



Zero-till wheat (*Triticum aestivum* L.): A Nepalese perspective

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ABSTRACT

Agriculture is the main occupation in Nepal and around 60.4% Nepalese are actively engaged in the agricultural sector. Wheat is the third most important cereal crop after rice and maize in terms of area and production, in Nepal. Currently, less than 2% area of the total wheat cultivation, is under zero-till wheat. Zero tillage (ZT) is a vital component of resource conserving technologies (RCTs) that are implementing to produce crops with lower inputs resulting in higher profit. ZT of wheat after rice generates significant benefits at the farm level, both in terms of significant yield gains (6–10%, particularly due to more timely planting of wheat) and cost savings (5–10%, particularly tillage savings) as compared to conventional tillage (CT). The paper reviews the prospects of ZT wheat technology in Nepal, based on the published information. ZT is the most widely used technology of wheat in Nepal, among other resource - conserving technologies. ZT wheat yielded 3.44 t ha⁻¹ whereas CT wheat yielded 3.22 t ha⁻¹. The total cost incurred under ZT wheat is NRs. 39,431 whereas NRs. 48,300 is of CT. The benefit: cost ratio was found 2.38 in ZT compared to 1.81 in CT which was 31.5 % more over the CT method of wheat cultivation. Hence, ZT technology in Nepal is cost-effective technology facilitating 15 days earlier sowing of wheat with higher yield and needs to be promoted on a large scale.

Keywords: Conventional tillage, rice-wheat system, yield, reduced tillage, resource-conserving technology



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1 Introduction

Nepal is a small land-locked mountainous country with diverse agroecologies, culture and agriculture (Gauchan and Shrestha, 2017). Wheat (*Triticum aestivum* L.) is one of the most important food crops worldwide for human nutrition, originated 8000–10,000 years ago (Dubcovsky and Dvorak, 2007; Brenchley et al., 2012). Wheat covers 17% (one sixth) of the total cultivated land in the world (Shrestha et al., 2018) feeding about 40% (nearly half) of the world population and providing 20% (one fifth) of total food calories and protein in human nutrition (Gupta et al., 2008). Wheat is the third most important cereal crop after rice and maize in terms of area and production, in Nepal. In Nepal, currently 21%

land is used for agricultural crop production and wheat was cultivated in 7,03,992 ha with production of 20,05,665 metric tons, in the fiscal year 2075–76 (2018–19) (MoALD, 2020). Among wheat cultivated area currently less than 2% is only under zero-till. Increasing water and labor scarcity and high cost of production as well as climate change are compelling farmers to change to zero tillage technology of wheat from conventional farming. One of the major hindrances to optimum production of wheat on the 13.5 million hectares of land (rice – wheat system) in the Indo - Gangetic flood plains (IGPs) of South Asia is late planting and resulting in poor plant stands due to low tillering. Late harvest of the previous rice crop, as there are mostly long duration rice varieties or long

turnaround time from rice harvest to wheat planting are two major causes of late wheat planting (Hobbs and Giri, 1997). Reduced or zero tillage options are becoming more effective in overcoming the late planting and poor plant stands in the rice-wheat systems of Asia.

The process of direct drilling of wheat seeds using zero-till seed drills fitted with inverted T-openers to place seed and fertilizers into a narrow slot with only minimal of soil disturbance and without land preparation is called Zero till (ZT) technology. ZT is also known as zero till, no till, direct seeding and direct drilling/planting without tillage (Erenstein and Laxmi, 2008). The existing ZT technology in the IGP uses a tractor - drawn zero-till-seed drill to seed wheat directly into unplowed fields with a single pass of the tractor. The typical ZT drill has Inverted - T openers and opens a number (6–13) of narrow slits for placing seed and fertilizers at the depth not more than 5 cm into the soil (Tripathi, 2014). The most widely used ZT drill in Nepal has nine Inverted - T openers at a distance of 17.5 cm to 20 cm; jointed with clamp. In contrast, conventional tillage (CT) practices in wheat typically involve 'intensive tillage with multiple passes of the tractor to accomplish plowing, harrowing, planking, and seeding operations' mechanically (Erenstein et al., 2008).

In various researcher-managed field trials across South Asia, ZT with and without residue retention ('conservation agriculture' implies ZT with residue retention) has demonstrated considerable agronomic and economic benefits, while improving the environmental footprint of agriculture by reducing energy costs and improving soil fertility and water use efficiency (Erenstein and Laxmi, 2008; Chauhan et al., 2012; Gathala et al., 2013; Mehla et al., 2000). Agronomic factors leading to productivity advantages in ZT wheat are related to (i) time - savings in crop establishment, allowing earlier sowing and, hence, reducing risks of terminal heat stress during the grain-filling phase; (ii) better control of weeds, such as *Phalaris minor*; (iii) better nutrient management; and (iv) water savings (Gathala et al., 2013; Mehla et al., 2000).

Long term adoption of the ZT resulting in acidification of the surface soil which further affects the supply and distribution of other nutrients within the rhizosphere. Under ZT, a significant lowering of pH observed at the upper soil 0-7.5 cm on silt loam soil (Dick et al., 1986). In Kentucky, soil acidity with ZT observed due to decomposition of organic residues at the surface with subsequent leaching of organic acids into mineral soil (Blevins et al., 1977; Moschler et al., 1973). ZT reported to increase the bulk density to the highest level (1.69 Mg m^{-3}) while residue incorporation lowered it (1.59 Mg m^{-3}) (Gangwar and Singh, 2010). ZT performance is still in question because of higher weed biomass (Bhatt, 2017).

Most of the Nepalese farmers are resource – poor. Very few farmers possess their own tractors and specialized seed drills required to implement the ZT technology of wheat. As a result, adoption of ZT largely hinges on affordable access to custom hire services. Competition of crop residues between ZT use and livestock feeding, burning of crop residues, availability of skilled and scientific manpower are also the major constraints for promotion of ZT in Nepal. The need to develop the policy frame and strategies is urgent to promote ZT (Sah, 2017). This article reviews and synthesizes the experience with ZT wheat in the rice – wheat systems of Nepal.

2 Prerequisites of zero-till wheat

Soil moisture Land should be moist at the time of planting wheat under zero tillage, so that the seed drill can be operated under unploughed land after the rice harvest. If there is no sufficient moisture, one pre-sowing irrigation should be provided before sowing of wheat (Tripathi, 2014).

Land topography The land where zero- till wheat is going to be practiced should not be undulated. The land should be well prepared at the time of puddling of land, in rice season (Tripathi, 2014). Laser-assisted precision land leveling considered as a precursor technology for RCTs has been reported to improve crop yields and input-use efficiency including water and nutrients (Jat et al., 2006). Different studies have confirmed that laser levelling technology will decrease farming costs in different cultivation and harvest stages (Abdullaev et al., 2007). Laser land levelling causes the reduction of pesticides consumption, improves the use of nutritious materials and reduces consumption of chemical fertilizers (Abdullaev et al., 2007; Jat et al., 2006; Gonzales et al., 2009). Decreasing the amount of water consumption, uniform distribution of water, reducing irrigation frequency and time and water wasting are among the most important impacts (Abdullaev et al., 2007; Jat et al., 2006; Jehangir et al., 2007; Gonzales et al., 2009; Das et al., 2018; Shahani et al., 2016; Ashraf et al., 2017). Reducing the use of seeds, uniformity of germination and crop growth and increasing yield have been mentioned in some studies (Abdullaev et al., 2007; Jat et al., 2006; Jehangir et al., 2007). Jat et al. (2006) noted that the amount of fuel consumed by pump engine for pumping water and agricultural machinery would be reduced by this technology. Also, land leveling led to an increase in the cultivable area (farm useful area) and under-cultivated area based on accessible water supply. Abdullaev et al. (2007) and Jat et al. (2006) indicated that farmers' income will be increased by levelling lands. Other impacts of land levelling are reducing family workforce and the number of laborers

Table 1. Benefits of zero-tillage over conventional tillage for the planting of wheat after rice in Haryana, India

Item	Farmers' perceptions	Researchers' findings
Sowing	Wheat sowing earlier by 5 - 8 days (small-to-medium farms) to 2 weeks (large farms)	On average, wheat sowing can be advanced by 5 – 15 days
Fuel savings	Not available	On average 60 litre diesel ha ⁻¹
Cost of cultivation	US\$ 42-92 ha ⁻¹	US\$ 37- 62 ha ⁻¹
Plant population	20 – 30 % more plants in zero-tillage fields	13.5% more plants in zero-tillage fields
Weed infestation	20% less and weaker weeds in zero-tillage fields	43% fewer weeds in zero-tillage fields
Irrigation	Saves 30 - 50% water in the first irrigation and 15 - 20% in subsequent irrigations	36% less water used, on average
Rice stem borer infestation	Less, because of less stubble sprouting	Winter coolness impairs sprouting and thus borer development. Beneficial insects in stubble help control borers
Rice stubble	Decayed faster	Decayed faster
Fertilizer-use efficiency	High	Higher because of placement
Wheat yields	Higher than under conventional system depending on days planted earlier	420-530 kg more ha ⁻¹

needed for different farming operations (Abdullaev et al., 2007; Akhtar, 2006).

Weed management Before operating the zero till seed cum fertilizer drill, the land should be either free or made free from weeds. If the land is not free from weeds, use of non - selective herbicides is suggested; before 7 days of sowing of zero-till wheat (Tripathi, 2014).

Calibration of zero-till-seed cum fertilizer drill Calibration is needed before practicing zero-till wheat to ensure appropriate amount of seed and fertilizer to be placed in the soil, simultaneously (Tripathi, 2014).

Trained driver The driver should be well trained for operating zero-till-seed cum fertilizer drill (Tripathi, 2014).

3 Impact of zero tillage

3.1 Crop yield

Research from Pakistan and India have reported the higher wheat yields following the adoption of ZT in rice–wheat rotations. In 34 zero-tillage on-farm trials over 3 years in the rice-growing belt of the Pakistan Punjab, higher yields were observed with zero-tillage than the farmers' practice. This is mainly due to the time saved in land preparation that enabled a more timely planting of wheat crop. It has been reported

from the simulation study that planting time of wheat regulates yield, governed by the climatic parameters, mainly through temperature and delayed planting results in significant losses in yield (Rai et al., 2004). Based on on-farm trials in Haryana, Mehla et al. (2000) estimated a ZT induced yield gain of 15.4%, which they attributed to timely sowing (9.4%) and enhanced fertilizer- and water use efficiency, as well as weed suppression (6.0%).

A field experiment conducted in Nepal during the winter season of 2012 and 2013 showed that grain yield under conventional and zero tillage was at par. However, the yield was slightly higher (5.48%) with conventional tillage than zero tillage in 2012 and 5.33% higher in 2013 (Pandey et al., 2016). Since wheat was sown on the same date under zero and conventional tillage, the yield might have been lower with zero tillage. Another field experiment in Nepal conducted during the wheat growing seasons of 2013 to 2016 showed that conventional tillage yielded significantly higher grain yield than zero tillage in first year but was at par in the second and third year (Pandey and Kandel, 2020).

3.2 Cost comparison under zero tillage systems with conventional practices

ZT has the potentiality to saves in energy, water, labor as well as other inputs. ZT drastically reduces the tillage operations and the cost of the tillage operation—a major cost of crop production in the IGP. The ZT drill potentially saves seed and fertilizer, plac-

Table 2. Expenditure and income (NRs ha⁻¹) in wheat production using ZT and CT methods of sowing in farmers' field of Kailali district, Nepal during 2017-18

Particulars (Cost NRs.)	Zero tillage	Conventional tillage	Change (%)
Variable cost			
Cost of human labour	8000	8,800	10
Cost of machinery labour	11,250	20,250	80
Cost of seeds	6,600	8,250	25
Cost of fertilizer	7,531	3,450	-54
Cost of herbicides	2,700	2,700	0
Cost of irrigation	3,000	4,500	50
Total variable cost	39,081	47,950	23
Fixed cost	350	350	0
Total operational cost	39,431	48,300	23
Gross income	93,657	87,598	-7
Net income	54,226	39,258	-28
Benefit : cost ratio	2.38	1.81	-24

ing them at the desired depth and vicinity and in the right quantities as compared to broadcasting (Erenstein and Laxmi, 2008). Two factors contributing to the overall profitability of ZT are : (i) the value of the yield increase (the 'yield effect') and (ii) the savings in production cost (the 'cost-saving effect'). The ZT yield effect averages Rs 2030 ha⁻¹ (US\$ 45) across IGP studies. The ZT cost-saving effect averages Rs 2320 ha⁻¹ (US\$ 52) across IGP studies (Erenstein and Laxmi, 2008). The production cost and returns of wheat production using ZT and CT methods has been depicted in Table 2. The table reflected that the gross incomes were NRs. 93,657 ha⁻¹ in ZT and NRs. 87,598 ha⁻¹ in CT method of wheat cultivation. The net returns of wheat were NRs. 54,255.5 ha⁻¹ in ZT and NRs. 39,298 ha⁻¹ in CT method of wheat production. The net income of ZT method were found higher due to higher grain yield and lower production cost than the CT method of wheat cultivation. The total cost of production amounted to NRs. 39,081 in ZT method and NRs. 47,950 in CT method. The lower cost of production was due to lower expenses on human labour by 10%, machinery labour by 80%, seed cost by 25%, irrigation cost by 50%, and no cost for the land preparation in ZT compared to the CT method of wheat cultivation. The benefit: cost ratio was found 2.38 in ZT compared to 1.81 in CT which was 31.49% more over the CT method of wheat cultivation. Yield, expenditure and income in ZT and CT methods of wheat production in farmers' field at Kailali district, Nepal during 2017-18 has been presented in Table 3.

3.3 Impact on soil

ZT improves the soil physical, chemical and biological properties but it might have some adverse con-

sequences *viz.* increased bulk density (Bhatt, 2017). Under-ground water pollution chances are very small under ZT because of dramatic reduction in runoff. Further, under zero tilled plots, herbicides are very quickly broken down by soil organisms into harmless compounds (Duiker and Myers, 2005). When such agrochemicals are used in intensively ploughed soil they move more freely beyond the vadose zone compared to how it would be in the zero tilled plots. Conservation tillage practices, such as zero and minimum tillage are viable answer to the uplift the soil environment as it includes the full residue onto the plots (Miura et al., 2008; Bhatt and Khera, 2006). Therefore, conservation tillage approach is a must for practising sustainable and climate smart agriculture by covering the bare soils, minimizing the erosion losses.

3.4 Impact on environment

Straw retain on the soil surface reduces weed seed germination and growth, moderates soil temperature and reduces loss of water through evaporation. Crop residue is also an important source of fodder for animals in the IGP countries. Despite these potential benefits, however, large quantities of straw (left over after rice and wheat harvesting) are burnt each year by farmers to facilitate land preparation for crop planting in Nepal too. It is estimated that the burning of one ton of straw releases 3 kg particulate matter, 60 kg CO, 1460 kg CO₂, 199 kg ash and 2 kg SO₂. Nowadays, new seed drills have been developed which are able to cut through crop residue, for zero-tillage crop planting. These seed drills help to avoid burning of 10 t ha⁻¹ of straw which potentially reduces release of about 13–14 tons of carbon dioxide (Gupta et al., 2004). Elimination of burning on just 5 mil-

Table 3. Yield, expenditure and income in ZT and CT methods of wheat production in farmers' field at Kailali district, Nepal during 2017-18

Particulars	Zero tillage	Conventional tillage	Change (%)
Grain yield (kg ha ⁻¹)	3440	3224	-6.28
Straw yield (kg ha ⁻¹)	2811	2516	-10.49
Total cost (NRs.)	39431	48300	22.49
Gross income (NRs.)	93657	87598	-6.47
Net income (NRs.)	54226	39298	-27.53
Cost of grain production (NRs. kg ⁻¹)	10.65	14.20	33.40

lion hectares would reduce the huge flux of yearly CO₂ emissions by 43.3 million tons (including 0.8 million ton CO₂ produced upon burning of fossil fuel in tillage). Zero-tillage on an average saves about 60 L of fuel ha⁻¹ thus reducing emission of CO₂ by 156 kg ha⁻¹ yr⁻¹ (Grace et al., 2015; Gupta et al., 2004).

3.5 Socioeconomic and system impacts of zero tillage in Nepal

Locally adapted resource conserving technologies, RCTs (zero tillage, reduced tillage, surface seeding, bed planting systems) are really a boon to farmers and the biophysical environment. RCTs hold potential to improve management of natural resources and provide sustainable increases in productivity. Zero tillage technology provides opportunities to reduce the cost of production with remarkable savings on water and nutrients, increase in yield, improved efficiency in using the resources, and benefits the environment. This would help the farmers to gain more profit from ZT as compared to that of CT. Thus, economic condition of the farmers would rise to some extent accompanying increased social status, in the long run. Exercising of ZT in wheat opens the scope for new technologies including the application of ZT to other crops (e.g., pulses and cereals) and permanent beds. ZT also has the potential of increasing cropping intensity and diversity in selected areas of Nepal (e.g., moving towards double cropping in rice–fallow systems; introducing triple cropping in rice–wheat systems).

The ever increasing demand for basic cereals in the future would need to be met largely through increased productivity, allowing some land (and other resources) for diversification for greater income generation. Clearly, market forces and national and provincial policies will drive the pace and form of the diversification. An additional factor influencing the diversification of rice – wheat systems (RWSs) would be the new 'platform' made possible by the RCTs. Cultivating wheat via zero tillage technology facilitates wheat sowing 15 days earlier as compared to that of conventional tillage. The limited human labour and time required for the use of tractor as well as pumping sets for irrigation could also be consider-

ably reduced along with requirement of diesel which ultimately reduced the cost of cultivation in case of ZT method. For the upliftment of zero tillage technology of wheat in Nepal, the government should either donate ZT seed-cum-fertilizer drill to the farmers' cooperatives or lower the tax in import of it from neighboring countries.

4 Conclusions

Zero tillage technology of wheat is facilitating wheat sowing by 15 days earlier in Nepal which is also cost effective, less labour requirement, higher fertilizer-use efficiency and higher yielding very crucial technology.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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