Climate Smart Viticultural Technologies for Sustainable Quality Grape Production

Edited by
Dr. Deependra Singh Yadav
Dr. Roshni R. Samarth
Dr. Sujoy Saha
Dr. N. Balasubramani

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2023

ICAR-National Research Centre for Grapes (ICAR-NRCG) Pune &
National Institute of Agricultural Extension Management (MANAGE), Hyderabad
(Autonomous Organizations under the
Ministry of Agriculture and Farmers Welfare, Govt. of India)

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Foreword

Grape is one of the high value export-oriented fruit crop commercially grown in our country. Like any other agricultural crops, Grape cultivation in India is more challenging due to changing climatic conditions and occurrence of several biotic and abiotic stresses. Climate change has imposed increasing warm and dry conditions on vineyards. Wine quality and yield are also drastically influenced by climatic conditions and depend on complex interactions between temperatures, water availability, plant material, and viticultural techniques. In majority of the viticultural practices, the revenue generated are largely driven by yield.

Similarly, the quality potential of the grapes is also important, as it can significantly affect the quality of the resulting wine and ultimately affects the consumer's price. To address the climate and climatic variability and remain internationally competitive, strategically designed interventions at various stages of viticulture are required.

In view of this, ICAR-National Research Centre for Grapes (ICAR-NRCG) and National Institute of Agricultural Extension Management (MANAGE) organized a collaborative training program for the extension functionaries and brought out this e-book by covering various technologies in Climate smart viticulture, Agromet advisory services for management of climate risks, canopy management in grapes, innovations in grape processing, role of artificial intelligence, crop insurance in horticultural crops and so on. It covers all the calendar of activities to be followed at different growth stages of grapevine under different agro-climatic conditions. This publication also gives insights on weather forecast based management of diseases and bio-intensive management of diseases for quality and residue compliant grapes. This e-book will serve as an exhaustive source of information and guideline for grape growers, State Govt. officers, researchers, students and other stakeholders in India.

I congratulate Dr. Deependra Singh Yadav Dr. Roshni R. Samarth and Dr. Sujoy Saha from ICAR-National Research Centre for Grapes (ICAR-NRCG) and Dr. N. Balasubramani from MANAGE for compiling this e-publication. I also appreciate all the experts who contributed chapters giving insights about various vineyard practices and scientific validated technologies and innovations in viticulture.

(Dr. P. Chandra Sekhara)
Director General, MANAGE

Foreword

Indian viticulture is unique because it is carried out in a variety of agro-climatic conditions. Among the table grape producing countries, India ranks second after China. The area under grape cultivation has increased in multitudes in the past few decades and the market demand for Indian table grapes has also increased manifold. However, erratic shifts in the climate verticals not only affected the yield and quality of the produce, but also alter the phenology of the grapevines. A consistent trend in the rise of atmospheric temperature is manifested in many of the plant phenological stages happening prematurely, e.g., flowering, berry setting, and maturity. These in turn lead to changes in the whole management schedule of a vineyard.

In India, majority of the grape vineyards are located in semiarid climate. Climate changes may aggravate the problems of irrigation water availability and salinity. The elevated carbon dioxide levels may increase productivity in arid and semiarid regions, but the drought stress caused by higher evaporative demand may override beneficial effects of increased carbon dioxide in the atmosphere. Developing heat-tolerant grape varieties and salt- and drought-tolerant rootstocks, is a time-consuming process and until new varieties/technologies are developed to improve water use efficiency and cope up with salinity, the emphasis needs to be given on propagation of existing crop production techniques that can mitigate the impact of climate change. There is also likelihood of change in the incidence and pattern of diseases and insect pest infestations. Due to unseasonal rains, which lead to serious downy mildew and bunch rot incidences, a significant yield reduction is often observed. To remain internationally competitive and to supply quality grapes to domestic consumers round the year, a number of strategic interventions are required. Artificial intelligence and machine learning, precision viticulture, decision support system, zero-waste processing, and biointensive strategies for nullifying biotic stresses are some of the key areas that need to be shared among stakeholders, academia and research community to help farmers producing better crops with superior qualities.

ICAR-NRCG, Pune is a premier institute established with the mandates of basic, applied and strategic research on grapes as per the needs of the farmers and agro-industry stakeholders, efficient transfer of technologies, and successful implementation of a comprehensive food safety-traceability system to promote export of fresh grapes. Keeping this in backdrop, the training course organized by ICAR-NRCG in collaboration with MANAGE was designed to provide a good insight into the advances in various facets of viticulture, and to deliberate the issues related to climate resilient, sustainable grape production and trade.

Date:17.03.2023 (Kaushik Banerjee)

Place: Pune Director

Contents

Climate smart viticulture technology

Shivanand Neji, Manager

Amicus Agro Tech, Gadhinglaj-416502, Maharashtra

India is among the first 10 countries in the world in production of grapes. Maharashtra produces 71% of total production and Karnataka is the second largest producer with a 24 % share in total production. The ideal temperature for grape production is 25 to 32^{0}C and humidity between 40 to 60%. Temperature and humidity above or below this optimum range causes limitation to vegetative growth, yield and quality of production. The Bureau of Meteorology, Australia published a 400 years average temperature graph in 2018. According to this graph from 1970 global average temperature is rising rapidly. In 1970 global temperature for the first time reached 0.5^{0}c more than average temperature and presently the global temperature has reached all time high of 1^{0}c more than average temperature. This will impact nature, ecosystem and productivity of crops including grapes.

Before 1970, the El Nino phenomenon occurred in between 7 to 10 years. Now a days after 2000, the frequency is reduced 3 to 5 years. Several studies have been conducted to measure the effect of climate change on productivity and quality of table grapes produced. Changes in temperature and rainfall patterns have both positive and negative impacts on viticulture.

The rising temperature impacts nature's eco-system and growth and productivity of crops. High temperature, elevated ultraviolet rays and increased atmospheric carbon dioxide concentration influence the maturity and physiology of grapes. Rate of soil erosion and degradation is faster in higher temperature and in heavy rainfall spells.

Draught and flood both are harmful for quality production. Heat and waves occurring frequently cause hot and dry weather while cold waves fall in fall of minimum temperature which causes chill. These waves significantly impact plant health by thermal stress. Thermal stress causes leaf chlorosis these events yield and cold wave flows can kill the plant resulting in total crop failure. Rising co_2 concentration is associated with higher vegetation, lower quality and increased pest attack. Life cycle of pests completes faster than usual in case of high co_2 level.

As increasing temperature accelerates the decomposition rate of organic matter it influences water and nutrient storage capacity. For sustainable production we have to slow down the degradation process and maintain soil structure to prevent erosion at extreme weather events. Healthy soil can help in resilience to such events. We have to improve irrigation technology to manage water precisely to reduce water pollution and soil contamination. Use nutrients according to growth stage requirement and quantity by soil and petiole analysis report. We have to improve our practices to minimize air and water pollution along with increasing carbon levels.

For sustainable viticulture we need to focus on producing long term crops and a minimal impact on environment such as soil, water, air can change climatic conditions. We have tried to find balance between food production and preservation of the ecological system. The factors affecting crop yield and quality are soil structure and fertility, the quality available water, local climate, diseases or pest attack. The climate smart viticulture should comprise a set of locally tuned strategies, for short term to the long term adaptation and mitigation technologies and decisions support system.

While developing grape variety for ongoing climatic changes following points should be accounted for. The grape variety should have high yield along with early maturity. The variety should perform well in extreme weather events like water logging, drought like condition and tolerance to salinity. It should have low physical and phsiological disorder with tolerance to pests and diseases. It must have good aroma, taste and sugar content. Before choosing a variety, local climatic conditions and soil type is to be considered.

To improve the production practices adoption of new technologies has to develop. The ICAR- National Research Center for grapes has designed a Decision Support System (DSS) for grapes. In this technology grape growers can get a precise forecast of disease and pest attack and their intensity for next seven days. This technology works on weather history and forecast, crop stage and location of vineyard. Grape growers with this technology can take proper decisions to control or prevent disease. The Design Support System (DSS) reduced the number of spraying to the tune of 28-30% which in turn reduced the cost of spraying by 20-25%. The decision making power of grape growers increased as scientific information and forecasts reached grape growers on a daily basis. This also contributed to the overall improvement in knowledge of grape growers.

Farmers will get suggestions of suitable chemicals to prevent or control pest and disease keeping MRL & PHI. Grape growers can get knowledge about nutrient and water requirements from DSS in which last two day irrigation or rainfall data will provide water requirements by considering the rate of evaporation, crop stage and soil type. From the petiole analysis report farmers get knowledge about nutrient requirements. We can reduce wastage of water by using wisely and precisely. We can also reduce production cost and environment pollution.

From the last two decades, viticulture is using another one valuable tool i.e. remote sensing which produced remotely sensed images of vineyards that have relationships with grape health, soil condition and yield. With the rising availability of high spatial and temporal resolution datasets, increasing computing power and advances in image processing software, the opportunities for vineyard interrogation through spatial analysis are increasing. Remote sensing and image analysis techniques are becoming more accessible. For remote sensing, satellites, microsatellites, aircrafts and drones are used to take multi or hyper spectral images. colour infrared photography records reflectance in the green and red wavelengths of visible life and in the near infrared range from reflectance to get bare land, vegetation , leaf area , plant health , soil moisture at a grid of 3 to 10 meter.

The current and future application of these technologies and artificial intelligence in vineyards are discussed in relation to soil properties and topography, vegetative growth, canopy architecture, nutrient and water status, leaf area and health crop and area forecasting. Technologies of enormous potential for growers, their adoption and use, will depend on user friendly software and devices at affordable cost.

Constraints

For disease and pest forecast, accurate observation and weather forecast are required but in India, accuracy of weather forecast is around 60 to 70 % there is not enough weather observation data (Weather Stations). Field to field climatic conditions may vary i.e. soil type, structure; canopy which will impact on disease and nutrient uptake. Growers spray history is also not considered while forecasting the disease.

Efficacy of chemical and spray equipment have to be considered some diseases require more coverage. Local situations and micro climate may develop within the canopy. Canopy conditions and previous disease history conditions of the plot have to be considered. If proximal sensors are installed periodical calibration and tuning will be required. For remote sensing grid size of images are higher and some time it will take 5 to 10 days to go to the next image. In monsoon or cloudy conditions ground data is not available as clear weather required while passing imagery devices.

Sustaining grape production under changing climatic conditions

A K Upadhyay, Principal Scientist (Soil Science)

ICAR- National Research Centre for Grapes

Pune, Maharashtra-412307

Grape being a temperate crop adapted well under tropical conditions of India by following double pruning (foundation and fruit pruning) and single cropping. In India, grape is cultivated as solo crop dominated by Thompson Seedless variety and its clones, occupying > 70% acreage. In India, during last fifteen years, the area under grapes has increased from 52.1 thousand ha (2002-03) to 140 thousand ha (2020-21) (NHB database), an increase of 2.6 times. The production during the corresponding period increased by 2.38 times, however productivity of the vineyards has remained near 21 tonnes/ha.

From 2006 onwards, climate variability is being observed in grape growing region affecting vineyard productivity. The climatic factors like temperature and precipitation changes slowly but could lead to severe droughts or unseasonal events like cyclones, hailstorms, unseasonal rains etc. Further, even though the quantity of precipitation remained same, nevertheless trends have changed to less number of rainy days, more intensity and less duration. Grapes majority of acreage is confined to Maharashtra and Karnataka concentrated in the agro-ecological region- (K4Dd3) with the mean annual precipitation ranging between 600 and 1000 mm, covers about 40 per cent of annual PET demand (1600 and 1800 mm). Many of the districts in these areas are drought prone and vine performance is affected due to moisture and temperature stress.

The most imminent challenges facing by wine, table grape and raisin industries in arid and semiarid regions are probably not heat waves per se, but increasing drought and salinity because of higher evaporation coupled with declining water availability.

Moisture Stress

Globally temperature is on the rise influencing the crop performance. Atmospheric surface temperature in India has increased in the last century by about 1°C and 1.1°C during winter and post-monsoon months, respectively. This has already stressed the water requirements for agriculture. In grapevine water requirement differs based on the phenological stages. As stress being desirable at certain growth stages e.g. Bud differentiation stage, Flowering stage. Studies in different grape growing regions on impact of moisture stress on phenology has observed the impact of moisture stress on growth, yield and quality. The yield loss in different moisture stress scenarios ranged from 6.4% to as high as 26.2 % during the period of experimentation. Mild water stress (50% of recommended irrigation schedule) during shoot growth stage coupled with dry period during foundation pruning season could cause yield loss upto 26.2%. The sugar accumulation rates are lower in the moisture stressed vines as compared to vines irrigated with recommended irrigation schedule.

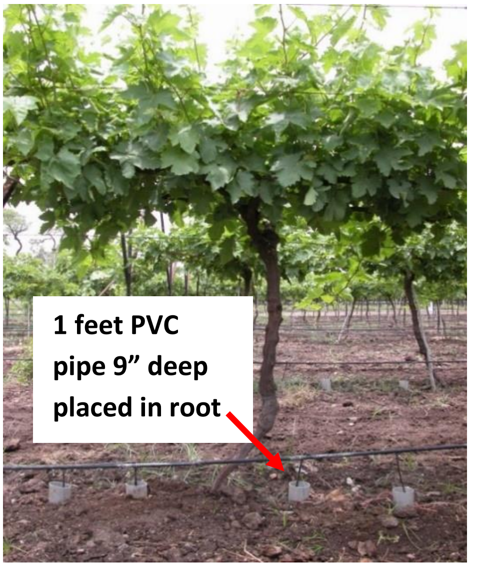


Figure 1: Subsurface irrigation

ICAR-NRC Grapes has standardized irrigation schedule based upon pan evaporation and crop growth stage through surface drip for Thompson Seedless vines. This led to 52% savings in irrigation water over farmer's practice. Institute has developed approaches to enhance productivity by utilizing water saving technologies *viz.*, subsurface irrigation, combination of mulch with antitranspirant and partial rootzone drying technique. These technologies were also demonstrated in the farmer's field. In Jath (Sangli Dist.), a saving of 25.8% and 46.8% irrigation water was recorded respectively under recommended irrigation schedule and subsurface irrigation technique over farmer's practice.

At Palsi (Sangli Dist.), recommended irrigation schedule and partial rootzone drying technique could save 31.6% and 19.1 % of irrigation water, respectively. Similarly, in Fantasy Seedless vines, subsurface irrigation and partial root zone drying techniques, respectively, used 121mm and 65 mm less irrigation water, however produced only 2t less berry yield than recommended irrigation schedule. Utilisation of Decision support system that handles queries on irrigation, nutrition and problems caused due to moisture and temperature stress is new initiative to address the concerns of moisture and temperature stress. ICAR-NRC Grapes has developed and launched Web and mobile based DSS applications.

Temperature stress

Rise in temperature can shift grapevine phenological stages such as budburst, flowering, veraison, harvest and thereby yield. In fact, the seasonal changes can influence the formation and ratio of sugar in berries. In a study covering 18 years, the percentage of fruitful buds in Thompson Seedless correlated highly with air temperature and hours of sunshine during a 20-day period at the beginning of a season. The annual succession of phenological stages of grapevines is commonly observed to be accelerated with a rise in temperature leads to earlier flowering, veraison and harvest.

Our studies showed that in Thompson Seedless vines pruned on 1^{st} May, sprouted earlier (12 days) as compared to the vines pruned on 1^{st} April (17 days). This difference in days taken to sprout in the vines pruned on 1st April could be attributed to low day time RH (< 20%) along with high temperatures between 9 am to 6 pm. Further, vines pruned on 1st May had less number of fruitful canes may be due to early onset of monsoon leading to cloudy weather conditions. The vines pruned in April (Foundation pruning) and October (Fruit pruning) had significantly higher yield as compared to vines pruned in May (Foundation pruning) and fruit pruned in November.

The decrease in yield in the second case was due to early onset of monsoon leading to cloudy weather conditions during the fruit bud differentiation stage in Foundation pruning season. The accumulated Growing degree days (°C) ranged from 1450.60 to 1464.60 in different pruning dates during Fruit pruning season. However, the number of days taken to accumulate the growing degree days ranged from 117 to 128 under different pruning treatments.

Unseasonal events

Widespread weather extreme events like cyclonic disturbance, hail, unseasonal rainfall, frost and temperature stress during the productive period from 2009 onwards is playing havoc. Earlier the traditional grape growing areas in Nasik etc. were safe by these extremes as the period between October to March used to be dry months. Further, time of occurrence of these events has a direct bearing losses to the growers. Frost event in Nasik in February, 2012 severely affected the vineyard productivity especially where crop was in late berry development stage. In the case of hail storm events (2014), covering most grape areas in Maharashtra and North Karnataka, the extent of damage in individual vineyards, varied from 20 to 100 per cent. Young vineyards were severely affected with impact on productivity being felt even in the subsequent year.

Early onset of monsoon effects the fruitfulness especially in the May pruned vines due to excess soil moisture and cloudy weather conditions.

Average fruitfulness in vineyards pruned between 1st to 26th May was 23% compared to 89% in vines pruned from 1st April to 24th April. Unseasonal rains during early growth stage in fruit pruning season leads to severe downy mildew infestation and crop loss whereas during ripening stage, results in severe berry cracking and possibility of loss of entire produce. The events of rainfall during October, 2017 is testimony to the extent of losses vineyards pruned between 1 to 15 September, 2017 have suffered mainly due to inflorescence necrosis.

The vines pruned during late September and early October suffered from low bunch emergence as the early emerging bunches were converted into tendrils. Even less rains during ripening stage will affect the post- harvest shelf life.

Plastic cover to protect crop in extreme weather events

Currently the major destination of export for grapes is European Union. But the export was mainly confined to February – April window. However, during last few years, the grapes from Chile, South Africa and Peru are also making their presence during this period. It is therefore, necessary for India to diversify its grape export to different markets. Already efforts are underway to tap the export market of China, Far East (Korea), even Australia and New Zealand. For this the crop needs to be ready by December-January. It implies pruning vineyards early from July-September during the monsoon period, which involves risk.

Use of plastic cover can protect the crop from extreme weather events especially unseasonal rains, low temperature and hailstorms. Studies at ICAR-National Research Centre for Grapes shown that the use of plastic cover in vineyards has favourable impact on vine growth and productivity. We observed the significant increase in yield from 8.34t/ha under open conditions to 18.59t/ha under plastic cover. The use of plastic cover technology has also been validated in 2017, when rainfall event occurred during early growth stage in fruit pruning season. The vines in the open and under hailnet experienced severe downy mildew infestation leading to very low productivity. Further, irrigation water requirement could also be reduced by 20%. Thus plastic cover technology appears to be promising for areas where such extreme weather events are more likely.

Figure 2. Use of plastic cover in vineyards

The plastic cover on the vineyards has the following advantages:

1. The problem of inflorescence necrosis/ flower drop/ bunch rot in addition to heavy incidence of Downy mildew is addressed through plastic cover.
2. Plastic cover protects the vines from damage to the vine parts (cordons, trunk, canes) and bunches from hails.
3. It also reduces the berry cracking incidence due to unseasonal rains (accompanied with hails).
4. Plastic cover on vineyards reduces the impact of temperature on vine growth and productivity.
5. Due to low transpiration loss from the leaves, the irrigation water requirement is also reduced by 20% under plastic cover especially during fruit pruning season.
6. To avoid glut in the market and improve profitability, risk free early pruning can also carried out.

Specification and Cost of installation:

The plastic cover used should be woven laminated film, UV stabilised to 580 kLy (Indian conditions) with anti-thermic properties (25% thermicity). It should have 85 to 90% light transmission with 65 ±5% light diffusion with cloth weight of 140±5% gsm/sqm. It should also have anti-sulphur, anti-drip and anti-dust properties. The cost of plastic per acre ranges between Rs 2.75 – 4.5 Lakhs depending upon whether it’s imported or indigenous. The life of the plastic cover could range from 3 to 5 years depending upon quality of plastic. The cost of structure ranges from Rs 2.5 – 3.5 Lakhs/acre for erecting on existing structure, whereas, for erecting independent support structure irrespective of Y trellis, the cost may range between Rs 4.11 to 5 Lakhs/acre.

Irrigation scheduling and moisture conservation techniques in vineyard

A K Upadhyay, Principal Scientist (Soil Science)

ICAR- National Research Centre for Grapes

Pune, Maharashtra-412307

The water requirement varies with different growth stages of vine. At certain stages of the vine, moisture stress is beneficial (fruit bud differentiation) while moisture stress during more vegetative growth leads to less fruit bud which is harmful.

From foundation pruning to bud differentiation stage (normally mid-April to May) the water requirement is maximum. Vines should not be stressed in order to obtain canes of desired thickness (8-10 mm) and sufficient canopy. In the fruit bud differentiation stage, irrigation should be reduced to facilitate better bud differentiation. Shoot maturity and fruit bud development stages coincides with rainy season, but still there is a need to irrigate the vines as the rainfall is highly erratic, non-uniform distribution and gap between two rainy events are more.

In the fruit pruning or forward pruning season, the vines should be irrigated timely 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 (berry dropping) helps in reducing berry set which are otherwise to be thinned. Berry growth to veraison period 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. During the period from veraison to harvest, the vines should not be over-irrigated in order to avoid berry cracking and delay in harvest. Moisture stress at this stage however results in berry drop. During resting period (after harvest) the vines can survive on available soil moisture in heavy soils. If the rest period is more than 15-20 days, the vineyard should be irrigated every week based upon the temperature but adequate care should be taken to discourage new growth.

Irrigation scheduling: water requirement of grapes varies with the atmospheric aridity and the stage of the growth of the vines. Scheduling of water is to be based on the pan evaporation reading, which is an index of water lost from the plant. Further, quantum of water applied should conform to the crop requirement at a given stage. This calls for irrigation scheduling.

The grapes grafted on rootstocks have better root systems for exploitation of soil moisture from deeper layers and hence less irrigation water is required compared to own rooted vines. On the basis of experimental data generated at NRC Grapes on Thompson Seedless vines raised on Dogridge rootstock, the best irrigation scheduling for grape grafted on rootstock under saline irrigation is given in table 1. These recommendations are for guidance purpose only and may change based on site conditions.

Table 1. Irrigation schedule for Thompson Seedless vines raised on Dogridge rootstock

Growth Stage	Expected duration (days after pruning)	Water requirement (litres/day/hectare per mm of evaporation)	Month of operation	Expected Pan evaporation (mm)	Approximate water (litres /hectare/day)
Foundation Pruning					
Shoot growth	1-30	4200	April-May	8-12	33,600-50,400
Shoot growth	31-40	4200	April-May	8-12	33,600-50,400
Fruit bud differentiation	41-60	1400	May-June	8-10	11,200-14,000

Cane maturity and Fruit bud development	61-120	1400	June-August	0-6	0-8,400
121days - fruit pruning	121 -	1400	August-Fruit pruning	0-6	0-8,400
Fruit Pruning					
Shoot growth	1-40	4200	October-November	6-8	25,200-33,600
Bloom to Shatter	41-55	1400	November - December	4-6	5,600-8,400
Berry growth and development	56-70	4200	December - January	3-6	12,600-25,200
Berry growth and development	71-105	4200	December - January	3-6	12,600-25,200
Ripening to Harvest	106-harvest	4200	January - March	8-10	33,600-42,000
Rest period	Harvest to Foundation pruning	-	March-April	8-10	-*

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.

1. Salinity: Salts are added to the soil by irrigation water and accumulate in soil.
2. Soil permeability: Salt water or relatively high sodium water may reduce soil permeability.
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.
4. Problems associated with a water pH above 8.40 or below 6.5 are usually related to toxicity, nutritional imbalances or soil permeability. Nutrients such as nitrogen may cause excessive vigour and lowered yields. Water high in bicarbonate may result in an objectionable white deposit of lime on leaves or berries. Problems related to high bicarbonate in irrigation water can be reduced by addition of sulphuric acid at controlled rate to reduce water pH to 6.50.

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. General guidelines for evaluating water quality are given in Table 2. 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 EC_w (dS/m)	< 1.00	1.0 – 2.7	> 2.7
Permeability: Affects rates of water movement into the soil and through soil EC_w (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

Peacock and Christensen Interpretation of soil and water analysis

NOTE: Guidelines are flexible and should be modified when warranted by local practices, experience, special conditions. Interpretations are based on chemical analyses of the soil saturation extracts from soil samples representing a major portion of the root zone-usually the top 2 to 3 feet of soil.

Techniques to reduce evapo-transpiration: The prime grape growing areas in Maharashtra and North Karnataka suffer varying degree of moisture stress. Use of antitranspirant (Antistress) on Thompson Seedless vines during foundation pruning season i.e. 4-6 ml antistress / litre after 30, 60 and 90 days after pruning and two sprays @4 ml antistress / litre at 25 and 55 days after fruit pruning in combination with bagasse mulching could save 25% of irrigation water. The usage of Antistress or any antitranspirant, should be checked for any restrictions on its application based on Good Agricultural Practices and the market requirements. Plastic mulching can also be used. The thickness of the plastic should be at least 25 microns. Both plastic and organic mulch also reduces weed incidence in the vineyards. Another solution could be sub surface irrigation, wherein the irrigation water is conveyed directly to the root zone.

This technique can reduce irrigation water requirement by 25 % by applying irrigation directly in the root zone at 9 inches depth in heavy soils and at 4 inches depth in light soil in the existing surface drip irrigated system. Any hollow pipe of 2.5 inches diameter open on both sides (PVC pipes, earthen pipes, discarded plastic bottles) with holes on lower side and microtubes can be used for delivering irrigation water in the root zone in heavy soils. This irrigation technique also reduces weed incidence.

Irrigation water having electrical conductivity less than 1dS/m, residual sodium carbonate less than 1.25 meq/L, sodium adsorption ration less than 8, chlorides less than 4 meq/L and boron less than 1 ppm are considered safe for irrigating the vineyards. However, availability of poor quality of irrigation water provides considerable challenge to the grape growers to efficiently manage their vineyards for attaining optimum yield. Usually vineyard productivity is reduced noticeably before visual symptoms are noticed on the vines. To cope up with salinity, vines were raised on Dogridge rootstock.

However, studies at NRC Grapes suggest that it cannot exclude sodium. Under saline irrigation, vines grafted on Dogridge rootstock has shown the tendency to accumulate sodium in excess leading to K deficiency, reduced fruitfulness and death of perennial vine parts. The rootstock 110R and B-2/56 (a clone of 110R) has the property to exclude sodium and can perform under such conditions as compared to Dogridge rootstock. Use of soil amendments like gypsum 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.

Soil management for nutrition and problematic soils

A K Upadhyay, Principal Scientist (Soil Science)

ICAR- National Research Centre for Grapes

Pune, Maharashtra-412307

In India, grape is mainly grown in the semi-arid tropics with more than 90 % of the area concentrated in Maharashtra and North Karnataka. Majority of the vineyards are either raised on heavy soils or on marginal lands. Though grapes can be cultivated on varied soil conditions, deep and well-drained soils with pH range of 6.5 – 8.0 is ideal. The soil pH above or below this range is known to restrict availability of some nutrient elements and thus inhibit growth and development. The weather is mostly dry with less number of rainy days (30- 40 days) during the year. Once planted, it stays at the site for atleast 10-15 years. Favourable rooting environment and proper understanding of the phenology is key to efficient water and nutrient management. Being double pruned and single cropped, the nutrient requirement differs between both the pruning seasons. However, this region suffers from abiotic stress namely moisture and salinity stress.

Nutritional requirement of vines differ with crop growth stages. The grapevines are drip irrigated and the same technique can be efficiently used for delivering nutrients based on crop growth stages, split intervals and on demand. Fertigation allows the application of nutrients precisely and uniformly to the wetted volume where active roots are concentrated. This improves the fertilizer use efficiency as compared to conventional practice of direct application of fertilizer to the soil. Studies carried out at NRC Grapes on Thompson Seedless vines raised on Dogridge rootstock have clearly shown 60 % saving in the fertilizer when applied through drip over soil application. The nutrient doses given for fertigation should be modified according to the petiole nutrient status of the vines, as over the year's nutrient build up in the soil increases. For better results fertigation interval should not be more than three days and nutrient doses should be applied in equal splits depending upon the number of days in a particular stage. Nutrient present in the irrigation water and the contribution of organic manures should also be taken into consideration. Generally, it is recommended to apply 25 t FYM/ suitable other organic sources every pruning season to improve the soil physico-chemical and biological properties. Grow a green manure crop in the rainy season. It also helps in suppressing the weeds. Plough the green manure crop when it is in flowering stage. Fertigation schedule for grapes are given in table 1. The quantity of nutrient given are guidelines for distributing the NPK doses at different growth stages and may vary based on the site and climatic conditions.

Table 1. Fertigation schedule for Thompson Seedless vines raised on Dogridge rootstock

Growth stages	**Expected duration (days after pruning)**	**Nutrient application (kg/ha)**		
		N	**P_2O_5**	**K_2O**
Foundation pruning season (April – October)				
Shoot growth	1-30	60	-	-
Shoot growth	31-40	20	35.5	-
Fruit bud differentiation	41-60	-	71	-
Cane maturity and Fruit bud development	61-120	-	-	80
121 days - fruit pruning	121 -	-	-	-
Fruit pruning season (October – March)				
Shoot growth	1-40	80	-	-

Bloom to Shatter	41-55	-	26.5	-
Berry growth and development	56-70	-	26.5	-
Berry growth and development	71-105	80	-	80
Ripening to Harvest	106- harvest	-	-	80
Rest period	Harvest to Foundation pruning (20 days)	26	18	26

Majority of the grape growing areas in Maharashtra and North Karnataka are alkaline in reaction and also calcareous. The grapevines are able to tolerate calcium carbonate level upto 5%. Calcium deficiency in calcareous soils is not common and do not require specific fertiliser application unless vineyard soil has high pH or sodium. Certain climatic conditions (cold or rainy) or nutrient imbalance in soils may cause Ca deficiency in fruits (berries) which can be corrected by two to three foliar applications or bunch dipping between fruit set and veraison stage @ 0.3 to 0.5% (calcium chloride or calcium nitrate). Magnesium application must be done only if needed based on petiole test value, since in many vineyards ground water irrigation source may add substantial quantities of Mg in soil. To maintain Magnesium level in soil, apply magnesium sulphate @ 100 kg per hectare per pruning season in four splits. Among the micronutrients, zinc and iron are the most commonly deficient nutrients. Due to large variation of calcium carbonate in soil, no specific recommendations are available. Apply sulphur at an average of 50 kg per acre and boron 2 kg per acre per season in nutrient deficient vineyard.

Plant tissue analysis is used as diagnostic tool for detecting hidden hunger and nutrient deficiencies before the deficiency symptoms become visible. In grapevines, petioles are most sensitive to the changes in nutritional status and their nutrient composition helps in taking appropriate decisions for nutrient management. Grape petioles are sampled twice under double pruning and single cropping season for regular monitoring for nutrient status of vines during the bud differentiation stage and full bloom stage and once during full bloom stage in single pruning and single cropping system. The optimum level of petiole nutrient contents for Thompson Seedless vines grafted on Dogridge rootstock are given in Table 2.

Table 2. Optimum range of rootstock petiole nutrient contents for Thompson Seedless vines grafted on Dogridge

Nutrient	**Bud differentiation stage**	**Full bloom stage**
Macronutrients		
N (%)	1.20 – 1.53	1.44 – 1.80
P (%)	0.387 – 0.472	0.283 – 0.356
K (%)	0.590 – 0.680	1.61 – 2.95
Ca (%)	0.727 – 1.03	0.508 – 0.81
Mg (%)	0.877 – 1.28	0.579 – 0.870

Calcareous soil: Calcareous soils have high calcium carbonate content that upon dissolution results in a high bicarbonate (HCO_3^-) concentration in solution which buffers the soil in the pH range of 7.5 to 8.5. The presence of $CaCO_3$ directly or indirectly affects the chemistry and availability of nitrogen, phosphorus, magnesium, potassium, manganese, zinc, copper and iron. Improving calcareous soils requires not only reducing the soil pH but also neutralizing calcium carbonate in soil. For this the most cost effective solution is elemental Sulphur. To neutralize all calcium carbonate in the soil will require very heavy investments in Sulphur application. This is not practical. Instead of acidifying and neutralising the entire top foot of soil, one approach is to treat a portion of the rooting environment so that plants can grow without pH-induced chlorosis. Localized acidification can be accomplished by applying

Sulphur in the drip wetted area which effectively reduces the quantity of Sulphur applied to one-third. Application of 50-100 kg elemental Sulphur in each pruning season on a per acre basis will be desirable depending upon $CaCO_3$ content. If soil has high calcareous content, regular application for atleast 2-3 year will be required. Even reduction in soil pH will improve the availability of phosphorus and micronutrients in the soil.

The high pH of the soil affects the nitrogen mineralization in the soil, thereby reducing the nitrogen use efficiency. So, to maximise the nitrogen use under such situations, it is imperative that ammonium sulphate or urea are applied in splits through fertigation so, that along with water the nitrogen reaches to the root zone where they are utilised immediately and not left for ammonia volatilisation losses on the surface.

With regard to phosphorus, a variety of management practices can be used to slow natural fixation processes and increase the efficiency of applied fertilizer P for crop growth. Soluble P fertilizers (phosphoric acid, triple superphosphate, ammonium phosphates etc.) are the preferred source in calcareous soils. Organic matter has been found to interfere in the fixation reactions of P with lime. Thus application of more organics in the soil will improve the P availability to the vines.

High Ca levels in soils suppress Mg and K uptake by crops. Use of soluble potassium sources like sulphate of potash, potassium nitrate etc. in multiple splits through fertigation will improve the potassium availability to the grapevine.

Apart from that, 3-4 foliar application of potassium during foundation as well as fruit pruning season is advised. Application of soluble magnesium sources like Magnesium sulphate, magnesium nitrate etc. in multiple splits through fertigation will improve the magnesium availability to the grapevine.

Apart from that, 3-4 foliar application of magnesium during foundation as well as fruit pruning season is advised.

Iron is considerably less soluble than Zn or Mn in soils with a pH value of 8. Infact, high pH, high lime content and active lime leads to lime induced iron deficiency. Thus, inorganic Fe contributes relatively little to the Fe nutrition of plants in calcareous soils. Wherever, the problem of lime induced iron chlorosis is there, inorganic iron fertilizers like Ferrous sulphates should be applied in more splits and in high quantity through fertigation to make it available to the plants. The other option is soil application of Fe-EDDHA, chelated form of iron. Foliar sprays (2-3 no.) of ferrous sulphate (@ 2 g/L) will provide temporary relief. However, the pH of the spray solution should be acidic.

Zinc is also less available in calcareous soil due to high pH of the soil. Around 15-20 kg Zinc Sulphate on per acre basis will be sufficient per pruning season. This should be coupled with foliar sprays (1-2 g $ZnSO_4$/L) to improve the petiole zinc content.

Sodic soil

Soils are considered sodic if more than six percent of the CEC is occupied by sodium, and highly sodic if the figure is greater than 15 percent. The sodium dominates the exchange complex in comparison to calcium and magnesium and thereby affects the soil structure. The sodium weakens the bonds between clay particles when wetted. This results in dispersion of clay particle and swelling of the soil.

The clay particles then block the pore spaces thereby restricting the movement of water and air through the soil. This leads to water logging, less water storage in soil, soil crusting and more runoff from the soil. When soil is repeatedly wetted and dried and clay dispersion occurs, it then reforms and solidifies into almost cement-like soil with little or no structure. The clay soils are at a greater risk than course textured soils for excess sodium to bind to them and cause breakdown of soil structure.

The problems related to sodicity in different regions are becoming obvious in vineyards having ESP in the range of 6-8 percent depending on soil potassium levels and soil type. Irrigation water is the major source of sodium hence those having irrigation water high in sodium needs planning to reduce its build up right from planting stage. The impact of the sodicity is both direct and indirect. The indirect impact is due to poor soil structure. Soil with poor structure or compact soil will reduce the root growth, soil aeration and ultimately nutrient uptake thus making the vine weak. The weak vines will be vulnerable to disease and pest attack.

Table 3. Estimated efficiencies for various materials to reclaim sodic soils compared to gypsum

Material	**Tons of materials equivalent to 1000 kg of gypsum**
Gypsum	1000
Sulfuric acid	570
Sulfur	180
Lime-sulfur	750

Leaf blackening and necrosis has been found in the vineyards due to sodium toxicity and potassium deficiency. The symptoms are sometimes observed first on upper leaves of the shoot and sometimes on the lower leaves. The symptoms are observed on both grafted as well as ungrafted vines mainly under saline irrigation. This leads to poor fruitfulness, premature leaf fall and even death of perennial vine parts. The studies carried out at ICAR-NRC Grapes revealed that Dogridge rootstock couldn't restrict sodium uptake under saline irrigation (water rich in Na).

The most common method to improve sodic soil is by applying amendments like gypsum or sulphur (Table 3). Gypsum is calcium sulphate

($CaSO_4 \cdot 2H_2O$). The solubility of the gypsum is very low (2.0–2.5 g/l) hence, soil should be sufficiently moist to dissolve the gypsum.

In case of calcareous soils, sulphur should be used as amendment. The sulphur reduces the pH of the soil thereby leading to dissolution of calcium carbonate. This calcium then replaces sodium in the exchange complex. For leaching water one should use low sodium containing water. Evaporation should be reduced so that salts from lower layers do not come to surface. For this mulching will be very helpful.

Figure 1. Mulching in vineyards

		
Leaf blackening and Necrosis	Calcareous soil	Fe deficiency

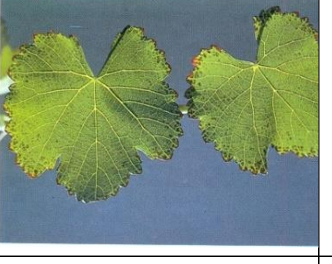
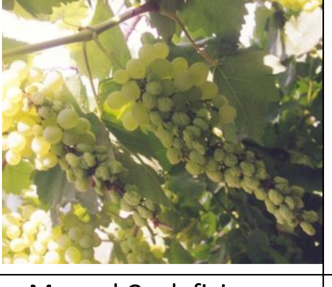
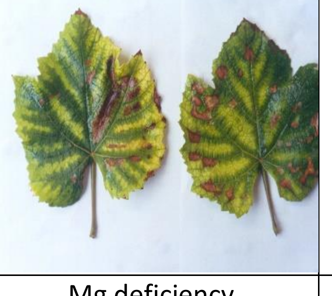
		
Zn deficiency	Zn deficiency	Salt injury
		
Nitrogen deficiency	Mn deficiency	K deficiency
		
B deficiency	B toxicity	P deficiency
		
Mg and Ca deficiency	Mg deficiency	

Figure 2. Nutrient deficiency and toxicity symptoms

Bio-intensive management of diseases for quality and residue compliant grapes

Sujoy Saha, Principal Scientist (Plant Pathology)

ICAR- National Research Centre for Grapes

Pune, Maharashtra-412307

Grapevine crops are present in many countries, and they are subject to a variety of pathogenic attacks. Emphasis is placed here on pathogens that, by attacking grapevine organs such as leaves and grapes or wood, decrease plant productivity and longevity and diminish wine quality, causing considerable economic losses to the viticulture sector. The main leaf and berry pathogens are anthracnose or powdery and downy mildews. A bio-intensive disease and pest management module based on minimum use of pesticides, induction of systemic resistance in vines, use of naturally occurring biological control agents(BCAs) and conservation of natural enemies was developed and implemented for production of residue compliant quality grapes at ICAR-NRCG. In order to improve and secure BCA efficacy from one year to another, the approach consists in testing BCAs in mother vines during the propagation process and in vineyards. Induction of plant resistance and/or physiological stress of pathogenic fungi is a consequence of BCA application on grapevines. New combinations of BCAs with different modes of action can be used. Depending on the BCAs, their incidence, and the behavior of specific BCAs on various cultivars, their influence on indigenous grapevine–microbial communities over time may vary.

In all bio-intensive plots, *T. asperelloides* 5R was applied twice before fruit pruning and three to four times after pruning to induce systemic resistance in grapevines against diseases. Four to five sprays of *T. afroharzianum* NAIMCC-F-01938 were given as foliar spray. Only few systemic fungicides were used at high disease risk periods, based on weather and crop growth stage based disease predictions.

B. subtilis DR-39 was applied twice in the 30 day before harvest period so as to enhance bioremediation. During 2018-19, many growers who were growing grapes for domestic markets also adopted the bio-intensive strategy. Multipesticide residue analysis of the grapes harvested from 59 such farmers, showed that 53 samples complied to EU MRLs, while a large number had 'Zero residues' in the sense that the number of detections were <5, the residue value of each detected pesticide was < 1/3rd of EU MRL, and the cumulative value of the residues was < 1 ppm

During foundation pruning the contact fungicides are mostly used like copper fungicides, mancozeb, metiram etc. with occasional use of biocontrol agents. The schedule of using BCAs, along with biorational fungicides during fruit pruning is briefly given below:

Days after pruning	**Crop stage**	**Disease / Pest risk**	**Management strategy**	**Remarks**
Pre-pruning period	Two weeks before pruning	Downy mildew(DM) and powdery mildew(PM), anthracnose (AN) inoculum	• Soil application of *Trichoderma* @ 2 L or kg / acre or *Bacillus* @ 1 L or kg / acre. • Spray *Trichoderma* 5 ml or g /L to cover vines completely including main stem and cordons	• For induced systemic resistance (ISR) & to reduce inoculum in soil • To reduce pathogen inoculum present in the vineyard
	1 week before pruning	Downy and powdery mildew, anthracnose inoculum	• Spray *Trichoderma* 5 ml or g /L to cover vines completely including main stem and cordons • Soil application of *Trichoderma* @ 2 L or kg / acre or *Bacillus* @ 1 L or kg / acre	• To reduce pathogen inoculum present in the vineyard • For ISR & reduce inoculum in |soil

	1-2 days before pruning	Downy and powdery mildew, anthracnose inoculum	• Downy mildew infected leaves should be collected and dispose in compost pit	• To minimize carry over inoculum
After fruit pruning				
1-2	Dormant buds	Downy and powdery mildew, anthracnose	• Diseased canes and dead wood should be removed • Mix mancozeb 75 WP (5 g / L) with Hydrogen Cynamide (30-40 ml / L) paste for cane swabbing. • If the un-pruned block is in close vicinity of pruned block, and the pruning in that block is not likely to take place within 5- 8 days, it will be essential to spray *Trichoderma* in un-pruned block.	Preventive measure This will help in killing pathogen inoculum if present on canes.

Days after pruning	**Crop stage**	**Disease / Pest risk**	**Management strategy**	**Remarks**
4-5	Dormant to swollen bud	Downy mildew and powdery mildew	Soil application of *Trichoderma* @ 2 L or kg / acre or *Bacillus* @ 1 L or kg / acre	For ISR
8-10	Initiation of sprouting	Anthracnose	Carbendazim 50 WP @ 1.0 g/L or Thiophanate methyl 70 WP @ 0.75 g/L	In the event of rains to protect young growing tips
		Downy mildew and bacterial spot	Spraying of mancozeb 75 WP @ 2 g /L or Dusting of mancozeb 75 WP @ 2.5 kg per acre	Preventive application If the conditions are wet (rains or heavy dew)
11-15	At three leaf stage	Downy mildew and powdery mildew	Soil application of *Trichoderma* @ 2 L or kg / acre or *Bacillus* @ 1 L or kg / acre	For ISR & to reduce inoculum in soil

11-15	At three leaf stage	Downy mildew	Spray any of CAA fungicide formulations- (Iprovalicarb 5.5 + Propineb +61.25)-66.75WP @ 2.25 g/L or Mandipropamid 23.4% SC @ 0.8ml/L or (Ametoctradin 27 + Dimethomorph 20.27)-47.27 SC @ 0.8- 1ml/L or Dimethomorph 50 WP @ 1.0 g/L + Mancozeb 75 WP @ 2.0 g/L as tank mix or (Cymoxanil 8 + Mancozeb 64)-72 WP @ 2g/L	Preventive
			Fosetyl-Al 80WP@ 4 g/L or Potassium salt of phosphorus acid @ 4 g/L as a tank mix with mancozeb 75WP @ 2g/L or propineb 70WP @ 3g/L can be preferred if weather conditions are wet because these are better systemic fungicides under wet conditions	
15 to 35 days after pruning	Early shoot growth – 3 leaf stage to flowering	Downy mildew	Spray any of CAA fungicide formulations- (Iprovalicarb 5.5 + Propineb +61.25)-66.75WP @ 2.25 g/L or Mandipropamid 23.4% SC @ 0.8ml/L or (Ametoctradin 27 + Dimethomorph 20.27)-47.27 SC @ 0.8- 1ml/L or Dimethomorph 50 WP @ 1.0 g/L + Mancozeb 75 WP @ 2.0 g/L as tank mix or (Cymoxanil 8+Mancozeb 64)-72 WP @ 2g/L. Total number of sprays of CAA and	Preventive based on weather risk

Days after pruning	Crop stage	Disease / Pest risk	Management strategy	Remarks
			cymoxanil based fungicides should not exceed three in a season. Applications of these fungicides should be taken up before and after the rainy spell when the humidity is relatively low and should be avoided in high humidity conditions during the rainy spell. Fosetyl-Al 80WP @ 4 g/L or Potassium salt of phosphorus acid @ 4 g/L as a tank mix with mancozeb 75WP @ 2g/L or propineb 70WP @ 3g/L can be preferred if weather conditions are wet because these are better systemic fungicides under wet conditions.	Preventive based on weather risk
			If wet conditions continue for more than three days continuously, use of non-systemic fungicides such as dithiocarbamates e.g. mancozeb 75WP @ 2g/L or propineb 70WP @ 3g/L, should be preferred for spray in place of CAA fungicides or cymoxanil to avoid sporulation and secondary infection. It is very critical to repeat CAA systemic fungicide applications after rainy spell stops.	Wet conditions for more than three days will lead to sporulation and initiate secondary infection.
			Fungicides may get washed off during long rainy spell, use of bioagents such as *Trichoderma* or *Bacillus* will help in reducing disease incidences.	

			Soil application of *Trichoderma* @ 2 L or kg / acre or *Bacillus* @ 1 L or kg / acre	For ISR & reduce inoculum in soil. Can be applied through drip irrigation system.
15-35		Anthracnose	Dithiocarbamate fungicides used for downy mildew control will be effective for anthracnose control and no separate application may be required. In case of incidence, application of difenoconazole 25EC@ 0.5ml/L should be given which will also help in reducing shoot vigour and reduce downy mildew risk.	
15-35		Powdery mildew	Spray Hexaconazole 5EC @ 1ml/L or difenoconazole 25EC@ 0.5ml/L or (Fluopyram 200+Tebuconazole 200)-400SC @ 0.5ml/L or Myclobutanil 10 WP @ 0.4g/L or Tetraconazole 3.8EW @ 0.75ml/L	Fungicide coverage to the inner canopy is very essential for powdery mildew management and this is the correct stage to ensure that inner canopy is covered.
15-35		DM / PM/ AN	Spray *Bacillus subtilis* 2.0 ml or g /L or *Trichoderma* sp. 5 ml or g /L.	-
36 to 50 days after pruning	Flowering to fruit set	Powdery mildew	Spray Hexaconazole 5EC @ 1ml/L or Tebuconazole 25SC @ 1ml/L or difenoconazole 25EC @ 0.5ml/L or (Fluopyram 200+Tebuconazole 200)-400SC @ 0.5ml/L or Myclobutanil 10 WP @ 0.4g/L or Tetraconazole 3.8EW @ 0.75ml/L or (Pyraclostrobin 25+Fluxapyroxad 25)-50SC @ 0.2ml/L or Metrafenone 50SC @ 0.25ml/L	-

		Downy mildew	Spray Fosetyl AL 80 WP @ 3.0 g/L or Potassium salt of phosphorus acid @ 4g/L + mancozeb 75WP @ 2g/L or propineb 70WP @ 3g/L	-
			In the event of possibility of heavy rains and dew, application of spray oil (mineral oil) will help in reducing the retention of water in cluster at flowering stage and thereby	-
			Application of mono potassium phosphate or SOP 2-3 g/L is known to help in reducing vigour as well as development of downy and powdery mildews. Curling due to Potassium deficiency reduces coverage of fungicides and provides favourable micro-climate for powdery mildew development.	-
		DM/ PM/ AN	Spray *Bacillus subtilis* 2.0 ml or g /L or *Trichoderma* sp. 5 ml or g /L.	-
50-60 days after pruning	Berry growth and developme nt	Powdery mildew	Spray Dinocap 48 EC @0.3-0.35ml/L Spray Chitosan @ 2g/L	Spray of Dinocap should be avoided earlier than this period as it may cause phytotoxicity on young leaves. Dinocap should also be avoided after this period as it may lead to residues.
		Powdery mildew	Spray *Ampelomyces quisqualis* 3 to 4 g/L or *Bacillus subtilis* 2.0 ml or g /L or *Trichoderma* sp. 5 ml or g /L. If minimum temperature is	

			above 10^{0}C and RH is more than 60 per cent.	
60 to 90 days after pruning	Berry growth to veraison	Powdery mildew	Spray sulphur 80 WG @ 2.0 g/L or difenoconazole 25EC@ 0.5ml/L (PHI 45 days) or (Fluopyram 200+Tebuconazole 200)-400SC @ 0.5ml/L or Myclobutanil 10 WP @ 0.4g/L or Tetraconazole 3.8EW @ 0.75ml/L or Pyraclostrobin 25+Fluxapyroxad 25-50SC@ 0.2ml/L or Metrafenone 50SC @ 0.25ml/L. Use of *Bacillus* alternatively with fungicides. *Bacillus* and *Ampelomyces* are compatible with (Fluopyram 200+Tebuconazole 200)-400SC and may be used in alternation with fungicides at 7-10 days interval.	Use the fungicides based on PHI mentioned in Annexure V of RMP
	Berry growth to veraison		Soil application of *Trichoderma* @ 2 L or kg / acre or *Bacillus* @ 1 L or kg / acre	For ISR & reduce inoculum in soil
After 90 days after pruning	Post varaison up to harvesting	Postharvest disease	Spray *Trichoderma* sp. 5 ml or g /L.	To control powdery mildew and may help to enhance degradation of pesticide residues
		Powdery mildew	• Sulphur 80 WG @ 2.0 g/L water; or Spray *Bacillus subtilis* 2.0 ml or g /L	*Bacillus* will also help in biodegradation of surface residues of pesticides
			Low residue risk options such as silver complex of Hydrogen peroxide or chlorine di oxide may be used if the active growth of powdery mildew is	Kindly note that it will kill the biocontrol agents also.

			noticed.	
	20 days before harvest	Postharvest disease	Spray *Trichoderma* sp. 5 ml or g /L.	To control powdery mildew, post-harvest decay, and may help to enhance degradation of pesticide residues
	10 days before harvest	PM / Postharvest decay/pesticide residues	Spray *Bacillus subtilis* 2.0 ml or g /L or *Trichoderma* sp. 5 ml or g /L.	To control powdery mildew, post-harvest decay, and may help to enhance degradation of pesticide residues

Conclusion:

Our recent observations in vineyards have revealed that whenever consistent applications of bio control agents have been given diseases and pests incidences are lesser even if the conditions are favourable for their incidence/infestation. Regular application of biocontrol agents reduces the disease inoculum and pest population over a period of time which in turn reduces the number of application of pesticides and this will have a direct influence on the input cost of the growers. Initially the cost of biocontrol agents may be high but their application will eventually reduce the cost of production by lowering the cost of pesticide application.

Agromet advisory services for management of climate risks in agriculture

Dr. Kripan Ghosh, Agricultural Meteorology Division,

India Meteorological Department, Shivajinagar, Pune

Background

Weather is the major factor in crop growth and production. While all other physical factors, inputs and agronomic practices can be manipulated, vagaries of weather cannot be controlled. However, adverse effects on crops can often be mitigated. Thus, risk in agricultural operations can be minimized by the provision of weather information properly interpreted for their agricultural significance, containing advisories of the impending weather for farm operations and disseminated well in advance. This is by far the most crucial of all services that can be rendered to the farming community efficiently.

Agromet Advisory Services in India

Agrometeorological Advisory Service (AAS) rendered by India Meteorological Department (IMD), Ministry of Earth Sciences (MoES) is a step to contribute to weather information based crop/livestock management strategies and operations dedicated to enhancing crop production and food security. AAS provide a very special kind of inputs to the farmers as advisories that can make a tremendous difference to the agriculture production by taking the advantage of benevolent weather and minimizing the adverse impact of malevolent weather. This has a potential to change the face of India in terms of food security and poverty alleviation.

Milestones in Agromet Services

- 1945 **-** Farmers Weather Bulletin
- 1976 **-** Agromet Advisory Services (AAS) at State Level
- 1991 **-** AAS at Agroclimatic Zone Level

- 2008 - AAS at District Level
- 2012 - Gramin Krishi Mausam Sewa (GKMS) Scheme
- 2018 - Experimental AAS at Block Level (200 Blocks in 24 States)
- 2022 - AAS at block-level ~3100 blocks and plans to extend to ~ 6500 blocks.

IMD, MoES, in collaboration with Indian Council of Agricultural Research (ICAR), is running an operational AAS, *viz.*, Gramin Krishi Mausam Sewa (GKMS), in India, which represents a small step towards agriculture management in tune with weather and climate variability leading to weather proofing for farm production. Under AAS, needs of farming community are defined through ascertaining information requirement of diverse groups of end-users. It emerged that prime need of the farmer is location specific weather forecast in quantitative terms. Hence, the same was developed at District level and made operational in June, 2008. Thereafter, mechanism was developed to integrate weather forecast and climatic information along with agrometeorological information to prepare district level agromet advisories outlining the farm management actions to harness favourable weather and mitigate impacts of adverse weather. A system has also been developed to strengthen the information outreach to communicate and disseminate the agromet advisories. The institutional dissemination channels such as farmer association, Non-Governmental Organizations (NGOs), progressive farmers and other stakeholders are also engaged. With the introduction of upgraded high-resolution models, the service is further being extended to the block level from 2018. Operational mechanism involving different organizations for implementation of AAS is presented in Fig. 1.

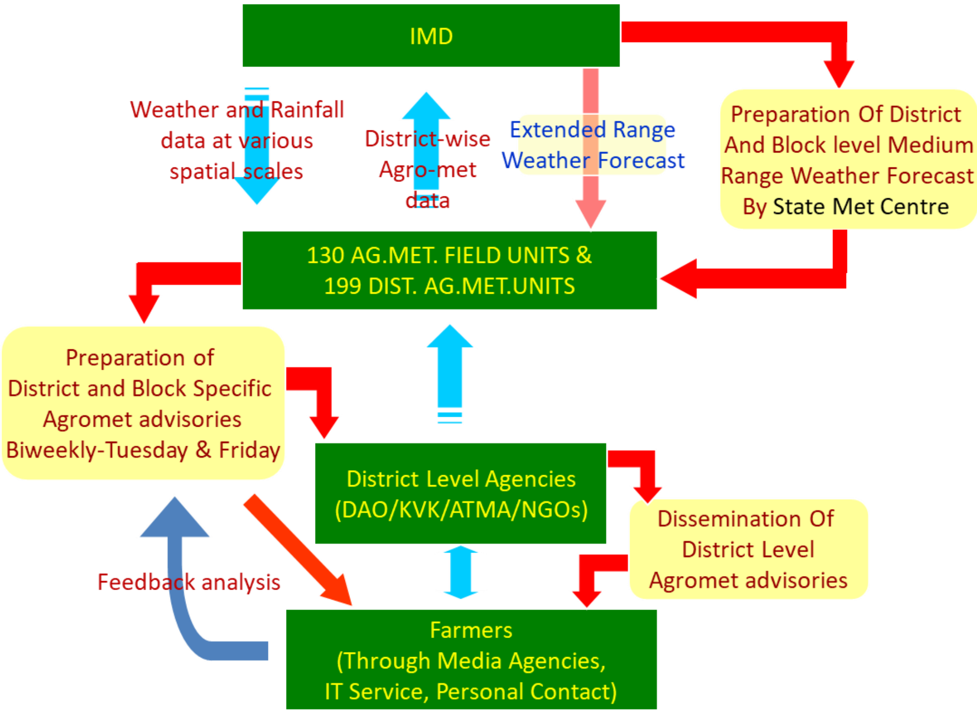


Figure 1. Operational mechanism involving different organizations for implementation of AAS

The main emphasis of the existing AAS system is to collect and organize climate/weather, soil and crop information, and to amalgamate them with weather forecast to assist farmers in taking management decisions. This has helped to develop and apply operational tools to manage weather related uncertainties through agro-meteorological applications for efficient agriculture in rapidly changing environments.

Weather Forecast for Agriculture

Weather forecast for agriculture is a specialized forecast issued to serve an important segment of the county's economy. The development of this service is necessary since modern day agricultural operations are becoming increasingly dependent upon detailed and accurate predictions of meteorological elements. Meteorological information is important for making many operational decisions and agriculturists need weather information, both the long range for strategic decisions and short range for tactical decisions

In general, during recent years, the skill of weather and climate forecasts in India has improved considerably. The improvement is noticed especially in monsoon forecasts, heavy rainfall warnings and tropical cyclone warnings and alerts. The successes in predicting the Tropical Cyclones, heavy rainfall event, deficient rainfall during monsoon are the best examples for the improvement in prediction capability during the recent years.

The weather forecasting is carried out in the following categories of temporal ranges-

- Now casting - a few hours in advance
- Short Range - up to 3 days in advance
- Medium Range - 3-10 days in advance
- Extended Range - 10-30 days in advance
- Long Range - season in advance

IMD has made enormous improvement in the accuracy and lead time of forecasts for various usage including AAS due to introduction of advanced numerical weather prediction models, improved data (both conventional and non-conventional) & its assimilation and high speed computers. This trend is expected to continue as more sophisticated numerical models of the atmosphere and oceans are being developed. Using inputs from extensive observational networks and employing a host of global, regional and meso-scale models IMD started issuing the quantitative district level medium range weather forecast up to next 5 days which was made operational since 1st June, 2008. Similar quantitative medium range weather forecast at block level has been started from 2018. The products comprise of quantitative forecasts for major weather parameters *viz.*, rainfall, maximum temperature, minimum temperatures, wind speed, wind direction, relative humidity and cloudiness. National Weather Forecasting Centre (NWFC), IMD, New Delhi generates these products using high resolution (12.5 km) GFS model, *viz.*, T1534.

The products are disseminated to Regional Meteorological Centres (RMC) and also to Meteorological Centres (MC) of IMD located in different states. These offices undertake value addition to these products using synoptic interpretation of model output and communicate to 130 AgroMet Field Units (AMFUs), located with State Agricultural Universities (SAUs), institutes of ICAR, Indian Institute of Technology (IIT) etc. and 199 District Agromet Units (DAMU) located at the Krishi Vigyan Kendras (KVK) under the network of ICAR on every Tuesday and Friday.

Translating forecast into crop advisories

Application of weather forecast to generate crop advisories is linked to accuracy, spatial domain of validity and temporal range. In view of these requirements of farming community, district level forecasts are issued for above listed parameters for next 5 days and are translated into crop specific advisories keeping in view their phenological stages for guidance on cultural practices.

District-specific medium-term forecast information and advisories help maximize output and avert crop damage or loss. It also helps growers to anticipate and plan for chemical applications, irrigation scheduling, disease and pest outbreaks and many more weather related agriculture-specific operations. Such operations include cultivar selection, their dates of sowing/planting/transplanting, dates of intercultural operations, dates of harvesting and also performing post-harvest operations. Agromet advisories help in increasing profits by consistently delivering actionable weather information, analysis and decision support for farming situations such as: to manage pests through forecast of relative humidity, temperature and wind;

manage irrigation through rainfall & temperature forecasts; protect crop from thermal stress through forecasting of extreme temperature conditions etc.

Long-range forecasts could provide the indications of monsoon rainfall variability. There are at least four significant aberrations in rainfall behaviour that could upset established crop calendars and yields:

1. The commencement of rains may be quite early or considerably delayed.
2. There may be prolonged “breaks” during the cropping season.
3. There may be spatial and/or temporal aberrations.
4. The rains may terminate considerably early or continue for longer periods.

To deal with these aberrations, farmers could respond to forecasts to undertake measures:

- Change variety for one with shorter or longer duration;
- Change crop species or mix of species, especially combinations of cash and food crops;
- Implementation of soil and water conservation techniques;
- Increase or decrease of area planted, either total, by crop, or by upland or lowland location;
- Adjust timing of land preparation;
- Increase or decrease of borrowing for inputs;
- Sell or purchase of livestock depending on anticipated cost and availability of feed; or
- Remaining in village or migration to seek off-farm employment or better grazing for livestock.

The AAS Bulletins are issued at block/sub-district, district, State and National levels to cater the needs of local level to National level. The block/sub-district and district level bulletins are issued by AMFUs and DAMUs and include crop specific advisories including field crops, horticultural crops and livestock. At present these bulletins are issued for all the agriculturally important districts (~700) and around 3100 blocks in the country. In addition to that, Impact based forecast (IBFs) for agriculture are also being prepared by AMFUs and DAMUs based on the severe weather warnings, whenever situation arises, for different districts of various States and UTs across the country.

The State level bulletin is a composite of district bulletins helping to identify the distressed districts of the state as well as plan the supply of appropriate farm inputs such as seeds, irrigation water, fertilizers, pesticides etc. These bulletins are jointly prepared by State Meteorological Centre of IMD and AMFUs and mainly used by State Government functionaries. This is also useful to Fertilizer industry, Pesticide industry, Irrigation Department, Seed Corporation, Transport and other organizations which provide inputs in agriculture. This bulletin is a significant input to the State level Crop Weather Watch Group (CWWG) meeting. Presently, these bulletins are issued for all the states of the country. National Agromet Advisory Bulletins are prepared by Division of Agricultural Meteorology, Climate Research and Services, IMD, Pune, using inputs from various states.

This bulletin helps to identify stress on various crops for different regions of the country and suitably incorporate advisories. Ministry of Agriculture is prime user of these bulletins, which help to take important decisions in Crop Weather Watch Group (CWWG) meetings at National level. The bulletins are also used by a large number of other agencies including fertilizer, pesticide industries.

Agrometeorological support for farm management

Weather based farm advisories as support system has been organized after characterization of agroclimate, including length of crop growing period, moisture availability period, distribution of rainfall and evaporative demand of the regions, weather requirements of cultivars and weather sensitivity of farm input applications. All these are used as background information. Following are the ingredients of a typical AAS Bulletin to reap benefits of benevolent weather and minimize or mitigate the impacts of adverse weather;

i) District specific weather forecast, in quantitative terms, for next 5 days for rainfall, cloud, max/min temperature, wind speed/direction and relative humidity, including forewarning of hazardous weather events likely to cause stress on standing crop and suggestions to protect the crop from them.

ii) Weather forecast based information on soil moisture status and guidance for application of irrigation, fertilizer and herbicides etc.

iii) The advisories on dates of sowing/planting and suitability of carrying out intercultural operations covering the entire crop spectrum from pre-sowing to post harvest to guide farmer in his day to day cultural operations.

iv) Weather forecast based forewarning system for major pests and diseases of principal crops and advices on plant protection measures.

v) Propagation of techniques for manipulation of crop's microclimate e.g. shading, mulching, other surface modification, shelter belt, frost protection etc. to protect crops under stressed conditions.

vi) Reducing contribution of agricultural production system to global warming and environment degradation through judicious management of land, water and farm inputs, particularly pesticides, herbicides and fertilizers.

vii) Advisory for livestock on health, shelter and nutrition.

Occurrence of extreme weather in different seasons

Most of the natural hazards are weather related-

- Winter (Jan-Feb) : Western Disturbances, Cold Wave, Fog
- Pre-Monsoon (Mar-May) : Cyclonic Disturbances, Heat Wave, Thunder Storms, Squalls, Hail Storm, Tornado
- Monsoon (Jun-Sep) : Southwest Monsoon Circulation, Monsoon Disturbances like heavy rain
- Post-Monsoon (Oct-Dec) : Northeast Monsoon, Cyclonic Disturbances

Nature of impacts and management of extreme weather on Agriculture through AAS

a. Cold injury and frost: A key factor in protection of crops from cold injury is stable air temperatures and snow covers throughout the winter. Thaws, resulting in packing or disappearing snow cover, worsen dormancy conditions and reduce or destroy the protective properties of snow cover. The prevention of crop damage by frost can be controlled by breaking up the inversion that accompanies intense night time radiation. This may be achieved by heating the air which are strategically located throughout the agricultural farm. Other methods of frost protection include sprinkling the crops with water, brushing (putting a protective cover of craft paper over plant) and the use of shelterbelts (windbreaks). Long periods of extreme cold weather combined with other meteorological phenomena can result in the loss of winter crops, fruit crops and vineyards due to frost injury. Low soil temperature at the depth of plant roots can cause frost injury. Such reductions in soil temperature occur with strong frosts, in the absence of snow cover and with deep freezing of the soil. Most frost injury to winter crops takes place in the first half of winter before sufficient snow cover has formed. In the second half of winter frost injury happens in regions with unstable snow cover. Under low temperatures basically a plant dries out and the protoplasm (the living part of cells) dies. Damage to the part of a plant does not always result in damage or destruction of the whole plant. A determining factor is the degree of frost injury to a tillering node; if it is heavy the whole plant will perish. The winter crops most frequently destroyed by frost are those grown on uplands, where snow cover is less and the depth of soil freezing is greater. The main agrometeorological factor influencing frost damage in winter crops is low soil temperature at the depth of the tillering node. Long (three days or more) and intensive cooling causes complete devastation of the crops.

Sample Advisory for Frost injury

- ✓ Apply irrigation to safeguard the crops *viz.*, apple, pear, early sown wheat from cold/frost injury.
- ✓ During evening hours, wipe out the water droplets on the leaves by pulling rope from two sides of field. This will prevent formation of ice crystals.

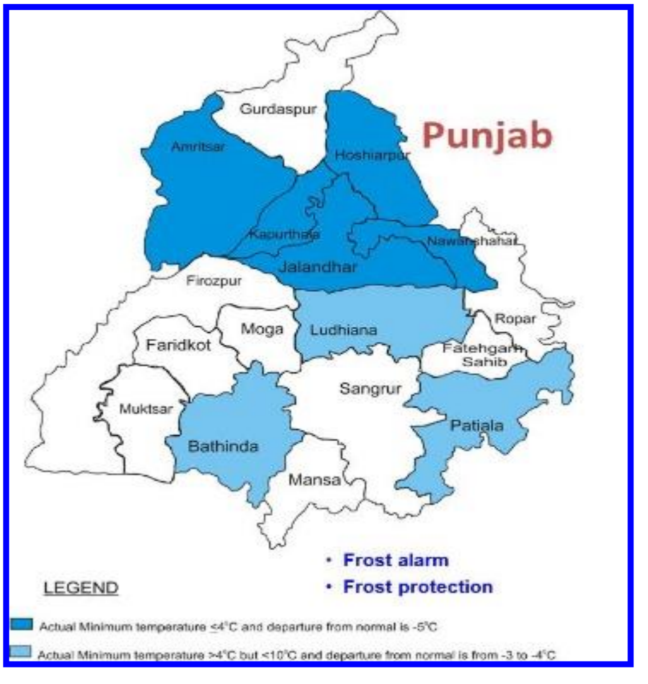


Figure 2. Map indicating frost injury

b. High temperature: It causes increased evapotranspiration, induced sterility in certain crops, poor vernalization, survival of pests during winter etc. High temperatures at night are associated with increased respiration loss. 'Heat waves', lengthy spells of abnormally high temperatures are particularly harmful. An abnormal rise of temperature above normal may be fatal to crops, if exposed.

Sample Advisory for Heat injury

✓ As temperature is still higher than normal, it may inhibit plant growth and yield of wheat; farmers are advised to irrigate the field at frequent interval to bring down canopy temperature as there was no significant rain over the State for last few weeks and dry weather will prevail for next five days.

c. Winds: Winds in dry climatic zone affect growth of the plant mechanically and physiologically. The sand and dust particles carried out by wind damage plant tissues. Emerging seedlings may be completely covered or alternatively, the roots of young plants may be exposed by strong winds. Winds also cause considerable losses by inducing lodging, breaking the stalks and shedding of grains and ultimately decreasing the yield. Many agricultural lands have been lost through wind action by the encroachment of sand dunes. Dust storms and sand storms, which carry away the top humus soil, lead to deterioration and degradation of the landscape and desertification. Physical damage to plant organs or whole plants (e.g. defoliation, particularly of shrubs and trees) is due to the soil erosion; excessive evaporation.

Wind is an aggravating factor in the event of bush or forest fires. Crop damage by winds may be minimised or prevented by the use of windbreaks (shelterbelts) which reduce the impact of wind speed. These are natural (e.g. trees, shrubs, or hedges) or artificial (e.g. walls, fences) barriers to wind flow to shelter animal or crops. Properly oriented and designed shelterbelts are very effective in stabilizing agriculture in regions where strong wind cause mechanical damage and impose severe moisture stress on growing crops. Windbreaks save the loose soil from erosion and increase the supply of moisture to the soil in spring.

Sample Advisory for Winds

✓ Wind speed is greater than 20 knots and likely to be greater than 34 knots; avoid applying fertilizer to the crop in the particular districts.

✓ Apply necessary fertilizer in the remaining districts of the state as wind is calm.

d. Hailstorms, thunderstorms and dust storms

The arid regions of India are characterised by frequent and strong winds which are partly due to considerable convection during the day time. The usually sparse vegetation is not capable of slowing down the air movement; so the dust and sand storms occurred frequently in the regions. Also, as winter season proceeds towards spring, the temperature rises initially in the southern parts of India giving rise to thunderstorms and squally weather which are hazardous in nature.

The hailstorm frequencies are higher in the Assam valley followed by hills of Uttarakhand. During recent years Marathwada, Vidarbha, Northern Maharashtra and parts of Western Maharashtra experienced the unprecedented hail storms and unseasonal rainfall. Because of this, there was a great damage of standing *rabi* crops in Maharashtra. Under such situation, advisories are issued both during pre and post hailstorm occurrence.

Pre-hailstorm advisory: Before the hailstorm, farmers are advised to give mechanical support to the crops. Harvest the matured crops and keep in a safe place.

Post hailstorm advisory: After the hailstorm also give the mechanical support to the crops and collect the dropped fruits and destroy the same.

Figure 3. Crop losses due to hailstorms

Dissemination of Agrometeorological Bulletins

The task of AAS is to provide information to help farmers make the best possible use of weather and climate resources. While disseminating the information, it is presumed that the farmers possess relevant knowledge and skills. Although concerted efforts are being made to set up two-way communication, but as of now the information flow is largely one-way. As agro-meteorologists at AMFUs have less frequent interaction with the farmers, good communication and working relationships have been set up with the agricultural extension, Krishi Vigyan Kendra, Kisan Call Centre etc. to promote participatory methods for interactions with farmers. Due care is being taken regarding content of the message which must be relevant to the weather-based decision making by the farmer. This involves the identification of weather & climate sensitive decisions including relevant agromet advisories by interactions between the weather forecasters from Meteorological Centres of IMD and the agriculture scientists from SAUs, ICAR, AMFUs etc.

Weather forecast and Agromet Advisories are communicated to the farming community using multi-channel dissemination system like All India Radio, Television, Electronic and Print Media, internet (Websites of IMD, ICAR, SAUs, IITs, KVKs), telephone, extension system of State Agriculture Department, social media etc. Agromet Advisories are being disseminated through SMS using mKisan Portal launched by the Ministry of Agriculture & Farmers' Welfare (MoA&FW), Govt. of India and also private companies under Public Private Partnership (PPP) mode and extension mechanism of ICAR-KVKs. Biweekly and weekly inputs are also provided to DD Kisan channel for 'Mausam Khabar' and 'Krishi Darshan' programmes respectively.

IMD also monitors rainfall situation & weather aberrations and issues alerts & warnings to the farmers time to time under GKMS scheme. SMS-based alerts and warnings along with advisories on suitable remedial measures are also being sent during extreme weather events like cyclone, deep depression etc. through Kisan Portal to take timely operations by the farmers. Such alerts and warnings are also shared with State Department of Agriculture for the effective management of calamity.

With the advancement of ICT, Farmers access the weather information including alerts and related agromet advisories specific to their districts through the mobile App viz., 'Meghdoot' launched by Ministry of Earth Sciences, Government of India. These weather details are also accessible by farmers through another App 'Kisan Suvidha', launched by Ministry of Agriculture & Farmers Welfare. Also, a few AMFUs have developed mobile Apps to facilitate quick dissemination of agromet advisories to the farmers of their region.

Social media is also used for quicker dissemination of forecast and advisories to the farmers. At present farmers of 1,22,093 villages in 3,654 Blocks have been covered through 16,499 WhatsApp groups. State Agriculture Department officials of District and Block level are also included in these WhatsApp groups. Moreover, advisories are also being circulated through a number of Facebook pages created by AMFUs and DAMUs.

Efforts are being continuously made to integrate the weather forecast and agromet advisories with the mobile app and websites of State Department of Agriculture of different States and to utilize their extension system to enhance outreach of advisories up to village level. The integration has been completed for Bihar, Chhattisgarh, Gujarat, Haryana, Madhya Pradesh, Meghalaya, Nagaland, Odisha, Rajasthan, Tamil Nadu and Uttarakhand for the benefit of the farmers of these states.

IMD is taking continuous efforts to popularize the services among the farming community as well as to enhance the understanding of farmers regarding sensitivity of crops and livestock to weather by organising Farmers' Awareness Programmes (FAPs) in collaboration with AMFUs and DAMUs in various parts of the country. IMD along with the experts from AMFUs and DAMUs also participate in Kisan Melas, Farmers' Day etc. to create awareness about the services and understand the problems of farmers so that more farmers get benefitted with improved services.

Generation of Agromet products

Agrimet Division, IMD is preparing the following products:

- Spatial Variation of weather parameters at different temporal scales.
- Satellite products: IMD in collaboration with Space Application Centre (SAC), Ahmedabad is generating Normalized Difference Vegetation Index (NDVI), Reference Evapotranspiration and Insolation maps.
- Weekly: Vegetation Condition Index (VCI), Vegetation Health Index (VHI), Temperature Condition Index (TCI).
- Soil Moisture: Realized (Daily) and Forecast (Twice a week on Tuesday and Friday).

Besides, IMD prepares the maps for Standardized Precipitation Index (SPI) for weekly, bi-weekly and seasonal scales and has also started preparing weekly SPI Forecast. All these products are being generated under PAN India mode usng Geospatial technology and are uploaded in the Divisional website and communicated to the AMFUs for preparation of more appropriate agromet advisories at district level.

Generation of Block level Agromet Advisories

Keeping the need for Agromet Advisory Services (AAS) to be more location specific and to be extended to all farming households in the country into consideration, the network of GKMS scheme is being extended to district level by establishing additional 530 District Agromet Units (DAMUs) in the premises of Krishi Vigyan Kendras (KVK), a joint initiative of IMD and ICAR. This is being implemented with active support from State Agriculture Universities and State Government with the objectives to provide block level AAS and warnings. As on date, DAMUs have been established in 199 KVKs. Nodal officers at KVKs have been designated to guide and steer the meeting of expert panel to help in the development of the block level AAS. Expert panel consists of Agriculture experts from KVK and Agriculture officer at district level from SDA.

IMD in coordination with AMFUs and DAMUs are preparing Block Level Agromet Advisories for around 3100 blocks. Like District level Agromet Advisories, Block Level Agromet Advisories are also prepared on every Tuesday and Friday and displayed in the website of Agricultural Meteorology Division, IMD, Pune.

Extension and outreach and collection of feedback from farming community

Regular feedback from farmers, State Agricultural Departments and Agricultural Universities / ICAR and other related Institutes is being collected and processed for further improvement of services. Feedback information are also being collected from Krishi Vigyan Kendras, ATMA, CSCs, NGOs, VRCs and VKCs. Officers of the AAS units participated in Kisan Melas to understand the problems of large groups of farmers. For improvement of the agromet advisory bulletins, regular discussions are held among IMD and Agricultural officers at the State AAS unit level and also with scientists in Agricultural Universities / ICAR and other related Institutes.

Farmers' awareness programmes (FAP): FAPs are being organized in different States by AMFUs with objective of creating awareness about usefulness of Agromet Advisory Services (AAS) and weather / climate information among the farming community and also to help to increase the interaction between the local farming communities and the MCs, AMFUs and KVKs. AMFUs are also arranging field visits, field demonstration, farmer interactions and also participate in Kisan Melas.

Following linkages have been established at district level to disseminate the agromet advisories as well as receive the feedback information on crop, soil, pests and diseases etc.

- ✓ 130 AMFUs (one in ~ 5 Districts)
- ✓ 530 KVKs in the country
- Impart skill through orientation programs to rural masses
- Organize vocational trainings, demonstrate latest technologies and its refinement in farmers' field conditions
- Organize demonstrations to generate awareness & feedback
- ✓ ATMA
- ✓ District Agriculture Offices
- ✓ Local Media

Future Projection under GKMS

It is proposed to downscale the Agromet Advisory Services at relatively smaller areas of the country. The main objectives of the proposed project would be:

- To improvise the existing District level Agromet Advisory Services (AAS) (in order to deliver the AAS to farmers at block level with village level advisory).
- To provide last mile connectivity to farmers for accessing the personalized agromet advisory services.
- To extend the agromet advisory services to the new areas like livestock, fisheries etc.
- To establish appropriate dissemination system to reach each and every farmer in the country.
- To address the climate and climatic variability through high resolution agromet advisory service system.

The beneficiaries of the proposed service include:

- The small, marginal and large farmers engaged in cultivation of cereal crops, cash crops horticultural and plantation crops.
- Livestock and fisheries Farmers.
- Different high valued crop growers like mango, apple, grapes etc. in the country.
- State and central level planners formulating the strategies for crop cultivation.

There are number of stakeholders, like State Agricultural Universities, Department of Agriculture (both State and Central Governments), Krishi Vigyan Kendras, ATMA, NGOs, Crop Growers' Associations and others, involved in this project. All the stakeholders are being consulted periodically in enhancing the services. All the beneficiaries are involved in the scheme by organising different farmer's awareness programmes etc. and understanding their weather requirements.

Canopy management for adverse climatic condition

R.G. Somkuwar, Principal Scientist (Horticulture)

ICAR- National Research Centre for Grapes

Pune, Maharashtra-412307

Grape is an important fruit crops grown on an area of about 1.60 lakh hectare. It is grown widely in Maharashtra followed by Karnataka, Tamil Nadu and Mizoram. The yield in grape vineyard started declining with the onset of problems like drought and salinity in the grape vineyard. Use of rootstock became important to sustain the yield. However, with the change in climate, the grape cultivation is becoming difficult. In grapes, canopy and yield management begin from the time of foundation pruning. The canopy management practices during both pruning (foundation and forward pruning) is important. The grape grower is trying to balance the cultural operation between foundation pruning and forward pruning.

Ideal canopy management begins with careful and proper vine canopy architecture. This starts from vine spacing, number of cordons, shoot orientation on the cordon, number of canes per unit area, etc. The choice of training system will impact canopy design, vine performance and management practices. Canopy management is practiced to obtain optimum yield, improve fruit quality, reduce the risk of diseases and facilitate other vineyard operations. In a grape vineyard, these objectives can generally be achieved use of proper canopy management practices so that the microclimate in the grapevine canopy can be improved. Open canopies helps in reducing disease pressure, since it has less humidity and more improved airflow.

The vine's microclimate comprises a number of factors including solar radiation, temperature, wind speed, humidity, and evaporation. When the canopy microclimate is altered by canopy management techniques, it is not only sunlight levels that change but temperature, humidity, wind speed, and evaporation too. Therefore, variation in canopy microclimate has implications for grapevine yield, fruit composition and quality, and disease incidence.

1. Training

Grapevine is trained to achieve high quality production. There are number of training systems used worldwide, however, no single training system is appropriate for all situations. Based on the vine vigour, degree of vineyard mechanisation and availability of the skill workers the selection of training system is decided. Training system used in vineyard should fulfil the following requirements.

1. The training system should be cheap and economical.
2. The training system should help to expose maximum leaf area to the sunlight for better photosynthesis.
3. The vine trained to any type of training system should promote maximum bud break.
4. The training system should offer a scope for mechanization with respect to efficient fungicide/ insecticide sprays, harvesting of maximum produce and pruning practices.
5. The training system should support the crop load to harvest good quality grapes.

The training of grapevine is performed to train different vine parts in the initial year. These are as below.

1.1 Training of rootstock

After the re-cut of rootstock in the field (before grafting), the selected shoots are trained to the bamboo sticks so as to encourage straight growth of trunk after grafting. This helps in storage of required food material in the developing trunk.

1.2 Training the trunk of grafted vine

The grafted vine is tied with bamboo stick so as to train the trunk straight.

1.3 Training of primary arms on Y trellis

Immediately after re-cut of grafted vines, the shoot grows vigorously. This shoot should be pinched six inch below the first wire so as to train the primary shoot in a slanting position. This will avoid the direct sunlight exposure of the primary arm.

1.4 Training of secondary arms (cordon)

The cordon development should be done based on the vigour of the vine. Due to the presence of prominent apical dominance in Thompson Seedless and its clones, the cordon development and training should be done following 'stop and go' method. This will help to obtain complete cordon with desirable length during the first year.

2. Pruning

The pruning can be defined as removal of plant parts to obtain appropriate number of fruiting units. The objective of pruning includes

1. Controlling the size and form of a vine.
2. Increasing the fruiting area on a vine.
3. Maintaining the balance between vegetative growth and fruiting.
4. Optimizing the production potential of a vine.
5. Obtaining the better quality fruit from a vine.

The pruning is done based on the prevailing weather conditions in that region. Under central parts of India, the vine grows vigorously throughout the year. Hence, double pruning pattern is followed for grape cultivation. The vines are pruned during April by leaving basal single bud on the shoot proximal to the cordon. Since, the whole portion of cane is pruned; this pruning is called as back pruning. Fruit pruning is done during October for fruits, hence, it is also called as fruit pruning. During fruit pruning, the matured canes are pruned either after knot on the sub-cane or at 6-7 bud position in case of straight canes. However, the pruning position varies with cane vigour and varieties.

3. Canopy Management

Canopy management refers to the practices followed to obtain the ideal characteristics in various canopy components to realize the maximum yield of quality grapes.

3.1 Canopy architecture

Canopy refers to the size and shape of vine structure. The size and shape of the canopy is dependent on canopy components such as primary arms and cordons, canes, shoots and also on a given trellis/ training system.

The ideal canopy should fulfil the following requirements:

1. It should give the grapevine a desirable shape and support the crop load.
2. It should offer scope for convenient field operations and mechanization.
3. It should have adequate number of fruitful canes.
4. It should allow sufficient light and ventilation into the canopy during the growth season.
5. It should give maximum proportion of quality grapes per unit area.
6. It should have sufficient foliar coverage to nourish and protect bunches during the fruiting season (November-March).
7. It should avoid overlapping of the foliage to facilitate efficient photosynthesis by every leaf.

8. It should offer scope for effective spray coverage with pesticides and growth regulators.

9. It should not build up micro-climate that is congenial for disease development.

The requirement of canopy during each pruning under tropical region is as below.

3.2 Canopy management after foundation pruning

1. The ideal stage for shoot thinning is at 4-5 leaf stage. This helps in reducing the loss of nutrients from the vine.
2. The number of shoots retained on vine should be 0.70-1.0 per ft^2 for quality produce.
3. The canopy should be open during April-September to facilitate optimum sunlight harvesting required for efficient photosynthesis.
4. The shoots on each cordon should be vertically positioned to harvest maximum sunlight required for fruit bud differentiation.
5. While removing the excess shoots from the cordon, remove both vigorous and weaker shoots so that all the shoots will be uniform in diameter. This will promote uniform bunch development after fruit pruning.
6. Vines with vigorous shoots should follow sub cane system while straight cane is followed in less vigorous vines.
7. While making the sub cane, pinch the shoot to 7- leaves at 9- leaf stage so as to develop proper sub-canes.
8. Top the side shoot again at 5th leaf when it is at 7- leaf stage.
9. Impose soil moisture stress at 7+5 leaf stage. This helps in increasing the fruit bud differentiation.

10. Top the shoots to 15- leaves (7+8) when the shoots start maturing. This helps to store enough food material and advance cane maturity.

3.3 Canopy management after fruit pruning

1. Before fruit pruning, collect the canes (about 40 canes/acre) of different thickness (6-8 mm, 8-10 mm and >10 mm diameter) and examine their buds under microscope for position of fruitful bud. This helps to decide pruning position to obtain maximum number of bunches.
2. The canes of 6 mm and less thickness are to be removed during fruit pruning.
3. Swab hydrogen cyanamide only to apical 2-3 buds on each cane. This helps in early and uniform bud break.
4. Based on the bud-break and the bunch emergence, shoot thinning is to be performed at 4-5 leaf stage.
5. Bunches are to be retained based on vine spacing. Retain one bunch for every 1-1.5 ft^2 of canopy for quality grapes.
6. Excess shoot removal to be done at 4-5 leaf stage.
7. Bunch thinning should be followed at pre- bloom stage only.
8. Retain only one or two bearing shoots on each cane. If the cane diameter is more than 8 mm, retain two bearing shoots and only one shoot if the diameter is less than 8 mm.
9. Encourage the shoot growth by applying more nitrogen and water until one month after fruit set.

10. Thin the berries and clip the clusters to reduce the number of berries in relation to the cane thickness. Retain 16 berries in a cluster per mm diameter of the cane.

11. Position the shoots appropriately to provide shade to the bunch on the South-West side of the canopy.

12. Retain only 100-120 berries in a bunch and remove all excess berries. This operation should be done immediately after berry setting. This helps in proper berry development and achieving the desirable berry size for quality produce.

13. Shoot topping is done at 10-12 leaf above bunch after fruit pruning to avoid competition for nutrients by the shoot and consolidate the food material in the developing bunches. This helps in increasing the berry size.

14. To increase the berry size, girdling is one of the important operations beside use of growth regulators and cluster thinning. All these are complementary to each other. Therefore care should be taken to use these practices judiciously. Girdling helps in increasing the berry size at least by one mm diameter.

15. The time of girdling differs among varieties. In Thompson Seedless, the girdling is done at 4-6 mm berry size whereas in Sharad Seedless, it is done at 6-8 mm berry size.

Weather forecast based management of diseases in grapes

Sujoy Saha, Principal Scientist (Plant Pathology)

ICAR- National Research Centre for Grapes

Pune, Maharashtra-412307

Downy mildew (*Plasmopara viticola* (Berk. & Curt.) Berl. & de Toni), Powdery mildew (*Uncinula necator* (Schw.) Burr.) and Anthracnose (*Elsinoe ampelina* (de Bary) Shear, anamorph *Sphaceloma ampelinum* de Bary (Syns. *Gloeosporium ampelophagum* (Pass.) Sacc.), the three most important diseases of grape, have rapid repeating cycles in the same season and have potential to develop into epidemics if proper control measures are not taken in time and cause severe to near total losses.

In major grapes growing areas in Maharashtra, Andhra Pradesh and Karnataka regions adjoining Maharashtra, 'two pruning - one yield' system of grape cultivation is followed wherein foundation pruning is done during April and forward or fruit pruning is done during October. The growth after foundation pruning is not exposed to high disease risk, as by the time rain start the leaves are already matured. Matured growth is easily managed. Only young growth when gets wet or humid conditions are in risk of diseases and infections on young growth leads to economic losses. In most grape growing areas mentioned above, normal time of forward pruning is around 15th of October, but it can range from first week of July to last week of November. From disease management point of view forward pruning taken before 15th of October, has greater risk of downy mildew, as there are more chances of rains and temperature is warmer. After forward pruning about 8-10 days are needed for sprouting of buds. Thereafter on an average every three days interval new leaf is developed. At fifth leaf there will be a bunch, which takes about 35 to 45 days from forward pruning to develop to flowering stage and by 50 to 55 days fruits set in. First 50 to 55 days after pruning, risk of damages due to downy mildew infection on bunches is very high. Rains and heavy dew during this period helps development of downy mildew on bunches. Leaf wetness for continuous period of three hours after sunrise is favorable for new infection. If such conditions prevail during first 55 days of pruning sprays of fungicides are needed at shorter intervals for effective control of downy mildew. Berries develop to 10 to 12 mm size within first 70-75 days of forward pruning and thereafter the risk of downy mildew gradually reduces. Rains during November and December are rare, but in years when it rains during November or thereafter, heavy losses due to downy mildew are observed. Normally, 5 to 6 sprays of fungicides are required during first 55 days of pruning for effective management of downy mildew. This number of sprays may be increased to 9 in the event of rains during November December, while it can be reduced to 3-4 when wet weather is absent after forward pruning.

Because all these three diseases can cause near total losses under favourable environmental conditions, growers as a precaution rigidly follow pre-determined spray schedules throughout the susceptible period. While such a system may be advantageous when environmental conditions are continuously favourable for disease development, it often leads to increase in cost of cultivation due to extra use of fungicides and labour when environmental conditions are not favourable for diseases. Under unfavourable weather conditions, risk of losses due to diseases are much less and plant protection cost can be reduced by increasing gap between two preventive sprays or by using less costly non-systemic fungicides instead of costly systemic fungicides, during low disease risk periods.

The occurrence and severity of these diseases is dependent on weather conditions and hence, it is possible to forecast likely risk of development of these diseases in prevailing meteorological conditions based on thorough knowledge of their epidemiology. For such predictions 'Disease Forecasting Models' have been developed. These models are used for taking day to day decisions on spraying of fungicides in vineyards for disease management. The data on critical weather parameters for disease development are primary inputs for such models. Even though diseases are the interaction of host plant, the pathogen and environment, the disease forecasting models estimate disease risk in prevailing weather conditions, assuming the active pathogen is always present. Thus decision on sprayings can be taken after considering condition or growth stage of the host plant.

Some of the relevant information for forecasting of above three diseases has been summarised below:

Downy mildew

Primary inoculum:

In southern India from April to June the pathogen survives in soil as oospores or resting sporangia or on twigs as dormant mycelium. Primary inoculum becomes active if soil and / or foliage remains wet at least for 22 to 24 hours due to rain / irrigation / dew and when temp. is above 9–10^{o}C (Mathew and Heyns, 1969; Magarey and Wicks, 1985). Primary inoculum produces sporangia, which germinate to develop water-borne zoospores. These zoospores infect foliar plant parts through stomata or lenticles. The 'oil spots' and downy growth consisting of wind borne sporangia are developed after about 3-7 days of incubation, depending on temperature and plant growth stage.

Secondary inoculum:

Sporangia developing out of infections caused by primary inoculum are secondary inoculum and are responsible for spread and development of the disease in vineyard under favourable conditions of weather, plant growth stage etc.

Weather parameters

(i) Sporulation:

- At least 4 hours of darkness, more than 98 % RH, and temperature more than 13^{o}C is required for sporulation on lesions (Bleaser and Weltrian,1978; Brook, 1979).

(ii) Infection:

- Availability of viable sporangia and > 2 hrs. leaf wetness during early morning, is required for infection.

- The disease is developed early and is more severe in vineyards irrigated at shorter intervals than in those irrigated at longer intervals.

- On the basis of regression analysis scientists have indicated that following conditions favour primary infection

i. Rainy weather for 3-4 days sufficient to keep the leaves wet

ii. Temperature: 17 – 32.5^{o}C

iii. Afternoon RH more than 48 %

- For secondary spread mean maximum temperature from 27-30°C, mean minimum temperature from 11-22.5°C and RH from 88-90°C were favourable.

- Similarly, it has been shown that the disease can occur when temperature is in the range of 10.2 to 31.5°C, and RH is in the range of 47–97% for three days. However, the rate of disease multiplication becomes zero if during these three days the temperature remains more than 28°C for 17 hours, and more than 90% RH is maintained for only 9 or less hours.

Growth stage and disease:

Earliest downy mildew infection can occur at 3-leaf stage after budbreak. A new leaf becomes susceptible after every 3 days. Relatively older leaves (34-

48 days old) develop disease faster than younger (14-18 days old) leaves. Flower buds show maximum downy growth. In case of mustard and pea size berries downy growth is restricted to pedicle end, while no growth is seen on berries whose diameter is more than 12.5 mm or 1 month after their set.

Powdery mildew

Primary and secondary inoculum:

Dormant mycelium in buds is the primary source of inoculum, which becomes active as the new shoot develops from the bud. Conidia, which are air borne, and develop on foliar parts are responsible for secondary spread. It is believed that the powdery mildew is active throughout the year in at least one grape growing area in southern India.

Weather parameters:

- Low humidity, cloudy weather are favourable for disease development, while heavy rains, and hot and dry weather are unfavourable for the disease.
- The pathogen does not grow if temperature is below 10^{o}C or above 37.7^{o}C (Butler and Jones, 1949).
- Minimum temperature in the range of 20.1 – 21.9^{o}C and RH in the range of 57.6- 68.2% were favourable for powdery mildew.
- More than 40% RH during afternoon, with temperature ranging between 17 – 34^{o}C helps in the establishment of epiphytotic of powdery mildew.
- Temperature in the range of 11–32^{o}C and more than 57% RH favoured the disease development. While temperature below 8.6^{o}C or above 34^{o}C and RH below 47% show zero rate of disease development.

Growth stage and disease:

The fungus can attack all growth stages of vines. Berries are susceptible from 2 weeks after bloom till veraison. After veraison normally the disease is not developed on berries, but green rachis can develop powdery mildew infection affecting shelf life of the table grapes.

Anthracnose

Primary and secondary inoculum:

Cankerous lesions on the canes, budspurs, stems and branches are the main primary inoculum. Rain / dew are required for the sporulation of the pathogen. Young developing tissue in the foliage are susceptible. The fungus can invade directly. The conidia developing from lesions caused by primary inoculum are secondary inoculum. The secondary inoculum produces conidia which again causes infection. This cycle repeats itself many times in the season depending on weather conditions.

Weather parameters:

- Presence of high temperature along with high RH during new shoot development favours the disease. Relative humidity and precipitation were more important for disease development than temperature. Rain or dew favoured the spread of the spores and their germination. Already formed lesions continue to increase in size even in the absence of rain.

- The fungus grows in temperature between 9–35°C, while maximum growth and sporulation was observed at 29°C and no growth at 40°C.

- The disease appeared when mean max. temperature was in the range of 29–29.8°C, mean min. temperature was in the range of 21–22°C, and when the RH was in the range of 82–95%.

- Rainfall of 49.99 mm distributed over 3-16 days per week and prevalence of cloudy weather helped to cause severe infection on susceptible young tissues.

- Darkness was most congenial followed by diffused light for the growth and sporulation of the fungus

Growth stages:

The disease occurs on all young green plant of the vines. A 20-day-old leaf becomes resistant to anthracnose.

Methods of disease forecasting

Above mentioned epidemiological information is used for developing forecasting models, where regression equations are established indicating relations of key factors such as weather parameters (Rain, Temperature, R.H., Leaf wetness period etc.), Susceptible growth stage/ variety, Time lapsed after last spray (systemic/ nonsystemic) of fungicide, with rate of disease development. With the help of such equations one can estimate the rate of disease development under prevalent conditions in specific area or vineyard. With the help of such estimated rate of disease development predictions are made on the possibility of disease outbreak with reasonable accuracy and well in advance of actual outbreak of the disease. Growers thus can undertake suitable control measure well in time and only when it is actually required. Forecasting of diseases thus will be beneficial in two ways

1. For effective control of disease by application of suitable fungicides when inoculum load is minimum and before the severe outbreak of the disease

2. For avoiding unnecessary sprays when there is no possibility of disease outbreak

Basic requirements for forecasting diseases:

1. Weather data recording device, which can record data continuously at predetermined intervals

2. Forecasting model that can predict the possibility of disease outbreak using recorded weather data and other vineyard information

3. Specific recommendations on control measures to be adopted under predicted severity of disease outbreak

Currently compact computerized devices consisting of all three above requirements are available commercially for the forecasting of specific diseases of specific crops. Computer softwares for forecasting grape diseases and pests are also available outside the country, which can be used on any PC if weather data is available.

Forecasting based disease management

Downy mildew

What is actually done on computer can also be done manually? One such forecasting model for forecasting of downy mildew in grapes was proposed and it is mentioned below as an illustrative example.

Tentative forecasting can be done with the help of manually recorded observations. However it is practically very difficult to record the needed observations as many of them are to be observed during night. Automatic weather data recorder therefore is indespensible to record authentic data on which the accuracy of the forecasting is dependent. In India several organizations offers Automatic Weather Stations (AWS) alongwith software for disease forecasting which can be easily installed in vineyards, which shows weather data and disease risk on small LCD screen with press of button. ICAR-NRC for Grapes, recently has developed model for management of downy mildew and powdery mildew which can take data from any AWS. The model is licensed to several users.

Secondary infection checklist **Date : --------------**

Secondary Infection Checklist	
Question	**Answer**
Are downy mildew oil spot present?	Yes / No
Was the RH more than 98% for a minimum of 4 hours?	Yes / No
Was the temperature equal to or more than 13°C during the above?	Yes / No
Did the above occur at night (darkness)?	Yes / No
Were leaves wet from irrigation, rain or dew for at least 2 hours from dawn?	Yes / No
Has significant vine growth occurred since the last cover spray?	Yes / No
If No to any one of the above questions, the disease cannot spread	

Primary infection assessment checklist	Date :--------------------
0 4 8 12 16 20 24	Hours
---	Irrigation hours
---	Irrigation units
---	Period of rain
---	Soil wetness
------------	Water splash
------------	Leaf wetness
Question	**Answer**

Was the temperature greater than 10°C for the duration of the wet period?	Yes/No
Was the wet period caused by greater than 10 mm of rain or irrigation?	Yes/No
Did the soil remained wet for continuously wet for than 20 hours?	Yes/No
Did the significant water splash occur from the rain or irrigation in the 18 to 24 hrs. period of soil wetness?	Yes/No
Did the leaves remain wet for at least 2 hours in the 18 to 24 hours period of soil wetness?	Yes/No
Has significant vine growth occurred since the last cover spray?	Yes/No
The assessed risk of primary infection occurring is as follows if answers for questions are All Yes One No Two or More No High Low Nil	

Powdery mildew forecasting model

For germination of the spores minimum temperature should not be less than 6°C. For infection and spread 17°C temperature is required. Germination of spores, infection and spread of the disease is maximum between 21-30°C. If the leaf temperature is between 31.5-33.5°C, then spores will not germinate.

Research conducted at Agriculture Meteorology Centre for Higher Studies, Agriculture College, Pune has shown that maximum incidence of powdery mildew will be at 10.5-30.7°C temperature and 53.4-97% RH. Powdery mildew does not grow at temperature below 7.7 or above 33.3°C or at RH below 47.4%. Based on temperature and relative humidity the 'climatic disease severity values' were fixed in a scale of 0-2 as shown below:

Micro-climate at canopy	**Climatic disease severity value**		
	0	**1**	**2**
Minimum temperature (°C)	<7.7	7.7-10.5	>10.5
Maximum temperature (°C)	>33.3	31.1-33.3	<31.0
Maximum RH (%)	>99	<86	86.99
Minimum RH (%)	<47	47-57	>57

Using daily observations on all four parameters, disease severity values for the day are estimated. The cumulative values are estimated for 4 to 8 successive days. When the cumulative total of these values exceeds 34 the risk of powdery mildew starts. Severity of the disease risk is determined on number of days required to accumulate cumulative value 34. The spray for management of powdery mildew should be taken up during the risk period. While choice of fungicides and time of spray is based on severity of risk and actual growth stage in vineyard in question.

Growers can record the data on temperature and RH in their vineyards by the use of minimum-maximum thermometer and wet and dry bulb thermometer and use this chart to forecast powdery mildew in their vineyards. ICAR-NRC for grapes, Pune has made the disease forecasting and decision support system available to grape growers and the program is installed in computer, and input on weather parameters and growth stage in entered manually to get the estimated risk of powdery mildew and advice on actions to be taken for management of the diseases.

Weather forecasting and disease management

All disease forecasting methodologies mentioned above are based on actual weather data recorded on weather stations. However, now technology is available to forecast weather very accurately for next 7 days. Forecast on possibility of rain, extent of cloud cover, temperature, humidity, etc is obtained using satellite information. Many website give such forecast free of cost. NRC for Grapes, Pune gives summery of weather forecast of 7 days, for major grape growing areas on their web site. http://nrcgrapes.nic.in/ On this website click on menu "**Weather forecast based grape advice**" to get the weather forecast and related advice on plant protection. To know more details on weather at location of your interest one can see different links given on this page. Those links are

http://www.weather.nic.in/current.htm , http://www.imd.gov.in/section/nhac/wch/todaywch.htm ,http://www.imd.gov.in/section/nhac/distforecast/INDIA.htm

http://wxmaps.org/pix/prec6.html ,

http://www.accuweather.com/world-forecast.asp?partner=accuweather&traveler=0&locCode=ASI|IN|IN021|JUNNAR&metric=1 ,http://fallingrain.com

All above sites give information based on relatively low resolution data of satellites, where level of accuracy is relatively low. Information given is village or city specific. Now a days, very small location specific weather forecast can be generated, using high resolution satellite data. Using GPS (Geographical Positioning System) one can easily find out longitude and latitude of location of interest, and locate that location on globe in digital map. Using the geographical position of any location, and high resolution satellite data, one can generate weather forecast for that location. If the weather forecast is accurate, one can estimate level of risk of the important diseases in a similar manner as it is estimated from recorded weather data. In case of grapes, risk of disease is normally associated with growth stage also. If both, weather related risk and growth related risk is known one can take decision whether control measure is needed or not.

How weather forecast helps in scheduling sprays for management of downy mildew and powdery mildew?

Location specific weather forecast for next 5to 7 days is now a days available on internet. Information on forecast of rain is often useful in scheduling sprays for management of downy mildew, especially during critical stages of growth. In most cases rainy condition do not last for period more than 2 to 3 days. Preventive spray given before rains often protects vineyard from downy mildew for 2 to 3 days of rainy condition. Even if new downy mildew infection takes place, its establishment and appearance of first symptom such as oily spots and subsequent sporulation needs at least 3 days after infection in most favourable conditions. This means if the preventive spray is given just before rains, the grower can safely wait for 3 to 4 days of rainy weather and give subsequent spray only after rains have stopped. However, this can be effectively done when location specific weather forecast is available. If probable time of expected rains is known sprays can be given 1 to 2 days before rains and then if required next spray can be given after receiving few showers and on the day when rains are not likely. Second spray can also be decided on the basis of actual presence of active disease in vineyards, and forecast on possibility of rains during next few days. With such a strategy many sprays can be avoided and sprays can be given when actually needed.

Overcast cloudy conditions often present continuously for long period without actual rain in the area. Such conditions often increase the risk of powdery mildew. Powdery mildew sprays are often given at long intervals based on growth stages. These intervals can be reduced or extended based on information on cloud cover.

Strategies for Choice of fungicides in disease management

List of recommended fungicides for use in grapes for management of different diseases is updated every year by ICAR-NRC for Grapes, Pune. All the fungicides listed the list not only have been tested effective by ICAR-NRC for Grapes, Pune or the Centres of All India Co-Ordinated Research Project, but necessarily have label claim registered with Central Insecticide Board (CIB), where in target disease, dose, PHI (Preharvest interval), and MRL (Maximum Residue Limit) is mentioned. Therefore any of the fungicide listed in the list can be used for management recommended target pathogen.

The fungicides have been classified in to two catogories viz. systemic fungicides and non-systemic fungicides. Downy mildew risk after forward pruning starts after 3 leaf stage (10 to 12 days after forward pruning) and lasts normally up to fruit set (About 50 days after forward pruning.). During this period shoot is continuously growing giving out one leaf at 3 days interval. This means at every 3 days one leaf on each can will be emerged which is not protected by fungicide sprays. To protect such leaves systemic fungicides are needed. Fungicides are efficiently systemic in young growing leaves, hence they are best used on young leaves.

Systemic fungicides are very specific in their mode of action and thus pathogen can develop resistance against systemic fungicides relatively with ease. Non-systemic fungicides have multipoint mode of action and so, resistance development against non-systemic fungicides is very rare. Resistant fungus to systemic fungicide can be killed by non-systemic fungicide. Hence, use of systemic fungicide along-with non-systemic fungicide, or spray of non-systemic fungicide within short interval after the spray of systemic fungicide, will often help in reducing the chances of field establishment of resistant pathogen against systemic fungicide in vineyard.

Suggested spray interval for most systemic fungicide formulations is 5 days during risk period for downy mildew. If presence of favourable conditions for target disease within 5 days after spray of systemic fungicide are observed, additional spray of non-systemic fungicide effective against same target disease is suggested for better disease management.

The pathogens develop resistance against some systemic fungicides, much faster than other fungicides. Such fungicides are classified as high risk fungicide. FRAC (Fungicide Resistance Action Committee) a official technical group of "Crop Life International" collects all relevant information and classify every fungicide under high risk, medium risk, low risk and no risk groups.The detail updated information is available on their website http://www.frac.info/frac/publication/q_publication.htm The FRAC also prepare resistant management strategy for every group of fungicides.

Like fungicides some pathogens develop resistance to most systemic fungicides much faster than other pathogens. Such pathogens are also high risk pathogen. For example downy mildew develops resistance much faster than powdery mildews. Thus use of high risk fungicides for downy mildew has double risk.

Theoretically, chances of development of resistance are more when high risk fungicide is used as curative instead of preventive. Hence, high risk fungicides should not be used as curative, or after the outbreak of the disease. However, in case of downy mildew very few fungicides have been classified as medium risk or low risk fungicides. Fungicides amisulbrom, cymoxanil, dimethomorph, and iprovalicarb are medium risk fungicides among recommended fungicides for management of downy mildew. Hence, it is suggested to use them during early growth stages or as curative when unavoidably needed.

For management of powdery mildew, fungicides belonging to triazole group (SBI fungicides) are more preferred, over strobilurin (Q_OI fungicides) fungicides as later are high risk fungicides. In the recent times, use of biological control agents are highly recommended along with fungicides.

Germplasm for combating climate change

Dr. Roshni R. Samarth, Senior Scientist (Plant Breeding)

ICAR- National Research Centre for Grapes

Pune, Maharashtra-412307

Frequent weather aberrations are becoming common phenomenon. But this sudden change in weather has hampered the crop yield and quality drastically. Short term changes has effected the crop through biotic stress, while the prolonged persistence of these changes has resulted in stresses through abiotic conditions. Occurrence of unfavourable condition which hinders the normal plant growth and development including the reproductive cycle is known to be stress condition to plants. Prolonged stress conditions directly or indirectly involved in both biotic as well as abiotic condition. Plants have various signaling mechanism to recognize the stress and respond. Sometimes they develops their own mechanism to tolerate/escape the stress by morphological, biochemical or physiological means.

- Biotic stress: Biotic stress is defined as a stress that is caused in plants due to damage instigated by other living organisms, including fungi, bacteria, viruses, parasites, weeds, insects, and other native or cultivated plants (Newton *et al.,* 2011).

Eg. Grapes. Disease: Downy mildew, powdery mildew, anthracnose, bacteria leaf spot. Insects: Mealybugs, thrips, jassids, stem borer, mites, flea beetle, etc.

- Abiotic stress is the negative impact of non-living factors on the living organisms in a specific environment. The non-living variable must influence the environment beyond its normal range of variation to adversely affect the population performance or individual physiology of the organism in a significant way.

Eg. Drought, salinity

To combat with such climatic changes genetic resources have significant role. Many genetic resources are being identified for certain traits of interest and can be utilized to upgrade the commercial variety with the trait of interest. Such material can are useful as genetic resources to inherit the traits in the recipient variety. Genetic Diversity refers to the range of different inherited traits within a species. In a species with high genetic diversity, there would be many individuals with a wide variety of different traits. Genetic diversity is critical for a population to adapt to changing environments. It strengthens the ability of population to resist/tolerate diseases, pests, changes under climatic stresses. Gene variations underpin their capacity to evolve and their flexibility to adapt.

Plant hormones, salicylic acid (SA), jasmonic acid (JA), and ethylene play central roles in biotic stress signaling. Several transcription factors (TFs) are mediators in multiple hormone signaling. Plant defenses against biotic stresses involve numerous signal transduction pathways. Abscisic acid (ABA) is reflected as the main hormone involved in the perception of many abiotic stresses. However, ABA has a positive effect on biotic stress resistance. Under abiotic and biotic stress, ABA acts antagonistically with ethylene, which induces liability of the plant against disease attack. Under abiotic stress ABA increases and induces stomatal closure. As a result, the entry of biotic attackers through stomata is prevented. Therefore, under such situations, the plant is protected from abiotic and biotic stress. Kinase protein signals also interact with ROS and ABA leads to plant defense enhancement. Pathogenesis-related (PR) proteins are critical for plant resistance against pathogens and when plants are attacked; their expression is strongly upregulated. It is suggested that with an increase in ABA expression of specific TFs like C-repeat binding factors

(CBFs), and cup-shaped cotyledon mediated by ABA could be enhanced, which induces upregulation of PR genes.

Biotic stresses

Most of the commercial grape varieties are belong to *Vitis vinifera* and are susceptible to diseases such as downy mildew, powdery mildew and anthracnose. These diseases have significant impact on yield and quality of grapes.

Downy mildew

1. Downy mildew is caused by fungus *Plasmopara viticola*. Pathogen develops under cooler and humid condition. It have potential of 100 per cent losses if occurs during flowering. Also heavy infection at berry development reduces the quality too. Frequent untimely rains after fruit pruning particularly at flowering and berry setting stage have hampered the crops significantly.

Figure 1. Downy mildew

2. Several American and Asian Vitis species like *Muscadinia rotundifolia*, *V. riparia*, *V. cinerea*, *V. labrusca*, *V. rupestris*, *V. berlandieri*, *V. lincecumii* show variable levels of resistance.

3. The resistance to downy mildew has been shown to be quantitatively inherited.

4. Quantitative trait loci (QTLs) for resistance to downy mildew have been identified and molecular maps based on populations segregating for disease-resistant traits, including resistance to downy mildew, are available. These sources can be used in breeding programme for developing of downy mildew resistant variety.

There are many loci reported for downy mildew resistant, but chances are to break the resistant. Hence pyramiding of resistance own its importance to withstand during the congenial conditions.

Examples of disease resistant varieties developed:

- **Regent** is one of the commercially successful resistant wine grape varieties developed in Germany.

- Among table grape varieties, **Carolina Black Rose and Maroo Seedless**, two coloured varieties have been developed through interspecies hybridization.

Powdery mildew: Grapevine powdery mildew (PM) is caused by the obligate biotrophic fungus *Erysiphe necator* Schwein. (previously *Uncinula necator*). The powdery mildew fungus can infect all green tissues of the vine. Small, white or grayish-white patches of fungal growth appear on the upper or lower leaf surface. If blossom clusters are affected, the flowers may wither and drop without setting fruit. Infected cluster stems may wither and dry up, resulting in berry drop (shelling). Berries are susceptible to infection from early bloom through three to four weeks after bloom.

- The Run1 locus was mapped to linkage group 12 and it encompasses a string of resistance genes, three of which were found closely linked to a marker co-segregating with resistance. The mechanism by which Run1 confers resistance is thought to be hypersensitive reaction (HR) mediated death of the leaf epidermal cell attacked by the pathogen.

Table 1. QTLs identified with major downy mildew-resistance, located on linkage groups (LGs)

Symbol	Chromosome	Original species of trait	Symbol	Chromosome	Original species of trait
Rpv1	12	*M. rotundifolia*	Rpv15	18	V. piasezkii
Rpv2	18	*M. rotundifolia*	Rpv16		
Rpv3	18	*V. rupestris*, *V. lincecumii*, *V. labrusca* or *V. riparia*	Rpv17	8	
Rpv4	4	Regent	Rpv18	11	
Rpv5	9	*V. riparia*	Rpv19	14	*V. rupestris*
Rpv6	12, 2	*V. riparia*	Rpv20	6	
Rpv7	7	Bianca	Rpv21	7	
Rpv8	14	*V. amurensis*	Rpv22		
Rpv9	7	*V. riparia*	Rpv23		
Rpv10	9	*V. amurensis*	Rpv24		
Rpv11	5		Rpv25	15	
Rpv12	14	*V. amurensis*	Rpv26	15	
Rpv13	12	*V. riparia*	Rpv27		
Rpv14	5	*V. cinerea*			

Table 2. Resistance sources for powdery mildew

Symbol	Chromosome	Original species of trait	Symbol	Chromosome	Original species of trait
Ren1	13	Kishmish vatkana	Ren7	19	*V. piasezkii*
Ren2	14	Illinois 547-1	Ren8	18	
Ren3	15	Regent	Ren9	15	Regent
Ren4	18	*V. romanetii*	Ren10	2	Seyval blanc
Ren5	14	*M. rotundifolia*	Run1	12	*M. rotundifolia*
Ren6	9	*V. piasezkii*	Run2	18	*M. rotundifolia*

Table 3. Major sources for different commercially important traits

Trait	Donor source	Reference
Downy mildew resistance	Regent, Prior, Bronner, V. rotundifolia, V. amurensis	Yu et al., 2012
Powdery mildew resistance	Regent, James	Eibach et al., 2007
Anthracnose	Chinese Vitis sp. like V. piasezkii, V. pseudoreticulata, V. romanetii and American Vitis species like V. aestivalis, V. champinii, V. shuttleworthii, V. vulpine, V. rotundifolia	Wang et al., 1998 Mortensen, 1981
Drought tolerance	V. californica, V. champinii, V. doaniana, V. longii, V. girdiana, and V. arizonica	Padgett-Johnson et al., 2003
Salt tolerant	V. berlendieri, V. riperia, V. candicans, V. longii and V. champini	Ray, 2002

Abiotic stresses

Drought and salinity are main issues to be concern. Limiting water availability and quality have escalated the salinity issue. Most of the time these two come together. Salt tolerance is usually explained in terms of chloride exclusion capacity.

Optional rootstocks to be used for improvement

• *Vitis berlendieri*, *Vitis riparia*, *Vitis rupestris*, *Vitis champinii*

➢ Depending upon their root architecture, water uptake properties, ion exclusion properties etc.

Eg.

- Strong chloride excluders: 140 Ru, St. George and Schwarzmann
- Drought resistance with moderately strong salt exclusion: Rootstock Ramsey (syn. Salt Creek)

Choice of rootstock:

***Vitis riparia* based** – shallow roots, water sensitive, low vigor, very early maturity: 5C, 101-14, 16161C (3309C)

***Vitis rupestris* based** – broadly distributed roots, relatively drought tolerant, moderate to high vigor, midseason maturity: St. George, 1202C, 1103P

***Vitis berlandieri* based** – deeper roots, drought tolerant, higher vigor, delayed maturity: 110R, 140Ru (420A, 5BB)

Important factors: soil depth, rainfall, soil texture, water table

Root architecture

Reflects its water needs and utilization

• The density of roots in the soil profile also varies

– Evenly distributed

– Primarily deep

– Primarily shallow

The root architecture and density of the deep and surface roots relates directly to nutrient and water uptake:

• Some plants hydraulically lift water from deep in the soil profile to keep the surface roots active

• These characters vary and allow rootstocks to be more or less drought tolerant and impacts their ability to take up nutrients

Eg.

• Mostly deep roots: Ramsey, 140Ru, 1103P, 110R

• Broadly distributed roots: 1103P, Freedom, Harmony, St. George, O39-16, 5BB, 420A Mgt

• Primarily shallow roots: 101-14 Mgt, Schwarzmann, 101-14 Mgt, 5C, 420A, 16161C

Breeding rootstocks to tolerate drought

Factors to be considered:

- Root architecture – shallow to deep rooting angles
- Root density – two tiered to even distributions
- Hydraulic lift
- Water use efficiency / productivity

What anatomical traits influence drought tolerance?

- Root angle
- Xylem diameter / distribution
- Storage capacity

- Stomatal distribution

Improvement for stress tolerance/resistance by the means of:

1. Introduction of tolerant genotype

Already developed genotypes known for various types of tolerance can be introduced/imported. If it has commercial value, it can be directly used as variety. If the genotype having tolerance/resistance do not have commercial value, its trait of interest need to be transfer in the commercial variety through hybridization or other mean.

2. Selection: Spontaneous mutation is more common in grape crop.

Most of commercial Indian table grape varieties are clones of introduced varieties such as Thompson Seedless (clones: Sonaka, Manik Chaman, Tas-A-Ganesh, etc.) and Kishmish Chernyei (clones: Sharad Seedless, Nanasaheb Purple Seedlss, etc.). Similarly under persistent stress condition, vine have ability to change expression for its survival. Most often such changes are stable. Such cane need to be separately to developed into multiple vine for screening various traits of interest.

Other option is through induce mutation. Any physical and chemical agents are available for induction of mutations. Treated planting material is grown for screening the trait of interest. But many times such mutations fails due to prolific vegetative growth and shy bearing.

Eg.: Das and Mukherjee (1968) used chemicals (ethyl methane sulphonate, diazomethane) for obtaining downy mildew resistance vine.

3. Hybridization: Through crossing of commercial variety with the tolerant donor parent. Hybridization in grapes is tedious and time consuming due to small flower size. Further genetic combining ability and trait heritability is at most important. Due to long generation time, high heterozygosity, inferiority of fruits of donor parents elevate the complications for development

of desired genotype. But it is the method for creation of various gene combinations. Recombinants developed by hybridizations can further be used for screening for various objectives.

4. Molecular aided selection

If the gene function is well studied and the information is publically available, linked primers can de designed to screen the trait of interest.

Although the developing variety with trait of interest through hybridization programme, it is the way to get wider variability. Availability of variability is key to combat with various stresses. The genomic information being deciphering various traits of interest from last two decades. Such information will be useful in varietal development programme with precision.

Protection of plant varieties and farmers right

Dr. Roshni R. Samarth, Senior Scientist (Plant Breeding)

ICAR- National Research Centre for Grapes

Pune, Maharashtra-412307

Being the member of World Trade Organization for the legal ground for international trade and to comply with Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement, Government of India opted for an effective *sui generis* system for protection of breeders and farmers right. Bill was passed in Parliament of India on "**Protection of Plant Varieties and Farmers' Rights Act 2001**" or **PPVFRA (2001)**. The Rules were framed in 2003, and the Authority was established on November 11, 2005.

Protection of Plant Variety and Farmers Right Authority (PPV&FRA) is establish to protect plant varieties, rights of plant breeder as well as farmer. Farmers are conserving genetic resources from long time and those resources are being utilized in improvement of crops. This act recognizes their contribution in crop improvement and protect their rights. This system also encourages development of new plant varieties. Without permission of registered breeder, no one can sell, export, import or produce seed or propagating material of protected variety.

Any person who bred the variety is entitled for registration of his/her variety.

Intellectual property and agriculture

- Granting IPR to plant breeders' aims at stimulating private investments, thus improving farmers' possibilities to use new plant varieties that are developed based on scientific breeding methods.

- Sustainable use of agriculture bio-diversity, the rights farmers, and also to food and nutrition security and human rights.
- Focused on few crops of major economic importance, and on breeding strategies

Varieties that can be registered (Source: PPVFRA)

- **New:** A variety which is developed by any agency or individual including farmer in India or any agency or individual abroad that has not been in trade or in use as a breeding line, for more than one year from the date of submission of application if it is from India, and for more than four years or six years (in case of trees/vines only) from the date of submission of application if it is from any other country
- **Extant:** Plant variety already in existence for not more than 15 years at the time of notification of the plant species for registration by the Authority and to be registered within stipulated period as per species/category as specified by the Authority at the time of notification. The extant variety category is introduced to facilitate those varieties to be put under a certain level of protection though these are not novel, and are represented by any one (never both or all) of the following:

1. **Variety of Common Knowledge:** An existing variety known to be in trade not beyond fifteen years or eighteen years in trees or vines but beyond one year in India or beyond 4 years (or 6 years in the case of trees or vines) in other countries.
2. **Variety notified under Seeds Act, 1966**: (Registration valid from the date of notification to a total of 15 years)
3. **Farmer's Variety:** An existing variety developed as a selection by a farmer or a community from the existing traditional variety or a landrace as cultivated by farmers, that does not involve any specific breeding methods of choosing parents, crossing these, growing these for variability or in vegetatively

propagated species any activity that involves use of growth regulators or media for layering, budding, grafting, cutting, or use of nursery for commercial production of rooted plants, etc.,

- **Essentially derived variety**

An EDV is always a variety derived for a targeted trait that is missing in an existing registered variety (initial variety) or a crossed product (hybrid) of two such initial registered varieties (parents of an existing registered hybrid), while retaining the expression of the characteristics of its initial variety or initial parents of hybrid in the resulting variety or hybrid such that the resulting EDV.

An EDV can be developed through any of the known methods of breeding such as, genetic engineering, mutation breeding, tissue culture derived variation (somaclonal variation), backcross breeding, any other cytological approaches which only change limited characters in the initial variety.

Plant breeder and farmers right

Plant breeder's right

- Production and Marketing
- Sell
- Export

Farmer's right: Hold, use, share, sell farm produce of variety (restricted to non-commercial scale)

Research exemption: Use of protected material for research

DUS testing

Test for differentiating new variety from the existing varieties. It ensures

- Novel - new and not in general cultivation
- Distinctness - for at least one or two traits
- Uniformity – homogeneous

- Stability – stable performance for claimed trait over location and time

Period of protection

- Trees and vines: 18 years from the date of grant of certificate of registration

- Other plants: 15 years from the date of grant of certificate of registration

- For extant varieties notified under Section 5 of Seeds Act, 1966 - 15 years from the date of notification under Section 5 of the Seeds Act, 1966

Benefits of protection of plant variety act

- Development of improved varieties for farmers
- Increase in farmer’s income
- Development of international market

Climate change regime: Innovations in grape processing

Ajay Kumar Sharma, Nishant A Deshmukh, Prashant H Nikumbhe
Mr Rohit Palghadmal and Dr Ganesh N Jadhav
ICAR-National Research Centre for Grapes, Pune-412307

Introduction

Climate change poses a severe threat to the future of the environment as it is directly related to agriculture, biodiversity, human society, and nearly every facet of our beautiful world. The magnitude of the effects depends on the amount of emissions; in general, more frequent heatwaves, droughts, floods, and persistent sea level rise and global temperature increases are expected (IPCC, 2018). Effect of climate change will contribute to uncertainty about future water availability in many regions. It will affect precipitation, runoff and snow/ice melting, with effects on hydrological systems, water quality and water temperature, as well as on groundwater recharge. In many regions of the world, increased water scarcity under climate change will present a major challenge for climate adaptation. Climate change is likely to affect the frequency and intensity of extreme events also. The magnitude of impacts of extreme events on agriculture is already high and being observed in different regions of various countries. As highlighted by the latest assessment report of the Intergovernmental Panel on Climate change (IPCC), climate change augments and intensifies risks to food security for the most vulnerable countries and populations. climate change impacts may reduce income level and stability, through effects on productivity, production costs or prices. Such variations can drive sales of productive capital, such as cattle, which reduces long-term household productive capacity (FAO, 2015).

Climate change and grape quality

Geographically, grapevines are historically cultivated on six out of seven continents, between latitudes 4° and 51° in the Northern Hemisphere

(NH) and between 6° and 45° in the Southern Hemisphere (SH). The grapevines are spread across a large diversity of climates (oceanic, warm oceanic, transition temperate, continental, cold continental, Mediterranean, subtropical, attenuated tropical, arid, and hyper arid climates), but with the majority grown under temperate climatic conditions. Worldwide, grape-growing regions are often classified into so-called Winkler regions according to heat summation measured in cumulative growing degree days (GDD), a scheme originally proposed by Amerine and Winkler (1944). Each 1 °C increment in mean temperature adds 214 GDD to the standard growing season. Therefore, if one assumes an average increase from the present of 1.5 °C by 2020, cumulative heat units would increase by 321 GDD. A 2.5 °C increase by 2050 would add 535 GDD to the current heat units. This simple estimate shows that the projected rise in temperature associated with global climate change (IPCC 2007) will likely shift several of the world’s growing regions into the next higher Winkler region by 2020 and that this shift will affect most regions by 2050. Elevated CO2 will stimulate the yield without having any negative or positive repercussion on grapes at maturity stage. Acid and sugar contents were also stimulated by rising CO2 levels up to a maximum increase in the middle of the ripening season (8–14%); however, as the grapes reached the maturity stage, the CO2 effect on both quality parameters almost completely disappeared (Bindi et al. 2001). They cited that an increase in the fruit sugar concentration and a reduction in acidity levels under elevated CO2 but the response of other components contributing to flavour and aroma of grapes was heterogeneous and indicated a significant “chamber effect”, with plants grown outside responding differently than plants in open-top chambers with or without elevated CO2 (Gonçalves et al. 2009). While high temperatures tend to accelerate grape ripening, too much heat can inhibit or even denatured berry proteins, and may lead to symptoms of sunburn. Model calculations performed for Australian wine regions also project a forward shift in harvest date, which was arbitrarily defined as grapes reaching soluble solids content of 20 °Brix (Webb et al. 2007). Elevated temperature would bring variation in quality of grape berries. In some of the regions, however, the temperature of the ripening period may become too hot to produce balanced wines from some or all grape varieties (Sharma et al. 2013).

Grape processing and Innovations

Grapes are mainly processed in the form of wines. About 44% of total grape production of world is turned in to wines while 5-6% is utilized for raisin making. Climate change impacts on viticulture are changing world wine region distribution. The new regions may become suitable for grape growing same time available grape regions may not able to produce quality grapes for processing. In fact, the growing suitability of environmental conditions in new viticultural areas, coupled with the improvement of the wine-making techniques, are leading to a reshaping of the global wine production and trade. The impact of climate change in viticulture became a relevant issue for winegrowers during the last years, mostly because of the detrimental consequences that warmer temperatures, prolonged drought periods, and other adverse climate conditions, showed on grape production and wine quality (Leolini et al. 2021). Warmer temperatures, determining increases of sugar concentration in grapes at the ripening stage, may lead to osmotic issues in yeasts (*Saccharomyces cerevisiae*), with consequent concentrations may cause growth inhibition or lysis in microorganisms. This is turn, may result in sluggish alcoholic fermentations, whose occurrence have been reported to increase drastically in hot years (Coulter et al. 2008), and pose a significant problem to the wine industry. Also, under high temperatures during harvesting, vine metabolism may be inhibited leading to reduced metabolite accumulations, which may affect wine aroma and colour. The warmer temperature conditions can transform the flavour of wine, which are identical depends on the delicate chemistry of grapes and growing conditions of particular region.

Accurate monitoring and prediction of grape maturity are becoming ever more important as climate change affects harvest dates, length of the growing season, and grape quality. AI and Machine Learning tolls will become platforms to produce quality wines under climate change. Researchers have already started work in these areas and fruitful results are coming. An AI-powered platform is available where uses of satellite imagery, weather data, and information on grape variety to **predict sugar content with 96% accuracy, TA levels with 91% and pH with 98% accuracy**. The grape berries are monitored and predicts weekly changes in sugar levels without the need to be physically present in the vineyard are predicted. Grape Maturity Maps, produced by combining satellite imagery and AI, visualize maturity variation are able to a guidance to allow differential harvesting. Such type technologies are available and will help in making quality produce from grapes under climate change regime.

Grapes are being processed in the form of wines and raisins under tropical conditions of India where high temperature prevails at the time of harvesting. These conditions are very suitable for grape drying. Use of weather forecast based advisory system is very helpful to avoid the grape drying where rains are expected. Many groups are working at grass root level and supporting grape growing community to manage insect-pests and diseases with minimal applications of agrochemicals. Same pattern can be utilized in raisin making also. Dipping of grape bunches in solution of ethyl oleate and potassium carbonate is required for faster grape drying as the dipping of grape bunches in solution creates micro cracks on epidermis of grape berries. Same can be creates by machines also. Grape drying without chemical dipping is able to produce quality raisins Pawar et al. (2021). Food Safety and Standards Authority of India (FSSAI) has defined the microbial limits in various food materials including raisins. If raisins are stored at more than 70% humidity, fungal and yeast growth can observe easily. Same time, if moisture content in raisins is more than 20%, the product will become uneatable due to higher microbial load. The microbes may get entry at any stage of grape drying including harvesting, raisin processing, storage, distribution etc. Hence, to manage the microbial entry in the raisins, the check points should be fixed for observations with storage at low temperature (4°C). Edible coating is good option. Edible coating is defined as a thin layer of edible material form as a film on the surface of the fruits and vegetables. This coating can affect the respiration and moisture loss. Some advantages of edible coating are as it is palatable, reduces environment pollution, great effect on taste properties develops nutritional value, improved texture, reduced microbial load, etc. Various combinations of guar gum and glycerol were tried and found that the combination of 0.25% (guar gum (and 40% (glycerol) maintained raisin quality up to 40 days when store under ambient conditions.

In case of juice Manjari Medika is found capable to change the scenario by giving juice with functional properties as well as sustainability in grape growing system by adopting zero waste processing of this variety. Zero waste concept is based on utilization of every waste or by-product developed during juicing of grapes. For this purpose, grapes are used for juice purpose and left-over pomace is again processed and dried. The seeds are separated from dried pomace. The seeds again utilized for extraction of grapes seed oil while other material is processed in the form of powder. This grape pomace powder is noted with high nutraceutical properties. For utilization of pomace powder, a technology is developed. Up to 15% maida is replaced by this pomace powder when cookies were prepared. These cookies have more nutritional and functional properties with dark natural colour. The prepared cookies contain dietary fibers also (Sharma et al. 2018). The enriched cookies are well accepted by members of panel during sensory evaluation studies. Other than cookies, pomace powder can be used in making breads also. The technology for enrichment of breads by addition of Manjari Medika pomace powder has already been demonstrated well. Addition of pomace powder will certainly enrich the breads and enhanced nutritional and functional properties. The enriched breads are found with high nutraceutical values with attractive colour (Sharma et al. 2019). The grapeseed oil has very high amount of PUFA (Polyunsaturated fatty acids). Grape seed oil is used in different ways worldwide. India is importing high quantity of grape seed oil from different countries. By adopting zero waste technology, grape seed oil will be generated during the process. Work on retraction of grape seed oil from Manjari Medika has been standardized. Fatty acid profiling of Manjari Medika grape seed oil is in progress and other studies have been initiated for establishing medicinal values of grape seed oil obtained from Manjari Medika.

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Insurance for horticulture crops in Maharashtra

Vinaykumar awate

Joint Director Agriculture (Ext,) and Chief Statistician, M.S. Pune

In the era of global warming and climate change, we experience extreme climatic situation. This type of unusual climatic change affects the human kind as well as crops in many ways. The adverse climatic condition affects horticulture crops and it leads to economic loss to the farmer. To protect the farmers from such kind of economic loss an insurance scheme for horticultural crops was started on pilot basis in 2011-12 in Maharashtra for few crops. Now after the beginning of Pradhan Mantri Fasal Bima Yojna in 2016-17, the Restructured Weather Base Crop Insurance Scheme for Horticulture Crops is also being implemented under PMFBY. This scheme is being implemented in two seasons namely Mrug Bahar and Ambiya bahar.

The main features of this insurance are as

1. Mrug bahar crops included - Pomegranate, Santra , Orange , Chiku , Guava, Lemon, Custard Apple , Grapes (8 crops)
2. Ambiya Bahar Crops included - Santra , Orange , Cashew, Pomegranate , Mango, Banana, Grapes , Strawberry , Papaya (9 crops)
3. Since 2020-21 the participation for lonee farmers is optional.
4. Since 2020-21 per farmer area, crop insurance area limit is 4 ha. per year including all notified crops for insurance.
5. In case the actuarial crop insurance premium is 35%, then in this farmers share is 5%, Govt. of India insurance premium subsidy is 12.50% and Govt. of Maharashtra insurance premium subsidy is 17.50%

6. If the Acturial premium is above 35%, then premium above 35% has to be shared equally by farmer and state as 50:50.

7. Farmer can participate online through www.pmfby.gov.in portal , for which bank details and land details with Geo tag photo of orchard to be insured is required /or they can approach Commom service centre (apale Sarkar) for enrollment.

8. Only orchards with minimum Productive Age are considered for insurance.

Table 1. Productive age of different fruit crops

Sr. No.	Fruit crop	Productive age in years
1	Mango, Sapota, Cashew	5
2	Lemon	4
3	Mosambi ,Santra, Guava, Custard Apple	3
4	Pomegarnate, Grapes	2
5	Papaya, Strawbery and Banana	Annual

9. Revenue circle (consist of 10 to 15 villages) is notified as insurance unit. Minimum area required for insurance notification for particular crop in that revenue circle is 20 Ha. productive orchard area.

10. Last date of participation for insurance (2022-23) are as

A. Mrug Bahar Crops

Fruit crops- Mrug	**Last Date for participation**
Santra, Grapes, Guava,Lemon	14^{th} June
Mosambi , Chiku (Sapota)	30^{th} June
Pomegranate	14^{th} July
Custard Apple	31^{st} July

B. Ambiya Bahar Crops

Fruit crops- Ambiya	Last Date for participation
Grapes	15th October
Mosambi , Banana, Papaya	31st October
Santra, Cashew, Mango (Konkan)	30th November
Mango (Other Than Konkan)	31st Decemeber
Pomegranate	14th January

11. Climatic perils covered under insurance and sum insured per ha. are as

A. Mrug Bahar

Table 2. Trigger, period and sum insured per ha.

Crop name	Triggers	Insured Period	Sum Insured in Rs.
Santra	1. Low rainfall 2. Long break in mansoon	15th Jun to 15th July 15th July to 15th Aug.	**80,000**
Mosambi	1. Low rainfall 2. Long break in mansoon	1st July to 31st July 1st Aug to 31st Aug	**80,000**
Guava	1. Low rainfall 2. Long break in mansoon and high temp.	15th Jun to 14th July 15th July to 15th Aug	**60,000**
Sapota	High RH and Heavy rainfall	1st July to 30th Sep	**60,000**
Pomegranate	1. Break in rainfall 2. Heavy rainfall	15th July to 15th Oct. 16th Oct to 31st Dec	**1,30,000**
Lemon	1. Low rainfall 2. Long break in mansoon	15th Jun to 15th July 16th July to 15th AUg	**70,000**
Custard Apple	1. Break in rainfall 2. Heavy rainfall	1st Aug to 30th Sep 1st Oct to 30th Nov	**55,000**
Grapes (C)	Rainfall, Humidity and low Temp.	15th Jun to 15th Nov	**3,20,000**

B. Ambiya Bahar

Table 3. Trigger, period and sum insured per hectare

Crop name	Triggers	Insured Period	Sum Insured in Rs.
Santra	1. Unseasonal rain 2. Low Temp 3. High Temp	1st Dec to 15th Jan 16th Jan to 28th Feb 1st Mar to 31st May.	**80,000**
Mosambi	1. Unseasonal rain 2. High Temp 3. Heavy rain	1st Nov to 31st Dec 1st Mar to 31st Mar 15th Aug to 15th Sep	**80,000**
Pomegranate	1. Unseasonal rain 2. High Temp 3. Heavy rain	15th Jan to 31st May 1st April to 31st May 15th Aug to 15th Sep	**1,30,000**
Cashew	1. Unseasonal rain 2. Low Temp	1st Dec to 28th Feb 1st Dec to 28th Feb	**1,00,000**
Banana	1. Low Temp 2. Speedy Wind 3. High Temp	1st Nov to 28th Feb 1st Mar to 31st July 1st April to 31st May	**1,40,000**
Grape	1. Unseasonal rain 2. Low Temp	16th Oct to 30 April 1st Dec to 28th Feb	**3,20,000**
Mango (konkan)	1. Unseasonal rain 2. Low Temp 3. High Temp 4. Speedy Winds	1st Dec to 15th May 1st Jan to 10th Mar 1st Mar to 15th May 16th April to 15th May	**1,40,000**
Mango (Other than konkan)	1. Unseasonal rain 2. Low Temp 3. High Temp 4. Speedy Winds	1st Jan to 31 st May 1st Jan to 28th Feb 1st Mar to 31st Mar 1st April to 31st May	**1,40,000**
Starwbery	1. Unseasonal rain & RH 2. Unseasonal rain, RH & High Temp 3. Low Temp	15th Oct to 30th Nov 1st Feb to 30th April 1st Dec to 31st Mar	**2,00,000**
Papaya	1. Low Temp 2. Speedy Winds 3. Heavy rain & RH	1st Nov to 28th Feb 1st Feb to 30th Jun 15th Jun to 30 Sep	**35,000**

Hailstorm triggers for Ambiya Bahar

Crop Name	Trigger Period	Sum insured/ha in Rupees
Santra , Mosambi	1st Jan to 30th April	26667
Pomegranate	1st Jan to 30th April	43333
Cashew	1st Jan to 30th April	33333
Banana	1st Jan to 30th April	46667
Grapes	1st Jan to 30th April	106667
Strawbery	1st Jan to 30th April	66667
Mango	1st Feb to 31st May	46667
Papaya	1st Jan to 30th April	11667

12. The triggers for grape crop in Mrug bahar are as

Weather Triggers & Period	Triggers & Compensation amount (Rs./ha.)
1. **Rainfall, Relative Humidity and Temperature Dt. 15 June to 10 July**	• During this period, if rain falls 10 mm or more for 3 consecutive days, the humidity will be 70% or above and the temperature will be 10 degrees Celsius or above then compensation of Rs. 25,600/- is payable. • During this period, if rain falls 10 mm or more for 4 consecutive days or more, the humidity will be 70% or above and the temperature will be 10 degrees Celsius or above then compensation of Rs. 64,000/- is payable. (Maximum Payout Amount Rs. 64000/-)
Rainfall, Relative Humidity and Temperature Dt. 11 Jul to 30 Aug.	• During this period, if rain falls 10 mm or more for 4 consecutive days, the humidity will be 60% or above and the temperature will be 10 degrees Celsius or above then compensation of Rs. 38,400/- is payable. • During this period, if rain falls 10 mm or more for 5 consecutive days or more, the humidity will be 60% or above and the temperature will be 10 degrees Celsius or above then compensation of Rs. 96,000/- is payable. (Maximum Payout Amount Rs. 96,000/-)
Rainfall, Relative Humidity and Temperature	• During this period, if rain falls 10 mm for 3 consecutive days, the relative humidity will be 60% or above and the temperature will be 10 degrees Celsius or above then compensation of Rs. 64,000/- is payable.

Dt. 1 Sep. to 15 Nov. (Berry formation stage)	• During this period, if rain falls 10 mm or more for 4 consecutive days or more, the relative humidity will be 60% or above and the temperature will be 10 degrees Celsius or above then compensation of Rs. 1,60,000/- is payable. (Maximum Payout Amount Rs. 1,60,000/)

13. For Grape crop Mrug Bahar notified districts and talukas are as

A. Nashik Dist.:- Baglan, Chandvad, Devla, Kalvan, Dindori, Niphad, Malegaon

B. Pune Dist.:- Baramati, Indapur

C. Sangli Dist.:- Palus,Tasgaon, Miraj, Kavathe Mahakal, Khanapur (14 talukas)

14. For Grape crop Ambiya Bahar notified districts are Nashik , Ahmednagar, Dhule , Buldhana, Sangli, Solapur, Pune, Aurangabad , Osmanabad, Jalna, Satara, Beed, Latur, Nanded ,Kolhapur (15 Dist.)

15. The triggers for grape crop in Ambiya bahar are as

Weather Triggers & Period	**Triggers & Compensation amount (Rs./ha.)**		
1. Unseasonal rainfall Per Day (mm) (Phase wise multiple event would be payable subject to maximum payout)	Dt. 16 Oct. to 7 Nov.	Dt. 08 Nov. to 30 Nov.	Dt. 1 Dec. to 31 March
(>=4) 4 mm or more	4200	10,700	10,700
(>=11) 11 mm or more	6,450	16,000	21,500
(>=21) 21 mm or more	8,300	32,600	26,300
(>=31) 31 mm or more	10,800	48,300	43,000
(>=41) 41 mm or more	16,100	1,28,700	54,100 + 50% of remaining amount of Phase I & Phase II
(>=51) 51 mm or more	32,250	1,72,000	64,550 + 100% of remaining amount Phase I & Phase II

<table>
<tr><td>Maximum Payout</td><td>32,250</td><td colspan="2">1,72,000</td><td colspan="2">64,550 + 100% of remaining amount Phase I & Phase II</td></tr>
<tr><td>Maximum Payout of all Phases (Rs.)</td><td colspan="5">2,68,800/-</td></tr>
<tr><td rowspan="3">2. Low Temperature(1 Dec. to 28 Feb) (Single event would be payable subject to maximum payout)</td><td colspan="5">Daily minimum Temperature (Degree Celsius) (Rs/Ha.)
(Insurance Cover Period (1 Dec. to 28 Feb)</td></tr>
<tr><td>3.51 to 4.00</td><td>3.01 to 3.50</td><td>2.51 to 3.00</td><td>2.01 to 2.50</td><td>less than or equal to 2.00</td></tr>
<tr><td>10,200</td><td>15,400</td><td>20,500</td><td>30,700</td><td>51,200</td></tr>
<tr><td>Maximum Payout</td><td colspan="5">51,200</td></tr>
</table>

16. Performance of RWBCIS for all crops for 2016-17 to 2021-22

Year	Applications No.	Area Insured Ha.	Premium paid Rs. In crore		Claim Amount Rs. In crore	Claim Ratio %
			Farmers Share	Total Premium		
2016-17	185571	183338	102.28	732.08	392.88	**53.67**
2017-18	141610	162613	93.33	741.53	580.23	**78.25**
2018-19	350450	307838	177	1185.77	1435.01	**121.02**
2019-20	491250	422221	255.24	1437.55	1129.18	**78.55**
2020-21	430334	312549	189.11	686.97	304.55	**44.33**
2021-22	284062	208965	174.26	734.3	855.59	**116.52**
Total	**1883277**	**1597524**	**991.22**	**5518.2**	**4697.44**	**85.13**

So, in last 6 years total Rs. 5518.20 crore premiums is paid to the insurance companies, in which farmers premium share is of Rs. 991.22 crore and Rs. 4697.44 crore compensation is given to the farmers. So, the scheme is very beneficial to the farmers.

17. For Grapes –Premium and Claims for 2016-17 to 2021-22

Year	No. of Applications	Area Insured in Ha.	Sum Insured (Rs. in Crore)	Gross Premium (Rs. in Lakh)	Claim amount (Rs. in Lakh)	Benefited Farmers	Claim %
2016-17	16088	14447	364	9591	321.17	3608	**3.35**
2017-18	12138	13210	348	7806	736.05	6443	**9.43**
2018-19	11586	10508	324	4338	3331.37	11086	**76.80**
2019-20	25519	20173	657	9868	2744.81	15527	**27.82**
2020-21	12439	7661	245	4200	2443.62	12371	**58.18**
2021-22	1835	1042	33	384	1614.95	1834	**420.68**
Total	79605	67041	1971	36186	11191.98	50869	**30.93**

So, for grapes in last 6 years total Rs. 361.86 crore premium is paid to the insurance companies, and Rs. 111.92 crore compensation is given to the farmers .In the year 2021-22 the claim ratio is 421% which is the highest.

For insurance claims weather data is obtained from Mahavedh project, in which automatic weather stations are established in every revenue circle. Data about temperature, humidity, rainfall, wind velocity, wind direction are collected in central project monitoring unit. This is supplied to Government and insurance companies for claims calculation under this weather based insurance scheme.

As per the experience of last 6 years the insurance cover proved helpful in safeguarding the economic loss to the horticulture farmers.

Artificial intelligence and it’s role in agriculture

Mr. Palash Sontakke, Professor,

MIT-ADT University, Lonikalbhor, Pune

What is artificial intelligence?

It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.

Yes, but what is intelligence?

Intelligence is the computational part of the ability to achieve goals in the world. Varying kinds and degrees of intelligence occur in people, many animals and some machines.

Isn't there a solid definition of intelligence that doesn't depend on relating it to human intelligence?

Not yet. The problem is that we cannot yet characterize in general what kinds of computational procedures we want to call intelligent. We understand some of the mechanisms of intelligence and not others

• **Human-like** (“How to simulate humans' intellect and behavior on by a machine.)

- Mathematical problems (puzzles, games, theorems)
- Common-sense reasoning (*if there is parking-space, probably illegal to park*)
- Expert knowledge: lawyers, medicine, diagnosis
- Social behavior

- **Rational-like**:
    - Achieve goals, have performance measurement
    - Introduction
- **Thought processes**
    - "The exciting new effort to make computers think .. Machines with minds, in the full and literal sense" (Haugeland, 1985)
- **Behavior**
    - "The study of how to make computers do things at which, at the moment, people are better." (Rich, and Knight, 1991)
- **History (Important milestones)**
    1. McCulloch and Pitts (1943)
        - Neural networks that learn
    2. Minsky (1951)
        - Built a neural net computer
    3. Darmouth conference (1956):
        - Logic theorist (LT)- proves a theorem in Principia Mathematica-Russel.
        - The name "Artificial Intelligence" was coined.
    4. 1952-1969
        - GPS- Newell and Simon
        - Geometry theorem prover - Gelernter (1959)
        - Samuel Checkers that learns (1952)
        - McCarthy - Lisp (1958), Advice Taker, Robinson's resolution
        - Microworlds: Integration, block-worlds.
        - 1962- The perceptron convergence (Rosenblatt)

5. 1966-1974 a dose of reality
    - Problems with computation
6. 1969-1979 Knowledge-based systems
    - Weak vs. strong methods
    - Expert systems:
        i. Dendral:Inferring molecular structures
        ii. Mycin: diagnosing blood infections
        iii. Prospector: recomending exploratory drilling (Duda).
    - Roger Shank: no syntax only semantics
7. 1980-1988: AI becomes an industry
    - R1: Mcdermott, 1982, order configurations of computer systems
    - 1981: Fifth generation
8. 1986-present: return to neural networks
9. Recent event:

AI becomes a science: HMMs, planning, belief network

Brain vs. Computer

- In AI, we compare the brain (or the mind) and the computer
- Our hope: the brain is a *form* of computer
- Our goal: we can *create* computer intelligence through programming just as people become intelligent by learning
- But we see that the computer is not like the brain
- The computer performs tasks without understanding what its doing
- Does the brain understand what its doing when it solves problems?

So what does AI Do?

- Most AI research has fallen into one of two categories

1. Select a specific problem to solve
    - Study the problem (perhaps how humans solve it)
    - Produce the proper representation for any knowledge needed to solve the problem
    - Acquire and codify that knowledge
    - Build a problem-solving system
2. Select a category of problem or cognitive activity (e.g., learning, natural language understanding)
    - Theorize a way to solve the given problem
    - Build systems based on the model behind your theory as experiments
    - Modify as needed

Both approaches require

- One or more representational forms for the knowledge
- Some way to select proper knowledge.

Field of Agriculture

- Sector status in India

▫ Growth of socio-economic sector in India

▫ Means of living for almost 66% of the employed class in India

▫ Acquired 18% of India's GDP

▫ Occupied almost 43% of India's geographical area

- Huge investment made for Irrigation facilities etc. in 11^{th} five year plan
- **Introduction of de-regulation in agriculture sector**

▫ Opens competition for agriculture products

▫ Removal of unnecessary restrictions — movement, stocking, and so on

▫ Good price to farmer

▫ Substantial technology growth in coming years

Identified Areas for enhancing Agriculture sector

• **Needs monitoring on**

▫ Agricultural crop conditions

▫ Weather and climate

▫ Ecosystems

• **Decision support for agricultural planning and policy-making**

• **On the basis of AI interest**

▫ Computational Intelligence in Agriculture and the Environment

• Optimizing different types of bio-systems

• Testing and fitting of quantitative models

▫ Intelligent environment control for plant production systems

▫ Intelligent robots in agriculture

▫ An expert geographical information system for land evaluation

▫ Artificial neural network for plant classification using image processing.

▫ Control of green house.

ICAR-National Research Centre for Grapes (ICAR-NRCG), Pune &
National Institute of Agricultural Extension Management (MANAGE), Hyderabad
(Autonomous Organizations under the
Ministry of Agriculture and Farmers Welfare, Govt. of India)