Resource Conserving Technologies in South Asia: Frequently Asked Questions



National Agricultural Innovation Project (NAIP)
Indian Council of Agricultural Research (ICAR)
International Maize and Wheat Improvement Center (CIMMYT)
Cereal Systems Initiative for South Asia (CSISA)

Citation: Jat, M.L.; Singh, Ravi G.; Sidhu, H.S.; Singh, U.P; Malik, R.K.; Kamboj, B.R.; Jat, R.K.; Singh, Vicky; Hussain, Israil; Mazid, M.A.; Sherchan, D.P.; Khan, Aqil; Singh, V.P.; Patil, S.G. and Gupta Raj. 2010. Resource Conserving Technologies in South Asia: Frequently Asked Questions. Technical Bulletin. International Maize and Wheat Improvement Center, New Delhi India. pp 44.

This publication was jointly supported by National Agricultural Innovation Project (NAIP) of the Indian Council of Agricultural Research (ICAR), Cereal Systems Initiative for South Asia (CSISA) and International Maize and Wheat Improvement Centre (CIMMYT). The views expressed in this publication are those of authors and do not necessarily reflect the views of NAIP, ICAR, CSISA or CIMMYT.

Resource Conserving Technologies in South Asia: Frequently Asked Questions

M L Jat, Ravi G Singh, H S Sidhu, U P Singh, R K Malik, B R Kamboj, R K Jat, Vicky Singh, Israil Hussain, M A Mazid, D P Sherchan, Aqil Khan, V P Singh, S G Patil and Raj Gupta

National Agricultural Innovation Project (NAIP)
Indian Council of Agricultural Research (ICAR)
International Maize and Wheat Improvement Center (CIMMYT)
Cereal Systems Initiative for South Asia (CSISA)
CG Block, National Agriculture Science Centre (NASC) Complex, DPS Marg,
New Delhi 110 012, India

2010

Authors

M L Jat, Cropping Systems Agronomist, CIMMYT, New Delhi

Ravi Gopal Singh, CSISA Hub Coordinator, Bihar Hub

H S Sidhu, CSISA Hub Coordinator, Punjab Hub

U P Singh, Professor (Agronomy), BHU, Varanasi

R K Malik, CSISA Hub Coordinator, Eastern UP Hub

B R Kamboj, Associate Professor (Agronomy), CCSHAU, KVK, Yamunanagar

R K Jat, Research Scientist (Weed Science), CIMMYT, Begusarai

Vicky Singh, Research Scientist, CSISA, Punjab Hub

Israil Hussain, Ag Engineer, Bangladesh

M A Mazid, CSISA Hub Coordinator, Dinazpur Hub

D P Sherchan, CSISA Hub Coordinator, Chitwan Hub

Aqil Khan, CSISA Hub Coordinator, Faisalabad Hub

V P Singh, Professor (Agronomy), GBPUAT, Pantnagar

S G Patil, Dean College of Agriculture, UAS, Raichur

Raj Gupta, South Asia Coordinator and Head CIMMYT, India & Bangladesh

Contents

Conservation Agriculture (CA) vis-à-vis Resource Conserving Technologies (RCTs)

1. What is Conservation Agriculture?

Conservation Agriculture (CA) is about adoption of innovative crop rotation in which crops are planted in minimum, no-till or drastically reduced tillage systems with some crop residue retention on the soil surface to reduce unproductive losses of water through evapo-transpiration and control weeds. Thus, CA is a concept for optimizing crop yields, and economic and environmental benefits.

2. What are the key elements of CA?

The key elements of CA include no-tillage, adequate retention of crop residues on the soil surface for mulching, innovative cropping systems and measure to reduce soil compaction through controlled traffic. Freewheeling of the farm machinery in moist fields creates ruts and compacts soil. This must be avoided if zero-till is to be practised for a longer time. These CA principles are not site-specific but represent 'unvarying objectives' that are practised to extend CA technologies efficiently across all production conditions. The way crop management is practised in different ecologies (*e.g.* plains and sloppy lands) may vary the importance of the "unvarying objectives' according to local situations, resource endowments of the farmers and farming systems. CA practices have been widely adopted in tropics/subtropical and temperate regions of the world for rain-fed and irrigated systems. Acreage of Cconservation agriculture is increasing steadily worldwide to cover about 108 m ha globally (7% of the world arable land area). Thus, CA is an innovation process of developing appropriate CA implements, crop cultivars, *etc.* for iterative guidance and fine-tuning to modify crop production technologies.

[Please note the distinction between Conservation Tillage (CT) and Conservation Agriculture. CT only refers to tillage practices that leave at least 30% of the soil surface covered by residues. Soil Conservation (SC), Conservation Tillage (CT) and Resource Conservation Technologies (RCTs) are not synonymous with Conservation Agriculture].

3. What differentiates CA from other RCTs?

Resource Conserving Technology (RCT) is a broad term that refers to any management approach or technology that increases factor productivity including land, labour, capital and inputs. RCTs include a wide range of practices including: no-till / minimum tillage, surface seeding, skip furrow irrigation inter-cropping, water harvesting and supplemental irrigation, mulching and residue

management, live fences and vegetative barriers. It may be clarified that not all RCTs may be compatible with CA (*e.g.*, land levelling in presence of residues).

4. What is the acceptability rate of zero tillage by South Asian farmers?

Farmers are gradually accepting zero tillage. The estimated total acreage of no-till /zero-till crops including direct seeded rice and surface seeded crops mentioned previously in South Asia (India, Pakistan, Nepal and Bangladesh) has been more than 3.0 million hectares in 2007-08. Zero-till is increasingly being adopted because it gives more yields at less cost, saves labour and water.

5. What are few major lessons learnt through adoption of ZT wheat?

The ZT wheat has a very positive impact on water and nutrient use efficiency, cost reduction and yield improvement due to timely sowing of wheat. There is a need to further accelerate the adoption of this technology in the irrigated areas. Even though the pace of adoption of CA is less than desired but there has been a dramatic reduction in tillage, leading towards minimum tillage. The zero-till technology can be adopted on long term basis without any adverse effect on biotic or abiotic factors. Zero tillage should always be practised with some surface retained residues. Residues moderate the soil temperature and conserve soil moisture for a longer time by reducing unproductive loss of water. This moderates the canopy temperature and keeps it cool.

Tillage and Crop Establishment Options

6. What is crop establishment?

Crop establishment is a sequence of events that includes seeding, seed germination, seedling emergence and development to the stage where the seedlings could be expected to grow to maturity. Establishment depends on the complex interaction over time of seed, soil, climatic, biotic, machinery and management factors. Therefore, it very important to understand the process of crop establishment and the factors that govern establishment for realizing potentiality of a particular tillage option under a set of situations.

7. What are crop establishment options for increasing the sustainability of rice-wheat systems?

Rice seedlings are generally transplanted in puddled soils. However, it can be grown as a direct seeded crop as well as transplanted crop in unpuddled soils either on the flats or raised beds. Rice nursery can be transplanted manually or by using a mechanical transplanter. Wheat can be established on flats or raised beds with zero-till ferti-seed drill/bed planter in reduced or no-till situation. Conventionally, wheat is planted after several ploughing, disking and planking operations. In rice-wheat cropping system, conservation agriculture can become a reality only if the practice of transplanting rice seedlings in puddled soil can be avoided.

Numerous field trials have shown that puddling can be avoided, and rice can be grown with some of the conservation agriculture practices evolved for the wheat crop. As the new systems of tillage and crop establishments are still evolving, farmers should give due attention to issues of weeds,

cultivar choices, nutrient and water management. Dry direct seeded rice is emerging as a viable alternative to puddle transplanted rice.

8. What is meant by zero tillage?

Zero-till system refers to planting crops with minimum of soil disturbance. In this, seeds are placed directly into narrow slits 2-3 cm wide and 4-7 cm deep made with a drill fitted with chisel, "inverted T" or double disc openers without land preparation.

9. Do farmers need to close the slit after seeding?

Sometimes farmers feel that birds will pick the seed from the narrow open slit if not closed through planking. Our experiences do not support this contention particularly when seed is placed 5-7cm deep into the soil. Open slits, on the other hand, facilitate seed germination and emergence of wheat and other crops, particularly in winter season due to significant dew factor. Presence of residues on the soil surface conserves soil moisture, helps control weeds and also saves seed from the birds to pickup.

Germination in open slits under zero tillage

10. What are the advantages of bed planting system?

Bed planting promotes saving in irrigation, inter cropping and diversification. Bed planting helps in overcoming abiotic stresses (salinity or temporary water logging). It saves the costly seed and improves seed quality and yields.

11. How zero tillage system is different from reduced tillage system?

Zero tillage disturbs the soil minimally to the extent of placement of the seeds and fertilizer nutrients in the very narrow slits, opened with inverted T / chisel type openers or the double disc type openers. With punch planter, soil disturbance during seeding is minimal. Mechanical punch planter operates like manual dibble. In the reduced till system, tillage per se still exists, but number of preparatory tillage operations are reduced significantly. Disk plow or inversion plow are generally avoided in reduced till systems. Planting with strip-till drill and rotavator drill represents reduced till system. Any light/shallow tillage before planting with zero-till drill is also representative of reduced till system. Experience has now shown that rotavator is not a useful technology and hence should be avoided.

12. How long can zero tillage systems be practised continuously?

Zero tillage for crops such as wheat can be practised continuously without disadvantage with a few common caveats: rice is not puddled and weeds can be effectively and economically controlled. Surface mulch and herbicide use for 2-3 transition years can greatly reduce weed problems in zero-

till. Experience has shown that zero tillage in rice-wheat cropping system can be practised continuously for more than 5-6 years.

13. Is zero tillage possible in all types of soils?

Yes, zero-till system can be practised on most soils, except excessively hard set, compacted and wet soils.

14. What are advantages of zero tillage in partially reclaimed alkali or saline soils?

In most partially reclaimed alkali soils, only the surface soil has been ameliorated through gypsum usage. Tillage with cultivator or a disc harrow brings subsurface soil to the surface, increasing sodicity in the seed zone. Similarly, after a pre-sowing irrigation, salinity in the seed zone is minimum, increasing with soil depth. Tillage by inversion plow or harrow will bring the saline soil underneath to the soil surface increasing the salinity in the seed zone. Any increase in the levels of sodicity/ salinity in the seed zone will decrease germination of salt-sensitive cultivars. Since zero-till system does not disturb the soil, crop stand establishment is often better in zero-till reclaimed fields. In partially reclaimed sodic/ alkali soils, bed planting may give best results as it doubles rooting depth in ridges.

When irrigation water is saline, it is better to seed crop in furrows, and let the salts accumulate in ridges. To leach these salts out of the ridges, rain water should not be allowed to go out of the fields, and ridges may be kept submerged during monsoon.

15. What is the difference between surface seeding and zero-till planting?

With surface seeding, seeds are placed onto the surface of untilled soils. This can be done in a wet soil condition or dry with the later followed by irrigation to facilitate seed germination.. In either case, surface seeding entails no soil disturbance whereas typical zero-till systems cause minimal soil disturbance during opening of the slits. Surface seeding can be done either by seed broadcasting method or by placing seed/fertilizer in rows by machine. Crops, such as wheat, lentil, mungbean linseed, green peas, Brassica and chickpea can be successfully surface seeded. In addition to reduced labour requirements, surface seeding can facilitate timely establishment when soil wet and machine access limited.

Surface seeded wheat in zero till

16. What planting system is best for moderately (partially reclaimed) alkali soils?

Zero tillage is useful for planting crops in partially reclaimed soils. Seeds placed in undisturbed partially reclaimed surface soil layers facilitate good germination and growth. Conventional tillage

of such soils rather brings forth the sub-surface alkali (sodic) soil to the seed zone and thus adversely affects germination and crop stand. In partially reclaimed sodic lands, bed planting may give best results as it doubles rooting depth in ridges. When irrigation water is saline, it is better to seed crop in furrows, and let the salts accumulate in ridges. To leach these salts out of the ridges, rain water should not be allowed to go out of the fields, and ridges may be kept submerged during monsoon.

Wheat planted on raised beds in Sodic lands

Wheat planted in furrows and saline water application

17. How does zero-till planting benefit farmers who plant their crops on time?

Zero-till eliminates the need for the number of tillage operations, reduces planting time and saves fuel and labour costs in both timely planting and late planting situations. It has also been observed that yield gains due to zero-till planting are more in areas where late planting is a common feature as compared to timely sown areas. Thus, farmers in the eastern IGP who routinely plant their crops late can have twin benefits of higher yields and reduction in tillage cost by adopting zero-till planting. Experience has shown that the benefits of ZT are even greater in early sown wheat because of increase in the input use efficiency.

18. Why should one shift to zero tillage system? What are its advantages over the conventional systems of planting wheat and other upland crops?

Traditionally, farmers sow wheat after rice after tilling their fields for 6-8 times with disc-harrow and cultivator, followed by 2-3 planking. This increases production cost, delays wheat planting, and also results in losses of residual soil moisture after rice harvest which could have been used for establishment of the succeeding wheat crop. In contrast, zero tillage saves planting time, fuel and water, can improve the efficiency of applied fertilizers nutrients, reduces populations of Phalaris minor, reduces wear and tear of tractor, and helps reduce air pollution. It is observed that zero tillage increases farmers' profit by Rs. 2,200-3,000/ha (US$50-70). Zero tillage saves water and reduces weed pressure.

In undisturbed condition, water flows over the soil surface quicker and so a light irrigation can be applied in zero-till fields. With tilled soils, irrigation water front advances slowly resulting in more water infiltrating into the plowed soil layers causing a waterlogged type situation leading to yellowing of the leaves. Zero-till wheat has little or no yellowing following irrigation.

19. What are the reasons for poor germination and seedling emergence?

Delayed emergence of seedlings indicates a symptomatic problem of the low soil moisture in seeding zone, deep placement of seed, surface crusting, salt buildup and/or use of poor quality seed material. When crops are dry seeded, it is most important to place seed close to soil surface (reduce seed depth to recommended half depth) and irrigate the fields immediately to facilitate proper germination. In crusting soils, it is better to seed dry in controlled traffic plots (wide beds) and then use the traffic lanes for irrigation to avoid germination problems due to surface crusting. It is advised to irrigate slowly so that sufficient moisture is subbed into the beds for proper germination.

20. What should be the proper moisture regime for seeding with zero-till drill?

In zero tillage system, germination and emergence of seedlings is better when soil moisture content is 3-4% more at sowing time as compared with the conventional tillage. If wheat planting is delayed, then soil moisture typically becomes sub-optima without irrigation. If irrigation is applied earlier, then anchored rice stubbles become too week and interfere with wheat planting. This problem can be resolved by using a turbo seeder or dry seeding the wheat crop and then applying irrigation water, if turbo seeder is not available for planting.

21. How good crop stand can be established with post-sowing irrigation in zero-till fields?

When crops are dry seeded, it is most important to place seed close to soil surface (reduce seed depth to recommended half) and irrigate the fields immediately to facilitate proper germination. In crusting soils, it is better to seed dry in controlled traffic plots (wide beds) and then use the traffic lanes for irrigation to avoid germination problems due to surface crusting. It is advised to irrigate slowly so that sufficient moisture is subbed into the beds for proper germination.

22. What measures farmers should adopt to plant their crops timely when soil moisture is less at the sowing time?

The zero-till options that farmers can exercise in different situations for planting are outlined as under:

- If the soil has sufficient moisture (at crop harvest) but is likely to be lost quickly due to strong winds, it is better to advance first irrigation by a week to ensure good crop stand. Retaining crop residue on surface can help to reduce moisture loss.
- If soil is relatively dry and pre-sowing irrigation is likely to further delay seeding, it is best to place seeds within surface 2-3 cm and apply a light irrigation immediately thereafter to fasten seed germination and to have a good crop stand. If dry seeding is inevitable practice,

wide bed controlled traffic technique for seeding and irrigation avoids crusting problems and facilitate good crop stand.

Advancing planting through dry seeding

- Pre-sowing irrigation promotes weeds establishment ahead of crop. In order to control weeds, farmers generally practice very shallow ploughing or use of systemic pre-plant herbicides (glyphosate). Stale seed beds technique (allow weed to germinate before planting) can reduce the weed pressure if pre-plant herbicides are used to control germinated weeds before crop planting. In case of direct dry seeded rice, a combined use of pre- and post-emergence herbicide can prove very useful for a significant reduction of weed pressure.

23. Do RCTs (zero tillage and bed planting) suitable for dry land farming?

Yes, zero tillage has greater potential in untapped dry land areas. Zero tillage with surface retention of crop residues or other mulching sources aim at increasing soil moisture storage, reduce soil erosion and buildup of soil organic matter that would directly benefit the productivity of dry lands. Raised beds with tide ridges help in conserving *in-situ* soil moisture and have a direct bearing on the crop productivity. The residue management complements further in improving moisture/nutrient storage and crop yield. Hedge planting with wind breaks would further benefit in conserving soil moisture.

24. Is proper land management essential before deploying RCTs in dry lands?

Yes. Land levelling, terrace and inter-terrace management improve moisture storage. The residues complement the land management in preventing run-off and soil erosion.

Zero-till Rice-Wheat Systems

25. What are the pre-requisites for obtaining higher yield in zero tillage system?

For good crop stand in zero-till system, it is important that fields are properly levelled, kept weed-free, have sufficient soil moisture at planting time and the drill is properly calibrated and levelled. Residues of the previous crop, if lodged, create serious problem in the planting operations of the drill fitted with inverted T openers. It is better to use turbo seeder to overcome residue raking problems in combine harvested areas and also where previous crop has lodged. Drills with double

Paired row planting of rice

disk coulters can also be used. If a normal zero-till drill is to be used for planting into loose residues, chopper should be used before zero tilling to facilitate an easier planting. Sowing with a properly maintained drill in paired rows helps improve crop productivity by nearly 5%. Paired row planting mimics raised bed planting in some ways and improved crop yields.

26. Do wheat yields increase with zero tillage?

Puddling in rice adversely afftect the wheat yields. In order to improve wheat yields, it is prudent that rice and wheat crops are grown as direct seeded crops or rice be transplanted without puddling. It facilitates timely planting and improves crop stand establishment and yields. Zero-till typically results in higher profits both through cost reducing (~ US$ 50-70 Rs 2,200-3,000/ ha) and yield enhancing effects. Experimental results suggest that zero tillage improves the productivity of wheat and other winter crops more in the eastern Gangetic plains than north-west plains. Yield data in figure (??) indicate that the benefits of timely planting could be as high as close to a ton/ ha in eastern plains.

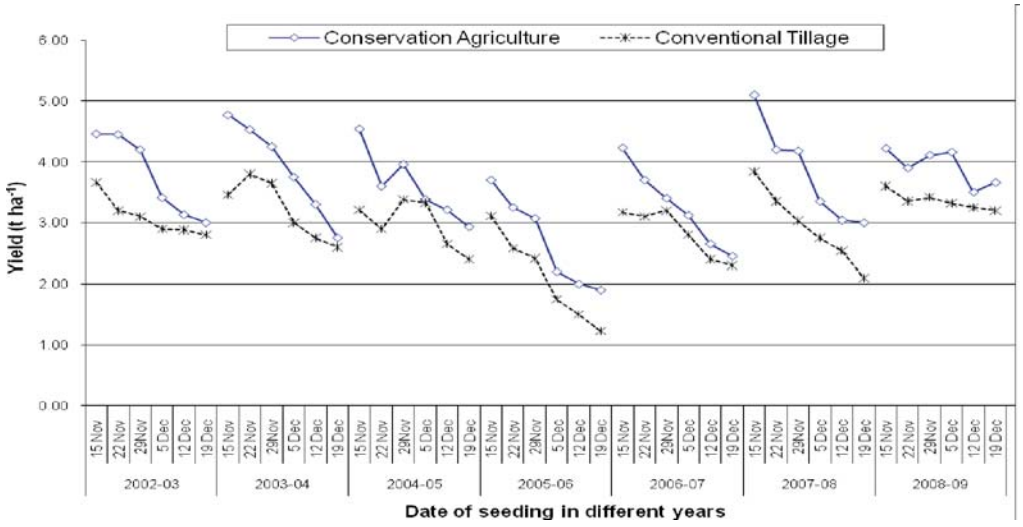
27. What is the magnitude of the productivity loss due to late planting of wheat?

Optimal wheat planting time in the north-west parts of the Indo-Gangetic Plains (IGP) was earlier considered to be around 8-15 November, whereas in the eastern Gangetic plains the second half of the November was considered best. Delayed planting can result in yield losses of 30-35 kg/ha/per day in north-west parts of IGP and 50-65 kg/ha/day in the east. More yield losses in eastern Gangetic plains are due to the shorter duration of cooler temperatures that favour wheat growth.

However, due to recent changes in climate, new emerging evidences suggest that it is better to plant wheat in the first half of November across the IGP.

28. How can ZT help farmers avoid late planting of wheat and other winter crops?

Sowing of wheat and other winter season crops often gets delayed because of the previous crop (late transplanting of rice crop, long-duration scented rice and cotton vacating the fields late in the



Wheat yields in conservation agriculture till and conventional tillage under different seeding dates for seven years (2002-03 to 2008-09) (Source: U.P. Singh)

season). The delays could be from 3-6 weeks using zero tillage machines. Farmer can plant wheat and other crops if he can enter his rice fields with a tractor without creating ruts.

29. How can wheat be planted if the rice soils are too wet or have passed the surface seeding soil moisture conditions?

Operation of the tractor in the wet condition spoils the level of the fields and creates ruts. To avoid late planting of wheat and other crops after rice harvest, it is best to go for surface seeding under such situations. If the soil moisture is relatively less than the optimal for surface seeding (soil moisture generally glistens on applying pressure), it is advised to toss the seed and irrigate to avoid delay in planting.

30. Can mungbean relay cropping into wheat make late irrigation for heat stress mitigation more profitable?

High temperature can shorten the grain filling period, hasten maturity, and reduce harvest index and the grain yield in wheat. In order to overcome the potentially adverse affect of heat stress, it is usually beneficial to irrigate wheat during grain fill. Many farmers, however, do not apply this last irrigation for fear of crop lodging. If mung or another suitable green manure crop is seeded into standing wheat and then immediately irrigated, two benefits can be realized from the late irrigation for wheat : mitigating heat stress and establishing a legume crop. Mungbean does not affect combine operations in wheat and will not itself be damaged if the cutting blade is raised by 15 cm above the soil surface.

CA Machinery

31. What is a zero-till drill and how it is different from the conventional drill?

Conventional seed drill generally has seed and fertilizer boxes, wide shovel type furrow openers, seed metering device, seed and fertilizer delivery tubes and seed depth control wheels. Zero-till ferti-seed drill has all these components except that the wide furrow openers are replaced with chisel or "inverted T" type openers to place seeds and fertilizers in narrow slits with minimal soil disturbance. To facilitate seeding into loose residues, double disc type furrow openers and star-wheel (dibble) type openers can also be used with the existing zero-till seed-cum-ferti-drill. Farmers conventionally plank after seeding to cover seeds planted with the conventional seed drills. Zero-till seed-cum-ferti-drill planted crop does not require planking. In fact, zero-till performance improves if seeds of *rabi* crops are not covered. This is mainly due to dew factor, received in significant amounts to facilitate germination.

Inverted T opener

32. How zero-till drill is different from zero-till planter and which is better?

The zero till-drill and planters are different in respect to seed metering system but not in relation to furrow openers. In zero-till drills, the seed flow is continuous and there is no mechanism for maintaining seed to seed distance in a row and also the drills are mainly suitable for some specific crops. Whereas zero-till planters always maintain seed to seed and row to row distance and can be used as multi-crop planters. The multi-crop planters are always better than drill if they fit in to different cropping systems. The planters also have adjustable tines for planting different crops.

33. What is the difference between the bed planter and the zero till machine? Is it that zero-till drill can be used for planting on raised beds?

If a bed shaper is attached to the front bar of the zero-till drill, it converts into bed planter. Raised beds can be formed after preparatory tillage with a disc harrow. The shaper simultaneously opens furrows and makes raised beds. After beds are formed they can be kept permanently with minimal reshaping performed on an 'as needed' basis. Shape, size and spacing between raised beds can be adjusted depending on the crop to be seeded and spacing between front tractor tyres. For many tractor models, raised bed and furrows which are 37 and 30 cm wide, respectively, are best suited. Furrows can be kept 15cm deep. It is possible to reshape beds and place seeds and fertilizers nutrients in a single operation with the bed planter (FIRB planter). If the shaper is not needed to reshape raised beds, it can be removed or raised up.

Zero-till multi-crop planter

Raised bed planter

34. How much area can be sown with a zero-till machine?

A trained tractor operator can plant one acre in an hour. Zero-till seed-cum-ferti-drill can typically plant 4-5 hectares in 8 hours. Custom service providers, who operate in double shifts, can cover about 10-12 hectares per day.

35. How does ZT affect fuel consumption?

Energy requirement for pulling 9-11 tyne conventional seed drill and zero-till drill is almost the same. The fuel consumption usually ranges between 10 and 12 litres per hectare. A properly serviced 25 horse power tractor can easily pull a zero-till ferti-seed drill without any extra load on the tractor in the proper soil moisture regime. But the major advantage of ZT systems is that the energy requirement for land preparation are foregone but needed with conventional seed drill.

36. How to reduce soil compaction due to tractor movement in zero-till situation?

Controlled traffic, entering the field from fixed points and operating the tractor in the same tracks each time, is an efficient way to avoid wide spread soil compaction in ZT. In raised bed planting systems, only furrows used for irrigation are compacted by tractor operations. In these systems, controlled traffic in the furrows also serves to reduce deep percolation of irrigation water. Alleyways for controlled traffic are not typically planted. In most circumstances, the planting arrangements required to accommodate these alleyways do not reduce yield.

37. Are there any yield losses in controlled traffic zero-till planting system?

By not seeding in the tractor tracks, border effect compensates for the missing rows, saves costly seeds and it does not in any way reduce crop yields. The tyre tracks can subsequently serve as

irrigation-cum-drainage channels and also as operation galleries for mechanical inter-culture operations, chemical sprays and soil application of fertilizer nutrients in the standing crop. Border effect (more light and space) is more prominent in the raised bed planting system where after every two rows, one seed row is missed.

Controlled Traffic Planting

38. How land levelling is important in adoption of zero tillage technology?

Land levelling facilitates uniform application of irrigation water and optimizes nutrient-water interactions for higher productivity. Land levelling by a laser-assisted precision land levelling system can save up to 25 % irrigation water and improve crop yields and input use efficiency by several notches. It is a precursor technology that will enhance benefits of zero-tillage and any other crop establishment system such as bed planting.

39. Is zero tillage advised for all cropping systems?

Zero tillage has been practised throughout the world in the wide range of cropping systems. In some situations, such as planting wheat after sugarcane, it becomes necessary to use a disc harrow for easy working with zero-till drill and for avoiding damage to drill from hard sugarcane rootstocks. With zero-till ferti-seed drill fitted with star wheel (punch planting) openers, problem of residues or rootstocks mentioned above can be easily eliminated. Shallow tillage (zero harrowing) may also be necessary if weeds are a problem in the field. Zero tillage can be done in one or both the crops grown under most of the predominant cropping systems like rice-wheat-mungbean, cotton-wheat, rice-maize, peral millet-wheat, sorghum-wheat, rice-pulses, sugarcane-wheat, *etc*.

40. What is the new machine– Turbo seeder?

The new machine called 'Turbo Seeder' is a modified, advanced and light weight version of the PAU-ACIAR developed 'Happy Seeder' to plant in presence of loose and or anchored residues. Turbo seeder differs from Happy Seeder in type of the cutting blades, provision for adjustment of the rows, seed metering system and is lighter in weight. This seeder/ planter can be operated with a 35HP tractor unlike the Happy seeder which required a double clutch heavier duty tractor. Turbo seeder has been found to work satisfactorily in combine harvested fields. This machine has been field tested extensively in Punjab, Haryana and other states. This machine can easily handle over 8 tons/ha of rice crop residues provided they are uniformly spread across the field.

41. Why crop planted with rotavator generally lodges? Is it a good tillage implement?

Rotavator was introduced to farmers as a reduced till implement. However, the farmers who used this machine have pointed out that rotavator:

Combo Happy Seeder

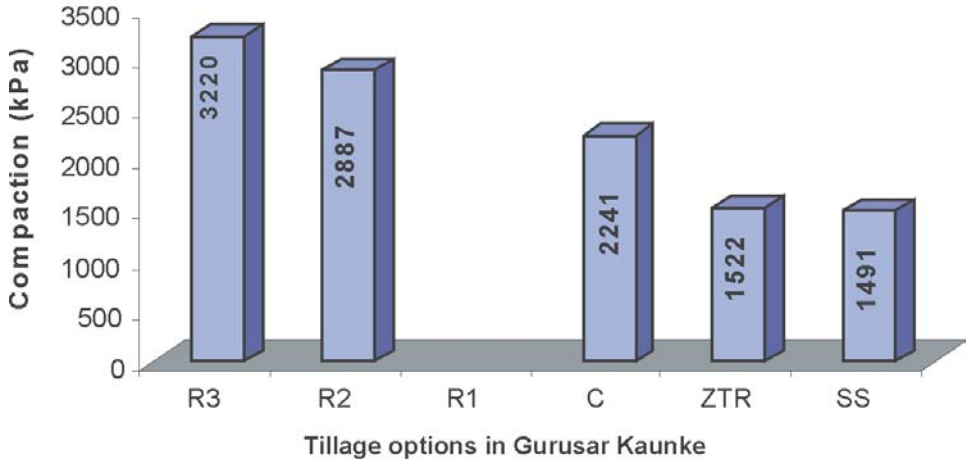
Turbo Happy Seeder

- Reduces infiltration rate and causes temporary water stagnation after an irrigation and rainfall event.
- Causes yellowing especially after irrigation at crown root initiation stage in wheat.
- Leads to uneven seed depth and decreased tillers per plant.
- Poor root development– Roots are surface feeder which leads to crop lodging.
- It increases the population of Phalaris minor.

Rotarator Till-Broacast Sowing

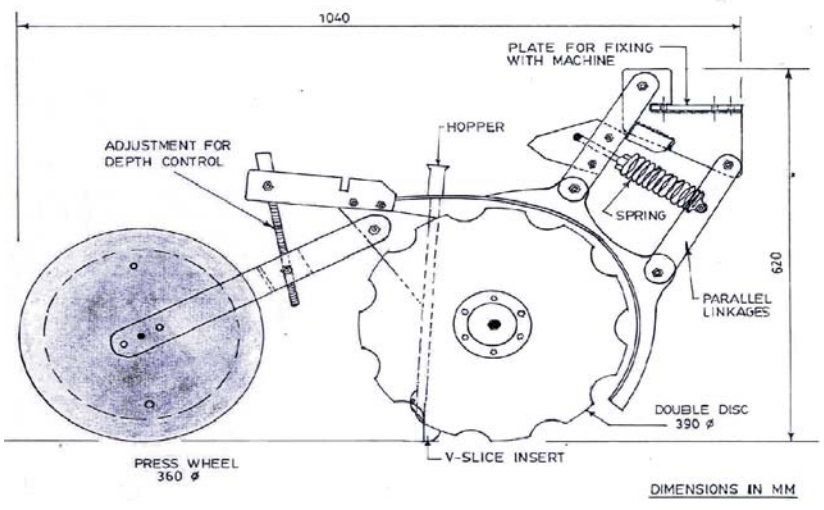
- Crop yields either remain same or decrease as compared with conventional tillage.
- Does not allow crop planting and fertilizer application in rows (placement of seed and fertilizer).
- Need clean fields for tillage thereby promote burning of crop residues.
- Causes soil compaction of 15-20 cm soil layer.
- Requires more nitrogen and phosphorus to harvest similar yields.

Since the rotavator has introduced bad practices of seeding and fertiliser application by broadcasting, and residue burning, causing soil compaction and all other associated adverse affects, its use should be discouraged and avoided unless the new blades become available. However, if the L shaped blades of rotavator can be replaced with C type blades, it can be easily converted into strip till planter/drill with advantage.



Effect of different tillage practices on soil compaction (KPa) (Source: H.S. Sidhu)

42. What is the notched double disc opener?



Design of notched double disc opener (Source: H.S. Sidhu)

A notched double disc furrow opener can also be used for direct drilling or in a no-till drilling machine. This opener can be mounted very easily on simple bar and then to three point linkage on the tractor. Self-cleaning 11 and 15 notch 15 inch discs aggressively chew through the residue to clear a path for the machine to provide precision seed placement in a V-Slice (groove) in moist soil-below the cut of the disc blades. The notched disks are self-sharpening, self-cleaning, high chromium alloy capable of handling light residue loads. Each furrow opener is spring loaded and independent, and follows the geometry of the field hence keep seed depth uniform. But these furrow openers are costlier than the inverted T type furrow openers.

43. What is straw management system (SMS) for combine harvester and why it is required?

To avoid straw burning, efforts were made to develop suitable equipment for direct drilling in combine harvested paddy fields, *i.e.* second generation drills like Turbo Happy Seeder and powered rotary discs, *etc*. These second generation drills help in direct sowing of wheat in combine harvested rice field without straw removal or burning. However, evenly spread loose straw is a precondition for the smooth operations of all second generation drills and this operation takes around 8-13 man-h/ha for spreading of loose straw. It was also observed that it is very difficult to spread the entangled dry loose rice straw due to its light weight. A straw management system

(SMS) as an attachment to the existing conventional combine harvester for managing and spreading the loose straw evenly in the harvested area. Very simple two-counter rotating discs are provided and the drive to the counter rotating discs of SMS is given from the engine/tractor PTO through belt and pulley and its spreading efficiency was found to be 85 90%. The cost of this attachment is about Rs. 15000/-.

Straw Spreader attachement in combine harvestor (Source: H.S. Sidhu)

44. What is the machine called relay wheat planter in standing cotton?

The self-propelled and tractor drawn machine that can plant wheat in standing cotton is called relay planter. In cotton-wheat cropping system of south Asia, the wheat productivity is generally 1 to 1.5 t/ha low compared to wheat planted after rice mainly due to delayed planting as cotton vacates the field late. In this condition, a small self-propelled planter has been developed and successfully demonstrated for relay planting of wheat. The tractor drawn planters are also available but due to non-availability of high clearance tractors across south Asia, farmers are not able to use them. This planter has a very high potential to bridge the yield gap in cotton-wheat system.

2-Wheel relay planter

Relay planted wheat in cotton

45. Who provides CA equipment?

Farmers need good prototypes of seed and fertiliser drills and planters for seeding into unploughed fields in the presence and absence of crop residues covering the soil surface. Although the national policy focuses on agriculture and the manufacturing sectors, little attention is paid to farmers' need for good agricultural implements. The largest private sector- agriculture is mainly serviced by the small and marginal private entrepreneurs (SMEs). In promotion of conservation agriculture the custom service providers (*e.g.,* laser land levelling, zero-till, seeding, input dealers and contract farming units) are playing a very significant role. Unfortunately, in spite of the acknowledged role of these services in the national economy, the sector doesn't feature adequately in research since it

is perceived as involving mainly the job-less, who are considered as unable to generate opportunities at the lower skill levels. In reality, services such as on land levelling, and zero-till/ raised bed planting are providing employment opportunities to job-less rural youths and trade-induced employment in manufacturing and transport related sectors.

Crop Establishment and Growth

46. Are all modern crop cultivars suitable for planting in zero-till systems?

All modern cultivars do not not perform equally well in the zero-till, surface seeding and bed planting systems. Modern cultivars that are vigorous in the initial growth stages and cover soil effectively compete better with weeds. All such cultivars generally should be preferred choice of the farmers if prevailing marketing and pricing policies also permit such cultivar choice. For direct dry seeded rice (with or without some preparatory tillage) , the following rice cultivars are well adapted:

Cultivar choice for DSR in different production environments

Sl. No.	Areas/Cropping Systems	Preferred Variety/ Hybrids
1.	Punjab, India (Rice-wheat)	PAU 201, Arize 6129, Pusa 1121 (Sugandha 4), CSR-30, Pusa Basmati-1, Proagro 6444
2.	Western UP and Haryana (Rice-wheat, Rice-potato-wheat /maize /sunflower)	CSR-30, Pusa 1121 (Sugandha 4), Pusa 2511 (Sugandha 5), PRH-10, Pusa Basmati-1, Tarawadi Basmati, PAU 201, Pant Dhan-12, Sharbati, Arize 6129, Proagro-6444
3.	Eastern UP (Rice-wheat, rice-maize pulses, Rice-potato-maize)	NDR 359, Sarjoo 52, Mahsoori, Swarna (MTU 7029) Moti, PAU 201, Arize 6129, Proagro 6444
4.	Tarai of Uttaranchal (Rice-wheat)	Nidhi, UPRI-92-79, Narendra-359 and PD 4, Sarbati, PR-113, HKR-120, Sarjoo-52
5.	Bihar (Rice-wheat, rice-maize/pulses, Rice-potato-/+ maize)	Rajendra Mahsuri-1, Swarna, MTU 1001,PAU 201, NDR 359, Prabhat (OPV), PHB -71, Proagro 6444 RH 664 (hybrids)
6.	Tarai of Nepal (Rice-wheat/pulses)	Sona Masuli, Hardinath, Radha-4, Radha-11
7.	Bangladesh (Rice-rice, rice-wheat, rice-maize, rice-potato-/+maize)	BRRI Dhan 33, BRRI Dhan 39, BRRI Dhan 44 and Zata
8	Multi-location trials by DRR Hyderabad (rice-rice, rice-maize/pulses)	IET 9994, Vikas, Rasi, Krishna Hamsa
9	Punjab, Pakistan (Rice-wheat)	Basmati Super, Basmati-385, IRRI-6, KSK-282, Niab-9

47. What are the precautions for high productivity of direct dry seeded and unpuddled transplanted rice on the raised beds and flats?

High crop yield can be obtained if important points mentioned as under are taken into consideration:

- Field should be properly levelled.
- Choose suitable cultivar based on upland and lowland conditions.
- Pendimethalin should be pre-requisite as pre-emergence in upland conditions.
- Make sure that the raised beds are not missed (there should be 100 beds in 67 m).
- Seed depth should not be more than 1-3 cm.
- Seed rate should not be more than 20 kg/ha for medium-fine rice and 10 kg/ha for fine scented rice.
- Transplant 2-rows at 25 cm on each bed and keep spacing between plants at 10 cm.
- Don't reshape the beds in rice season. Keep beds shallow for easy submergence.
- Use pretilachor or other herbicides within 2 days of seeding rice.
- Keep soil submerged up to 10-15 days after seedling emergence.
- Keep some crop residues on surface or practice green manuring.

48. What are the other crops besides that can be planted with zero-till machine?

Zero-till drills of different makes are usually fitted with various seeding devices such as fluted rollers, cupping devices, inclined rotating disc plates with notches/cells, vertical plates. Drills with fluted rollers can easily handle large sized seeds but planting of crops with small and light weight seeds such as Indian mustard or rice having long awns and hairs on the seed coat is difficult. For seeding small grains, farmers generally mix sand/ash with seed to increase volume of the seeding material for uniform distribution. The multi-crop planter-cum-zero-till machine, available in the market, can sow almost all cereal and pulse crops. The different type of seed metering systems fitted to planters/drills are depicted below.

A **B** **C** **D** **E**

Seed metering systems: A-Fluted roller, B- Cupping type, C- Inclined plate, D-Brass roller, E- Vertical plate (The metering systems except A are precise and can be used as multi-crops)

49. What is the procedure for calibrating a seed-cum-fertilizer drill?

Seed metering devices can increase or decrease seed rates within specified limits. To calibrate to a desired seed rate, first fix seed metering lever in appropriate seed rate delivery notch. Measure circumference of drive wheel (Cd). Measure width of the drill (Wd) or else multiply the number of tynes with distance between two tynes. Put seed material in seed box and rotate drive wheel manually to ten full rotations and collect seed delivered from each tube separately in polythene bags. Weigh seeds in each bag and also determine the total seed weight (Sw). If the difference in seed weight between individual delivery tubes is more than 10%, contact a mechanic to adjustment or repair the drill. Repeat operations with fertilizers in box to find weight of fertilizer material (Fw) delivered in 10 full rotations of the drive wheel as described. Calculate seed and fertilizer application rate per hectare using the following formula:

$$\text{Seed rate (kg/ha)} = \{Sw / (Cd \times Wd)\}$$

where Sw (or Fw) = Total weight of the seeds or fertilizers released in 10 revolutions (gm)

Cd = Circumference of drive wheel (m);

Wd = Width of the drill (m).

Fertilizer rate (kg per hectare) can be determined using the same formula by substituting the total weight of fertilizer released in grams (Fw) in place of total weight of seeds (Sw).

It is cautioned that calculated seed and fertilizer rates can differ by 5% from the actual rates due to drag and slippage of the drive wheel depending upon the soil moisture, surface roughness, presence of crop residues and field level. Carry out minor adjustment in seed/fertilizer rates by testing the drill in the field.

50. What is the role of tractor speed in resultant crop stand?

Theoretically, speed of the tractor does not affect number of revolutions of the seed metering device per unit distance travelled. However, in practice, tractor speed more than 4-5 km/h increases slippage of the drive wheel on uneven surfaces. Increased slippage leads to uneven crop stand that may result in reduced yields. To have good crop stands and reduced labour in filling gaps or in thinning operation, it is advisable to run tractor at the speed closer to 4-5 km/h.

51. Should seed rates change in zero-till crops?

Since seed is drilled with ZT drill, less seed is needed than traditional broadcasting system.

52. How can one control seed depth in zero-till planted crops?

Zero-till drills have depth control wheels to regulate placement of seeds/fertilizers at the desired depths. Through adjustment of the knobs/ screws, wheels can be lifted up or down to regulate depth for seed placement. A precisely levelled field facilitate seeding at desired soil depth.

53. Is it possible to place seeds in narrow slits without spill over?

With a good quality zero-till ferti-seed drill, generally all seeds and fertilizers can be placed in the narrow slit and birds can not pick these seeds. However, some seeds may still fall in the vicinity of the slit, depending upon the surface roughness and the tractor speed. To avoid picking of these seeds by birds following measures can be adopted:

- Treat seeds before sowing with cow dung to give foul smell. This seed treatment is good for surface seeding but creates problem with seed flow in the drill. Don't treat seeds with poisonous substances.
- Anchored /standing residues of the previous crop may be mulched with a 'shrub master/ chopper' after seeding. Mulching stops birds from picking even spilled-over seeds and significantly improves initial crop growth. Some of the spill- over seed germinates after first irrigation if not picked up by the birds.

54. Is it necessary to use primed seed in zero-till system?

Seed priming generally improves germination and helps in early emergence of seedlings. For priming, rice and wheat seeds may be soaked in water for 6-8 hours and then dried in shade before seeding. Although priming is not needed with good soil moisture, it is a low risk and low cost practice which can aid the uniformity and timeliness of crop establishment in many circumstances.

55. Can seed priming be combined with seed treatment before seeding with the zero-till drills?

The primed seed when treated with some chemical molecules such as maize with Gaucho and wheat with Cruiser type molecules improve initial vigour of the young seedlings. For this reason a new term 'crop enhancement' is used.

56. Is planking necessary in zero-till wheat?

Planking is usually done to establish a good soil-seed contact in tilled soil and to avoid seed picking by birds. In zero-till planted systems, birds are usually not able to pick seeds due to narrow and deep slit. An additional advantage of keeping slits open is that seeds exposed to air in winter nights gain moisture from the humid ambient atmosphere. And resistance of the soil to seedling emergence is minimal. So there is no need to cover seeds placed in narrow slits by planking particularly in winter crops.

57. Does rains after planting with zero-till drill prevent germination of crops?

Rains after seeding in ZT may cause crusting and also close open slits to delay emergence of the seedlings. However, it will not typically stop it. If the soil surface is partially covered with residues (*e.g.,* with Conservation Agriculture), soil slaking and crusting are minimal. If crusting is a problem and it hardens on drying, it is better to apply light irrigation to weaken the strength of the siliceous crust. Iron rich crusts can only be weakened mechanically.

58. How to plant timely in inadequate soil moisture situations of zero-till system?

In situations where planting is getting late or already delayed and soil moisture is inadequate, a pre-sowing irrigation is likely to further delay the sowing of crop and also facilitate the weeds to establish ahead of the crop. In such situations, it is advisable to place the seed at shallow depth in relatively dry field and apply a light irrigation subsequently. Remember, depth of seed placement should be reduced to half or less in such a situation.

59. How to seed crops in excessively moist soils to avoid late planting?

After rice harvest, or after the rainfall even during monsoon season, it is not possible for the soils to attain workable moisture conditions soon enough for tillage with machinery. Under these circumstances, farmers are often either unable to plant, plant very late in the season, or are forced to keep the fields fallow. Surface seeding is a good option for timely establishment of crops under such situations. In this seeds are tossed directly on to the wet soil surface with crop residues. Soil moisture for surface seeding is adjudged optimum if soil moisture glistens in foot prints. If it does not, it is better to apply little more water to achieve desired moisture for surface seeding. Some crops like linseed, lentil, pea and Brassica can be easily grown.

60. What is seed enrichment? Does it improve seed germination?

Seed enrichment is a practice of enriching seeds with essential nutrients for growth. This can be achieved by treating seeds with dilute nutrient mixture solutions before planting. Alternately, nutrient mixture solutions sprayed at the grain-filling stage can enrich the seeds that can be used for next season planting. Nutrient enriched seeds typically result in more vigorous initial crop growth.

61. Does zero-till adversely affect root growth?

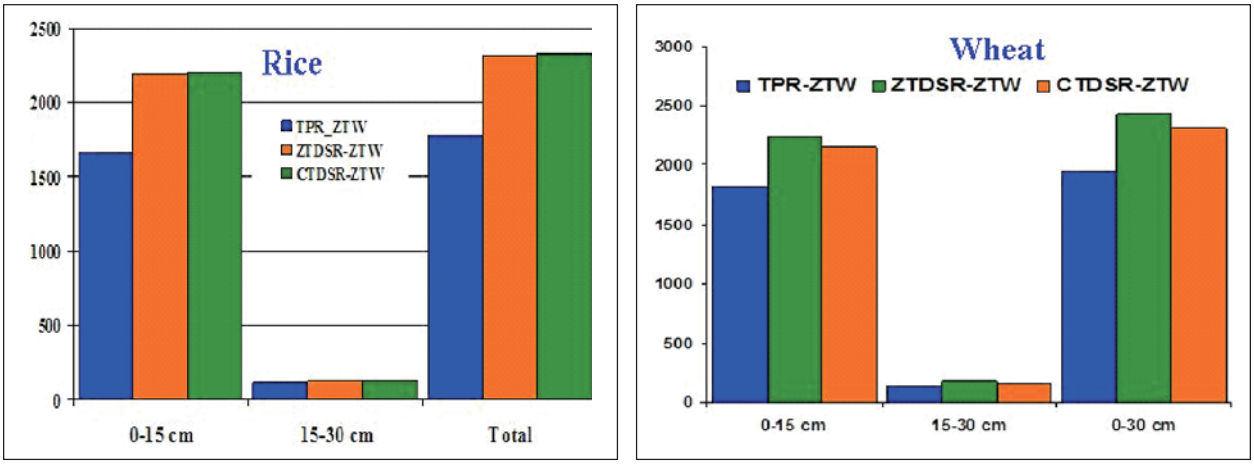
Root growth is adversely affected by soil compaction and mechanical resistance to root penetration. Soil compaction is more under free wheeling of the tractor. With controlled traffic soil compaction is reduced and resistance to root penetration is relatively less due to better soil moisture regimes under sufficient residue retention situations. Thus, favourable soil moisture regimes and reduced soil compaction under zero-till favour profuse root development than conventionally tilled systems.

Narrow wheel

62. Can lodging be reduced by planting crops with zero-till and raised-bed planting systems?

It is generally observed that crop lodging is less in zero-till and raised-bed planted crops. In zero-till system, plant seems to receive good mechanical support from undisturbed soil in the close vicinity of the narrow slits. Also higher root biomass provides better anchorage to plants against

lodging. In zero tillage and bed planting, both root mass and depth are higher than conventional tillage, more particularly compared to rotavator tillage and broadcasting wherein roots become surface feeder due to sub-surface compaction.



Root biomass (kg/ha) under different tillage options in rice-wheat system (Source: M.L. Jat)

63. Are there any other non-monetary measures that can further improve yields of zero tilled crops?

Farmers' participatory trials have confirmed that paired row planting of crops such as wheat and rice improves crop productivity by 4-6% without any extra efforts and inputs. For paired row planting, we only need to adjust seeding tynes. Paired row planting, in some way, mimics benefits of raised bed planting system. But it is crucial to maintain an adequate plant population for higher productivity.

64. What is relay cropping in cotton-wheat system and how does it improve productivity?

In cotton-wheat system, the succeeding crop of wheat is generally planted after the cotton crop vacates the fields. This generally delays wheat planting (beyond November 25 - up to end of December) and in late planted cotton situations, wheat is planted up to middle of January or not planted at all). Late planting after mid November decreases wheat yields at the rate of 32-35kg/ ha/day. In order to avoid grain losses due to late planting of wheat and also avoid fallows, the crop is timely planted into standing cotton using a mini tractor or a high clearance tractor such as to avoid damage to cotton. Thus, planting of wheat into growing cotton situation is termed as relay cropping. Relay cropping of wheat in cotton results in significant yield advantages to both the crops. Farmers are able to take an additional picking of cotton, and timely planting of wheat improves its productivity.

65. What is the scope of inter-cropping in sugarcane or maize based cropping systems?

Sugarcane is a long duration crop and once planted farmers have to take a ratoon as well. The acreage of cane crop is decreasing in the region due to increasing production costs, yield

stagnation, marketing and milling issues. In order to improve productivity of cane crop and also the land use efficiency, farmers now practice inter cropping systems in sugarcane and maize based cropping systems.

With introduction of new planters, it is now possible to seed maize and accompanying crop in just one or two operations. Cane planting has also been partially mechanised. The bed planters can open desired ditches/furrows and seed wheat or onion or coriander, *etc.* on the wide beds. Bed planting techniques facilitate and promote inter-cropping in maize or sugarcane based cropping systems.

In maize based cropping system, winter vegetables can be grown along with maize using bed planters. Wide bed planting technique is widely used by farmers to grow onion, garlic, wheat, chickpea and Brassica as intercrops in autumn planted sugarcane.

66. How to achieve good crop establishment in jute and how the seed rates can be optimized for reducing cost of production?

In general, the jute is grown by random broadcasting of very high seed rate (6-7 kg/ha) that leads not only to higher cost of cultivation but also poor yields due to high plant density and random plant geometry leading to plant competition. The jute can successfully be planted in row geometry using multi-crop planters having precise seed metering systems with 1.5 to 2.0 kg seeds/ha. This not only reduces the cost of seed by 1/4th but also leads to higher productivity.

Residue Management

67. What are the harmful effects of burning crop residues?

Burning of crop residues causes air pollution and results in losses of nutrients. It also adversely affects beneficial soil micro-flora and fauna.

68. How does anchored and loose residue left by the combine interfere with zero-till operation?

Anchored crop stubbles generally do not interfere with operation of tynes of the zero-till drills. Only loose residues interfere with zero-till drill operation. The problem can be reduced if 11 tynes are distributed on the 3-bars steel frame in 3-4-4 fashion. It facilitates anchored and loose straws to flow between tynes easily and thus reduces raking of the crop residues by the tynes. Alternatively, one can use coulter-type double-disc openers or punch planters for seeding.

69. How chopping of anchored stubbles with a chopper or shrub master helps in early growth and vigour of wheat?

Yes, chopping anchored stubbles with shrub master creates mulch which conserves soil moisture, controls weeds and moderates soil temperature in winter and summer. Mulch forming by chopping of anchored straws is easily done in controlled traffic after seeding.

70. How to go for zero tillage in loose residues?

Residue management for zero tillage has never been a problem in the manually harvested rice fields. This is a problem, however, in combine harvested areas. Combines separate grains and then throw a swath. These loose straws either need to be removed or spread evenly in the field to avoid raking problems for zero-till drill tynes. If mechanical spreaders can be fitted with commercially available models of the combine harvesters, loose straws can be shredded and evenly distributed in the field. It is easy to seed through shredded and evenly distributed straw. Else use coulter-type double-disc planters or punch planters for seeding into loose residue.

71. What should the height of rice stubbles be for good yields with zero-till wheat?

For the success of a permanent zero-till system, some crop residues must be left in the fields. When crop residues of 20-30 cm height are left on the field, an estimated 3-4 tonnes of organics are returned to the soil. This helps maintaining soil fertility and improves crop growth. Anchored straws (cereal crops) of any height do not pose problem in zero-till drill operation. But, it is difficult to avoid raking problem in the event of crop lodging.

72. What if crop residues are not available to cover surface in drylands/rainfed areas?

India has the highest net acreage (83 mha) under rain-fed/dry land farming in the world having very low productivity mainly due to non-adoption of moisture and temperature buffering technologies. Zero tillage with surface cover (mulching) helps in buffering soil moisture and temperature. However, as crop residues are mainly utilized for animal fodder, the alternate vegetation sources can be used. Different vegetation sources are listed below.

Suitable species of different vegetation types as alternate mulching material in dry lands

Trees	Perennial Mulching Materials (Chopped)	Live Fence
• Drum stick PKM1	• Ipomea	• Thor
• *Ailanthus excelsa*	• Sesbania	• Ratanjot
• Neem	• Acacia spp.	• Karonda
• *Sesbania sesban*	• Cassia spp.	• Hena
• Leucinea	• Butea monosperma	• Prosopis juliflora
• *Murraya koegnia*	• Gliricidia sepium	• Soapnut
• *Gmelina arborea*	• Leucinea	
• Custard apple	• Any other locally available hard biomass	
• Gauva (few species)		
• *Emblica officianalis*		

73. How does ratoons of rice affect wheat yield and how sprouting can be controlled?

In rice-wheat systems of Indo-Gangetic Plains, it does not affect at all. It is observed that sprouts begin to die soon after the temperature begins to fall in winter by the end of November.

However, resprouting and ratooning is a problem in rice-rice systems in peninsular India and other similar agro-climates. Under such cases, rice ratoons can be managed using following practices:

- Pre-plant application of paraquat (0.5 kg a.i./ha) or 2 l of commercial product, *e.g.* gramaxone (24%). Paraquat is a non-selective (total killer) contact herbicide and kill all green vegetation and don't have any residual activity.
- Atrazine @ 1.25 kg a.i./ha alone (pre-emergence or early post-emergence) can be used for controlling weeds together with rice rations. Alternatively, a combination of atrazine (0.65 kg a.i./ha) with alachlor (1 kg a.i./ha) (pre-emergence only) can be used only at stages.
- Ammonium sulphate (2%) or vegetable oil (2%) mixed with glyphosate can also be used to improve efficiency of applied glyphosate.
- Glufusinate (Basta), a non-selective herbicide can also be used for control of rice ratoons together with weeds.

74. Is it that farmers face problems in manual harvesting of wheat in left-over anchored stubbles of rice crop?

No, by the time crop matures, rice stubbles are already nearing decomposition and that do not creats any hindrance in harvesting of wheat.

75. How retention of residues in zero tillage improves soil health?

Residues serve as a source of energy for the fauna, which facilitate 'biological tillage'. Stubbles increase earthworm population, predators' diversity and their density in the field. Thus, crop residues increase organic carbon, enrich plant nutrients, improve soil structure and hence improve soil health.

76. Is it that crop residues increase incidence of plant diseases?

The significance of the relationship between some pathogens and abundance of residues should be kept in mind while opting for incorporation or surface retention of residues. In zero-till systems, residues are retained on the soil surface. Some plant pathogenic fungi and bacteria could be carried over from previous season crop. It is suggested to consult an expert if previous crop had significant disease infestation or disease infestation increases.

77. How residues of the previous crops can be managed and their burning avoided before planting of a summer / kharif or rabi crop?

Residues can be managed in several ways such as: (i) planting into loose and anchored residues (full residue retention) using turbo seeder or a Combo Happy seeder, and (ii) partially bailed out for use as animal feed. Residues can even be incorporated into surface soils using a plough. Incorporation requires tractor energy and also leads to temporary immobilization of nutrients

especially nitrogen. When it is intended to incorporate residues of wheat before rice transplanting, it is best to incorporate them using disk plow, irrigate and apply a bag or urea to facilitate early decomposition. Residue retention has now become a viable option due to the availability of new machines like turbo seeder. The ultimate goal of residue management is to provide an optimal ground cover and facilitate its alternate economic uses by livestock as feed.

A B

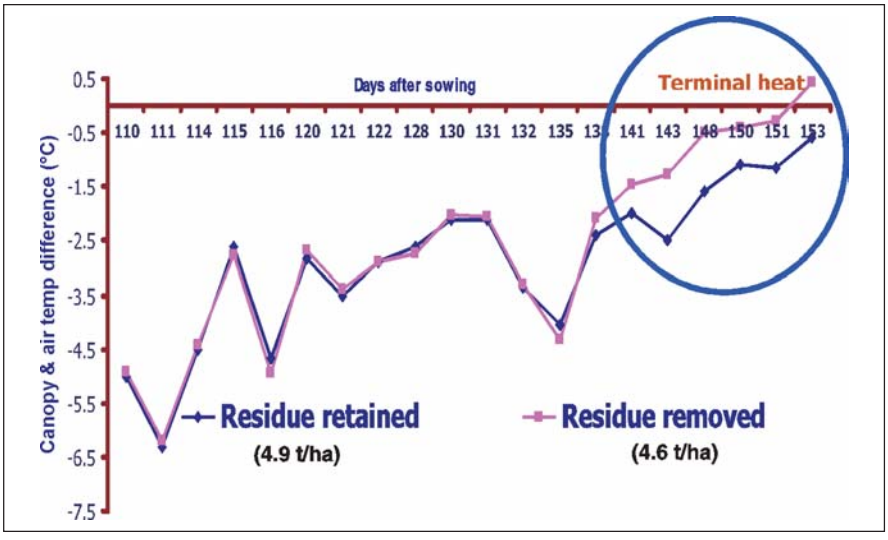
Contrasting seeders for planting wheat after rice: (A) Roto-seeder that promotes residue burning, and (B) Turbo seeder that promotes residue retention

78. What are benefits of residue retention?

Residue retention buffers diurnal fluctuations in soil temperature– keep soils cool in summer and warm in winter season. Thus, by reducing the extent of fluctuations in soil temperature, surface mulches improve the comfort zone of plants and roots do not have to adjust to extreme fluctuations in day and night temperatures. Mulching reduces the unproductive losses of soil moisture through evaporation from bare soil surface, helps reduce weed infestation and temporary nitrogen immobilization due to incorporation, builds up more organic carbon in the system, reduces soil erosion by dissipating the beating action of rain drops. Surface retained residues have been seen to significantly improve the performance of summer moong due to above enumerated effects. Presence of residues on the surface, increases termite population but due to their saprophytic nature do not harm the growing crops and move deeper down in the soil when soil temperatures dips down in winter. Termites help recycle residues and act as early decomposers.

79. How terminal heat stress can be handled through Conservation Agriculture practices?

Terminal heat stress can be handled through adequate soil moisture supplies. This can be ensured through irrigation or by cutting back the unproductive losses of soil moisture through surface mulching and make more water available for transpiration. It has a cooling effect on the crop canopy and enhances the grain filling period.

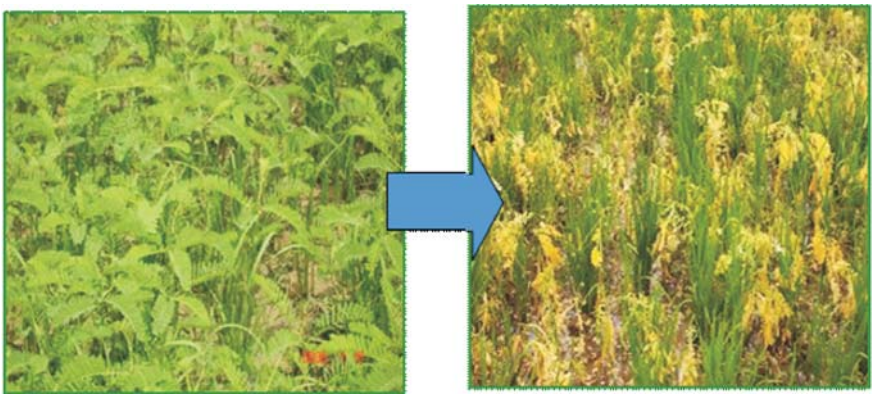


Effect of surface residue retention (mulch) in zero tillage on canopy temperature in wheat at reproductive, grain filling and maturity stages (110 to 153 DAS) (Source: M.L. Jat)

Nutrient Management

80. Is it possible to grow a green manure crop in zero-till systems?

Any green manure crop can be sown with zero-till machine alone or as an intercrop with rice depending on the water availability during peak summer. If green manure legume is inter-cropped with rice, it saves irrigation water compared to growing a green manure before rice planting. Green manure crop of 20-30 days old (Sesbania, sunhemp, cowpea) can be killed by herbicides, such as 2,4-D without any adverse affect on the rice. But, do not use broad-spectrum herbicides, they may kill young rice seedlings also. Sesbania inter-cropping helps control weeds, creates surface mulch and fixes atmospheric nitrogen. This system is still under further testing.



Direct seeding of rice co-cultured with Sesbania; inter-cropped Sesbania is killed with 2,4-D after 25-30 days of growth controls weeds, add organics and nutrients for healthy growth of rice crop

81. In presence of mulch, how should nitrogen fertilizer be top-dressed?

In zero-till system, mulching can be accomplished by retaining the anchored residues of the previous crop or by chopping them to cover soil surface. With anchored residues, urea can be top-dressed easily. But top-dressing of nitrogenous fertilizers is not easy in fields mulched with residues of the previous crop. Surface covered with residues do not allow top dressed nitrogen to reach the plant roots leading to significant losses of N due to volatilization. Traditionally, half of total N, P and K are applied basal in wheat and other crops. Nitrogen necessarily has to be combined with the irrigation schedules. Traditionally, N is top dressed with first irrigation, applied to wheat 21 days after sowing. It is observed that if wheat is planted in mulched fields, farmers have to delay irrigation and hence also the N application. Thus, there is a need to reschedule nitrogen application and irrigation in presence of crop mulch. In mulched ZT fields, it is better to band place 80% of the recommended nitrogen at sowing or apply it with pre-plant irrigation, if seed damage is anticipated. The remaining N can be applied based on LCC and/or on Green Seeker based recommendations.

82. Is it that placement of fertilizers and seeds together in the same slit adversely affect germination of crop planted with zero-till ferti-seed drill?

Normally, south Asian farmers apply 120kg nitrogen, 60kg phosphorus and 40kg potassium each and 5kg zinc per hectare. Nearly half of the total N fertilizer requirement, and full dose of phosphorus, potash and zinc is applied as the basal dose. These fertilizers are delivered from fertilizer tank through a tube into slits made with zero-till chisel point openers for placement of seeds. Thus, seeds and fertilizers are in the same grove but machine places fertilizers below seeds to avoid seed damage. Application of full dose of nitrogen as basal may increase seed-fertilizer contact and reduce germination by 5-6%. Damage to seed can be avoided by delivering fertilizers through separate tynes between seed rows.

Schematic arrangement of seed-cum-fertilizer tynes on a 3-bar zero till drill

83. What is the appropriate method of fertilizer application in surface seeded crops?

Surface row-seeded crops are generally sown in undisturbed wet soils when it is difficult for tractor or even animal-drawn implements to operate. Normally, seeds and fertilizer nutrients are placed on the wet soil surface and covered with residues of the previous crop. Subsequent dose of fertilizer can also be broadcasted, followed by a light irrigation for soil incorporation. In row planted crops, fertilizers can be band placed manually or with machine during an inter-cultural operation.

84. Are there crop losses in the practice of single band fertilizer placement compared to split fertilizer application?

Generally, nitrogenous fertilizers are applied in splits to match crop nutrient requirements at different plant growth stages. Our experience in wheat suggests that irrigation systems in south Asia are more supply-driven. Generally, farmers are unable to irrigate and apply N timely. Mismatches between crop N requirements and irrigation water availability to incorporate surface broadcast fertilizer can result in reduced yield of wheat. In these circumstances, a better strategy is to apply 80% of the total N as basal at planting.. When balance 20% N is top-dressed at flowering / grain filling stage, it increases grain quality (protein content) in wheat.

85. What is the impact of the single dose of N fertilizer application on the nutrient losses status of rice?

All fertilizer nutrients are not equally mobile in soils. Under aerobic conditions, relatively mobile nutrient such as nitrate (NO_3^-) moves deeper into soil profile but not beyond the reach of the active root system of crops such as wheat. Under anaerobic puddled conditions with water table close to soil surface, NO_3^- -N gets transformed into ammonical (NH_4^+ -N) form and is adsorbed on the negatively charged clay particles, thus not able to move freely with water. This reduces losses of deep placed N. In case of dry seeded rice (DSR), it is advocated that soil should be kept wet after 2 weeks of seedling emergence, and hence even a single deep placement of total N can be practised.

86. Can zero-till planting reduce leaf yellowing in wheat after first irrigation?

Leaf yellowing is less common in zero-till wheat because less water is applied in the first irrigation compared to conventional tilled system. In traditionally planted wheat, leaf chlorosis/ yellowing is generally more intense in wheat planted in partially reclaimed alkali soils. Poor aeration after irrigation or rainfall event leads to imbalances of iron, phosphorus and other nutrients. To ameliorate and overcome transitory yellowing, farmers are advised to apply 10 kg urea or 5kg of di-ammonium phosphate (DAP) in calcareous soils. In slightly acidic soils, use of calcium ammonium phosphate is likely to improve the situation.

87. Is it true that phosphorous fertilizer efficiency is better in rice-wheat system when applied to wheat crop than to both the crops?

Rice and wheat crops have contrasting edaphic environments. Prevailing anaerobic conditions during rice enhances P and iron availability to meet crop demands. So a more efficient and rationale use of phosphatic fertilizers would be to use it in wheat rather than in rice crop.

88. How should farmyard manure/compost be applied in zero-till wheat?

Farmyard manure can be applied a day or two after planting zero-till wheat. It partially covers seed in slits and avoids soil crusting. Farm yard manure is mostly applied in rice in NW India.

Irrigation Management

89. Are irrigation requirements of zero-till wheat and conventional wheat same?

The crop-water requirements are often determined by several factors including crop season, evaporative water demands, crop growth, and phenology and nature of soils. Agronomic practices such as planting methods and mulching can change components (evaporation, transpiration) of total crop-water requirement. Zero-till wheat planted in residual moisture of rice does not need pre-sowing irrigation and uses much less water in first irrigation as compared to conventional tillage system. Zero-till planted crop on the flat surface thus, saves 10-12 centimetre water per hectare.

With flood irrigation method a minimum of 5-cm water can be applied in well levelled fields. Much less water is used per irrigation in furrow irrigation. Thus, in raised bed furrow irrigation (FIRB) system, the frequency and number of irrigations can be increased so that same water is applied in small parcels to increase water-use efficiency.

90. Is there a need to prepare check basins in zero-till fields normally required in conventional tilled fields?

Check basins are needed only when fields do not have a good level. In laser levelled fields you do not need check bunds and with zero-till you do not lose the precise field level. When zero-till system is practised in combination with controlled traffic (described earlier), there is no need to make bunds or check basins. In controlled traffic, compacted tractor tramlines can easily serve as irrigation channel. Although it is unnecessary to make check basin in precisely levelled zero-till fields, yet farmers still use bund maker to make check basins to irrigate crops.

91. How can zero-till increase soil moisture available for plant growth?

Farmers practice zero-till system in two ways: (i) planting a crop after complete removal or burning of residues of the preceding crop, and (ii) partial burning and removal of residues. In the presence of anchored or loose stubbles, crop residues act as surface mulch that reduces evaporation losses and thereby increases profile soil moisture. Zero-tilled fields also have less soil cracking and bypass of irrigation water leading to relatively more uniform moisture distribution. Moreover, especially when residues are retained at the soil surface, run-off is reduced and more water recharges the soil.

92. Is pre-sowing irrigation needed for zero-till wheat?

When wheat crop, after rice, is planted on time, the residual soil moisture is often sufficient for germination of wheat seed. If residual soil moisture is less, it is advised to seed at shallow depth and then immediately apply a light irrigation. Pre-sowing irrigation helps weeds to germinate ahead of the main crop giving them an undue advantage. But, if weeds are not a problem and there is time for seeding, pre-sowing irrigation can be applied. If crop planting is already getting late, pre-sowing irrigation in no-till system is likely to further delay planting by several days. In tilled fields, pre-sowing irrigation may further delay planting. But if weeds are a serious problem and no pre- or post-emergence herbicides are readily available to farmers, stale bed technique could prove very useful.

93. What is the appropriate time for first pre-sowing irrigation in zero-till wheat?

There is usually sufficient soil moisture after timely harvest of rice crop to facilitate sowing of wheat crop in the residual soil moisture. It is, therefore, no need either for pre-sowing irrigation or for change in the irrigation schedule. In the presence of crop residue mulches, first post-sowing f irrigation can be delayed by a week or so, which otherwise is usually applied after 21 days seeding. Increased soil moisture through watering, reduces resistance of soil to root penetration in zero-till system. Therefore, advancement of first irrigation by 4-7 days (about two weeks after sowing of wheat) is advised in case of zero-till fields without mulching.

94. How does advancing first irrigation affect crop maturity and yield?

Germination will be poor whenever crop is planted at the suboptimal soil moisture. Advancing first irrigation helps in speedy germination of un-germinated seeds, resulting in proper plant population and uniform crop stand and maturity. Any delay in first irrigation may cause uneven crop stand and increase competition from the already established seedlings leading to poor growth and thus reduced production.

95. Is it that zero-till rice-wheat system leads to reduced mining of ground water?

Rice is traditionally grown as the puddled transplanted crop. Puddling destroys soil structure, increases compaction, and reduces deep percolation of water. This reduces moisture storage in soil profile and also aquifer recharge. In permanent zero-till rice-wheat system, rice can either be direct seeded or rice seedlings can be transplanted in untilled fields irrigated in evening to soften the soil for transplanting. Obviating the need for puddling facilitates conditions conducive to recharging soil profile and ground water during monsoon. Besides ground water recharge, it takes less irrigation volumes for the water to advance in undisturbed soils.

96. Is it that quantity of water used in first irrigation in unploughed and mulched fields lesser than conventional tilled plots?

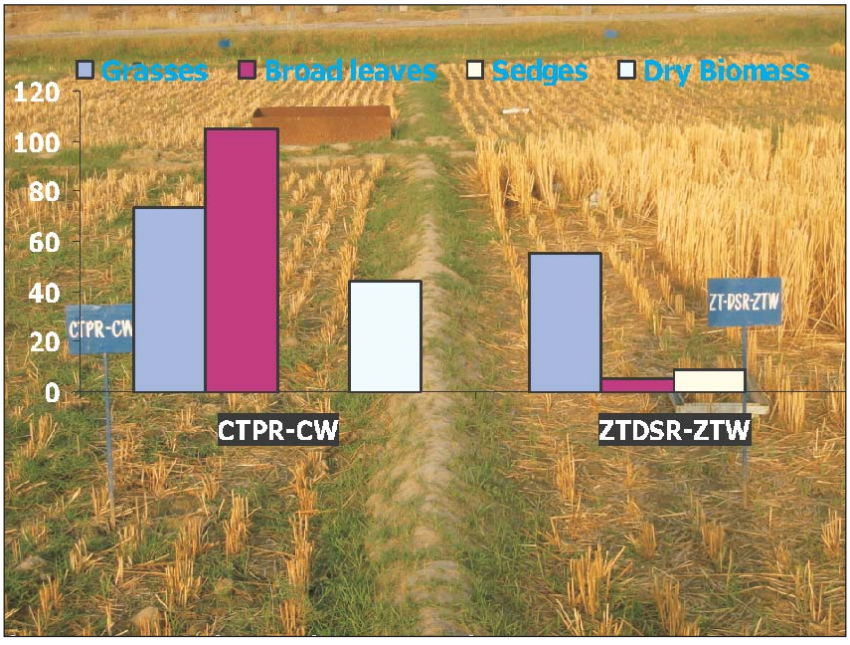
The irrigation water spreads quickly in the unploughed fields and this results in lesser deep percolation losses at the canal end. In zero-till wheat, about 1,000 m^3 ha^{-1} of irrigation water is saved due to planting in residual soil moisture from the previous rice crop and application of a light first irrigation.

Weed and Pest Management

97. How does zero-till system change weed composition?

There are several hypotheses for this. With conventional tillage, seed bank of the weeds buried in subsurface soil layers comes to the surface. When rice is established as a puddled transplanted crop, lighter seeds float on water and get deposited on the soil surface. Main reason for change of

weed flora seems to be the use of herbicides for control of grassy weeds and non-adoption of any measure to control broad leaf weeds in wheat over the time in zero-till systems. This increases population of perennial and broad leaf weeds in the zero tillage system. Also control of Phalaris minor (Gulli danda) reduces competition for other broad leaves weeds. Thus, it seems that several factors contribute to shifts in weed composition.



Weed dynamics under CA v/s conventional till rice-wheat system after 6 years (Source: Mahesh Gathala)

98. How zero tillage has affected the Phalaris minor population over years?

Less soil disturbance reduces germination and emergence of Phalaris minor (Gulli danda). Field trials have indicated that Phalaris minor population is reduced by nearly 40% in the first year of zero tilling as compared with conventionally tilled fields. After several cycles of zero-till planting and herbicide usage, populations of Phalaris minor can be reduced significantly in the rice-wheat system.

99. What measures are taken to control weeds in wheat crop?

Weeds of rice crop could carry over to wheat. Also some weeds can germinate after rice harvest. The best strategy is to control these weeds in the rice season. In eastern IGP, problem of carry over weeds and germinating weeds is quite acute due to delayed planting. Under such situations, glyphosate can prove as a very useful herbicide. If these weeds are to be tackled in wheat season, application of tpre-seeding herbicides 1 day before sowing of wheat can control them. It has been observed that Phalaris minor germination is low in zero-till fields as compared to conventionally tilled fields. But if weed population is above the economic threshhold level, then grass killers, such as isoproturon, sulfosulfuron, clodinafop-propargyl and fenoxaprop-p-ethyl should be applied 30-35 days after sowing. For control of broad leaf multiple weeds, 2,4-D or metsulfuron methyl should be sprayed at 35-40 days after planting. It is best to use boom-type nozzles with pressure regulators

for uniform spray and to save on herbicides and to avoid phyto-toxicity symptoms. Continuous use of a specific herbicide may result in development of resistance to herbicide use, so use different herbicides every alternate year.

100. How can weeds of kharif season be controlled before planting wheat?

Perennial weeds of *kharif* season, if present in good number, adversely affect wheat yields. Pre-seeding applications of broad-spectrum herbicides such as glyphosate kill all these weeds. Annual weeds of rice die towards maturity of rice or in winter and hence pose no major threat.

101. Is glyphosate (roundup) use necessary before wheat planting?

No, glyphosate is only required when weeds emerge before wheat planting, as in late-sown conditions. If wheat is sown timely in residual soil moisture of rice, weeds do not emerge before wheat planting.

102. How to improve weed control efficiency of glyphosate?

For better efficacy of glyphosate it is essential that weeds should be in active growth stage (turgid leaves) which can be ensured through application of irrigation water. Water used for spray should be clean and mud-free. Addition of 2,4-D (2-3 ml/l) with glyphosate also improves glyphosate efficacy against weeds.

103. What are chemical molecules that can be used by farmers to control weeds in RWCS?

There are many options to control different weeds and these have been listed below.

Recommendations of herbicide molecules for weed management

Herbicide	Application Time	Dose (g ai. /ha) (Spray volume,l water ha^{-1})	Application, (DAS/ DBF)	Weed Control			Remarks
				Grasses	broadleaf	Sedges	
Glyphosate (Non-selective systemic)	Pre-plant	1000-1500 (500)	1-7 DBF	***	***	**	For all crops
Paraquat (Non-selective contact)	Pre-plant	500 (500)	0 DBF	**	***	*	Controls annual weeds
Alachlor (Lasso)	Pre-emergence	1000 (500)	2-3 DAS	***	*		For legumes and maize legumes inter-cropping

Contd...

Contd...

Herbicide	Application Time	Dose (g ai. /ha) (Spray volume,l water ha^{-1})	Application (DAS/ DBF)	Weed Control			Remarks
				Grasses	Broad leaf	Sedges	
Atrazine	Pre/ early post-emergence	1000 (500)	2-15 DAS	***	***	*	For maize, sorghum, pearlmillet, sugar cane
Pendimethalin (Stomp/ 30 EC, Stomp xtra)	Pre-emergence	800-1200 (500)	2-3 DAS	***	*	*	For wide range of crops
Pyrazosulfuron (Sathi)	Pre-emergence	20 (500)	12-20 DAS	**	*		For rice, weak on grasses, controls Leptochloa
2,4-D [Ethyl ester 38 EC/ Sodium salt 80 WP (Weedmar. Heera)]	Post-emergence	500 (1315)	30-35 DAS		**	*	For wheat, rice, Solonum, Malwa, lathyrus and Physalis escapes commonly
Azim sulfuron	Post-emergence	17.5 (400)	12-25 DAS	*	***	***	For rice and effective on Cyperus rotundus
Bispyribac (Nominee Gold)	Post-emergence	25 (500)	15-25		*	**	For rice, Eragrostis, Leptocloa, Digera escapes common, needs saturated soils
Carfentrazone (Affinity 50 WDG)	Post-emergence	20 (500)	25-30 DAS				For wheat, controls Solonum, Malwa, lathyrus and Physalis. Contact action, weed regeneration problem
Clodinafop (Topik 15WP)	Post-emergence	60 (400)	30-45 DAS	***			For wheat, also legumes
Ethoxy (Sun rice)	Post-emergence saturated soils	18 (500)	12-20 DAS		**	**	For rice. Needs sulfuron
Fenoxaprop (Whip Super) Fenoxaprop (Rice Star)	Post-emergence	60 (500)	14-21 DAS	**			For rice, and also control grasses in standing legumes

Contd...

Contd...

Herbicide	Application Time	Dose (g ai. /ha) (Spray volume,l water ha^{-1})	Application (DAS/ DBF)	Weed Control			Remarks
				Grasses	Broad leaf	Sedges	
Fenoxa-propethyl (Puma super/ Puma power 10 EC)	Post-emergence	100-120 (500)	30-35 DAS	**			For wheat, effective Cynodon
Isoproturon (Iso-guard)	Post-emergence	1000 (500)	25-30 DAS	**	*		For wheat, effective on Phalaris, however no control of resistance biotypes of Phalaris
Mesosulfuron + Iodosulfuron (Atlantis 3.6 WG)	Post-emergence	12+2.4 (400)	30-35 DAS	***	**	**	For wheat, loxic to wheat at high soil moisture
Metsulfuron (Algrip 20 WP)	Post-emergence	4 (400)	30-35 DAS		**	**	For wheat, Solonum and Physalis escapes common
Penoxulam	Post-emergence	22.5 (500)	12-25 DAS	***	**	**	For rice, needs saturated soils, Eragrostis, Leptocloa, Digera escapes commonly
Quizalofop (Targa Super 10 EC)	Post-emergence	50 (500)	30-45	***	*	*	For legumes, jute
Sulfosulfuron (Leader 75 WG)	Post-emergence	25 (500)	30 -35 DAS	***	**	*	For wheat, residual toxicity kills succeeding maize
Sulfosulfuron + metsulfuron (Total 80 WDG)	Post-emergence	30+2 (40)	30-35 DAS	***	**	**	For wheat, Solonum, Malwa and Physalis escapes common
Tank Mixtures							
Glyphosate + 2,4D-EE	Pre-plant	1000+250 (300)	7-10 DBS	**	**	***	Controls of broad leaf and sedges before maize, rice or wheat

Contd...

Contd...

Herbicide	Application Time	Dose (g ai. /ha) (Spray volume,l water ha^{-1})	Application (DAS/ DBF)	Weed Control			Remarks
				Grasses	Broad leaf	Sedges	
Alachlor + Atrazine	Pre-emergence	1250+375	3-5 DAS	**	**	*	For maize
Atrazine + Pendimethalin	Pre-emergence	500+500 (500)	3-5 DAS	***	***	*	For maize
Azimsulfuron + Bispyribac	Post-emergence	17+12.5 (500)	12-20 DAS				For rice, effective on Cyperus rotundus
Propanil + Triclopyr	Post-emergence	3000+500 (500)	15-25 DAS				For rice, temporary phyto-toxicity problem
Intercropping systems							
Pendimethalin (Stomp 30 EC/ Stomp xtra 37% CS)	Pre-emergence	1000-1500 (500)	2-3 DAS				For wide range of crops
Oxyflurofen	Pre-emergence	62- 80 (500)	2-3 DAS				Sugarcane inter-cropping system, garlic/ onion, transplanted vegetables
Other crops							
Metribuzin (Sencor)	Pre-/early post-emergence	250- 400 (500)	2-3 DAS	**			Potato, tomato, chillies and also as early post in peas
Oxyflurofen	Pre emergence	62- 80 (500)	2-3 DAS	**			Transplanted vegetables, garlic, onion
Chlorimurian (Cloban 25 WP)	Post-emergence	9 (500)	10-20 DAS				Soybean
Imazethapyr (Persuit/ Lagam 10 SL)	Post-emergence	65 (500)	10-20 DAS				For soyabean, groundnut, summer legumes

104. What are the effective weed management molecules for zero-till jute?

In zero tillage conditions, pre-plant application (1-7 days before planting) of glyphosate @ 1000-1500 ml a.i. /ha in 500 litres of water can knock down all the emerged weeds. For control of second

flush of weeds, post emergence application of quizalofop (Targa Super 10 EC) @ 50 g a.i./ha in 500 litres of water at 30-45 days after sowing can provide very good control of grasses, broad leaves weeds and sedges.

105. What is the impact of zero tillage on natural enemies of insects?

A wide range of natural enemies (34) and soil fauna (*e.g.* millipedes, carabids and root weevil) are found in rice fields. The population densities of insects of economic importance are almost similar in the tilled and no-till fields. Zero tillage was found to favour the population of useful parasites.

106. How zero-till plots with stubbles affect rodent population?

Farmers often complain regarding increased rodent attack; however, several researches undertaken don't prove this perception. It is a field-specific problem, not the technology-specific (zero-till). If rodent menace is feared, traps and chemical control measures should be adopted.

107. Is it true that intensity of stem-borer attack increases in zero-till rice-wheat system?

It is a common apprehension that pest will move from puddled transplanted rice to zero-till wheat. But, it is observed that rice stem borers do not survive in winter, and hence there is no increase in attack of this pest in wheat crop. Monitoring of long-term ZT sites have shown that stem borer incidence does create problem in ZT wheat.

108. What is the impact of the crop residues on the termite population?

Termites are generally problematic in hot-arid and semi-arid conditions. Termites move deeper into the soil during winter and begin to move upwards in monsoon. Crop residues on the soil surface are likely to provide food substrate to termites and stop them to attack crop. Besides, termites can be controlled effectively with use of chlorpyriphos.

Significant termite activity is seen in maize fields planted subsequently for wheat. There is no need to worry about it. Termites act as good recyclers/decomposers of maize stubbles. It must, however, be mentioned that it is important to plan irrigation well in advance.

In zero-till termites attacks on residues and not crop

109. How weeds are managed in direct seeded or transplanted rice crop?

Direct dry seeded rice suffers on two counts: (i) iron chlorosis, and (ii) weed pressure. The first problem can be resolved by shallow submergence after seedling emergence for 10-15 days and the weed can be controlled through herbicides. If weeds are a major problem before direct dry seeding of rice (DSR) or zero-till transplanted rice, pre-seeding herbicides (glyphosate) have proved very useful. Staright pretilachlor

which is registered in India under the trade name RIFIT can be used in DSR either as pre-emergence application (drilled rice only) or early-post in combination with propanil or another post-grass killer.

- Pendimethalin can serve the same purpose but it seems that its spray immediately after seeding has some adverse effects on germination. Due to the drier conditions in DSR, the chemical dose can be increased to 1000-1500 g ai/ha (as compared to 500-750 g ai/ha in transplanted rice). It will provide residual control of new germinations of annual grasses, broad leaf weeds and sedges.
- In upland condition, pendimethalin (1000 g a.i. /ha) as pre-emergence is pre-requisite in DSR for controlling the weeds like Eragrostis, Brachiria and other broad leaf weeds.
- Bispyribac (25 g a.i./ha) at 20 DAS effectively controls the grasses and broad leaf weeds except Eragrostis and Physalis minima.
- A combination of pendimethalin (pre) and bispyribac(post) effectively controlled the complex weed flora in rice.
- Propanil or fenoxaprop can be used for the control of grasses.
- Propanil can only be applied after drainage of standing water.
- For control of broad leaved weeds, 2,4-D can be applied after weed emergence.
- For control of sedges, tank mixture of propanil+trichlopyr has been found effective against Cyperus iria, Cyperus deformis and Fimbristyllis sp.

Sometimes, Sesbania grown as green manure crop becomes a weed. It has been observed that 2,4-D and triclopyr can be used to kill Sesbania at the recommended dose. Glyphosate is not effective against Sesbania even at 3x dose.

110. What will happen to problems associated with perennial weeds once than ZT is done on long-term basis?

The use of pre-seeding herbicides like glyphosate will deplete the huge reserve food of perennials in ZT system. As well as a good crop wheat or rice will not allow these weeds to manufacture more food. The dry weed of such weeds in the standing crop will-less than the conventional tillage. The population of such weeds in long run, in fact, will reduce over the years.

Multi-boom self propelled sprayer

Low-cost multi-boom high clearance sprayer

Multi-crop PCR planter for drilling in residues

Direct seeded rice co-cultured with Sesbania (Brown manuring)

Multiple cropping in sugarcane systems through raised bed planting

Raised beds in laser levelled field facilitate uniform application of water across field

CIMMYT

International Maize and Wheat Improvement Center (CIMMYT)

CG Block, National Agriculture Science Centre (NASC) Complex,
DPS Marg, Pusa Campus, New Delhi 110 012, India
Telephone + 91 (11) 65441938, 25842940, Fax + 91 (11) 25842938

Visit our World Wide Web site at http://www.cimmyt.org