Technical Bulletin No. 18

Foundation Pruning in Grapes

भाकृअनुप-राष्ट्रीय अंगूर अनुसंधान केंद्र, पुणे
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1. Introduction

Grape *(Vitis vinifera L.)* is one of the most important horticultural crop in the country. More than 90% of grape cultivation is concentrated in states of Maharashtra and Karnataka. Majority of the produce is for table and raisin purpose with hardly 1-2% being utilised for juice and wine making. The area under grape cultivation has increased more than three folds from 2003-04 to the present i.e. 2018-19. The yield levels are also one of the highest in the world. In spite of high yield per unit area obtained, the proportion of export quality grapes required for the international market is still low. The proportion of export quality in a vineyard varies from 2 to 8 tons per acre. This is mainly due to the conditions of high temperature, moisture and salinity stress in the major grape growing areas. Thus, rootstock have become mainstay of the grape cultivation. Further, cultural practices like training, pruning, water and nutrient management in the vineyard are in some instances arbitrarily followed.

The grape cultivation involves double pruning and single cropping in major areas. The two pruning seasons are foundation and fruit pruning seasons. The practices followed during foundation pruning contribute to fruit bud differentiation in the developed canes and also quality production during fruit pruning season. The production of quality grapes mainly depends upon the cultural practices followed during the foundation pruning. This bulletin discusses in detail the practices to be followed during foundation pruning season to achieve desired fruitfulness and cane maturity with sufficient food reserves in a cane for quality grape production in the fruiting season.

2. Resting phase (after harvest till foundation pruning)

Each cane measuring 8-10mm diameter produces a bunch weighing approx. 300 - 400 g. A grape vineyard producing 10-12 tonnes per acre and more depletes storage reserves in the vines. The harvest period during Feb.- March coincides with the rise in temperature ranging from 36°C to as high as 40°C or more and low relative humidity even less than 20%. As the vine is exhausted, there is a need to provide nutrients and irrigation water during the rest period to allow the physiological process to continue (Fig.1). The leaves though mature are still photosynthetically active and could increase the food reserves within the permanent vine parts. So, care should be taken to keep the leaves green and active and not dry and fall. After foundation pruning, it takes at least 20 - 25 days for the leaves to develop and be photosynthetically active. If the vine reserves after harvesting are not augmented, then after pruning, sprouting either in terms of the no. of sprouts or uniformity in sprouting is affected adversely. It is thus, prudent to keep the vines after harvest for 15 - 20 days at least under rest period so that, it is able to increase its reserve during the resting period.

Providing need based irrigation and nutrition will maintain the green leaves on the vine, which could still produce some food and augment the food reserves in the vine. Apply 10 - 15 kg urea, 25 - 30 kg


Fig.1: The vine after harvest

SSP and 10 - 15 kg sulphate of potash (SOP) per acre every 15 - 20 days till foundation pruning is not done. The quantum of irrigation water applied should be approx. 5000 - 6000 L / acre, once in a week. Care should be taken to reduce / stop the water in case new growth is observed on the shoot. Flooding the vineyard is not advised as it will lead to wastage of water. Concentrate irrigation water application in the root zone only.

Red spider mites and mealybugs may cause damage to the vines at this stage. Feeding due to red spider mites can reduce chlorophyll content of leaves and in case of severe infestation, the leaves may dry and fall affecting photosynthetic ability. Application of Sulphur 80 WDG @ 1.5-2.0 g/L or abamectin 1.9 EC @ 0.75 ml/L or bifenazate 22.6 SC @ 0.5 ml/L water may be applied if mite infestation is observed. Mealybugs feed on phloem and deplete the plant from storage food reserve. Plant wash with buprofezin 25 SC @ 1.25 ml/L water may be given to manage mealybugs.

3. Pre - pruning practices

3.1. Planning for fertilizer application schedule

Planning fertilizer schedule requires the understanding of soil fertility status and irrigation water quality. Simultaneously, the petiole test report of the previous season should also be kept handy to arrive at judicious nutrient application schedule. Each plot is different in soil texture, structure and its fertility status and thus, the fertilizer need will differ from one plot to another. Even the irrigation water particularly, the bore and well water contains nutrients like nitrogen, calcium, magnesium etc. Hence, it is necessary to test soil and irrigation water before the foundation pruning for judicious use of fertilizers. The nutrient input from organic manures should also be taken into consideration while deciding the quantity of nutrients to be applied. While procuring the fertilizer, it is also necessary to check the label details on the fertilizer bag so that it meets the specifications as per Fertilizer Control Order (1985) of Government of India.

Fig.2: Calcareous soil

Though grape is cultivated on varied soil and climatic conditions, deep and well-drained soils with pH range of 6.5-7.2 is ideal. The soil pH above or below this range is known to restrict availability of nutrient elements and thus, inhibit growth and development of the grapevine. In a soil with more than 7.5 pH, it is advisable to apply 25kg/acre elemental sulphur in the rootzone to obtain desirable soil pH. Many of the grape growing soils are calcareous in nature. The calcium content in soil ranges from 3 to 20 % and sometimes even more (Fig.2). In general, the presence of calcium carbonate directly or indirectly affects the chemistry and availability of nitrogen, phosphorus, magnesium, potassium, manganese, zinc, copper and iron. For uptake of these nutrients, it is necessary to improve calcareous soils. This requires reducing the soil pH and neutralizing calcium carbonate in soil. Even reduction in soil pH will improve the availability of phosphorus and micronutrients. If soil test values are not available then application of 50 kg/acre of elemental sulphur in each pruning season will be desirable. If soil has high calcium carbonate content, regular application for at least 2-3 year will be required. To improve the efficacy of sulphur applied, sulphur should be applied along with organic manure like farm yard manure (FYM), compost, etc. and mixed properly in the root zone.

The problems related to sodicity in different grape growing regions are becoming obvious in vineyards having ESP in the range of 6-8 percent depending on soil type. The sodium in the soil dominates the exchange complex in comparison to calcium and magnesium and thereby affects the soil structure adversely. Irrigation water is the major source of sodium. Hence, vineyards utilising irrigation water high in sodium (> 100ppm) needs planning to reduce sodium build up right from planting stage. The most common method to improve sodic soil is by applying amendments like gypsum or sulphur. Gypsum is calcium sulphate ($CaSO_4 \cdot 2H_2O$). It acts by replacing the sodium on the soil exchange complex with calcium and the sodium thus, displaced from exchange complex is leached by applying more water. In case of calcareous soils, sulphur should be used as amendment. Restoration of sodic soils is slow because soil structure, once destroyed, improves slowly. Soil practices to break the crusts and green manuring / FYM / compost / sulphuric acid / molasses application, etc. will improve the soil structure and lead to better leaching of sodium along with irrigation water. Use of FYM @ 10 ton / acre along with the recommended amendments before pruning can be followed. Flooding the land with large quantities of water should be avoided unless desired for leaching of sodium. Evaporation should be reduced so that salts from lower layers do not come to surface. The practice of mulching can help to reduce the evaporation.

3.2. Soil and water test

Before starting the foundation pruning, the soil samples should be drawn from the root zone of the grapevine to a depth of 30 cm at 15-20 cm away from the dripper (Fig.3). Simultaneously, the irrigation water should also be tested for its quality. Irrigation water particularly from ground water sources can supply large quantities of nutrients like nitrogen (nitrate-N), magnesium, calcium, etc. to meet vine needs. Hence, application of fertilizer should be based on soil and irrigation water analysis.

Fig. 3: Soil sample to be drawn

3.3. Trench opening and nutrient application

Opening the trench serves two purposes namely, soil loosening and root cutting (Fig.4) apart from application of fertilizer / amendments and organic manure. The roots developed during the last season generally becomes black or brown. These have become inefficient in absorbing nutrients and water for supply to the foliage. Hence, new roots need to be developed. Opening of trenches in between the vines will result into root cutting which will then help to initiate the development of new roots (Fig.5). These roots so formed will be more efficient.

The trench with 2-2.5' width and 6-8" deep should be opened at least 15-20 days before foundation pruning (Fig.6). The trench should be opened at 1' away from the trunk of the vine as the grafted vine do not produce roots near the trunk and there is no damage to the trunk during the operation.

Fig. 4: Cutting of roots during back pruning

Fig. 5: Development of white roots


Fig. 6: Breaking the bund and opening the trench

The fertilizer application should be based upon the soil, water and previous season petiole test. In the open trench, 10t /acre FYM mixed with sulphur/ gypsum depending upon the soil test should be applied in the trench. Based on the soil analysis status, as a basal dose, nutrients like phosphorus in the form of single super phosphate @100 kg/acre should be added in the trench. The basal nutrients should be mixed with FYM before application to reduce nutrient fixation. The FYM applied will improve aeration in the bund, water holding capacity and release the nutrients to the vine upon decomposition.

3.4 Preparation of bund

After the trench opening, organic matter should be placed at the bottom while well rotten farm yard manure should be spread above it. The canes after crushing through cane crusher can also be spread in the trench (Fig.7). The fertilizers like single super phosphate/amendments like sulphur and gypsum can also be added in the trench. The soil is then covered. This process is called as bund making. By this process, the root zone will receive good aeration that will help in development of white roots. These roots are more efficient than the old roots and also improves the efficiency of nutrient use.


Fig. 7: Bund opening and application of FYM and crop residue

4. Foundation pruning

Fig. 8: Back pruning

The most important factor which has contributed to the successful grape cultivation in the tropical region in India is the practice of pruning grapevine twice in a year. Pruning the vine directly influences the number of shoots, thereby regulating the vegetative growth. This has a direct bearing on the potential crop level. After harvest of fruit, the grapevine is allowed to enter into rest period for atleast 15-20 days and fed small quantity of fertilizers and irrigation to replenish the vine reserves. The grapevine is pruned in April leaving single bud (Fig.8). This is referred to as foundation or back pruning. Since, this operation is being carried out during April, it is also called as April pruning. After back pruning, the vine under tropical condition passes into three different growth stages i.e., vegetative growth, fruit bud differentiation and cane maturity. Because of the favorable condition available during April month, the whole process of fruit bud differentiation gets accelerated so that the vine gets enough time for the formation of flower bud primordia in the bud and also the time for maturity of the cane so as to supply the required food material for bunch development in the next season (fruit pruning).

All the canes grown on each cordon will not be of same diameter. Hence; there will be uneven shoot growth during the next season. Considering this, back pruning is generally done leaving single bud on the cane. Care to be taken to remove all the unwanted buds alongwith infected leaves to avoid the risk of disease incidence in the coming months.

4.1 Use of hydrogen cyanimide

The back pruning is done during summer months when the temperature exceeds 38-40°C and relative humidity drops below 30%. This results in erratic bud break and also delayed bud sprouting.

Fig. 9: Application of hydrogen cyanamide

For uniform bud sprouting, application of bud breaking chemical i.e. hydrogen cyanamide (H_2CN_2) is generally recommended. Hydrogen cyanamide is generally applied within two days from pruning (Fig.9). The concentration used for swabbing the buds depend upon the weather prevailing during the period of pruning. When the temperature ranges between 35 to 40°C and relative humidity is 25-30%, the concentration of hydrogen cyanamide used should be from 20 to 25 ml/L water.

4.2 Water spray and covering the vine with shade nets

The hot summer conditions with very low humidity leads to delay and uneven bud sprouts. For uniform bud sprouts, weather condition (temperature and relative humidity) plays an important role. Water spray on cordons during the time when the temperature is at its peak i.e. 2.0 to 3.0pm) will help to build up the relative humidity near the bud. In addition, covering the vines with shade nets can also help to reduce the temperature and increase relative humidity in the vineyard (Fig.10).

Fig. 10: Covering the cordon with shade net

Fig. 11: Uniform bud sprouts under shade net

Under such situation, the bud sprouts will be early and uniform (Fig.11). However, shadenet should be removed after 3-5 leaf stage.

5. Vegetative growth stage (1-40 days after pruning)

5.1 Bud sprouting and shoot vigour

After the foundation pruning, the bud sprouting is initiated in 12-14 days. Depending upon the weather conditions the sprouting is completed in about 16-20 days (Fig.12). For uniform bud

Fig. 12: Sprouting after back pruning

Fig. 13: Mulching in the vineyard

sprouting, irrigation water based on pan evaporation rates to achieve desired canopy is applied. Expected pan evaporation during first 40 days may range from 8-12 mm per day. Accordingly, the irrigation water required will range from 13,600 to 21,800 L/acre/day. However, the quantity of irrigation water to be applied should be based upon the vine growth, soil and weather conditions. If the soil is at field capacity (wapsa), then irrigation water application should be skipped till the soil moisture goes below field capacity or vine shows moisture stress. Mulching in the vineyards will be beneficial as it reduces the irrigation water requirement by 6-8%, and also regulates the rootzone temperature (Fig.13). Different type of mulching material can be used in the vineyard (plastic, sugarcane thrash, crop residue, etc). However, plastic mulch should be avoided during foundation pruning as it increases the temperature in root zone thereby damaging the white roots. For organic mulches like bagasse, crop residues etc. to be effective, the thickness of mulch should be at least be 2.5".

During the shoot growth stage, 30kg N/acre (65 kg urea) and 100kg / acre single super phosphate should be applied, upto 30 days after pruning. In case if phosphorus has been applied before pruning as a basal dose then, single super phosphate need not be applied. If soil is calcareous, then instead of urea, ammonium sulphate @ 140kg/acre should be applied. Application of zinc and boron during 20-40 days will help to promote desired shoot growth. If the soil test value indicates micronutrient deficiency, then micronutrients (Zn, Fe, Mn and Boron) after bud swelling stage through drip should be applied. Normally in the calcareous soil, the vine will express the deficiency of these micronutrients. Based upon soil test value, apply 15-20kg/acre each of zinc sulphate, ferrous sulphate and manganese sulphate. Generally, under the condition of high magnesium content in soil, additional application of magnesium is not advised. However, it is recommended to apply starter dose of magnesium @ 15 kg/acre.

5.2 Removal of excess shoots

Removal of excess shoots is often the most important canopy management practice followed during the season. This helps in regulating the vegetative growth. On each vine, there will be more than 70 shoots of different diameter. Retention of all the shoots will lead to formation of dense canopy. Shoot thinning reduces excess shoots to both adjust crop and reduce shading, thereby improving the light penetration and air movement in the canopy.

For proper bunch development, depending upon the objectives of grape production (e.g. export, local market and raisin making), the shoot retention needs to be followed. During foundation

Fig. 14: Stage of excess shoot removal

Fig. 15: Removal of double and downward shoots

pruning, for every square feet area allotted to each vine, 0.50 to 0.60 no. of shoots are retained. Shoot thinning is generally done at 6-7 leaf stage (Fig.14). During this stage, the leaves are not photosynthetically active; hence, the loss of food material will be minimum. On each vine, the shoots of different thickness will be available. For example, 5-10% are more vigorous, 70-80% shoots of uniform thickness while 5-10% shoots will be weak and late sprouted. Likewise, on each cordon, double shoots, downward growing shoots, etc. will be there, leading to crowding in the canopy. This will lead to reduction in photosynthetic activity due to lack of penetration of sunlight in the canopy and also disease and insect pest build up due to favourable microclimate. Hence, these should be removed (Fig.15). However, while removing the excess shoots, only uniform growing shoots of similar thickness are retained with equal spacing between the shoots on each cordon. This will facilitate for uniform distribution of sunlight in the canopy and major cultural practices in the next season like GA_3 spray, bunch dipping in GA_3 solution, berry thinning, etc.

5.3 Sub cane vs. straight canes

After the bud sprouting, the shoot growth enters into vegetative phase that lasts for 30 days from the date of foundation pruning. Under the condition of availability of enough irrigation water and nutrient supply, the shoot grows at a faster rate. At this stage, the growth needs to be kept under control. The excess growth that would have exhausted the nutrient reserve is diverted through development of sub cane (Fig.16). The vigorous growing shoots are pinched at 7^{th} leaf when the total growth is at 9-leaf stage (Fig.17). The side shoots sprouted after pinching of main shoot (Fig.18) are allowed to grow till 7-leaf and then again pinched at 5-leaf (Fig.19). During this growth stage, the shoot starts changing its colour from pink to milky white. This is an indication of initiation of cane maturity. At this stage, the initiation of fruit bud differentiation will be experienced. The shoot growth in general slows down. However, the change in weather condition during the period of fruit

Fig. 16: Stage of sub cane development

Fig. 17: Pinching for sub cane

bud differentiation will lead to initiation of shoot growth. This growth is again pinched at 3-leaf when the shoot is at 5-leaf stage.

Under the condition of water shortage, the growth of shoot will be less thereby hampering the vegetative growth. Even after pinching the shoot at 7-leaf stage for sub cane development, there will be no sprouting of side shoot. Under such situation, the requirement of 16-17 leaf for higher photosynthetic activity in the cane will not be fulfilled. The cane will be weak and hence, due to lack of sufficient food material, bunch development will be hampered. To avoid this situation, only straight cane should be allowed to develop (Fig.20). Once the shoot growth reaches upto 13th leaf, pinching of shoot tip may be done at 11th leaf position. This will help to store required food material in the shoot for bunch development in the coming season.

The newly emerging shoots are relatively more sensitive to damage by thrips, mealy bugs and flea beetles. The period of foundation pruning normally coincides with hotter and drier summer months

Fig. 18: Single sub cane

Fig. 19: Double sub cane

Fig. 20: Pinching for straight cane

(April-May) in majority of the grape growing areas. This type of weather is highly congenial for build-up of population of thrips and mealy bugs. Hence, timely and appropriate measures need to be undertaken against these pests in order to avoid serious damage.

Mealybug infestation could lead to malformation of growing shoots (Fig.21) hence, preventive plant wash at dormant bud stage with buprofezin 25 SC @ 1.25 ml/L (water volume 1.5 litre per vine) may be given. If shoot malformation is seen during initial growth stages, foliar application of imidacloprid 17.8 SL @ 0.4 ml/L water may be given again (Fig.22). At sprouting, preventive application of imidacloprid 17.8 SL @ 0.4 ml/L water (water volume 750 L/ha) is helpful to prevent damage by mealybugs and flea beetle (Fig.23-24).

During active shoot growth, thrips may cause serious damage to tender leaves and stem (Fig.25-26). Application of fipronil 80 WG @ 0.06 or emamectin benzoate 5 SG @0.22 g /L or cyantraniliprole 10 OD @ 0.7 ml/L or spinosad 45 SC @ 0.25 ml/L or spinetoram 11.7 SC @ 0.3 ml/L water (water volume 1000 L/Ha) may be given to manage thrips.

Fig. 21: Leaf malformation (Bunchy appearance) due to mealybug

Fig. 22: Shoot malformation due to mealybug

Fig. 23: Linear holes in leaves due to flea beetle damage

Fig. 24: Flea beetle feeding on young bud

Fig.25: Thrips damage on growing shoot

Fig. 26: Thrips damage on tender stem

6. Fruit bud differentiation stage (40 to 70 days from pruning)

6.1 Use of plant growth regulators

Foundation pruning is generally done during the first fortnight of April. However, due to delay in fruit harvest, the foundation pruning may also get delayed as 15-20 days period rest is given to the vine. From the time of foundation pruning, generally 120-150 days are required for cane maturity. The duration may also vary depending on the weather condition during the growth period. Timely pruned vineyards lead to proper cane development and cane maturity. This vineyard can then be pruned for fruit during first week of October while the harvest will be done during March in the next season.

Fig. 27: Stage of PGR spray

The vineyards pruned during April month will receive full sunlight for effective fruit bud differentiation. Sunlight plays an important role in fruit bud differentiation. In addition to the sunlight, spraying of plant growth regulators (PGR) like 6-BA and Uracil is generally recommended during this stage (Fig.27). At 40th and 50th day after foundation pruning, foliar spray of 6-BA @10ppm helps to increase the ratio of cytokinin: gibberellins. In addition, the foliar spray of uracil @ 50ppm at 45th day after foundation pruning helps to increase the proportion of nucleic acids required for effective fruit bud differentiation. Many times the application at 40th day may not correlate with the stage of shoot, hence, the stage at which 3-4 lateral leaf emerged after pinching for sub cane may be considered for spray of 6-BA. During the period of fruit bud differentiation, the shoot growth is kept under control. This helps to reduce gibberellins and increase cytokinin content in the growing shoot. The reduced shoot vigour results into higher fruit bud differentiation in the vine (Fig.28).

Fig. 28: Fruitfulness in relation to inter nodal length

Under the condition of non-availability of irrigation water or late harvest of fruits, the foundation pruning is delayed and could be carried out from last week of April to May. This stage could then coincide with, cloudy weather and build-up of higher humidity in the vineyard leading to higher vigour (Fig.29). Hence, to control the vigour, application of nitrogen and irrigation should be reduced or stopped altogether. Once the vigour is controlled, then as per the requirement, they may be applied.

Fig. 29: Vigour of late pruned vines (LHS) and Suckers on late pruned vines (RHS)

The vineyards pruned after May will not receive enough sunlight required for fruit bud differentiation since the weather will be cloudy all the time. Hence, achieving fruit bud differentiation without application of plant growth regulators becomes difficult. The schedule of application of 6-BA and uracil will be same as that of timely pruned vineyards, however, the number of applications will increase depending on the weather condition.

During the first year of framework development, the cordon is developed following stop and go method. This method involve the development of canes in two instalments. By this method, the requirement of canes per vine can be fulfilled, however, all the canes cannot be developed at a time. For effective fruit bud differentiation in a developing cane, application of PGR becomes necessary. In majority of the cases, the growers are applying cytokinin based PGR that becomes excess. The period of cordon and cane development coincides with high temperature where the irrigation water becomes an important issue. The gibberellins in the vine reduces while the cytokinin level increases thereby leading to development of the symptom of swelling on a shoot (Fig.30). Under severe cases, the shoot bends from the swollen part and breaks. Hence, it is advised to minimize the use of cytokinin based PGR.

Fig. 30: Swelling on the shoot

6.2 Application of fertilizer and irrigation (41- 60 days)

Petiole test: To know the status of vine for a given nutrient, petiole testing is done. During this period (45days after foundation pruning), the petioles should be sampled. For petiole testing, the petioles from the fully mature leaf at 5th node position from the base of a cane are collected randomly and tested for nutrient status in the vine. Around 100 to 120 petioles will be sufficient for analysis of nutrients. If the test report indicates the nutrient (s) as excess or very high, the decision on application or withdrawal of nutrient application is taken.

Fig. 31: Potash deficiency on leaf


Fig. 32: Ferrous deficiency on leaves

During the period of fruit bud differentiation, single super phosphate @150kg/acre should be applied based upon soil and petiole test values. Application of water soluble fertilizers like 12-61-0 should be avoided during this stage as it contains nitrogen that could lead to new growth thereby affecting the fruit bud differentiation. Sometimes, potassium deficiency symptom such as inward leaf curling or shiny spot or marginal leaf yellowing is observed on leaves during the first month of growth (vegetative growth) (Fig.31). Under such condition, two foliar spray of sulphate of potash @ 3-4g/L at 3 days interval should be given followed by 15-20kg/acre application of sulphate of potash through drip. In case of low magnesium content recorded in petiole test, magnesium (not exceeding 0.5% concentration) should be sprayed followed by soil application of 25 kg magnesium sulphate per acre in three splits. Zinc and boron application preferably by foliar sprays during 40 - 60 days based on the petiole test report should be followed. Lime induced ferrous deficiency, likely to be observed during this period will require foliar spray of Ferrous sulphate @ 2g/L atleast twice followed by soil/ drip application of ferrous sulphate @ 15-20 kg / acre (Fig.32).

During this period, the irrigation is reduced to 1/3rd compared to first 40 days to facilitate fruit bud differentiation and control vine vigour. Expected pan evaporation during this stage may range from 8-10 mm. Accordingly, 4500 to 5800 litres of irrigation water per acre per day basis will be needed. Excess irrigation or soil moisture at this stage will result in poor fruitfulness. In case of deep black soil, it is advised to stress the vineyard one week prior to initiation of this stage.

6.3 Pest management

Weather conditions before the beginning of monsoon rainfall may favour thrips population build up. This may cause damage to new leaves and tender shoots. During monsoon, incidence of leaf eating caterpillars, especially *Spodoptera litura* F. may increase leading to severe defoliation of leaf (Fig.33-34). Installation of 'Spodlure' sex pheromone traps @ 8-10/ ha or light traps @ 1 per hectare

Fig. 33: Skeletization of leaf by *Spodoptera litura* first instar larva

Fig. 34: *Spodoptera litura* late instar larva feeding on grapevine leaf

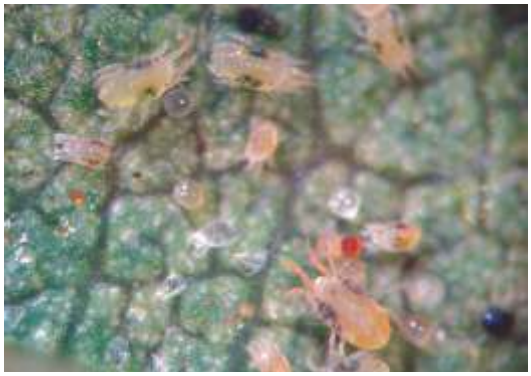

Fig. 35: Red spider mites

Fig. 36: Web formation on underside of leaf due to red spider mite infestation

may be helpful in judging the onset of caterpillar infestation and aid in undertaking timely control measures. Fipronil 80 WG @ 0.06 g/L water or emamectin benzoate 5 SG @0.22 g/L water (water volume 1000 L/Ha) can help in controlling both thrips and caterpillars. Alternatively, application of SINPV @ 250 LE/ha can effectively control the larvae of *S. litura*.

If mealybug infestation is observed, spot application of buprofezin 25 SC @ 1.25 ml/L (water volume 1.5 litre per vine) may be given. Sighting of web formation at underside of leaves may be noticed on older leaves due to mite infestation (Fig.35-36). Sulphur 80 WG @ 2.0 g/L will help to control mites in the vineyard.

6.4 Disease management

As the monsoon commences during this period, the vines are susceptible to downy mildew, anthracnose and bacterial leaf spot infection.

Fig. 37: Hanging shoots from the trellises leading to downy infection

In case of downy mildew, all shoots emerging from the crown near ground level should be removed. Shoots hanging from trellises towards ground should be tied on trellises or can be removed as the situation demands. This is done to avoid proximity of tender leaves and shoots to soil as downy mildew inoculum in soil becomes active after few major rains in June-July (Fig.37). Preventive application of mancozeb 75WP@ 2g/L or bordeaux mixture @ 0.5 % or copper hydroxide @ 2.0 g/L or copper oxychloride @ 3.0 g/L at 15-20 days interval may help in controlling the disease

7. Cane maturity stage (61-90 days)

7.1 Indication of cane maturity

During the period of fruit bud differentiation, the vegetative growth is kept under control by reducing irrigation water. As such this stage coincides with cloudy weather, rainfall, high humidity and drop in temperature. Hence, the irrigation water should be applied only when required. Normally, if the soil is at field capacity, there is no need to give irrigation. With the change in the rainfall pattern, number of rainy days are reducing. Hence, the interval between two rainy days could be as high as 15-20 days. Under such conditions, the irrigation water requirement could range from 2500 to 3500 L/acre/day. The reduced growth helps in either fixing or establishment of fruitful bud. The cane maturity generally starts from 60 days after foundation pruning and completes after 90 days depending upon the soil type, weather condition and irrigation water applied.

At this stage, the purple color at the base of shoot gets slowly converted into milky white. This is also called the indication of cane maturity (Fig.38). The vegetative growth at this time needs to be kept under control by applying potassic fertilizers. Removal of 3-4 basal leaf on each shoot will also help to reduce relative humidity in the canopy thereby advancing the cane maturity.


Fig. 38: Indication of cane maturity

To advance the cane maturity, based upon soil and petiole test, 64kg/acre sulphate of potash (during 60 to 120 days after foundation pruning) should be applied. In case of potassium deficiency, there is a possibility of leaf curling on the vine (Fig.39). The curling will be more prominent if the deficiency coincides with rains. In severe deficiency, yellowing on the margin of the leaves will also be visible. If the deficiency is not corrected, then its affect in the succeeding fruit pruning season leading to small bunch size / reduced fruitfulness could be seen. Growing of green manure crop in the rainy season will help in improving the soil fertility and suppressing the weeds. The green manure crop should be ploughed back into the soil at flowering stage for better results.

Fig. 39: Leaf curling due to potassium deficiency

The barks present on the cordon and trunk can soak water and have sponge like effect (Fig.40). It will lead to increase in relative humidity when the temperature starts rising during monsoon season. This provides conducive climate for the development of downy mildew disease. Removal of 3-4 basal leaves on the shoot will help in proper aeration in the canopy thereby reducing the relative humidity. Removal of bark

Fig. 40: Loose bark on cordon

before the monsoon will be helpful not only for the control of disease but also reduce stem borer population.

7.2 Leaf blackening and necrosis (sodium toxicity and potassium deficiency)

Fig. 41: Leaf blackening and necrosis caused by K deficiency and excess Na

Due to the presence of sodium in irrigation water exceeding 100ppm, the sodium levels in the soil increases. This leads to accumulation of sodium in the vines. At the same time with Dogridge rootstock having preference for sodium over potassium, possibility of potassium deficiency is high. The symptoms differ from the classic K deficiency with respect to the location. The symptoms are sometimes observed first on upper leaves of the shoot and sometimes on the lower leaves. Initially the leaves turn black and later on necrotic (Fig.41). This leads to poor fruitfulness, premature leaf fall and even death of perennial vine parts.

Use of soil amendments like gypsum, sulphur based upon soil test value in combination with green manuring, compost or FYM along with heavy doses of sulphate of potash as soil application helps in reducing this problem. Gypsum should be applied in 3-4 splits. After application, mix the gypsum with soil. The soil should be sufficiently moist to solubilise the gypsum. This is followed by applying irrigation water to leach down the sodium. It is always advisable to apply organic matter (FYM/ compost/ green manure/ crop residues) to improve the soil infiltration rate, before mixing gypsum to increase quick removal of sodium from the soil. Generally, 120-150 kg of sulphate of potash per acre should be applied. Out of these, apply 50 kg SOP during shoot growth stage to counter the uptake of sodium in the vines.

7.3. Training of vines

Open canopy always help in reducing the relative humidity and increases aeration in the vineyards. The individual shoot needs to be placed on the foliage wire and tied with sutali (Fig.42). This helps in uniform distribution of sunlight on all the shoots and advances the cane maturity. The air passing through canopy will also help to reduce the relative humidity. During this stage, the shoot growth will also be kept under control thereby increasing the lignification. Open canopy with controlled growth will have higher proportion of cytokinin indicating the good health of the vine. Such vines do not tend to be susceptible to diseases and insect pests.

7.4. Pest management

Fig. 42: Vine trained on wire

The cane maturity stage generally coincides with active monsoon period. Prevalence of high relative humidity coupled with rains and cloudy conditions may increase the risk of infestation of leaf eating caterpillar *(Spodoptera litura)*. The female moth lays eggs in groups, called egg mass on the lower surface of leaves. Neonate larvae of *S. litura* feed on chlorophyll content of the leaves by scrapping leaf surface. It leads to formation of silver network of larval feeding galleries on leaves which later turn brown and falls. The grown up larvae feed voraciously on leaves leaving behind only veins. This causes hindrance in photosynthetic activities. The pupation occurs in soil or in dried fallen leaves near the base of plants or inside holes made by stem borers.

The high relative humidity conditions are congenial for population build up of natural enemies like predatory coccinellids and parasitoids that help to check the infestations of mealybug in vineyards (Fig. 43 and 44). Hence, use of broad spectrum insecticides such as methomyl, fipronil, lambda cyhalothrin, etc. that adversely affects the natural enemies of insect pests should necessarily be avoided. Alternatively, use of entomogenous fungi, *Metarhizium anisopliae* @10^6 cfu/ml will be helpful. The prevailing high humidity will help in establishing this entomogenous fungi and managing infestations of both mealybugs and ants associated with them. For the management of

Fig. 43: Exit hole of parasitoid *Anagyrus* spp. from mealybug body

Fig. 44: Grub of indigenous lady bird beetle *Scymnus* sp. feeding on mealybug colony on grapevine


Fig. 45: *Celosterna scabrator*

Fig. 46: *Stromatium barbatum*

mites if required, sulphur 80 WDG @ 2.0 g/L water is effective. Excess shoot growth due to high humidity conditions may lead to build up of thrips population and reduce coverage during insecticide applications. Thus, excess shoot growth should be removed during this period.

Fig. 47: *Dervishiya cadambae*

Celosterna scabrator, Stromatium barbatum and *Dervishiya cadambae* are the major stem borer species infesting grapevine in peninsular India (Fig. 45 to 47). All three stem borer species cause extensive damage to the sapwood and heartwood of grapevine stem and reduce both vitality and productivity of the vines. Most of the adults of all the three species emerge during monsoon period and lay eggs.

Installation of light traps outside the vineyards will be helpful in monitoring the initiation of emergence of stem borer adults so that timely management can be carried out. The light traps can help in managing the adults of *D. cadambae*. Adults of stem borer will remain hidden under the loose bark of grapevine stem and cordons and majority of the eggs are also laid under this loose bark. Therefore, if this loose bark is removed just before the onset of monsoon, the adults will not find places to hide and lay eggs in the vineyard and thus, stem borer infestation will reduce. Further, removal of loose bark will help in exposing adults and eggs, if present any, on main trunk and cordons for their management by insecticides.

S. barbatum species of stem borer is pest of 6-7 years or older vineyards. The grubs of this species feeds inside the stem and convert the stem wood into powder like termites. Primarily this is pest of dead wood, therefore, it prefers older vineyards in which deadwood formation is there. The adults may start emerging during the first week of June and by mid-June majority of adult emergence takes place. However, small numbers of stem borer adults may keep on emerging till September. Just after adult emergence, washing of main stem and cordons with fipronil 80 WG @ 0.06 g/L, lambda cyhalothrin 5 CS @ 0.5 ml/L or imidacloprid 17.8 SL @ 0.3 ml/L water alternatively, during night will help in controlling adults. Lambda cyhalothrin 5 CS @ 0.5 ml/L is also effective in killing eggs of this species. The adult emergence and egg laying period during first fortnight of June is the only period when this species can be controlled. If this period is missed, then this stem borer cannot be controlled as no insecticide will be effective in controlling the larva and pupal stages. The larval period is of about 9 months. There is no external symptom on the plant visible in the vineyards infected by this species. During December to March months, when larva is feeding on the dead dry wood, the feeding sound can be heard in the old vineyards. More than 100 grubs of stem borer can be found in a single plant in case of high infestation. Two to three years of infestation can reduce the productivity of vineyards by 50%. This stem borer normally goes into pupation during second fortnight of March to mid-May. The pupal period is of about four weeks and the adult will remain inside the stem and wait for monsoon rains to start.

The time of adult emergence and oviposition for *C. scabrator* is exceedingly long which starts with the initiation of monsoon and lasts for about 120-150 days. The eggs are laid inside the stem by making a cut and covering with a substance which hardens after some time. Therefore, targeting adults and eggs for management is not feasible. The larva start feeding inside and make galleries. The best way to manage *C. scabrator* is to tag infested plants, tear apart the gallery and remove the larva.

D. cadambae adult moths emerge during the June-July moths and lay eggs. It's young larvae feed under the bark and later instars bore inside and make galleries. Regular monitoring, removal of loose bark and two washes of stem and cordon with lambda cyhalothrin 4.9 CS @ 2.5 ml/L water (water volume 2 litres per plant) at 7-10 day interval followed by single application of *M. brunneum* when the young larvae are feeding under loose bark is effective.

7.5 Care of vines

Control of new shoot growth

During this stage, the cloudy weather with rainfall results into increase in gibberellins in the vine. This will lead to emergence of new shoot thereby delaying cane maturity (Fig. 48). The food material diverted to new shoots from the matured canes and thus the growing shoot will become weak.

Fig. 48: Excess growth during rains

Fig. 49: Removal of excess growth

Fig. 50: Hard pinching leading to inflorescence

Fig. 51: Pinching of only shoot tip

Therefore, timely removal of unwanted shoots/excess growing shoots is necessary for ensuring proper growth and maturity of the canes (Fig.49). Many times, the growers either delays shoot pinching or the growing shoot is removed with 5-6 buds. This removal of growing shoots with 5-6 buds is called hard pinching. Under this condition, the new growth starts at a faster rate leading to emergence of many inflorescence on a vine (Fig.50). This is generally experienced after 16th or 17th leaf. Looking at emergence of bunches on new growth, the growers gets confused that in the coming season (fruit pruning), there may not be bunches on the vine. Normally the fruitful zones lie near to the knot developed on a cane (in case of sub cane) or at 6 to 8th bud position (in case of straight cane). Therefore, the growers are advised to avoid hard pinching and remove only the shoot tip (Fig.51).

7.6. Disease management

Anthracnose is extremely severe during this period as the vines receive intermittent showers and drizzles (Fig.52). Pruned material should not be dumped near the vines because if they are retained close to vineyard and open on soil surface, it may get wet with rain and air borne spores of the pathogens such as *Elsinoe / Colletotrichum* will again infect new shoots. Typical 'shot hole' symptoms are seen on the leaves (Fig.53). Spores overwintering in the cordons and infected canes form the primary source of infection will spread in the vineyard with the rains. Application of thiophanate methyl 70WP or carbendazim 50 WP @ 1g/L twice at weekly interval gives good control of the disease. Sprays of copper fungicides suggested for control of downy mildew will also control anthracnose. Drip application of *Trichoderma* sp. should be done especially when relative humidity is high due to intermittent showers.

The combined effect of humidity and warm temperature predisposes the vines also to bacterial leaf spot disease and minute water soaked lesions (Fig.54) are seen on the lower surface of the leaf, which enlarge and become angular (Fig.55). In severe cases, it causes complete defoliation of leaves. Mancozeb applied for downy mildew infection will simultaneously control bacterial leaf spot as well. Copper oxychloride/hydroxide can also control the disease effectively.

Many times mixed infection of anthracnose and bacterial leaf spot occurs simultaneously and in such cases application of kasugamycin 5% + copper oxychloride 45% @ 0.75 g/L yields good result.

Once there is a break in the rain, but still the cloud cover along with high relative humidity prevails, there is a probability of a powdery mildew attack (Fig.56). The canopy, being dense during this time, further predisposes the vines to the disease. Efforts should be made to allow air and sunlight to enter the vines. Application of sulphur 80WDG@ 2.5g/L can control the disease effectively. However,

Fig. 52: Anthracnose spreading from the older canes to the new shoots

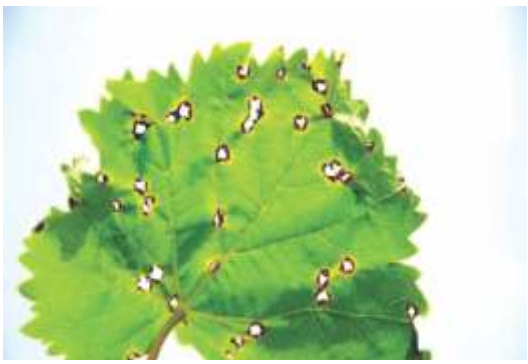

Fig. 53: Typical "shot hole" symptoms on the leaves

Fig. 54: Minute water soaked lesions on lower leaf surface

Fig. 55: Angular spots become light to dark brown

Fig. 56: White powdery patches on upper surface of leaves

sulphur should not be sprayed if temperatures are very high (35-40°C) as it may cause phytotoxicity. Alternatively, potassium bicarbonate 5.0 g/L may be applied with a silicon-based adjuvant @ 1ml/L.

8. The vine before fruit pruning

At cane maturity stage, reducing the amount of irrigation water and application of potassic fertilizers help in controlling excess shoot growth and improves cane maturity. This leads to cane thickening and advancing of cane maturity. The external color of the cane becomes brown and the pith inside the cane becomes darker in color indicating that the cane is fully matured (Fig. 57). Such cane has more food reserve than the immature canes. In comparison to the mature canes, the immature canes have white color pith indicating less food reserve in such canes (Fig.58). The immature canes do not produce quality bunches but most of the time it is observed that the bunch on such canes gets converted into filage. The bud seen under electron microscope gives clear indication of the availability of proper bunch.

Fig. 57. Mature cane on vine

Fig. 58. Immature cane

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