Evaluation of Non-Puddled and Zero Till Rice Transplanting Methods in Monsoon Rice[1]

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Abstract

The need to reduce costs of farming and reverse the decline of soil fertility in the multi-cropped farming systems in the Indo-Gangetic plains has led to success in conservation agriculture zero till crop establishment in many winter crops. Yet, attempts to bring direct seeding, reduced till, and conservation agriculture technologies to the following monsoon rice crop has met with mixed result resulting in a mixed conservation agriculture / conventional till system. The problems are many but mostly stem from the fact that most direct seeded rice technologies use heavy tractors and seed drills that must seed well before monsoon rains and even pre-monsoon rains begin in order to enter the fields. Compounding this problem is that most farmers and farmlands of the Indo-Gangetic plains have little capacity for water control, either from supply side or drainage. For conservation agriculture direct seeding technologies in lowland rice areas, this lack of control means that early sown, newly emerging direct seeded rice seedlings are: 1) at risk from drought; and or 2) at risk from prolonged submergence, literally drowning from early monsoon rains in fields that that have no drainage. The main objectives of the experiment, begun at NWRP, Bhairahawa Nepal were to compare three reduced till and zero till transplanted rice with and without mulch for weed control comparisons. All treatments have yielded exceptionally well as compared to farmers practice, leading authors to believe that this reduced till zero till rice transplanting may be a viable option in rice environments that limit direct seeded rice options. As the options include manual hand transplanting and appropriate technology low cost rice transplanter, these technologies should also increase the access of poor farmers to new conservation agricultural

1. Background

The Green Revolution and the eradication of malaria turned a single cropping Terai of Nepal and India into double and even triple cropping systems. This led to a huge increase in cropping area and created the single largest cropping system in the Nepal terai, the Rice-Wheat system. Elsewhere in Asia the farmers intensified their rice based system with rice – rice and even rice – rice –rice which have been shown to be remarkably stable. The 1963-vintage Long-Term Continuous Cropping Experiment at IRRI found, for example, that soil organic matter increases in flooded fields, even when farm workers cart away, three times a year, all above-ground crop residues along with tons of grain. "Well-managed irrigated rice ecosystems are masterpieces of ecological vitality and sustained productivity," observes Roland J. Buresh, who manages the experiment. (Fredenburg 2006)

Yet, been more and more farmers have chosen to diversify their systems. Many times its economics that drives the diversification, but lately too it is environmental, health, and nutrition factors. Drought driven by climate change is perhaps the foremost threat to these rice based systems and certainly the most familiar. Pumping costs are increasing and farmers are finding themselves in competition with peri-urban areas for water resources. Even the stable east Asian rice systems are diversifying due to this costly water combined with market opportunities- notably rising demand for animal feed- that encourage farmers to rotate rice with maize. The sustainability of these diversified rice systems have been questioned. Fading productivity due to nutrient mining, declining soil organic matter, and aggravated pest pressure are most often quoted. The catch is that rice lands removed from continuous flooding typically suffer (Fredenburg 2006), but also allow more people to prosper.

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2. Sustainability of Rice Wheat Systems

The long-term fertility experiments also showed yield stagnation or decline in rice – wheat systems (Regmi et. al., 2002). Mulching/manuring for field crops is in extreme competition with the energy-cooking needs of farm family households. Residue incorporated with recommended NPK produced similar yield or even lower in case of wheat to that of recommended NPK only. But the same amount of residues used as mulch with recommended NPK showed positive impact on rice and wheat yield (Tripathi, et. al. 2003).

In Nepal, Rice transplanting is the most common method of rice crop establishment in the lowland. As a traditional practice, in and Nepal and elsewhere, transplanting is done on well tilled and puddled soil. Puddling not only consumes much energy and time from the tillage point of view but also consumes a large quantity of the total water requirement in rice[7].

Nearly 80 % of all monsoon rice, has a spring fallow after its winter crop and that exacerbates the weed problems. Tillage for monsoon rice actually begins 1-2 months prior to onset of rain to control weeds in late April and early May. Tillage will commence in early June again for weed control and to open the ground for just prior to the rains. These early operations many times are not included in researchers costs for rice. If rains are delayed more than a month, additional dry land tillage may be necessary. Once the onset of monsoon begins farmers scramble to get their fields puddle. This time of year tillage services are at a premium and rental costs can nearly double. In short, tillage for monsoon rice is intensive and very costly and farmers need to spend a considerable amount time and money in land preparation.

Rice transplanting is costly and cumbersome. Labor shortages at the peak work period aggravate the situation, and farmers are forced to transplant seedlings at less than the optimal stage. Puddling to a greater extent creates soil physical condition detrimental to the following crop in rice based cropping system (Hobbs and Morris, 1996). Puddling makes land preparation difficult for the following wheat or other winter crops, resulting in cloddy soil structure, loss of soil moisture, delayed planting and inadequate seed-soil contact (Sharma, et. al., 1995).

3. New Tillage and Crop Establishment Technologies for Rice in Nepal

In the last decade various projects and centers across south Asia are testing and promoting an amazing array of new machinery and agronomy options for reduced till and conservation agriculture rice crop establishment. In one accounting[8] there are more than 17 distinct new machinery and agronomic based rice crop establishment options being researched and promoted in the south Asia region.

In Nepal, new rice crop establishment technologies for puddled rice have been tested along with farmer field demonstrations with little or no adoption by farmers. Adhikari et al (1997) tested seedling broadcasting against traditional method in rice establishment and reported that yield different was not significant, but there was 57% saving in labor cost in transplanting. The IRRI rice drum seeder has also been widely tested as an alternative method to traditional transplanting. The use of IRRI model manual rice transplanter could save 2/3 of the total rice establishment costs while increasing yields (Gami and Justice 1997). In another experiment, it was observed that direct (wet) seeding with drum seeders had higher marginal return by 21% to 25% compared to traditional transplanting method (G Sah et al., 2007).

In Nepal for DSR in reduced tilled (non-puddled) and zero till soils there have also been a wide variety of testing and farmer field demonstrations. For DSR reduced till and zero till with two and four wheel tractor machinery to be successful, irrigation facilities must be available or critical timing with pre-

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[7] By some estimates nearly 20% of all water for monsoon rice is necessary just for puddling operations.

[8] See Confusing New TCE in Rice in MECHNET #3 September 2003 http://www.naef-nepal.org/mechnet_archive.htm

monsoon rains must occur. In their experiment Tripathi et al, (2003) direct seeded zero till rice produced significantly higher straw yield and similar grain yield to that of transplanted rice. In a farmers' field experiment, it was found that power tiller reduced till direct seeded rice was significantly superior to hand broadcasted dry direct seeded rice and conventionally transplanted rice, however it was marginally superior to hand broadcasted wet seeded rice (Tripathi, 2004). In another farmer's field trial, G. Sah et. al (2007) plowed experimental fields once approximately one month after wheat harvest and a second single pass plowing (both dry tillage - no puddling) followed by DSR with two and four wheel tractor seeders. In this experiment the DSR rice grain and straw yields were slightly higher than the conventional puddled method but the net returns or cost savings to farmers was significantly higher for both the DSR treatments.

4. Problems with Direct Seeded Monsoon Rice

Despite the high levels of experiments and demonstrations in the above mentioned technologies farmer adoption in DSR / zero till rice is wanting. In new transplanted or DSR technologies for puddled rice technologies there is no adoption by farmers. It is the same for zero till DSR rice. Small successes have come from DSR non-puddled rice. Adoption in summer 2006 approached 100 hectares in Bara and Parsa Districts. From the authors own experiences and in discussions with the above scientists and engineers the small success in adoption appears to been due to the costs saving and refinement of weed control technologies including use of reduce tillage and newly available herbicides from India.

Additionally, in our discussions with the scientists, engineers and farmers DSR adoption in non-puddled reduce till rice has been affected negatively by early and heavy pre-monsoon rains. In all the research sites experiments and farmer field trials have been negatively affected and even destroyed by too much or too little water (In Annex One we provide a table that summarizes these problem and benefits). The authors feel though there are two critical problems farmers and researchers are facing in DSR reduced or zero till rice: 1) too little water or 2) too much water.

4.1 Too Little Water Too little water or late pre-monsoon and monsoon rains prima facie should help the establishment of DSR by allowing easy and timely field access by two and four wheel tractor machinery followed by post sowing irrigation. Therefore, for success and field access by machinery, direct seeded rice must be sown early in the season (even before most nurseries are established) and then must rely on timely and even early monsoon rains or pre-monsoon irrigation for their survival. But this technique we are finding is many times defeated by reluctance and even complete refusal to pump water for summer rice by the majority of our farmers[9]. This refusal to irrigate early planted monsoon rice can be mitigated by: 1) in areas where cheaper surface irrigation water systems are available; and 2) by using smaller Chinese two-wheel tractor and reduced till seeder that can get into wet fields later at the outset of rains of the monsoon season. Exacerbating these problems is that since these DSR experiments begun in earnest in that the last six years in Nepal, Nepal has seen little or no normal monsoon seasons. And the likelihood normal and evenly spread rains is seemly fading if predictions of global climate change are borne out. Additionally, without rain and cloud cover in the early season puzzling seedling damage in direct seeded rice has been noticed early in the pre-monsoon season, even when there is seemingly adequate soil moisture. A series of emails discussing this problem in July 2003 led some to theorize that the soil surface temperatures may soar very high due to high levels for radiation in this season and lack of any residue or ground cover. It was noticed that walking barefooted on this dry crusted soil was uncomfortably hot.

4.2 Too Much Water Much of the lowlands in Nepal (and the Indo-Gangetic plains) has little capacity for water control, either from supply side or drainage. This lack of drainage especially in heavy or extensive pre-monsoon rains means that emerging rice seedlings are at risk of mortality from prolonged

[9] IN our discussions with farmers they may pump two to three times in drought conditions for conventionally transplanted rice but will pump no more as they claim it is not economically feasible to do so for monsoon rice. There is also a cultural prohibition to pumping water in monsoon rice in many localities in Nepal. Farmers report that if they pump water they will be ridiculed by their neighbors as foolish because water that may come tomorrow or the next day from the sky, which is free. This happens even when they watch their crop wither due to prolonged drought.

submergence, literally drowning from early monsoon rains in fields that have no outlet or drainage. This has happened repeatedly in several trials in Nepal and on a recent tour of Bihar Indian we talked to a group of farmers in one demonstration site where one out of five DSR zero till sites survived the heavy pre-monsoon rains.

The authors have, along side their cooperating farmers, directly experienced the problems listed above while testing new tillage and crop establishment practices for monsoon rice (and at times catastrophically so). Our target farmers in Rupandehi District where lowlands with heavy soils are common are simply refusing to take the timing risks (early or delayed rains) alone. This left us scratching our heads about what to do next. One of us (Justice) had heard years earlier of a technique in south East China, where farmers simply took normal rice seedlings and transplanted into untilled fields[10]. It slowly occurred to us that the transplanted reduced till / zero till rice might offer a way of getting around with the timing issues and risks of reduced till or zero till DSR.

5. Objectives

Therefore, a non-puddled transplanted rice experiment was begun[11] at NWRP, Bhairahawa during Kharif season 2004 with the following goals.

- To evaluate non-puddled rice transplanting techniques with other tillage options
- To observe effect of mulching on weed control and rice grain yield
- To get feedback from the laborers who are transplanting out the seedlings in the non-puddled reduced till and zero till fields.

6. Materials and Methods

The experiment consisted of three treatments: 1) manual rice transplanting on tilled plot; 2) manual rice transplanting in strip tilled plot; and 3) transplanting of rice with manual rice transplanter in zero-tilled plot. Three plots each containing 0.10 hectares each were selected at NWRP, Bhairahawa for the experiment. One fourth of each experimental plot was mulched with 2.5 cm thick chopped wheat straw after wheat harvest. The plots were inundated and left as such for a week for the weeds to come. The herbicide Glyphosate @ 12 ml/lit and 500 lit/ha was then sprayed in the all the plots except in the mulched sub-plots.

Rice variety Sabitri was selected for the experiment and dapog method was used to prepare seed mats for transplantig. Seed was soaked in water for 24 hours and incubated for 48 hours. After preparing land, 1m X 5m seed beds were raised 10-15 cm high and carefully leveled. Perforated plastic sheet was laid over the beds and 1 inch thick mud was sprayed evenly over it. Pre-germinated rice seed was broadcasted evenly over the mud and covered with wheat straw. Seed beds were irrigated 3 times a day. After five days, mulch was removed and beds were flooded. The same seedlings were used for manual transplanting.

For the full-till plot, land was tilled two passes with 9-tine cultivator on a 4-wheel tractor and planked. Field was flooded and allowed to remain so for about three days. Sixteen days old seedlings were transplanted on the plots without puddling. For the strip-till plot, the plot was tilled with power tiller strip-till drill with the tillage width of 6 cm and the strips 20 cm apart. Plots were flooded and sixteen days old seedlings were transplanted manually without puddling. For the no-till plot, plots were inundated and allowed to remain as such for about three days. Rice was transplanted with IRRI-model manual rice transplanter without tilling. All three treatments were transplanted out on the same day. Full-till plot was rotated with wheat after land preparation. Other plots were rotated with power tiller zero tillage wheat (two-wheel tractor).

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[11] Funding began from a small grant from National Agricultural and Environmental Forum and now the experiment has been regularized via Nepal Agricultural Research Council.

Fertilizer was applied @100:30:30 N:P:K kg/ha. DAP was drilled with strip-till drill in the strip till plot, while, other fertilizers were broadcasted manually after transplanting. Insecticide Quinolphos was used to control insects.

On maturity, plants were harvested and observations on biomass, grain yield, No. of tiller/m2, plant height, panicle length, No. of filled/unfilled grain/Panicle and thousand grain weight were recorded. Five samples were collected from each treatment and each sample was treated as a replication. Collected data was analyzed using Genstat 5.

7. Results and Discussion

7.1 Effect of tillage Tillage did not have any significant influence on grain yield and yield attributes in the first year. However, grain yield difference was highly significant in the second year, where zero-tilled transplanted rice produced the highest grain yield. Analysis of two year combine data did not show significant yield difference among the treatments but zero-tilled transplanted rice produced the highest grain yield. Tiller count and straw yield was significant, where zero-tilled treatment produced significantly higher number of tiller and highest straw yield.

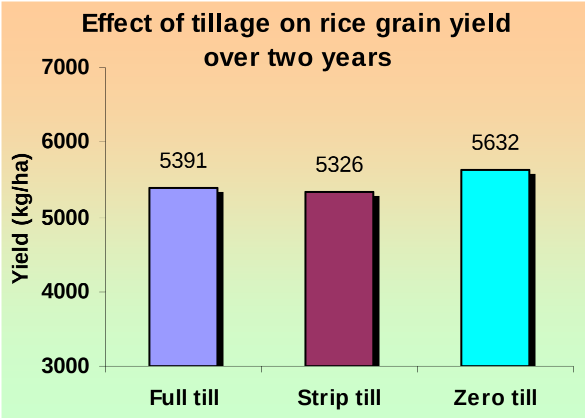

Figure 1: Effect of tillage on grain yield

Table 1: Effect of tillage on rice grain yield and yield attributes over two years

Treatment	Tiller	TGW	Straw	Grain yield
Full till	269.1	20.82	5805	5391
Strip till	284.3	20.30	5487	5326
Zero till	305.2	20.56	5948	5632
LSD	29.22	0.532	463.4	269.3
CV	14.2	3.6	11.2	6.9
F-test	HS	NS	HS	NS

7.2 Effect of mulching Mulching had significant effect of grain yield in the first year but did not show any significant effect in the second year. Mulching produced significantly lower grain yield than no-mulch in the first year but other yield attributing factors were the same. But in the second year, mulching did not show any significant effect on grain yield or other yield attributing factors. On analyzing the two year data, mulching produced significantly lower grain yield than the no-mulch treatment.

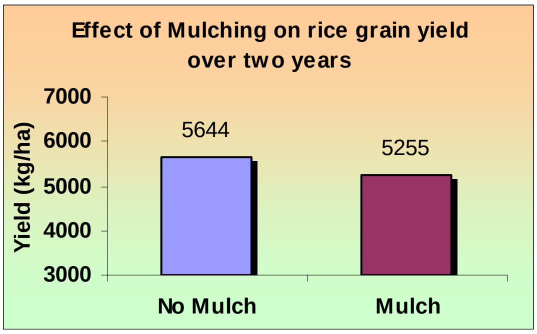

Figure 1: Effect of mulching on rice grain yield – two years

Table 2: Effect of mulching on rice grain yield and yield attributes over two years

Treatment	Tiller	TGW	Straw	Grain yield
No Mulch	290.7	20.60	5987	5644

Mulch	281.8	20.52	5507	5255
LSD	23.86	0.434	378.3	219.9
CV	14.2	3.6	11.2	6.9
F-test	NS	NS	NS	HS

7.3 Tillage and mulching interaction Grain yield difference was significant in the first year, where strip-tilled transplanted rice produced the highest grain yield of 5943 kg/ha followed by zero-tilled transplanted rice (5395 kg/ha) and full tillage without mulching (5370 kg/ha). Full tillage with mulching produced the lowest grain yield of 4527 kg/ha. The yield difference was highly significant in the second year, where zero-tillage mulching treatment produced the highest grain yield of 6536 kg/ha followed by full tillage without mulching (5991 kg/ha) and full tillage with mulching (5674 kg/ha). Strip tillage with mulching produced the lowest grain yield of 5198 kg/ha.

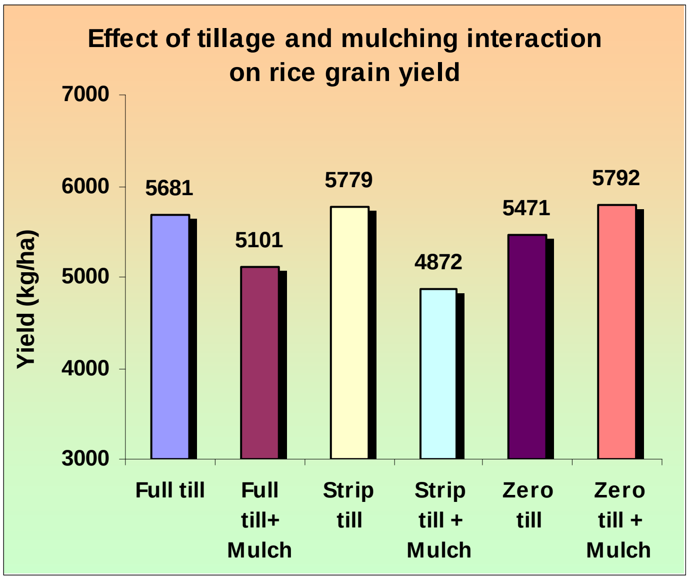

Figure 3: Two year Effect of tillage on grain yield

Two year combine analysis of the data shows highly significant yield difference among the treatments. Zero-tillage with mulching produced the highest grain yield of 5792 kg/ha followed by strip-tillage (5779 kg/ha), full tillage (5681 kg/ha), zero-tillage (5471 kg/ha), full tillage with mulching (5101 kg/ha) and strip tillage with mulching (4872 kg/ha). This inconsistency in grain yield might be due to the change in soil structure that might be taking place in different ways in different treatments. As for the reduced yield in mulching, it is difficult to see the real impact on crop yield in short term, as it is the matter of organic content build up in the soil (J Tripathi, 2003). Fluctuation in the yield might be due to the beginning of stratification of residues in the soil profile, which starts when a specific tillage system is adopted (Hernanz et al., 2002).

Table 3: Effect of tillage and mulching interaction on rice grain yield and yield attributes over two years

Treatment	Tiller	TGW	Straw	Grain yield
Full till	287.4	20.72	6200	5681
Full till + Mulch	250.9	20.92	5411	5101
Strip till	289.1	20.29	5919	5779
Strip till + Mulch	279.5	20.31	5056	4872
Zero till	295.5	20.78	5841	5471
Zerotill + Mulch	314.9	20.34	6054	5792
LSD	41.33	0.752	655.3	380.9
CV	14.2	3.6	11.2	6.9
F-test	NS	NS	NS	HS

8. Feedback from the laborers

While transplanting with IRRI model manual rice transplanter, rice transplanting on mulched area was more difficult. The forks had difficulty pushing through the residue and therefore seedlings did not come into as much contact with the soil as is usual (soil did not grab/hold the seedlings as well). The machine's lever had to be pressed harder than the other non-mulched areas and in some instances gap filling was necessary.

In manually hand transplanted area, labors also stated that it was more difficult to transplant through the mulch. In the non-mulched plots labors stated that rice transplanting was more difficult than puddled field, although they did not complain about the pain in hand. Labor requirement was higher as compared to the traditional transplanting. Only 1-2 man-day/.03 hectares is required for normal transplanting but in these non-puddled field, 2-3 man-day/.03 hectares was required. The authors suspect that may be a learning or acclimatizing curve involved and that with continued use of zero till rice transplanting the times may come down.

Main objective of the strip tillage was to aid the laborers making it easier to transplant into the strips and keep the seedlings in rows. But this objective could not be fulfilled as the labors could not trace the strips in the flooded field. Hence, it became random transplanting. Therefore this treatment will be left out in the future work.

9. Additional observations

9.1 Water percolation Though not measured, water percolation rate was observed higher in all the reduced till/zero till fields as compared to the puddled field. Among the fields, zero-till plot retained water for longer duration than in other reduced till fields. This leads us to believe that the tillage increases the infiltration and percolation rate of the field, somewhat opposed to what other CA researchers are finding.

9.2 Higher residue levels and nutrient cycling Plant height in the mulched part was lower in comparisons to the non-mulched part in all the treatments in the first year. From the very beginning, plants turned yellow and, except with no-till TPR, could not recover. This could be due to the consumption of fertilizer by decomposing straw. But this phenomenon did not occur the second year. There was no noticeable difference in color or plant height. It could have been a nutrient problem with in the field or that the previous year's straw decomposition might have supplied the excess nitrogen needed to decompose the fresh straw. This is also in line with other conservation agriculture research that with time zero till aids in increasing the soil health by increasing its soil structure, aids in promotion of biologically diverse soil microbes and fauna, and to nutrient cycling in the soil profile.

9.3 Weed control As there was no pre-monsoon rain in the first year, straw suppressed weeds in the mulched area. But in the second year, there was heavy pre-monsoon rain, and weeds were not suppressed by straw, as the main weed in the fields is a perennial weed-cynodon dactylon. Mulch alone may not provide the weed control necessary. Many are hopeful that the weed suppression that was provided by conservation agricultural to other cropping systems (and the reduction of herbicide use) may play out for the rice based cropping systems. But to get to that point herbicides or heavy hand weeding may continue to be necessary.

9.4 Effects of field access by labor and machine on inundated soil There is some concern about the loss of soil structure (puddling with the feet) from repeated entry into the muddy field by the transplanting and weeding crews. Also, though the use of light weight IRRI type manual rice transplanter with two narrow 15 centimeter wide skids may not affect the soil one way or another but the use of heavier powered transplanters with large wide skids and means of traction (cage wheel/tires, or caterpillar tracks) will provide large surface smears and/or puddling. What this means for true conservation agriculture remains to be researched.

10. Recommendations

10.1 Breeding for CA rice Another way to get around the problems of submergence and extended dry periods and the more aerobic environment that CA rice fosters, is for the national and international research centers to begin the selection of existing submergence/drought tolerant rice varieties and even begin breeding for conservation agriculture aerobic flourishing rice.

10.2 Integrated weed control For most rice farmers in the world water, used as a herbicide, will only become more dearer. Also, the use of higher levels of mulch for weed control is difficult for the poorer farmers especially in the absence of stall feeding, in the eastern Gangetic plains. For zero till rice to be successful with the farmers other innovative and integrated weed control must be found, especially for small and poor rice farmers who will predictably have difficulty affording or sourcing expensive herbicides and their sprayers. In addition to mulch, improved manual weeders could be incorporated into the integrated weed management. Additionally, there are new sulfuron based molecules becoming available for the scourge of zero till rice-*cyprus rotundus and cynodon dactylon*. The possibility for promotion of well trained herbicide spraying service providers for small and large farmers should be also be explored. Lastly, as CIMMYT scientist Ken Sayre relates[12] that there is much confusion about how much mulch should be retained for improving soil health and controlling weeds and that researchers should focus on "rational residue retention". He hypothesizes that in the rice wheat systems of the mechanized and wealthier north western Gangetic plain, merely 1/3 of the rice residue retained may enough to meet these CA needs. Levels and needs may be different in the poorer less mechanized and heavier soils of the eastern Gangetic plain.

10.3 Move to farmer field trials With the initial successes on the research farm's exploratory trial researchers need to move as quickly as possible to begin farmer field trials, especially to gauge better manual hand transplanting crews' reactions and abilities to adapt to reduced till / zero till conditions.

11. Conclusion

Though problems persist, and further investigations are needed, the positive grain yield results along with feed back from the laborers, points to the possibility that reduced till and zero till transplanting of rice, may eliminate the current risks surrounding direct seeded reduced till and zero till rice in lowland areas lacking drainage and provide the same flexibility of timing with monsoon rains that conventional rice planting offers. It is intended not to replace direct seeded rice but simply add another conservation agriculture methodology for farmers to choose from on an as needed basis. Additionally, reduced till and zero till manual hand transplanted rice offers CA rice methodologies to small and poor farmer who might not afford or have access to more expensive tractor based technologies. Yet, the use of existing manual or powered mechanical rice transplanting machinery also offers drudgery reduction and labor saving efficiencies to small and large farmers alike in applying CA rice to lowland rice fields.

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ANNEX ONE: Summery of problems and benefits in new tillage and crop establishment technologies in rice

Problems with Puddled-Monsoon Rice	**Benefits of Puddled-Monsoon Rice**
Delays the planting-transplanting of rice till the onset of monsoon.	Very good weed control for both rice and the follow on winter crop.
Destroys soil structure for following winter non-puddled crops	Higher soil moisture retention, low percolation rate and hence requires less frequent irrigation
Reduces soil microbial and zoological biodiversity and concomitant soil health.	No nutrient loss by seepage.
Increases water consumption at the time of establishment	Under continuous rice cropping areas there appears to be no yield declines.
Matures late, forcing farmers for late sowing of winter crops, which substantially reduces the yield	Farmers switching from continuous rice cropping are experiencing declines in soil health
Problems with Direct Seeded Monsoon Rice	**Benefits of DS Monsoon Rice**
Early monsoon rain may not allow CA machinery (zero till drills etc) to enter the field	Potentially increased soil health and structure especially in zero till.
Lack of drainage in lowland rice causes prolonged inundation and seedling mortality	Decreased water consumption during establishment
Need for chemical control of weeds	Most of the direct seeded rice have line sowing, which makes mechanical weeding feasible
Lack of puddling, especially in lighter upland soils, may increase infiltration may lead to soil drying out reduced yields or need for additional irrigation	Low establishment cost as seed bed preparation, seedling uprooting and field puddling costs are saved
Farmers refusal to irrigate summer rice	Matures 7-10 days earlier than transplanted rice, encourages timely wheat seeding and increased cropping intensity