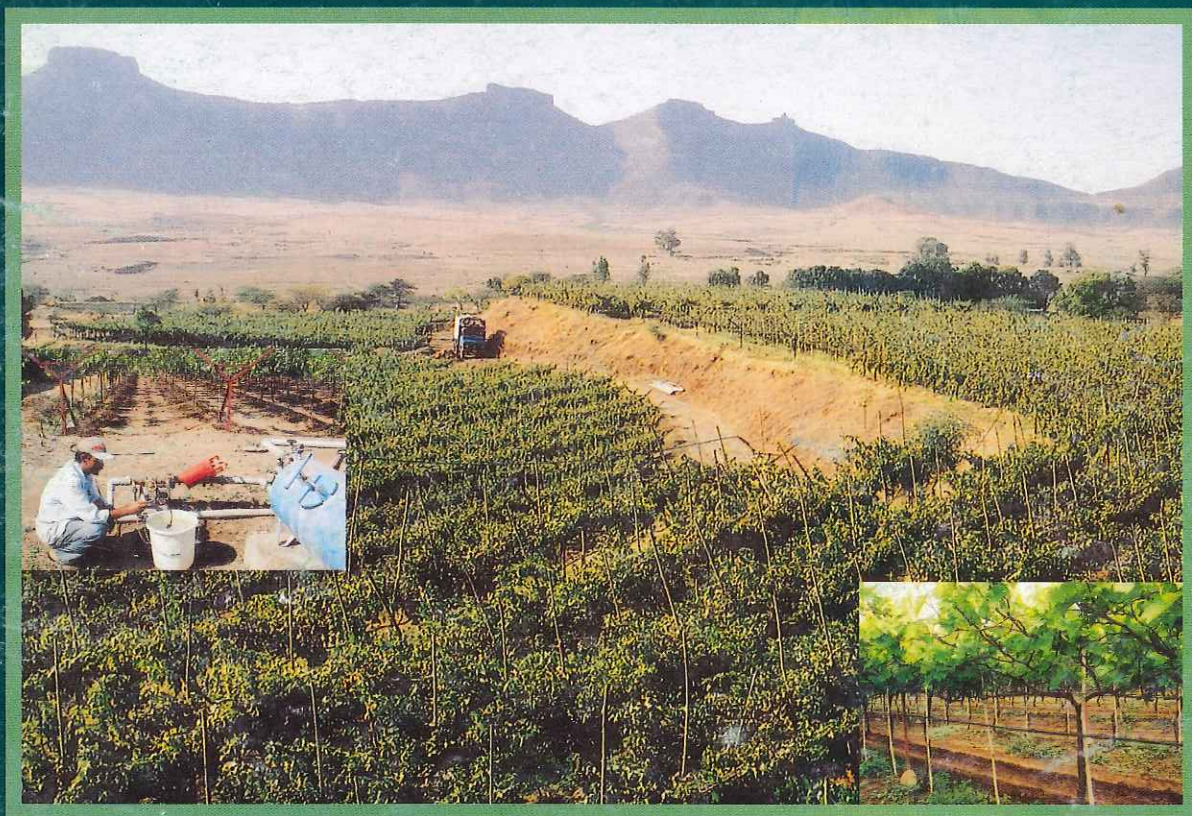


# Fertigation in Grapes

Jagdev Sharma



**NATIONAL RESEARCH CENTRE FOR GRAPES**

(Indian Council of Agricultural Research)

P. B. No.3, P.O. Manjri Farm, Solapur Road, PUNE - 412307.

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## Preface

Fertigation is an important technique in viticulture for the efficient use of both the nutrients and the water which account significantly for total cost of production in grape cultivation. Fertigation has many advantages in terms of better distribution and higher uniformity of fertilizers, better and immediate penetration of nutrients, lower nutrient losses from the soil surface and thereby less pollution of underground water resources, control of dose as per the stages of crop, saving of labour and convenience. However, its application has only some limitations like high cost of commissioning initially and the cost of liquid fertilizers and nutrients.

Considering the importance of this technique in efficient use of fertilizers, nutrients and water, and its labour saving and convenience, it is receiving good response from grape growers and therefore, an attempt has been made to compile all the research and technical information, generated so far by the Centre and the elsewhere in the form of bulletin entitled 'Fertigation in Grapes'.

This bulletin contains various topics on the fertigation viz. fertilizer properties and their quantities, equipments used for the application of fertilizers, choice of fertilizers, irrigation water quality in combination with fertigation, nutrient needs of crop at various stages using this technique and its impact on yield and quality. This information will certainly give more insight in application of this technique in reducing the total cost of production. Furthermore, the recommended fertigation schedule given in the bulletin will precisely apply the fertilizers, nutrients and water at various stages of berry development and thereby regulate the total yield with appropriate quality. The information given in the bulletin will serve as guidelines for the grapevine growers for deciding fertigation requirements at various stages of crop. Further, this bulletin will be handy information not only to the grape growers but also for students and researchers engaged in this line of work. I also take this opportunity to acknowledge the help of all the concerned of this Centre in the preparation of this bulletin.

Place : Manjri, Pune

Date : April 2003



**P. G. ADSULE**

(Director)

## **1. Introduction**

Heavy soil applications of fertilizers aggravate the soil salinity related problems and also result in more nutrient losses in the form of fixation, leaching and volatilization depending upon the type of nutrient. To cope up with the problems of soil salinity and irrigation water scarcity, growers have installed drip irrigation system. Since under drip irrigation system only a limited soil volume is wetted, the fertilizers are also to be applied in wetted zone only. Incorporating fertilizers in irrigation water is a vital part of drip irrigation. The success of drip irrigation is to a good degree, due to improved supply of nutrients to the plants. Drip irrigation is widely used in grapes and other methods of fertilization are less suited for this system of irrigation.

### **1.1 Need for fertigation**

Fertilizers alone account for about 50 per cent of the total input costs in grape cultivation. Fertilizer use efficiency is very low in grapes due to various biotic and abiotic stresses as a result of which heavy doses of fertilizers are applied. The vines are considered inefficient users of nutrients applied in soil and only 5–10 % of N, 5–7 % of P and 6–12 % of K are utilized by vines (Jacob and Uexkell, 1958), therefore, the heavy doses seem to be justified (Madhavrao, 1972). Majority of the grape growing areas in India fall under the semi-arid climate. The fertilizer use efficiency is low in these areas mainly because of unfavourable soil conditions (heavy or sandy soil texture, high pH, high lime content, poor physical properties, soil salinity and sodicity) and irrigation water quality (high soluble salt content and scarcity of irrigation water). Under such circumstances fertigation improves the nutrient use efficiency to a greater extent.

## **2. What is fertigation?**

Application of nutrients through irrigation water is generally referred to as fertigation. This allows flexible fertilizer programmes, which are not feasible in case of direct soil application. The main advantages are control of timing, concentration, location and proportion of the nutrients. Fertigation is adaptable to all pressurized irrigation methods such as sprinkler, drip, micro-sprinkler and center pivot etc. being used in variety of crops. In water scarcity areas drip irrigation is widely used in Indian viticulture.

### **2.1 Advantages of fertigation**

Fertigation offers many advantages over conventional method of soil application. Some of the advantages are highlighted here.

### **2.1.1 Higher efficiency**

- i. Better distribution and higher uniformity of fertilizer application as a result of their application in dissolved form in irrigation water.
- ii. Better and immediate penetration of fertilizers into the soil.
- iii. The possibility of dividing the yearly amount of fertilizer into many small applications, thus increasing availability.
- iv. Lower nutrient losses from the soil surface, for example, nitrogen loss due to volatilization.
- v. The possibility of adjusting fertilization to the needs of each crop growth stage.
- vi. Reduction in doses of applied nutrients (Sharma *et. al.* 2002 and Smith *et. al.* 1979).
- vii. The technique is thought to be particularly suited to sandy soils for minimizing leaching losses (Hayens, 1986).

### **2.1.2 Control of fertilizer dose**

- i. Accurate fertilizer quantities may be applied through automatic control system in accordance with a pre-established schedule.
- ii. The possibility of full control over process allows the application of micro-elements through the irrigation system. Micro-elements are usually expensive and by repeatedly applying small doses during an extended period, we are able to increase their availability significantly.
- iii. Fertigation adapts easily to automatic irrigation control system, increasing the precision.
- iv. Fertigation allows maintaining a proper nutrient levels in poor soils of low nutrient retention capacity, and thereby enabling farming of marginal soils.
- v. Properly managed fertigation may reduce ground water pollution (Willis and Davis, 1991).

### **2.1.3 Saving labour and convenience**

- i. Since fertigation easily adapts to irrigation system the labour savings are great particularly in automatic system (Colapietra, 1987).
- ii. Operation is fast and convenient.
- iii. A single person can operate the whole system from control head and thus dependency on labour is reduced.

### 3. Fertilizer properties and its requirement

#### 3.1 Fertilizer properties

It is most important to understand the fertilizer properties before going for their application to achieve maximum use efficiency.

##### 3.1.1 Elemental composition

N, P, K content in all types of fertilizers is expressed as per cent. The expression of nitrogen is always as pure nitrogen. Phosphorous and potassium have traditionally been expressed in oxide forms ( $P_2O_5$  and  $K_2O$ , respectively). The terms phosphate and potash indicate that this tradition is being followed. A combined fertilizer (9-4-8) given by a manufacturer without actually describing the compounds used for creating the fertilizers means 9 per cent N, 4 per cent  $P_2O_5$  and 8 per cent  $K_2O$  unless specified otherwise.

Conversion of P to  $P_2O_5$  and K to  $K_2O$

$$1 \text{ kg P} = 2.29 \text{ kg } P_2O_5$$

$$1 \text{ kg K} = 1.21 \text{ kg } K_2O$$

##### 3.1.2 Specific weight

It is important to know the specific weight in liquid fertilizers and when using liquid fertilizers, volume should be measured preferably.

$$\text{Specific weight} = \text{weight (kg)} / \text{volume (liter)}$$

e.g. phosphoric acid

$$\text{weight} = 1.7 \text{ kg}$$

$$\text{volume} = 1 \text{ liter}$$

$$\text{Specific weight} = 1.7/1.0 = 1.7 \text{ kg/liter}$$

##### 3.1.3 pH

In liquid fertilizers pH is measured in the genuine solutions. Solutions with a pH below 3.5 are considered to be highly corrosive to metals. Optimal availability of all the nutrients is in a pH range of 6.0 – 6.5. In high bicarbonate waters acidic fertilizers should be added to avoid or at least minimize precipitation of  $CaCO_3$ , which may clog the drippers. Electrical conductivity and pH of some of the commonly used fertilizers are given in table 1.



**Table 1. pH and EC of some fertilizers at a concentration of 1 g/l in distilled water**

Fertilizer	pH	EC (dS/m)
Ammonium sulphate	5.4	1.06
Urea	8.0	0.001
Liquid ammonium nitrate	6.6	0.87
Potassium nitrate	8.5	1.00
Mono-ammonium phosphate	4.0	1.00
Mono-potassium phosphate	4.5 – 5.0	0.75

### 3.1.4 Acidity and basicity of fertilizers

Acidic fertilizers are those which will increase residual acidity in acid soils or reduce the residual alkalinity in alkaline soils e.g. ammonium-N fertilizers (urea, ammonium nitrate, ammonium sulphate and ammonium phosphates etc.), phosphoric acid etc. while fertilizers which increase residual alkalinity in alkaline soils, or reduce the residual acidity in acid soils are called alkaline fertilizers e.g.  $\text{NaNO}_3$ .

### 3.1.5 Mixing compatibility

Mixing the solutions of two soluble fertilizers can sometimes result in the formation of a precipitate. Such cases indicate that these fertilizers are not mutually compatible, and special attention has to be paid to avoid mixing them in one tank. Their solutions should be prepared in two separate tanks. If two chemical compounds with a relatively high water solubility rate are mixed and new compounds with a lower solubility are created, this will always be the direction of reaction.

If  $\text{KNO}_3$  is mixed with ammonium sulphate, potassium sulphate will be created and excess amount of K in the solution will precipitate. High Ca, Mg and bicarbonate content in irrigation water will induce precipitation if phosphatic fertilizers are added.

**Table 2. Inter-compatibility of soluble fertilizers**

Fertilizer.....Abbr.	Ur	AN	AS	MAP	MKP	PN	PN+Mg	PN+P	SOP	CN	CaCl <sub>2</sub>	Mg+N
Urea.....Ur												
Ammonium nitrate.....AN	C											
Ammonium sulphate.....AS	C	C										
Mono-ammonium phosphate..MAP	C	C	C									
Mono potassium phosphate....MKP	C	C	C	C								
Multi-K (potassium nitrate)....PN	C	C	L	C	C							
Multi-KMg.....PN+Mg	C	C	L	L	L	C						
Multi-NPK.....PN+P	C	C	C	C	C	C	X					
Potassium sulfate.....SOP	C	C	C	C	C	C	C	C				
Calcium nitrate.....CN	C	C	L	X	X	C	C	X	L			
Calcium chloride.....CaCl <sub>2</sub>	C	C	L	X	X	C	C	X	L	C		
Magnesium nitrate.....Mg+N	C	C	C	X	X	C	C	X	C	C	C	
Magnesium sulfate.....MgS	C	C	C	X	X	L	C	X	C	L	L	C

C – Compatible, L – Limited compatibility, X – Incompatible

Table 2 makes it clear that neither phosphoric nor sulphate fertilizers should be mixed with calcium fertilizers in the same tank. This separation prevents precipitation of calcium phosphate or calcium sulphate compounds in the tank or in the pipeline.

### 3.1.6 Solubility for fertigation

Fertilizers that are used in fertigation system must have a high rate of solubility. e.g. urea, ammonium nitrate, ammonium sulphate, mono-ammonium phosphate, phosphoric acid and potassium nitrate etc. to name a few from many grades available in the market.

### 3.1.7 Hygroscopicity

Hygroscopicity refers to the moisture absorption by the solid fertilizers from atmosphere. Moisture absorption results in clod formation. Their application in solid state is difficult and non-uniform. Some manufacturers add additives to fertilizers to avoid moisture absorbance, however, most of the additives are insoluble and may clog the emitters.

### 3.1.8 Time and length of storage

Some chemical compounds decompose after a certain period of time. It is important to know this duration and not to store those fertilizers longer than the recommended time.

### 3.1.9 Influence of temperature on solubility of fertilizers

Solubility determines the amount of water needed to dissolve the fertilizers for fertigation. Solubility of fertilizers is affected by temperature. Solubility of some of the commonly used fertilizers is given in table 3.

**Table 3. Fertilizers and their solubility at various temperatures**

	Solubility (g/l) in distilled water	
	20°C	30°C
Ammonium sulphate	750	780
Urea	1060	1330
Potassium sulphate	110	130
Potassium nitrate	320	460
Mono-potassium phosphate	226	280
Mono-ammonium phosphate	374	464
Magnesium nitrate	225	256
Magnesium sulphate	71	91

### 3.1.10 Contribution to salinity

With the exception of urea all liquid fertilizers are salt solutions. They increase the salinity of irrigation water. There is a relationship between the concentration of dissolved salts, expressed in milliequivalents per liter and EC of the solution. Each 10 milliequivalents of salts per liter contribute to 1 decisiemen per meter (dS/m) to EC. The increase in EC is not linear to the increase in fertilizer solution concentration.

## 3.2 Fertilizer requirements

### 3.2.1 Determining the desired amount of fertilizers to supply the nutrients

This can be determined by the following equation when solid fertilizers are used :

$$F_w = 100 \times N_w / N_c (\%)$$

$F_w$  = Fertilizer dose (kg / acre or ha)

$N_w$  = Nutrient dose by weight (kg / acre or ha)

$N_c$  = Nutrient concentration in fertilizer

$N_c$  (%) is 46 for urea, 33 for ammonium nitrate and 21 for ammonium sulphate.

e.g. if 260 kg N / acre is recommended then 565.22 kg urea or 787.88 kg ammonium nitrate or 1238.09 kg ammonium sulphate will be required .

In case of liquid fertilizers:

$F_v$  = fertilizer volume (l /acre or ha)

$F_w$  = Fertilizer dose (kg/acre or ha)

$S_w$  = Specific weight of fertilizer solution (varies with fertilizer).

e.g. if 65 kg of liquid ammonium nitrate ( $F_w$ ) per acre are recommended and  $S_w$  of the ammonium nitrate is 1.3 kg/litre.

$$F_v = 65/1.3 = 50 \text{ litre/acre}$$

Specific weight of unknown liquid fertilizer solution can be found out by the formula : specific weight = weight of fertilizer (kg) / volume (litres)

e.g.  $1.7 \text{ kg} / 1 \text{ litre} = 1.7 \text{ kg/litre}$

### 3.2.2 Dilution ratio and fertilizer solution concentration

This is the relation between the volume of the concentrated solution and the total volume of the final solution as calculated by the following equation:

$$F_c (\%) = 100 \times q / (q + Q)$$

$F_c$  = Fertilizer concentration in the irrigation water.

$q$  = Injector discharge rate (l/hr)

$Q$  = Irrigation system discharge rate (l/hr)

e.g. If 100 litre of liquid fertilizer per hour is ( $q$ ) injected in 1900 litres of water ( $Q$ ) then the dilution ratio will be

$$F_c (\%) = 100 \times 100 / (100 + 1900) = 10000 / 2000 = 5\%$$

## 4. Equipments for fertigation

### 4.1 Fertilizer injection equipments

Wide range of injectors namely fertilizer tanks, venturi and various injection pumps are available in the market for injecting the fertilizer solutions in to the irrigation water.

### 4.1.1 The batch tank system

The principle of operation includes a throttling valve, which forces some of the mainline flow through a batch tank, which is connected to mainline (Fig.1). Flow diversion from the main line is accomplished by a pressure gradient of 0.1 to 0.2 atmospheres.

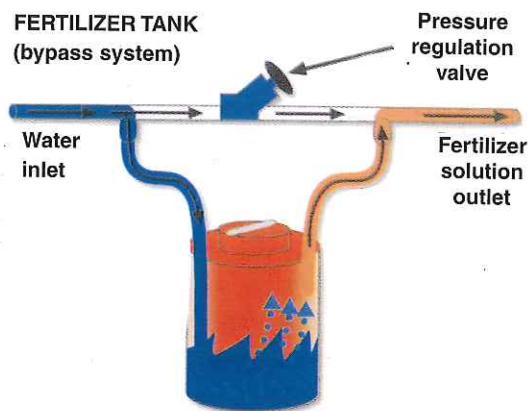


Fig. 1. Fertilizer tank.

The irrigation water enters the tank through 1/2" to 3/8" pipe and water with fertilizer solution flows into the mainline. The injection rate depends upon the pressure gradients (Table 4).

Four times water than the tank volume should pass through the tank to carry the fertilizer solution into the irrigation system. This is a time-tested device and has been in use since last 30 years.

Table 4. Pressure gradient and its injection rate in pipes of different diameter

Pressure gradient (atmosphere)	Injection rate 1/hr	
	Pipe dia. 1/2"	Pipe dia. 3/8"
0.1	660	320
0.2	990	500
0.3	1200	650
0.4	1350	760
0.5	1500	850
0.6	1650	940
0.7	1500	1030

### 4.1.2 Venturi injector

This injector operates on the venturi principle, where a flow constriction with specific entrance and exit design installed on pipeline, creates a vacuum due to increased velocity of flow through the constriction (Fig 2). The injection rate depends upon the pressure differential across it. This pressure differential is between 5% and 75% according to the injector's design. It operates with the pressure of the irrigation system and is light and portable and withstands corrosive materials. However, there are some limitations associated with it. It causes large pressure losses. Many models lose at least one third to half of the inlet pressure. Hence, where the inlet pressure is not high enough than the required pressure for operating drip irrigation system, its use should be avoided. Variations in pressure affect the injection rates.

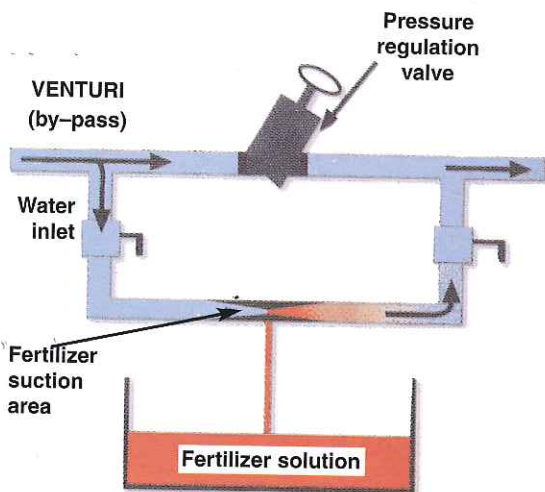


Fig. 2. Venturi injector

The inlet pressure required for the operation ranges from 1.4 bars to 9.8 bars (with suction hoses 12 mm in diameter) depending upon the model. Wide ranges of venturi injectors are available for use.

### 4.1.3 Injection pumps

A variety of pumps (diaphragm, piston, roller and gear pumps) are used for injecting the fertilizer solution from tank into the irrigation system. The pumps create higher pressure than existing in the irrigation system. The piston and diaphragm pumps are most commonly recommended due to their reliability and accuracy. The pumps provide continuous and uniform concentrations in the irrigation water. There is no pressure loss in the system. But these are costlier than batch tank and venturi.

Non-hydraulic pumps require external energy and only fertilizer solutions can be injected.

Comparison of ion concentration of chemicals in the irrigation water over time and potential distribution of fertilizers in the root zone for different injection methods is shown in Fig. 3 and 4, respectively. Among the various injection equipments fertilizer tank and venturi are most commonly used and are most suitable for Indian vineyards. However, where inlet pressure is low the fertilizer tank should be used.

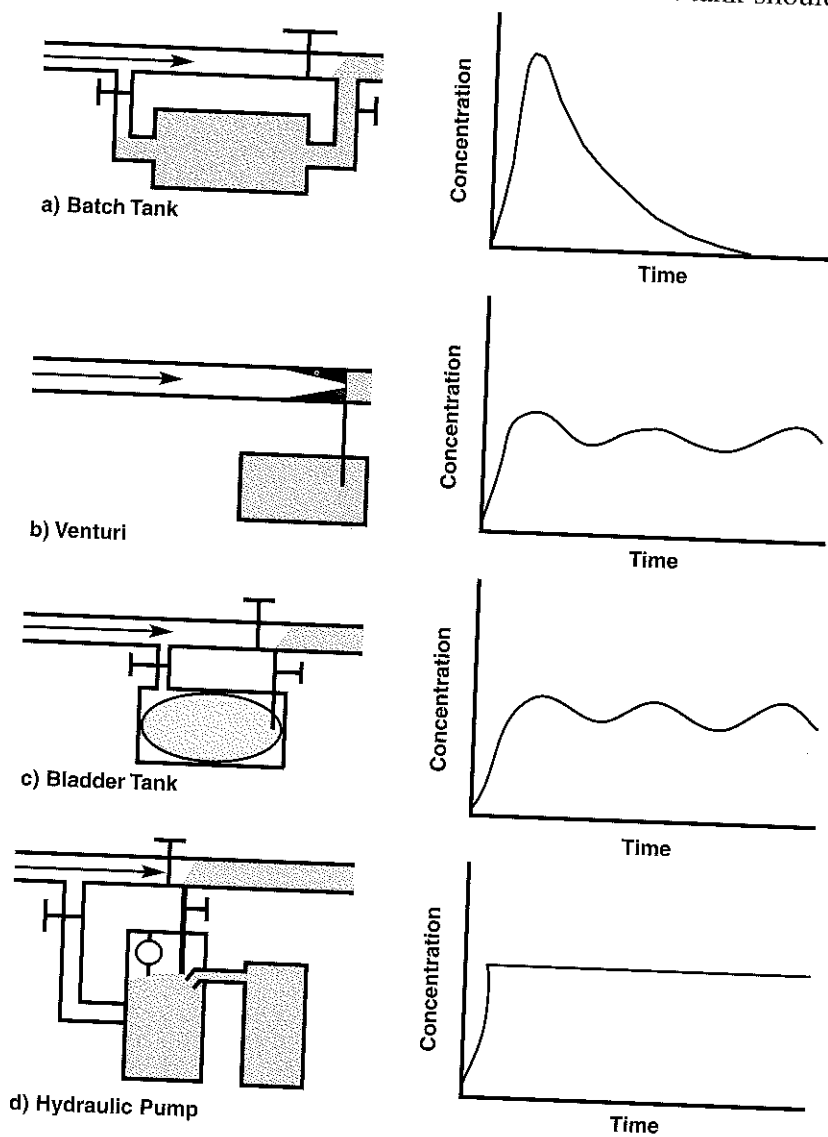
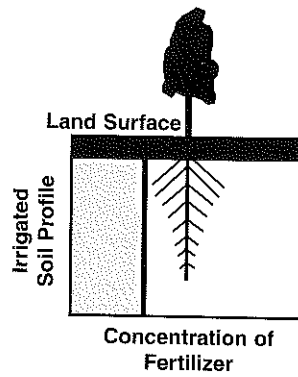
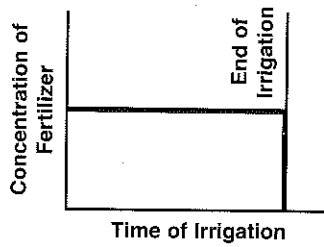
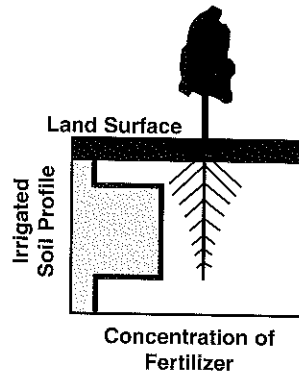
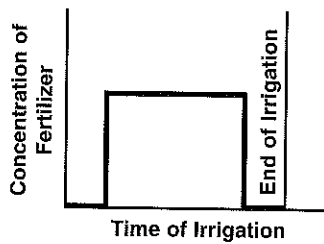


Fig. 3. Comparison of ion concentration of chemicals in the irrigation water over time for different methods of injection.

A) INJECTOR ALONE



B) INJECTOR + AUTOMATION



C) TANK METHOD

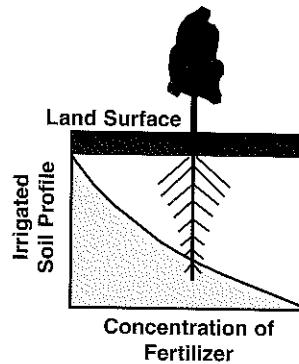
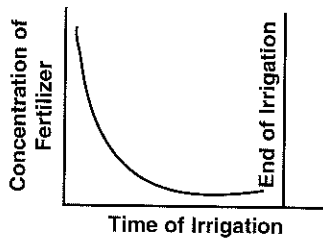


Fig. 4. Potential distribution of fertilizers in the root zone with different injection methods.

## 4.2 Equipment selection criteria for fertigation

Equipment for fertigation are manufactured in different types and models, differing in their properties, having advantages, limitations and different prices. The user should have the knowledge of discharge rate, capacity, energy requirement, reliability and accuracy of the equipments before buying to meet the individual requirement.



#### 4.2.1 Injector discharge

Knowing the capacity of the injection device enables us to calculate the amount of fertilizer solution we may inject into the irrigation system during the time available. To calculate the fertilizer requirement, the following equation is used.

$$q = A \times F_v/t,$$

$q$  = injector discharge rate (l/hr)

$A$  = Area (ha/acre)

$F_v$  = Fertilizer solution volume (litre/ha or acre),  $t$  = Injection duration (hr)

For example if 100 liters of fertilizer solution are to be applied per acre in two hours then the injector discharge should be

$$q = 1 \times 100/2 = 50 \text{ l/hr}$$

#### 4.2.2 Tank capacity calculation

Minimum volume ( $T_v$ ) of fertilizer in the tank to supply fertilizers during single irrigation turn is calculated with the following equation

$$T_v = F_v \times A$$

$T_v$  = Tank volume,  $F_v$  = Fertilizer solution volume e.g. 200 liters

$A$  = Area (ha/acre) e.g. 2.5 acres

$$T_v = 200 \times 2.5 = 500 \text{ liters}$$

#### 4.2.3 Energy requirement

A source of energy is required to make the injection possible. This energy may be in the form of hydraulic energy supplied by the pressure in the irrigation system, electricity or an internal combustion engine. The choice depends upon the price and availability.

#### 4.2.4 Reliability and accuracy

The equipment should distribute the fertilizer uniformly otherwise fertigation may cause losses.

### 5. Choice of fertilizers

In calcareous soils pH is buffered at around 7.5 thus  $\text{NH}_4^+$  containing fertilizers that produce insoluble calcium precipitates result in more volatilization losses e.g.  $(\text{NH}_4)_2\text{HPO}_4$ . In contrast, volatilization losses are reduced with  $\text{NH}_4^+$  containing fertilizers that produce soluble Ca product e.g.  $\text{NH}_4\text{NO}_3$ . The equation given below describes the fate of applied ammonium sulphate.



Since  $\text{CaSO}_4$  is only slightly soluble, the reaction proceeds to the right and  $\text{NH}_3$  volatilization is favoured.  $\text{NH}_3$  losses also increase with increasing fertilizer rate and with less liquid compounds than dry N sources.

Choice of P fertilizer sources depends upon the soil type. Ammonium polyphosphates due to its chelation or sequestering reaction with metal cations maintain higher concentration of micro-nutrients in solution. Mono-ammonium phosphate solution has pH of 3.5 compared to pH 8.0 for DAP and hence formation of insoluble P reaction products is reduced in calcareous soils. Agricultural grade green acid (phosphoric acid) containing 35–55%  $\text{P}_2\text{O}_5$  can be applied in the soil or irrigation water and it is particularly effective in alkaline and calcareous soils. Application of organic matter results in formation of organophosphate compounds which are more easily assimilated by plants. Organic matter also reduces the contact of the fertilizer with the soil thereby reducing the fixation. During the decomposition of the organic matter several organic acids are produced which also help in solubilization of the fixed phosphates in the soil.

Potassium fertilizers like  $\text{KNO}_3$ ,  $\text{K}_4\text{P}_2\text{O}_7$ ,  $\text{K}_2\text{HPO}_4$  etc. being high analysis fertilizers with low salt index are more effective in saline-alkaline conditions. Potassium sulphate has the advantage of supplying sulfur and is best source of K under high pH and calcareous soils. Absorption of K is fast when applied in  $\text{KNO}_3$  form but it also supplies N which is not desirable in the later stages (ripening period). In case of deficiency, sulfates are more beneficial than elemental sulfur because conversion of S to  $\text{SO}_4^{2-}$  is not a rapid process. Apart from soil condition the choice of fertilizer is also influenced by crop growth stage and climatic conditions.

## 6. Irrigation water quality and fertigation

The fertilizers or any other chemicals applied through water interact with the components of irrigation water. There are number of fertilizers that increase the pH of the irrigation water and cause the precipitation of the salts thereby blocking the irrigation system. The problems associated with fertigation increase when the total dissolved salts in the irrigation water exceed 500 ppm. Analysis of individual cations and anions is necessary because EC is not true measure of the potential hazards associated with different ions. Hence irrigation water should be analyzed for calcium, magnesium, sodium, manganese, iron, boron, nitrates, sulphates, chlorides, carbonates, bicarbonates, pH, EC, RSC (residual sodium carbonate) and SAR (sodium adsorption ratio). Calcium concentration in the water plays a crucial role in the formation of precipitates (insoluble compounds). In calcium rich waters use of sulphate fertilizers results in formation of gypsum whose solubility is low. The

solubility of the gypsum also decreases with increase in temperatures, so the problem of precipitation is aggravated particularly in summers.

Water containing high bicarbonates is likely to induce Fe-deficiency. Polyphosphates containing fertilizers react with Ca and Mg to form precipitates that clog filters and emitters. So it is better to apply these fertilizers directly to the soil where irrigation waters contain substantial amounts of Ca and Mg to prevent clogging.

### **6.1 Acidification of irrigation water for improved nutrient use efficiency**

Best results of fertigation are obtained when the pH of the irrigation water is around 6.5 – 5.5. At this pH calcium and magnesium remain in solution and do not cause precipitation. Since most of irrigation waters have alkaline pH, the fertilizers having acidic pH should be preferred. The data on acidity of the fertilizer supplied by various companies are generally based upon the resultant acidity in the distilled water and in practice we do not use distilled water for irrigation except in the greenhouses where de-ionised water is used for certain crops. Individual growers should test the resultant acidity i.e. the effect of fertilizer on reducing the pH of the water in the irrigation water, which is actually being used for irrigation to decide the choice between the fertilizers, as the cost differences may be substantial. In calcareous soils it is possible to use the irrigation water even having pH values less than 5.50 as the buffering capacity of these soils is very high. But low pH may corrode the system. The pH less than 3.50 cause more damage to the irrigation system.

Using certain acids like sulphuric, nitric and phosphoric can reduce the pH of water. Besides reducing the pH these acids also provide valuable nutrients namely S, N and P, which has to be considered while fertilizing the vineyards. Acids when used for reducing the pH react with bicarbonates of the water and convert it into  $H_2O$  and  $CO_2$ . The acid to be used should be handled with care by using gloves etc.

**Caution :** Never add water to the acid; always add acid to the water. The amount of acid required varies with the quality of the water.

## **7. Relative nutritional need of vines at different phenological stages**

Vine requirements for different nutrients vary at different growth stages. Higher levels of N are to be applied in the first 30 days after back pruning and 40 days after forward pruning to promote strong shoot growth for achieving desired canopy. Nitrogen needs are less during fruit bud differentiation period. Early application of N as compared to P and K was found to favour fruit bud differentiation (Srinivasan and Muthukrishnan, 1972). The requirement of P is more during the bud formation and bud differentiation period (30–60 days after back pruning depending upon the variety).

Phosphorous is needed for promoting root growth and fruit bud formation. Application of phosphorous 30–40 days after back pruning was found to favour fruitfulness in Anab-e-Shahi (Nanaya, 1966). Potash needs are relatively high during 61–90 days after back pruning as it makes fruit buds strong and bold, promotes cane maturity and diameter. Potash requirement is also high during the fruit growth and ripening period. According to Abdulla and Saffic (1965) more K is required one month after berry set as compared to bloom time. Potassium when applied 50 days after pruning stimulated cell differentiation for inflorescence primordia (Srinivasan, 1968). Later application of P and K (30–50 days after pruning) were found to promote fruitfulness in Anab-e-Shahi (Nanaya, 1966). More N and K contents in the leaves at flowering compared to fruit maturity have been reported by Shikhamany and Satyanarayana (1972). More magnesium is required during the fruit bud differentiation after back pruning. Magnesium acts as carrier for P and helps in better P utilization. Magnesium requirement is again higher during 71–100 days after forward pruning to prevent interveinal chlorosis and promote carbohydrate synthesis by leaves. Zinc is essential to normal leaf development, shoot elongation, pollen development and set of fully developed berries. Pollination and fruit set are physiological processes of the grapevine most sensitive to low boron levels at that time. Both Fe and Mn assist in chlorophyll formation and hence almost all the vine growth stages are sensitive to the deficiencies.

## **8. Effect of fertigation on yield and quality**

Colapietra (1987) observed higher yield and sugar content in berries as a result of fertigation. Availability of N, P and K fertilizers was increased by fertigation and was reflected in fruit and petiole analysis and improved yields compared with conventional methods.

Applying fertilizers via drip irrigation gave highest yield and economic viability (Schevchenko-IV, 1992). Potassium induced magnesium deficiency has been observed during fertigation as a result of enhanced K/Mg antagonism as compared to manual fertigation (Conradie and Myburgh, 2000)

In sandy soils increasing N and K rates beyond 80 and 60 kg/ha/year, respectively, did not increase the yield of Buketraube variety (Conradie and Myburgh, 2000). Sharma *et al.* (2002) observed 60 per cent saving in N, P, K doses as a result of fertigation in Thompson Seedless grapes in heavy soil of Maharashtra and increasing the fertilizer doses beyond 40 per cent of the recommended did not increase the yield. Fertigation also increased the fruit yield.

## **9. Recommended fertigation schedule**

The superiority of fertigation over conventional fertilization is evident from the above findings. Fertigation has become the need of hour in Indian viticulture also to

sustain the production of grapes and minimize soil and environment related hazards. The vines are normally pruned in the month of April (back pruning, also called as foundation pruning) and again in the month of October (forward pruning, also called as fruit pruning).

Keeping in view the nutrient requirement of vines at different stages, three fertigation schedules were tested in heavy soils using urea, phosphoric acid and potassium sulfate as N, P, K sources. The recommended fertigation schedule is given in Table 5 and economics of fertigation is given in Table 6.

**Table 5. Fertigation schedule for table grapes**

Growth stage (Days after pruning)	N (kg/ha)	P <sub>2</sub> O <sub>5</sub> (kg/ha)	K <sub>2</sub> O (kg/ha)
<b>Back pruning</b>			
Pre-bud differentiation (1-30 days)	80	-	-
Bud differentiation (31-60 days)	-	213.1	-
Post-bud differentiation (61-120 days)	-	-	80
<b>Forward pruning</b>			
Pre-bloom (1-40 days)	80	-	-
Bloom set and shatter (41-70 days)	-	106.6	-
Berry growth up to veraison (71-105 days)	80	-	80
Veraison to harvest (106-130 days)	-	-	80
After harvest (Rest period >20 days)	26.6	35.5	26.6
<b>Total</b>	<b>266.6</b>	<b>355.2</b>	<b>266.6</b>

**Table 6. Fertigation vis-à-vis soil application in relation to yield, quality & cost**

	Yield (t/ha)	TSS (°B)	Bunch No.	Bunch wt. (g)	Present ferti-lizer cost (Rs.)	Additional yield (t/ha)
Fertigation	35.4	23	64	310	39,674	3.3
Direct soil application	32.1	24	60	298	42,285	-

This fertigation schedule demonstrates the relative need of N, P and K at different stages of vine growth and their application after the particular stage does not give desired benefits. The nutrient doses given for fertigation should be modified according to the petiole nutrient status of the vines, as over the years nutrient build up in the soil increases. For better results fertigation interval should not be more than three days. The nutrient doses should be applied in equal splits depending upon the number of days in a particular stage as given in the schedule. Farm yard manure and other organic sources of nutrients should also be applied to maintain soil health and their contribution be considered while deciding the nutrient doses.

## 10. Making fertigation more efficient

### 10.1 Do's and Don'ts

- i. For uniform distribution of fertilizers the irrigation system pressure and discharge should be allowed to stabilize first. This may take from few minutes to half an hour depending upon the type of irrigation system and area being irrigated. Adding the fertilizers without pressure stabilization results in uneven distribution. Under these circumstances some of the plants will get more fertilizer, which may prove detrimental.
- ii. The fertilizers may damage the system components e.g. membranes of the pressure compensated drippers pressure regulators and metal parts. So the system should be flushed with clean water after fertigation is over for at least 10–15 minutes.
- iii. If the irrigation time is longer than the time required for fertigation, the fertigation should be towards the end of irrigation keeping a margin for flushing of the system. The different nutrients should be applied separately to avoid possible precipitation.
- iv. When  $\text{NO}_3^-$ -N is applied, to avoid leaching, it should be applied towards the end of the irrigation.
- v. In heavy soils it is preferred to apply larger quantities of  $\text{NH}_4^+$  and  $\text{K}^+$  in batch fertigation as they move slowly.
- vi. Chelates should not be used in irrigation water or fertigation solution having pH less than 3.5.
- vii. Applying more water than required will have triple negative effect in that fertilizers may be leached, more salts will be added to the soil and ground water will be polluted.
- viii. For fertigation/chemigation to be effective proper irrigation schedule should be followed and fertigation has to be timed as per irrigation schedule and not to time irrigation to suit fertigation.
- ix. Do not mix iron fertilizers with phosphoric fertilizers, as both of them will become ineffective. Similarly, zinc fertilizers should not be mixed with phosphatic fertilizers. By dissolving the above types of fertilizers together low solubility compounds are formed and actual function of fertigation gets defeated.
- x. Best way to feed the micronutrients is to feed them through soil as some of the micronutrients are highly immobile in the plant system. Chelated sources of micronutrients as well as ordinary soluble sources of the micronutrients can be easily applied through fertigation.
- xi. Each fertilizer injecting system requires a definite pressure for its operation, which should be born in mind to ensure proper and uniform distribution of the

- fertilizers. The details should be obtained from the manufacturer regarding the pressure and other requirements of the injectors.
- xii. Most important is applying the fertilizers at the right stage without which the entire fertigation/fertilization programme becomes ineffective.

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