

## Research Article



# Evaluation of Conservation Tillage System Performance for Rainfed Wheat Production in upland of Pakistan

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**Abstract** | Tillage and crop residue management practices are key considerations for crop production in rain-fed areas. The objective of the current study was to explore the possibility of practicing conservation tillage systems for reducing input cost of small holder farming community of Pothwar, Pakistan. A two-year field study was carried out with a split plot design, having conventional tillage (CT), minimum tillage (MT), reduced tillage (RT) and zero tillage (ZT) systems in main plots, while residue retained (R<sup>+</sup>) and removed (R<sup>-</sup>) in sub-plots. The results showed that seedling emergence, wheat biomass and grain yield were statistically same under CT (83 plants m<sup>-2</sup>, 6.02 Mg ha<sup>-1</sup>, 3.32 Mg ha<sup>-1</sup>, respectively), MT (83 plants m<sup>-2</sup>, 5.90 Mg ha<sup>-1</sup>, 3.26 Mg ha<sup>-1</sup>, respectively) and RT (72 plants m<sup>-2</sup>, 5.92 Mg ha<sup>-1</sup>, 3.20 Mg ha<sup>-1</sup>, respectively) tillage systems with retention of crop residues, while significantly lower values were recorded under ZT without residue return (54 plants m<sup>-2</sup>, 4.33 Mg ha<sup>-1</sup>, 2.02 Mg ha<sup>-1</sup>, respectively). The gross margins were highest with crop residue return under RT (Rs. 109375) followed by MT (Rs. 101800) and CT (Rs. 97840), whereas ZT without residue return gave the lowest gross margin of Rs. 7187. The study indicated that reduced tillage (chiseling) with retention of crop residue is a promising conservation tillage practice for economical benefits and sufficient wheat yields in rainfed Pothwar, Pakistan.

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**Keywords** | Minimum tillage, Reduced tillage, Zero tillage, Residue management, Grain yield, Gross margins

## Introduction

Pothwar is the largest rainfed tract of northern Punjab, Pakistan, where fallow-wheat rotation is the most common practice on about 80% of the area (Razzaq et al., 2002). The six-month-fallow starts from the harvest of previous wheat in May and continues till the seeding of next wheat crop in October. The rainfall is erratic, scanty and 70% of the rain is received during monsoon (fallow period) in the form

of torrential rainstorms which not only lead to water losses but also the loss of soil through erosion. Current farmer's practices during fallow period comprise of moldboard plowing followed by 8-12 tillage operations with tine cultivator for moisture conservation and weed control (Zahid et al., 1991; Ishaq et al., 2003). Low crop productivity is the common feature of the agriculture of area; however, there is great potential of increasing crop productivity if efficient use of resources and reduced input costs are ensured.

Conservation tillage system (minimum tillage, direct drilling, zero tillage etc) is being advocated worldwide for sustainable crop production which involves minimum soil disturbance and leaving crop residues on soil surface. The potential advantage of conservation tillage practices over conventional practices is due to leaving residue on soil surface that reduces erosion by providing barrier against rain-splash and runoff, reduces evaporation and increases infiltration (Franzuebbers, 2002). Crop residue also increases soil organic carbon that improves soil aggregation (Madari et al., 2005) soil water availability (Unger, 1994; Drury et al., 1999), number of biopores (Francis and Knight, 1993) that may facilitate root growth (Martino and Shaykewich, 1994) and water holding capacity. In short, conservation tillage with presence of residue on soil surface interfaces all soil ecology (Huang et al., 2008). This system also saves time and fuel cost (Baker et al., 2007) which is very important for small holder farmers of developing countries like Pakistan. However, the benefits of conservation tillage are dependent on soil properties, climatic condition of the area and the number of the years since the tillage system has been implemented (Rhoton, 2000).

Conservation tillage systems have been thoroughly studied under different ecologies (Fabrizzi et al., 2005) and worldwide adopted on about 117 M ha. Out of total about 47% area is located in North America, 34% in South America and 14% in Australia. Ironically Asia has only 2.2% area under conservation tillage (ICARDA, 2012). The deficient research and development under developing countries including Pakistan demonstrate which is in fact missed the opportunity. Therefore the current study was conducted with the objective to evaluate different variants of conservation tillage with and without residue return in comparison with conventional intensive tillage system for crop production and economic returns for smallholder farmers of Pothwar, Pakistan.

## Materials and Methods

Conservation tillage experiment was initiated in 2012 on a sandy clay loam soil at PMAS-Arid Agriculture University Research Farm Chakwal Road (latitude 33°36'0"N, longitude 73°02'0"E) in semi-arid dryland Pothwar, northern Punjab, Pakistan. The soil has sand 560 g kg<sup>-1</sup>, silt 190 g kg<sup>-1</sup> and clay 250 g kg<sup>-1</sup>, pH around 7.85 and SOC 5.2 g kg<sup>-1</sup>. The climate of the experimental site is semi-arid, very hot in summer

and low temperature in winter with 70% of the rain received during monsoon in the form of heavy showers.

### Detail of treatments

The experiment was initiated on an area of 6000 m<sup>2</sup> with treatments arranged in a split plot design having four replications. The main plot treatments were tillage systems i.e. Conventional Tillage (CT), Minimum Tillage (MT), Reduced Tillage (RT) and Zero Tillage (ZT). The sub plot-treatments involved residues retained (R<sup>+</sup>) and residues removed (R<sup>-</sup>). One year earlier than installation of treatments, the field was left without tillage and crop to offset the residual effects of previous tillage practices. In CT plots, the soil was ploughed with moldboard plow at the start of monsoon followed by 8-10 time shallow cultivation with tine cultivator applied after each major rainfall for weed control and moisture conservation. Wheat sowing in these plots was done with seed-cum-fertilizer drill. In MT, the field was also ploughed with intensive moldboard on the onset of monsoon and four time cultivation with tine cultivator, while sowing was done with conventional seed-cum-fertilizer drill. In RT, one time chisel plough was applied at the start of monsoon and then during fallow period weeds were controlled with roundup herbicide (Glyphosate @ 1 L acre<sup>-1</sup>) and wheat was sown through direct drilling with zero tillage drill. In ZT, field remained undisturbed for entire fallow period and weeds were controlled with roundup herbicide when needed. Winter wheat was directly sown with zero tillage drill. In sub-plot treatments +R involved just harvest of the previous crop spikes and retention of all the stubbles in field. In case of -R the crop was harvested with reaper and there was no crop residues left in field. The recommended doses of fertilizer NPK i.e. 100-60-30 in the form of urea, diammonium phosphate (DAP) and sulfate of potash (SOP) were used. Wheat was planted at seed rate of 100 kg ha<sup>-1</sup>.

The crop samples were collected by randomly casting the square quadrat of 1 m<sup>2</sup> at three places in each replication of the treatments. For crop biomass plant samples were placed in oven, dry weighed was measured and for yield grains were separated from spikes and average grain yield was presented in Mg ha<sup>-1</sup>. Harvest index was calculated by dividing grain yield into total biomass and multiply by hundred.

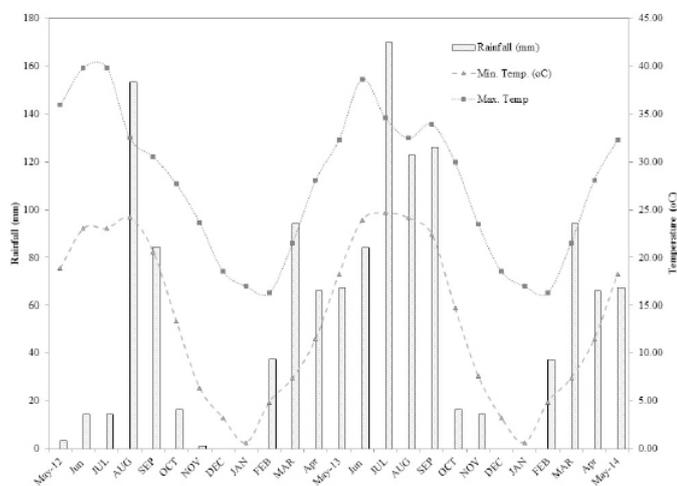
The profitability of different tillage systems were

measured by calculating gross margins and efficiency coefficients. The gross margin is gross income less the variable costs incurred in achieving that income. Variable costs were those which were directly attributable to the enterprise: *e. g.* tillage, weed control, seeding, fertilization and harvest operations. The gross margin was not equivalent to gross profit because it did not include fixed or overhead costs such as depreciation, interest payments or permanent labor, all of which had to be met regardless of enterprise size (Scott, 2001). All input costs and output prices used in the economic calculations were those recorded during the experiment in (Table 1). The efficiency coefficient was calculated by dividing gross income with the total variable cost incurred for achieving that income.

**Table 1:** Detail of inputs and outputs under different tillage treatments used for economic analyses.

Detail of Inputs and Outputs	2012-13	2013-14
Inputs (Rs.)*		
M.B Plough /hr	1200	1400
Roundup Spray /L)	1050	110
Cultivator /hr	1000	1200
Seed drill	1200	1200
Fertilizer DAP/50 kg	4500	4500
Fertilizer Urea /50 kg	2000	2000
Seed /50 kg	2500	2800
Fungicide /L	600	700
Harvest /hr	1800	2200
Threshing /hr	2100	2400
Outputs (Rs.)		
Grain yield/40 kg	1200	1200
Straw yield/40 kg	320	350

\*: Rs (Pakistani rupees) 1 US\$ = 98 Rs



**Figure 1:** Monthly rainfall and mean maximum and minimum temperature during experimental period.

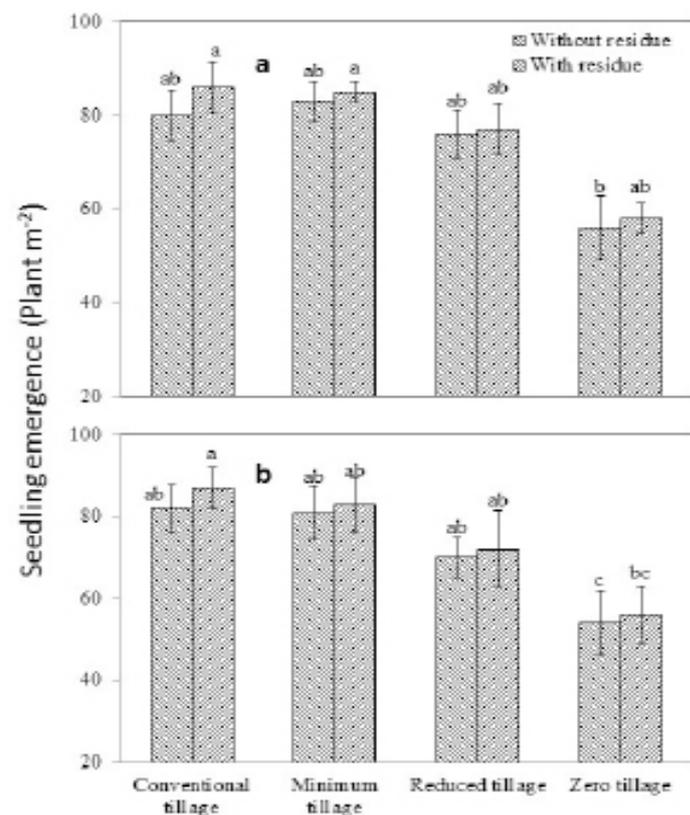
*Metrological data and statistical analysis*

Metrological data on temperature, rain fall during experimental year was collected from agro-metrological centre at Chakwal (Figure 1) and the data for statistically analysis was collected for various parameters was subjected to analysis of variance (ANOVA) under split-plot design and means was compared at 5% level of significance by Least Significance Difference (LSD) test (Steel et al., 1997).

**Results and Discussion**

*Seedling emergence*

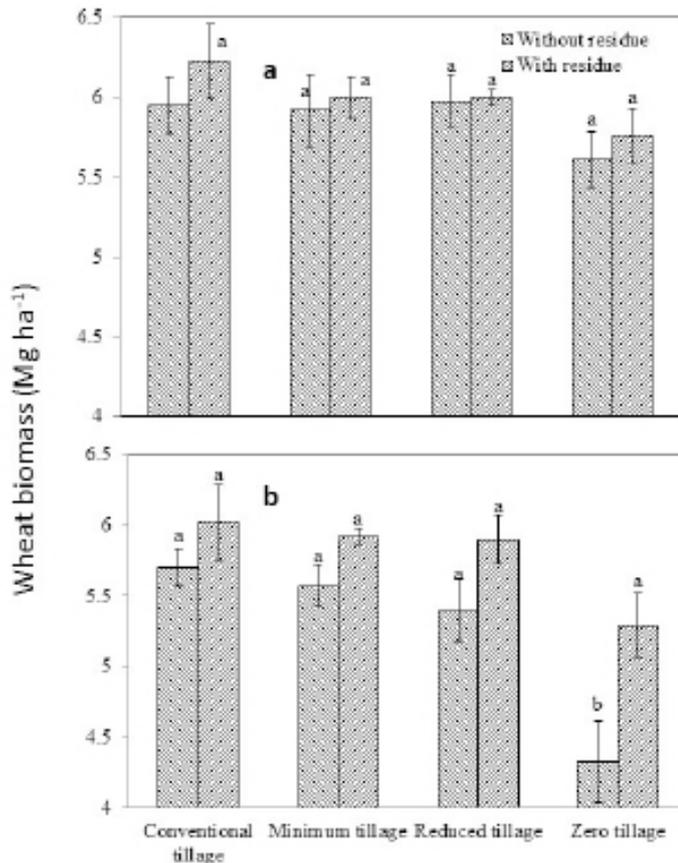
Seedling emergence was significantly affected by different tillage systems with and without retention of crop residues. In both years the seedling emergence Figure 2a and b was significantly higher under CT followed by MT and RT with and without retention of crop residues. The seedling emergence was low under ZT in both years (56 and 54 plant m<sup>-2</sup>) without retention of crop residues as well as with retention of crop residues (58 and 56 plant m<sup>-2</sup>).



**Figure 2:** Seedling emergence under the tillage treatments with and without crop residue for the two years: (a) 2012-13, (b) 2013-14 was low under zero tillage without retention of crop residues.

Seedling emergence is the important parameter for crop establishment and ultimately contributes to crop biomass and yield. The higher seedling emergence in

tilled plots may be related to higher moisture storage during fallow period, reduction in bulk density and pulverized soil that provide a favorable condition for crop germination while in ZT plot there was a compacted layer on soil surface during crop sowing and establishment. (Chiroma et al., 2006; Thomas et al., 2007) reported improved seedling emergence due to adequate and proper water availability. There is dire need to improve germination under zero tillage treatments.

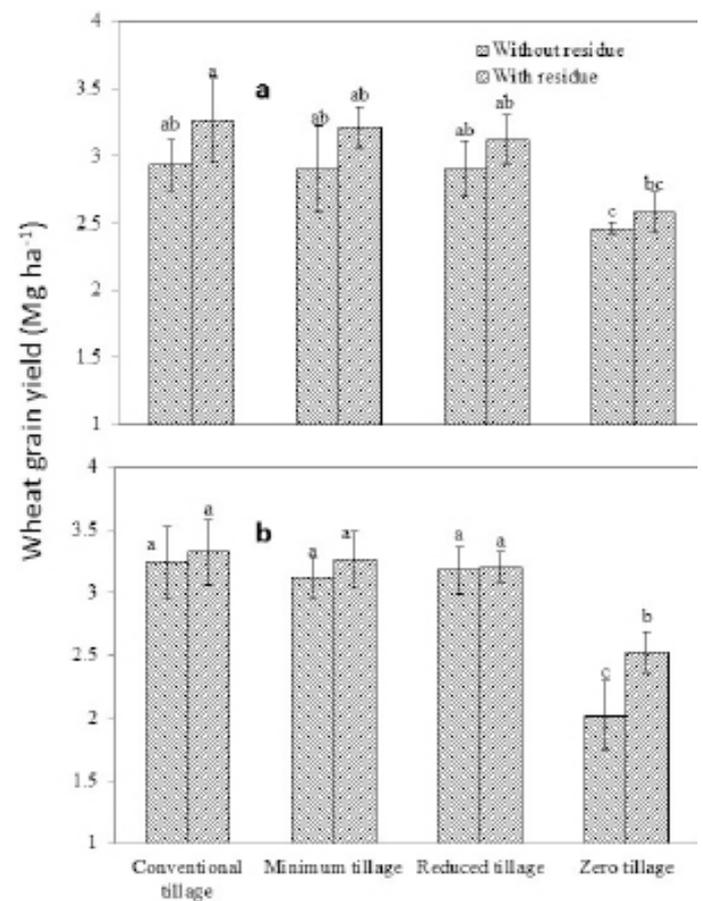


**Figure 3:** Wheat biomass under the tillage treatments with and without crop residue for the two years: (a) 2012-13, (b) 2013-14 was low under zero tillage without retention of crop residues.

**Crop biomass**

Crop biomass in 2012-13 was numerically higher under CT 6.02 Mg h<sup>-1</sup> followed by MT 5.92 Mg h<sup>-1</sup> and RT 5.9 Mg h<sup>-1</sup> with retention of crop residues while lower values were observed under ZT 4.33 Mg h<sup>-1</sup> without retention of crop residues (Figure 3a). The same trend was also observed during the year 2013-14 (Figure 3b), that wheat crop biomass was significantly higher under CT with retention of crop residues. In both experimental years the trend under different tillage systems was CT > MT > RT > ZT with and without retention of crop residues. The retention of crop residues also helped to increase biomass than without retention of crop residues under different tillage systems.

The better biomass yield during both years under CT is due to higher water content at wheat sowing and loosening of surface soil due to intensive ploughing that resulted in better seed-soil contact and hence germination. The intensive ploughing also loosened the soil which may have helped the roots to penetrate deeper and extract more water and nutrients. (Gill et al., 2000) also conducted a tillage experiment in same region and concluded that mouldboard plough loosen the soil which help to increase crop biomass. The ZT plots had lower water content as well as a relatively compact surface layer that not only reduced seed germination but also hindered root penetration at initial crop stages.



**Figure 4:** Wheat grain yield under the tillage treatments with and without crop residue for the two years: (a) 2012-13, (b) 2013-14 was low under zero tillage without retention of crop residues.

**Grain yield**

Wheat grain yield was also significantly affected by different tillage systems with and without retention of crop residues. In 2012-13 grain yield was significantly higher under CT 3.26 Mg h<sup>-1</sup> followed by MT 3.21 Mg h<sup>-1</sup> and RT 3.12 Mg h<sup>-1</sup> then by ZT 2.58 Mg h<sup>-1</sup> with retention of crop residues (Figure 4a). Lower values were observed under ZT 2.46 Mg

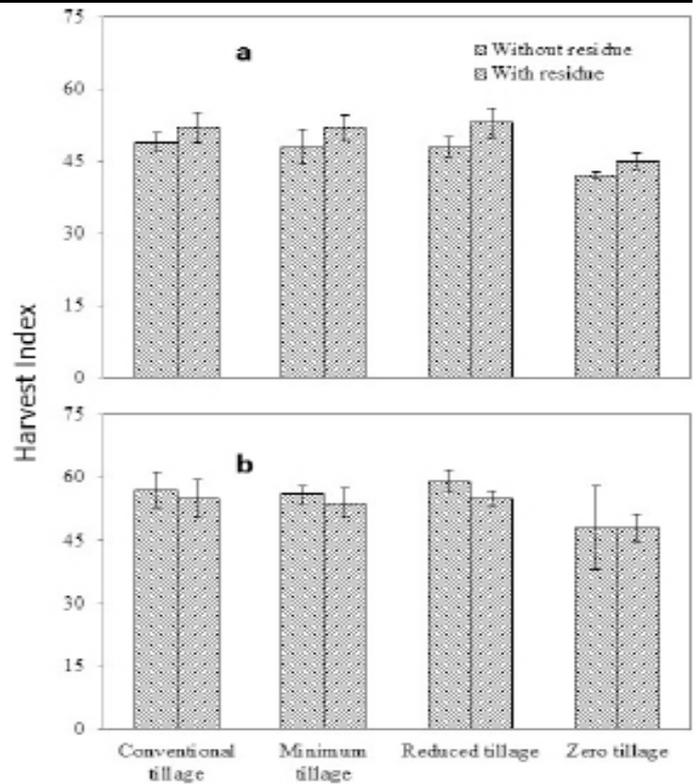
h<sup>-1</sup> without retention of crop residues. The same tendency during 2013-14 (Figure 3b) was also noted i.e. CT>MT>RT>ZT. The yield was low under ZT without retention of crop residues. In all tillage systems retention of crop residues showed pronounced effect on grain yield than no residue especially in CT, MT and RT plots.

In CT, MT and RT plots the higher grain yield was also due to higher water infiltration, enough residual moisture stored during fallow period, seed bed preparation which reduced bulk density and provided better condition for initial crop germination and development that led to establishment of a bumper crop and ultimately increased crop yield. Also in RT plots the higher grain yield may be attributed to breaking of sub-surface hard pan by chisel plough which enhanced higher water penetration in lower depth during fallow period that encouraged root development and thus helped for better crop establishment. In ZT plots the lower grain yield was related to inferior crop establishment due to poor initial crop germination. The retention of crop residues also showed promising effect to increased wheat yield than without retention of crop residues. The decrease of crop yield in ZT plots may be related to delay in initial crop germination. In ZT plots there was surface compacted layer that may have affected the crop germination and establishment which ultimately decreased crop yield. (Radford et al, 2001; Gemtos and Lellis, 1997) also reported that late germination decreased crop yield. The compacted top layer also restricts root development (Whalley et al., 1995).

### Harvest index

Harvest index was also affected by different tillage systems with and without retention of crop residues during first experimental year. The harvest index value was statistically similar under CT, MT and RT with retention of crop residues but low under ZT without residue retention. In 2<sup>nd</sup> experimental years during 2013-14 the trend remained same under different tillage system (Figure 5b). The HI was higher without retention of crop residues.

The HI was low under ZT with and without retention of crop residues. Luvier (2007) founded no significant effect of different tillage systems on harvest index. (Ahadiyat and Ranamukhaarachchi, 2008) observed that harvest index was higher under conventional tillage than conservation tillage systems.



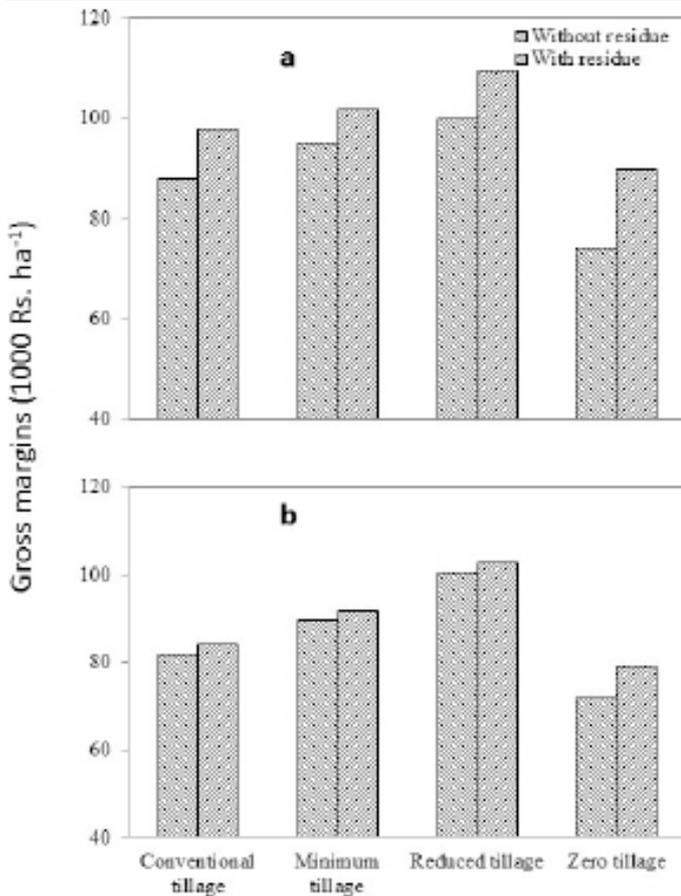
**Figure 5:** Wheat crop harvest index under the tillage treatments with and without crop residue for the two years: (a) 2012-13, (b) 2013-14 was not effected by different tillage systems and residues management.

### Gross margin and efficiency coefficient

The result of gross marginal return illustrate that during 2012-13 highest GM return was recorded under RT (Rs. 109375) followed by MT (Rs. 101800) and CT (Rs. 97840) with retention of crop residues while least GM was recorded under ZT (Rs. 44975) without retention of crop residues (Figure 6a). The trend remained same during 2013-14 in 2<sup>nd</sup> experimental year where RT (Rs. 100380) remained higher followed by MT (Rs. 89590) and CT (Rs. 81990) Figure 5b. The lower amounts of GM (Rs. 41400) were observed under ZT.

In order to decide on tillage systems with best economic return per investment, efficiency coefficients were calculated. The efficiency coefficients during 2012-13 were 4.24 for ZT followed by RT (4.13) and MT (3.55) with retention of crop residues while lower under CT (1.76) without retention of crop residues (Figure 7a). The same trend was also observed during 2013-14 i.e. higher under ZT (3.57), RT (3.45) without retention of crop residues and lower under CT (1.75) with retention of crop residues (Figure 6b).

The higher gross marginal return and efficiency coefficient under RT demonstrated that reduced tillage

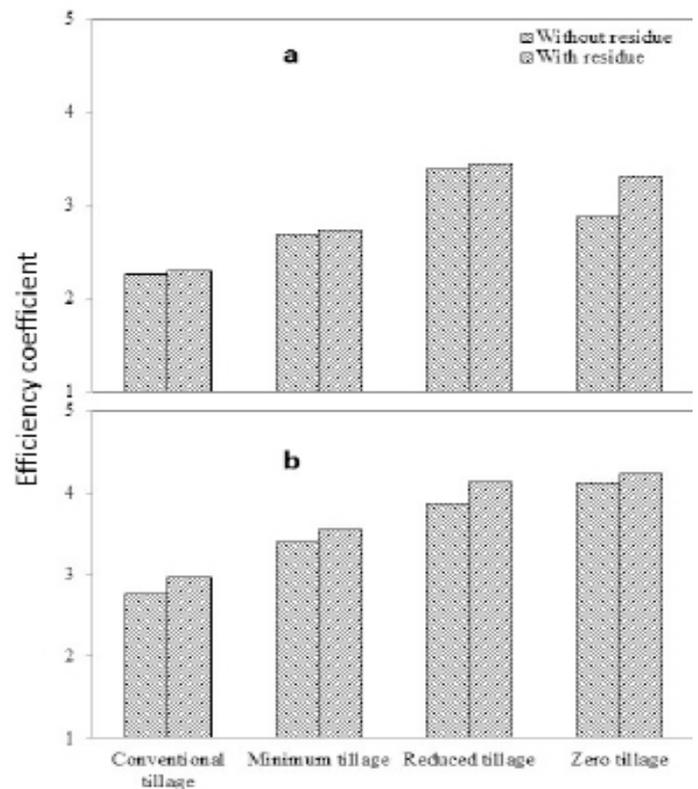


**Figure 6:** Gross marginal return under the tillage treatments with and without crop residue for the two years: (a) 2012-13, (b) 2013-14 was low under zero tillage with and without crop residues.

perform better economic in comparison with other tillage systems. (Ahmad et al., 2007) in the same region reported that conservation tillage was found to be economically beneficial compared to conventional tillage by reducing input cost. In Pakistan and India at rice-wheat system (Hobbs and Gupta, 2004) reported that zero tillage reduces the cost of production up to \$ 60 mostly due to decreasing fuel cost by 60-80 L per hectare and labor cost. (Jin et al.,2007) have also observed that conservation tillage is economically beneficial.

### Conclusions

From the two year field investigation our results confirmed that reduced tillage (chiseling) with retention of crop residue might enhance crop yield while conventional tillage system through moldboard plough without retention of crop residues increases input cost. We conclude that conservation tillage practices especially the reduced tillage (chiseling) with retention of crop residues has potential to improve soil quality and economic benefits for farmers while providing sufficient crop yield in rainfed upland of Pakistan.



**Figure 7:** Efficiency coefficient under the tillage treatments with and without crop residue for the two years: (a) 2012-13, (b) 2013-14 was higher under reduced tillage and zero tillage with and without crop residues.

### Author's Contribution

Muhammad Sharif conducted the research and wrote the article. Shahzada Sohail Ijaz, Muhammad Ansar, Ijaz Ahmad and Syed Abdul Sadiq reviewed the article and gave useful suggestion on editing and improvement of the article.

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