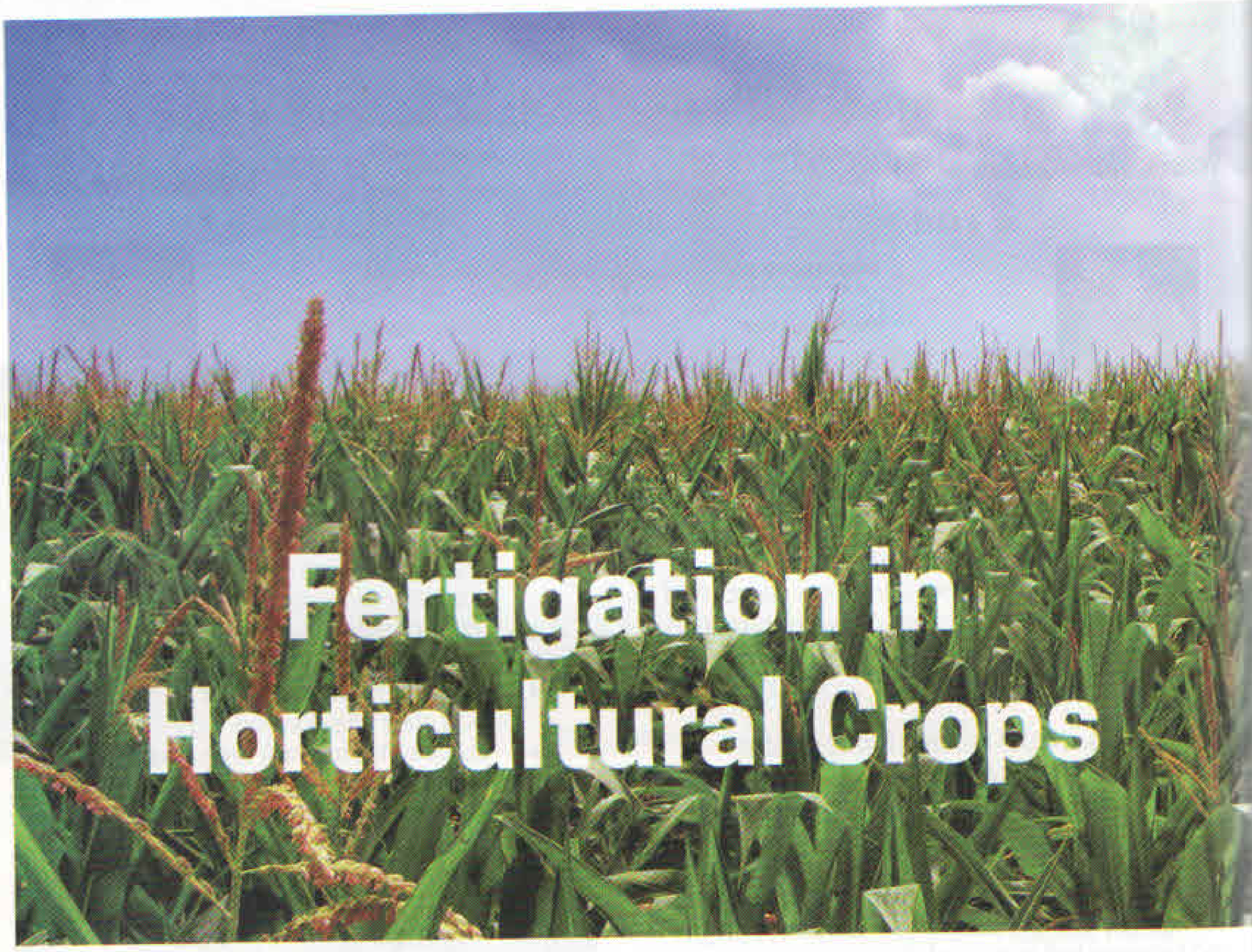


Fertigation in Horticultural Crops

AN.Ganeshamurthy and TR Rupa

Fertigation is the technique in which fertilizers go with the irrigation to plants. When combined with an efficient irrigation system both nutrients and water can be manipulated and managed to enhance the efficiency of fertilizer use and obtain the maximum possible yield of marketable production from a given quantity of these inputs. Often, solid fertiliser top-dressings are timed to suit management constraints rather than the horticultural requirements of the crop. Most growers will have experienced the dilemma of spreading fertiliser the day before heavy rain and then wondering how much of the fertiliser is either washed from the crop in run-off or leached below the root zone. Continuous small applications of soluble nutrients overcome these problems, save labour, reduce compaction in the field, result in the fertiliser being placed around the plant roots uniformly and allow for rapid uptake of nutrients by the plant. To capitalise on these benefits, farmers should be made aware of the need to take care in selecting fertilisers and injection equipment as well as in the management and maintenance of the system.

Horticultural crops in national economy

The horticulture sector covers fruits and nuts, vegetables and tubers, plantation crops, flowers,medicinal and aromatic crops, condiment and spices, mushroom, honey production etc. In India ,fruits and vegetables together contributes about 87 per cent of the total horticultural production of about 300 million tons during 2016-17. Under fruit crops – banana, mango and citrus fruits contribute 70 % of overall fruits production while in vegetables- potato, tomato, onion, brinjal and cabbage contribute 80 % of overall vegetable production. Amongst states – Andhra Pradesh, West Bengal, Uttar Pradesh, Maharashtra, Tamil Nadu, Bihar, Gujarat, Karnataka, Madhya Pradesh and Odisha are major contributors to horticultural production.

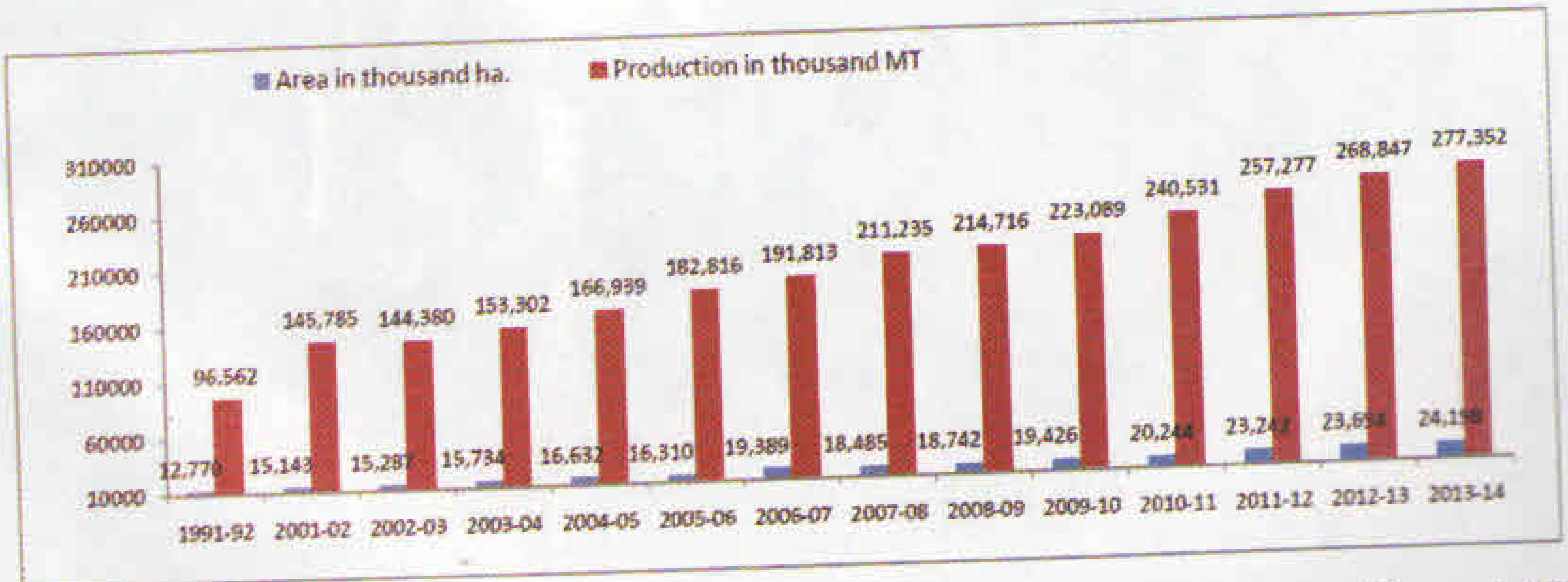
Trends in horticulture production in India:

Overall trends in horticulture growth between 1991-2013 are presented in figure 1. But the growth pattern in the recent decade is impressive. In the past one decade between 2003-04 and 2013-14, the area under horticulture increased by 26%. At the same time the productivity showed a spectacular increase by 81%. The trends in key horticultural crops production during the past one decade is presented in table 1-3.Within the horticulture, the fruit crops sec-

tor increased by 55% and production by 94%. Vegetables sector increased by 55% and 84%, respectively. Aromatic& Medicinal Plants sector showed a spectacular increase by 276% in area and 463% in production and that of floriculture sector by 153% and 296% respectively. The respective figures for plantation Crops sector are 19% and 24% and for spices sector 0.3% and 16%.

Figure 1- Area and Production Growth Trends for Horticulture Crops

Estimation of fertilizer requirement of different horticultural sectors:



The projected figures of horticulture production for 2040 are 340 million tons. To achieve this a tremendous effort is needed to enhance the productivity of crops. One of the major points in enhancing the production is through maintenance of soil health and enhanced use of fertilizers. Application of fertilisers to plantation, fruits and vegetable crops, though not uncommon, has not been considered adequately. Singh and Kalloo (1999) had projected 744 thousand tons N, 372 thousand tons of P205 and 272 thousand tons of K20 for vegetable crops. The decade after 2000 has seen a significant jump in the area, production and productivity of horticultural crops. Particularly the area has increased from 15 million hectare in 2001-02 to 25.0 million hectares in 2016 and the production from 146mt to 300 mt. and proportionately the fertilizer consumption has increased and hence there is need to reassess the requirement of fertilizers for horticulture sector in the country. Recently Ganeshamurthy et al. (2016) estimated the sector wise fertilizer consumption in horticulture. These estimates showed that today horticulture sector requires(Table 1) about 9.30 million tons of NPK fertilizers. The decadal trends haveshown that the consumption of NPK fertilizers in horticulture sector increased by 119%. Individual sector wise the fruit crops showed an increase by 153%, vegetables by 109% and plantation crops by 17%.

Soil and plant analysis

Fruit crops ,because of their deep root ramification, can take nutrients from deeper soil layers. Therefore, the general soil testing programme in which fertility status of 15 cm soil layer is assessed is not useful for fruit crops. Soil sampling from different layers up to 1.5 m will provide a better assessment of soil fertility status for fruit crops. Nutrient status of plant leaf is a better indicator of proper plant nutrition. Sampling of the particular plant portion provides better diagnosis of nutrient deficiency in the fruit crops. The plant part to be sampled and other conditions related

Table1- Horticulture sector wise NPK requirement(Kgs) during 2003-04 and 2013-14

Sector	2003-04			Total	2013-14			Total	% increase over the decade
	N	P_2O_5	K_2O		N	P_2O_5	K_2O		
Fruits	738857	393080.5	683162	1815100	1724261	1080930	1777036	4582226	153
Vegetables	475215	450647.5	506230	1432093	1032882	922450	1033186	2988518	109
Flowers	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aromatic & Medicinal Plant Crops	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plantation Crops	322500	157645	525940	1006085	383350	185130	607560	1176040	17
Spices	NA	NA	NA	NA	226785	151492.5	181486.5	559764	-
Grand Total	1536572	1001373	1715332	4253277	3367278	2340002.5	3599269	9306548	119

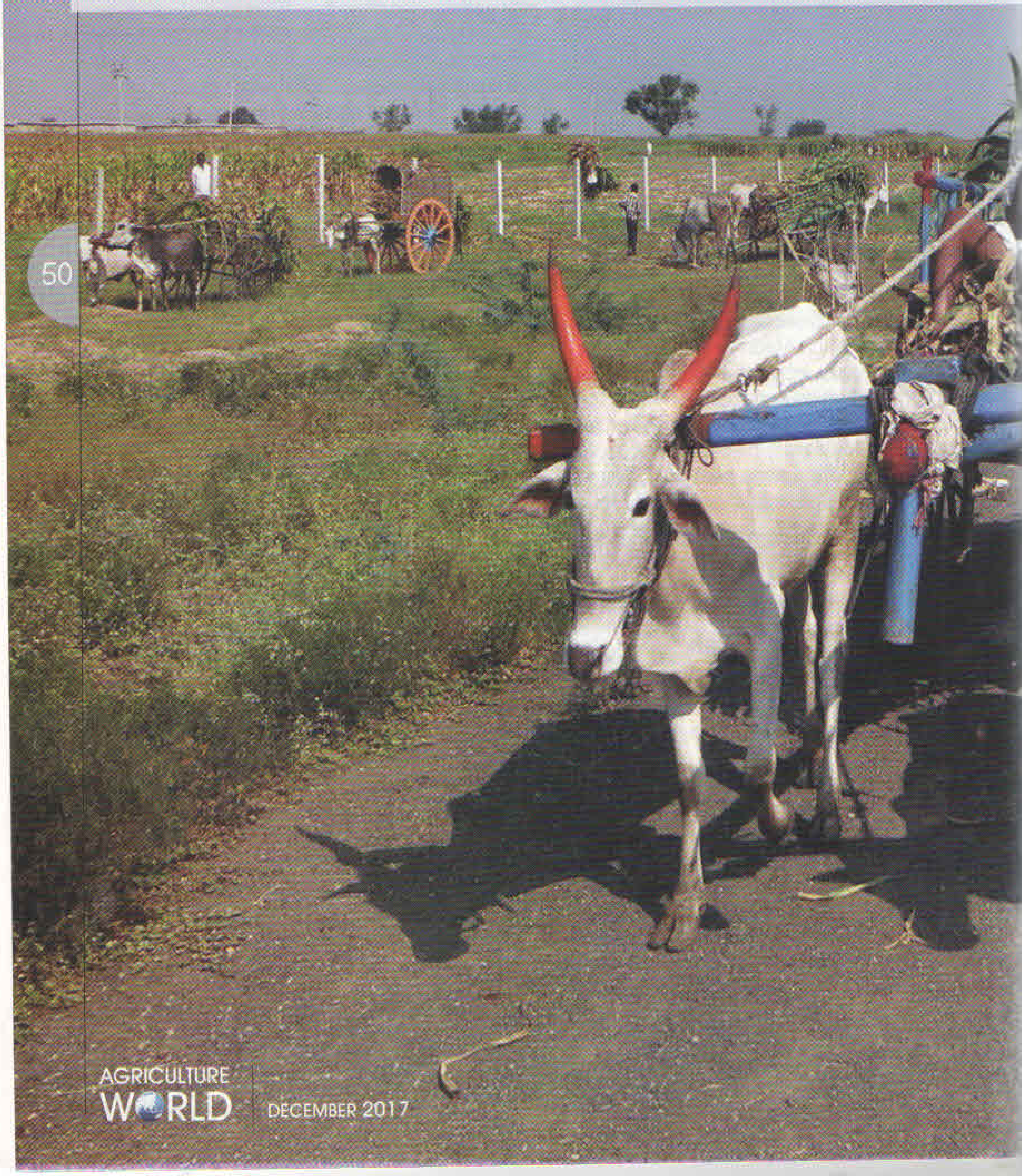


Table 2 - Plant Tissue Sampling Guidelines for Horticultural Crops

Crop	Plant part	Growth Stage/ Time
	Fruit Crops	
Banana	Petiole of 3rd open leaf from apex	Bud differentiation stage.
Cashew	4th leaf from tip of matured branch	At beginning of flowering
Custard Apple	5th leaf from apex	2 months after new growth
Fig	Fully expanded leaves, mid shoot current growth	July-August
Grapes	5th petiole from base	Bud differentiation stage for yield forecast. Petiole opposite to bloom time for quality
Citrus	3 to 5 month old leaf from new flush. 1st leaf of the shoot	June
Guava	3rd pair of recently matured leaves	Bloom stage (August or December)
Mango	Leaves + Petiole	4 to 7 months old leaves from middle of shoot
Papaya	6th petiole from apex	6 months after planting
Passion Fruit	Matured leaf opposite to last open flower	Bloom.
Pineapple	Middle 1/3rd portion of white basal portion of 4th leaf from apex	4 to 6 months.
Pomegranate	8th leaf from apex	Bud differentiation. In April for February crop and August for June Crop.
Sapota	10th leaf from apex	September
Phalsa	4th leaf from apex	One month after pruning
Ber	6th leaf from apex from secondary or tertiary shoot	Two months after pruning
	Vegetable Crops	
Bean	Upper most recent fully developed trifoliate leaves	
Cabbage	Wrapper leaf	2-3 months old
Carrot	Most recent fully matured leaf	Mid-grown
Cauliflower	Most recent fully matured leaf	At heading
Peas	Most recent fully developed leaflet	First bloom
Cluster bean	1st fully developed leaf	
Cucumber	5th leaf from tip	Flower bud start to small fruit
Brinjal	Leaf blades with midribs minus petioles from most recent fully developed leaf	
Garlic	Most recent fully matured leaf	Pre-bulb
Onion	Top-no white portions	1/3 to ½ grown
Tomato	Leaves adjacent to inflorescence	Mid bloom

Table 2 - Plant Tissue Sampling Guidelines for Horticultural Crops (Contd.,)

Crop	Plant part	Growth Stage/ Time
	Plantation Crops	
Coconut	Pinnal leaf from each side of 4th leaf	
Oil palm	Middle 1/3rd minus midrib of 3 upper and 3 lower leaflets from 17 frond of mature trees and 3rd frond of young trees	
Coffee	3rd or 4th pair of leaf from apex of lateral shoots	
Tea	Third leaf from tip of young shoots	
Clove	10th to 12th leaves from tip of non fruiting shoot	End of blooming period
	Ornamental crops	
Jasmine	Most recent fully developed leaf	
Chrysanthemum	4th leaf from tip, omit unfurled	Bud burst
Hibiscus	Most recent fully developed whole leaves	
Lilly	Most recent fully developed leaf	
Rose	Most recent fully developed compound 5th leaflet leaf	Flower bud pea size

Source: Ganeshamurthy and Raghupathi 2014

to their sampling is presented in Table 2.

Nutrients removed by horticultural crops:

Horticultural crops may absorb 500 to 1000 kg of NPK per hectare per year or even more under good management conditions. Many horticultural crops are heavy feeders and high yields can only be sustained through the application of optimal doses in a balanced proportion. Approximate quantities of nutrients removed by some important horticultural crops are given in Table 3. It is a general observation that the crop removal exceeds nutrients applied leading to mining of nutrients from soil in most of the cases. Only a part of the depleted plant nutrients are supplied through manures and fertilisers.

Nutrient management for horticultural crops is complex, requiring the integration of biological, chemical, and economic factors. Nutrient management for a sustainable horticultural production must include consideration of environmental, economical and social components. There is a need for integrated, balanced and effective fertiliser management to take care of proper replenishment and compensation of nutrient losses from soil and locked-up nutrients in the canopy of horticultural crops.

Fertilizer delivery techniques in fertigation of horticultural crops are sought for two reasons:

(i) Application of fertilizer in small doses spread across the entire growing season in an effort to match the crop nutrient requirements, to improve nutrient uptake efficiency, minimize losses, thus to maximize the returns per unit amount of fertilizer.

(ii) minimize nutrient leaching below the root zone, particularly of nitrate form of nitrogen, which can have negative impact on raising its concentration in the groundwater above the maximum contaminant limit that is recommended for drinking water quality.

In the case of large spacing planted tree crops, drip or under-the-tree micro sprinklers (micro irrigation) provide an opportunity to irrigate a certain portion of the total planted area, thus contribute to increased water uptake efficiency.

The advantages of localized soil fertigation include: combined application of water, fertilizers and pesticides with high precision and uniformity; improved distribution and control of water and nutrients in the soil; and the potential for application of water and nutrients in accordance with the demands of the plant.

Why fertigation in horticultural crops:

The advantages of fertigation are many. Among them the major are enhanced nutrient use efficiency and saving on water. For example if 100 kg of nitrogen is applied to soil then only 30 to 50 kg of this nitrogen can be used by the crop(Table 4). The same if applied through fertigation 95kg can be utilized. Similarly if water is applied through drip irrigation a lot of water can be saved even to an extent of 70% in many cases(Table 5).

There are different methods of fertigation. Unlike other methods of fertilizer application, fertigation is a bit complicated and farmers need to learn the technique before adapting to fertigation. The methodology adopted in the estimation of different parameters, including amount of fertilizers, frequency of fertigation, capacity of fertilizer tank, water requirement, capacity of drip system, injection rate and injection duration, has been discussed here:

Modern fertigation should be able to regulate:

- Quantity of fertilizer applied
- Duration of fertilizer applications
- Proportion of fertilisers
- Starting and finishing time.

Table 3 - Nutrient removal by some important horticultural crops

Crop	Yield, ton/ha	Nutrient removal (kg/ha)		
		N	P_2O_5	K_2O
Fruits				
Mango	15.0	100.0	25.0	110.0
Banana(Robusta)	57.5	322.0	73.0	1180.0
Citrus	20.0	22.0	12.0	57.0
Apple	29.0	18.0	2.0	40.0
Pineapple	84.0	150.0	45.0	530.0
Papaya	80.0	225.0	60.0	180.0
Grape	20.0	160.0	40.0	180.0
Vegetables				
Potato	28.0	202.0	50.0	225.0
Brinjal	60.0	175.0	40.0	300.0
Tomato	37.0	104.0	22.0	141.0
Cauliflower	50.0	250.0	100.0	350.0
Cabbage	37.0	112.0	28.0	112.0
Beans	35.0	130.0	40.0	160.0
Green peas	25.0	55.0	20.0	40.0
Lettuce	30.0	107.0	30.0	234.0
Spinach	25.0	120.0	45.0	200.0
Celery	20.0	140.0	55.0	220.0
Onion	30.0	73.0	36.0	68.0

Source: Ganeshamurthyet al., 2015

Mainly there are four systems in use. They are:

1. **Continuous application**- Fertiliser is applied at a constant rate from irrigation start to finish. The total amount is injected regardless of water discharge rate.

2. **Three-stage application**- Irrigation starts without fertilisers. Injection begins when the ground is wet. Injection cuts out before the irrigation cycle is completed. Remainder of the irrigation cycle allows the fertiliser to be flushed out of the system.

3. **Proportional application**-The injection rate is proportional to the water discharge rate, e.g. one litre of solution to 1000 litres of irrigation water. This method has the advantage of being extremely simple and allows for increased fertigation during periods of high water demand when most nutrients are required.

4. **Quantitative application**- Nutrient solution is applied in a calculated amount to each irrigation block, e.g. 20 litres to block A, 40 litres to block B. This method is suited to poly house grown crops and also for automation and allows the placement of the nutrients to be accurately controlled.

Fertilizers for fertigation

Only water soluble fertilizers can be used in fertigation. The important water soluble fertilizers are given below:

Speciality fertilizers

- Poly feed (19-19-19)

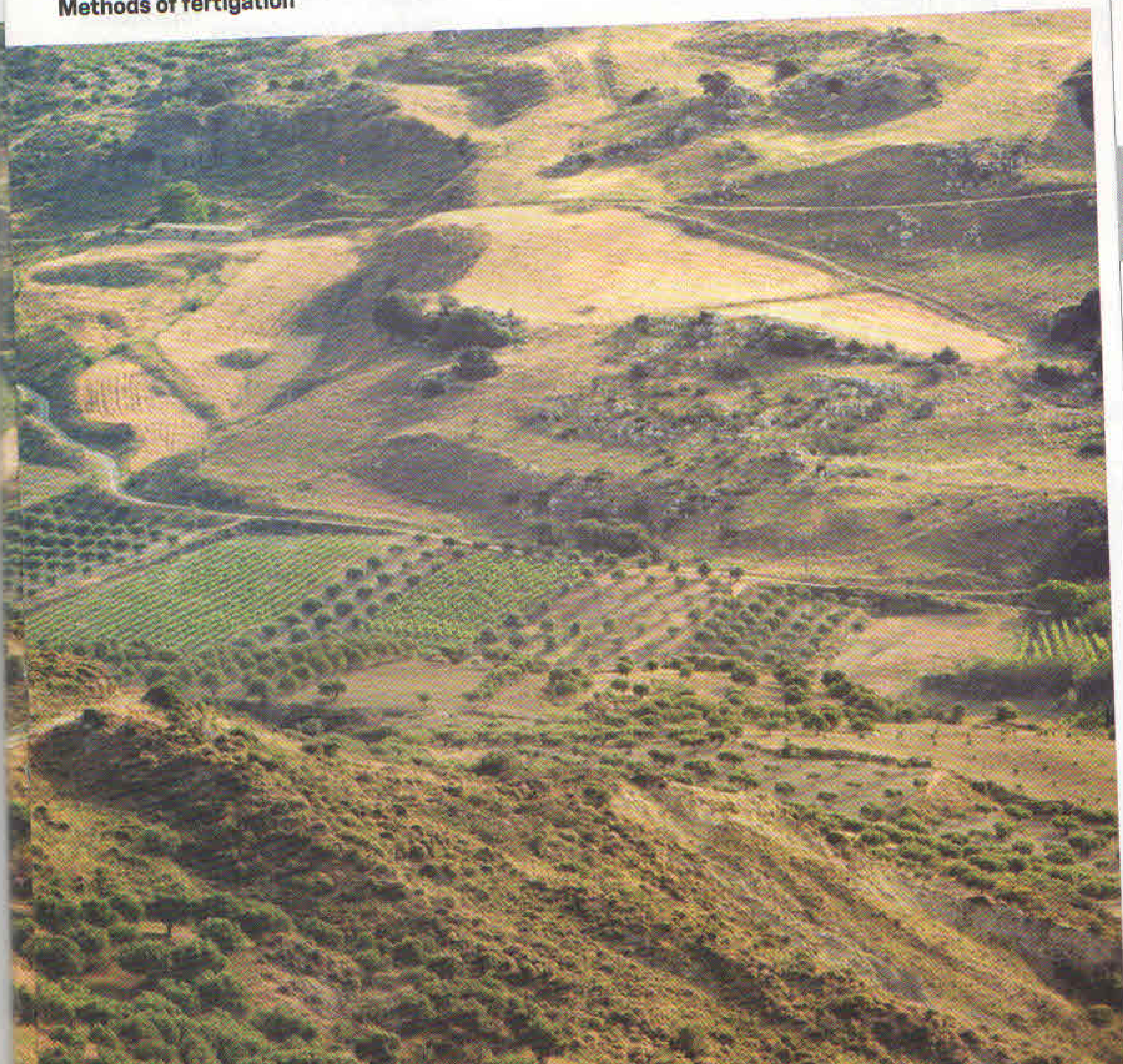
Table 4. A comparison of Fertilizer use efficiency under different application methods

Nutrients	Fertilizer use efficiency (%)		
	Soil application	Drip	Fertigation
N	30-50	65	95
P	20	30	45
K	50	60	80

Table 5. Water saving and Yield under fertigation

Crop	Water saving (%)	Yield(%)		
		Conventional Method	Drip	Fertigation
Banana	35	26	30	37
Sugarcane	29	120	160	207
Tomato	32	45	56	65

Methods of fertigation



- MAP (12-61-0)
- Multi -K (13-0-46)
- MKP (0-52-34) SOP (0-0-50)

Normal Fertilizers

- Urea (46-0-0)
- Muriate of Potash (0-0-50)
- Sulphate of Potash (0-0-60)

Injection methods and equipment

The selection of the correct injection equipment is very important. Incorrect selection of equipment can damage parts of the irrigation equipment, affect the efficient operation of the irrigation system and reduce the effectiveness of the nutrients. There are mainly three usual methods of injection:

1. suction injection
2. pressure differential injection
3. pump injection.

Suction injection:

This is the simplest method in which fertiliser is sucked through the intake of the pump. The pumping unit develops a negative pressure in its suction pipe (unless the suction is flooded). This negative pressure can be used to draw fertiliser solutions into the pump. A pipe or hose delivers the fertiliser solution from an open supply tank to the suction pipe. The rate of delivery is controlled by a valve. This connection must be tight to prevent air entry into the pump. Another hose or pipe connected to the discharge side of the pump can fill the supply tank with water. A high-pressure float valve can be used to regulate this inflow into the tank. If necessary the system can be automated with a direct-acting solenoid valve. For multiple block usage, two or more tanks can be set up in series and operated when required.

Advantages

- Very simple to operate; a stock solution does not have to be premixed.
- Easy to install and requires little maintenance.
- Ideal for dry formulations.

Disadvantages

- Concentration of solution decreases as fertiliser dissolves, placing most of the nutrients below the effective root zone if tank is operated when irrigation is commenced.
- Proportional fertigation is not possible unless several tanks are used.
- Limited capacity.
- Danger of suction air entering the pump unless all fittings are airtight.
- Risk of corrosion of pump bowl. Flushing the system is necessary.
- Risk of contamination of water supply if chemicals flow back down suction pipe when pumping unit stops. A check valve is necessary.

Pressure differential injection

A pressure differential tank system is based on the principle of a pressure differential being created by a valve, pressure regulation, elbows or pipe friction in the mainline, forcing water through a bypass pipe into a pressure tank and out again, carrying a varying amount of dissolved fertiliser.

This system has the following advantages

- Very simple to operate as the stock solution does not have to be premixed.
- Easy to install and requires little maintenance.
- Changing fertiliser is easy.
- Ideal for dry formulations.

However this system also has the following disadvantages

- Concentration of solution decreases as fertiliser dissolves, leading to poor placement of nutrients
- Requires pressure loss in main irrigation line.
- Tank must be able to withstand irrigation line pressure.
- Proportional fertigation not possible.
- Limited capacity.
- Accuracy of application is limited and determined by volume rather than by proportion.

Venturi system: A pressure differential venturi system can be installed as a bypass or inline. The venturi causes a rapid change in velocity producing a reduced pressure (vacuum) which draws the fertiliser solution into the line.Injection rates of 2 litres to 3000 litres per hour can be achieved.

Advantages

- Simple in design with no moving parts.
- Easy to install, requiring little maintenance.
- Fertiliser rates can be controlled with some accuracy.
- Low labour, as a month's supply of stock can be mixed in an inexpensive tank.
- Low cost.

Disadvantages

- Quantitative fertigation is difficult.
- Requires pressure loss in main irrigation line (can be 33%).
- Automation is difficult.

Pump injection

This is the most common method of injection of fertiliser into irrigation systems. Injection energy is provided by electric motors, impeller-driven power units and water-driven hydraulic motors. The pumps are usually rotary, gear, piston or diaphragm-type which deliver fertiliser solution from the supply tank into the pressurised mainline. This method can be very accurate. Pumps are generally not simple in design and can include a number of moving parts, so wear and breakdown are more likely. The three systems available are:

Electric injection pumps

Piston-activated pumps

Diaphragm-activated pumps.

Piston-activated and diaphragm- activated pumps

These are both hydraulic injection pumps and dominate the fertigation market at present. Electric injection pumps include single or multiple piston, diaphragm, gear and roller pumps. These can be regulated to achieve the desired rate by:

- Adjusting the length of the stroke of piston pumps
- Selecting the appropriate pulley diameter
- Using a variable-speed motor
- Semi-automation to adapt pump to receive electrical impulses from a water meter which can then be used to apply precise amounts of fertiliser.

Advantages

- Simple and effective.
- Relatively easy to install and maintain.
- Either proportional or quantitative fertigation is possible.
- No pressure loss in the main irrigation line. Suitable for high head systems.
- Automation is relatively easy.

Disadvantages

- Pumps must develop a minimum mainline pressure to operate.
- Need electric power source to operate.
- Injection rate not easily adjusted.

Piston-activated pumps

These are systems in which irrigation water operates a hydraulic motor that pumps the fertiliser solution into the system. Since the pump's maximum rate of injection is proportional to the pressure in the mainline, the required injection rate is easily adjusted by throttling the injection line by means of a valve fitted to the water main, and as the injection rate per pulse is known, the exact application of nutrients can be readily calculated. For high injection rates, two or more units can be operated in parallel. Injection rates of up to 320 litres/hour are possible.

Diaphragm-activated pumps

In this ,the water is pumped into the lower chamber that activates a rubber diaphragm in the drive unit which forces the diaphragm up, and in doing so via a drive rod, forces the fertiliser out of the injector into the irrigation system. On the return stroke the spent drive water is discharged from the lower chamber of the drive unit while simultaneously fertiliser solution is drawn into the injector. The cycle is automatically repeated. Injection rates from 3 litres to 1200 litres per hour are possible. There is an upper limit to the pressure available and they might not operate on high head systems.

Advantages

Fertigation is the technique in which fertilizers go with the irrigation to plants. When combined with an efficient irrigation system both nutrients and water can be manipulated and managed to enhance the efficiency of fertilizer use and obtain the maximum possible yield of marketable production from a given quantity of these inputs

- Very simple to operate, install and maintain. Either proportional or quantitative fertigation is possible.
- Rate of injection is easily adjustable.
- System is easily portable between paddocks.
- No pressure loss in main irrigation line.
- Automation is very easy.
- Not labour intensive.

Disadvantages

- Large number of working components.
- Sensitive to air pockets and needs a continuous water discharge to operate the piston or diaphragm. Pumps require a minimum line pressure.
- Spent 'drive water' is lost and discharged from the system.

Management

The effectiveness of fertigation is often dependent on the effectiveness of the irrigation system. The full advantages of irrigation and fertigation only become evident if the correct irrigation design is employed to meet plant requirements and to distribute water and fertiliser evenly. Because of the corrosive nature of many fertilisers, the components of the irrigation system that come into contact with corrosive solutions should consist of stainless steel, plastic or other non-corrosive materials. Concentrations of total nutrients in the mainline should not exceed 5 grams/litre. Always mix fertilisers in sufficient volume of water. The following formula can be used to determine the injection rate:

Maximum injection rate = $(5 \times Q \times L) \div (F \times 60)$

where:Q=irrigation pump discharge in litres per second, L = fertiliser tank volume in litres and F = amount of fertiliser in grams

For each crop there are many fertiliser programs. Fertigation allows you to change your program during the growing season, adjusting it to suit fruit, flower, shoot and root development. A program should be developed on the basis of leaf and soil analysis and tailored to suit the actual crop requirements. The majority of injectors available today can generally incorporate automatic operation by fitting pulse transmitters which convert injector pulses into electric signals. These signals then control injection of pre-set quantities or proportions relative to flow rate of the irrigation system. Injection rates can also be controlled by flow regulators, chemically resistant ball valves or by electronic or hydraulic control units and computers. If fertilisers are not completely dissolved and mixed prior to injection into the system, this may result in varying concentrations applied or blockages within the system. Suitable anti-siphoning valves or non-return valves should be installed where necessary to prevent backflow or siphoning of water, fertiliser solution, chemical solution etc. into fertiliser tanks, irrigation supply, household supply, stock supply and so on.

System hygeine

ertigation increases the quantity of nutrients present in an irrigation system and this can lead to increased bacteria, algae and slime in the system. These should be removed at regular intervals by injection of chlorine or acid through the system.

Chlorine injection should not be used while fertiliser is being injected into the system as the chlorine may precipitate these nutrients making them unavailable to the plant.

Systems should always be flushed of nutrients before completion of irrigation.

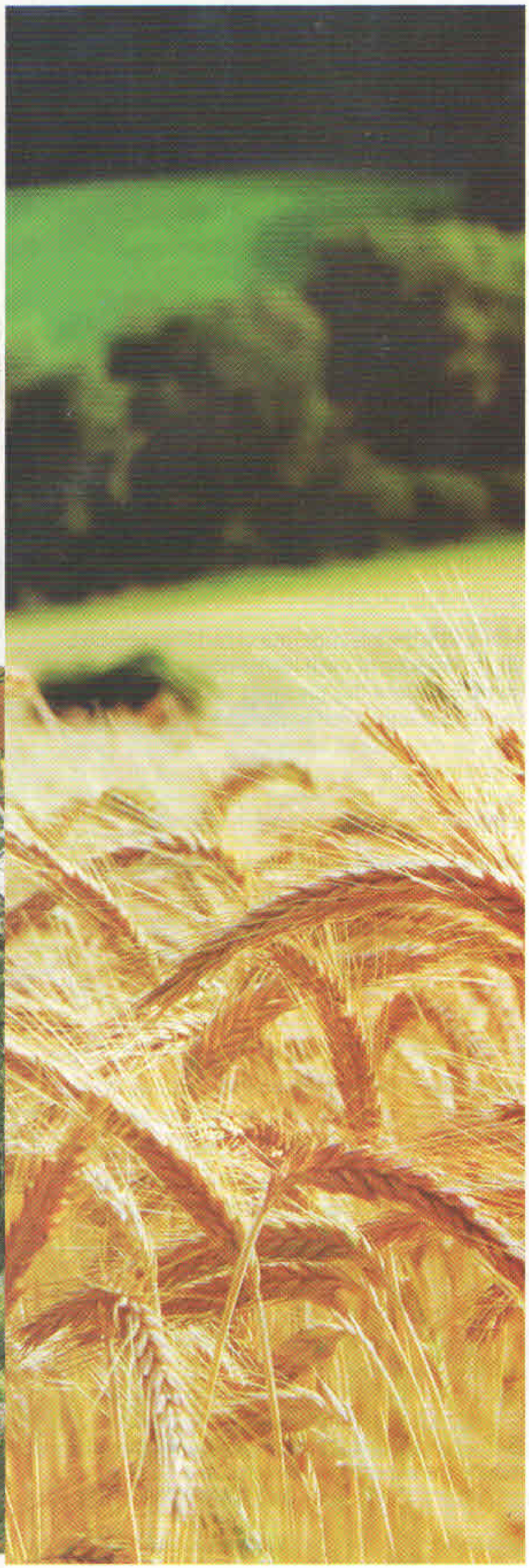
Before commencing a fertigation program, check fertiliser compatibilities and solubility.

During the irrigation season it is important to monitor:

- pH effects over time in the root zone
- soil temperature effect on nutrient availability
- corrosion and blockages of outlets
- reaction with salts in the soil or water.

Amount of Fertilizer Required

The amount of nutrients to be applied during any given fertigation and the total amount to be applied during the crop season depend on the frequency of fertigation, soil type, nutrient requirements of the crop and its availability in the soil. The nutrients applied to soil by the fertilizers are not fully available to the plant due to leaching, runoff, volatilization and adsorption losses. Therefore, a correction factor suggested by Tisdale is used to compensate for these losses. Required amount of fertilizers can be estimated as follows:



Horticulture sector requires about 9.30 million tons of NPK fertilizers. The decadal trends have shown that the consumption of NPK fertilizers in horticulture sector increased by 119%. Individual sector wise the fruit crops showed an increase by 153%, vegetables by 109% and plantation crops by 17%.

$Fn = R \times Fcf$

where, Fn is the nutrient requirement, kg/ha; R, recommended dose of fertilizer for the crop, kg/ha; and Fcf is the fertilization correction factor. If nutrient content of a given fertilizer is n%, then the actual amount of fertilizer (RF, kg/ha) required to meet the nutrient requirement can be estimated as follows.

$RF = b\ Fn \times 100g/n$

Frequency of Fertigation

The frequency depends on irrigation scheduling, soil type, nutrients requirement of crop and the farmer's preference. Fertilizers can be injected into the irrigation system at various frequencies such as once a day, once on alternate days or even once a week. In any case, it is extremely important that the nutrients applied in any irrigation are not subject to leaching either during that irrigation or during subsequent irrigations.

Capacity of Fertilizer Tank

The stock solution is prepared by dissolving the granular fertilizer in water. The amount of water needed to dissolve the required amount of granular fertilizer depends on its solubility. Depending upon the compatibility of the granular fertilizers, either one stock solution of N-P-K fertilizers or different stock solutions of N, P and K fertilizers are prepared separately. Stock solutions could be prepared for each fertigation or for injection during fertigations over a period of time. The capacity of fertilizer tank is calculated on the basis of frequency of fertigation, area irrigated in one application, application rate and concentration of stock solutions prepared for fertigation using the following formula:

$Vt = RF\ b \times Ag/bC \times nfg$

Horticultural crops may absorb 500 to 1000 kg of NPK per hectare per year or even more under good management conditions. Many horticultural crops are heavy feeders and high yields can only be sustained through the application of optimal doses in a balanced proportion

WhereVt is the capacity of fertilizer tank, l; C, concentration of the fertilizers in the stock solution, kg/l; nf , number of fertigations during the crop season and A is the irrigated area, ha.

Irrigation water requirement

Irrigation water requirement is estimated on the basis of monthly pan evaporation data and crop coefficient as follows.

$$V = Ep \times Kp \times Kc \times Cc \times A \times 10$$

where V is the total irrigation water requirement, l; Vd = (V/N), average daily water requirement, l/day; Kc , crop coefficient; Cc , canopy factor, (Cc = wetted area per plant area = 1.0 for field crops); Kp , pan coefficient (generally it is 0.8); Ep , total pan evaporation during the crop period, mm; and N is the crop duration, days.

Capacity of drip system

Capacity of drip system depends on the irrigation water requirement, daily operating hours, irrigation interval and water application efficiency. Drip irrigation system can be operated even for 24 h but only the required quantity of water is to be given. For the purpose, appropriate dripper capacity should be selected based on the infiltration rate of the soil and the water demand of the crop. It is advisable to irrigate through drip irrigation daily to avoid moisture stress to plants. Capacity of drip system is estimated using the following relationship.

$$Q=Vd \times T/(b\ \eta a \times tg)$$

where Q is the capacity of drip system, l/h; T, irrigation interval, days; La , water application efficiency (in fraction); and t is the duration of each irrigation, h.

Injection duration and rate of fertilizer solution

The fertilizer injection duration depends on the type of soil, nutrient and water requirements of the crop. A maximum injection duration of 45 min to 60 min is generally recommended with enough time for flushing of fertilizer residues from the drip lines before shutting the pump off. Injection rate refers to the volume of fertilizer, solution injected during a specific period of time. To inject the fertilizer solution at predetermined injection rate, the selected fertilizer applicator should be calibrated before starting the fertigation. After calibration, the duration of injection for different fertilizers may change as it depends on the concentration of the fertilizers in the stock solution and the desired quantity of nutrients to be applied during any fertigation. The discharge through the applicator depends on the duration of irrigation as well as on fertigation. The following equation may be used to determine the injection rate of fertilizer injector.

$$Qi=(RF \times A)/(nf \times C \times tf)$$

where Qi is the injection rate of fertilizer solution, l/h; tf , duration of each fertigation, h. If different stock solutions are prepared for supplying different nutrients, their respective injection rates may be determined separately. Selecting injection rate of any one nutrient, fertilizer injector is calibrated and then revised injection periods for different stock solutions are determined.

Concentration of nutrients in irrigation water

The actual concentration of nutrients needed in irrigation water depends on the fertilizing material and the crop requirement. The nutrient concentration in irrigation water can be determined as follows.

$$Cf=Fn \times 106\ Vd \times nf \times Rt\ e\ j/b\ g$$

whereCf is the concentration of nutrients in the irrigation water, ppm; and Rt , is the ratio between fertilization time and irrigation time (tf /t).

Fertigation is a very efficient method of nutrient supply to horticulture crops. The method requires initial investment and farmers require learning about this method for applying in their fields. Fertilizers used in this method are not the same used in general agricultural crops. They must be fully water soluble. Different methods of fertigation are available. Farmers may choose any of the methods depending upon the nature of crop, soil and terrain. By using this method of nutrient application farmers can save water and reduce the expenditure on fertilizers.