The Journal of Animal & Plant Sciences, 30(2): 2020, Page: 467-474
ISSN: 1018-7081

ASSESSMENT OF CROPPING SYSTEM PRODUCTIVITY, PROFITABILITY AND ECONOMIC EFFICIENCY OF WHEAT

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ABSTRACT

Cropping system throughout assessment exhibits importance for the crop production and cultural practices profitability. This field study was undertaken in semi-arid climate to devise suitable system. Wheat was sown in winter season while, summer crops include; cotton, maize and mungbean, which were sown under conventional tillage (CT), permanent beds (PB) and no tillage (NT) respectively. Yield and yield attributes were significantly influenced by tillage systems, highest productive tillers (m^{-2}), grains per spike and 1000-grain weight (g) was observed in permanent beds (PB). Grain yield (tha^{-1}) was also significantly higher (4.03 t ha^{-1}) in PB. System productivity in terms of wheat equivalent yield (WEY) of maize-wheat (MW) under PB was higher (10.26 t ha^{-1}) followed by mungbean-wheat in permanent bed (9.40 t ha^{-1}) and cotton-wheat in conventional tillage (9.26 tha^{-1}). Highest cultivation cost was observed in the cotton-wheat followed by maize-wheat under conventional tillage and least was observed in the mungbean-wheat in no tillage. Cotton-wheat (CW) gave maximum net field benefit (US$. 1606.53$ha^{-1}$) in under PB followed by mungbean-wheat (MbW) (US$.1411.72$ha^{-1}$). However, maximum benefit cost ratio (BCR) (3.77) was recorded in mungbean-wheat system. Moreover, the cotton-wheat in permanent bed system was the best possible option for acquiring high production and land use efficiency.

Keywords: Cropping system; wheat; net return; profitability; system productivity.

https://doi.org/10.36899/JAPS.2020.2.0041 *Published online March 02, 2020*

INTRODUCTION

World population is supposed to increase the figure of 9000` million by the year 2050 (FAO 2014). The challenge to feed this gigantic population is not easy task. Wheat known to be an essential food of human beings and is most widely grown crop (Dawe 2008). Above twenty percent calories to human provided by wheat worldwide (FAO 2014; Peter 2011; Braun *et al*., 2010). The average grain yield is much lower in Pakistan, regardless of higher yield potential (USDA 2016). Two principal constraints responsible for the lowering the crop yield includes; dependence on conventional practices and unwise selection of crop without assessing the capacity of the soil for crop production (Shehzad *et al*. 2016).

Monoculture (cereal-cereal) system becomes increasingly prone to insect pests and diseases attack owing to less diversity in crop selection (Ratnadass *et al*. 2012; David 2002). Thus, agricultural system productivity is decreasing constantly under such systems (Tilman *et al*. 2002). The recent persistence of growers on conventional tillage (CT) practices for making an ideal seed-bed resulted in hard-pan in root zone, which adversely affects crop productivity by hindering the growth of plant root system (Zhang *et al*. 2006; Micucci and Taboada 2006; Bertolino *et al*. 2010; Shahzad *et al*. 2016), eventually loss in terms of profitability encored at farm level.

Cereal based cropping system exhibits great importance in food chain/security (Timsina and Connor 2001; Ladha *et al*. 2003). Tanaka *et al*. (2002) stated rotations as different crops were grown in a specific order and/or specified pattern though, crop multifariousness was quite limited over the area. Higgs *et al*. (1990) and Crookston (1995) reported that the differences in crop yield were related with crop rotation was implied to the rotation effect. The meliorative effect of inclusion of legumes in cereal-based cropping system has long been documented (Bari and Islam 2009).

Conservation tillage system have advantage of increased yield of crops (wheat and cotton) in permanent beds compared with conventional system under irrigated semiarid climate (Boulal *et al*. 2012; Naresh *et al*. 2012). Moreover, Kienzler *et al*. (2012) reported that yield under conservation tillage practices were less and inconsistent in irrigated regions. In cotton-wheat cropping system, seeding of wheat after cotton resulted in incorporation of organic matter in soil in the form of cotton leaves and weed residues (Khan and Khaliq 2005). Zandastra (1976) revealed cropping system as crop production enterprise used to drive benefits from a given resource and specific environment condition. Conservation tillageis advantageous to soil biological, physical environment (Gathala *et al*. 2011; Sainju *et al*. 2008), and chemical properties by minimal soil disturbance and implementation of varied crop sequences (Farooq *et al*. 2011; Friedrich *et al*. 2017) resulting in augmentation of crop productivity. NT reduce cost, save soil moisture and increased yield (De Vita *et al*. 2007; Erenstein *et al*. 2008), reduced energy consumption (Garcua-Torres 2000), thus become more attractive than CT among the farmers (Hobbs, 2007).

Though number of studies was executed to evaluate of the impact of crop sequence on the wheat performance under various tillage practices, but there was no enlightenment on the economics of wheat based system in relation to different tillage regimes. Therefore, this field experiment was aimed at assessing the economic efficiency of various wheat-based cropping systems under different tillage practices.

MATERIALS AND METHODS

Site, soil and climatic conditions: A two-year field experiment was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (longitude 73°- 76° E, 31° - 26° N and 135 m elevation) Pakistan during 2014-15. The soil at Faisalabad was a sandy loam from the Lyallpur series. According to chemical analysis, soil had pH 7.6, 0.38% soil organic matter, 0.35 dS m^{-1} electrical conductivity, 0.05% total N, 6.88 mg extractable P kg^{-1}, 163 mg extractable K kg^{-1}.

Experimental details: The economics and profitability of wheat sown under tillage systems was assessed in four different wheat-based cropping systems. The cropping systems included in the experiment were 1) cotton-wheat, 2) maize-wheat, 3) mungbean-wheat system. The tillage practices evaluated were 1) conventional tillage (CT), 2) permanent bed, 3) (PB) no tillage (NT). The experiment was laid out according to randomized complete block design with split plot arrangements. Tillage practices were assigned to main plots, while cropping systems were arranged in sub-plots having three replications. The size of main and sub-plots was 20 m × 15 m, and 5 m × 3 m, respectively.

Crop husbandry: Before seedbed preparation, pre-soaking irrigation of four inch was applied before cultivation. When soil reached at field capacity, seedbeds were prepared as per treatment. All the crops included in the study were sown according to recommendations by the Department of Agriculture Extension, Punjab, Pakistan (Shahzad *et al*. 2017). In total, five irrigations were applied to wheat crop in order to avoid the negative effects of moisture stress throughout the crop season (Table 1). All the crops were harvested manually at their harvest maturity. At harvest maturity, three central rows from each plot of a given crop were harvested, sun-dried for one week, threshed manually, grains were separated, and weighed to calculate grain yield which was converted into tons per hectare. The grain yields of all crops were adjusted at 10% grain moisture contents. Data regarding grain yield of wheat crop used to compute the economics. The yield data of the crops was recorded for the computation of the economics and profitability.

Expenses incurred: The variable and fixed costs incurred were calculated according to current market rates of inputs in US Dollar (US$). For summer crops, the fixed cost included the cost of fertilizers transport/application and the land rent. The cost of land preparation, seed, sowing, irrigation application, fertilizers, and harvesting varied among all summer crops. Similarly, for wheat crop, the total fixed cost included seed cost, sowing, fertilizers transportation, irrigation and fertilizers application, and crop harvesting. The cost of land preparation was considered as variable cost. Total expenditure incurred was computed by adding the variable and fixed costs of summer and winter crops for respective treatments.

Economic and marginal analysis: The economic and marginal analysis was performed following the CIMMYT (1988). The grain and straw yields from each crop were multiplied with the unit market price to determine the income (US$ ha^{-1}). The market rates of product in US dollar (US$) per 40 kilograms (kg) are as follow; Cotton = US$ 25 per 40 kg; Maize= US$ 9 per 40 kg; Mungbean = US$36 per 40 kg. Total income of a cropping system was calculated by adding the income of grain and straw yields of each summer and winter crop. Net benefit returns were obtained by subtracting total expenditures from the relevant total income. Benefit-cost ratio (BCR) was calculated by dividing the total income by total expenditures. Moreover, marginal rate of return (MRR) was also calculated to find out the most cost-effective treatment of the study. MRR was determined by arranging the variable cost of treatments in descending order. The respective net field benefits of treatments were also placed in order. Changes in variable cost and net field benefits were calculated by subtraction. Data were analyzed for partial budget analysis and marginal analysis. The performance of different cropping system in terms of wheat equivalent yield (WEY) was computed using the formula: $WEY\ (crop) = Y_a\ (P_x)/P_b$.

Where, Y_a is the yield of crop 'a' (t/ha of economic harvest), P_a is the price of crop 'a', and P_b is the price of wheat (Schlegel *et al*. 2016). Production efficiency in terms of kg/ha/day was calculated according to (Kundu and Mahapatra 2014).

Statistical analysis: Analysis of variance (ANOVA) test was performed using statistical software 'Statistix 8' (Analytical software, Tallahassee, Florida, USA) for windows, while difference among the treatment means was determined using Tukey's (HSD) at $P \leq 0.05$ and $P \leq 0.01$.

RESULTS AND DISCUSSION

Production in various cropping/tillage systems: Tillage significantly affected the yield and yield parameter of wheat, as wheat yield under permanent beds was significantly ($P \leq 0.05$) higher by 10.11% compared to conventional tillage planting system (Table 2). However, wheat planted in no tillage yielded 21.04% lower compared to conventional tillage. The yield of wheat also differed significantly ($P \leq 0.05$) under different cropping systems. Maximum wheat grain yield (3.60 tha^{-1}) was recorded under maize-wheat system followed by cotton-wheat (3.53 tha^{-1}) as compared to other systems. On other hand, permanent beds gave highest yield (4.03 t ha^{-1}) than other tillage systems. This increased wheat production in bed sowing ascribed to the provision of improved water and nutrient uptake and soil health to the crop (Shahzad *et al*. 2016; Khan *et al*. 2012). The number of tillers ha^{-1}, number of grains $spike^{-1}$ and 1000-grain weight were significantly affected by diversified tillage treatments (Table 2).

Income beared from various cropping/tillage systems: Different cropping sequences were economically analyzed (Table 3), revealed that cotton-wheat system required highest cost of cultivation in conventional tillage. The greatest cost was incurred due to the more investment in terms of management practices (tillage operations) and fertilization. The lowest cost of cultivation was incurred in mungbean-wheat cultivated under no tillage. Permanent bed saves capital, requires less tillage operation and higher benefit: cost ratio (BCR) compared to the conventional tillage Shah *et al*. (2016). Gross and net income was also highest for cotton-wheat system in permanent bed.

Farmers are interested in high benefits from the crops therefore; net field benefits (NFB) were calculated against the variable costs. Maximum net field benefit (US$. 948.67$ha^{-1}$) was observed in cotton followed by mungbean (US$.733.72$ha^{-1}$) and maize (US$. 425.40ha^{-1}) in permanent bed during summer season (Table 4a). While, minimum net field benefit was found in the no tillage. Table 4b reveals that maximum net field benefit (US$. 664.11$ha^{-1}$) was observed in wheat grown after maize in permanent bed followed by the cotton-wheat (US$. 657.86$ha^{-1}$) in conventional tillage. The minimum net field benefit (US$. 428.47$ha^{-1}$) was observed in the wheat grown after mungbean in no tillage system. Thus, this study proved no tillage as low-input tool for cultivation compared to other tillage systems on account of no land preparation and minimal fuel consumption (Shahzad *et al*. 2017; Akbarnia and Farhani 2014; Iqbal *et al*. 2002).

Benefit cost ratio (BCR) is also important indicator to farmers because they are interested in the increased net returns by managing the total cost of production. In summer, maximum BCR (2.42) was found in the mungbean under permanent bed followed by mungbean (2.27) in conventional tillage while, lowest BCR (1.21) was observed in no tillage cultivated maize (Table 4a). During the winter season, maize-wheat system in permanent bed gave highest (2.78) BCR followed by the cotton-wheat in permanent bed (2.76) and least BCR (2.22) was observed in mungbean-wheat in no- tillage (Table 4b). The income gained from bed sown wheat in terms of net economic returns and BCR were also highest in rice-wheat cropping system (Shahzad *et al*. 2017; Conner *et al*. 2003). Maximum BCR in maize-wheat system in permanent bed was attributed to its less cost of production and more gross income as compare to other treatments. Marginal analysis also suggested more benefits of bed sowing in this experiment. Likewise**,** highest marginal rate of return was observed in maize, followed by cotton and then mungbean under permanent bed respectively, during summer 2014 (Table 5a). In winter 2014-15 highest marginal rate of return was obtained in cotton-wheat followed by the maize-wheat rotation followed by mungbean-wheat system in permanent bed respectively (Table 4a).

Land resource use efficiency (LRUE) and production efficiency (PE) was conferred in Table 6. Highest land resource use efficiency (87.12%) was recorded in the cotton-wheat sequence. Moreover, highest production efficiency (23.07$kgha^{-1}day^{-1}$) was also recorded in cotton-wheat under permanent bed system; Khalid *et al*. (2014) also found the same results in the cotton-wheat system. The maize-wheat system recorded as second highest efficient system of production (20.06 $kgha^{-1}day^{-1}$) with land resource use efficiency of 70.96 percent. The lowest production efficiency (13.24 $kgha^{-1}day^{-1}$) was recorded in no tillage cotton-wheat system; while, lowest land resource use efficiency was observed in the maize-wheat system under all the tested tillage treatment. The mungbean-wheat cropping system utilized land for shorter duration thus had lowest land resource use efficiency among all the tested treatments

Table 1. Agronomic practices of individual crop followed during experimentation.

Crop	Variety	Seed rate (kgha^{-1})	Spacing (cm × cm)	No. of irrigation	Fertilizers N:P:K (kgha^{-1})	Intercultural operation
Wheat	FSD-2008	120	22.5	5	120:80:0	2
Cotton	MNH-886	25	75 × 75	12	200: 115:0	3
Maize	DK-6789	25	75 × 75	8	250: 115:0	2
Mungbean	Mung-6	25	8× 30	3	23:57:0	1

Table 2. Effects of tillage and crop rotation on yield and yield attributes of wheat.

Main effect/ level	Productive tillers (m^{-2})	Grains per spike	1000-grain weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})
Tillage					
Conventional	232±2.96a	42±0.67a	41.34±0.32a	3.66±0.14b	10.24±0.14b
Permanrnt bed	242±3.18a	44±0.12a	42.53±0.15a	4.03±0.22a	10.65±0.12a
No till	199±2.60b	39±0.30b	39.13±0.23b	2.89±0.11c	8.33±0.11c
Rotation					
Cotton-wheat	226±1.76	39±0.14	40.88±0.35	3.53±0.14ab	9.73±0.10
Maize-wheat	225±2.54	39±0.20	41.26±0.24	3.60±0.17a	9.76±0.05
Mung-wheat	222±1.64	39±0.34	40.88±0.33	3.45±0.19b	9.73±0.07
Tillage	**	**	**	**	**
Crop	NS	NS	NS	**	NS
Tillage x crops	NS	NS	NS	**	*

Means values of three replicates ± SE. Mean values followed by the similar letters within columns don't differ significantly ($P \leq 0.05$). One star (*) mean values show significant, two stars (**) show highly significant mean values.

Table 3. Economic analysis of wheat under different wheat based cropping system.

Tillage	Cropping system	[a] Cost of cultivation (US$. ha^{-1})	[b] Gross Return (US$. ha^{-1})	[c] Net Return (US$. ha^{-1})	[d] Return per invested (US$)
Conventional	Cotton-wheat	1172.46±1.87a	2072.43±1.72b	899.98±1.59c	2.31±0.05c
	Maize-wheat	1083.53±0.67b	1792.89±1.02c	709.36±0.93e	2.53±0.01b
	Mungbean-wheat	700.92±1.72g	1571.40±2.69e	870.49±1.52cd	1.81±0.06d
Permanent bed	Cotton-wheat	1073.81±1.97c	2286.96±1.29a	1213.16±1.03a	1.89±0.05d
	Maize-wheat	988.39±0.75e	1800.29±1.09c	811.90±1.02d	2.22±0.01c
	Mungbean-wheat	666.74±0.64h	1698.61±0.67d	1031.87±0.59b	1.65±0.02e
No tillage	Cotton-wheat	995.37±1.99d	1596.45±1.25e	601.08±0.98f	2.66±0.0b
	Maize-wheat	934.23±1.58f	1401.30±1.46f	467.07±1.23g	3.00±0.01a
	Mungbean-wheat	575.54±1.09i	1226.59±1.09g	651.05±0.98ef	1.88±0.01d

[a] Cost of cultivation; total cost form sowing to harvesting, [b] Gross Return; income without excluding the cost, [c] Net Return; income excluding the cost, [d] Return per invested; income by investing 1US$.

Table 4a. Effect of different tillage system on net field benefit and BCR of Kharif crops.

	Treatment	Yield (t ha^{-1})	Yield Value (US\$. ha^{-1})	Straw Value (US\$. ha^{-1})	[a] Gross income (US\$. ha^{-1})	Total cost (US\$. ha^{-1})	[b] Net field benefit (US\$. ha^{-1})	BCR
Cotton	Traditional tillage	2.91±0.03^{b}	1724.26±6.40^{b}	94.95±0.0	1819.22±3.94^{b}	1144.75±1.30^{a}	674.47±4.61^{b}	1.59±0.02^{b}
	Permanent bed	3.21±0.02^{a}	1907.91±4.08^{a}	94.95±0.0	2002.86±5.8^{a}	1054.19±0.69^{b}	948.67±5.01^{a}	1.90±0.01^{a}
	No tillage	2.19±0.05^{c}	1299.62±3.40^{c}	94.95±0.0	1394.57±3.90^{c}	1007.32±1.82^{c}	387.25±4.52^{c}	1.38±0.03^{c}
Maize	Traditional tillage	6.38±0.04^{a}	1362.90±7.89^{a}	63.18±0.01	1426.08±7.34^{a}	1024.57±0.51^{a}	401.51±6.84^{a}	1.39±0.01^{b}
	Permanent bed	6.12±0.04^{b}	1307.49±8.27^{b}	58.81±0.04	1366.30±4.22^{b}	940.89±0.52^{b}	425.40±3.74^{a}	1.45±0.01^{a}
	No tillage	4.96±0.02^{c}	1060.53±3.30^{c}	56.69±0.03	1117.22±5.74^{c}	924.17±0.21^{c}	193.05±5.54^{b}	1.21±0.01^{c}
Mungbean	Traditional tillage	1.35±0.01^{b}	1154.15±6.68^{b}	28.49±0.0	1182.63±6.68^{b}	520.71±0.67^{a}	661.92±6.01^{b}	2.27±0.01^{b}
	Permanent bed	1.43±0.02^{a}	1220.89±6.94^{a}	28.49±0.0	1249.38±4.69^{a}	515.66±1.69^{b}	733.72±5.24^{a}	2.42±0.03^{a}
	No tillage	1.00±0.02^{c}	856.01±4.16^{c}	28.49±0.0	884.50±3.66^{c}	447.51±1.42^{c}	436.99±2.75^{c}	1.98±0.03^{c}

NOTE: All prices in US\$ indicate US dollar; Cotton = US\$ 25 per 40 kg; Maize= US\$ 9 per 40 kg; Mungbean = US\$36 per 40 kg

[a] Gross income were calculated by multiplying the field price of crop by the adjusted yield; field price of crop was calculated by taking the price that farmers receive for crop when they sell it, and subtracting all the associated costs associated with harvest, and sale proportional to the yield.

[b] Net field benefits are calculated by subtracting gross income from total costs;

Table 4b. Effect of different tillage system and crop rotation on total cost, net field benefit and benefit cost ratio.

Tillage	Cropping system	Wheat Yield (t ha^{-1})	Wheat Yield Value (US\$. ha^{-1})	Straw yield (t ha^{-1})	Straw Value (US\$. ha^{-1})	[a] Gross income (US\$. ha^{-1})	Total cost (US\$. ha^{-1})	[b] Net field benefit (US\$. ha^{-1})	[c] BCR
Conventional tillage	Cropping system	Wheat Yield (t ha^{-1})	Wheat Yield Value (US\$. ha^{-1})	Straw yield (t ha^{-1})	Straw Value (US\$. ha^{-1})	[a] Gross income (US\$. ha^{-1})	Total cost (US\$. ha^{-1})	[b] Net field benefit (US\$. ha^{-1})	[c] BCR
	Cotton-wheat	3.67±0.01^{cd}	819.20±3.18^{cd}	10.23±0.04^{b}	116.56±0.46^{b}	935.76±3.53^{cd}	413.85±3.10^{ab}	521.91±5.21^{cd}	2.28±0.15^{de}
	Maize-wheat	3.76±0.04^{c}	838.81±3.80^{c}	10.40±0.05^{ab}	118.48±0.60^{ab}	957.29±4.25^{c}	415.81±5.08^{a}	541.47±4.08^{c}	2.32±0.13^{cd}
	Mungbean-wheat	3.55±0.05^{d}	791.20±4.09^{d}	10.10±0.04^{b}	115.11±0.42^{b}	906.31±4.91^{d}	411.05±4.09^{b}	495.26±4.38^{d}	2.22±0.13^{e}
Permanent bed	Cotton-wheat	4.08±0.01^{a}	909.50±2.04^{a}	10.64±0.04^{a}	121.21±0.44^{a}	1030.71±2.45^{a}	372.85±0.24^{c}	657.86±2.24^{a}	2.76±0.01^{a}
	Maize-wheat	4.11±0.02^{a}	916.48±4.86^{a}	10.64±0.04^{a}	121.18±0.45^{a}	1037.66±5.31^{a}	373.55±0.49^{c}	664.11±4.82^{a}	2.78±0.01^{a}
	Mungbean-wheat	3.90±0.02^{b}	870.82±4.19^{b}	10.67±0.18^{a}	121.54±2.02^{a}	992.36±2.36^{b}	368.98±0.42^{d}	623.38±1.91^{b}	2.69±0.01^{b}
No tillage	Cotton-wheat	2.84±0.03^{e}	632.93±5.75^{e}	8.31±0.01^{c}	94.73±0.14^{c}	727.66±5.71^{e}	315.88±0.57^{e}	411.79±5.22^{e}	2.30±0.01^{cd}
	Maize-wheat	2.92±0.04^{e}	651.67±4.89^{e}	8.24±0.04^{c}	93.92±0.49^{c}	745.59±4.32^{e}	317.75±0.89^{e}	427.84±8.43^{e}	2.35±0.02^{c}
	Mungbean-wheat	2.91±0.03^{e}	650.09±5.45^{e}	8.42±0.06^{c}	95.98±0.65^{c}	746.06±6.08^{e}	317.59±0.55^{e}	428.47±5.54^{e}	2.35±0.02^{c}

[a] Gross income were calculated by multiplying the field price of crop by the adjusted yield; field price of crop was calculated by taking the price that farmers receive for crop when they sell it, and subtracting all the associated costs associated with harvest, and sale proportional to the yield.

[b] Net field benefits are calculated by subtracting gross income from total costs.

[c] BCR; benefit cost ratio

Table 5a. Effect of different tillage system on marginal analysis of Kharif crops.

Crop	Tillage	Cost that vary (US$. ha^{-1})	Marginal cost that vary (US$. ha^{-1})	Net field benefit (US$. ha^{-1})	Marginal net benefits (US$. ha^{-1})	Marginal rate of return (%)
Cotton	No tillage	139.26	-	387.26	-	
	Permanent beds	186.13	46.87	948.67	561.42	1198
	Traditional tillage	276.68	90.56	674.47	-274.21	-303
Maize	No tillage	108.97	-	193.05	-	-
	Permanent beds	125.69	1761	425.40	232.35	1389
	Traditional tillage	209.36	83.67	401.52	-23.89	-29
Mungbean	No tillage	100.99	-	457.95	-	-
	Permanent beds	135.48	34.49	788.34	330.39	958
	Traditional tillage	167.27	31.79	689.81	-98.53	-310

Table 5b. Effect of different tillage system and crop rotation on marginal analysis of wheat.

Tillage	Cropping system	Cost that vary (US$. ha^{-1})	Marginal cost (US$. ha^{-1})	Net field benefits (US$. ha^{-1})	Marginal net (US$. ha^{-1})	Marginal rate (%)
Conventional tillage	Cotton-wheat	111.01	-	411.78	-	-
	Maize-wheat	167.99	56.97	657.86	246.07	432
	Mungbean-wheat	208.99	41.00	521.91	-135.95	-332
Permanent bed	Cotton-wheat	112.89	-	427.84	-	-
	Maize-wheat	168.68	55.79	664.11	236.28	423
	Mungbean-wheat	210.96	42.26	541.47	-122.64	-290
No tillage	Cotton-wheat	112.73	-	428.48	-	-
	Maize-wheat	164.12	51.39	623.38	194.91	379
	Mungbean-wheat	206.19	42.07	495.26	-128.13	-305

Table 6. Economic yield of individual crop, wheat equivalent yield (WEY), Production efficiency and Land resource use efficiency (LRUE) of different Wheat based cropping systems (pooled data for cropping seasons).

Tillage system	Economic yield (t ha^{-1})		^{a}WEY kharif (t ha^{-1})	^{b}WEY system (t ha^{-1})	Total duration (days)	Production efficiency (kg/ha/day)	LRUE (%)
	Cotton	Wheat					
Conventional tillage	2.91±0.03^{b}	3.67±0.01^{cd}	5.59±0.03^{b}	9.26±0.04^{b}	167+149=318	17.57±0.08^{b}	87.12
Permanent bed	3.21±0.02^{a}	4.08±0.04^{c}	6.18±0.02^{a}	10.26±0.04^{a}	167+149=318	23.07±0.09^{a}	87.12
No tillage	2.19±0.05^{c}	2.84±0.05^{d}	4.21±0.05^{c}	7.05±0.06^{c}	167+149=318	13.24±0.12^{c}	87.12
	M^{ai}z^{e}	W^{hea}t					
Conventional tillage	6.38±0.04^{a}	3.76±0.01^{a}	4.42±0.04^{a}	8.18±0.05^{b}	119+149=268	16.48±0.05^{a}	73.42
Permanent bed	6.12±0.04^{b}	4.11±0.02^{a}	4.24±0.04^{b}	8.34±0.01^{a}	119+149=268	15.81±0.01^{b}	73.42
No tillage	4.96±0.02^{c}	2.92±0.02^{b}	3.44±0.02^{c}	6.36±0.04^{c}	119+149=268	12.82±0.12^{c}	73.42
	Mun^{g}	W^{hea}t					
Conventional tillage	1.35±0.01^{b}	3.55±0.03^{e}	5.19±0.01^{b}	8.74±0.06^{b}	110+149=259	20.06±0.05^{a}	70.96
Permanent bed	1.43±0.02^{a}	3.90±0.04^{e}	5.49±0.02^{a}	9.40±0.02^{a}	110+149=259	17.28±0.05^{b}	70.96
No tillage	1.00±0.02^{c}	2.91±0.03^{e}	3.85±0.02^{c}	6.77±0.04^{c}	110+149=259	14.38±0.3^{c}	70.96

[a] WEY; wheat equivalent yield, [b]WEY system; wheat equivalent yield of system

Conclusion: In conclusion of present study, the result counseled that cotton-wheat was the ultimate best crop sequence in mixed-cropping in terms of economic gains. The cotton-wheat cropping system gave highest net field benefit (NFB) and marginal rate of return (MRR) in the semiarid environment. The cotton-wheat cultivation in permanent beds gave highest land use efficiency. Moreover, highest production efficiency was also ascertained in cotton-wheat cultivation system in permanent bed. Thus, present study helps the farmer to choose cropping system according to the availability of resources.

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