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किसान गज़ट

As the Rains Withdraw

Toward Harvest

Late-Kharif Care and the Turn to Rabi

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The Closing Weeks of Kharif: Guiding the Crop to a Full Harvest

Aarav Mehta
CCS Haryana Agricultural University, Hisar, Haryana, India

Abstract

The last weeks of the kharif season decide how much of the crop's promise is actually gathered. As the monsoon withdraws, the crop enters the stages at which yield is formed and filled, while moisture declines and late pests and diseases press upon it. This article introduces the theme of the present issue, explaining what the crop needs in its closing weeks, the hazards of the late season, and the decisions that carry the harvest safely into the store. It also looks ahead to the turnaround into rabi, for which the same weeks are the time of preparation.

The kharif season does not end with the last shower of the monsoon. It ends in the field, in the weeks when the crop moves from growth to the making of grain, and it is in these weeks that the promise of the season is either realised or quietly lost. A crop that has come through sowing, weeding, and the pressures of the wet months may still be diminished by a fortnight of neglect at its close, and one that has struggled may still be brought to a respectable harvest by attentive care at the end.

This issue is devoted to the closing weeks of kharif and to the turn that follows them. The articles that follow examine the management of the late crop, the harvest itself, the handling of what is gathered, and the preparation of the field for the rabi season that begins almost before the kharif crop has left the ground. This first article sets out the character of the late season and the tasks it brings.

The Character of the Late Season

The late kharif period has a character of its own. The rains, which for months have been abundant and often excessive, begin to falter and then to withdraw. Days remain warm but the humidity falls, the soil begins to dry from the surface downward, and the crop, having built its framework of stems and leaves, turns its resources toward the formation and filling of grain or produce. It is a period of transition, in the weather and in the crop alike.

This transition matters because the crop's needs change with it. Earlier in the season the concern was to manage excess: to drain the field, to check weeds, to prevent the diseases that flourish in wet warmth. Now the concern shifts toward sufficiency: to see that moisture, nutrients and protection last until the crop is ready. Recognising the change, and adjusting management accordingly, is the first requirement of the closing weeks.

What the Crop Needs at This Stage

The reproductive stages, flowering and the filling of grain, are the stages at which a crop is most sensitive to any shortage. A check at this point cannot be made good later, for the number of grains and their weight are settled here and nowhere else. Whatever the crop needs in these weeks, it needs promptly, and what it does not receive is subtracted directly from the yield.

Water is the first of these needs, and where any source of irrigation exists it should be reserved for this period rather than spent earlier. Nutrition is the second, though its role is now one of maintenance rather than of stimulation; a late application intended to push growth is generally wasted, while the correction of a visible deficiency may still be worthwhile. The third need is protection, for the pests and diseases of the late season attack the very organs in which the yield is stored.

The Withdrawal of the Monsoon

The withdrawal of the rains is the defining event of the late kharif season, and its timing determines much. When the monsoon holds until the crop has filled, the season closes gently and the harvest is gathered from a crop that has had what it needed. When the rains withdraw early, the crop is left to finish on the moisture stored in the soil, and a terminal deficit develops at the worst possible moment.

This risk of terminal stress is examined in the article that follows. Here it is enough to note that the withdrawal of the monsoon should be watched as carefully as its arrival, and that a farmer who sees it coming can act, by giving a supplementary irrigation if water is available, by conserving the moisture that remains, and by adjusting expectations and plans to the season that is actually unfolding.

Threats That Come Late

Some of the most damaging pests and diseases of kharif crops appear only in the closing weeks, when the crop is at its most valuable and its capacity to recover is least. Grain and pod feeders, late blights and rots, and the birds and rodents that follow a ripening crop can all take a significant share of a harvest that is otherwise assured. Vigilance does not end when the crop begins to ripen; in a sense it becomes more important.

Late-season protection also demands particular care over the safety of the produce. Any treatment applied close to harvest must respect the interval prescribed before the crop is gathered, or residues may remain in the grain or vegetable that reach the consumer and depress the price. Protecting the crop and protecting its quality are, at this stage, the same task.

From the Field to the Store

The harvest is not a single moment but a sequence of operations, each of which can add to or subtract from what the farmer finally holds. Judging maturity correctly, cutting at the right time, drying to a safe condition, threshing without damage, and storing soundly are all steps at which loss occurs when they are done carelessly and is avoided when they are done well. Grain lost after harvest is grain grown at full cost and gained not at all.

Later articles in this issue treat these operations in turn. Their common lesson is that the value of a crop is not settled when it is cut, and that the care given to produce after harvest deserves the same seriousness as the care given to the standing crop.

Looking Ahead to Rabi

The closing weeks of kharif are also the opening weeks of preparation for rabi. The moisture left in the soil at the end of the monsoon is the foundation on which much rabi cultivation rests, and the speed with which a field is cleared and prepared determines how much of that moisture survives to serve the next crop. Decisions about which rabi crops to sow, and the arrangements for their seed, are best made now rather than when the sowing window has already opened.

The two seasons therefore overlap, and the farmer who manages the overlap well gains twice: a full kharif harvest and a rabi crop sown in good time into moist, well-prepared ground. The later articles of this issue address this turnaround and the planning it requires.

Conclusion

The closing weeks of the kharif season are short but decisive. In them the crop forms and fills its yield, the monsoon withdraws, late pests and diseases press upon a valuable crop, and the harvest must be judged, gathered and stored. In the same weeks the ground must be readied for rabi. Attention given now protects everything that the season's earlier work has built, and prepares the season that follows. The articles that follow set out, in detail, how that attention is best directed.

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Terminal Moisture Stress: Protecting the Crop as the Monsoon Withdraws

Priya Nair
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu

Abstract

When the monsoon withdraws before the kharif crop has finished filling its grain, the crop faces a moisture deficit at the stage where it can least afford one. This article discusses terminal moisture stress: how it arises, why it is so damaging, and the measures through which its effects can be reduced. It considers the value of a single late irrigation, the conservation of residual soil moisture, the management of the crop to reduce its demand for water, and the choices that build resistance to terminal stress into future seasons.

Of all the moisture deficits a kharif crop may face, the one that arrives at the end of the season is the most costly. A dry spell early in the crop's life delays or thins it, but leaves time for recovery. A deficit at flowering and grain filling strikes at the formation of yield itself, and what is lost there is lost for good. When the monsoon withdraws while the crop is still filling, this is precisely the situation that arises, and it is known as terminal moisture stress.

Terminal stress is common because the withdrawal of the rains and the ripening of the crop are events that frequently overlap, particularly where sowing was late or where a long-duration variety was chosen. Understanding how the stress develops, and what can be done as it develops, allows farmers to protect a large part of the yield that would otherwise be forfeited.

How Terminal Stress Develops

As the monsoon withdraws, the crop is left to draw upon the water stored in the soil. For a time this reserve is sufficient, and the crop shows no distress. But evaporation from the surface and transpiration from the crop continue to draw it down, the surface layers dry first, and the roots must reach deeper for what remains. When demand exceeds what the soil can supply, the crop begins to experience stress.

The signs are familiar: leaves roll or wilt during the hottest part of the day, the crop loses its colour, and ripening is hastened. This premature ripening is the heart of the damage, for the crop shuts down its filling before the grain has reached its full weight. The harvest that follows is lighter, the grain smaller and often shrivelled, and its quality and market value are reduced along with its quantity.

Why the Timing Matters So Much

The severity of terminal stress depends on how early in the filling period it begins. Stress that arrives when the grain is nearly mature does comparatively little harm, for the crop has already accumulated most of what it will hold. Stress that arrives at flowering or at the beginning of filling is far more serious, reducing both the number of grains that set and the weight of those that do.

This is why a farmer must watch the progress of the crop and of the drying soil together. The question is not simply whether the soil is drying, but whether it will remain able to supply the crop until the crop no longer needs it. When the answer is doubtful, the case for intervention is strong, and the earlier the intervention comes, the more it saves.

The Value of a Single Late Irrigation

Where any water is available, from a farm pond, a well, or a canal, a single irrigation given during the filling period is among the most valuable applications of water in the whole agricultural year. It relieves the stress at the moment of greatest sensitivity, allows filling to continue to its natural end, and can preserve a substantial share of the yield that would otherwise be lost. The same quantity of water applied earlier, when the crop was not short, would have achieved comparatively little.

This is the principle of life-saving irrigation applied to the end of the season. Water stored during the monsoon should therefore be held in reserve against this possibility rather than spent freely while the rains continue. A farmer who enters the late season with water in hand is far better placed than one whose reserve has already been drawn down.

Conserving the Moisture That Remains

Where no irrigation is possible, the object becomes to make the moisture already in the soil last as long as it can. A mulch of crop residues over the soil surface slows evaporation and keeps the upper layers moist for longer. Breaking a surface crust, where one has formed, creates a loose layer that checks the upward movement of water and reduces the loss from below.

Weeds deserve particular attention at this stage. Every weed left standing in a drying field is drawing water that the crop needs at its most critical moment, and removing them, even late, returns that water to the crop. In a season closing under moisture deficit, weed control is a moisture-conservation measure as much as a competition measure.

Reducing the Crop's Demand

The demand a crop makes on the remaining moisture can also be moderated. Operations that disturb the soil unnecessarily, exposing moist earth to the air, should be avoided once the reserve has become precious. Any practice that damages the root system or checks the crop adds to its difficulty and should likewise be set aside until after harvest.

A well-nourished, healthy crop withstands terminal stress better than a weak one, because its root system is deeper and its tissues are better able to function under strain. Much of the resistance a crop shows at the end of the season is thus the accumulated result of how it was managed from the beginning.

Building Resistance for Future Seasons

Terminal stress recurs, and the most effective protection against it is built before the season rather than during it. Sowing in good time, so that the crop's filling period falls while the rains are still likely, is the single most powerful measure. Choosing a variety whose duration matches the length of the season available achieves the same end from the other direction, allowing the crop to finish before the reserve runs out.

Practices that increase the soil's capacity to store water, above all the building of organic matter, extend the reserve on which the late crop draws. Fields well supplied with organic matter carry their crops noticeably further into a dry finish than depleted ones, and this advantage compounds over the seasons.

Conclusion

Terminal moisture stress arrives at the stage where a crop can least withstand it, hastening ripening and shrinking the grain that the season's work has produced. Its effects can be greatly reduced: by holding water in reserve for a single well-timed late irrigation, by conserving the moisture left in the soil through mulching, tillage and weed control, and by avoiding operations that add to the crop's burden. In the longer term, timely sowing, suitable varieties and richer soils build resistance into the system itself. The withdrawal of the monsoon need not take with it the harvest the season has prepared.

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Late-Season Pests and Diseases: Guarding the Yield in the Final Weeks

Rohan Singh
Punjab Agricultural University, Ludhiana, Punjab, India

Abstract

The final weeks before harvest bring their own pests and diseases, which attack the grain, pod or fruit at the moment when the crop is most valuable and least able to recover. This article discusses the management of late-season problems in kharif crops, including the monitoring that detects them, the pests that feed directly on the produce, the diseases that develop as the crop matures, and the protection of the harvest from birds and rodents. It emphasises the pre-harvest interval and the safe, considered use of any treatment applied close to harvest.

A crop approaching harvest represents the whole investment of the season, and it is at just this point that a distinct set of pests and diseases becomes active. Some feed directly on the developing grain or pod; others rot the maturing produce; still others, birds and rodents, take the crop as it stands in the field or lies drying on the threshing floor. Because the crop can no longer compensate for what is taken, the losses of the late season are subtracted straight from the harvest.

Vigilance in these weeks is therefore as important as at any earlier stage, and in some respects more so. The measures available are fewer, because the nearness of harvest restricts what may safely be applied, and the value at stake is greater. Careful monitoring and considered, restrained action are the keys to protecting the yield in its final weeks.

Why the Late Season Is Different

Earlier in the crop's life, damage to leaves or stems may be made good by subsequent growth. A crop that loses foliage in its vegetative stage often recovers and yields well. Once the crop has entered filling, no such compensation is possible: the plant is no longer producing new structure, and any organ damaged now is simply lost from the harvest.

Furthermore, the pests of the late season tend to attack the harvestable part directly. A borer in a pod or an ear feeds on the grain itself; a rot in a maturing fruit destroys the produce rather than the plant. The relationship between damage and loss is thus far more direct than at earlier stages, and even a modest infestation can be costly.

Monitoring the Ripening Crop

Regular examination of the crop remains the foundation of protection. Walking through the field rather than viewing it from the bund, examining plants at several points, and inspecting the ears, pods or fruits themselves, rather than only the foliage, reveals problems while they are still contained. Damage concealed within a pod or an ear is easily missed by a casual glance.

Traps installed earlier in the season continue to give useful warning, and their catches should still be counted and recorded as the crop ripens. What monitoring provides is not merely the knowledge that a pest is present but a sense of how numerous it is and whether its numbers are rising, which is what a sound decision to act, or not to act, actually requires.

Pests That Feed on the Produce

Borers and pod feeders are the most damaging of the late-season insects, entering the ear, pod or fruit and consuming the developing grain within. Because they feed inside the plant part, they are protected from most treatments once established, and control depends on acting when they are still moving on the surface or newly hatched. This is exactly the window that regular monitoring identifies.

Sucking pests may also build up in the late crop, weakening it and, in some cases, transmitting disease. Their natural enemies are usually present and, if they have been conserved through the season by restraint in spraying, they often keep such pests in check without further intervention. This is one of the returns that an integrated approach pays at the end of the season.

Diseases of the Maturing Crop

Diseases that affect the ear, pod or fruit as it matures can spoil produce that is otherwise ready to harvest, and warm, humid weather following a late shower is particularly favourable to them. Discolouration of grain, rotting of pods, and lesions on fruits are the visible signs, and once established such infections are difficult to arrest.

Prevention rests chiefly on measures taken earlier: a healthy, well-spaced crop that dries quickly after rain, good drainage, and the removal of infected residues. Late in the season, the most effective response to a developing infection is often to harvest promptly once the crop is mature, rather than to leave it standing where the infection can spread further.

Birds, Rodents and the Standing Crop

As grain ripens it attracts birds and rodents, whose losses can be substantial in a crop left standing after maturity. Damage of this kind rises sharply the longer the ripe crop remains in the field, so timely harvesting is itself among the most effective protections. Where the crop must stand, scaring devices and vigilance during the vulnerable hours help.

Rodents deserve particular attention, for they damage the crop in the field, again during drying, and once more in store. Keeping bunds and field margins clear of dense weed growth removes the shelter in which they breed, and attention to the surroundings of the threshing floor and the store prevents losses continuing after the harvest is gathered.

The Pre-Harvest Interval

Any treatment applied to a crop near harvest carries a particular responsibility. Every product has a prescribed interval that must elapse between its application and the gathering of the crop, and this interval exists so that residues fall to safe levels before the produce is eaten or sold. It is stated on the label, and it must be observed strictly.

Ignoring the interval risks harm to those who consume the produce and to the farmer's own returns, for produce carrying detectable residues may be rejected or discounted. Where the interval cannot be respected, the correct decision is not to apply the treatment. Preferring the safest available measures, and reserving stronger ones for cases where the threat to yield is real, is the sound course throughout the late season.

Conclusion

In the final weeks before harvest the crop is at its most valuable and its least resilient, and the pests and diseases of this period attack the produce itself. Regular, close monitoring of ears, pods and fruits, prompt and targeted action where the threat is genuine, protection of the standing crop from birds and rodents, and timely harvesting together guard the yield that the season has built. Above all, any treatment applied at this stage must respect the pre-harvest interval, so that the crop reaches the store and the market both whole and safe.

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Role of Multi-Layer Cropping for Enhancing Land Use Efficiency

Deepika Ujjwal[1], Dr. C.M. Yadav[2] and Dr. Lalchand Kumawat[2]
[1]*Maharana Pratap University of Agriculture and Technology, Udaipur*
[2]*Krishi Vigyan Kendra, Bhilwara-I*

Abstract

The multi-tier or multi-layer cropping system is an approach designed to maximise agricultural productivity on limited landholdings. By cultivating several crop species at different heights on the same plot, the system uses vertical as well as horizontal space to create a layered ecosystem that improves resource efficiency and biodiversity. It allows higher yields, reduced pest infestation and better economic returns per unit area. This article sets out the principles underlying multilayer farming, the steps involved in establishing such a system, the matching of crop types to layers, its advantages and limitations, and the evidence for its effects on resource conservation, yield, weed suppression and soil health.

The multi-tier cropping system, also known as multi-layer farming, is an innovative approach designed to maximise agricultural productivity for landholders. By cultivating multiple crop species at different heights on the same plot, this system utilises vertical and horizontal dimensions to create a multi-layered ecosystem that enhances resource efficiency and biodiversity. The method allows for higher yields, reduced pest infestation, increased biodiversity and better economic returns per unit area. Multi-layer farming has proved effective in providing year-round income, fostering environmental sustainability and offering a viable solution for small and marginal farmers in resource-constrained areas.

The concept of multilayer farming is founded on the principle of complementary resource utilisation rather than competition among component crops. Each crop occupies a specific ecological niche within the production system. Tall-growing species intercept direct solar radiation in the upper canopy, medium-height crops utilise filtered light in the intermediate layer, while shade-tolerant vegetables or leafy crops grow efficiently under reduced light conditions. Similarly, differences in rooting depth allow plants to exploit water and nutrients from different soil horizons, thereby minimising interspecific competition and improving overall resource-use efficiency.

Core Principles Underpinning the System

At its foundation, multilayer farming depends on high planting density paired with the efficient, deliberate use of manure, water, soil, labour and vertical space. It is oriented toward lowering both production costs and the volume of external inputs required, while steering cultivation practices toward organic and sustainable methods that help secure food and nutritional security at the household level. Irrigation management is treated with particular care in this context, since excess watering can damage the crop stand; moisture needs to be maintained at the right level rather than maximised.

How Crops Develop Within a Layered System

When four or five crops are grown together in tiers, each develops at its own pace and reaches a different final height. The crop occupying the deepest position in the soil is typically the slowest to emerge, since deep-rooted species generally take the longest to germinate. Above it, a second crop emerges at a shallower depth, germinating faster than the deep-rooted crop but slower than whatever occupies the uppermost tier. A third crop, positioned at the soil surface, is selected specifically for rapid growth and early maturity, so that it can be harvested and cleared quickly to make room for the next planting cycle. The final, uppermost crop is the slowest to reach its full height and maturity, often a fruiting species, and is planted more sparingly, in designated positions within the layout.

What the System Sets Out to Achieve

1. Making the most efficient use of available land, water, manure and fertiliser.
2. Advancing sustainable approaches to agriculture more broadly.
3. Raising the output of multiple crops within a defined time frame.
4. Generating strong income from a single piece of land.
5. Reducing competition between crops and weeds.
6. Providing a setting in which allelopathic interactions between species can be studied further.
7. Limiting soil erosion.
8. Preserving soil texture and fertility over time.

Setting Up a Multilayer System, Step by Step

- **Crop selection:** species are chosen deliberately for their differing heights and maturity timelines, so that the tiers complement rather than compete with one another.
- **Field preparation and layout:** regular geometric plots, squares and rectangles in particular, tend to work best for organising a multi-tier planting.
- **Seed quality:** seed should be pure, vigorous and capable of delivering a strong yield.
- **Seed treatment:** disinfection protects against soil- and seed-borne disease.
- **Irrigation:** adequate water is essential to sustain transpiration and photosynthesis; the ring-basin method has proved particularly effective in this context.
- **Weed control:** hand weeding, hoeing and sickling are the primary manual techniques used.
- **Nutrient management:** compost, NPK fertilisers and farmyard manure (FYM) all play a central role in supporting healthy crop development.
- **Post-production handling:** once harvested, produce is packaged and brought to market for sale.

Matching Crop Types to Their Layer

- Species placed below or at the soil surface generally have thick, well-developed roots and a preference for shaded conditions.
- Leafy vegetables are well suited to the surface layer, where they can be harvested directly by pulling.
- Climbing species require staking and careful training so that their growth stays controlled; left unchecked, they can spread across the shade structure itself.
- Upright-growing plants benefit from pruning to conserve space and are generally the last tier to be harvested, once the others have been cleared.

Advantages

- Creates year-round employment and a steady income stream for farmers.
- Can cut investment costs roughly fourfold relative to polyhouse cultivation, since the shade structure can be built from inexpensive, locally available materials such as bamboo and grass rather than specialised greenhouse infrastructure.
- Allows crops to receive adequate light even during peak summer heat, owing to the design of the layered structure.
- Helps retain soil moisture.

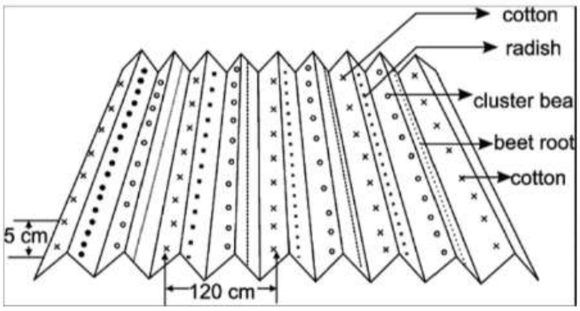
- Improves the efficiency with which nutrients are used.
- Offers some buffering against the effects of climate variability, one of its more notable benefits.
- Suppresses weed germination, which in turn supports higher productivity.
- Enables farmers to harvest a wider range of agricultural products from a comparatively small area of land.

Disadvantages

- Possible negative interactions between species, including allelopathic effects.
- Labour requirements are relatively high.
- Mechanisation is difficult to apply within the system.

Effect of Multilayer Farming on Resource Conservation

Jakhar *et al.* (2012) found that a papaya–ragi : pigeonpea (6:2) with gliricidia arrangement markedly reduced surface water runoff, while a papaya–ginger : pigeonpea (8:2) with gliricidia combination cut soil erosion significantly; the same papaya–ginger–gliricidia system also showed the best infiltration performance among the systems tested. Sultana *et al.* (2020) reported that pairing bitter gourd with elephant foot yam produced a higher land equivalent ratio than alternative layouts. Tejaswini *et al.* (2022) observed that elephant foot yam grown alone intercepted more light across its life cycle than most combinations, a result statistically comparable only to elephant foot yam + cluster bean + palak.



Effect of Multilayer Farming on Crop Yield

Singh *et al.* (2013) found that combining elephant foot yam with ridge gourd raised the elephant-foot-yam-equivalent yield above other tested arrangements. Swain (2014) reported that a mango–guava–turmeric system produced the highest mango-equivalent yield among the combinations studied. Meena *et al.* (2017) observed that coriander-equivalent yield peaked under a ber–fenugreek–okra layout.

Effect of Multilayer Farming on Weed Suppression

Sankaranarayanan *et al.* (2012a) found that a cotton–coriander–vegetable cowpea–cluster bean system reduced weed dry weight at 15, 30, 60 and 90 days after sowing while achieving the highest weed-smothering efficiency among the systems tested. Sankaranarayanan *et al.* (2012b) similarly reported that cotton grown with cluster bean, vegetable cowpea and dolichos produced the lowest weed dry weight and the strongest weed suppression. Tejaswini *et al.* (2022) found that an elephant foot yam–sweet corn–cowpea combination achieved both the lowest weed dry weight and the highest weed-smothering efficiency.

Effect of Multilayer Farming on Soil Health

Jakhar *et al.* (2012) reported that organic carbon, available phosphorus (P_2O_5) and cation exchange capacity (CEC) each peaked under different combinations: papaya + ginger : pigeonpea (8:2) + gliricidia for available P_2O_5 and CEC, and papaya + ragi : pigeonpea (6:2) + gliricidia for organic carbon. Taken together, these results indicate that well-designed multi-tier layouts improve the chemical condition of the soil alongside their effects on conservation and yield, and so support environmentally sustainable farming practices.

Conclusion

Taken as a whole, the evidence points to multilayer farming as a genuinely holistic and sustainable response to the constraints imposed by limited land availability. By combining fruit crops, field crops, legumes and vegetables in a location-specific, vertically organised layout, the system consistently raises overall productivity, makes fuller use of the resources already available to a farm and delivers stronger financial returns than conventional single-tier cultivation.

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Judging Maturity: Harvesting Kharif Crops at the Right Time

Kavita Sharma
SK Rajasthan Agricultural University, Bikaner, Rajasthan, India

Abstract

Harvesting at the correct stage of maturity is among the simplest ways of protecting yield and quality, yet it is easily got wrong. A crop cut too early has not filled; one left too long sheds, shatters and deteriorates. This article discusses how maturity is judged in the principal kharif crops, the losses that follow from harvesting too early or too late, the influence of weather on the decision, and the practical arrangements, of labour, equipment and threshing floor, that allow a farmer to harvest at the moment the crop is ready.

A crop announces its readiness, but not loudly, and the signs are easily misread. Harvest is often governed by the calendar, by the availability of labour, or by what the neighbours are doing, rather than by the condition of the crop itself. Yet the stage at which a crop is cut affects both how much is gathered and how well it keeps, and few decisions of the season are so consequential for so little cost.

Judging maturity is a matter of observation and of knowing what to look for in the particular crop. It also requires readiness, for the window within which a crop should be harvested is often narrow, and a farmer who recognises maturity but cannot act upon it for a week gains nothing from the recognition.

The Cost of Harvesting Too Early

A crop cut before it has finished filling has not accumulated all the dry matter it would have held. The grain is lighter and often shrivelled, the yield is lower, and the produce commands a poorer price. Immature grain also carries more moisture, dries unevenly, and is more prone to damage in threshing and to spoilage in store.

Early harvesting is usually driven by anxiety, about weather, about theft, about the availability of hands, and the anxiety is not always misplaced. But the cost is real, and where the crop is only a few days from maturity, waiting those few days is almost always the better course.

The Cost of Harvesting Too Late

Delay carries its own penalties, and in many crops they are heavier. Ripe grain shatters from the ear and pods split and shed their seed, so that the harvest is scattered on the ground before it can be gathered. Ripe standing crops attract birds and rodents, and each additional day of exposure adds to their toll.

Quality suffers as well. Grain left standing after maturity may discolour, particularly if it is wetted by a late shower and then dried, and in some crops germination may begin in the ear. Lodging becomes more likely as stems weaken, making harvesting slower and losses greater. The value of a crop, once mature, begins to decline from that day onward.

Recognising Maturity in the Field

The signs of maturity differ between crops but follow a common pattern. The plant loses its green colour and dries from the lower leaves upward; the grain hardens and can no longer be dented easily with the thumbnail; the moisture in the produce falls, and the crop begins to rustle rather than swish when it moves in the wind. In pulses, the pods change colour and dry, and the seed rattles within. In many vegetables and fruits, colour and firmness are the guides rather than dryness.

Because a field does not mature uniformly, the judgement should be based on a sample drawn from several parts of it rather than on the plants nearest the bund, which are often ahead of the rest. Examining plants from the centre and from different corners gives a truer picture of when the field as a whole is ready.

Crops That Must Be Cut Promptly

Some crops tolerate a delay in harvest; others do not. Pulses and oilseeds are particularly prone to shattering, and in these crops the difference between the right day and a week later can be considerable. They are often best cut slightly before full dryness and allowed to complete their drying in the stack or on the floor, where the seed that separates is not lost.

Crops harvested for fodder as well as grain, and vegetables harvested for the market, are governed by different considerations again: fodder quality declines as stems coarsen, and vegetables are graded on tenderness and appearance rather than on dryness. In each case the standard is set by the use to which the produce will be put.

Weather and the Harvest Decision

A late shower falling on a ripe or a cut crop can do serious damage, wetting grain that must then be dried again, encouraging discolouration and mould, and turning the threshing floor to mud. The weather forecast is therefore a legitimate part of the harvest decision, and where rain is expected, bringing a nearly mature crop in a little early is often the prudent choice.

Conversely, a settled spell of dry weather is an opportunity to be taken, allowing the crop to be cut, dried and threshed in one continuous operation with the least handling and the least risk. Planning the harvest around the weather, rather than in spite of it, avoids much of the loss that occurs at this stage.

Being Ready to Act

Because the window is narrow, arrangements should be made in advance rather than when the crop is already standing ripe. Labour engaged, machinery serviced and tested, the threshing floor cleared and prepared, bags and covers obtained, and transport arranged: each of these takes time that is not available once the crop is ready. Readiness converts a correct judgement of maturity into an actual gain.

Where machinery is hired, booking it early matters especially, since demand peaks precisely when every field in the locality matures together. A farmer who has secured the use of equipment for the right days is not forced to harvest early or to wait past the proper stage.

Conclusion

Harvesting at the right stage costs nothing but attention, and it protects both the quantity and the quality of the crop. Cutting too early forfeits filling that the crop had still to do; cutting too late forfeits grain to shattering, birds, weather and deterioration. By learning the signs of maturity in each crop, sampling the field fairly, watching the weather, and arranging labour and equipment in advance, farmers can harvest at the moment the crop is ready, and carry into the store the full measure of what the season has produced.

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Drying and Threshing: The Operations That Decide Grain Quality

Arjun Verma
GB Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Abstract

Between the cutting of a crop and its arrival in the store lie drying and threshing, two operations in which a large share of post-harvest loss occurs. Grain that is threshed while too moist is damaged; grain that is stored before it is properly dry will not keep. This article discusses the drying of kharif produce to a safe condition, the threshing methods available and the care each requires, the preparation of the threshing floor, and the cleaning and grading that follow. Careful handling at this stage preserves both the weight and the value of the harvest.

The harvest is not secure when the crop is cut. Between cutting and storage lie drying and threshing, and it is here that a considerable part of the loss suffered by Indian farmers occurs, quietly and often unnoticed. Grain broken in threshing, scattered on an unprepared floor, or stored before it has dried is grain grown at full cost and lost at the last step.

These operations reward care out of proportion to their difficulty. None of them requires expensive equipment or specialist knowledge; what they require is attention to moisture, cleanliness and timing. The kharif harvest, gathered at the end of a wet season and often in uncertain weather, makes that attention especially necessary.

Why Moisture Governs Everything

The moisture content of the produce determines almost everything that follows. Grain that is too moist is soft: it bruises and breaks under the blows of threshing, and broken grain fetches a lower price and keeps badly. Grain that is too dry becomes brittle and also cracks. Between these extremes lies a condition at which the grain separates cleanly from the ear or pod without damage, and threshing is best done at that stage.

For storage, the requirement is stricter still. Moist grain respires, heats and supports the growth of moulds and the multiplication of insects, and a store loaded with insufficiently dried produce may be spoiled within weeks. The kharif crops, harvested when the air is still humid, are particularly at risk, and drying them thoroughly before storage is not a refinement but a necessity.

Drying the Produce

Most drying on Indian farms is done in the sun, and done well it is entirely adequate. The produce should be spread in a thin, even layer on a clean surface, turned at intervals so that it dries uniformly, and gathered before the dew falls in the evening. A thick, unturned heap dries on the outside while remaining damp within, and the damp core is where spoilage begins.

The surface matters as much as the method. Drying directly on bare earth allows soil, stones and moisture from below to enter the produce; a paved floor, a clean tarpaulin or matting keeps the grain clean and speeds the drying. Where late showers threaten, the produce should be heaped and covered quickly and then spread again as soon as the sun returns, since grain left wet under a cover heats rapidly.

A simple test of dryness is often enough: well-dried grain is hard, makes a sharp sound when poured, and cannot be dented with a thumbnail or bitten without effort. Where a moisture meter is available, through a cooperative or a market yard, it removes the guesswork and is worth using before produce is committed to a long period in store.

Threshing Methods and Their Care

Threshing may be done by beating the crop against a hard surface, by treading, or by machine, and each method has its place. Manual methods are slow but gentle, and remain suitable for small quantities and for crops such as pulses whose seed damages easily. Mechanical threshers handle far larger quantities and relieve a severe labour bottleneck at a busy time.

Where a machine is used, its adjustment is critical. A thresher set too aggressively breaks and cracks the grain; one set too gently leaves grain unthreshed in the straw. The speed and clearance should be set to suit the crop and its moisture and checked on a small quantity before the bulk is put through, and the settings should be revisited if the crop being fed becomes drier through the day.

Machines also demand attention to safety. Threshers are among the commonest causes of serious injury on Indian farms. Guards should be in place, loose clothing avoided, the machine stopped before any blockage is cleared, and tired operators relieved rather than pressed on into the night.

The Threshing Floor

A clean, firm, level threshing floor prevents much of the loss that occurs at this stage. Grain spilled onto loose earth cannot be recovered; grain gathered from a swept, hard surface can. The floor should be prepared before the harvest begins, cleared of the residues of the previous crop, and kept free of stones and clods that would contaminate the produce.

Its surroundings matter too. A floor sited away from thoroughfares and dense vegetation suffers less from rodents and from stray animals, and one on slightly raised ground is not flooded by an unexpected shower. Simple precautions of this kind cost nothing and preserve a measurable share of the harvest.

Cleaning and Grading

Threshed produce carries chaff, dust, straw, weed seeds and immature or damaged grains, and removing them improves both the keeping quality and the price. Winnowing, whether by hand in a breeze or with a fan or cleaner, removes the lighter fractions; sieving separates by size; and hand picking removes the obvious foreign matter that remains.

Clean produce keeps better because the trash it contains carries moisture, insects and mould spores into the store. It also sells better, since buyers discount lots that must themselves be cleaned. Where grading by size or quality is possible, it often repays the effort, allowing the better fraction to be sold at a better price rather than the whole lot at an average one.

Handling Seed for the Next Season

Produce intended for use as seed deserves separate and gentler handling. Seed damaged in threshing may look sound but germinate poorly, and mechanical threshing set for grain is often too harsh for seed. Where a portion of the crop is to be kept for sowing, it is worth threshing it separately and more gently, drying it carefully and storing it apart from the rest.

Selecting the seed lot from a good part of the field, from healthy, well-filled plants rather than from the general heap, adds to its value further. The care given to seed at this stage is repaid at the start of the following season.

Conclusion

Drying and threshing are ordinary operations, and precisely for that reason they are often given less attention than they deserve. Yet moisture governs whether grain threshes cleanly and stores soundly; the setting of a thresher governs how much is broken; the condition of the floor governs how much is recovered; and cleaning governs both keeping quality and price. Attention at this stage costs little and preserves a great deal, carrying the harvest into the store whole, clean and dry.

Preparing Fields for Rabi: The Turnaround Between Two Seasons

Neha Kapoor
Chaudhary Charan Singh Agricultural University, Haryana, India

Abstract

The interval between the clearing of the kharif crop and the sowing of the rabi crop is short, and how it is used decides much about the season that follows. This article discusses the turnaround between the two seasons: the clearing of the field, the handling of crop residues, tillage suited to the moisture available, the levelling and layout of the land, and the sequencing of operations so that sowing is not delayed. A quick, well-managed turnaround conserves moisture, saves time and gives the rabi crop the start it needs.

In much of northern India the rabi crop must be sown within a few weeks of the kharif crop leaving the field. The interval is short, the work is heavy, and the moisture in the soil is declining throughout it. How that interval is used, whether the field is cleared and prepared promptly and with the right operations, or left while other tasks intervene, has a large influence on the rabi crop that follows.

The turnaround is therefore not a pause between seasons but a phase of its own, with its own objectives: to clear the land, to prepare a seedbed, to conserve the moisture that remains, and to do all of this quickly enough that sowing falls within the crop's proper window. This article considers how those objectives are best met.

Why Speed Matters

Every day between harvest and sowing is a day in which the soil loses moisture from its surface, and in rain-fed rabi cultivation that moisture is the crop's whole supply. A field prepared and sown promptly draws upon a fuller reserve than one prepared three weeks later, and the difference shows in germination, in early vigour and finally in yield.

Speed matters for a second reason: the rabi crops have their own optimal sowing windows, beyond which yield declines steadily. Late sowing exposes the crop to unfavourable conditions at its sensitive stages and shortens the season available to it. Much late sowing has its origin not in a deliberate decision but in a slow turnaround, and is avoidable.

Clearing the Field

Clearing begins with the removal of the harvested crop and continues with the handling of what remains: stubble, straw, haulms and the residues of threshing. The field should be cleared promptly, both to free it for preparation and to deny shelter to the rodents and insects that would otherwise carry over into the next crop.

Volunteer plants and the weeds that spring up after harvest deserve attention at this point as well. They are easily destroyed by the first tillage while they are small, and doing so prevents them from setting seed and from drawing on the moisture the rabi crop will need. A field cleared early is also a field on which the following operations can proceed without interruption.

Crop Residues: A Resource, Not a Nuisance

The residues left by a kharif crop are frequently treated as an obstacle to be removed as quickly as possible. They are in fact a substantial store of organic matter and nutrients, and the manner of their disposal has consequences that outlast the season. Incorporating residues into the soil returns that organic matter and improves the soil's structure and its capacity to hold water.

Where residues are heavy and time is short, they may instead be retained on the surface, where they act as a mulch that checks evaporation and suppresses weeds while the field is bare. Sowing into retained residue is possible with suitable equipment and is increasingly practised. What should be avoided is burning, which destroys the organic matter, harms the soil surface and its organisms, and pollutes the air. The subject is treated more fully in the next issue.

Tillage Suited to the Moisture Available

The tillage a field needs after the kharif harvest depends on the crop that was grown, the state of the soil and, above all, the moisture present. Where the soil is moist, tillage should be minimal and prompt, sufficient to prepare a seedbed but no more, since every additional pass exposes moist soil to the air and dries it. Excessive cultivation in a drying field is among the commonest and least noticed causes of poor rabi germination.

Where the field has been under rice, the puddled layer may need breaking to restore structure and drainage for the crop that follows, and this is best done while the soil is at the right moisture, neither sticky nor hard. Working a soil too wet destroys its structure; working it too dry produces large clods that cannot be broken down without repeated effort. Judging that moment is the essential skill of the turnaround.

Levelling and Layout

A level field allows water, whether from irrigation or from winter rain, to spread evenly, and prevents the low spots that waterlog and the high spots that dry. Levelling is most easily done during the turnaround, while the field is bare, and the effort is repaid through every irrigation of the season that follows.

The layout of the field should be settled at the same time: the position of channels and drains, the size of the plots or beds, and the arrangement of any ridges and furrows the crop will need. Deciding this before sowing, rather than improvising afterwards, makes the management of water simpler for the whole season.

Sequencing the Work

The turnaround places heavy demands on labour and machinery at exactly the moment when every farm in the locality needs both. Sequencing the work, deciding which fields will be cleared first, when equipment will be required, and where labour will come from, prevents the delays that arise when everything is left to be arranged as it becomes urgent.

Preparation made before the harvest helps here as it does elsewhere: equipment serviced, seed and fertiliser obtained, and the plan for each field settled in advance. The farmer who has arranged these things can move from harvest to sowing without a pause, while one who has not may lose the very weeks that matter most.

Conclusion

The weeks between the kharif harvest and the rabi sowing are short, busy and consequential. Clearing the field promptly, treating residues as a resource rather than a nuisance, tilling no more than the soil requires and at the right moisture, levelling and laying out the land while it is bare, and sequencing the work so that nothing waits on an unmade arrangement together conserve moisture and bring the sowing forward. A brisk, well-managed turnaround is one of the surest investments a farmer can make in the rabi season.

Conserving Residual Moisture for the Rabi Crop

Vivek Joshi
Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, Madhya Pradesh, India

Abstract

In much rain-fed rabi cultivation the crop lives on the moisture left in the soil at the end of the monsoon. Conserving that residual moisture through the turnaround and the early weeks of the crop is therefore decisive. This article discusses where residual moisture is lost, and the practices that preserve it: prompt sowing, minimal and timely tillage, surface mulching, weed control, sowing depth and method, and the longer-term building of the soil's own capacity to store water. Moisture saved at this stage is moisture available when the crop most needs it.

When the monsoon ends, the soil of a field holds a reserve of water accumulated over the season. In irrigated areas this reserve is a useful supplement; in the large rain-fed tracts where rabi crops are grown on stored moisture alone, it is the whole basis of the crop. Everything the crop will draw upon between sowing and harvest is, in those fields, already in the ground on the day the monsoon withdraws.

The reserve is finite and begins to decline at once. It is lost to evaporation from the bare surface, to weeds, to the drying effect of unnecessary cultivation, and to the simple passage of time. Conserving it is thus a matter of reducing these losses during the weeks when the field is bare and the crop is young, and it is among the most valuable things a farmer can do in this period.

Where the Reserve Goes

Evaporation from the surface is the largest loss, and it is greatest when the soil is bare, when the surface is moist, and when the air is dry and warm, which is precisely the condition of a cleared field in October. Water moves upward through the soil to replace what has evaporated, so that the loss continues from below the surface and not merely from it.

Weeds are the second great consumer. A field that greens over with weeds after harvest is transpiring the rabi crop's water supply into the air, and does so unnoticed because nothing appears to be wrong. The third loss is caused by the farmer: each unnecessary tillage operation turns moist soil to the surface, where it dries within hours.

Sowing Promptly

The most effective conservation measure is simply to sow soon. A crop sown early into a full reserve germinates readily, establishes a root system while moisture is still ample, and reaches the depth at which water remains before the surface has dried. A crop sown three weeks later must germinate in a drier seedbed and grow its roots in soil already depleted.

Prompt sowing also means that the moisture being lost from the field is at least being lost through a crop rather than from bare ground, where it produces nothing. Every week saved in the turnaround is therefore a week of the reserve transferred from waste to use.

Tillage That Conserves Rather Than Dries

Tillage should be reduced to what the seedbed genuinely requires. Each pass of an implement brings moist soil to the surface and exposes it, and repeated passes to produce a fine tilth can cost more moisture than the improved tilth is worth. A single well-timed operation that leaves a workable seedbed is better than three that leave a perfect one.

Where tillage is undertaken, doing it while the soil is at the right moisture reduces both the effort and the loss. Some shallow cultivation that breaks a surface crust and creates a loose layer over the moist soil beneath can actually reduce evaporation, by interrupting the upward movement of water. The principle is to disturb the surface just enough to check that movement, and to leave the deeper, moist soil undisturbed.

Mulching the Bare Field

A cover of crop residues on the surface shields the soil from sun and wind and markedly slows evaporation. Where the kharif crop has left straw or haulms, retaining a part of them on the surface rather than removing or burning them turns a residue into a moisture-conservation measure at no cost. The same cover suppresses the weeds that would otherwise draw on the reserve.

Residue cover has the further advantage of moderating soil temperature and of adding organic matter as it breaks down, so that its benefits extend beyond the season. Where machinery permits sowing directly into retained residue, the reserve is conserved through the sowing itself, which is the point at which conventional preparation costs the most.

Controlling Weeds Before and After Sowing

Weeds that establish in the bare field between harvest and sowing should be destroyed while they are small, when a single shallow operation is enough and little moisture has yet been taken. Left to grow, they consume water steadily and become harder to remove, and their seed adds to the burden of later seasons.

After sowing, the early weeks are again critical, since the young crop competes poorly and every weed removed leaves water for it. In a crop living on stored moisture, weed control is not principally about nutrients or light; it is about water, and it should be judged on that basis.

Sowing Depth and Method

Where the surface has dried but moisture remains below, seed should be placed into the moist layer rather than into the dry one above it. Sowing a little deeper than usual, with a drill that opens a furrow to the moist zone and closes it behind the seed, gives reliable germination where broadcasting onto a dry surface would fail.

The furrow should be closed and the surface left firm over the seed, so that the seed is in contact with moist soil and the passage for evaporation is closed. Attention to this detail often decides whether a crop emerges evenly or in patches, and an uneven stand cannot be corrected later.

Building the Reserve Itself

Beyond the practices of a single turnaround lies the longer question of how much water the soil can hold at all. A soil rich in organic matter, with good structure and an unimpeded profile, absorbs more of the monsoon rain and retains more of it against evaporation than a depleted, compacted one. Building organic matter through manures, residues and green manuring raises the ceiling on the reserve available every year.

Measures that increase infiltration during the monsoon itself, contour cultivation, bunding, the breaking of hardpans, likewise fill the reserve more fully before the rabi season begins. Conservation of residual moisture thus begins long before the kharif crop is harvested.

Conclusion

For rain-fed rabi crops, the moisture left in the soil at the end of the monsoon is the entire supply, and it begins to diminish from the moment the rains stop. Sowing promptly, tilling sparingly and at the right moisture, keeping residues on the surface, controlling weeds early, and placing seed into the moist layer together preserve a large part of that reserve for the crop. Over the longer term, a soil built up with organic matter holds more to begin with. Water conserved in these weeks is water available when the crop is filling its grain.

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Climate-Resilient Vegetable Production

Rohitashv Sharma[1], Dr. C.M. Yadav[2] and Dr. Lalchand Kumawat[2]

[1]PhD Scholar (Horticulture), Rajasthan College of Agriculture, MPUAT, Udaipur

[2]Krishi Vigyan Kendra, Bhilwara-I

Abstract

Climate change is emerging as one of the most significant threats to global vegetable production, affecting crop growth through rising temperatures, erratic precipitation, increasing soil salinity, elevated atmospheric CO_2 and air pollution. Vegetables, being highly sensitive to environmental fluctuations and highly perishable in nature are particularly vulnerable to these stresses, which manifest as reduced fruit set, altered flowering, poor produce quality and increased susceptibility to pests and diseases. Heat and cold stress disrupt photosynthesis, respiration and hormonal balance, while water stress-whether drought or waterlogging-impairs cellular functions and aggravates soil-borne diseases. Rising soil salinity, projected to affect nearly half of India's arable land by 2050, disturbs ion homeostasis and nutrient uptake, while air pollutants and elevated CO_2 levels further alter plant-pathogen and plant-pest interactions in complex ways. The major climatic stresses impacting vegetable crops and examines a range of adaptive strategies being developed to build resilience, including the breeding and grafting of stress-tolerant varieties, adjusted agronomic and soil management practices, efficient water management through drip irrigation and rainwater harvesting, integrated pest management responsive to shifting outbreak patterns. The findings underscore those climate-resilient vegetable production requires an integrated, multi-pronged approach combining genetic, agronomic and policy-level interventions to safeguard food and nutritional security in an increasingly unpredictable climate.

Climate change refers to a shift in the average values of climatic factors-temperature, rainfall, humidity, and atmospheric gas composition-along with related properties, occurring over an extended period across a wide geographic area. It can also be understood as any long-term alteration in weather patterns, whether driven by natural fluctuations or human activities. Worldwide temperature increases, shifting rainfall trends, rising sea levels, greater UV exposure and more frequent extreme weather events such as droughts and floods are already reducing agricultural output and these impacts are projected to intensify over the coming decades as global climate change progresses.

Vegetables are essential for food and nutritional security, yet their highly perishable nature means prices spike sharply during droughts or floods, making them unaffordable for low-income populations. Small and marginal farmers who rely heavily on vegetable cultivation are likely to bear the brunt of climate change impacts. Consequently, elevated temperatures combined with inadequate soil moisture stand out as key contributors to declining vegetable yields. Every stage of plant development, from vegetative growth through flowering and fruit formation, is strongly shaped by climatic conditions. Rising temperatures paired with unpredictable, inconsistent rainfall can interfere with normal plant growth processes, ultimately reducing overall crop output.

How Climate Change Is Affecting Vegetable Crops

Heat stress

Ongoing global warming, coupled with an increase in extreme weather occurrences, is significantly disrupting the planting and harvesting cycles of vegetable crops. Temperatures recorded prior to the flowering stage strongly influence both fruit-set percentage and overall yield. Elevated heat interferes with photosynthetic activity, respiration, plant water balance and cell membrane integrity, while also altering hormone levels and both primary and secondary metabolic compounds extreme heat can even prevent seeds from germinating. Research suggests that for every 1°C rise in average temperature, fruit yield drops by roughly 100 kg per 1,000 m². Conversely, during cooler periods, insufficient temperatures and low light levels can lower both yield and product quality. Cold conditions have been linked to malformed and seedless fruit, cracking and discoloration of pepper skins and irregularly shaped tomatoes. Low temperatures also directly affect the taste and sensory qualities of vegetable produce.

Additionally, warmer global conditions are expected to increase the prevalence of fungal pathogens including *Alternaria*, *Fusarium*, *Penicillium*, and *Phytophthora*.

Water stress (drought and waterlogging)

Since water availability is directly linked to climate patterns, water scarcity has become one of the biggest threats to crop production and vegetables are especially vulnerable to it. When drought conditions set in the concentration of salts and minerals in the soil rises, pulling water out of plant cells through a process called osmosis. This weakens the plant from within internal solute levels rise, water potential drops and key functions like cell membrane stability and photosynthesis begin to break down. Waterlogging causes the opposite problem: excess water fills up the air pockets in the soil that plant roots depend on for oxygen. As droughts become longer and more frequent, this also worsens certain soil-borne diseases, including pea root rot, onion white rot and grapevine black foot disease.

Water logging/flooding

Flooding harms vegetable crops mainly by starving the roots of oxygen. Without enough oxygen, plants are forced to switch from their normal energy-producing process to a less efficient one and this also triggers a spike in the production of a compound called ACC, which is a building block for the plant hormone ethylene. At the same time, excess soil moisture creates ideal conditions for harmful fungi such as *Fusarium*, *Rhizoctonia*, *Sclerotium*, *Pythium* and *Phytophthora* to spread more aggressively, putting further stress on the crop.

Heat wave

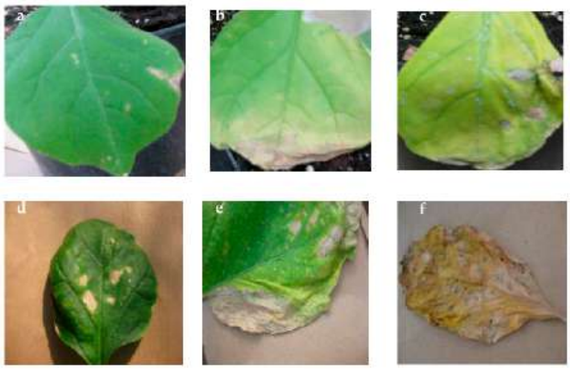
Salinity stress

Roughly 6.74 million hectares of land across the country are currently affected by salt accumulation. Projections indicate that an additional 10 percent of land area becomes salinized each year, and by 2050, close to half of all cultivable land could be salt-affected. This growing salinity problem stems largely from low rainfall, elevated surface evaporation rates, natural weathering of parent rock material, the use of saline water for irrigation, and suboptimal farming practices. The earliest indicators of salt stress in plants include wilting, leaf yellowing, and slowed growth. As the condition progresses, symptoms become more severe-green tissues develop chlorosis, leaf edges begin to burn, tissue necrosis sets in and the oldest leaves show visible scorch marks. When salts build up around the root zone, they trigger osmotic stress and interfere with the plant's internal ion balance, simultaneously blocking the uptake of vital nutrients like potassium, calcium and nitrate while allowing sodium and chloride to accumulate to harmful levels.

Air pollutants and UV radiation

Airborne pollutants including sulphur dioxide, ozone and acid rain have a direct impact on both plant tissues and the pathogens that infect them. Numerous studies have documented that foliar pathogens behave differently in plants exposed to polluted air. Pollutants can also indirectly affect pathogens that attack plant roots, such as nematodes, through changes they induce in the host plant. Notably, even relatively low concentrations of these pollutants in the range of 50 to 100 parts per billion can make plants more susceptible to disease and worsen existing infections. At these concentrations, sulphur dioxide and ozone have been shown to intensify fungal and nematode-related diseases by promoting spore germination, facilitating fungal invasion, and accelerating egg hatching along with the penetration and reproduction of plant-parasitic nematodes.

strengthened carbon-based plant defences and slower insect development rates, as documented across multiple studies. Additionally, higher CO_2 levels have been found to worsen the severity of powdery mildew infections in cucurbit crops caused by the fungus *Sphaerotheca fuliginea*.



Salinity stress

Drought stress

CO_2 effects on physiology and produce quality

Through photosynthesis, plants transform atmospheric carbon dioxide into glucose, which serves as the building block for organic plant matter. As a result, atmospheric CO_2 concentration significantly influences crop productivity by affecting core processes such as primary photochemical reactions, photoprotective mechanisms and the plant's capacity to sequester carbon. Certain ripening processes can be suppressed under elevated CO_2 conditions, likely because high CO_2 levels trigger stress responses that downregulate the genes responsible for ripening. Elevated atmospheric CO_2 also has mixed effects on pest dynamics: it boosts feeding activity in caterpillars and reproductive rates in aphids while weakening nitrogen-based plant defence mechanisms, though it can simultaneously offer some benefits, including greater predation by natural enemies, enhanced effectiveness of foliar Bt applications,

Genetic and Breeding Strategies

The selection of cultivars bred or identified for tolerance to specific stresses is the foundation of climate-resilient vegetable production, since it builds resistance into the crop before the season begins. Table 1 lists public varieties and cultivars of the major vegetable crops together with the stresses to which each has shown resistance or tolerance.

Role of grafting for stress tolerance

Grafting has emerged as another powerful tool for building climate resilience, particularly in solanaceous and cucurbit crops. By joining a high-yielding scion variety onto a vigorous, stress-tolerant rootstock, growers can confer traits such as soil-borne disease resistance, salinity tolerance and improved water- and nutrient-use efficiency without altering the fruit characteristics consumers expect.

Table 1. Heat-, drought- and salinity-tolerant cultivars and varieties of major vegetable crops.

Vegetable crop	Public variety / cultivar	Stress resistance / tolerance
Okra	Pusa Bhindi-5	Yellow Vein Mosaic Virus (YVMV) resistant
	Kashi Pragati and Kashi Kranti	Cold and frost resistant
	Pusa Sawani	Salinity
Brinjal	DBL-175	Wide adaptability across states

Vegetable crop	Public variety / cultivar	Stress resistance / tolerance
	Kashi Sandesh, Kashi Taru and Thar Sandesh	Cold and frost
	Pragati, Pusa Bindu and ICS-BR-1351	Salt tolerant
	PKM-1, Kashi Sandesh, Kashi Taru and Kashi Himani	Waterlogging
Chilli	G-4, Samrudhi and Arka Lohit	Drought
	Pusa Jwala	Heat stress
	Kashi Abha	Multiple stress
Tomato	Arka Rakshak, Arka Abhed, Arka Samrat	Disease resistant (early blight and others)
	Pusa Sadabahar, Arka Meghali, Arka Vikash and Varkha Bhar-1 & 2	Cold and frost
	Arka Meghali and Arka Vikas	Drought
	Thar Anant and Pusa Sadabahar	Heat
	Pusa Seetal	Fruit set up to 8 °C
	Pusa Hybrid-1	Fruit set up to 28 °C
Onion	Agrifound Dark Red, Arka Kalyan and Raseedpura local	Waterlogging
Bitter gourd	Pusa Hybrid-4	General resilience / hybrid vigour
Bottle gourd	Thar Samridhi and Pusa Santusthi	Cold, heat and salt
	Hisar-2	Salinity
Ridge gourd	Thar Karni, Thar Tapish and Pusa Sneha	Drought, and cold and frost
Muskmelon	Pusa Madhurima and Pusa Sarda (IARI)	Salinity–alkalinity
Watermelon	Thar Manak	Heat, and cold and frost
Cucumber	Pusa Barkha	High temperature
Radish	Pusa Chetki	High temperature
French bean (rajma type)	Kashi Bauni Sem-3 and Kashi Bauni Sem-9 (IIVR)	Cold and wilt
Cowpea	Arka Garima, Arka Suman and Arka Samrudhi	Drought
Dolichos bean	Arka Jay, Arka Amogh, Arka Soumya and Arka Sambhram	Drought
Carrot	Pusa Vrishti	High temperature and high humidity

Table 2. Common vegetable grafting combinations used for climate and stress resilience.

Vegetable crop	Rootstock	Resilience trait
Tomato (*Solanum lycopersicum*)	Interspecific hybrid rootstocks, e.g. Maxifort, Beaufort [*Solanum lycopersicum* × *S. habrochaites*]	Soil-borne disease resistance; salinity and drought tolerance; vigour
Eggplant / brinjal (*Solanum melongena*)	Turkey berry / torvum rootstock [*Solanum torvum*]	Bacterial wilt and nematode resistance; waterlogging tolerance
	Sticky nightshade [*Solanum sisymbriifolium*]	Nematode and disease resistance
Cucumber (*Cucumis sativus*)	Figleaf gourd [*Cucurbita ficifolia*]	Cold tolerance and Fusarium wilt resistance
	Bottle gourd [*Lagenaria siceraria*]	Heat and drought tolerance; vigorous root system

Vegetable crop	Rootstock	Resilience trait
Watermelon (*Citrullus lanatus*)	Bottle gourd [*Lagenaria siceraria*]	Fusarium wilt resistance and drought tolerance
	Interspecific squash hybrid, e.g. Shintosa [*Cucurbita maxima* × *C. moschata*]	Cold tolerance and soil-borne disease resistance
Melon (*Cucumis melo*)	Squash rootstock [*Cucurbita moschata*]	Fusarium wilt resistance and salinity tolerance
	Wild cucumber, horned melon [*Cucumis metuliferus*]	Root-knot nematode resistance
Pepper / chilli (*Capsicum annuum*)	Vigorous pepper hybrid rootstocks [*Capsicum annuum*, selected vigorous lines]	Bacterial wilt resistance and improved vigour
	Interspecific hybrid rootstock [*Capsicum annuum* × *C. baccatum*]	Nematode and soil pathogen resistance

Agronomic and Cultural Practices

Adjusted sowing and planting calendars

Adopting production systems suited to the specific crop being grown is essential for improving water-use efficiency and helping vegetables adapt to increasingly hot and dry growing conditions. One of the simplest yet most effective strategies are adjusting sowing or transplanting dates to avoid the periods of peak temperature and water stress that are expected to intensify during the crop's growing season. Building soil carbon reserves further supports this adaptation and can be achieved through several complementary practices: selecting improved crop varieties, extending crop rotations particularly those incorporating perennial crops that direct more carbon into root systems below ground minimizing or eliminating bare fallow periods, correcting nutrient deficiencies as they arise, and shifting toward cropping systems that depend less heavily on fertilizers, pesticides and other external inputs. Alongside these calendar and soil-based adjustments, drip irrigation plays a complementary role by minimizing water losses from runoff and deep percolation, achieving water savings of 50 to 80 percent compared with most conventional surface irrigation methods.

Mulching

Mulching involves applying a protective covering over the soil around plants, primarily to support healthier growth, earlier crop maturity, higher productivity and partial protection of the harvested produce through effective weed suppression. Its role extends beyond weed control by forming a protective layer at the soil surface, mulching creates a favourable microclimate that helps regulate soil temperature, retain humidity, support surface fermentation processes and maintain a steady supply of carbon dioxide to the plant. This becomes particularly important during prolonged dry spells, which can severely hinder crop growth and development, especially in light-textured, sandy soils that drain quickly and retain little moisture. Reducing water loss through evapotranspiration is therefore essential to ensuring vegetable crops receive adequate moisture during such dry periods. Several types of mulching materials are used depending on the crop and climatic need, including transparent plastic film, black and coloured film, white film and photodegradable or biodegradable film mulches, each offering different levels of temperature regulation and moisture retention.

Raised-bed cultivation

In regions prone to flooding, growing vegetables on raised beds has been shown to improve yields by enhancing soil drainage and reducing the anoxic (oxygen-deficient) stress that waterlogged conditions impose on plant root systems. Complementing this approach, vegetable cultivation under clear plastic rain shelters can further protect developing fruits from the direct impact of heavy rainfall while also minimizing field waterlogging during the monsoon season. Together, raised-bed planting and rain-shelter cultivation during the rainy season offer practical, low-cost solutions for maintaining vegetable productivity in flood-prone and high-rainfall areas.

Crop diversification and intercropping

Farmers should be growing multiple vegetable species or varieties together, rather than relying on a single crop, spreads climate risk across plants with different tolerances to heat, drought or pests. Crops should be having different nature in relation to growth habits, growing period, climatic condition etc. The climatic conditions are sudden change then one crop more sensible to this condition but other is tolerant so growing more crop to reduce the risk of falling. Use intercropping pattern planting two or more crops in the same field simultaneously, such as a tall crop improve shade-tolerant one also improves microclimate conditions (shade, humidity, wind buffering).

Soil and nutrient management adaptations

Application manure (FYM, compost, vermicompost etc.), green manuring for improve the water holding capacity of the soil. They also help in maintain the microbial activity, micronutrients, soil structure and fertility for better root penetration. Practices like minimum tillage and residue retention also protect soil structure and reduce erosion during intense rainfall events, helping maintain long-term productivity as climate variability increases.

Protected cultivation

Cultivation of crops under protected structures such as greenhouses, polyhouses and shade net houses, protect the crops from unfavourable environmental conditions such as high and low temperatures, drought, flooding and soil pH stresses thereby improving plant productivity. In this row tomato, capsicum and parthenocarpic cucumber cultivation under protected cultivation fetches higher yield and quality fruits.

Water Management for Resilience

Drip and micro-irrigation

Drip and micro-irrigation systems deliver water directly to the root zone of each plant through a network of tubes and emitters, instead of flooding the whole field. This drastically cuts losses from evaporation, runoff and deep percolation, achieving water savings of roughly 50 to 80 percent compared to traditional surface irrigation. Because water and dissolved nutrients reach plants precisely and consistently through fertigation, crops experience less moisture stress even during dry spells, leading to better yield stability and produce quality. These systems are especially valuable for climate resilience since they let farmers maintain optimum soil moisture even when water availability is unpredictable.

Rainwater harvesting and conservation

Capturing and storing rain water through farm ponds, check dams, rooftop collection or contour trenches (in mountain regions) for use during dry periods and reduce depleting groundwater. Other techniques such as growing cover crops and constructing bunds or terraces in slopes help retain soil moisture and reduce runoff after heavy rain. Deep tillage, deep root crops also conserving water in farm.

Anti-transpirants

Anti-transpirants are substances applied to plant surfaces to reduce water loss through transpiration, helping crops cope with limited water availability. Their benefits include optimized yield, healthier crop growth, normally sized grains, better seed quality, reduced irrigation frequency, water savings when combined with drip irrigation, and improved drought management under resource-constrained conditions. Anti-transpirants are broadly classified into four types based on their mode of action.

- *Reflecting Type:* These materials coat the leaf surface to reflect sunlight, thereby lowering leaf temperature and reducing transpiration. Common examples include kaolinite, lime, hydrated lime, zinc sulphate, and magnesium carbonate—all low-cost and locally available options.
- *Stomata-Closing Type:* These compounds work by inducing partial stomatal closure, directly limiting water vapor loss. Substances such as abscisic acid, chlormequat (CCC), and atrazine, when applied at low concentrations, have

shown anti-transpirant activity; however, many chemicals in this category can be toxic or slow plant growth if not carefully dosed.

- *Film-Forming Type:* These materials form a thin protective film over the leaf surface upon spraying, creating a physical barrier that restricts water vapor diffusion from leaf to atmosphere. Silicones, waxes, polyethylene compounds, and fatty alcohols are commonly used film-forming anti-transpirants.
- *Growth Retardant Type:* Chemicals like cycocel (CCC) suppress shoot growth while promoting root development. Reduced shoot growth lowers overall transpiration demand, while a more extensive root system improves the plant's ability to draw water from deeper soil layers, enhancing drought tolerance.

Integrated Pest and Disease Management

Pest management

Insect pests cause a yield loss of 33-40%. Growers relay on chemical control as first choice. Around 13- 14% of total pesticides used in the country are applied on vegetables. Parasitoids like *Apanteles taragamae* and *Therophilus javanus* both effectively managed *Maruca vitrata* (legume pod borer), *Diaphania indica* (cucurbits pest) and *Thala flavoorbitalis* (eggplant fruit and shoot borer). As plant protection measure, application of neem oil/neem seed kernel extract (4%), *Trichoderma*, *Jeevaamrit* and *Panchagavya* are effective and safe for vegetable crops. The number of predators, viz. spiders in cowpea and Coccinellids in cabbage survives and multiply significantly in organic field.

Disease management

Crop rotation with cereals reduces wilt of pea. Apply Trichoderma powder @ 5 kg/ha in soil within a week of ploughing of green manure crops is beneficial. Applying soil solarization covering the soil with a polythene sheet before transplanting eggplant and tomato has been shown to reduce Verticillium wilt incidence by 25 to 95 percent. Biological seed treatment by priming on seed, soaking the seeds, seedling dipping, dry powder treatments etc. are helpful. Treatment of Trichoderma (spore concentration 106 to 109 /ml) @ 5-8 g/kg of seeds or 10-20 g powder per m^2 area in nursery bed is essential. Green manuring of sunhemp along with soil application of Trichoderma @ 3-5 kg/ha, managed most of vegetable diseases. Foliar spray of *Aspergillus niger*-V isolate, control Alternaria blight and die-back/Anthracnose of chillies.

Conclusion

Due to climate change, the frequency of extreme weather events like heat, cold, drought, flooding, salinity stresses and changes in the level of atmospheric CO_2 or ozone have been tremendously increased. The exposure of vegetable crops to these types of abiotic stresses reduces yield and quality. Some of the key physiological and biochemical effects of abiotic stresses are membrane damage, oxidative burst, reduction of chlorophyll content and photosynthesis rate. So, to sustain the productivity of vegetable crops under changing climatic scenarios both adaptation and mitigation strategies are needed. Climate smart production practices, climate-resilient varieties, use of PGPR, suitable cultural practices, diversified cropping systems and mulching are required to be adopted.

Planning the Rabi Season: Crops, Varieties and Seed

Ananya Rao
Bihar Agricultural University, Sabour, Bihar, India

Abstract

Decisions taken before the rabi season begins, which crops to sow, in what proportions, of which varieties, and with what seed, set the terms on which the whole season will be conducted. This article discusses rabi planning: assessing the water and moisture actually available, matching crops and varieties to that assessment and to the sowing date, spreading risk across crops, and arranging seed of the right quality in good time. Planning made deliberately, and early, is the foundation of a productive and resilient winter season.

A season is largely decided before it starts. By the time the rabi crop is sown, the choices that matter most, of crop, of variety, of proportion of land, and of the seed that will be used, have already been made, and the management that follows can improve or spoil the outcome but cannot fundamentally change the terms. Planning is therefore not a preliminary to the season but its most consequential part.

The weeks around the kharif harvest are when this planning must be done, since seed must be arranged, fields allocated and inputs obtained before the sowing window opens. A plan settled at that point can be carried out promptly; one improvised as the window closes results in late sowing, whatever seed happens to be available, and a season conducted on someone else's terms.

Beginning with the Water

The first question in rabi planning is how much water the season will actually have. This means both the moisture stored in the soil at the end of the monsoon and the irrigation that can reasonably be expected, from a canal, a well, a pond, or the winter rains. An honest assessment is essential, and a season following a weak monsoon must be planned differently from one following a generous one.

Everything else follows from this assessment. A field with assured irrigation can carry a crop with high water requirements; a field with only residual moisture cannot, and attempting one there wastes both seed and effort. Matching the ambition of the plan to the water available is the single most important discipline of rabi planning.

Matching Crops to Conditions

Rabi offers a range of crops with different requirements, and the range is itself the farmer's chief resource. Cereals generally repay good conditions with high yields but need assured moisture; pulses and oilseeds tolerate more limited water and often finish sooner, and the pulses leave the soil enriched. Vegetables demand attention and inputs but return higher value from a smaller area where a market can be reached.

The crop chosen should also suit the soil, the drainage of the field, and the household's own needs for food, fodder and income. A plan that provides grain for the family, fodder for the animals and a marketable surplus is more robust than one that concentrates entirely on a single saleable crop, however profitable that crop appears at the time of sowing.

Variety and Sowing Date Together

Variety and sowing date must be decided together, since the right variety for an early sowing is often the wrong one for a late sowing. Where sowing will be timely, a variety of full duration can use the whole season and yield accordingly. Where the turnaround has been slow and sowing will be late, a shorter-duration variety that matures before the heat of spring will yield better than a long-duration one caught by terminal stress.

Varieties also differ in their tolerance of the particular difficulties of a locality, whether cold, salinity, drought or the prevalent diseases. Extension services and research recommendations identify the varieties suited to each region and situation, and following that guidance builds the appropriate resilience into the crop without the farmer needing to judge the underlying traits.

Spreading the Risk

Concentrating the whole holding on one crop of one variety exposes the household to the full consequences of any single failure, whether from weather, disease or a fall in price. Dividing the land between two or three crops, and using more than one variety of the main crop, spreads that exposure, so that a difficulty affecting one is unlikely to affect all.

Diversification also spreads the demands on labour and water across the season, since crops of different durations mature at different times, and it provides a variety of produce for the household. In an uncertain climate this is prudence rather than timidity, and it costs little in expected returns.

Arranging Seed in Good Time

Seed is the most common cause of an otherwise sound plan going wrong, because it is required at exactly the moment when everyone requires it. Estimating the quantity needed, allowing for the seed rate of each crop and the area intended, and obtaining it before the sowing window opens, prevents the substitution of whatever is available for what was actually chosen.

Quality matters as much as availability. Certified seed of a known variety, of good germination and free from admixture and weed seed, establishes a uniform, vigorous stand, and the difference is visible from emergence onward. Where farm-saved seed is used, it should be seed that was selected, threshed gently and stored carefully, and its germination should be tested before it is sown rather than assumed.

Preparing Inputs and Arrangements

Alongside seed, the plan should settle what fertiliser and manure will be applied and when, what seed treatment will be used, and what equipment will be needed for sowing. Manures that must decompose should be applied early enough to do so; soil test results, where available, should inform the fertiliser plan rather than being consulted after the event.

Arrangements for credit, for insurance, and for the hire of machinery are best made at this stage too. Each takes time, and each is far harder to arrange in the middle of a sowing season than a few weeks before it. Planning ahead here converts intentions into an operation that can actually be carried out on the day the field is ready.

Conclusion

The rabi season is shaped by decisions taken before it begins. Assessing honestly the water that will be available, matching crops and varieties to that water and to the likely sowing date, spreading risk across more than one crop, and securing good seed and the necessary inputs in good time together give the season its best foundation. Made deliberately and early, in the weeks when the kharif harvest is being gathered, such planning turns the turnaround between two seasons into a beginning rather than a scramble.