

Rain Deficit Moisture Stress Management in Horticulture crops

Aberrant monsoon may lead to moisture deficit which may affect the horticultural crops also in few states. As a step towards preparedness, advisory plan for horticultural crops have been developed in three parts containing general and crop specific recommendations to be adopted by the growers.

Part A: General recommendations

1. Selection of suitable crops and varieties:

In vegetable crops like dolichos bean, cowpea, cluster bean, lima bean, chilli, drumstick, brinjal, okra are suitable for rain-fed cultivation. Among these, legume vegetables can be recommended for contingency crop-planning in an eventuality of late monsoon rains. Varieties having good root system and capacity to recoup after the alleviation of stress need to be selected. Depending upon situation, it is recommended to use short duration varieties.

2. Improved method of seedling production:

Improved method of seedling production such as Protray grown seedling using coco peat, nylon net protection and bio-fertilizers/bio-pesticide inoculation at nursery stage has good potential for obtaining sturdy, uniform and healthy seedlings. These seedlings when transplanted in the main-field will establish better with less root damage and fare better in overcoming biotic and abiotic stresses particularly during water stress conditions.

3. Adoption of soil and moisture conservation techniques:

Contour cultivation, contour trip cropping, mixed Cropping, tillage, mulching, zero tillage, are some of the agronomical measures for the *in-situ* soil moisture conservation. Mechanical measures like contour bunding, graded bunding, bench terracing, vertical mulching etc. also need to be followed for effective soil and moisture conservation in dry lands. Another technology for efficient utilization of runoff is water harvesting recycling. Rainwater harvesting includes collecting runoff water into dug out ponds or tanks in small depressions, gullies and into storage dams of earth or masonry structures. Rain water harvesting is possible in areas having rainfall as little as 500 to 800 mm. Depending on the rainfall and soil characteristics, 10-50 % of the runoff can be collected in farm pond. Surface run off thus collected in a farm pond can be used to provide protective irrigation in the period of prolonged dry spell or through microirrigation techniques.

4. Enhancing soil organic matter content:

Constant efforts must be made to improve the soil organic carbon. Incorporation of crop residues and farm yard manure to soil improves the organic matter status, improves soil structure and soil moisture storage capacity. Organic matter content of the soil can also be improved by fallowing alley cropping, green manuring, crop rotation and agro forestry. Vegetable being short duration crop and having faster growth phases, the available organic matter needs to be properly composted. Vermi composting can be followed for quicker usage of available organic matter in the soil and improving the soil moisture holding capacity.

5. Application of foliar nutrition:

The foliar application of nutrients during water stress conditions helps in the better growth by quick absorption of nutrients. The spraying of K and Ca induces drought tolerance in vegetable crops. Spraying of micronutrients and secondary nutrients improves crop yields and quality.

6. Use of drip irrigation:

Drip irrigation has proved its superiority over other conventional method of irrigation, in horticulture due to precise and direct application of water in root zone. A considerable saving in water, increased growth, development and yields of fruits and vegetables and control of weeds, saving in labour under drip irrigation are the added advantages. Drip irrigation can be adopted in fruit crops and also to all vegetable crops including closed spaced crops like onions and beans. The saving in water is to the tune of 30-50 % depending on the crop and season. Generally inline drip laterals having emitting point spaced at 30cm distance and emitting at the rate of 2LPH is selected for vegetable crops. In crops like chilli, brinjal, cauliflower and okra paired row planting is practiced and one drip lateral is used for two crop rows.

7. Use of micro sprinkler irrigation:

Depending upon situation and availability of water, this technology can be used for fruits and vegetable crops. The cost of initial establishment is lower compared to drip system. Further in summer the sprinkling of water helps in reducing the microclimate temperature and increasing the humidity, thereby improving the growth and yield of the crop. The water saved is to the tune of 20 to 30 per cent.

8. Moisture saving methods under limited water resource conditions:

The following methods may be adopted under limited water conditions to save water:

- a) **Water saving irrigation method:** Under limited water situations, water-saving irrigation methods like alternate furrow irrigation or widely spaced furrow irrigation and drip irrigation systems can be adopted. Studies conducted on methods of irrigation in capsicum, tomato, okra and cauliflower indicated that adopting alternate-furrow irrigation and widely-spaced furrow irrigation saved 35 to 40 per cent of irrigation water without adversely affecting yield.
- b) **Mulching Practices in Vegetable Production** - The technique of covering the soil with natural crop residues or plastic films for soil and water conservation is called mulching. Mulching can be practiced in fruits and vegetable crops using crop residues and other organic material available in the farm. Recently plastic mulches have come into use due to the inherent advantages of efficient moisture conservation, weed suppression and maintenance of soil structure. Wide variety of vegetables can be successfully grown using mulches. In addition to soil and water conservation, improved yield and quality, suppression of weed growth, mulches can improve the use efficiency of applied fertilizer nutrients and also use of reflective mulches are likely to minimize the incidence of virus diseases. For vegetable production generally polyethylene mulch film of 30micron thick and 1 to 1.2 m width is used. Generally raised bed with drip irrigation system is followed while laying the mulch film.

9. Wind breaks, hedges and intercropping:

To overcome the adverse effect of high temperature and dry winds, tall growing trees need to be planted all along the boundary of the farm. Inter cropping of vegetable crops of the area can be practiced in orchards during summer months. Maize/ Sorghum can be grown all along the border of the plot to mitigate the effect of desiccating winds.

10. Use of protected cultivation of vegetables:

In peri-urban regions where climate does not favour year round production of crops in the open field, vegetable production can be taken up in protected environment. Protective structure is a facility to protect crop from biotic and abiotic constraints. Structures for protected cultivation include green houses, plastic/net houses and "tunnels". Commonly used protected structures are polyhouses and net or shade houses. Rain-shelter is a simple structure covered with polyethylene sheet which helps in producing the crops which are affected by excessive rainfall. The productivity of tomato, onions and melons are adversely affected in the event of high rainfall due to difficulty in managing the foliar diseases, lack of proper soil aeration and drainage and also depending on the nature of crop physical damage of the foliage and flower drop. Net house cultivation and shade net cultivation provide better microclimate especially during summer in minimizing the high temperature effect and improving the relative

humidity. The productivity of tomato, French bean and capsicum can be improved during high temperature period by using net/shade net on the top.

11. **Control of leaf miner and mite during high temperature stress.**

For management of leaf miner spray neem soap 4 grams / liter or triazophos at the rate 1.5 ml / l. To manage mites spray Abanectin 0.5 ml/l. Aphids may be observed in case of beans. Spray neem soap (1.0 %) or neem seed kernel extract (4.00 %).

Do's and Don'ts for Vegetable crops:

1. Establishing vegetation-free strips under the trees and between tree rows before growth begins.
2. In crop like Onion, drum seeder may be used for direct sowing.
3. Postpone transplanting of seedlings in the main field and also fertilizer application till the favorable soil moisture is prevailed.
4. Once the soil moisture condition becomes favorable transplanting of the seedlings may be taken up.
5. Resorting to foliar application of (water soluble) major nutrients.
6. Protection of young plants with partial shade.
7. In the inter spaces of crops weeding and inter-culture practices may be followed.
8. Thinning may be taken up to reduce the plant population.
9. Alternate furrow Irrigation may be taken up based on the availability of water.
10. Drip Irrigation may be followed. Pitcher irrigation wherever drip is unavailable for protective maintenance.
11. Plastic mulching and drip irrigation may be followed for better soil and moisture conservation and weed control.
12. Adopting the conjunctive use of surface and ground water as well as the use of non-conventional sources such as brackish water,
13. Waste water should not be utilized without pre treatment & safe reuse may be ensured.
14. Minimise use of those fertilizers which promote vegetative growth like nitrogen, use K and B as foliar spray to maintain plant turgor.
15. Reducing water losses during conveyance and distribution,
16. Use of super absorbent polymers such as Luquasorb for water absorption and slow release.

Do's and Don'ts for fruit crops:

1. *In situ* soil moisture conservation by trenching, contour/ field bunding, Gully Plugging, Loose boulder check dams may be taken up.
2. Use locally available organic mulches to conserve moisture *in situ* in the basin. Adopt to drip/ trickle irrigation for judicious use of water. *In situ* grafting on drought

resistant root stocks for better establishment of saplings. Practicing conservation horticulture such as inter crops and soil moisture conservation.

3. Avoid soil application of fertilizers till sufficient soil moisture is available.
4. Adopting to foliar nutrition of major nutrients under water stress conditions to enhance the nutrient uptake and use efficiency.
5. Provide protective irrigation through pitcher and protective shade to young plants to reduce the high evaporative demand.
6. In addition to drip irrigation and mulching for production of fruit crops under water limiting conditions, novel irrigation methods, like partial root zone drying (PRD), could be adapted in grapes, mango and citrus. The partial root zone drying method helps in development of a deeper root system.
7. For all fruit crops, basin mulching with locally available plant material and plastic mulch may be taken up.
8. Try to compost all the available plant waste materials and use it as organic manure to fruit and vegetable crops.
9. For all the horticultural crops, drip Irrigation may be followed. Pitcher irrigation wherever drip is unavailable, is suitable for protective maintenance.

PART B: CROP SPECIFIC RECOMMENDATIONS FOR PERENNIAL CROPS

FRUIT CROPS:

MANGO:

- i. During establishment stage of mango in the field, sub-soil irrigation through pitcher buried 10 cm from the plant, 1 foot below ground level, covered by a plastic plate and fed through a 3 cm diameter pipe with 1.25 liters of water applied/plant/day and mulched with sugarcane thrash mulch (1.0 kg/basin) results in better establishment.
- ii. Black polyethylene film (100 micro thick) helps in conservation of moisture and increase in root growth, flowering, fruiting and minimum fruit drop with enhancement in yield.
- iii. Rain water harvesting through opening of circular trenches around trees at a distance of 6 feet and width at 9 inches, as well as depth and mulching the trenches with dry mango leaves, helps in retaining sufficient moisture in the soil during flowering and fruiting and increase in yield.
- iv. Drip irrigation along with crop residue mulch helps in water saving. Drip irrigation with 0.6 volumes of water and plastic mulch significantly increases the yield. The water stress immediately after fruit set increases fruit drop in mango. Hence, protective irrigation is essential during the fruit development period.
- v. Due to high temperature stress in many areas leaf fall is observed. To overcome the leaf fall and to enhance the turgidity spray 0.2 % cent Potassium Sulphate.

Monsoon is delayed by 15 days : No adverse impact as fruits are already matured in early and mid season varieties ; fruit size and quality will be affected in late maturing varieties viz., Chausa, Mallika and Amrapali. But irrigation and mulching is required to be followed.

Monsoon is delayed by 30 days : No adverse impact as fruits are already matured in early and mid season varieties ; incidence of shoulder browning (fruit blemishes , tear stain) and post-harvest diseases will be minimum ; fruit quality will be good; fruit size and quality will be affected in late maturing varieties like, Chausa , Mallika and Amrapali etc., ; impact severity will increase. Further increased temperature, relative humidity during July-September will lead to telescoped harvests, market gluts , increased incidence of jelly seed formation (internal breakdown of pulp matrix) following rainfall. irrigation and mulching

Rainfall deficit at vegetative phase : Impacts adversely the production of vegetative shoots (potential fruiting wood of the ensuing season). But irrigation and mulching is required to be followed.

Rainfall deficit at reproductive stage: Favourable during fruit bud differentiation (FBD) stage. But irrigation and mulching is required to be followed.

Terminal drought : Crop prospects of ensuing season will be affected especially in light soils ; recurrent droughts lead to crop failure. But irrigation and mulching is required to be followed.

BANANA:

- i. The soil moisture deficit stress in banana during vegetative stage causes poor bunch formation, lower number and small sized fingers. The water stress during flowering causes poor filling of fingers and unmarketable bunches and reduced bunch weight and other growth parameters.
- ii. Providing irrigation through drip helps in reducing the adverse effects of water stress.
- iii. Plant Protection Measures - High temperatures along with low humidity are congenial for flare up of sucking pests like thrips and mites in fruit crops viz., mango, grapes, and pomegranate. Proper monitoring and timely spraying of recommend pesticides will bring down the severity of incidence. For thrips, insecticides like thiamethoxam 25WG@ 0.25 g/L or Acephate 75SP @1.5 g/l or spinosad 45 % SC @ 0.5 ml/l will bring down the thrips infestation. For mite management, dicofol 18.5 EC @ 2.5 ml/l or fenpyroximate 5SC @ 0.5 ml/l.

If monsoon is delayed by 15 days / 30 days :

- i. In most of the banana growing areas, usually planting of suckers / tissue culture plants should be taken up after the on-set of monsoon.
- ii. Since banana crop is not monsoon dependent, planting can be done according to the on-set of monsoon.

Rain deficit at vegetative and reproductive phase:

- i. In the scenario of rain fall deficit during the vegetative stage, farmers are advised to go for drip irrigation to conserve the water and also to provide the required water at root-zone to increase the water use efficiency
- ii. As a mitigation measure, 0.1mM salicylic acid (140 mg/litre of water with surfactant) foliar spray can be given to the plant @ 250 ml/plant
- iii. Foliar application of Kaolinite (5%) during vegetative state reduces the transpiration water loss.
- iv. Foliar fertilization with five sprays of 3% Polyfeed (19:19:19), i.e., 30g litre-1 of water along with surfactant at 15 days interval during vegetative stage is recommended.
- v. Mulching of the soil surface either with black polythene or with plant material / leaves of banana etc. can be spread around the basin to reduce the water loss.
- vi. Growing green manure crops around the plant and mulching is recommended.
- vii. Application of 5kg Rice husk ash or composted coir pith in the pit at the time of planting is recommended to increase the water holding capacity in the rhizosphere.
- viii. Instead of open irrigation, sub-surface irrigation is recommended.

Terminal drought: In the case of terminal drought, growing of banana with sub-surface irrigation, plastic mulching, mitigation with salicylic acid, foliar spray of water soluble fertilizer and leaves retaining with 5-6 leaves is recommended to help in overcome the drought situation.

POMEGRANATE:

If monsoon is delayed by 15 or 30 days and rain deficit at vegetative phase:

- Crop residue recycling to build organic carbon reserves to improve soil health and water holding capacity to cope with dry spells
- In-situ moisture conservation using organic or inorganic mulches should be practiced with immediate effect. Locally available organic plant wastes or plastic mulches (white/black/ pervious mulches)
- Avoid applying fertilizer till sufficient soil moisture is available or fertigation may be adopted for efficient use of limited available/harvested rainwater.
- Reduce intercultural operations to minimize the loss of moisture

- Removing suckers and water sprouts
- Conserve the stored water in ponds and earmarking for use of life saving irrigation in critical stages of the crops.
- Make raised ridges along the rows around the plants.
- Apply Hydrogel in the root zone of the plant below drippers. Mix 500g hydrogel in 5 Kg fine sand/soil; apply 20 g of this mixture/tree
- Take sprays of abamectin 1.95 EC @0.5ml/l if mite infestation is seen due dry conditions.

Rain deficit at reproductive phase

- Spray Gibberelic acid (GA) 10mg/l+ 0.5ml/l spreader sticker at full bloom
- Spray boric acid 2g/l + 0.5ml/l spreader sticker within 20 days of fruit set in the evening. Repeat after 1 month
- Next day spray N-(2-chloro-4-pyridinyl) phenyl urea(CPPU) [*common name for chlorfenuron*] @5ml/l +0.5ml/l

Terminal drought

In addition to the measures mentioned above the number of fruits should be reduced depending on assured water available with the farmer. Sprays of 2,4-Dichlorophenoxy acetic acid (2,4-D) 10mg/l in plants below 4 years repeat after 10 days if required may be taken in case of fruit dropping. In plants above 4 years 1 spray of 20mg/l may be sprayed.

GUAVA

Monsoon is delayed by 15 days : Early winter crop will be affected, therefore, supplementary irrigation and mulching should be done.

Monsoon is delayed by 30 days : Rainy season crop will be affected (reduced fruit size and quality); prospects of winter crop gets affected/delayed winter crop but crop size and quality may improve. Supplementary irrigation and mulching be provided.

Rainfall deficit at vegetative phase : Delayed winter crop. Supplementary irrigation and mulching be provided.

Rainfall deficit at reproductive stage : Rainy season crop will be affected; Delayed winter crop. Supplementary irrigation and mulching be provided

Excess rainfall leading to flooding : No adverse effects; incidence of diseases and pests may increase. Management of pests and diseases is important.

Terminal drought : Total crop output will be affected. Irrigation and mulching should be provided.

AONLA

Monsoon is delayed by 15 days : Fruit size and development gets affected. Supplementary irrigation and mulching be provided.

Monsoon is delayed by 30 days: Fruit size and development gets affected. Fruit drop may occur. Supplementary irrigation and mulching be provided.

Rainfall deficit at vegetative phase : Gets affected. Supplementary irrigation and mulching be provided.

Rainfall deficit at reproductive stage : Not applicable as it occurs during March-April

Excess rainfall leading to flooding : Excess vegetative growth resulting in reduced reproductive growth ; prolonged flooding situation may result in death of plants; incidence of thrips and rust increases. Improving drainage; pests and diseases management is important.

Terminal drought : Reduced yield arising from fruit drop, low fruit size. Irrigation and mulching should be provided.

INTERCROPS

Monsoon is delayed by 15 days : Sowing of *kharif* crops will be delayed. Irrigation and mulching should be provided.

Monsoon is delayed by 30 days and at vegetative phase : Already sown rhizomatous (turmeric, ginger), tuber (*Amorphophallus*), get affected. Supplementary irrigation and mulching be provided.

Terminal drought : Adversely affected

LITCHI:

- Litchi being an evergreen plant, the maintenance of optimum soil moisture is critical for growth, development and fruit production.
- It is adapted to warm subtropics, cropping best in region with brief dry frost free winters and long, hot summers with high rainfall and humidity.
- If rainfall is evenly distributed, litchi is grown successfully and supplementary water requirement depends upon cultivar and evaporation demand.
- To achieve faster growth of the plant, no water stress should be permitted, while in the reproductive phase water stress is beneficial at the time of panicle emergence, flowering and fruit bud differentiation (February-March).
- Light irrigation but at frequent short intervals during summer months and cleaning of the basin is advocated (April-May).
- Certain physiological disorders like poor sex ratio, poor fruit set, heavy fruit drop and high fruit cracking and sunburn of the fruit are more intense under water deficit in the rhizosphere and can be minimized with proper water management (March-May).
- Early flushing, proper vegetative growth and shoot development are very much influenced by the timely onset of monsoon, without any additional irrigation (June-September).
- Intercultural operations, pruning and training operation and summer ploughing is followed just after harvesting of the fruits, dependent on cultivars (June-July).
- Arrival of monsoon brings, great change in weather conditions, immediately the atmosphere becomes saturated with moisture and relative humidity goes high (>90 %). It also marks disappearance of dry heat, scorching loo, winds and appearance of wet and cold air, thunderstorms, cumulus clouds having overhead, which give a good boost to vegetative growth of litchi.

- The phase change i.e. vegetative to reproductive stage require induction of cool/low temperature with mild stress condition with restricted or no supplemental irrigation.
- Fruit development, fruit yield and quality require regular monitoring of nutrients and moisture with good management practices during pre-monsoon period for economically viable harvest.

If monsoon is delayed by 15 days :

- New litchi fruit plantations, under area expansion programme, which is generally associated with onset of monsoon, will be delayed.
- Cost of handling and maintenance of planting material will increase.
- In case of early varieties (cvs. Shahi, Rose Scented) cost of two irrigations will increase while in case of late varieties (cvs. China, Late Bedana) cost of at least one number of irrigation will increase.
- The adult plant of litchi (>10 years), which is supposed to be drought tolerant and can survive 4-12 weeks without water will start developing its adaptive abiotic stress tolerance mechanism like shading of leaves, delay in flushing, curving/dropping/bending of leaflets and will force the plant to go in resting phase with restricted overall vegetative growth and vigour.
- Overall, the exhausted commercial bearing litchi plants/trees need immediate application of nutrition and irrigation, just after the harvesting of fruits, will be less effective under the conditions of delayed monsoon.
- The required pruning and training operations followed just after the harvest of fruits, which cause decrease in the canopy density, needs immediate application of manures and fertilizers for early emergence of new flushes will be affected and influence the next season fruiting due to non or late emergence of current season shoots.
- In case of delayed monsoon, atmospheric humidity remains very low consequently, evapo-transpiration rises considerably during this period (June), the root activity and nutrient use efficiency are badly affected, ultimately affecting the overall vegetative growth and vigour of plant, may lead towards declining phase and revival will take time during that annual cycle.

If monsoon is delayed by 30 days :

- Area expansion programme by new litchi fruit plantations which is generally associated with onset of monsoon, will be delayed.
- Cost of handling and maintenance of planting material will increase.
- In case of early varieties cost of four numbers of irrigation will increase while in case of late cost of two numbers of irrigation will increase to maintain the annual growth and reproductive cycle of the fruiting trees.
- Delay in the emergence of early flushing will influence the vegetative growth, shoot maturity, flowering and fruiting of the coming season.
- Shoot growth and vegetative growth will be slow.
- Drying of newly emerged flushes and shoot tip burning may occur.
- The adult plants/trees of litchi (>10 years) will start developing stress tolerant mechanism to be in resting phase to overcome the stress condition created due to delayed monsoon and ultimately affecting the due vegetative growth of the season.

- Litchi has low ability to transport water from root to leaves and in case of delayed monsoon and lack of moisture in the root zone may seize many physiological and metabolic processes of the plant body. As wet soil alone with applied irrigation cannot prevent the development of tree water stress.

Rain deficit at vegetative phase :

- Establishment of new plantations will be a difficult feature.
- During critical crop growth stages, too many days without rain can adversely affect the proper vegetative growth, may lead to crop failure during the coming season.
- Shoot growth and canopy spread will be slow.
- Litchi trees may undergo the process to develop stress tolerant adaptive mechanism to remain in resting phase rather than to go for normal vegetative growth during the season and will affect the health and fruit production of the crop.
- As mentioned above, that litchi has low ability to transport water from root to leaves, the proper management practices (application of organic manures, use of mulching) with supplementary irrigation through efficient and effective methods may reduce the ill effect of the situation created due to deficit rainfall.
- The important factor i.e., a high rate of relative humidity (RH), which favours fast vegetative growth, is lacking in the situation of deficit rain during the vegetative phase, always an important factor can be managed by providing an adequate supply of water through irrigation.
- On the whole, litchi appears to suffer moisture stress on hot, dry, windy days of low RH, require timely implementation technologies with proper management practices.

Rain deficit at reproductive stage :

- The phase change i.e. vegetative to reproductive stage is very crucial for litchi fruit production, which require induction of cool/low temperature in conjunction with the conditions of low moisture in the rhizosphere as well as low humidity in the atmosphere, hence deficit rain with no supplemental irrigation creating mild stress condition is beneficial for better transformation into reproductive stage in litchi cultivation.
- The mature shoots developed from the early appeared flushes only undergo in resting phase and bring floriferous condition with created mild stress condition during winter season.
- Practices of withholding irrigation two months prior to the expected time of panicle emergence, no intercultural operation, no pruning and training operation, mulching beneath the canopy spread area etc. is recommended and had proved beneficial during this initiation (period) of reproductive stage.

Terminal drought :

- Drought is a major abiotic factor, which excessively limits growth and vigour of the litchi plants/trees in general and limits fruit production.

- In case of litchi production system in India the critical period for irrigation is from the end of March to the onset of monsoon i.e. June as that is the time when fruit development and vegetative growth occur, drought condition may be managed through proper irrigation management through various improved systems of irrigation.
- One of the major consequences of drought condition is inhibition of metabolic functions, reduced rate of photosynthesis and reduced root activity in rhizosphere. Consequently, nutrient use efficiency is decreased, resulting decline in quantum of fruit production and quality of fruits.
- From March onwards, when temperature starts rising in the places and the atmospheric humidity remains very low consequently, evapo-transpiration rises considerably during this period and if the litchi orchard is not frequently irrigated during this period, there may be occurrence of many physiological disorders (fruit cracking, sunburn and fruit drop).
- As mentioned that litchi has low ability to transport water from root to leaves, hence, to overcome the drought condition, proper watering of the orchard to the level till it regains capacity to effectively run the metabolic processes with reduced cell turgor (as visible from leaflets vigour), management practices (application of organic manures, use of mulching), proper pruning and training operation to keep the reduced height of the trees and spreading canopy along with supplementary nutrition and irrigation through improved and efficient methods, may reduce the ill effect of the situation created due to drought.

PLANTATION CROPS:

OIL PALM:

Oil Palm is a perennial crop and is mostly grown under irrigated conditions except Kerala and Mizoram. As the growth of oil palm is indeterminate in nature, the vegetative and reproductive stages are continuous and cannot be separated.

If monsoon is delayed by 15/30 days – In oil palm plantations, soil moisture can be conserved by mulching with leaves cut while harvesting fresh fruit bunches, male inflorescences and empty fruit bunches providing windbreaks, application of anti-transpirants/growth regulating chemicals and by removal of young inflorescences. In hilly terrains, mulching, formation of half moon terraces bench terraces, contour bunding and planting on the contour line, use of drip irrigation system and construction of water storage tank for irrigation could be followed for soil and water management.

Rain deficit at vegetative, reproductive and terminal drought – The quantity of water given to oil palm throughout the year by drip/micro-jet irrigation is strictly based on recommended schedule. The data relating to pan evaporation or Penman's estimate of evaporation for a particular place is multiplied by a crop factor of 0.7 is taken into consideration for arriving at the correct irrigation schedule. In general, the water requirement of oil palm is scheduled viz., June – Sept.:100-150 litres/palm/day; Oct. – Feb.:160-170 l/palm/day; Mar. – April: 215-265 l/palm/day; May – June: 350 l/palm/day.

COCONUT, COCOA AND ARECANUT
If monsoon is delayed by 15 days

Crop	Contingency measures
Coconut	<p>To avoiding nut dropping, irrigation needs to be continued.</p> <p>Prophylatic bud rot treatment by crown application of Bordeaux mixture 1.0% or Mancozeb 75 wp 5g/300 ml or phosphorus acid (Akomin) solution (0.5%) @ 300 ml/palm at bimonthly interval (First application may be completed before 15th June).</p> <p>Removal of the stem bleeding affected portion & swabbing the wound with fungicide Hexaconazole 5EC (5.0 % solution) or application of a paste of talc formulation of <i>Trichoderma</i> on the affected area.</p> <p>Adopt proper recommended prophylactic management measures for rhinoceros beetle and red palm weevil.</p>
Arecanut	<p>To avoiding nut dropping, scorching and necrosis, irrigation need to be continued.</p> <p>Prophylatic bud rot/ fruit rot treatment by crown application of Bordeaux mixture 1.0% or phosphorus acid (Akomin) solution (0.5%) @ 300 ml/palm at bimonthly interval (First application may be completed before 15th June).</p>
Cocoa	<p><u>To control of tea mosquito bug in the event of infestation:</u> Spray any one of following insecticide lambda cyhalothrin (0.003%) 5 EC 0.6 ml/ L or Imidacloprid 17.8 SC 0.25ml/ L. Repeat the spray 15 to 20 days after first spray if the infestation persist.</p> <p><u>To control mealy bug:</u> Spray fenthion (0.04%) 80 EC 0.5 ml/ lit or dimethoate (0.06%) 30 EC 2 ml/lit. If reoccurrence of the pest is noticed, give second spray after an interval of 30 days.</p>

2. If monsoon is delayed by 30 days

Crop	Contingency measures
Coconut	<p>Irrigation need to be continued to avoid nut dropping leading to reduction in yield.</p> <p>Prophylatic bud rot treatment by crown application of Bordeaux mixture 1.0% or Mancozeb 75 wp 5g/300 ml or phosphorus acid (Akomin) solution (0.5%) @ 300 ml/palm at bimonthly interval (First application may be completed before 15th June).</p> <p>Removal of the stem bleeding affected portion & swabbing the wound with fungicide Hexaconazole 5EC (5.0 % solution) or application of a paste of talc formulation of <i>Trichoderma</i> on the affected area.</p>

	Gradient outbreaks of scale insects (<i>Aspidiotus destructor</i>) and slug caterpillars (<i>Macroplectra nararia</i> / <i>Conthyla rotunda</i>) and sporadic outbreaks of inflorescence caterpillar, <i>Batrachedra arenosella</i> may occur in endemic spots. Otherwise the aforesaid three pests are of minor pests infesting coconut.
Arecanut	<p>Inflorescence die back (The disease is already prevailing in most of the areca growing areas) Removal and destruction of diseased dried bunches as a phytosanitary measure to reduce the inoculum.</p> <p>Spraying with zineb or mancozeb (0.2 %) at the time of opening of female flowers and one more spray after 40-45 days.</p> <p>Severity Spindle bug (<i>Carvalhoia arecae</i>), red and white mite (<i>Raoiella indica</i> and <i>Oligonychus indicus</i>) and scale insect infestation may increase due to extended summer. To control spindle bug, spray spindle leaf and inner most leaves of palms in infested plantations with dimethoate (0.06%) 30 EC 2 ml/ lit of water. To control red and white mites, spray Kelthane 18 EC (0.036%) or dimethoate (0.06%) 30EC @ 2 ml/litre of water to the lower surface of leaves. Repeat spraying at an interval of 15 to 20 days if there is reoccurrence of pest.</p> <p>For scale insect: Spraying dimethoate (0.06%) 30EC 2ml/litre of water to the tender bunches was found to be effective in containing scale insects.</p>
Cocoa	Infestation of tea mosquito bug and mealy bug may flare up by delayed monsoon. Above mentioned control measures need to be adopted.

3. Rain deficit at vegetative phase

Crop	Contingency measures
Coconut	Life saving irrigation is needed for the pre-bearing coconut plants.
Arecanut	<p>To control basal stem rot, root feeding with 100 ml of Hexaconazole (5.0 % solution) at quarterly intervals and basin application of <i>Trichoderma</i> enriched neem cake @ 2 kg/palm (50g of <i>T. viride</i> talc formulation mixed with 2 kg neem cake at the time of application).</p> <p>Initial growth and establishment of arecanut seedlings will be affected due to incidence of red and white mites, scale insects. Recommended arecanut management measures mentioned above may be taken up.</p>
Cocoa	Control measures for tea mosquito bug need to be continued. Cherelle rot can be controlled by spray with Carbendazim (0.05 %), or mancozeb 0.2 %.

4. Rain deficit at reproductive stage

Crop	Contingency measures
Coconut	<p>Prevent nut dropping and abortion of flowers irrigation is needed at least once in 15 – 30 days depending on the soil type.</p> <p>Though raised as a rain fed crop, coconut is sensitive to moisture stress during reproductive phase which is a continuous process.</p> <p>Incidence of coconut eripophyid mite, <i>Aceria guerreronis</i> could escalate in the event of continuous drought.</p>
Arecanut	Incidence of scale insects may flare up in the event of continuous drought.
Cocoa	Cherelle rot can be controlled by spray with Carbendazim (0.05 %), or mancozeb 0.2 %. Infestation of tea mosquito bug and mealy bug on the pods may affect pod yield and quality. Above mentioned control measures need to be adopted.

5. Terminal drought

These crops cannot withstand drought for long as these are irrigated crops. Life saving irrigation is needed for survival of the plants.

Crop	Contingency measures
Coconut	<p>The following activities may be taken up as part of cultivation practices to prevent the effects of deficit rain/moisture or excess rainfall.</p> <p>Above mentioned diseases like basal stem rot, stem bleeding and leaf blight may become severe and kill the palms. Fungicidal application for individual diseases need to be taken up to save the palm.</p> <p>Drought conditions/low rainfall conditions</p> <ol style="list-style-type: none"> Mulching with coconut/arecanut leaves/coir pith Husk burial in interspaces – 1.5 m width and 1.0 m depth with 5-6 layers of husk Drip irrigation with fertigation Water harvesting structures recommended for the region
Arecanut and cocoa	<p>The following activities may be taken up as part of cultivation practices to prevent the effects of deficit rain/moisture or excess rainfall.</p> <p>Drought conditions/low rainfall conditions</p> <ol style="list-style-type: none"> Mulching Drip irrigation with fertigation

CASHEW:

Majority of the cashew plantations established in India are under rainfed condition and very few only are under irrigation. The cashew adapted well in west and east coast regions and subsequently spread to hilly and plain regions of Karnataka, Tamil Nadu, Gujarat, Chhattisgarh, and NEH States. The cashew is suitable to diverse climatic conditions and rainfall pattern ranging from scanty rainfall region (around 800 mm) to heavy rainfall region (around 4000 mm) thus showing its wide adaptability.

If monsoon is delayed by 15-30 days

The cashew is planted after onset of monsoon from June to September. If there is delay in onset of monsoon, planting should also be delayed coinciding with monsoon. In fact, fresh grafts when planted require sufficient soil moisture for initial establishment and hence cashew is planted during monsoon season. Whenever there is drought situation after planting they need protective irrigation. The irrigation through pitcher (hold pots) is recommended in dry land situations.

Rain deficit at vegetative phase

Established plants survive even in adverse soil moisture conditions. If the drought situation persists due to low rainfalls in the rainy season, there is every possibility of yield getting affected. Under such situation to reduce the yield loss, one or two protective irrigation may be given wherever irrigation facilities exist. However, mulching of basin by dry biomass is helpful in conserving soil moisture.

Rain deficit at reproductive phase

Due to the non-uniform distribution of rainfall over the years, cashew experiences severe moisture stress particularly during reproductive phase from December to May, which adversely affects its flowering and fruit set causing flower drying and immature nut drop. Under severe moisture stress situations drying of flowers, poor fruit set and nut development owing to field loss is observed. To overcome such problems, proper soil and water conservation measures like crescent bund, trenching, inward basin etc. coupled with coconut husk burial or mulching has been found useful.

Supplemental irrigation of 200 litres of water/plant once in 15 days during January to March from water collected in ponds through rain harvesting helps in flowering and nut development by improving the microclimate with increased humidity. It also leads to increased nut and kernel weight by reducing flower and nut drying to some extent.

Drip irrigation during fruit development stages wherever water is available may be helpful during the drought situation to rainfed cashew crop. Normally for west coast of Dakshina annada irrigation by drip at 30 litres/tree/day for mature cashew plantations (10 to 15 years) is recommended.

Terminal drought

The rainfall deficit at terminal phase or cessation of rains at early stage also adversely affects the cashew nut yield particularly in late maturing varieties. To maintain the proper soil moisture regime, the harvesting of rain water and recycling them during deficit period is suggested. Moreover, adoption of soil conservation measures and installation of drip wherever water source is available will be helpful.

PART C: CROP SPECIFIC RECOMMENDATIONS FOR VEGETABLE and SPICES CROPS

1. When the monsoon is delayed by 15 days

a) Vegetable varieties suitable for growing under such condition

Vegetable	Variety
Brinjal	Kashi Sandesh, Kashi Taru, Pusa Kranti, Pusa Anmol, Pb Sadabahar
Tomato	Kashi Vishesh, Kashi Anupam, Kashi Aman, Arka Rakshak, Arka Samrath
Chilli	Kashi Anmol, Arka Lohit, Kashi Early, IHR -Sel. 132
Drumstick	PKM-1, PKM-2, Kokan Ruchira
Cowpea	Kashi Kanchan, Kashi Shyamal, Kashi Gauri, Kashi Nidhi, Pusa Barsati, Pusa Rituraj
Bottle gourd (round)	Punjab Round, Pusa Sandesh, Narendra Shishir, Punjab Komal
Okra	Kashi Pragati, Kashi Vibhuti, Varsha Uphar, Hisar Unnat
Early cabbage	Pusa Ageti, Golen Ball, Rare Ball, Sri Ganesh Gole, Quisto, Kranti
Early cauliflower	Early Kunwari, Kashi Kunwari, Pusa Deepali, Arka Kranti, Pusa Early Synthetic, Pant Gobhi- 2
Spinach Beet	All Green, Pusa Palak, Pusa Jyoti, Pusa Harit, Arka Anupama
Radish	Kashi Sweta, Kashi Hans, Pusa Chetki, Pusa Desi, Punjab Ageti

Production strategies

- Grow short duration varieties as suggested in above table
- Raise crop on ridge-furrow or furrow irrigated raised bed planting system
- Two spraying of water soluble mixed fertilizers (19:19:19 NPK) @ 5-7 g/lit, 30 days after crop establishment ensure early and vigorous plant growth
- Ensure staking of crop wherever required.

Plant protection strategies

Recommended plant protection measures for control of pests & diseases may be followed.

2. When the monsoon is delayed by 30 days

Vegetable varieties suitable for growing under such condition

Vegetable	Variety
Cluster bean	Pusa Sadabahar, Pusa Mausami, Pusa Navbahar, Durga Bahar, Sharad Bahar, Durgapur Safed
Cowpea	Kashi Kanchan, Kashi Unnatil, Kashi Gauri, Pusa Barsati, Pusa Rituraj
Dolichos bean	Kashi Haritima, Pusa Early prolific, Pusa Sem-2, Pusa Sem-3, Rajni, Konkan Bhusan, Arka Jay, Arka Vijay,
Drumstick	PKM-1, PKM-2, Kokan Ruchira
Brinjal	Kashi Sandesh, Kashi Taru, Pusa Purple Long, Pusa Kranti, Pusa Anmol, Punjab Sadabahar, Arka Sheel, Arka Kusumakar, Arka Navneet, Arka Shirish
Amaranth	Chhoti Chaulai, Badi Chaulai, CO-1, CO-2, CO-3, Pusa Keerti, Pusa Kiran, Arka Suguna, Arka Arunima.

Production strategies

- Use of organic mulch such as paddy straw, dry grass, etc @ 7-10 tones/ha
- Use of organic manures (FYM 15 tones/ha or vermicompost 10 tones/ha) to enhance water holding capacity of soil
- Ensure life saving irrigation at least during critical growth stages such as active growth, flowering and fruit enlargement. If there is water shortage, alternate furrow irrigation should be practice
- Do not allow weeds to grow during plant's early growth stage
- Perform tillage operations only in upper 5cm soil layer.

Plant protection strategies

Sucking insect pest viz. jassids, whitefly, Aphids, thrips, mites, etc may be a major problem. In drought condition, chance of occurrence of diseases in vegetables is less (except viral diseases).

For management of sucking pests, the following strategies may be followed:

- Seed treatment with imidacloprid or Thiomethoxam @ 3-5gm/kg seed
- Foliar spray of imidacloprid 17.852 @ 0.55 ml/L, Thiomethoxam 25 wG @ 0.35g/L or Thiocloprid 21.7 SC @ 0.65ml/L.
- For mites - Abametin @ 0.5ml/L, Spiromesifer @1 ml/L, Chlorofenpyr @1ml/L, Poersite 2-3 ml/L or Fenzaquin @2 ml/L
- Botanical insecticides- Neem based insecticide @ 5 ml/L
- Bio-agents- *Verticellium lecani* -5 g/L.
- For Mealy bugs- Chlorpyriphos 20EC @ 2 ml/L or Imidacloprid @ 05 ml/L.
- For sporadic incidence of Lepidopteran pest (Caterpillar)-Indoxacorb 0.5 ml/L, Emamectin benzoate @ 0.35 gm/L or Flubendamide @ 0.5 ml/L.

Under erratic/ unpredictable/ inconsistent/ irregular rainfall

Production strategies

- Grow crop on ridge-furrow (25-30 cm high) or furrow irrigated raised bed (90 cm wide and 20 cm high) planting system to avoid water logging situation
- Grow vegetable crops and varieties that can sustained both under scanty and heavy rainfall condition as suggested in table above
- Train cucurbit vegetables over bower system
- Ensure life saving irrigation at least during critical growth stages such as active growth, flowering and fruit enlargement.
- Do not allow weeds to grow during plant's early growth stage.

ONION

In onion only *kharif* crop (20 % area) is rain-fed. *Rabi* onion, which is the main crop (60% area) and late *kharif* (20% area) are grown as irrigated crops. Thus, drought/rainfall deficit has relevance mainly to *kharif* crop. *Kharif* crop of onion is grown mainly in Maharashtra, Karnataka, Gujarat and some parts of Rajasthan.

If monsoon delayed by 15 days: This may not have much effect on the *kharif* onion as this crop can be transplanted from July to August. The nursery raising will be rather easier, as onion seedlings are difficult to be raised under rains. The following strategies are suggested in this situation.

1. Varieties having wider adaptability (suitable for *kharif* as well as late *kharif*) namely Bhima Super, Bhima Raj, Bhima Red, Bhima Shubra, Agrifound Dark Red, Arka Kalyan, Arka Pragati, Baswant 780 and Phule Samarth may be grown.
2. Nursery may be raised during second week of June in such a way that seedling of about 35-50 days could be transplanted.
3. Raise seedlings on a raised bed with drip or micro sprinkler irrigation system to use available irrigation water judiciously. In case, drip irrigation facility is not available, apply irrigation water through water sprinkler cans.
4. Minimum three to four irrigations need to be given in nursery.
5. Seedlings should be protected by providing partial shade nets.
6. Apply stubble mulch (paddy straw) until seed germination to avoid evaporation.
7. Apply well decomposed organic manures @ 0.5t / 1000 sq m.
8. In case of poor seedling growth, foliar application of water soluble NPK fertilizer (for example 5g/liter 19:19:19 NPK) may be given for quick recovery.

If monsoon delayed by 30 days

1. The strategies as listed above should be followed.
2. The other alternative can be to go for direct seeding of onion (Seed rate 8-9 kg/ha) on raised bed with drip or sprinkler irrigation system as this crop matures 1 month earlier than the seedling transplanted crop.
3. Use sets if available for raising *kharif* crop as this crop matures 45 days earlier than the seedling transplanted crop.

Rain deficit at vegetative phase

Three to four irrigations are essential during active vegetative growth stage depending upon soil type i. e. at establishment stage (10-20 DAT), active vegetative growth stage (30-40 DAT) and bulb initiation stage (40-50 DAT). To cope up with rain deficit at this stage the following advisory may work.

1. Raise crop on raised beds with drip irrigation.

2. Harvest rain water by making storage ponds which will help to provide two to three life saving irrigations during drought. Irrigation water should be applied as per soil moisture level and crop requirement only.
 3. Spray anti-transparent Kaolinite @ 5% to reduce water loss through transpiration as per requirement.
 4. Cover soil surface with organic mulch such as paddy/wheat straw, or fodder to reduce evaporation.
 5. In case of poor crop growth, foliar application of water soluble NPK fertilizer (for example 5g/liter 19:19:19 NPK) may be given for quick recovery.
 6. Foliar application of sulphur 85% WP @ 1.5-2.0 g/liter for quick recovery during active vegetative growth stage.
 7. Foliar application of micronutrient mixture containing Zn, Mn, Fe, Cu, B at 30, 45 and 60 DAT for better crop stand (5 ml/liter).
 8. Well decomposed organic manures equivalent to 20 t FYM/ha may be applied 15-30 days before transplanting.
 9. During dry spell, thrips population may increase above economic threshold level (30 thrips/plant), in that case spray Profenophos 1ml/L or Carbosulfan 2ml/L or Fipronil @ 1.5ml/l for effective management.
- **Rain Deficit at reproductive stage:** Reproductive phase in onion does not occur during *kharif* season.
 - **Terminal drought :** One irrigation is sufficient at 85 days after transplanting. That may be provided by drip irrigation using harvested rain water.

Note: The above strategies can also be followed for late *kharif* and *rabi* crops in case of deficiency of irrigation water.

SPICES CROPS:

	BLACK PEPPER
Late onset of monsoon by 15 days	<p>Established plantations</p> <ul style="list-style-type: none"> ○ Mulch the basins & interspaces with green leaves. ○ Spray lime 1% or kaolinite on foliage to reduce transpiration as well as heat load. ○ Postpone new planting/gap filling ○ Irrigate the crop @ 8-10 litres/day/vine (drip irrigation) or 50 litres/week/vine (hose irrigation) ○ To prevent termite attack on live supports, drench the soil with chlorpyriphos 0.075% and spray on support up to 1 m height; repeat spray after 21 days if necessary
	<p>Very young plantations</p> <ul style="list-style-type: none"> ○ Mulch the basins & interspaces with green leaves/coir pith compost. ○ Protect young vines by providing sufficient shade.

	<ul style="list-style-type: none"> ○ Irrigate the crop @ 5–8 litres/day/vine (drip irrigation) or 25 litres/week/vine (hose irrigation)
Late onset of monsoon by 30 days	<p>Established plantations</p> <ul style="list-style-type: none"> ○ Mulch the basins & interspaces with green leaves. ○ Spray lime 1% or kaolinite on foliage to reduce transpiration as well as heat load. ○ Postpone new planting/gap filling ○ Irrigate the crop @ 8–10 litres/day/vine (drip irrigation) or 50 litres/week/vine (hose irrigation) ○ To prevent termite attack on live supports, drench the soil with chlorpyrifos 0.075% and spray on support up to 1 m height; repeat spray after 21 days if necessary <p>Very young plantations</p> <ul style="list-style-type: none"> ○ Mulch the basins & interspaces with green leaves/coir pith compost. ○ Protect young vines by providing sufficient shade. ○ Irrigate the crop @ 5–8 litres/day/vine (drip irrigation) or 25 litres/week/vine (hose irrigation)
Drought during vegetative / reproductive stage	<ul style="list-style-type: none"> ○ Provide hose irrigation @ 35-40 litres/vine/week or 8–10 litres /vine/day (drip irrigation) till monsoon is resumed. ○ Apply organic manures like FYM @ 10 kg/vine and mulch the basin with green leaves (10 kg/vine)/coir pith compost (2 kg/vine) ○ Postpone new planting/gap filling ○ To prevent termite attack on live supports, drench the soil with chlorpyrifos 0.075% and spray on support up to 1 m height; repeat spray after 21 days if necessary
Terminal drought	<ul style="list-style-type: none"> ○ Mulch the basins & interspaces with green leaves/coir pith compost. ○ Protect young vines by providing sufficient shade. ○ Irrigate the crop @ 5–8 litres/day/vine ○ To prevent termite attack on live supports, drench the soil with chlorpyrifos 0.075% and spray on support up to 1 m height; repeat spray after 21 days if necessary

SITUATION	CARDAMOM
Late onset of monsoon by 15 days	<ul style="list-style-type: none"> ● Slash the weeds and apply as mulch ● Avoid new planting till monsoon sets in ● Provide drip @ 8 litres/clump/day (once in 10-12 days) or sprinkler irrigation (4 hours per day equivalent to 25 mm of rain) ● Provide adequate shade for young plants
Late onset of monsoon by 30 days	<ul style="list-style-type: none"> ● Slash the weeds and apply as mulch ● Avoid new planting till monsoon sets in ● Provide drip @ 8 litres/clump/day (once in 10-12 days) or sprinkler irrigation (4 hours per day equivalent to 25 mm of rain) ● Provide adequate shade for young plants
Drought during	<ul style="list-style-type: none"> ● Provide drip irrigation @ 8 litres/clump/day (once in 10-12 days) or sprinkler irrigation (4 hours per day equivalent to 25 mm of rain)

vegetative / reproductive stage*	<ul style="list-style-type: none"> • Apply green mulch • Provide adequate shade for young plants • Remove old and unproductive suckers
Terminal drought	<ul style="list-style-type: none"> • Provide drip irrigation @ 8 litres/clump/day (once in 10-12 days) or sprinkler irrigation (4 hours per day equivalent to 25 mm of rain) • Apply green mulch • Provide adequate shade for young plants • Remove old and unproductive suckers
*Cardamom is a perennial crop, and vegetative and reproductive phases occur simultaneously	
SITUATION	GINGER & TURMERIC
Late onset of monsoon by 15 days	<ul style="list-style-type: none"> • Provide thick mulch cover with green leaves/coir pith compost. • Growing suitable intercrops for shade
Late onset of monsoon by 30 days	<ul style="list-style-type: none"> • Cultivate short duration varieties • Growing suitable intercrops for shade
Drought during vegetative stage	<ul style="list-style-type: none"> • Irrigate the crop weekly once equivalent to 5 – 10 mm of rain • Apply green leaf/coir pith compost mulch
Drought during rhizome formation	<ul style="list-style-type: none"> • Irrigate the crop weekly once equivalent to 5 – 10 mm of rain • Apply green leaf/coir pith compost mulch • Ginger can be harvested and used for vegetable purpose
Terminal drought	<ul style="list-style-type: none"> • Harvest the crop
SITUATION	NUTMEG
Late onset of monsoon by 15 days	<ul style="list-style-type: none"> • Provide thick mulch cover with green leaves/coir pith compost around basin. • Provide adequate shade for young plants
Late onset of monsoon by 30 days	<ul style="list-style-type: none"> • Irrigate plants @ 50 to 100 litres/plant/week and apply green mulch • Provide adequate shade for young plants
Drought at reproductive stage*	<ul style="list-style-type: none"> • Irrigate plants @ 50 to 100 litres/plant/week and apply green mulch • Provide adequate shade for young plants
Terminal drought	<ul style="list-style-type: none"> • Irrigate plants @ 50 to 100 litres/plant/week and apply green mulch • Provide adequate shade for young plants
*Nutmeg is a perennial crop, and vegetative and reproductive phases occur simultaneously	

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