydraulic type)

Basic Mixing Rules for Fertigation

- The mixing container with 50 to 75% of the required water should be used in the mixture if mixing dry soluble fertilisers
- Always put acid into water rather than water into acid
- When chlorinating water with chlorine always add chlorine to water, and not vice versa
- Never mix an acid or acidified fertiliser with chlorine
- Always check the solubility and compatibility of different fertilisers to be used in fertigation
- Do not mix phosphorus containing fertiliser with another fertiliser containing calcium
- Do not mix concentrated fertiliser solution directly with another concentrated fertiliser solution
- Always add the liquid fertiliser material to the water in the mixing container, before adding dry soluble fertilisers

Practices of Fertigation

To capitalize on fertigation benefits, particular care should be taken in fertiliser preparation, dosification, fertiliser injection methods as well in the management and maintenance system.

Fertiliser Preparation

The application of fertilisers is executed by various methods.

- **Stock solution preparation** : Mix solid fertilisers as ammonium sulphate, potassium chloride, nitrate and phosphoric acid to prepare a tailor made stock solution. The stock solution is then injected into the irrigation system @ 2-10 L/m^3

- **Compound solid fertiliser mixtures** : Manufactured for use in fertigation, with ratios between the three major elements. Some compositions contain microelement in the form of chelates

- **Compound liquid fertiliser solutions** : The total nutrient concentration is 5-3-8, 6-6-6, 9-2-8 specified for use in the greenhouses. Some compositions contain microelement in the form of chelates

Generally two fertiliser tanks that contain the concentrated fertiliser solutions are used to separate those fertilisers that can interact. A possible combination is; tank "A" containing calcium nitrate, potassium nitrate, magnesium nitrate and microelements, whereas tank "B" contains ammonium sulphate, phosphoric acid. nitric acid; in this way P and Ca/Mg are in different tanks to avoid their precipitation. A third tank "C" contains an acid solution to control the pH of the fertiliser solution and to wash the irrigation system to avoid clogging of drippers.

Dosification

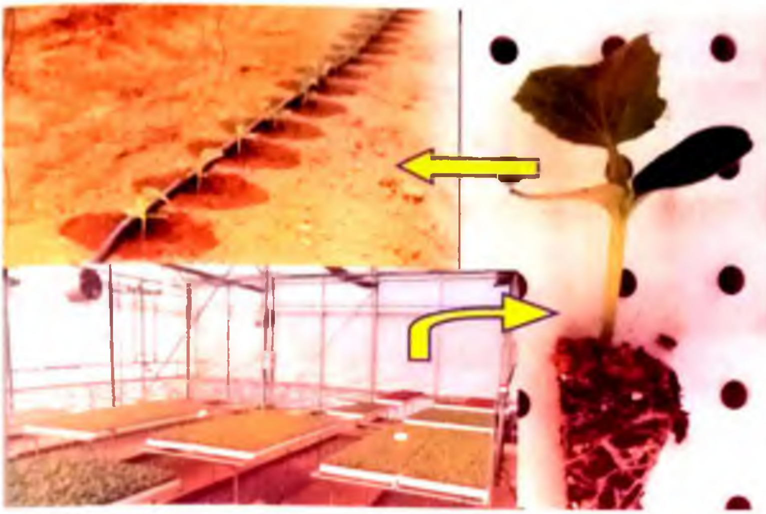
The two types of dosification depend on type of crops grown, soil type and farm management system.

Quantitative : It is the application of the plant nutrients in predetermined concentration to the irrigation system. The fertiliser is applied in a pulse after certain water goes without fertiliser using a fertiliser tank. The advantages of this method are low cost and low maintenance. The disadvantages are effect of water pressure change, concentration of fertiliser varies during its application and it does not work with automation.

Proportional : The nutrients are applied in a constant and proportional ratio to water sheet, so that the irrigation water takes a fixed concentration of the applied fertiliser. In this case the fertilisers are applied by direct injection through fertiliser pumps. The advantages are precise control of the dosification and the injection moment, no effect of water pressure change, easy automation. The disadvantages are high cost and high maintenance and complicate operation.

Fertigation Management in Plug-tray Nursery Raising Technology for Vegetables

The fertigation programme used in raising vegetable transplants affects the quality of the finished transplant and its ability to become established in the field. A well-grown transplant will have adequate nutrient reserves to ensure rapid establishment under a wide variety of field conditions. Vegetable transplants are usually fertilised with water soluble fertilisers, which are applied in the irrigation water. These materials vary in per cent nitrogen (N), phosphate (P_2O_5), and potash (K_2O); and in the micronutrient content. Growers should use fertilisers that have most of the nitrogen in nitrate form. Fertilisers having high concentration of urea should be avoided.



Seedlings from nursery to field

Fertiliser analyses that are recommended for transplant production are as under :

Concentrations of N, P, K and ECs for 100 ppm solution of various water soluble fertiliser materials for use in vegetable transplant production.

Fertiliser analysis	Rate for 100 ppm N (g/100 litres of water)	Parts per million (ppm)			Electrical Conductivity (EC) mmhos/cm*
		N	P	K	
20-20-20	50	100	43	83	0.40
20-10-20	50	100	21	83	0.60
20-08-20	50	100	17	83	0.75
17-05-19	59	100	12	92	1.0
15-05-19	67	100	14	83	0.70
14-00-14	71	100	0	83	0.85

*Electrical Conductivity of a 100 ppm solution in micromhos. The EC values were determined with a conductivity meter using distilled water. The EC values obtained will vary depending on the background EC of the water source.

A high concentration of phosphate (P_2O_5) may promote excessive seedling elongation under certain conditions. Use a fertiliser with a low to medium phosphate concentration. An alternative is to use a fertiliser with no phosphate (such as 14-0-14) for most feedings, and apply a high-phosphate fertiliser periodically (once every four or five feedings) to promote growth. Do not withhold phosphate completely, as this will delay field establishment.

Transplants should be watered as required and the nutrient solution concentration and application frequency should be modified to promote the desired amount of growth. Fertiliser requirements vary depending on cell size (larger cells require less fertiliser), and the nutrient charge of the growing media (less fertiliser should be used if the media have a high nutrient charge).

Fertigation Requirements of Transplants

Different vegetable crops vary in their response to fertiliser, so the feeding programme must be modified for different crops as per requirement. Tomato are very responsive to fertilisers but excess of fertility will reduce transplant quality. While feeding at every watering, fertiliser concentration of 50 to 100 ppm N should be used depending on the stage of plant development. It is advantageous to do feeding less often at a higher concentration. For weekly feeding, use a concentration of 250 to 350 ppm N. Peppers require more fertilisers than tomatoes therefore if feeding is done at every watering, then approximately 100 ppm N may be used but if feeding is done less often then higher concentration may be used. Cole crops do not require as much fertiliser as other crops and 100 to 150 ppm N application weekly should be sufficient under most conditions. Since cucurbits have a relatively short growing cycle compared to other crops therefore two to four applications of 100 to 150 ppm N at weekly interval should be sufficient to produce good quality vine crop transplants. Generally, the nutrient uptake by the roots is low at low temperature during winter season therefore concentration need to be increased accordingly and vice versa during summers when the nutrient uptake automatically increases. The Nitrogen dose should be 140-150 ppm N during winter and it should not be more than 90-100 ppm N during summers.

Calculation of Fertiliser Solution Concentrations

The concentration of fertiliser solutions is usually expressed in parts per million (ppm) of nitrogen. To determine how much fertiliser material is required to produce a solution of a desired concentration, use the following formula:

$$\text{Quantity of fertiliser required (grams)} = \frac{\text{solution concentration (ppm)} \times \text{solution volume (litres)}}{10 \times (\%\ \text{N of fertiliser material})}$$

For example, to make a 100 ppm solution of 20-10-20 fertiliser in a 500 litre tank, the amount of fertiliser required is

$$\text{Quantity of fertiliser required(grams)} = \frac{(100 \times 500)}{(10 \times 20)}$$

Therefore, quantity of fertiliser required is 250 grams.

Fertigation Management in Greenhouse Crops

The growth of vegetables and flowers in greenhouses built on sandy dunes and with inert substrates requires a special and precise control of the fertigation because the CEC of these growing media are very low and therefore they do not provide nutrients. The only source of nutrients is fertigation. Growing plants in containers allow the collection of the leaching water and its comparison with irrigation water. The measurement of EC, pH and nutrients concentration of the leached solution indicates if fertilisers are being applied in excess or in deficient and therefore allows the consecutive correction of the fertigation regime. It is recommended to collect the leached solution from the containers and the solution from the drippers, and to compare both solutions on a daily basis. A higher value of EC in the leached solution than in the applied solution indicates that the plant absorbs more nutrients than water, therefore we must apply greater amount of water to the plant. On the other hand, if the difference between the EC of the leached solution and the incoming solution is less than 0.4-0.5 dS/m, we must apply a leaching irrigation to wash the excess salt.

The optimal pH value of the irrigation solution must be around 6 and the pH of the leaching solution should not exceed 8.5. A more alkaline pH in the leaching solution indicates that pH in the root zone reaches a value that causes phosphorus precipitation and decreases micronutrient availability. When pH in the leachate is higher than that of irrigation water we must adjust NH_4/NO_3 ratio of the irrigation solution by increasing the NH_4 proportion. When pH in the irrigation solution is higher than 6, we must add acid to the solution to lower the pH. The chloride accumulation in the root zone can be removed by applying irrigation without fertiliser.

Role of Major Nutrients in Horticultural crops

Nitrogen

- It is a constituent of proteins, enzymes, vitamins and plant hormones
- It gives vigorous vegetative growth and dark green colour to plants
- It produces early growth and delays maturity of plants
- It governs the utilisation of potassium and phosphorous
- Its deficiency results in retarded vegetative growth
- Excess levels result in abundant foliage and dark green colour

making plants more susceptible to pest and disease attack. Excess level diminishes phosphorous uptake

Phosphorous

- It is found in younger parts-flowers, seeds and maturing fruits
- It enhances maturity of crop, root growth and development
- It enhances activity of rhizobia and formation of root nodules
- Its deficiency results in retarded root growth and shoots with very small leaves with dark green colour, which later turns into bronze colour
- Its deficiency delays flowering and reduces fruit-bud formation
- Excess of phosphorous results in interveinal chlorosis in younger leaves

Potassium

- It is involved in cell division, synthesis and translocation of carbohydrates
- It is found abundantly in young leaves, root tips and meristematic tissues
- It plays a unique role in osmotic regulation, opening and closing of stomata
- It improves the colour, flavour and size of fruits
- Its deficiency symptom first appears on recently matured leaves
- Lack of potassium leads to shoots with poor growth

Fertigation Scheduling for Horticultural Crops

Nutrient management in fertigation is important for increasing the crop productivity and also quality of produce. Plant needs nutrients throughout their growth stages. For the newly planted fruit trees the dosage for first year fertigation is 10% of the recommended dose of fully mature fruit trees and it will gradually increase by 20% of the dosage for the succeeding years. In horticultural crops, these stages vary from crop to crop viz. initial and final stage, vegetative stage, flowering stage, flowering and fruiting stage etc. Fertigation scheduling indicating the crop wise stages along with nutrients concentrations of N, P and K in terms of ppm (1 ppm N = 1 mg N / litre of water) are given for - fruit crop (Table 1), vegetables under open field cultivation (Table 2), vegetables under protected cultivation (Table 3) and flowers under protected cultivation (Table 4). From the farmers perspective, month wise nutrient doses in horticultural crops are converted in 100% water soluble fertilisers urea phosphate (17:44:0), urea and SOP in user friendly way and given for - fruit crops (Table 5), vegetables under open field cultivation (Table 6), vegetables under protected cultivation (Table 7) and flowers under protected cultivation (Table 8). The proposed fertigation scheduling (Tables 1to 8) is general recommendation for all types of soil. However, it is strongly recommended to get the soil testing done and adjust the nutrient dosage accordingly.

Fertigation scheduling for horticultural crops will benefit farmers in increasing the yield and quality of produce through efficient use of water and nutrients.

Mango

Peach

Mausambi

Kinnow

Plate 1 : Drip Irrigation in Fruit Crops

Cole Crops

Onion

Chilli

Tomato

Plate 2 : Drip Irrigation in Vegetables under Open Field Cultivation

Capsicum

Cucumber

Green House Tomato

Cherry Tomato

Plate 3 : Drip Irrigation in Vegetables under Protected Cultivation

Gerbera

Rose

Chrysanthemum

Lilium

Plate 4 : Drip Irrigation in Flowers under Protected Cultivation

Table 1. Fertigation scheduling in fruit crops

Crop	Spacing		Plants	Fertigation schedule	Dose			Total			Yield
	Plant to plant	Row to row			N	P	K	N	P	K	
	m	m	No /ha		ppm	ppm	ppm	Kg / ha	Kg / ha	Kg / ha	q / ha
Kinnow	4	5	500	Initial and final stage - October - June	30	15	30	338	169	338	200
				Fruiting stage - July - September	60	30	60				
Mausambi	4	5	500	Initial and final stage - October - June	30	15	30	338	169	338	180
				Fruiting stage - July - September	60	30	60				
Lemon	4	5	500	Initial and final stage - October - June	30	15	30	338	169	338	300
				Fruiting stage - July - September	60	30	60				
Orange	4	5	500	Initial and final stage - October - June	30	15	30	338	169	338	200
				Fruiting stage - July - September	60	30	60				
Peach	4	5	500	Initial and final stage - July - Dec	30	15	30	400	200	400	200
				Flowering & fruiting stage - Jan - June	60	30	60				
Chiku	5	5	400	Initial and final stage - June - Dec	30	15	30	313	157	313	200
				Flowering & fruiting stage - Jan - May	60	30	60				
Ber	5	8	250	Initial and final stage - April - Oct	15	7.5	15	154	77	154	400
				Flowering & fruiting stage -Nov - March	30	15	30				
Aonla	5	8	250	Initial and final stage - April - Oct	10	5	10	103	51	103	300
				Flowering & fruiting stage - Nov- March	20	10	20				
Mango	5	6	333	Initial and final stage - July - Jan	30	15	30	268	134	268	120
				Flowering & fruiting stage - Feb - June	30	15	30				
Guava	5	6	333	Initial and final stage - Feb - Aug	30	15	30	252	126	252	300
				Flowering & fruiting stage - Sept - Jan	30	15	30				
Strawberry	0.3	0.3	83333	Vegetative stage - Oct - Nov	50	30	60	115	73	163	250
				Flowering - Dec	60	50	80				
				Fruiting and harvesting - Jan - March	50	30	80				

Table 2. Fertigation scheduling in vegetables under open field cultivation

Crop	Spacing		Plants	Fertigation schedule	Dose			Total			Yield
	Plant to plant	Row to row			N	P	K	N	P	K	
	m	m	No./ha		ppm	ppm	ppm	Kg / ha	Kg / ha	Kg / ha	q / ha
Tomato*	0.3	1.2	27778	Vegetative stage- Oct	25	15	30	111	67	133	500
				Flowering - Nov	50	30	60				
				Flowering and harvesting - Dec - March	50	30	60				
Brinjal	0.5	1.2	16667	Vegetative stage- Oct	25	15	30	109	65	111	300
				Flowering - Nov	50	30	50				
				Flowering and harvesting - Dec - March	50	30	50				
Onion	0.1	0.2	500000	Vegetative stage- Nov - Dec	50	30	50	124	75	143	250
				Bulbous stage - Jan - March	75	45	90				
				Harvesting - April	0	0	0				
Garlic	0.1	0.2	500000	Vegetative stage- Oct - Nov	25	15	30	88	53	111	150
				Bulbous stage - Dec - Feb	50	30	60				
				Harvesting - March	50	30	70				
Chilli	0.3	0.4	55556	Vegetative stage- July - Aug	25	15	30	126	76	132	100
				Flowering - Sept	50	30	50				
				Flowering and harvesting - Oct -Dec	50	30	50				
Cabbage	0.3	0.3	83333	Vegetative stage- Oct	50	30	50	76	46	83	500
				Curd stage - Nov	75	45	80				
				Harvesting - Dec - Jan	50	30	60				
Cauliflower	0.3	0.3	83333	Vegetative stage- Oct	50	30	50	76	46	83	250
				Curd stage - Nov	75	45	80				
				Harvesting - Dec - Jan	50	30	60				
Broccoli	0.3	0.3	83333	Vegetative stage- Oct	50	30	50	76	46	83	150
				Curd stage - Nov	75	45	80				
				Harvesting - Dec - Jan	50	30	60				
Knolkhol	0.15	0.2	222222	Vegetative stage- Oct	50	30	50	76	46	83	250
				Heading stage - Nov	75	45	80				
				Harvesting - Dec - Jan	50	30	60				

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* Tomato - Semi - indeterminate type variety

Table 2. Fertigation scheduling in vegetables under open field cultivation

Crop	Spacing: Plant to plant (m)	Spacing: Row to row (m)	Plants (No /ha)	Fertigation schedule	Dose N (ppm)	Dose P (ppm)	Dose K (ppm)	Total N (Kg / ha)	Total P (Kg / ha)	Total K (Kg / ha)	Yield (q / ha)
Radish	0.15	0.2	222222	Vegetative stage- Oct	50	40	50	65	77	74	200
				Rooting stage - Nov	50	80	60				
				Harvesting - Dec - Jan	50	60	60				
Carrot	0.15	0.2	222222	Vegetative stage- Oct	50	40	50	65	77	74	250
				Rooting stage- Nov	50	80	60				
				Harvesting - Dec - Jan	50	60	60				
Beet root	0.15	0.2	222222	Vegetative stage- Oct	50	40	50	65	77	74	300
				Rooting stage- Nov	50	80	60				
				Harvesting - Dec - Jan	50	60	60				
Cucumber	0.3	1.2	27778	Vegetative stage- Nov	50	30	60	139	84	151	100
				Flowering stage- Dec	75	45	80				
				Harvesting - Jan - March	75	45	80				
Muskmelon	0.5	1.2	16667	Vegetative stage- Feb	25	15	30	91	54	131	200
				Flowering stage- March	50	30	60				
				Harvesting - April - May	25	15	40				
Watermelon	0.9	1.2	9259	Vegetative stage- Feb	25	15	30	91	54	131	250
				Flowering stage- March	50	30	60				
				Harvesting - April - May	25	15	40				
Bottle gourd	0.9	1.2	9259	Vegetative stage- Feb	25	15	40	87	52	139	300
				Flowering stage- March	50	30	80				
				Harvesting - April - May	25	15	40				
Bitter gourd	0.5	1.2	16667	Vegetative stage- Feb	25	15	40	87	52	139	150
				Flowering stage- March	50	30	80				
				Harvesting - April - May	25	15	40				
Ash gourd	0.9	1.2	9259	Vegetative stage- Feb	25	15	40	87	52	139	300
				Flowering stage- March	50	30	80				
				Harvesting - April - May	25	15	40				

Contd ...

Table 2. Fertigation scheduling in vegetables under open field cultivation

Crop	Spacing		Plants	Fertigation schedule	Dose			Total			Yield
	Plant to plant	Row to row			N	P	K	N	P	K	
	m	m	No/ha		ppm	ppm	ppm	Kg/ha	Kg/ha	Kg/ha	q/ha
Ridge gourd	0.5	1.2	16667	Vegetative stage- Feb	25	15	40	87	52	139	250
				Flowering stage- March	50	30	80				
				Harvesting - April - May	25	15	40				
Sponge gourd	0.5	1.2	16667	Vegetative stage- Feb	25	15	40	87	52	139	200
				Flowering stage- March	50	30	80				
				Harvesting - April - May	25	15	40				
Pointed gourd	0.5	1.2	16667	Vegetative stage- Feb	25	15	40	87	52	139	250
				Flowering stage- March	50	30	80				
				Harvesting - April - May	25	15	40				

Table 3. Fertigation scheduling in vegetables under protected cultivation

Crop	Spacing		Plants	Fertigation schedule	Dose			Total			Yield
	Plant to plant	Row to row			N	P	K	N	P	K	
	m	m	No /1000 m^2		ppm	ppm	ppm	Kg /1000 m^2	Kg /1000 m^2	Kg /1000 m^2	q /1000 m^2
Tomato	0.45	0.4	2773	Vegetative stage- Aug - Sept	100	50	100	35	12	39	150-200
				Flowering - Oct	200	60	200				
				Flowering and harvesting - Nov	250	80	250				
				Flowering and harvesting - Dec	250	80	250				
				Flowering and harvesting - Jan	250	80	250				
				Flowering and harvesting - Feb	250	60	250				
				Flowering and harvesting - March	250	50	250				
				Flowering and harvesting - April	100	50	200				
Cherry tomato	0.45	0.4	2773	Vegetative stage- Aug - Sept	100	50	100	35	12	39	30-40
				Flowering - Oct	200	60	200				
				Flowering and harvesting - Nov	250	80	250				
				Flowering and harvesting - Dec	250	80	250				
				Flowering and harvesting - Jan	250	80	250				
				Flowering and harvesting - Feb	250	60	250				
				Flowering and harvesting - March	250	50	250				
				Flowering and harvesting - April	100	50	200				
Capsicum	0.3	0.4	4160	Vegetative stage- Aug - Sept	100	60	100	32	15	36	40-50
				Flowering - Oct	180	80	180				
				Flowering and harvesting - Nov	220	100	220				
				Flowering and harvesting - Dec	220	100	220				
				Flowering and harvesting - Jan	220	90	220				
				Flowering and harvesting - Feb	220	90	220				
				Flowering and harvesting - March	220	90	220				
				Flowering and harvesting - April	100	50	200				

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Table 3. Fertigation scheduling in vegetables under protected cultivation

Crop	Spacing		Plants	Fertigation schedule	Dose			Total			Yield
	Plant to plant	Row to row			N	P	K	N	P	K	
	m	m	No /1000 m^2		ppm	ppm	ppm	Kg /1000 m^2	Kg /1000 m^2	Kg /1000 m^2	q /1000 m^2
Cucumber	0.3	0.4	4160	Crop cycle (August - October)							
				Vegetative stage - Aug	120	60	120	15	7	16	40
				Flowering - Sept	180	80	200				
				Flowering and harvesting - Sept - Oct	180	80	200				
				Crop cycle (Nov - Jan)							
				Vegetative stage - Nov	160	80	160	10	4	11	30
				Flowering - Dec	220	80	240				
				Flowering and harvesting - Dec - Jan	220	80	240				
				Crop cycle (Feb - April)							
				Vegetative stage - Feb	120	60	120	16	6	18	30
				Flowering - March	180	60	200				
				Flowering and harvesting -March-April	180	60	200				

Table 4. Fertigation scheduling in flowers under protected cultivation

Crop	Spacing		Plants	Fertigation schedule	Dose			Total			Yield
	Plant to plant	Row to row			N	P	K	N	P	K	
	m	m	No /1000 m²		ppm	ppm	ppm	Kg /1000 m²	Kg /1000 m²	Kg /1000 m²	Stems (No)
Rose	0.2	0.4	12000	Vegetative stage - Sept - Oct	80	50	60	28	17	25	270000
				Flowering and harvesting flush - Nov - March	100	60	80				
				Flowering and harvesting normal - April - August	80	50	80				
Gerbera	0.2	0.3	16000	Vegetative stage - Sept - Oct	70	50	60	17	12	17	650000
				Flowering and harvesting flush - Nov - April	80	60	80				
				Maintenance dose - May - August	40	24	40				
Chrysanth--emum	0.1	0.15	65000	Vegetative stage - Sept - Oct	80	50	60	21	13	19	90000
				Flowering and harvesting flush - Nov - April	90	60	80				
				Maintenance dose - May - August	50	30	50				
Lilium	0.15	0.2	32000	Vegetative stage - Sept - Oct	60	36	60	17	11	17	130000
				Flowering and harvesting flush - Nov - March	80	50	80				
				Maintenance dose - April - August	50	30	50				
Carnation	0.15	0.2	32000	Vegetative stage - Sept - Oct	50	30	40	14	8	13	300000
				Flowering and harvesting flush - Nov - March	60	40	60				
				Maintenance dose - April - August	40	20	40				

Table 5. Month wise fertigation scheduling in fruit crops

Crop	Particulars	Month wise application of water soluble fertilisers (kg /ha), CWR (m^3/ ha) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Kinnow 														
	CWR	264	362	632	1071	1423	1479	949	685	694	611	459	295	8923
	Irrigation	4	6	8	8	8	8	6	8	8	8	6	4	82
	Urea phosphate	9.0	12.3	21.6	36.5	48.5	50.4	64.7	46.7	47.3	20.8	15.6	10.1	383.5
	Urea	13.9	19.0	33.3	56.4	74.9	77.8	99.8	72.1	73.0	32.2	24.2	15.5	592.0
	SOP	15.8	21.7	37.9	64.3	85.4	88.7	113.8	82.2	83.2	36.7	27.5	17.7	675.0
Mausambi 														
	CWR	264	362	632	1071	1423	1479	949	685	694	611	459	295	8923
	Irrigation	4	6	8	8	8	8	6	8	8	8	6	4	82
	Urea phosphate	9.0	12.3	21.6	36.5	48.5	50.4	64.7	46.7	47.3	20.8	15.6	10.1	383.5
	Urea	13.9	19.0	33.3	56.4	74.9	77.8	99.8	72.1	73.0	32.2	24.2	15.5	592.0
	SOP	15.8	21.7	37.9	64.3	85.4	88.7	113.8	82.2	83.2	36.7	27.5	17.7	675.0
Lemon 														
	CWR	264	362	632	1071	1423	1479	949	685	694	611	459	295	8923
	Irrigation	4	6	8	8	8	8	6	8	8	8	6	4	82
	Urea phosphate	9.0	12.3	21.6	36.5	48.5	50.4	64.7	46.7	47.3	20.8	15.6	10.1	383.5
	Urea	13.9	19.0	33.3	56.4	74.9	77.8	99.8	72.1	73.0	32.2	24.2	15.5	592.0
	SOP	15.8	21.7	37.9	64.3	85.4	88.7	113.8	82.2	83.2	36.7	27.5	17.7	675.0

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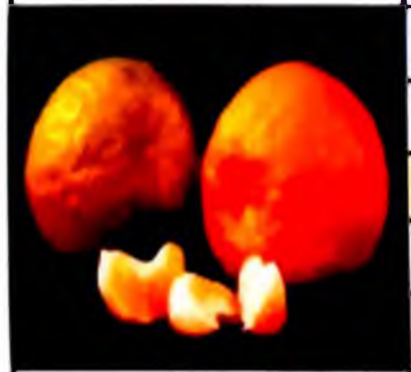
Table 5. Month wise fertigation scheduling in fruit crops

Crop	Particulars	Month wise application of water soluble fertilisers (kg /ha), CWR (m³/ ha) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Orange														
	CWR	264	362	632	1071	1423	1479	949	685	694	611	459	295	8923
	Irrigation	4	6	8	8	8	8	6	8	8	6	4	4	78
	Urea phosphate	9.0	12.3	21.6	36.5	48.5	50.4	64.7	46.7	47.3	20.8	15.6	10.1	383.5
	Urea	13.9	19.0	33.3	56.4	74.9	77.8	99.8	72.1	73.0	32.2	24.2	15.5	592.0
	SOP	15.8	21.7	37.9	64.3	85.4	88.7	113.8	82.2	83.2	36.7	27.5	17.7	675.0
Peach														
	CWR	248	340	595	1008	1339	1392	893	645	653	575	432	278	8398
	Irrigation	4	6	8	12	14	16	6	8	10	12	8	6	110
	Urea phosphate	16.9	23.2	40.6	68.7	91.3	94.9	30.4	22.0	22.3	19.6	14.7	9.5	454.1
	Urea	26.1	35.8	62.6	106.1	140.9	146.5	47.0	33.9	34.3	30.3	22.7	14.6	700.9
	SOP	29.8	40.9	71.4	121.0	160.7	167.0	53.6	38.7	39.2	34.5	25.9	16.7	799.3
Chiku														
	CWR	217	298	521	882	1172	1218	781	564	571	503	378	243	7349
	Irrigation	4	6	8	12	14	16	6	8	10	12	8	6	110
	Urea phosphate	14.8	20.3	35.5	60.1	79.9	41.5	26.6	19.2	19.5	17.2	12.9	8.3	355.8
	Urea	22.8	31.4	54.8	92.8	123.3	64.1	41.1	29.7	30.1	26.5	19.9	12.8	549.2
	SOP	26.0	35.8	62.5	105.8	140.6	73.1	46.9	33.9	34.3	30.2	22.7	14.6	626.3

Contd...

Table 5. Month wise fertigation scheduling in fruit crops

Crop	Particulars	Month wise application of water soluble fertilisers (kg/ha), CWR (m³/ha) and irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	T[illegible]
Ber 														
	CWR	248	340	595	1008	1339	1392	893	645	653	575	432	278	8[illegible]
	Irrigation	4	6	8	10	12	14	6	4	5	6	4	4	[illegible]
	Urea phosphate	8.5	11.6	20.3	17.2	22.8	23.7	15.2	11.0	11.1	9.8	14.7	9.5	17[illegible]
	Urea	13.0	17.9	31.3	26.5	35.2	36.6	23.5	17.0	17.2	15.1	22.7	14.6	270[illegible]
	SOP	14.9	20.4	35.7	30.2	40.2	41.8	26.8	19.3	19.6	17.3	25.9	16.7	308[illegible]
Aonla 														
	CWR	248	340	595	1008	1339	1392	893	645	653	575	432	278	8398
	Irrigation	4	6	8	10	12	14	6	4	5	6	4	4	83
	Urea phosphate	5.6	7.7	13.5	11.5	15.2	15.8	10.1	7.3	7.4	6.5	9.8	6.3	117.0
	Urea	8.7	11.9	20.9	17.7	23.5	24.4	15.7	11.3	11.4	10.1	15.2	9.7	180.5
	SOP	9.9	13.6	23.8	20.2	26.8	27.8	17.9	12.9	13.1	11.5	17.3	11.1	205.8
Mango 														
	CWR	264	362	632	1071	1423	1479	949	685	694	611	459	295	8923
	Irrigation	4	6	8	12	14	16	6	8	10	12	8	6	110
	Urea phosphate	9.0	12.3	21.6	36.5	48.5	50.4	32.3	23.4	23.6	20.8	15.6	10.1	304.2
	Urea	13.9	19.0	33.3	56.4	74.9	77.8	49.9	36.0	36.5	32.2	24.2	15.5	469.5
	SOP	15.8	21.7	37.9	64.3	85.4	88.7	56.9	41.1	41.6	36.7	27.5	17.7	535.4

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Table 5. Month wise fertigation scheduling in fruit crops

Crop	Particulars	Month wise application of water soluble fertilisers (kg /ha), CWR (m^3/ ha) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Guava 														
	CWR	248	340	595	1008	1339	1392	893	645	653	575	432	278	8398
	Irrigation	4	6	8	8	8	8	6	6	7	6	4	4	75
	Urea phosphate	8.5	11.6	20.3	34.4	45.7	47.5	30.4	22.0	22.3	19.6	14.7	9.5	286.3
	Urea	13.0	17.9	31.3	53.0	70.5	73.2	47.0	33.9	34.3	30.3	22.7	14.6	441.9
	SOP	14.9	20.4	35.7	60.5	80.4	83.5	53.6	38.7	39.2	34.5	25.9	16.7	503.9
Strawberry 														
	CWR	248	340	521							432	432	278	2251
	Irrigation	4	6	8							6	8	4	36
	Urea phosphate	16.9	23.2	35.5							29.4	29.5	31.6	166.1
	Urea	20.7	28.4	43.5							36.0	36.1	24.6	189.3
	SOP	39.7	54.5	83.3							51.8	51.8	44.4	325.5

Table 6. Month wise fertigation scheduling in vegetables under open field cultivation

Crop	Particulars	Month wise application of water soluble fertilisers (kg /ha), CWR (m^3/ ha) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Tomato														
	CWR	279	383	595							432	432	312	2433
	Irrigation	4	6	8							8	6	4	36
	Urea phosphate	19.0	26.1	40.6							14.7	29.5	21.3	151.2
	Urea	23.3	32.0	49.7							18.0	36.1	26.1	185.2
	SOP	33.5	46.0	71.4							25.9	51.8	37.5	266.1
Brinjal														
	CWR	279	383	595							432	432	278	2399
	Irrigation	4	6	8							6	6	4	34
	Urea phosphate	19.0	26.1	40.6							14.7	29.5	18.9	148.8
	Urea	23.3	32.0	49.7							18.0	36.1	23.2	182.3
	SOP	27.9	38.3	59.5							25.9	43.2	27.8	222.6
Onion														
	CWR	279	383	595	504							324	278	2363
	Irrigation	4	6	8	4							6	4	32
	Urea phosphate	28.5	39.2	60.9	0.0							22.1	18.9	169.6
	Urea	34.9	48.0	74.5	0.0							27.1	23.2	207.7
	SOP	50.2	68.9	107.1	0.0							32.4	27.8	286.5

Contd...

Table 6. Month wise fertigation scheduling in vegetables under open field cultivation

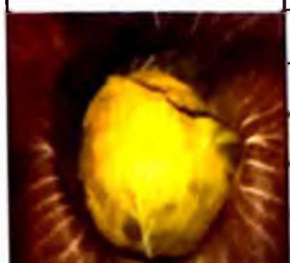
Crop	Particulars	Month wise application of water soluble fertilisers (kg /ha), CWR (m^3/ ha) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Garlic														
	CWR	248	340	521							432	378	243	2162
	Irrigation	4	6	8							6	6	4	34
	Urea phosphate	16.9	23.2	35.5							14.7	12.9	16.6	119.8
	Urea	20.7	28.4	43.5							18.0	15.8	20.3	146.7
	SOP	29.8	40.9	72.9							25.9	22.7	29.2	221.3
Chilli														
	CWR							670	564	653	575	432	243	3137
	Irrigation							6	7	8	8	6	4	39
	Urea phosphate							22.8	19.2	44.5	39.2	29.5	16.6	171.8
	Urea							28.0	23.6	54.5	48.0	36.1	20.3	210.4
	SOP							40.2	33.85	65.3	57.5	43.2	24.3	264.3
Cabbage														
	CWR	248									432	378	278	1335
	Irrigation	6									6	8	6	26
	Urea phosphate	16.9									29.4	38.7	18.9	103.9
	Urea	20.7									36.0	47.3	23.2	127.3
	SOP	29.8									43.2	60.5	33.3	166.7

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Table 6. Month wise fertigation scheduling in vegetables under open field cultivation

Crop	Particulars	Month wise application of water soluble fertilisers (kg /ha), CWR (m^3/ ha) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Cauliflower														
	CWR	248									432	378	278	1335
	Irrigation	6									6	8	6	26
	Urea phosphate	16.9									29.4	38.7	18.9	103.9
	Urea	20.7									36.0	47.3	23.2	127.3
	SOP	29.8									43.2	60.5	33.3	166.7
Broccoli														
	CWR	248									432	378	278	1335
	Irrigation	6									6	8	6	26
	Urea phosphate	16.9									29.4	38.7	18.9	103.9
	Urea	20.7									36.0	47.3	23.2	127.3
	SOP	29.8									43.2	60.5	33.3	166.7
Knolkhol														
	CWR	248									432	378	278	1335
	Irrigation	6									6	8	6	26
	Urea phosphate	16.9									29.4	38.7	18.9	103.9
	Urea	20.7									36.0	47.3	23.2	127.3
	SOP	29.8									43.2	60.5	33.3	166.7

Contd...

Table 6. Month wise fertigation scheduling in vegetables under open field cultivation

Crop	Particulars	Month wise application of water soluble fertilisers (kg /ha), CWR (m³/ ha) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Radish 														
	CWR	217									432	378	278	1304
	Irrigation	4									6	8	6	24
	Urea phosphate	29.6									39.2	68.7	37.9	175.4
	Urea	12.7									32.4	15.7	16.2	76.9
	SOP	26.0									43.2	45.4	33.3	147.9
Carrot 														
	CWR	217									432	378	278	1304
	Irrigation	4									6	8	6	24
	Urea phosphate	29.6									39.2	68.7	37.9	175.4
	Urea	12.7									32.4	15.7	16.2	76.9
	SOP	26.0									43.2	45.4	33.3	147.9
Beet root 														
	CWR	217									432	378	278	1304
	Irrigation	4									6	8	6	24
	Urea phosphate	29.6									39.2	68.7	37.9	175.4
	Urea	12.7									32.4	15.7	16.2	76.9
	SOP	26.0									43.2	45.4	33.3	147.9

Contd...

Table 6. Month wise fertigation scheduling in vegetables under open field cultivation

Crop	Particulars	Month wise application of water soluble fertilisers (kg /ha), CWR (m^3/ ha) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Cucumber 														
	CWR	279	383	595								432	312	2002
	Irrigation	4	6	8								8	6	32
	Urea phosphate	28.5	39.2	60.9								29.5	32.0	190.0
	Urea	34.9	48.0	74.5								36.1	39.1	232.7
	SOP	44.6	61.3	95.2								51.8	50.0	303.0
Muskmelon 														
	CWR		255	595	1008	1172								3030
	Irrigation		6	8	8	8								30
	Urea phosphate		8.7	40.6	34.4	39.9								123.6
	Urea		10.7	49.7	42.1	48.9								151.4
	SOP		15.3	71.4	80.6	93.7								261.1
Watermelon 														
	CWR		255	595	1008	1172								3030
	Irrigation		6	8	8	8								30
	Urea phosphate		8.7	40.6	34.4	39.9								123.6
	Urea		10.7	49.7	42.1	48.9								151.4
	SOP		15.3	71.4	80.6	93.7								261.1

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Table 6. Month wise fertigation scheduling in vegetables under open field cultivation

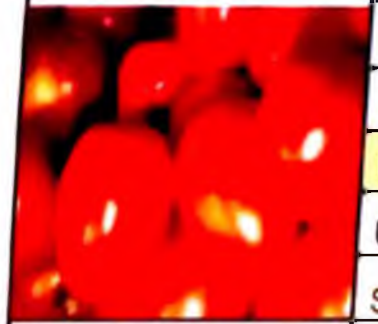
Crop	Particulars	Month wise application of water soluble fertilisers (kg /ha), CWR (m^3/ ha) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Bottle gourd														
	CWR		255	521	1008	1172								2956
	Irrigation		6	8	8	8								30
	Urea phosphate		8.7	35.5	34.4	39.9								118.5
	Urea		10.7	43.5	42.1	48.9								145.2
	SOP		20.4	83.3	80.6	93.7								278.1
Bitter gourd														
	CWR		255	521	1008	1172								2956
	Irrigation		6	8	8	8								30
	Urea phosphate		8.7	35.5	34.4	39.9								118.5
	Urea		10.7	43.5	42.1	48.9								145.2
	SOP		20.4	83.3	80.6	93.7								278.1
Ash gourd														
	CWR		255	521	1008	1172								2956
	Irrigation		6	8	8	8								30
	Urea phosphate		8.7	35.5	34.4	39.9								118.5
	Urea		10.7	43.5	42.1	48.9								145.2
	SOP		20.4	83.3	80.6	93.7								278.1

Contd...

Table 6. Month wise fertigation scheduling in vegetables under open field cultivation

Crop	Particulars	Month wise application of water soluble fertilisers (kg /ha), CWR (m^3/ ha) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Ridge gourd														
	CWR		255	521	1008	1172								2956
	Irrigation		6	8	8	8								30
	Urea phosphate		8.7	35.5	34.4	39.9								118.5
	Urea		10.7	43.5	42.1	48.9								145.2
	SOP		20.4	83.3	80.6	93.7								278.1
Sponge gourd														
	CWR		255	521	1008	1172								2956
	Irrigation		6	8	8	8								30
	Urea phosphate		8.7	35.5	34.4	39.9								118.5
	Urea		10.7	43.5	42.1	48.9								145.2
	SOP		20.4	83.3	80.6	93.7								278.1
Pointed gourd														
	CWR		255	521	1008	1172								2956
	Irrigation		6	8	8	8								30
	Urea phosphate		8.7	35.5	34.4	39.9								118.5
	Urea		10.7	43.5	42.1	48.9								145.2
	SOP		20.4	83.3	80.6	93.7								278.1

Table 7. Month wise fertigation scheduling in vegetables under protected cultivation (1000m²)

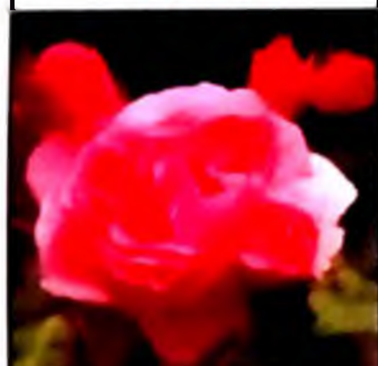
Crop	Particulars	Month wise application of water soluble fertilisers (kg /1000m²), CWR (m³/ 1000m²) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Tomato 														
	CWR	11	15	27	40				22	26	26	19	12	198
	Irrigation	4	6	7	8				6	8	8	6	4	57
	Urea phosphate	2.0	2.1	3.0	4.5				2.5	2.9	3.5	3.5	2.3	26.4
	Urea	5.3	7.6	13.4	7.0				3.8	4.5	10.0	9.3	6.0	66.8
	SOP	5.6	7.7	13.4	15.9				4.4	5.1	10.4	9.7	6.2	78.3
Cherry tomato 														
	CWR	11	15	27	40				22	26	26	19	12	198
	Irrigation	4	6	7	8				6	8	8	6	4	57
	Urea phosphate	2.0	2.1	3.0	4.5				2.5	2.9	3.5	3.5	2.3	26.4
	Urea	5.3	7.6	13.4	7.0				3.8	4.5	10.0	9.3	6.0	66.8
	SOP	5.6	7.7	13.4	15.9				4.4	5.1	10.4	9.7	6.2	78.3
Capsicum 														
	CWR	11	15	27	40				22	26	26	19	12	198
	Irrigation	4	6	7	8				6	8	8	6	4	57
	Urea phosphate	2.3	3.1	5.5	4.5				3.0	3.5	4.7	4.4	2.8	33.8
	Urea	4.5	6.2	10.8	7.0				3.6	4.3	8.4	7.7	4.9	57.3
	SOP	4.9	6.7	11.8	15.9				4.4	5.1	9.3	8.6	5.5	72.2

Contd...

Table 7. Month wise fertigation scheduling in vegetables under protected cultivation (1000m^2)

Crop	Particulars	Month wise application of water soluble fertilisers (kg /1000m^2), CWR (m^3/ 1000m^2) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Cucumber (Crop cycle - August - Oct)														
	CWR								29	33	29			91
	Irrigation								6	8	8			22
	Urea phosphate								4.0	6.0	5.3			15.3
	Urea								6.1	10.7	9.4			26.3
	SOP								7.0	13.2	11.7			31.8
Cucumber (Crop cycle - Nov - Jan)														
	CWR	14										22	16	51
	Irrigation	6										6	4	16
	Urea phosphate	2.5										4.0	2.8	9.4
	Urea	5.7										6.1	6.4	18.3
	SOP	6.7										7.0	7.5	21.2
Cucumber (Crop cycle - Feb - April)														
	CWR		15	28	51									95
	Irrigation		6	8	8									22
	Urea phosphate		2.1	3.9	7.0									12.9
	Urea		3.2	9.7	17.4									30.3
	SOP		3.7	11.4	20.4									35.5

Table 8. Month wise fertigation scheduling in flowers under protected cultivation (1000m²)

Crop	Particulars	Month wise application of water soluble fertilisers (kg /1000m²), CWR (m³/ 1000m²) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Rose														
	CWR	11	15	27	40	45	47	30	25	26	26	19	12	324
	Irrigation	4	6	7	8	8	8	6	6	8	8	6	4	79
	Urea phosphate	1.5	2.1	3.7	4.5	5.1	5.3	3.4	2.9	2.9	2.9	2.7	1.7	38.8
	Urea	1.9	2.6	4.5	5.2	6.0	6.2	4.0	3.3	3.4	3.4	3.2	2.1	45.8
	SOP	1.8	2.5	4.3	6.4	7.2	7.5	4.8	4.1	3.1	3.1	3.1	2.0	49.8
Gerbera														
	CWR	11	15	23	34	38	39	25	22	22	23	19	12	284
	Irrigation	4	6	7	8	8	8	6	6	8	8	6	4	79
	Urea phosphate	1.5	2.1	3.2	4.6	2.1	2.1	1.4	1.2	2.5	2.6	2.7	1.7	27.6
	Urea	1.4	1.9	2.9	4.2	2.5	2.6	1.7	1.5	2.4	2.5	2.4	1.5	27.5
	SOP	1.8	2.5	3.7	5.4	3.0	3.1	2.0	1.7	2.6	2.7	3.1	2.0	33.8
Chrysanthemum														
	CWR	11	15	27	34	38	39	25	22	22	26	22	14	295
	Irrigation	4	6	8	8	8	8	6	6	8	8	6	4	80
	Urea phosphate	1.5	2.1	3.7	4.6	2.6	2.7	1.7	1.5	2.5	2.9	3.0	1.9	30.7
	Urea	1.6	2.2	3.9	4.9	3.1	3.3	2.1	1.8	2.9	3.4	3.2	2.0	34.5
	SOP	1.8	2.5	4.3	5.4	3.8	3.9	2.5	2.2	2.6	3.1	3.5	2.2	37.8

Contd...

Table 8. Month wise fertigation scheduling in flowers under protected cultivation (1000m²)

Crop	Particulars	Month wise application of water soluble fertilisers (kg /1000m²), CWR (m³/ 1000m²) and Irrigation (No)												
		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Lilium														
	CWR	11	15	23	34	38	39	25	22	22	26	19	12	287
	Irrigation	4	6	8	6	8	8	6	6	6	8	6	4	76
	Urea phosphate	1.3	1.7	2.7	2.3	2.6	2.7	1.7	1.5	1.8	2.1	2.2	1.4	24.0
	Urea	1.5	2.0	3.1	2.8	3.1	3.3	2.1	1.8	2.2	2.6	2.6	1.6	28.8
	SOP	1.8	2.5	3.7	3.4	3.8	3.9	2.5	2.2	2.6	3.1	3.1	2.0	34.6
Carnation														
	CWR	11	15	23	34	38	39	25	22	22	26	19	12	287
	Irrigation	4	6	8	6	8	8	6	6	6	8	6	4	76
	Urea phosphate	1.0	1.4	2.1	1.5	1.7	1.8	1.1	1.0	1.5	1.8	1.8	1.1	17.9
	Urea	1.1	1.5	2.3	2.4	2.6	2.7	1.8	1.5	1.8	2.2	1.9	1.2	23.0
	SOP	1.3	1.8	2.8	2.7	3.0	3.1	2.0	1.7	1.8	2.1	2.3	1.5	26.3