Appropriate and Economical Use *of* Water in Grapevine cultivation

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Preface

Water is a very important input in both plant and animal life, besides its use for various purpose. Grapevine being perennial and commercial crop in rain fed areas, availability of water is of paramount importance. Further this has received more importance recently in drought prone areas due to continuous failure of rainfall consecutively for the last two years (2001–2003). Despite the use of most efficient and modern drip irrigation methods, the problem of availability of water and its quality is still influencing the grapevine cultivation in the country. Keeping this background in view, an earnest attempt has been made to compile all the research findings made so far by this Centre and also available in the literature and prepare this bulletin at appropriate time when the grapevine cultivation is threatened by the availability of water and its quality. This kind of situation is already prevalent in Sangli and Solapur districts of Maharashtra where major area prevails under this commercial fruit crop.

The bulletin entitled 'Appropriate and Economical Use of Water in Grapevine Cultivation' contains various topics on the use of water viz., need for water, symptom of moisture stress, effects of moisture stress and excessive irrigation, water quality and related factors, effect of saline water, appropriate use of water in grapevine following various techniques in different soil types. Important topics in water use particularly, the quality factors like salinity, and its long term effect have been covered. Requirement of water in grapevine after determining its ET values has been covered which is the most appropriate and precise method for defining the water requirement of plant. Topics related to drip irrigation like placement of drippers, uniformity of discharge and pressure, leaching of salts from the soil, regulation of drippers have been dealt in detail. Finally the irrigation scheduling has been recommended at various stages of growth of plant based on the experimental evidence collected at this Centre. Since the weather parameters and soil types vary from place to place, the application of this scheduling depends upon the weather data and soil type prevailing in the particular area. Requirement of water at various stages of grapevine growth varies and this is very critical for bud formation, budbreak, cane maturity, pollination, berry growth, ripening and harvest.

The information given in the bulletin will serve as guidelines for the grapevine growers for deciding the water requirement at various stages of crop. Further, this information is very useful to students, teachers and researchers engaged in viticulture. I also take an opportunity to acknowledge the help of all the concerned of this Centre in preparation of this bulletin to place before you.

Date : March 2003

Place : Manjri, Pune

P. G. ADSULE

CONTENTS

1. Introduction

Irrigation of agricultural land is the main water consumer besides human, industry etc. Irrigation significantly increases agricultural yields and farmers income, particularly in arid regions. The prosperous ancient civilizations developed near fresh water sources that were used for irrigation. In the years of drought, people were forced to migrate in search of water. Unfortunately innumerable wars were triggered by water scarcity as well. Majority of the area under grape cultivation falls under semi-arid-climate. Irrigation water scarcity and salinity are the twin problems faced by the grape growers in this region. To cope up with these problems growers have adopted the drip irrigation but the acute water scarcity has forced the growers to buy water to keep the vineyards alive. On the other hand the growers tend to over–irrigate the vineyards where water availability is unlimited. This results in salinity related hazards.

Economic Importance

Under arid and semi–arid climate where evapo–transpiration exceeds rainfall, grape vines cannot grow normally without irrigation. The irrigation requirement of the Thompson Seedless grapes, the major variety in India, ranges from 450 – 600 mm apart from rainfall received during monsoon under Madhya Maharashtra conditions. In the recent past the rainfall has shown a declining trend in some of the major grape growing belts of the state, resulting in complete drying of existing irrigation sources like open wells and bore wells. As a result, growers are forced to transport the water in tankers from as long as 20 – 30 km to keep the vineyards alive. This costs about Rs. 1200–1500 / day / ha depending upon the distance of transportation. Due to lack of rainfall, non availability of

Fig.1. Cluster drying due to severe moisture stress at flowering

Fig. 2. Vineyard under severe moisture stress

irrigation water and high costs involved in transportation of water there had been 100% yield losses (Fig.1 and 2) in some vineyards and many growers have even uprooted their vineyards. On the other hand, under unlimited water supply and without proper irrigation schedule, excessive irrigation also causes yield reductions. Excessive irrigation at bud differentiation stage drastically reduces the bunch number/vine. Similarly, excessive irrigation after veraison results in berry cracking and encourages fruit rot thereby reducing the quality.

2. Need for irrigation scheduling

Excessive irrigation as well as stress, both are harmful for the optimum crop production. Irrigation scheduling helps in maximizing the water use efficiency and yield. Irrigation scheduling is defined as scientific management of irrigation water to the crop based upon the crop water requirement under different soil and agro climatic conditions with an objective to maximize the water use efficiency. Irrigation scheduling also helps in using saline irrigation water successfully to some extent. It is important to apply different amounts of irrigation at different vine growth stages depending upon agro climatic conditions in order to supply sufficient water to prevent water stress to vines without adverse effects on the growth and productivity.

3. Symptoms of moisture stress

Under mild moisture stress vines exhibit leaf–curling symptoms (Fig. 3). The

Fig. 3. Leaf curling as a consequence of moisture stress

Fig. 4. Reduced shoot length due to moisture stress

symptoms are more pronounced during the mid–day and normally the leaves recover in the evening. Severe moisture stress results in reduced shoot growth and thickness (Fig. 4). Apart from this the internodes become short and leaves remain small. Prolonged moisture stress results in premature leaf fall. The canes exhibit false maturity symptoms.

4. Effects of moisture stress and excessive irrigation

In viticulture, the irrigation practices are aimed at achieving proper balance between vegetative and reproductive development since excessive shoot may have undesirable consequences. The control of shoot vigour to produce vine with balanced growth becomes imperative especially while dealing with vigorous varieties and also the rootstocks. Moisture stress and high temperature affects the total health productivity of vines (Fig. 5). Vines also suffer because of high moisture in the root zone caused by excessive irrigation / precipitation, especially in heavy soils. Lack of aeration in the root zone in such soils causes major physiological problems in the vine.

Fig. 5. Vineyards under varying degree of moisture stress

Moisture stress at budbreak results in delayed and uneven sprouting. As a result, the harvest time increases. Pire and Tololero (1993) reported reduced budbreak under low soil moisture conditions. The time taken for harvest was less when the irrigation was applied immediately after pruning. Moisture was found critical during berry swelling and ripening and soil moisture content should not fall below 50 per cent (Roth and Hrezo, 1992). Water deficits before and after veraison adversely affected the yield, fruit size and bud development. Stress before veraison was found more harmful than after veraison (Mathews and Anderson, 1989). Reduced fruit quality was observed due to reduced irrigation after veraison in Sauvignon Blanc (Bravdo *et. al.,* 1995). Irrigation levels did not significantly affect the juice acidity (Pire *et. al.*, 1989) and pH (Pire *et. al.,* 1989 and Oliveira, 1995). Water deficits after flowering resulted in greatest reduction in berry weight and water deficit after veraison had a minor effect on berry weight at maturity and berries were insensitive to water deficit during the month after harvest (McCarthy, 1997). Water stress reduced sugar accumulation in heavier cropping vines (Poni *et. al.*, 1994).

Irrigation after depletion of 60 to 80 per cent available water reduced plant growth, and the chlorophyll, IAA and GA3 contents of the leaves (Shawky *et. al.* 1996). Increase in soil water availability had direct and positive effect on leaf area, total production, weight and volume of berries and total acidity (Oliveira, 1995). Apart from leaf number, water stress reduced the node number (UssahatAnonta, 1996).

In the early growing season the irrigation should be frequent enough to produce an adequate vine leaf canopy. Once this is achieved irrigation should be just enough to maintain healthy canopy throughout the season. A fast development of canopy at the beginning of the season and slowing down of growth towards veraison and fruit ripening reduced competition between shoot tips and the developing berries and resulted in better quality and faster sugar accumulation (Bravdo and Hepner, 1987).

Excessive vegetative growth at fruit bud differentiation stage adversely affect the fruitfulness of the vine. Imposing stress at this stage helps in better fruit bud differentiation thereby increasing the fruitfulness of the vine. General implications / effects of moisture stress are summarized in table 1.

Table 1. Effects of moisture stress at various growth stages of vines

Stage	Impact	Effect
Growth season (April – September)		
Pre–pruning	Favourable	Accumulation of reserves
Budbreak	Harmful	Uneven and delayed budbreak
Shoot growth	Harmful	Weak buds
Fruit bud formation	Favourable	Help in bud differentiation
Fruit bud development	Harmful	Small clusters
Cane maturity	Harmful	Quick maturity and weak and thin canes
Fruiting season (October – March)		
Pre–pruning	Favourable	Accumulation of reserves
Budbreak	Harmful	Delayed and uneven
Shoot growth	Harmful	Reduced leaf: fruit ratio
Pollination	Favourable	Reduces fruit set (berry thinning)
Berry growth	Harmful	Reduces berry size
Ripening	Favourable	Improves quality
Harvest	Favourable	Improves storability

5. Irrigation and water quality

All irrigation waters contain varying amounts of soluble salts such as bicarbonate, chloride and sulphate salts of calcium, magnesium, sodium and others. Water quality for vines refers to the quantity and balance of dissolved salts in irrigation water. The representative samples of water to be used for irrigation should be tested for electrical conductivity (a measure of the total salt concentration) and for calcium, magnesium, sodium bicarbonate, chloride, boron and nitrate. Irrigation water quality is one of the more important factors involved in grape production. Vines take up irrigation water after it reaches equilibrium with the soil and remaining water from previous irrigation or rains. Successful long–term use of irrigation water depends on several factors other than its quality e.g. on farm water management, climate, soil, drainage characteristics and salt tolerance of vines. Of these, water management is more important.

5.1 Factors related to water quality in grape production

Good managers have used relatively poor water successfully and poor managers with subsequent severe salinity problems have misused relatively good water. Four types of grape production related problems have been recognized.

5.1.1 Salinity

Salts are added to the soil by irrigation water and accumulate in soil.

5.1.2 Soil permeability

Salt water or relatively high sodium water may reduce soil permeability.

5.1.3 Toxicity

Chlorides and boron accumulate in the leaves. Excessive accumulation cause leaf burn and reduce yields. Sprinkler applied water containing as little as 100 ppm chloride, 70 ppm sodium or 1 ppm boron may also cause injury. Damage from leaf absorption is much less if the relative humidity remains above 30 – 40 per cent.

Problems associated with a water pH above 8.40 or below 6.5 are usually related to toxicity, nutritional imbalances or soil permeability. Problems related to high bicarbonates in irrigation water can be reduced by addition of sulphuric acid at controlled rate to reduce water pH to 6.50.

5.1.4 Other factors

Nutrients such as nitrogen may cause excessive vigour and lowered yields. Water high in bicarbonates may result in an objectionable white deposit of lime on leaves or berries.

Water salinity with EC_w less than 1 dS/m is considered excellent for grapes under average vineyard management. Water salinity in excess of EC_w 1.0 dS/m may still be satisfactory if appropriate soil management practices are adopted. In Sangli region of Maharashtra vines grafted on popularly known as Dogridge rootstock are performing well even at irrigation water salinity as high as 3.94 m mhos/cm (Anonymous, 1999). General guidelines for evaluating water quality are given in Table 2 and 3. These guidelines are however, flexible and can be modified when warranted by local practices, experience, special conditions etc.

Table 2. Effect of various water parameters on the growth of grapevine

Water parameter and its effect	No effect	Increasing effect	Severe effect
Salinity: Affects water availability ECw (dS/m)	< 1.00	1.0 – 2.7	> 2.7
Permeability: Affects rates of water movement into the soil and through soil ECw (dS/m)	> 0.5	0.5 – 0.2	< 0.2
Adjusted SAR (An estimate of permeability hazard)	< 6.0	6.0 – 9.0	> 9.0
Toxicity: Specific ions cause toxicity and affect crop growth			
Sodium (meq / l)	< 20	–	–
Chloride (meq / l)	< 4	4 – 15	> 15
Boron (ppm)	<1	1 – 3	>3
Miscellaneous : Bicarbonate (meq / l)	< 1.5	1.5 – 7.5	> 7.5
Nitrate–N (ppm)	<5	5 – 30	> 30

There is a saying 'Hard water produce soft soils and soft water produce hard soils'. Extremely low salt water result in poor water penetration. Relatively high sodium reduce water infiltration and calcium improves it. Salinity effects on soil permeability are relatively less in clay than sandy loam. Low permeability soils should be irrigated more frequently or for longer duration.

Table 3. Clogging potential of physical, chemical and biological parameters of irrigation water used for drip irrigation

Parameters	Degree of problem		
	Little	Some	Servere
Physical			
Suspended solids (ppm)	< 50	50 – 100	> 100
Chemical			
pH	< 7.0	7.0 – 8.0	> 8.0
Dissolved solids (ppm)	< 500	500 – 2000	> 2000
Manganese (ppm)	< 0.1	0.1 – 1.5	> 1.5
Iron (ppm)	< 0.1	0.1 – 1.5	> 1.5
Hydrogen sulfide (ppm)	< 0.5	0.5 – 2.0	> 2.0
Biological			
Bacteria population (max. number per ml)	< 10000	10000 – 50000	> 50000

5.2 Long term effects of saline water irrigation

The possible effects of irrigation water salinity can be illustrated by the following example. Let us assume the applied water plus rainfall over several year period was too little, adequate leaching did not take place and salts accumulated. Further let us assume that 25,00,000 litres of water are being applied to each acre every year to satisfy vine water requirement but no extra water is applied for leaching for salt control. This application of water having EC_W = 1.5 dS/m would apply over

$$\frac{1.50 \times 640 \times 2500000}{100 \times 1000 \times 1000} = 2.40 \text{ tons of salt (2400 kg)}$$

Considering that the weight of one–acre foot soil 20,00,000 kg, this will increase the soil salinity by 1200 ppm(0.12%). In other words, it will increase the soil salinity by 3.30 dS/m if the water holding capacity of a soil is 40 per cent and bulk density is 1.4 m^3/kg.

6. Scheduling irrigation for the vineyards

Efficient irrigation requires knowledge of vine growth, soils, weather and relation between them, so that both the amount and timing of irrigation can be controlled. By manipulating the pruning some adjustments can be made to coincide the particular growth stage of the vines to avoid the harmful effects of the weather on vine growth and productivity e.g. preventing the bud differentiation stage to coincide with rainy period and cloudy weather results in better fruitfulness of the vines. It is also important to know root depth in order to know the amount of water needed to wet the soil up to that depth.

6.1 How to determine the need of grapevine

The careful balance to prevent water stress to vines without the adverse effects caused by excess water can be more readily achieved in arid and semi–arid regions where the vine growth is almost wholly dependent on irrigation. Timing the irrigation to achieve this desired balance is often achieved by rule of thumb methods, but there are three basic approaches. The first is to measure the soil water potential directly but this is difficult in practice. The other two approaches are use of grapevine as indicator and evapo–transpiration.

6.1.1 Soil moisture determination

A variety of methods and devices can be used to measure soil water. These include the feel method, gravitational method, tensiometer, electrical resistance blocks, neutron probe, phene cells and time domain reflectometer. These methods differ in their ease of use, reliability, cost and amount of labour required.

Feel method

As its name implies, the feel method involves estimating soil–water by feeling the soil. This method is easy to use, and many growers schedule irrigation in this way. However, this method is entirely subjective, the results depend on the experience of the individual making the measurement. The reliability of this method is usually poor unless the operator is very experienced. The feel method is not generally recommended and should be used only as a last resort.

Gravimetric Method

With the gravimetric method, soil moisture is determined by taking a soil sample from the desired soil depth, weighing it, drying it in an oven (for 24 hours at 105°C), and then reweighing the dry sample to determine how much water was lost. This method is simple and reliable. Unfortunately, it is not practical for scheduling irrigation because it takes a full day to dry the sample. In a sandy soil that dries quickly, irrigation may be needed before the laboratory results are obtained. However, this method is used for calibrating other devices for measuring soil–water.

Tensiometer

A tensiometer measures soil water suction (negative pressure), which is usually expressed as tension. This suction is equivalent to the force or energy that a plant must exert to extract water from the soil. The instrument must be installed properly so that the porous tip is in good contact with the soil, ensuring that the soil–water suction is in equilibrium with the water suction in the tip.

Tensiometers are quite affordable for scheduling irrigation. The only other equipment required is a small hand–held vacuum pump used for calibration and periodic servicing. Tensiometers are easy to use but may give faulty readings if they are not serviced regularly.

Tensiometers are best suited for use in soils that release most of their plant–available water (PAW) at soil–water suctions between 0 and 80 cb. Soil textures in this category are those that consist of sand, loamy sand, sandy loam, and the coarser–textured range of loam and sandy clay loam. Many clayey and silty soils still retain over 50 percent of their plant available water at suctions greater that 80 cb, which is outside the working range of a tensiometer. Tensiometers are not recommended for clayey and silty soils unless irrigation is to be scheduled before 50 percent depletion of the plant–available water.

Electrical Resistance Blocks

Electrical resistance blocks consist of two electrodes enclosed in a block of porous material. The block is often made of gypsum, although fiberglass or nylon is sometimes used. Electrical resistance blocks are often referred to as gypsum blocks and sometimes just moisture blocks.

Because of the pore size of the material used in most electrical resistance blocks, particularly those made of gypsum, the water content and thus the electrical resistance of the block does not change dramatically at suctions less than 0.5 bar (50 cb.) Therefore, resistance blocks are best suited for use in fine–textured soils such as silts and clays that retain at least 50 percent of their plant–available water at suctions greater that 0.5 bar. Electrical resistance blocks are not reliable for determining when to irrigate sandy soils where over 50 percent of the plant–available water is usually depleted at suctions less than 0.5 bar. The block's resistance can be related to the water content of soil by a calibration curve.

6.1.2 Using grapevine as indicator

A second method involves using plant itself as an indicator of the need for irrigation because it integrates the effects of the atmospheric demand and soils ability to supply water. Visual indications of the water stress include change in leaf colour, leaf orientations and leaf rolling etc. but these are normally associated with the severe stress.

6.1.3 How to determine the Evapo–transpiration

Third and simple approach to determine the vine need for water evapo–transpiration (ET) is usually based on climate, solar radiation, winds and growth characteristics of the vine. It can be calculated from various equations and can be estimated from pan data. An evaporimeter is a pan of standard size containing water and placed in a suitable location. Depth of water evaporating is daily measured. These pan data, multiplied by a factor suitable for grape, will give the ET for grapes growth in the vicinity of the pan.

Fruit yield and shoot growth in Thompson Seedless vines were used with daily irrigation at 0.50 vine evapo–transpiration (ETvine) rate and ETvine was found effective guide for average canopy vineyards in San Joaquin valley (Peacock *et. al.* 1987). Irrigating the vines based upon evapo–transpiration (determined from class A pan evaporation) at four days interval in drip irrigated vines was found most economic (Kovachev, 1988). Pan evaporation had a correlation coefficient of 0.882 with soil moisture tension and Lin and Yeh (1994) recommended 24 mm irrigation when pan evaporation reaches 4 –5 cm. Irrigation scheduling based upon daily evaporation using Bellani Plate atmosphere to measure evaporation electronically reduced the water consumption up to 70% compared to normal practice of irrigating the vines all season long at the peak use rate. This automatic scheduling procedure maintains the moisture content at or near field capacity throughout the irrigation season under fluctuating evaporative demand (Parchomchuk, 1996). Irrigating the vines to 70% of estimated evapo–transpiration produced best results including an improvement in vine quality. Irrigating volumes equal to evapo–transpiration and appropriated crop coefficients ranging from 0.60 to 0.75 were found best for irrigation volumes equal to evapo–transpiration and appropriate crop coefficients ranging from 0.60 to 0.75 were found best for vineyards for variety Italia (Caliandro, 1998). In vine growth bunch number and bunch weight increased with increasing irrigation rates but the differences were not marked beyond 75% of pan evaporation replenishment in Anab–e–Shahi vines under Bangalore conditions (Srinivas *et. al.* 1999). The use of pan evaporation coefficients less than 0.47 (including rainfall) is not recommended in semi–arid zone of Venezuela (Pire and Odeja, 1999). Sharma *et. al.* (2002) found 141% increase in water use efficiency in drip irrigated vines using pan evaporation and crop growth stages for irrigation needs in Thompson Seedless grapes grown in black cotton soil.

6.2 How to leach out the salts

As described earlier the salt build up is inevitable when there is not sufficient rainfall to leach out the salts. In order to obtain satisfactory yield and growth of vines it is important to leach out the salts from the root zone of the vine. If the salinity of the water and the average salinity tolerated by grapes are known, a good estimate of leaching requirement (LR) can be obtained from the equation of Rhodes (U.S. salinity laboratory, Riverside):

$$LR = \frac{EC_w}{5\ EC_e - EC_w}$$

When EC_w = salinity of irrigation water, EC_e = average soil salinity of root zone (tolerance value for acceptable yield loss). EC_e = 2.5 if 10% yield loss is acceptable. (EC_e = 1.50 if no loss is acceptable). If salinity of irrigation water is 1.5 dS/m then

$$LR = \frac{1.5 \times 100}{5 \times 2.5 - 1.5}$$

$$LR = \frac{1.5 \times 100}{12.5 - 1.5} = \frac{1.5 \times 100}{11} = 9.999 \times 1.5 = 14.985 = 15\%$$

This means that at least 15 per cent more water than required to meet vine ET level should be applied. In general, 15 per cent leaching traction is suggested as being more or less normal in irrigated agriculture.

6.3. Placement of drippers based on the moisture movement

The movement of water in the soil depends on the soil characteristics and dripper discharge. In coarse textured soils such as sand, the infiltration rate is high and the horizontal movement is small. In the heavy textured soils, such as clayey, the infiltration rate is low and there is more horizontal movement. Gravity and capillary forces are the main opposing forces affecting the water movement in the soil. Gravity force pulls the water down and capillary force which is formed in the soil categories causes sideways and upward movement of water. The capillary forces work against gravitational force. Since in heavy soils sideways movement is more, the dripper spacing will be more in heavy soils and smaller in sandy soils. The soil volume wetted by the drippers will be small in sandy soils. Therefore, intervals between the irrigation and the application per irrigation will be smaller. In other words light and frequent irrigation are required in light soils.

The moisture movement is also affected by dripper discharge rates. Bresler (1978) suggested the possibility of controlling wetted volume of soil by regulating the emitter discharge according to soil properties. Higher discharge rates increase the vertical movement due to influence of gravity (Roth, 1974). Pawar and Bhoi (2002) observed that the radial spread was inversely and vertical movement directly related with emitter discharge in clayey loam soils of Maharashtra (Table 4). The wetting patterns of soil obtained under different dripper discharge rates and dripper spacing are given in tables 5 – 8.

Table 4. Effect of emitter discharge and volume applied on the radial and vertical movement of water in clay loam soils

Emitter discharge (l /hr.)	Volume applied (l)	Maximum radial movement (m)	Vertical movement (m)
2	4	0.67	0.81
4	4	0.66	0.88
8	4	0.62	0.92
12	4	0.57	1.00

Table 5. Effect of dripper discharge and dripper space on the wetted strip width in medium soil, HC_S = 10 mm/hr (1 cm/hr)

Dripper discharge (l / hr)	Dripper space (cm)	Strip width (cm)
2	20	100.0
2	30	66.7
2	40	50.0
2	50	40.0
4	40	100.0
4	50	80.0
8	100	80.0

Table 6. Effect of dripper discharge and dripper space on the wetted strip width in heavy soil, HC_S = 2.5 mm/hr (0.25 cm/hr)

Dripper discharge (l / hr)	Dripper space (cm)	Strip width (cm)
2	25	320.0
2	50	160.0
4	50	320.0
4	100	160.0
8	100	320.0

Table 7. Effect of dripper discharge and dripper space on the wetted soil radius by one dripper

Dripper discharge (l/hr)	HC_s (cm/hr)	Wetted radius (cm)
1	2.5	11.3
2	2.5	16.0
4	2.5	22.6
2	1.0	25.2
4	1.0	35.7
8	1.0	50.5
2	0.25	50.5
4	0.25	71.4
8	0.25	101.0

Table 8. Effect of dripper discharge and dripper space on the wetted radius width by drip lateral in light soil, HC_s = 25 mm/hr (2.5 cm/hr)

Dripper discharge (l/hr)	Dripper space (cm)	Strip width (cm)
1	10	40.0
2	15	53.3
2	20	40.0
2	30	26.7
2	40	20.0
4	40	40.0
4	50	32.0

Normally, single lateral along the row is used to irrigate the vineyard due to economic considerations and drippers are placed between the space between the vines. Number of drippers per vine depends upon the plant spacing and soil types. In order to avoid development of high salinity zones between the two drippers (Fig. 6) the wetted areas by the drippers must overlap each other (Fig. 7).

Though two drippers per plant will be sufficient if the planting is done at 10 × 6 feet in heavy soils and if the infiltration rate or hydraulic conductivity of the soil is low (2.5 mm/hr) as is the case with heavy clayey soil. However, nowadays planting is done after making trenches in the soil and small bunds are made along the row, therefore, the hydraulic conductivity and infiltration rate improve and allow more downward movement and less lateral movement of moisture. Under such conditions, it is recommended to put 3 drippers of 4 lph discharge per plant for a planting distance of 6–8 ft. between the two vines. However, for practical reasons, (erratic electrical

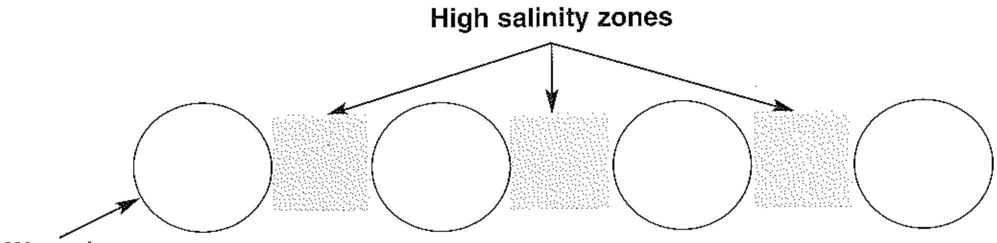

Fig. 6. Inappropriate pattern of wetting

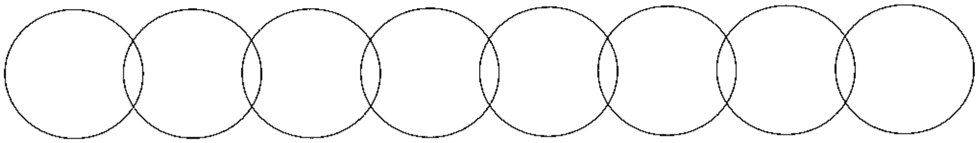

Fig. 7. Appropriate pattern of wetting

supply) drippers with higher discharge (8 lph) may be used if the time available for operating the irrigation system is not sufficient to meet the vineyard water demand.

6.4 Uniformity of discharge and pressure

According to the standard the discharge uniformity of the manufacturer must be ± 8%, while the uniformity of the sample must be ±2%. While designing a system the difference in discharge between first and last dripper in an operational area should not be more than 10 per cent and the difference in the pressure no more than 20 per cent.

6.5 Effect of pressure on discharge

Since it is recommended to use drip irrigation for better production due to various reasons, it is important to maintain proper pressure for operating the system. Most

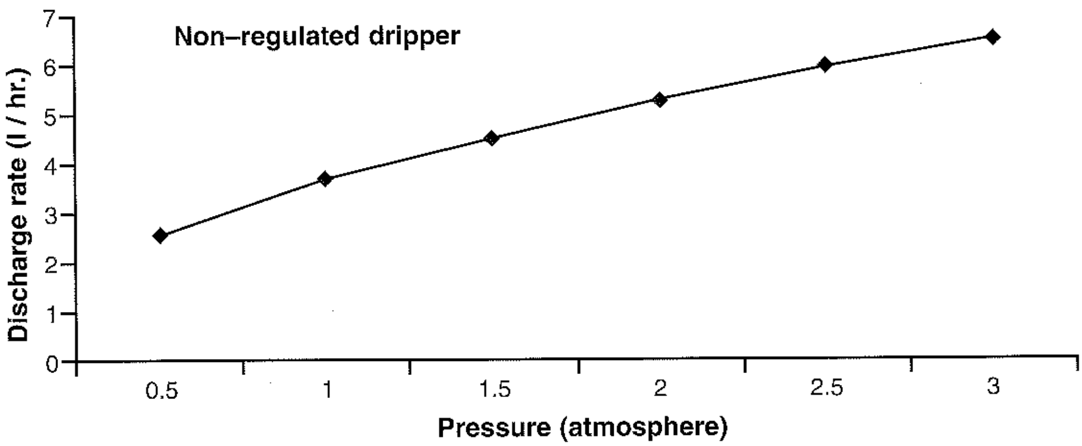

Fig. 8. Effect of pressure on the discharge rate of non–regulated dripper

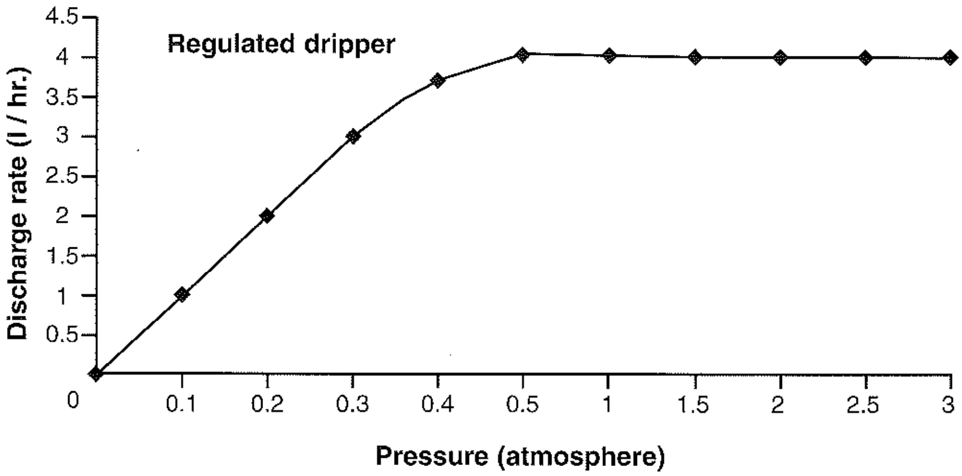

Fig. 9. Effect of pressure on the discharge rate of regulated dripper

drippers operate in the range of 1.0 to 2.0 atmospheres, but the regulated (pressure compensated) drippers can operate at a pressure of 4 atmospheres. When the pressure is less than one atmosphere with unregulated drippers, the discharge becomes very sensitive to changes in topography and the drippers tend to clogging. Variation in discharge rate also cause uneven distribution of fertilizers during fertigation.

6.6 Regulation of drippers

With unregulated drippers the discharge depends on pressure. The difference in pressure stems from friction of the water flow in pipes and topography. In regulated drippers diaphragm is used to keep the uniform discharge with in a certain pressure range, generally between 0.6 m and 40 m (4 bar). The regulated drippers allow uniform discharge in difficult topography and when there is enough pressure and allow the use of longer laterals. Discharge as affected by pressure with non–regulated and regulated drippers is shown in figure 8 and 9 respectively.

6.7 Recommended irrigation schedule for vines in heavy soils

Keeping in view the implications of moisture stress on different stages of vine growth and yield, seven new irrigation scheduling were tested for two consecutive years and four pruning seasons for vines grafted on popularly known as Dog Ridge B rootstock. The recommended irrigation schedule based upon pan evaporation (using 0.7 pan coefficient) is given in Table 9.

Table 9. Recommended irrigation schedule for various growth stages of grapevine based upon pan evaporation

Stage	Growth Stage	Quantity of water (l/ha) per mm of evaporation
	Foundation pruning	
I	Shoot growth (1– 40 days)	4200
II	Fruit bud differentiation (41–60 days)	1400
III	Shoot maturity (61–120 days)	1400
IV	Fruit bud development (121 days to pruning)	1400
	Forward pruning	
V	Shoot growth (1–40 days)	4200
VI	Bloom to shatter (41–55 days)	1400
VII	Berry growth (56–105 days)	4200
VIII	Ripening (106 to harvest)	4200
IX	Rest period (harvest to back pruning)	Nil

Table 10. Water use efficiency with recommended schedule

	Total quantity of water applied (l / ha)	Yield (t/ha)	Water Use Efficiency (WUE) (kg brix yield / ha mm water)
Previous recommended irrigation schedule	95,98,000	21.27	5.22
New recommended irrigation schedule	45,06,000	23.21	12.60

The water consumption in new irrigation schedule was reduced by 53 per ce[nt] without any adverse effects on yield and quality of the grapes. The water use efficienc[y] was 2.41 times higher with the new irrigation schedule (Table 10).

The first irrigation stage (Stage I) covers the period from foundation pruning t[o] bud differentiation stage (normally mid April to May). The water requirement i[s] maximum during this stage. Vines should not be stressed during this period in order t[o] obtain canes of desired thickness (8–10 mm) and sufficient canopy.

Second irrigation stage (Stage II) is the period of bud differentiation. Irrigatio[n] should be reduced during this period to facilitate better bud differentiation. Shoo[t] maturity (Stage III) and fruit bud development stages (Stage IV) coincides with rain[y] season but still there is a need to irrigate the vines as the rainfall is highly erratic an[d] distribution is not uniform. There are hardly 40–50 rainy days in a year. Most of the soils are heavy textured with low infiltration rate and much of the rainwater is lost as run off. Irrigation should be withheld till the soil is at field capacity after the rain.

Fifth stage (Stage V) begins with fruit pruning or forward pruning normally during the month of October. The vines should receive sufficient irrigation during this stage to promote strong shoot growth and adequate leaf area. Since fruit–set is not a problem in Indian vineyards, mild stress during berry set to shatter stage (Stage VI) helps in reducing berry set which are otherwise to be thinned. Berry growth to veraison period (Stage VII) is most critical stage as cell division and elongation are occurring in the fruit. Water stress at this stage reduces the berry size and yield. The eighth stage (Stage VIII) covers period from veraison to harvest. The vines should not be over–irrigated during this period to avoid berry cracking and delay in harvest. In highly vigorous vineyards the irrigation may be withheld for few days to discourage the new shoot growth. Depending upon the stored water in soil the irrigation may be stopped a week before harvest to increase sugar content in the berries. Moisture stress, at this stage, however results in berry drop. During rest period i.e. after harvest (Stage IX) the vines can survive on stored soil water in heavy soils. If the rest period is more than a month then the vineyard should be irrigated twice or thrice during this period.

In case of own rooted vines it is recommended to add approximately 30 per cent more water compared to grafted vines to obtain same yield levels and canopy. However, experimental evidences are lacking under Indian conditions in this regard. Use of pan coefficients for scheduling irrigation depends upon the local conditions as given in Table 11.

Table 11. Pan coefficient K_p for Class A Pan for different ground cover and levels of mean relative humidity and 24 hours wind (source: FAO)

		Case A : Pan surrounded by short green crop at different RH (%)			Case B* : Pan surrounded by dry fallow land at different RH (%)		
		Low <40	Medium 40–70	High <70	Low <40	Medium 40–70	High <70
Wind km/day	Upwind distance of green crop (A) or dry fallow (B) meters						
Light < 175	0	0.55	0.65	0.75	0.70	0.80	0.85
	10	0.65	0.75	0.85	0.60	0.70	0.80
	100	0.70	0.80	0.85	0.55	0.65	0.75
	1000	0.75	0.85	0.85	0.50	0.60	0.70
Moderate 175–425	0	0.50	0.60	0.65	0.65	0.75	0.80
	10	0.60	0.70	0.75	0.55	0.65	0.70
	100	0.65	0.75	0.80	0.50	0.60	0.65
	1000	0.70	0.80	0.80	0.45	0.55	0.60
Strong 425–700	0	0.45	0.50	0.60	0.60	0.65	0.70
	10	0.55	0.60	0.65	0.50	0.55	0.65
	100	0.60	0.65	0.70	0.45	0.50	0.60
	1000	0.65	0.70	0.75	0.40	0.45	0.55
Very strong >700	0	0.40	0.45	0.50	0.50	0.60	0.65
	10	0.45	0.55	0.60	0.45	0.50	0.55
	100	0.50	0.60	0.65	0.40	0.45	0.50
	1000	0.55	0.60	0.65	0.35	0.40	0.45

* For extensive areas of bare–fallow soils and no agricultural development, reduce Kpan values by 20% under hot windy conditions and by 5–10% for moderate wind, temperature and humidity conditions.

7. Do's and don'ts while irrigating the grapevine

7.1 Do's

i. Apply plentiful water after pruning to avoid uneven and delayed bud break.

ii. Apply mild stress during bud differentiation, berry set and shatter stage.

iii. Supply enough water during berry growth period.

iv. In highly vigorous vineyards, stop irrigation for few days to discourage new shoot growth after veraison to harvest period.

v. Maintain optimum pressure for uniform distribution of the water.

vi. Flush the dripline regularly.

vii. After a light rainfall (less than 5 mm) irrigate as per the evaporation rate for previous day to avoid salt injury.

viii. Use mulches (plastic and organic) for reducing irrigation water requirements.

ix. Leach out salts from the root zone before beginning of the each season.

x. Make bunds along the vine rows to facilitate leaching.

7.2 Don'ts

i. Do not stress the vines unless desired.

ii. Do not over–irrigate the vines during bud differentiation and after veraison to harvest stage.

iii. The irrigation interval should not be more than 3 days in heavy soils.

iv. Use short irrigation intervals for light soils to avoid leaching.

v. Do not over–irrigate during bunch emergence period.

vi. Do not allow to grow algae on the emitters.

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