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# Zero-tillage Technology and Farm Profits: A Case Study of Wheat Growers in the Rice Zone of Punjab

MUHAMMAD IQBAL, M. AZEEM KHAN and M. ZUBAIR ANWAR

## I. INTRODUCTION

The rice-wheat cropping zone of Punjab is the main producer of high-valued and fine quality basmati rice in Pakistan. The rice produced in this area is famous for its grain length and aromatic characteristics. Being an important export item, rice contributes significantly to the national foreign exchange earnings. Wheat is the other major crop of the rice-wheat system and being the staple food is central to national agricultural policies. Rice is grown on a vast area in this zone during *Kharif* mostly followed by wheat in the *Rabi* season. Studies have shown that a large gap exists between the potential and yields actually realised by the wheat growers of the area [Byerlee, *et al.* (1984); Hobbs (1985) and Sheikh, *et al.* (2000)]. Farmers' practices regarding land preparation for paddy, wheat planting time, and other conflicts endogenous to the rice-wheat based cropping system were identified as the major factors limiting wheat yield in the area. The flooded and puddled soils that are well suited for paddy production as compared to well-drained conditions required for wheat is such an example of the system conflicts.

The farmers in the rice-wheat zone of the Punjab predominantly grow basmati varieties, which are late maturing as compared to coarse varieties of rice. Therefore, paddy harvest is generally delayed at most of the farms in this zone. The late paddy harvest coupled with poor soil structure and loose plant residues create problems for preparation of a good seedbed and planting of wheat often gets late [Byerlee, *et al.* (1984)]. The farmers also had to resort to the broadcast method for wheat sowing which results in poor and patchy plant stands. Moreover, the occurrence of rain during land preparation operations may cause a further delay of 2-3 weeks in wheat sowing [Aslam, *et al.* (1993)]. Studies have reported that after the mid-November a day's delay in planting of wheat results in a yield loss of one percent per hectare [Randhawa (1979) and Hobbs and Butler (1988)].

Muhammad Iqbal is Research Economist at the Pakistan Institute of Development Economics, Islamabad. M. Azeem Khan and M. Zubair Anwar are Scientific Officers at the Social Sciences Institute, National Agriculture Research Centre, Islamabad.

The conventional tillage practices after rice harvest involve extensive ploughing with common cultivator an/or deep tillage implements for preparation of a fine seedbed for wheat planting which is time consuming as well as costly. In order to save on sowing time and the tillage costs, a new seed drill was introduced in early 1980s that made it possible to sow wheat in freshly harvested and untilled paddy fields utilising residual moisture. The drill was named as zero-tillage drill and the method of wheat sowing with this drill is called as zero-tillage technology. The on-farm experiments of wheat sowing with this technology were conducted in Pakistan during 1984-89. The results of this experimentation showed that the crop stand is improved for wheat sown with zero-tillage drill and a 10 to 40 percent higher yield can be realised under different soil types and wheat sowing regimes as compared to that obtained under conventional systems [Aslam, *et al.* (1989)]. Based on these findings a comprehensive zero-tillage pilot production programme was initiated in 1990 to expand the usage of the technology in the rice-wheat zone of Punjab [Aslam, *et al.* (1993)]. However, a perceptible use of the drill started only after 1997 when provincial On Farm Water Management Programme (OFMP) got involved in drill promotion efforts.

The zero-tillage technology is widely maintained as an integrated approach that can tackle the problem of wheat yield stagnation in the rice-wheat zone by improving planting time, reducing weed infestation, and enhancing fertiliser and water use efficiency [Malik and Singh (1995); Malik (1996); Hobbs, *et al.* (1997, 2002)]. It is observed that zero-tillage technology helps in reducing the *Phalaris minor* weed infestation and also enables timely seeding of the wheat crop [Hobbs, *et al.* (1997)]. With comprehensive efforts being done by OFWM, the new technology has entered now in the critical phase of mass-scale development and promotion. During the past two years substantial wheat acreage was sown with zero-tillage drill. It stood at about 30 thousand hectares during *rabi* 2000-01, which increased to almost 80 thousand hectares during *rabi* 2001-02. The experts attribute this acceleration in the adoption of the technology to its benefits like: reduction in sowing cost, increased fertiliser and water use efficiency, ease in operation at hard and low lying fields**,** and considerable improvements in wheat yields through timely planting and better crop stands established.

The results discussed above are based either on experiments conducted at the research stations or on scientists managed trials done on farmers' fields. The management skills of the farmers usually differ considerably from that of the scientists and they are often confronted with a multitude of constraints and a socioeconomic environment different from that faced by the scientists. Therefore, the newly developed technologies are anticipated to perform differently under farmers' practices. The purpose of this paper is to provide information regarding the current status of zero-tillage technology in the study area, quantify its impact, and offer evidence from farmers' fields to validate the above claims about benefits of the technology. The paper consists of four parts. Section II describes the sample and analytical techniques used. The results are discussed in Section III. The last section presents the summary of major findings of the study and suggests implications.

## II. METHODOLOGY

This study is based on a primary data set[1] collected through a formal survey of 94 farmers from the rice-wheat zone of the Punjab province of Pakistan. The sample includes randomly selected 74 wheat growers who adopted zero-tillage technology (fully or partially) and 20 neighbouring farmers using conventional wheat sowing methods. Two respondents were dropped due to faulty or missing data. The sample farmers come from seven major *tehsils* of Gujranwala, Narowal, Sialkot, and Sheikhupura districts. The block specific information (regarding output, inputs use and other variables) on each farm was recorded for all parcels of wheat crop sown using a particular planting method. As a result 154 observations were obtained and finally included in the analysis.

For the purpose of this paper, traditional wheat sowing method '*wadwatter*' is defined as a technique in which farmers exploit the residual soil moisture in harvested paddy fields to prepare seedbed for wheat planting using common cultivator and/or deep tillage implements. In this method they usually sow wheat seed by broadcasting it in the roughly prepared seedbed and cover it with soil using certain implements. The '*rauni*' method is referred to the technique in which a pre-irrigation is applied in order to get the optimal moisture conditions and prepare a fine seedbed for wheat planting and seed is sown either by broadcasting or planted in row with a seed drill or other implements and manners. In the zero-tillage method it is possible to place wheat seed at proper depth in the soil with a special drill using residual moisture without prior land preparation and causing the minimum disturbance to the surface of soil.

The study makes use of descriptive statistics, partial budgeting, and regression analysis techniques to determine the profitability and investigate whether or not sufficient evidence is available from farmers' fields that the zero-tillage technology leads to higher wheat yields, lower production costs, and greater fertiliser and irrigation water use efficiency etc? This is clearly a case of comparing wheat yield regression equations associated with zero-tillage and the conventional wheat sowing technologies i.e. testing that whether the intercept terms and the slope parameters in two equations are different or the same. The dummy variable approach was adopted for demonstrating the differentials in input use efficiencies under alternate wheat

[1]A multidisciplinary team consisting of agronomists, farm machinery engineers, agricultural economists, rural sociologists, and statisticians from the National Agricultural Research Centre, Islamabad collected the data during a formal survey of the study area in June 2001. The data pertains to the cropping year 2000-2001.

planting methods. This approach is well explained in Gujarati (1995) and Madala (1992). The following linear production function was assumed for wheat yield in the study area.

$$\text{YIELD} = \beta_1 + \beta_2\ \text{IPRINO} + \beta_3\ \text{TOTFERT} + \beta_4\ \text{PNRATIO} + \beta_5\ \text{WHTAREA} + \beta_6\ \text{PROPWEED} + \beta_7\ \text{PSOWNLAT} + \beta_8\ \text{DZEROTILL} + \beta_9\ \text{ZTxIRRINO} + \beta_{10}\ \text{ZTxTOTFERT} + \beta_{11}\ \text{ZTxPROWEED} + U$$

where

YIELD = Wheat yield (in 40 Kilogram Maunds per acre).
IRRINO = Number of Irrigations Applied to Wheat Crop.
TOTFERT = Total Fertiliser Nutrients Applied per acre of Wheat (in Kilograms).
PNRATIO = P-nutrient to N-nutrient Ratio.
WHTAREA = Total Wheat Area on the Farm (Acres).
PROPWEED = Proportion of Wheat Acreage Affected with Weeds.
PSOWNLAT = Proportion of Wheat Acreage Sown After 30th November.
DZEROTILL = Dummy Variable for zero Tillage (Zero-tillage Sowing Method = 1 Else = 0).
STxIRRINO = Zero-tillage Dummy Cross Number of Irrigations Applied.
STxTOTFERT = Zero-tillage Dummy Cross Total Fertiliser Nutrients Applied.
STxPROPWEED = Zero-tillage Dummy Cross Proportion of Wheat Acreage Affected with Weeds.
U = Random Error Term Independently and Identically Distributed with Zero Mean and Constant Variance .

## III. RESULTS AND DISCUSSION

In the rice-wheat zone, the level of moisture in the soil at the time of tillage after paddy harvest, soil texture, and the rice crop residue situation mainly affect farmers' choice of tillage methods. On the sample farms, about 66 percent of the total wheat area was planted with the conventional wheat sowing method of '*wadwatter*'. The farmers' using this method mostly apply 2 to 3 ploughing with disc and 3-4 ploughing with common cultivators making use of residual moisture in the field. While in the *rauni* method farmers first irrigated the field and then use 3 ploughing with common cultivator and 3 disc ploughings. These time consuming and costly conventional tillage practices of wheat planting are maintained as the important factors that may induce a rapid adoption of resource conserving zero-tillage technology.

The zero-tillage drill owners planted 75 percent of the total wheat acreage on their farm with zero-tillage drill (Table 1). The rental users of the zero-tillage drill

Table 1

*Area Allocations to Wheat under Various Methods (Percent Wheat Area)*

| Methods | Drill Owners | Rental Users | Conventional Farms |
|---|---|---|---|
| Zero-tillage | 74.5 | 46.6 | – |
| *Wadwatter* | 12.7 | 28.5 | 66.2 |
| *Rauni* | 12.8 | 24.9 | 33.8 |

planted about 47 percent of wheat area with this method. The rest of the wheat acreage was planted using the '*rauni*' or '*wadwatter*' methods. The main reasons behind using other methods were 'watter' problems (40 percent), difficulties in drill operations (20 percent) and the indifferent behaviour of drill owners for renting drill services (40 percent). The use of conventional methods of wheat sowing is higher at the farms renting drill services as compared to that at drill owner farms. This shows that a guaranteed access to the drill has helped farmers to opt for the low cost wheat sowing method of zero-tillage. A similar switchover is expected from the rental users in future as a result of rapidly growing number of the drills in the area.

The future intentions of the farmers to use zero-tillage technology were also explored to understand the pace of adoption for the coming years. The results clearly showed that farmers would allocate more area to zero-till wheat in the future. The drill owners indicated that they would plant 86 percent of the wheat area by zero-tillage drill during the next year whereas the rental users intended to plant 52 percent of the wheat acreage on their farms with this technology in the coming year.

**Wheat Planting Dates and Sowing Methods**

The proportion of wheat acreage planted in three sowing time intervals is presented in Table 2. A slight shift of 3 percent in wheat area planted late (after 30th November) to timely sowing (on or before 30th November) was observed. This shows that planting dates under all wheat-sowing methods were shifted earlier towards the first fortnight of November. In the case of *rauni* method, a 10 percent shift was seen from December to 15-30 November. The shift in wheat area from late planting to timely sowing is much higher for zero-tillage method than that with conventional methods. This upward movements in wheat acreage towards timely planting of the crop is very encouraging, particularly during initial phase of mass scale promotion of zero-tillage technology. It also shows the potential help that zero-tillage technology may render in resolving the rice-wheat planting time conflicts. This would be more evident during coming years when more drills will be available in the area and as the operational skills of the drill owners are improved overtime.

Table 2

*Proportion of Wheat Acreage Planted during Various Time Intervals by Planting Methods (Percent Wheat Area)*

| Planting Time | Zero-tillage Adopter Farms | | | Conventional Tillage Farms | |
|---|---|---|---|---|---|
| | Zero-till | *Wadwatter* | *Rauni* | *Wadwatter* | *Rauni* |
| Before 15 November | 37 | 35 | 25 | 43 | 36 |
| During 15-30 Nov. | 44 | 43 | 55 | 35 | 32 |
| After 1st December | 19 | 22 | 20 | 22 | 32 |

**Crop Stand Establishment**

Farmers' observations regarding the establishment of crop stand with the use of zero-tillage technology were also collected and their responses are presented in Table 3. A vast majority (79-87 percent) of the zero-tillage adopters maintained that the crop stand was established uniformly on their fields. However, the rest of the farmers indicated that they observed patchy wheat stand in fields sown with zero-tillage drill due to lack of drill operation skills and problem of residual soil moisture in the harvested paddy fields.

Table 3

*Farmers' Assessment of the Zero-tillage Wheat Crop Stand*

| Crop Stand Category | Owner User Farms | | Rental User Farms | |
|---|---|---|---|---|
| | Number | Percent | Number | Percent |
| Uniform | 26 | 78.8 | 31 | 88.6 |
| Somewhat Patchy | 6 | 18.2 | 4 | 11.4 |
| Very Patchy | 1 | 3.0 | – | – |
| Total | 33 | 100.0 | 35 | 100.0 |

**Wheat Area Affected with Weeds**

In the rice-wheat cropping system incidence of weeds in rice as well as in wheat crop is a growing problem causing heavy economic losses. Almost every farmer needs to apply herbicide for an effective weed control. Traditionally, farmers maintain that using the *rauni* method or deep-tillage implements can help in controlling weeds in wheat crop more effectively. However, the survey data revealed that the incidence of weeds is less frequent in zero-tillage fields as less percentage of the wheat area was covered with chemical control on these plots Table 4. The other scientists [Malik and Singh (1995); Malik (1996); Hobbs, *et al*. (1997); Mehla, *et* *al*. (2000)] also reported that the use of zero-till technique reduces weeds problem. Mehla, *et al*. showed that the population of *Phalaris minor* weed in zero-tillage plots was one-fourth of that observed in field sown using conventional tillage system (CTS).

Table 4

*Percent Weed Area Affected and Treated by Herbicide*

| Wheat Planting Method | Wheat Area (Acres) | Use of Weedicide | |
|---|---|---|---|
| | | Area | Percentage |
| Zero-tillage | 2247 | 1351 | 60.1 |
| *Wadwatter* | 591 | 444 | 75.0 |
| *Rauni* | 581 | 389 | 66.9 |

**Fertiliser Use and Efficiency with the Zero-tillage Drill**

The continuous rice-wheat rotation is quiet exhaustive in terms of soil fertility and application of sufficient fertiliser (NPK and others) is imperative to maintain the proper nutrient balances in the soil to sustain productivity at higher level and conserve soil fertility. The higher dose of fertiliser alone would not be of much help if the plants do not use up most of the added nutrients due to a faulty fertiliser application method. At present, majority of the farmers apply fertiliser using the surface broadcast method. Though the method is cost saving but is inefficient and patchy, and most of the nutrients are not available to the plants. Aslam, *et al*. (1993) pointed out that nitrogen application on the surface of the soil caused 20-25 percent loss in nitrogen use efficiency. Hobbs, *et al.* (2002) found that the zero-tillage technology increases fertiliser use efficiency because of its more precise placement. Some of the sample farmers were aware of the usefulness of this aspect of the zero-tillage method and expected higher wheat yield from the fields sown with it. No significant differences were observed in fertiliser use on wheat across sowing methods. The fertiliser use on zero-tillage and *rauni* fields was 59 kilograms of nitrogen and 28 kilograms of phosphorus per acre whereas on plots sown with *wadwatter* method slightly less fertiliser was used and averaged to 56 and 25 kilograms of N- and P-nutrients respectively Table 5. None of the farmers applied any potash nutrient to their wheat crop.

Table 5

*Fertiliser Use in Different Wheat Sowing Methods (Kilogram/Acre)*

| Type of Fertiliser | Zero-tillage | *Wadwatter* | *Rauni* |
|---|---|---|---|
| P-Nutrients | 28 | 25 | 28 |
| N-Nutrients | 59 | 56 | 59 |
| Total Nutrients | 87 | 81 | 87 |
| P-nutrient to N-nutrient Ratio | 0.475 | 0.446 | 0.475 |

**Wheat Yields and Zero-tillage Technology**

The farmers more frequently use yield as a yardstick to assess the performance of a given technology. They also consider its cost effectiveness but to a lesser extent. Therefore, the yield variations across sowing methods were analysed and the results are presented in the Table 6. Comparatively higher yields were realised from fields sown with *rauni* method than that obtained from plots sown using other methods. The yield with the *rauni* method was 37 *maunds* while that with zero-tillage and *wadwatter* was 33 and 28 *maunds* per acre respectively. Besides the low yield with the *wadwatter* method, the production costs were significantly higher. About 10 percent higher yield was obtained on the *rauni* fields compared to the zero-tillage wheat plots. This yield gap can be bridged and even exceeded in future as the farmers become more acquainted with the zero-tillage technology and acquire better drill operating skills. Considering high cost of conventional technology, per acre net returns realised with zero-tillage technology significantly excel those obtained under other sowing methods.

Table 6

*Average Wheat Yield with Different Sowing Methods (40 Kilogram/Acre)*

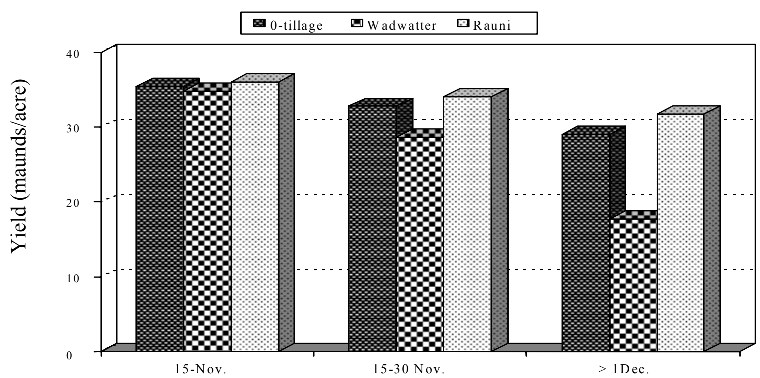
| Wheat Sowing Method | Maximum | Minimum | Average |
|---|---|---|---|
| Zero-tillage | 41.08 | 26.81 | 33.2 |
| *Wadwatter* | 34.60 | 26.61 | 28.5 |
| *Rauni* | 44.52 | 33.89 | 37.0 |

**Wheat Yield and Sowing Date**

The yields across various sowing methods were also compared on the bases of planting date intervals and are plotted in the following figure. It can be observed that comparable wheat yields were realised with insignificant difference across sowing method when planted before 15th November. The yields declined more sharply on *wadwatter* fields and yield gap widened more and more between *wadwatter* and the other two methods as wheat planting was delayed. This shows that the late wheat planting not only reduces yield but also the efficiency of inputs applied. Similar results are reported by Saunders (1990). The other scientist reported a linear decline in yield of 1-1.5 percent per day resulting from late planting [Ortiz-Monsanterio, *et al.* (1994); Randhawa, *et al*. (1981); Hobbs (1985, 2002)].

**Land Preparation and Seed Cost**

The farmers planting wheat with *wadwatter* method on an average apply 2.62 disc ploughings, 3.29 ploughings with common cultivator, and 2.78 plankings. In *rauni* method, the tradition is use 2.45 plankings, 3.08 disc and 3.04 ploughings with common cultivator. The costs of these land preparation activities in *wadwatter* and *rauni* methods averaged to 1358 and 1409 rupees per acre respectively. The sowing cost with zero-tillage technology was a nominal amount of 350 rupees per acre. Thus the farmers save more than 1000 rupees per acre just on land preparation by adopting zero-tillage. The average seed rate of 45, 50 and 48 kilograms per acre was observed under the *wadwatter*, *rauni*, and zero-tillage wheat sowing methods respectively. The corresponding seed costs amount to 338, 375 and 360 rupees per acre. The farmers used a higher seed rate than needed with zero-tillage method because influenced by their experience of poor germination in the past under conventional methods, they were not sure any better germination will result with new sowing method. The farmers are likely to reduce the seed rate overtime as they gain confidence through experience with zero-tillage and hence a decline in seed cost relative to other wheat sowing methods is expected in future.




**Fertiliser and Irrigation Cost**

It has been discussed earlier that the farmer in the study area apply 81 kilograms of fertiliser in wheat sown with *wadwatter* method and 87 kilograms of N-P nutrients per acre of wheat sown with *rauni* or the zero-till methods. This results in a per acre fertiliser cost of 1473 rupees in *wadwatter* and 1578 rupees each in *rauni* and zero-tillage method Table 7. The same cost of 286 rupees per acre was assumed for chemical weed control irrespective of the sowing method used. However, overtime the weed control cost in zero-tillage is expected to decline as observed by [Malik, *et al.* (2002) and Yadav, *et al.* (2002)] in case of India. The combination of zero-tillage and herbicide use resulted in reduced weed populations in India within 4 years time to a level where chemical weed control is no more required. The same needs to be confirmed in Pakistan over time by monitoring the benchmark fields.

During the *rabi* (winter) season canal water is not available to most of the wheat growers of the areas. Therefore, the majority of farmers use tubewell water for irrigation of wheat. Under *wadwatter* and zero-tillage method farmers applied three irrigations to their wheat crop, while in *rauni* method an extra irrigation is mostly used. The number of hours involved to irrigate an acre of wheat (especially during the first irrigation) varied a lot across various sowing methods. It took 3.5, 4.0, and 2.5 hours respectively to irrigate one acre of wheat sown with *wadwatter*, *rauni,* and zero-till methods. This variation in irrigation time results in significant differences in the irrigation costs associated with various sowing methods. The irrigation cost incurred with *wadwatter, rauni*, and zero till methods were respectively 1050, 1200, and 750 rupees per acre Table 7.

Table 7

*Gross Margin Analysis for Various Wheat Planting Methods*

| Items | *Wadwatter* Method | *Rauni* Method | Zero-tillage Method |
|---|---|---|---|
| **Land Preparation** | | (Rupees/Acre) | |
| Cultivator | 494 | 456 | 350 |
| Disc Plough | 524 | 616 | 0 |
| Planking | 139 | 123 | 0 |
| **Sub. Total** | **1157** | **1195** | **350** |
| **Seed @ Rs 300/40 Kg** | **338** | **375** | **360** |
| **Fertiliser** | | | |
| P-Nutrients | 553 | 603 | 603 |
| N-Nutrients | 920 | 974 | 978 |
| **Sub. Total** | **1473** | **1577** | **1581** |
| **Weeds** | **286** | **286** | **286** |
| **Irrigation** | **1050** | **1200** | **750** |
| **Grand Total** | **4304** | **4633** | **3327** |
| **Wheat Yield** (Maunds/Acre) | 28.5 | 37.0 | 33.2 |
| Price (Rupees/Maund) | 277 | 277 | 277 |
| **Total Returns** | **7895** | **10249** | **9196** |
| **Gross Margins** | **3591** | **5616** | **5869** |

**Gross Income and Margins**

The gross income under *wadwatter, rauni*, and zero-tillage methods was calculated as 7894, 10249 and 9197 rupees per acre respectively. The partial budget analysis of the three wheat planting methods showed that the zero-tillage wheat planting was more economical than the *wadwatter* or *rauni* methods. The zero-tillage method resulted in the gross benefits of 5869 rupees per acre, whereas the gross benefits with *rauni* and *wadwatter* methods were 5616 and 3591 rupees per acre respectively. The analysis shows that the farmers earn an extra income of 253 and 2278 rupees per acre of wheat sown with zero-tillage method as compared to that earned from wheat sown with *rauni* and *wadwattar* methods respectively (Table 7). The higher returns in case of zero-tillage method are going to provide a big incentive for the farmers to adopt this technology.

**The Regression Analysis**

The multiple regression equation assumed in Section II was estimated by using ordinary least squares method and the results are presented in Table 8. The F-statistics is significant at 1 percent level showing that the explanatory variables included in the model collectively have significant influence on wheat yield. An $R^2$ value of 0.534 suggests that about 53 percent variations in the dependent variable are explained by the independent variables included in the model. For a cross sectional data it represents quite a good fit and hints that the estimated model fits the data fairly well. The frequency of irrigation and the balance in which P- and N-nutrients are applied (PN-ratio) constituted the important determinants of wheat yield. The coefficients of these variables were positive and significant at 1 and 5 percent level respectively. The total nutrients of fertiliser applied showed a positive but insignificant affect on wheat yield.

The negative coefficient for zero-tillage dummy hints that the yield equation for wheat sown with this method has a smaller intercept. The coefficient for the cross term of irrigation and zero-tillage dummy is positive and significant at 10 percent level. It hints the fact that water use efficiency is enhanced in zero-tillage method. The cross terms of zero-tillage dummy with fertiliser and with proportion of wheat area affected with weeds are also positive but insignificant at 10 percent level. The presence of a slight to moderate multicollinearity due to high correlation among fertiliser, zero-tillage dummy and their cross term are resulting in high standard errors and consequently the insignificance of the coefficients for fertiliser and its cross term with zero-tillage dummy at 10 percent level. If we apply a one-tail test to check whether zero-tillage technology enhances fertiliser use efficiency or not, the coefficient turns out to be significant at 10 percent level. However, there is no evidence found that the zero-tillage reduces weed problem or its adverse effect on wheat yield.

Table 8

*The OLS Estimates of Parameter for Various Factors Affecting Wheat Yield*

| Variables | Coefficient Estimates | *t*-Value | Significance |
|---|---|---|---|
| Constant | 30.9430 | 8.112 | 0.000 |
| IRRINO | 2.4320 | 3.529 | 0.001 |
| TOTFERT | 0.0075 | 0.197 | 0.845 |
| PNRATIO | 4.6990 | 1.934 | 0.058 |
| WHTAREA | –0.0385 | –2.289 | 0.026 |
| PROPWEED | –1.2910 | –1.826 | 0.073 |
| PSOWNLAT | –14.0940 | –4.636 | 0.000 |
| DZEROTILL | –17.1800 | –2.353 | 0.022 |
| STxIRRINO | 2.6560 | 1.820 | 0.074 |
| STxTOTFERT | 0.0920 | 1.361 | 0.179 |
| STxPROPWEED | 0.8860 | 0.541 | 0.590 |

$R^2 = 0.534$ Adjusted-$R^2 = 0.454$ F = 6.645.

The results suggest that the curve of production function for zero-tillage sown wheat would start at a lower intercept. The resulted higher yield is due to the enhanced water and fertiliser use efficiency (the greater slope coefficients) and the yield losses saved due to improvement in sowing time because of the use of zero-tillage technology. In addition, considerable amount of costs will be saved due to the minimal tillage requirement of the technology and certain other beneficial externalities associated with its use.

## IV. CONCLUSIONS AND RECOMMENDATIONS

The study assessed the status of zero-tillage technology in the rice-wheat zone of Punjab. Such an assessment was required not only to understand the current status of technology but was also needed to provide feed back from farmers' field regarding its impact on wheat yield and farm incomes.

The wheat acreage sown with zero-tillage technology is expected to expand rapidly in the rice-wheat zone. The study confirms that the zero-tillage technology enhances water and fertiliser use efficiency. However, sufficient evidence was not available to prove any positive or adverse affect of the technology on incidence of weeds in wheat crop. It is suggest that this aspect of zero-tillage technology be focused more in future research. A multi-visit formal survey is suggested to get more correct and quantitative information for example, recording weed intensity (count per unit area) and its type instead of asking acreage infested.

The new technology reduces costs of production with comparable wheat yields to that obtained using other methods and thus results in higher net farm returns. The farmers of the area have started appreciating the reduced tillage cost aspect of the technology however they are not much convinced about the enhanced yields and increased input use efficiency of water and fertiliser. The proper promotion of these aspects of the technology would accelerate adoption and result in increased demand for the drills.

At present no systematic information is being generated to know the future demand for the drill and drills are often produced hurriedly to meet the high seasonal demand. The unforeseen high demands are in some cases met by using low standard material, less skilled labour and overburdening of the experienced workers. A mechanism of generating information on demand for the drill and proper monitoring needs immediate attention to ensure quality and cost effective manufacturing of drills. A panel of experts including agricultural engineers, the representatives of drill manufacturers and ideally also the members from farming community, should be designated to provide technical backup and vigilance for ensuring quality manufacturing of the drill according to predetermined standards. In addition, continuous research efforts are required to keep on improving the zero-tillage drill in the light of feedback on its performance in the field.

At present, the farmers are operating without a proper formal or informal training. The proper knowledge about operation and calibration of the drill under different farm and soil situations is essential to ensure efficient use of the drill. There is an urgent need of preparation of handouts containing information on critical aspects of drill use including: (a) management of appropriate field conditions; (b) seed and fertiliser mixing, (c) calibration of the drill; (c) replacement of parts; (d) trouble shooting, and (e) post season care and maintenance.

The large farmers initially purchased the drills (91 percent) and majority of them does not rent out the drill services to other farmers who may be interested in experimentation and evaluation of the technology. For a rapid expansion of the technology, the farmers who rent out tractor services should be provided an easy access to credit for purchase of drills and proper training in drill related operations be imparted to them. The cost effectiveness and yield advantages of this technology also need to be publicised for its rapid adoption. There are some government agencies that have difference of opinion on usefulness and the benefits of zero-tillage technology. These differences need to be resolved immediately.

Zero-tillage wheat sowing was mainly promoted to ensure timely sowing of wheat after late maturing fine varieties of basmati rice. Replacement of Basmati-370 by the early maturing Basmati-385 during mid-1980s resolved the wheat planting conflict to a certain extent. However, need for adoption of low cost zero-tillage technology is even more crucial in order to control ever increasing rice producing costs, solve the time conflict arising from some recently introduced long duration but very fine and high yielding rice varieties, and to conserve resources.

The market forces have led the farmers to replace basmati-385 rice with super-basmati and basmati-386 during 1990s. The area under super-basmati has increased considerably during 2001. This variety is not only late maturing but also very hard to thresh manually. Therefore, the use of combine harvesters is gaining popularity in the area. The harvesting of paddy by combine harvesters results in an increased level of loose straw and more than 6 inches high paddy stubbles in the harvested fields. These stables affect the performance of the zero-tillage drill and results in residue management problem even for planting of wheat with conventional methods. Handling of rice straw, especially the loose residues when using the zero-tillage drill in paddy fields harvested with a combine harvester, needs to be placed on the future research agenda. At present, farmers resort to burning of the loose residues that increases air pollution and damages the soil texture. This practice needs to be discouraged and certain equipment or technique need to be developed that allows planting of wheat under these conditions while maintaining some of the loose straw as surface mulch.

Rice-wheat is the dominant cropping system followed by majority of the farmers in the area. Presently, the zero-tillage drill is only used for planting wheat in the harvested paddy fields. In future, possibility of extension of the technology to sow wheat following other crops also needs to be explored.

A proper communication between farmers and various stakeholder of zero-tillage technology need to be established on modern lines. The foremost consideration needs to be accorded to two-way communication rather than treating farmers only as a recipient. The success of the widely used participatory approach lies in the fact that decisions are not preplanned and imposed from outside but are based on the analysis of circumstances at the site and are made by the farmers with the help of facilitators. It is proposed that similar procedures should be tested in transferring the zero-tillage technology package.

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## Comments

Importance of wheat in our agrarian economy can be judged from many different angles. It is the main staple diet of the majority of the people of the country. It contributes 12.1 percent to the value-added in agriculture and 2.9 percent to GDP. Because of its economic importance, it always remains in the discussion of the policy-makers and the agricultural scientists. Performance of wheat production has been severely damaged registering a –8.5 percent change in kg/hec in 2000-2001 due to the persistent drought condition for the last three years. On the other hand, rice is the second largest staple food crop and is also a major export item. It accounts for 6.6 percent in value-added in agriculture and 1.6 percent in GDP. Rice also have a –1.4 percent change in 2000-2001 in kg/hec. These negative growths in both the food items and export earner demand more attention from researchers. The present paper is an effort to deal with this problem. However, nothing is perfect in this universe and there are always chances for improvement. The following suggestions, if incorporated, will increase the scope of the paper.

### Methodology

Usefulness of any research depends upon the methodology used for the purpose of research. For the present study there is a disproportionate representation of the different groups of the farmers. The data set represents the 78 percent of the adopter of zero-tillage and 21 percent of the conventional wheat-growing farmers. Similarly this disproportionate trend is there in case of small, medium and large farmers (Large 66 percent, Medium 15 percent and Small 19 percent). The concept of small, medium and large categories is also debatable. Historically, in central Punjab it is easy to find small as compared to large farmers. But data set shows a different trend. Similarly, the data were collected from seven tehsils and have only 11 medium farmers mean only 1.5 farmer per tehsils. Furthermore, this classification has never been used in the discussion of the paper which, leaves a question mark in the mind of the reader, that why farmers were so classified?

### Results

The results of the study seems to be normal, but there are some typing errors, which must be carefully rectified. For example, Table 1 shows that 75 percent of the zero-tillage adopters have there own drill, but in the discussion this figure is 67 percent. Similarly in Table 6, which is about average yield, figures and the captions of the columns do not match with each other. Seed cost used for different sowing methods is also confusing. Cost of the seed is calculated as Rs 7.5 per kg. At this rate cost of the 48 kg of seeds must be Rs 360 instead of Rs 350 for zero-tillage growers. Same is the case with fertiliser and irrigation cost. Cost per irrigation is Rs 300 in case of *Wadwatter* and Zero-tillage and Rs 400 in case of *Rauni*. Such type of discrimination is difficult to understand.

**The Model (Regression Analysis)**

Perhaps this is the most interesting part of the paper. Here the researchers have assumed a linear yield function but in agriculture most of the relations are not additive but multiplicative. Keeping in view the problem in hand, it seems to be the right selection because multiplicative function will convert every thing into zero in case of non-user of zero-tillage technology due to the use of dummy variable. But the selection of correct variable is very much important. Methodology is silent about the use of variable numbers 8, 9 and 10. Definitely, there will be a need for these variable in the minds of researchers (which may be the efficiency parameter) but it must be shared with the readers. It seems to me that these are there to provide justification for lower $R^2$ value, which is normally acceptable in case of a large number of variables. Some other statistical indicators, like standard errors of the individual estimates, are also missing. As for the results of this multiple regression, they need some improvement in explanation. For example it is said about the explanation of the coefficient of the zero-tillage variable: "the negative coefficient for zero-tillage dummy hints that the yield equation for wheat sown with this method has smaller intercept". Intercept is a different concept and it must not be confused with the coefficient of the parameter. The negative sign must have an economic interpretation, which is missing in the discussion. In case of fertiliser use efficiency, the coefficient is not only very small but also insiginifcant. But just stating the presence of slight to moderate multicollinearity will not serve the purpose. What different methods were used to detect multicollinearity? Their results must be provided in the paper. Out of the nine selected variables, three important ones are insignificant and four are carrying negative sign. Explanatory power of the model can be increased by the proper selection of the variables, e.g., water use efficiency is positive, having a coefficient of 2.656, and is significant at 10 percent. It is known that water use and fertiliser application complement one another. A new variable can be constructed to know the water-fertiliser use efficiency for zero-tillage operation.

In the end I convey my good wishes to the team of researcher in their efforts to investigate the problem.

**Abdul Qayyum Mohsin**

Arid Agriculture University,
Rawalpindi.