Research Article

Impact of Zero Tillage on Productivity of Traditional Mung Bean-Wheat Cropping System of Punjab, Pakistan

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Abstract | Conventional mung bean-wheat production system in Punjab, Pakistan involves intensive tillage practices that increases cost of production and declines soil fertility. Zero tillage planting method provides an opportunity to improve crop yield, reduce production cost and GHG emission. Farmer participatory field trials were carried out at six locations in Punjab province, a major Mung bean-Wheat cropping zone to evaluate zero tillage based crop production system in comparison to the traditional tillage. The findings revealed that zero tillage produced 13% and 9 % higher wheat and mung bean yield, correspondingly in comparison to conventional tillage practice. This improvement in grain yield with zero tillage can be linked to better germination. Adoption of zero tillage planting technique reduced total cost of production by Rs. 6236 ha^{-1} and helped farmer to earn additional Rs. 25601 ha^{-1} in terms of annual net returns than prevailing conventional tillage system. The benefit-cost ratio under zero tillage was calculated as 2.19 whereas 1.84 under traditional tillage practice. The results confirmed that new initiative (zero tillage) proved to be economical and resource conserving compare to conventional tillage.

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Introduction

Conventional crop production systems involved ploughing, planking and pulverizing the soil that results in loss of soil organic carbon (Lal, 2004). High energy input is required in conventional tillage systems which increases production cost and contributes in emitting GHGs (Grace *et al*., 2012) environmental pollution, water waste and land degradation (Barzegar *et al*., 2004). Therefore, apprehensions about climate change are resetting the priorities for investments in conservation agricultural research. Considerable innovations have been made to make crop production sustainable, economical and environment friendly, however, conservation agriculture with minimum or no soil disturbance has potential to mitigate GHGs emission and minimize climate change.

Zero tillage is an environment friendly crop planting technique (Grace *et al*., 2012) that allows direct seeding of crop and fertilizer application with minimal soil disturbance. Zero tillage ensures timely sowing (Jat *et al*., 2009) of crops, reductes cost of production (Saharawat *et al*., 2010), positively effects soil physical, biological and chemical properties (Rashidi and Keshavarzpour, 2007) enhances soil organic

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matter (Lal, 2006). Zero tillage help in decreases CO_2 (Almaraz *et al*., 2009) and N_2O emission (Ussiri *et al*., 2009). It is also stated that zero tillage operations reduced water usage through improving physical condition of the soil, reduction in soil erosion, less surface evaporation losses and improved soil biological activity (Kassam *et al*., 2009). Zero tillage system also reduces the fuel burning needed for tillage operation, thereby endowing to the moderation of adverse effects of climate change (Grace *et al*., 2012; Jeetendra *et al*., 2015). The land preparation increases cost of production and delays wheat planting that exposes wheat to high temperature stress at reproductive stage (Sohail *et al*., 2014; Hobbs, 2007) and ultimately reduces yield (Hobbs, 2007).

Punjab is the main wheat and mung bean growing province of the country. During 2018, Punjab province produced 19.17 million tonnes of wheat and 0.94 million tonnes of mung bean from a cultivated area of 19.17 and 0.133 million hectares, respectively (GOP, 2018). Farmers usually practice conventional production system which involves intensive tillage that increases cost of production and deteriorate soil fertility. Although the benefits of reduced tillage or minimum tillage (Wolfarth *et al*., 2011; Plaza *et al*., 2017) are well documented (Iqbal *et al*., 2005; Powlson *et al*., 2012), however, no literature is existing regarding use of zero tillage in wheat mung bean production system in western part of Punjab in Pakistan. The study was carried out to compare zero tillage, which is reported to be high yielding, cost effective, resource conservative and environment friendly, with predominant conventional tillage production system for mung bean wheat crop rotation through farmer participatory approach.

Materials and Methods

Field trials were conducted at six farmer fields located in Bhakkar district (31° 37' 59.9988" N and 71° 3' 59.9976" E) of Punjab province in Pakistan. The study area falls in arid zone with average annual rainfall 203 mm. About 70% of the total annual downpour occurs in Monsoon season (July to September). Mung bean crop is traditionally grown in rotation with wheat. Mung bean is grown as summer crop from July to October. Whereas, wheat is grown during winter season (November to April). This conventional system is carried out in the study area for centuries. The soils of the study sites were sandy loam with 0.5% OM, pH 8.0, available phosphorus 3.34 mg per kg and available potassium 66 mg per kg of soil that showed deficiency of organic matter, nitrogen, phosphorus and potassium. The maximum and minimum temperature of the study area varies from 48°C to 4°C. Major irrigation needs of crop are met through canal water, however, tube-well water was applied during canal closures.

Experimental design

The farmer field trials comprised of two planting techniques that included (i) conventional tillage and (ii) zero-tillage with six farmer fields replicate. In wheat mung bean cropping system, wheat was grown in winter and mung bean in summer season. The study was conducted for two consecutive years during 2015-16 and 2016-17 on farmer field measuring 0.4 ha of plot size. A farmer participatory approach was used and on-farm trials were managed by researchers and farmers for two successive years.

Wheat crop management

In conventional tillage (CT) system, pre sowing irrigation was given on 5th of November and land was prepared with two operations of cultivator followed by planking with wooden plank. N and P fertilizers were applied @120:85 kg ha^{-1}, respectively, which is regular practice in the area. Basal NP fertilizer dose (85 kg P_2O_5 and 33 kg of N ha^{-1}) as DAP was broadcasted. Afterwards, 140 kg ha^{-1} seed of wheat variety Galaxy–2013 was broadcasted that was followed by shallow cultivation with cultivator and planking to mix seed and fertilizer in soil. In zero tillage planting system, no tillage operations were performed after pre-sowing irrigation. Wheat sowing and basal fertilizer application was done in single operation with zero tillage seed cum fertilizer drill manufactured by Greenland Engineers, Daska, Pakistan. Wheat variety Galaxy-2013 was planted at seed rate of 125 kg ha^{-1} by maintaining 20 cm as row to row distance. In both planting techniques, wheat crop was irrigated 5-6 times after planting. A total of 150 kg ha^{-1} of N as Urea fertilizer was given in two split applications after 25 and 50 days of sowing. Herbicide Affinity @ 2000 ml ha^{-1} was sprayed after 25-30 days of crop emergence to control narrow and broadleaf weeds in wheat. Wheat crop was harvested at physiological maturity during third week of April.

Mung bean crop management

After harvesting of wheat crop, pre-sowing irrigation for mung bean cultivation was done in fields during 2nd week of May. In conventional tillage (CT) planting system plots, fields were prepared with two operations with cultivator followed by planking. Afterwards, 30 kg ha^{-1} seed of mung bean variety AZRI Mung-2006 along with 30 kg N and 12 kg P ha^{-1} as DAP was drilled through Rabi drill with row and plant spacing of 30 and 10 cm, respectively. In zero tillage planting system, pre-sowing irrigation was applied during 2nd week of May. Afterwards, 30 kg ha^{-1} seed of mung bean variety AZRI Mung 2006 was drilled through Zero tillage seed cum fertilizer drill manufactured by Greenland Engineers, Daska, Pakistan while maintaining row to row and plant to plant distance of 30 and 10 cm, respectively.

Afterwards, mung bean crop was irrigated three time during the growing season with interval of 25 days. Mung bean crop was attacked by different kinds of insects, so insecticides were also sprayed at branching, flowering and pod formation. The relevant detail regarding insects and insecticides is provided in Table 1. Manual harvesting of mung bean was done in the last week of August and thrashed by using thrasher.

Crop emergence data was recorded 25 days after planting from all sites. At physiological maturity, three randomly selected samples from (2x2 m^2) area were taken from each planting systems in each farmer fields for both wheat and mung bean crops. Sun drying of samples were properly done and threshed to get grain and straw yield data.

Economics and statistical analysis

Economic analysis was conducted to compare the annual net returns of zero tillage system with farmer practice. Expenditure of each machinery operation is calculate based on prevailing rental value of farming equipment's operations. In Gross revenue, only income from grain was included. Net return was determined by calculating the difference of gross income and expenditure. Gross returns were divided by the total costs under each tillage systems to get BCR. Paired t-test was used for statistical analysis between the treatments using Stata version 10.1 software (Cameron and Trivedi, 2009).

Results and Discussion

Impact of zero tillage on wheat crop

Two year data showed that zero tillage produced significantly higher wheat grain yield in comparison with farmer practice during both years i.e. 2015-16 and 2016-17 (Table 2). Similarly, zero tillage also resulted in significantly higher wheat emergence as compared to farmer practice of seed broadcasting (Table 3).

The pooled data of study showed that mean grain yield, plant population and harvest index of wheat crop were greater in zero tillage system than farmer practice. Mean grain yield was 12% higher when wheat planted by zero tillage as compared to traditional farmer practice. Wheat mean grain yields of 3653 and 3349 kg ha^{-1} in zero tillage system were higher than 3128 and 3092 kg ha^{-1} during 2015-16 and 2016-17, respectively (Table 2). Tillage techniques affect wheat crop germination and there was 16 and 12% higher seedlings emergence during 2015-16 and 2016-17, respectively under zero tillage system than farmer practice (Table 3). At the same time, significantly higher mean biological yield (9850 kg ha^{-1}) of wheat was also found in zero tillage system than traditional tillage (9132 kg ha^{-1}; Table 2). Similarly, comparatively higher mean wheat harvest index (36.5) was noticed in zero tillage as compared to traditional broadcast technique (35) of wheat sowing (Table 3).

Higher grain yield and biomass production in zero tillage practices might be linked with better physic-chemical soil properties and improved soil organic matter (Jin *et al*., 2007). Sarwar *et al.* (2008) also reported similar results. However, improved wheat yield and yield contributing traits in conventional tillage practice with marginal return from reduced tillage treatment (Leghari *et al*. 2015).

Sonnleitner *et al.* (2003) also reported that no or reduce tillage practice with sensible crop residue management increased cumulative soil stability. No tillage lead to intact soil particles and improve water infiltration rates (Ekwue, 1992). Wang *et al.* (2000) also stated that conservation tillage might reduce water run-off and improved infiltration in than mouldboard plough treatment in Shanxi province. Intensive tillage was also indicated to enhance soil moisture content and crop yields in diverse locations (Hammel, 1995) Zero tillage improved amounts of available N and P in the top soil. Reyes (2002) also reported noteworthy escalations of available N and P in reduce or zero tillage practices than traditional deep ploughing.

Table 1: *Detail of insecticides used for insect control in Mungbean crop.*

Insect	Insecticide (ingredient)	Insecticide (brand name)	Crop stage at application	Dose (ml/ ha)
Whitefly, jassid and thrips	Imidacloprid (20 SL)	Confidor	Branching and flowering	500
Bugs	Lambda- cyhalothrin	Hunter/ boxer	Pod initiation and during pod formation	825
Armyworm, pod borer, semi looper, hairy caterpillar, cutworm and grasshoppers	Bifenthrin 10 EC	Talstar	Branching and flowering	625

Table 2: *Effect of tillage systems on Grain and Biological yields of wheat crop.*

Tillage systems	Grain yield (kg ha^{-1})			Biological yield (kg ha^{-1})		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean
Zero tillage	3653	3128	3390	10310	9390	9850
Conventional	3349	3092	3220	9275	8988	9132
t-value significance	2.069	1.526	2.666	2.030	1.198	2.136

*The results are significant at ***, **, * 1, 5 and 10 percent levels respectively.*

Table 3: *Effect of tillage systems on emergence and harvest index of wheat.*

Tillage system	Emergence (plants m^{-2})			Harvest index (%)		
	2015	2016	Mean	2015-16	2016-17	Mean
Zero-tillage	190	193	192	37	36	36.5
Conventional	178	177	178	35	35	35
t-value significance	5.86	6.12	8.485	2.030	0.964	2.104

*The results are significant at ***, **, * 1, 5 and 10 percent levels respectively.*

Effect of tillage practices on mung bean crop production

Zero tillage operation showed higher grain yield, crop emergence and harvest index of mung bean in comparison with traditional farmer practice. Zero tillage planting of mung bean crop produced 10% higher mean grain yield than conventional tillage. Zero tillage had mung bean yields of 827 and 881 kg ha^{-1} in comparison to 758 and 811 kg ha^{-1} in conventional tillage system during 2015 and 2016, respectively (Table 4). Mung bean grain yield under zero tillage system was higher in both years due to 17 and 24% higher mung bean germination in comparison with conventional tillage system during 2015 and 2016, respectively. Zero tillage system produced significantly higher biological yield of mung bean than conventional tillage in both years (Table 5). Comparatively higher mean harvest index (25.5) was recorded in mung bean under zero tillage than farmer practice (24.5; Table 5).

In this study, mung bean sowing under zero tillage system improved grain yield. Similar results were also conveyed by Sekhon *et al.* (2004, 2007). Singh *et al.* (2011) also reported higher mung bean grain yield in zero tillage. He obtained 3% higher average yield during adaptive trials with happy seeder, more improved form of zero tillage drill, as compared to conventional tillage. Porosity of soil also improved by reduced tillage operations and soil biological activity was enhanced (Brar *et al*., 2013). Moreover, zero tillage practices have greater soil water holding capacity than the tilled soils (Fern´andez-Ugalde *et al*., 2013) and ultimately improve production.

Table 4: *Effect of tillage systems on grain and biological yields of Mungbean.*

Tillage system	Grain yield (Kg ha^{-1})			Biological yield (Kg ha^{-1})		
	2015	2016	Mean	2015-16	2016-17	Mean
Zero-tillage	827	827	827	3653	3349	3513
Conventional	758	758	758	3128	3092	3111
t-value significance	0.458	0.982	0.369	2.069	1.526	0.213

*The results are significant at ***, **, * 1, 5 and 10 percent levels respectively.*

However, Amanullah *et al.* (2015) found comparatively lower yields of mung bean varieties under zero tillage operation as compared to conventional intensive tillage practice. This is may be due to preparation of soft seed bed, and better pulverization of soil, which provided promising growing condition for plant growth and nutrients availability than sowing with seed bed preparation (zero tillage).

Table 5: *Effect of tillage systems on emergence and harvest index of Mungbean.*

Tillage system	Emergence (plants m^{-2})			Harvest index (%)		
	2015	2016	Mean	2015-16	2016-17	Mean
Zero-tillage	24	25	24.6	26	25	25.5
Conventional	20	19	19.2	25	24	24.5
t-value significance	4.08	5.87	7.018	0.740	0.472	0.076

*The results are significant at ***, **, * 1, 5 and 10 percent levels respectively.*

Table 6: *Details regarding cost of production and cost benefit analysis of Zero tillage and farmer practice for Mungbean crop in Bhakkar district.*

Item	Zero tillage	Farmer practice	ZT-FP
Land preparation cost	0	2000	-2000
Seed cost (RS)	3600	3600	0
Planting cost	2500	2500	0
Fertilizer cost	4750	4750	0
Weedicide cost	2000	2000	0
Irrigation cost	2700	2700	0
Insecticide cost	5000	5000	0
Harvesting and thrashing cost	11250	11250	0
Production cost - total	31800	33800	-2000
Mung bean yield (kg/ha)	855	785	70
Price of mung (PKR / Kg)	90	90	0
Gross revenue mung	76950	70650	-6300
Cost benefit ratio	2.42	2.10	

Effect of tillage practices on mung bean-wheat cropping system

Zero tillage planting system improved the productivity of mung-wheat rotation in terms of monetary return, sustainability and resource conservation. Wheat and mung bean crop performed well under zero tillage technique in light textured soils of Bhakkar district Punjab. In both crops, better germination in zero tilled system improved crop stand establishment and that ultimately contributed towards comparatively higher grain yields in both mung bean that wheat crops. Improved grain yields of wheat and mung bean under zero tillage operation might be linked to beneficial effects of retaining soil surface residue in comparison to conventional tillage. Preceding crop residue cover might helped soil to retain better moisture, higher infiltration and reduced runoff in light texture soil. Zero tillage crop production system over long period with residue management input and improves soil organic matter and can help in halting the process of soil degradation (Amado *et al*., 2006). Retention of crop residue on soil surface in legume based crop rotation with zero tillage system improves plant population, enhance nutrients, reduce water requirements, improve soil fertility, soil physical conditions and ultimately crop yield (Sainju *et al*., 2008; Mohammad *et al*., 2003). At the same time, prevailing farmer practice in the study area require 4-5 preparatory tillage operations as compared to zero-tillage which does not require any land preparation tillage operation. Under zero tillage system, tillage operations were reduced and helped in reducing 15-20 litres of fuel usage per hectare. Carbondioxide emission can be reduced by 2.6 kg by saving one litre of fuel (Grace *et al*., 2012). This saving of fuel could be accompanied with reduction of 39-52 kg CO_2. It ultimately helped to less emission of CO_2 gas into the environment due to less burning of fossil fuel as compared to farmer practice and proved to be an environment friendly technology.

Table 7: *Details regarding cost of production and cost benefit analysis of zero tillage and farmer practice for wheat crop in Bhakkar district.*

Item	Zero tillage	Farmer practice	ZT-FP
Land preparation cost	0	4000	-4000
Seed cost (RS)	6000	7200	-1200
Planting cost	2500	2650	-150
Fertilizer cost	18950	18950	0
Weedicide cost	3000	3000	0
Irrigation cost	5400	5400	0
Harvesting and thrashing cost	19259	18145	1114
Production cost - Total	55109	59345	-4236
Wheat yield (kg/ha)	3513	3111	402
Price of wheat (PKR / Kg)	32.5	32.5	0
Gross revenue wheat	114173	101108	13065
Cost benefit ratio	2.07	1.70	

Economic analysis

Adopting zero tillage drill technology for wheat cultivation saved Rs. 4000 ha^{-1} in cost of land preparation as compared to farmer practice (Table 7). Farmers in the study area used 150 kg ha^{-1} of seed with broadcast method of sowing whereas zero tillage drill farmers used 125 kg ha^{-1} that helped in saving 25 kg ha^{-1} seed and reduced cost of seed to Rs. 1200 ha^{-1} (Table 7). With zero tillage drill planting, farmers got 0.4 t ha^{-1} more wheat yield that provided extra revenue of Rs. 13065 ha^{-1} in comparison with prevailing farmer practice (Table 7). Irrigation cost for wheat crop was same under both technologies.

Zero tillage planting helped farmers in saving Rs. 2000 ha^{-1} in land preparation cost of mung bean compared to conventional farmer practice (Table 6). However, all other expanses on planting, seed, fertilizer, irrigation, insecticides and thrashing were same in both planting system (Table 6). An increase of 70 kg ha^{-1} of mung bean resulted in additional revenue of Rs. 6300 ha^{-1} for zero till farmers in comparison with conventional tillage.

There is no significant difference in fertilizer cost between two planting methods, however, zero tillage technology might had better fertilizer use efficiency due to band application of fertilizer accompanied with seed in comparison to broadcast fertilizer application method in conventional system. Farmers apply fertilizer through broad cast method at planting which is less efficient as compared to applying it with drill. In Zero tillage planting technique, DAP is applied along with seed at the required depth and close to seed that improves availability of fertilizer to plants and may improve fertilizer use efficiency.

Zero tillage system (Rs. 76950 per ha^{-1}) in mung bean produced higher gross revenue as compared to conventional system (Rs.70650 ha^{-1}) that was attributed to saving in land preparation cost (Rs. 2000 ha^{-1}) and greater yield in zero tillage operation (Table 6). Benefit-cost ratio for mung bean crop was also higher (2.42) in comparison to zero tillage system than conventional cultivation method (2.10).

In case of wheat crop, higher gross revenue was earned in zero-tillage system (Rs. 114173 ha^{-1}) in comparison to conventional farmer practice (Rs. 101108 ha^{-1}). This higher net revenue with zero tillage linked to saving in cost of land preparation, seed and additional grain yield in zero tillage system that also contributed towards higher benefit-cost ratio (2.07) with zero tillage in comparison with conventional practice (1.70; Table 7).

Adoption of zero tillage in wheat-mung bean system saved Rs. 6236 ha^{-1} in cost of production in comparison with prevailing farmer practice (Table 8) that was mainly attributed to lower seed and tillage cost. Zero tillage system in wheat-mung bean system had Rs. 25601 ha^{-1} more return that was 32% higher as compared to farmer practice (Table 8). Zero tillage had higher benefit-cost ratio of 2.19 in comparison with 1.84 with farmer practice in wheat-mung bean cropping system (Table 8). Erenstein and Laxmi (2008) and Tripathi *et al*. (2013) also reported reduced production cost and increased net income in case of zero tillage rice-wheat production system in comparison to conventional puddled rice production system which involve intensive tillage and water use. Our farmer participatory on farm research work introduced cost effective, environment friendly and productive crop production system against a tillage intensive and high cost traditional system with environmental hazards.

Table 8: *Net returns and benefit-cost ratios of Wheat-Mungbean crop rotation under conventional and zero-tillage system.*

	Zero-tillage	Conventional tillage	Difference
Gross benefit (RS. ha^{-1})	191123	171758	+19365
Total cost (RS. ha^{-1})	86909	93145	- 6236
Net Returns (RS. ha^{-1})	104214	78613	+25601
Benefit-cost ratio (RS. ha^{-1})	2.19	1.84	

Conclusions and Recommendations

Zero tillage planting system reduced the farmer's total input expenditure by 6.7% that amounts Rs. 6236 ha^{-1} and increased net return by 32% (Rs. 25601 ha^{-1}) in comparison with farmer practice, comprised of intensive tillage practices. Zero tillage planting of wheat and mung bean crops produced 12 and 10% higher mean grain yield than conventional farmer tillage practice, respectively which is due to better germination and crop stand establishment. The technology also helped to reduce tillage operation that would be helpful to alleviate adversative effects of climate change.

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Novelty Statement

The present research work will help to promote sustainable, economical and environment friendly crop production. The adoption of the recommended resource conserving agricultural practices in this study has potential to mitigate the adverse impacts of climate change on crop production.

Author's Contribution

Imtiaz Hussain: Principal investigator, conceived the idea, Executed the trial and written manuscript.
Azhar Mahmood Aulakh: Crop management and data collection
Muhammad Sohail: Assisted in writing manuscript, statistical analysis of the data and served as corresponding author.
Khalid Hussain: Supervised the research work and given technical input and reviewed the manuscript before submission.
Ansaar Ahmed: Crop management and data collection.
Abdul Hamid: Statistical analysis of the data.
Muhammad Imtiaz: Reviewed the manuscript before submission and acquisition of the financial support for the project leading to this publication.

Conflict of interest
The authors have declared no conflict of interest.

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