Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(1): 770-774
Received: 03-11-2018
Accepted: 07-12-2018

Sanjay Sapkal
Division of Agricultural Economics, IARI, New Delhi, India

Umrao Bondar
Department of Agricultural Economics, MPKV, Rahuri, Maharashtra, India

Pramod Kumar
Division of Agricultural Economics, IARI, New Delhi, India

Amit Kar
Division of Agricultural Economics, IARI, New Delhi, India

GK Jha
Division of Agricultural Economics, IARI, New Delhi, India

Correspondence
Sanjay Sapkal
Division of Agricultural Economics, IARI, New Delhi, India

Economics of zero tillage and conventional methods of wheat production in North-Eastern indo-gangetic plains of India

Sanjay Sapkal, Umrao Bondar, Pramod Kumar, Amit Kar and GK Jha

Abstract
The paper has compared the economics of wheat production in North- Eastern Indo-Gangetic Plains of Bihar under zero tillage and conventional methods and assessed the contribution of technology and inputs to the increased productivity due to zero tillage (ZT). The net income has been found higher in ZT method, mainly due to lower cost of production compared to that in conventional method. The study has observed that ZT technology has potential to provide additional income to farmers and help in conservation of scarce resources. The decomposition of productivity revealed 48 per cent of the difference in productivity due to ZT and the rest due to changes in input use. Despite several economic and environmental advantages, adoption of ZT technology has been limited and one major constraint identified as the lack of extension activities followed by lack of technical knowledge. The study has suggested that ZT technology should be disseminated on a wider scale with the help of better technical and extension support to the farmers.

Keywords: Zero tillage, wheat production, economics, decomposition analysis, Bihar

Introduction
Rice-wheat systems provide the staple grain supply for about 8% of the world's population, making these systems critically important for global food security (Ladha *et al*. 2003; Timsina and Connor 2001). In South Asia, rice-wheat systems produce more than 30% of the rice and 42% of the wheat consumed and in general cover about 14 million hectares of cultivated land, with most of the area located in India and the IGP in particular. During the 1950s and early 1960s, South Asia suffered from frequent severe food shortages. Beginning in the late 1960s, however, production of rice and wheat increased dramatically throughout the region during the 'Green Revolution,' spurred by new high yielding wheat and rice germplasm, a favourable resource base, rapid expansion of irrigation infrastructure, and an extremely supportive policy environment. But, some recent studies indicate a slowdown in the productivity of growth in the rice-wheat systems of India (Kumar *et al*. 2004). Evidence from long-term experiments shows that crop yields are stagnating and sometimes declining (Duxbury *et al.* 2000; Ladha *et al.* 2003). Current crop cultivation practices in rice-wheat systems degrade the soil and water resources thereby threatening the sustainability of the system (Gupta *et al.* 2003; Ladha *et al.* 2003). This will require rapid changes towards technologies that are more productive but less resource-degrading.

In IGP, many farmers grow late-maturing, fine-grained basmati varieties of rice, causing late sowing of wheat. The delay of every successive day in planting beyond November third week decreases the grain yield progressively (Ali *et al*., 2010; Irfaq *et al.*, 2005; Sharma, 1992) [1, 11, 15]. Therefore, to avoid delay in planting and reduce the cost of production, farmers have started adopting resource conserving technologies such as zero tillage and surface seeding in wheat production (Gupta and Seth, 2007) [9]. Adoption of zero tillage in wheat cultivation saves input cost, fuel consumption and irrigation water-use (Malik *et al.*, 2003; Bhushan *et al.*, 2007) [14, 3]. Farmers prefer this technology to overcome farm labour shortage and minimize the impact of rising fuel prices. In view, of this it is important to compare the economics of wheat production with zero tillage and conventional methods and quantifying the contribution of technology and inputs into the estimated productivity gain due to zero tillage.

Methodology
Zero-tillage (ZT) has been interpreted here as the process of planting wheat seed after the harvest of rice directly on untilled soil which retains the rice crop residues. The conventional tillage (CT) refers to the intensive tillage with multiple passes of a tractor to accomplish land preparation for wheat sowing. Farmers in Bihar are rapidly adopting zero tillage technology

for wheat cultivation. For this study, Vaishali district was selected due to widespread adoption of zero tillage. From the Vaishali district, four climate smart villages (CSV) and four non-climate smart villages (Non-CSV) were selected having larger area under ZT in wheat. A total of 39 farmers from CSV who adopted zero tillage technology for wheat production were selected randomly. From the Non-CSV villages, 40 numbers of farmers practising conventional tillage method were selected. The characteristics and socio-economic conditions of both types of the households were almost similar. The primary data were collected during the years 2016-17 from 79 farmers.

The modern cost concept, i.e., costs A_1, A_2, B_1, B_2, C_1 and C_2, was considered for the estimation of cost of wheat production (*see* Appendix I). The cost C_1 was taken into account in this study to calculate net income and benefit-cost ratio. The cost C_1 included all direct expenses paid in cash and kind for crop production such as hired human labour, machine labour, seeds, fertilizers, irrigation, plant protection measures, overhead charges and imputed value of family labour. The overhead charges included land revenue paid to the state government, interest on working capital and fixed capital and charges paid for repairs, maintenance and depreciation of fixed assets (Central Statistical Organization, 2008) [5].

The cost of irrigation was calculated by multiplying the time required to irrigate the farm with cost of electricity or diesel consumption per hour. The cost of electricity was taken based on per unit rate fixed by the Bihar Electricity Distribution Corporation. The cost on human labour, machine labour and diesel were taken on actual expenditure basis. Gross income included the total value of main crop and by-products. Net income was calculated as the difference between gross income and cost of production (cost C_1).

In the present study, output decomposition model, as developed by Bisaliah (1977) [4], was used to quantify the contribution of various sources to the productivity differences between zero and conventional tillage methods. It was observed from various studies that introduction of technology has enhanced land productivity significantly (Balakrishna, 2012; Kiresur *et al.*, 2011) [2]. It is expected that the practice of zero tillage technology will result in changes in input-use pattern, which in turn will affect the land productivity. Hence, increase in land productivity in wheat is not only due to adoption of zero tillage method but also due to the changes in use of factors in production. The following output decomposition model was used in this study.

The Cobb-Douglas production function in logarithmic form for zero tillage method of wheat production is:

$$\ln Y_{cs}=\ln b_0+ b_1\ln X_{1cs}+ b_2\ln X_{2cs}+ b_3\ln X_{3cs}+ b_4\ln X_{4cs}+ b_5\ln X_{5cs}+ b_6\ln X_{6cs}+ U_{cs} \quad \ldots(1)$$

Where,

Y=Output (qtl);

X_1= Human Labour (man days);

X_2= Machine labour (hrs);

X_3= Seed (kg);

X_4= Fertilizer (kg);

X_6= Plant Protection Chemicals (gm);

X_6= Irrigation (hrs);

U= random disturbance term, in conformity with the OLS assumptions;

bo= scale parameter, and

b_i=slope parameters of the regression function (Production elasticities, i=1to 6)

The per hectare production function for conventional tillage method is given in Equation

$$\ln Y_{ct}=\ln a_0+ a_1\ln X_{1ct}+ a_2\ln X_{2ct}+ a_3\ln X_{3ct}+ a_4\ln X_{4ct}+ a_5\ln X_{5ct}+ a_6\ln X_{6ct}+ U_{ct} \quad \ldots(2)$$

Taking difference between the equation (1) and (2), the following decomposition model was arrived as follows:

$$\ln [Y_{cs}/Y_{ct}] = \{ \ln (b_0/a_0)\} + \{(b_1-a_1)\ln X_{1ct}+ (b_2-a_2) \ln X_{2ct}+(b_3-a_3) \ln X_{3ct}+ (b_4-a_4) \ln X_{4ct}+(b_5-a_5) \ln X_{5ct}+ (b_6-a_6) \ln X_{6ct}\} +\{b_1\ln (X_{1cs}/ X_{1ct}) + b_2\ln (X_{2cs}/ X_{2ct}) + b_3\ln (X_{3cs}/ X_{3ct}) + b_4\ln (X_{4cs}/ X_{4ct}) + b_5\ln (X_{5cs}/ X_{5ct}) + b_6\ln (X_{6cs}/ X_{6ct})\} +\{U_{cs}-U_{ct} \quad \ldots(3)$$

The left hand side of the equation (3) gives the total difference in productivity expressed as an approximate percentage over conventional tilled farm. The natural logarithm of the ratio of per hectare net returns of Zero Tillage adopter farms and conventional tilled farms is approximately a measure of percentage difference in net outputs of the two categories of farmers. The first bracketed term on the right hand side, the natural logarithm of constant terms, is the gap attributable to the neutral component of technology. It is a measure of neutral technological gap. The second bracketed term is the gap attributable to the non-neutral component of technology weighted by input use expenditure for conventional tilled farms. That is, it is a measure of non-neutral technological gap, after adjustment in the level of input use expenditure weighted by the slope coefficients of the production function fitted for the Zero Tillage technology adopter farms. Hence, it is the gap due to difference in the levels of input use between two category of farmers after making due adjustment for production elasticities of different inputs. The last component is a random term which the model could not take into account.

Results and Discussion

In the study area, crop production was the major activity reported by more than 80 per cent of the sample farms (Table 1).

Table 1: Table 4.1 Socio-economic characteristics of sample farm households

Sr. No.	Particulars	Vaishali farmers		Overall
		CSV	NCSV	
1	Sample size (No.)	39	40	79
2	Average age (years)	46.44	49.75	48.09
3	Average family size (No.)	7.4	7.7	7.55
4	Literacy (%)	65	57.5	61.25
5	Farming main occupation (%)	86.25	82.5	84.38
6	Farm size (ha)	1.83	1.78	1.81
7	Training access (Yes=1; otherwise=0)	61	7	34
8	Membership of organization (Yes=1; otherwise=0)	37	14	25.5
9	Credit access (Yes=1; otherwise=0)	56	19	37.5
10	Cropping intensity	176	158	167

The rice (*Oryza sativa*) crop was sown during the *kharif* season (June to November), whereas wheat (*Triticum aestivum*) was the major crops grown extensively by the farmers in the *rabi* season (November to May). Age of CSV farmers was lower than that Non-CSV farmers. It is observed that younger people are more receptive to new technology.

The family size of CSV farmers is smaller, are better educated and higher proportion had farming as a main occupation than those of Non-CSV farmers in study area. More number of CSV farmers were members of various organisations likes Farmers Club, Self-Help Groups, Grampanchayat, Co-operative societies etc. as compared to Non-CSV farmers, which could play a role in to get more exposure to the availability of various adaptation strategies to climate change. The CSV farmers have on an average three times more access to credit and five times more access to training as compared to Non-CSV farmers. The average farm size was also observed to be more in case of CSV farms (1.83 ha) as compared to Non-CSV farms (1.78 ha). At overall level, the cropping intensity on CSV sample farms is 18 per cent more than Non-CSV sampled farms.

Resource-use and Cost and Return Structure in Wheat Production

The major farm inputs used for the production of wheat in CT and ZT methods are mentioned in Table 2.

Table 2: Major farm inputs used in wheat production in North-Eastern IGP

Particulars	Zero Tillage	Conventional Tillage	Change (%)
Human labour (human days/ha)	42.9	49.2	-12.80
Machine labour (hours/ha)	2.7	11.3	-76.11
Seeds (kg/ha)	109	118	-7.63
Fertilizer (kg/ha)	303	320	-5.31
PPC (g/ha)	474	355	33.52
Duration of Irrigation (hr/ha)	18.97	25.92	-26.81

A perusal of Table 2 revealed that farmers saved 12.80 per cent human labour, 76.11 per cent machine labour and 26.81 per cent duration of irrigation in ZT compared to CT method of wheat production. Several studies have also shown that ZT method of wheat production provides several benefits such as saving of irrigation water, reduction in production cost, less requirement of labour and timely establishment of crops, resulting in improved crop yield and higher net income (Laxmi *et al*., 2007; Farooq *et al*., 2006; Erenstein *et al*., 2007) [13, 8, 13]. This suggests that by adopting zero tillage method, farmers can save a substantial quantity of resources which helps to overcome the problems of human and machine (tractor) labour shortage at the time of land preparation and sowing operations.

It was observed that most of the farmers in the study area were not convinced about the superiority of ZT technology. After practising ZT technology in wheat for 2 to 3 years, several farmers had reverted back to reduced tillage (RT) or CT method. This practice is being followed to avoid weed infestation. According to the farmers, till now there are no chemical weedicides which are effective in controlling weeds in ZT. As a general practice, harvesting and threshing are done with the help of a combine harvester machine and only a few farmers harvest wheat manually and thresh wheat by power-operated threshers.

The production costs and returns of wheat production using ZT and CT methods are presented in Table 3. Gross returns were Rs. 61910 per ha in ZT and 56776 per ha in CT. The return over operational cost amounted to Rs. 40514 per ha in ZT and Rs. 28231 per ha in CT method of wheat production. The net income was higher in ZT method due to higher yield and lower cost of cultivation as compared to CT method of wheat cultivation. The cost of cultivation amounted to Rs. 21396 per ha in ZT method and Rs.28545 per ha in CT method. The lower cost of cultivation was due to lower expenses on human labour (12.80 per cent), machine labour (76.11 per cent), irrigation (26.81 per cent) and other inputs like seed, fertilizers in ZT than in CT method. The benefit-cost ratio of 1.98 was observed in ZT as against 1.48 in CT method of wheat production.

Table 3: Cost and return in wheat production using Zero Tillage method in North-Eastern IGP

Particulars	Zero Tillage	Conventional Tillage	Change (%)
Cost on human Labour	7508	8610	-12.80
Cost on machine Labour	1620	6780	-76.11
Cost on seeds	3270	3540	-7.63
Cost on fertilizer	3856	4034	-4.41
Cost on PPC	2250	1690	33.14
Irrigation charges	948	1296	-26.85
Overhead Cost	1945	2595	-25.05
Total Operational cost	21396	28545	-25.04
Gross income	61910	56776	9.04
Return over operational cost	40514	28231	43.51
Benefit-cost ratio over cost C_1	1.98	1.48	19.28

There was significant difference in wheat yield with and without ZT method of cultivation (Table 4). It was about 9 per cent more with the application of ZT than with CT method. It was also observed that among the integrated conservation and resource management technologies, ZT for wheat was most successful in terms of crop establishment (Ladha *et al*., 2009) [12] and gain in yield ranging from 1 per cent to 12 per cent (Erenstein and Laxmi, 2008) [6].

Table 4: Yield, cost and return in CT and ZT methods of wheat production in NE IGP

Particulars	Zero Tillage	Conventional tillage	Change (%)
Yield (t/ha)	41	37.6	9.04
Operational cost (Rs/ha)	21396.4	28510	-24.95
Gross income (Rs/ha)	61910	56776	9.04
Net income (Rs/ha)	40513.6	28266	43.33
Cost of grain production (Rs/kg)	5.22	7.58	-31.13

The gross and net returns in ZT of wheat production were higher by 9.04 per cent and 43.33 per cent, respectively, as compared to in CT method. The higher net return obtained in ZT was mainly due to reduction in the total cost of cultivation by 24.95 per cent. Similar results have been reported by many other studies conducted on this aspect and explained the fact that the net revenue in wheat production was significantly higher under ZT than under CT method (Erenstein *et al*., 2007; Iqbal *et al*., 2002) [13, 10]. The cost incurred to produce a kilogram of wheat was Rs. 7.58 in CT and Rs.5.52 in ZT methods. Thus, the cost of wheat grain production was lower by 31.13 per cent in ZT as compared to in CT method. This analysis suggests that ZT technology offers ample scope to generate additional income and helps in conservation of scarce resources.

Decomposition Analysis

Using Equation (3), the values of production parameters and the geometric mean of input levels the total change in wheat output with the adoption of ZT technology was decomposed. The results are presented in Table 5. The per hectare production of wheat was about 13 per cent higher with ZT technology than with CT method. How much of this increased

output was due to technological change and how much of it was due to change in input levels were also computed and are given in Table 5.

Table 5: Estimated differences in wheat output between zero and conventional tillage methods

Sources of productivity Difference	Percent Contribution
Total observed difference in productivity	13.00
A. Due to difference in technology	47.94
B. Due to difference in input use level	
a) Human Labour	-15.06
b) Machine Labour	-10.04
c) Seed	-2.20
d) Fertilizer	2.72
e) Plant Protection Chemicals	-2.78
f) Irrigation	-7.24
C. Total Estimated difference in productivity due to all resources (A+B)	13.33

The estimated differences in productivity are due to technological change and due to input use between the two technologies which together contributed 13.33 per cent of increase in wheat yield in NE IGP. The contribution of technology in increase in wheat yield was around 47.94 per cent. It indicates that the farmer could increase returns from wheat by around 48 per cent just by shifting from conventional tillage to zero tillage. As the zero tillage technology has resource conserving potential, the impact of majority of input use level was observed to be negative. The change in fertilizer use contributed to around 2.72 per cent of the increased yield. Thus in order to increase the existing productivity of wheat, increase in level of ZT adoption is highly recommended. Technology influences the sources of output growth by shifting the values of scale and slope parameters of the production function (Bisaliah, 1977) [4].

Farmers' Perception on Impact of Zero Tillage Technology

Farmers who had adopted ZT method in wheat production were interested to continue with this method of sowing in future. According to farmers, ZT method was good in terms of seed germination and yield of wheat than the CT method. Sowing of wheat crop could be accomplished 10 to 15 days earlier than in CT method. Zero tillage considerably reduced the use of tractor and saved time and diesel in field preparation. They, however, reported that weed management was a problem in ZT method of wheat production. Many farmers were deprived of wheat sowing by ZT technique because of high demand and less availability of zero-till seed drill machines in the study area.

The Government is encouraging custom-hiring services through entrepreneurship development. In the study area, only a few large farmers owned zero-till seed drill machines. Small and marginal farmers accessed zero-till seed drill through custom-hiring from large farmers. Many farmers reported that during peak sowing period, accessing a zero-till seed drill machine was difficult.

Conclusions

The study has revealed that it is possible to save machine labour and irrigation water under zero tillage than under conventional method. Due to resource saving, net return has been significantly higher in zero tillage technology. Hence, this technology is an important alternative to save scarce resources and enhance the net farm income. The decomposition analysis has shown that per hectare production of wheat was 13 per cent higher in zero tillage than in conventional tillage method. In this improved production method, zero tillage technology contributed 48 per cent. By adopting this technology, farmers could save scarce resources and reduce the cultivation cost. The availability of zero-till seed drill needs to be accorded more attention to foster the adoption of zero tillage technology in wheat production.

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