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ECONOMIC EVALUATION FOR INTEGRATED USE OF GLYPHOSATE HERBICIDE AND TILLAGE COMBINATIONS APPLIED BEFORE SOWING OF RAIN-FED WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract

Low average yield, scarce soil moisture and less soil fertility are major problems of rain-fed wheat. Economic feasibility of different tillage systems integrated with glyphosate herbicide and wheat crop productivity was determined through field experiments conducted at the University Research Farm of Pir Mehr Ali Shah Arid Agriculture University Rawalpindi, Pakistan during summer and winter seasons of 2012-13 and 2013-14. Different combinations of tillage and glyphosate herbicide were used in the fallow period (summer season) that were consisted of following treatments viz. T_1 = 1 Mould board Plowing + 8 Cultivations, T_2 = No-Till + Glyphosate, T_3 = 1 Mould board Plowing + Glyphosate, T_4 = 1 MB Plowing + 4 Cultivations, T_5 = 1 Disc Harrowing + Glyphosate, T_6 = 1 Disc Harrowing + 4 Cultivations and T_7 = 1 Chiseling + Glyphosate. Results showed that the highest yield viz. 3.5132, 3.1242 t ha^{-1} were obtained in the case of conventional tillage (T_1) and reduced tillage (T_4), respectively with a net profit of 888.92 and 839.35 $ ha^{-1}. The yield was positively affected by tillage intensity. In conclusion, T_1 is recommended for getting maximum net return from wheat grown in rain-fed areas of Pakistan.

Key words: Tillage intensity; Glyphosate; Economic feasibility; Wheat productivity, Rain-fed wheat.

Introduction

Usually wheat is sown as winter crop in Pothwar Region of Pakistan and area under rain-fed wheat is 19 per cent of total wheat area of Pakistan. Wheat crop life cycle mainly depends on water availability. There should be enough moisture for germination of wheat in soil at sowing time, otherwise optimum growth and ultimately economical crop yield may not be achieved (Ali *et al.,* 2014). Water being an important factor for the crop growth and development is becoming limited day by day in Pakistan. In rain fed lands, water management and conservation is research goal to cope the water deficit conditions and improve food production. In the Pothwar Plateau, crop production is totally dependent on rainfall. About 70% of total annual rainfall is received during monsoon season (July to October) and about 30% during rest of the year (Ali *et al*., 2014). Owing to rainfall uncertainty and uneven distribution in Pothwar area, farming community is generally reluctant to invest in crop production and use lesser inputs to reduce loss during drought conditions. Scarcity of water significantly decreased the farmers' income. Wheat crop yield can be increased sustainably by conserving, utilizing and storage of moisture available during summer monsoon season which helps to make the rain fed lands more productive (Adnan *et al.,* 2009).

Tillage is an essential practice for seed bed preparation, soil moisture conservation and weed control. The physical properties of soil such as aggregates stability, soil water conservation and infiltration rate significantly influence soil productivity, sustainability and quality (David *et al*., 2006). Thus tillage has direct and indirect effect on water, soil and air quality and has the greatest impact on the environment and crop production. Tillage among different production factors, contributes up to 20 % in crop production. It affects emergence of plants, nutrients supply and water availability to plants by improvement in soil physical properties (Khurshid *et al.,* 2006). Traditional tillage can damage soil structure by continuous soil inversion, compaction and ultimately results in soil loss by water and wind erosion (Holland, 2004). Higher tillage intensity also increases the production cost of crops by increasing fuel or labour cost. Tillage also modifies soil factors associated with growth like soil moisture, temperature, nutrients and aeration which ultimately stimulates weeds infestation (El-Titi, 2003).

There is a necessity to develop soil moisture conservation techniques for rain fed wheat spending lesser inputs on sustainable basis that can easily be adopted by the farmers of rain fed areas. Conservation agriculture is spreading in other countries of the world, but a little work has been done in our rain fed cropping system especially in Pothwar region. As all agro-ecosystems are different; therefore, present study was helpful for comparison of tillage systems. A number of studies have been conducted on crop productivity in this rain fed area, however systematic investigation on economic feasibility of different tillage systems integrated with glyphosate herbicide applied at fallow period in wheat-fallow cropping system is rarely done.

The objectives of present study were to assess the yield of wheat along with economic feasibility of different tillage systems, integrated with glyphosate (a non-selective herbicide) applied at fallow period that could ultimately be used further in future for better tillage management strategies.

Materials and Methods

The proposed study was conducted on sandy loam soil of Kahuta soil series belonging to the great group Udic Haplustalfs at University Research Farm of Arid Agriculture University Rawalpindi (latitude 33°36'0" N, longitude 73°02'0" E, and altitude 500 masl), Pakistan. The experiment was carried out for two years during the summer and winter seasons of 2012-13 and 2013-14. The experimental soil possessed following properties (EC: 0.92 $dScm^{-1}$; pH: 7.20; organic matter: 0.63%; saturation percentage: 36%; available phosphorus: 5.32 mg kg^{-1}; available potassium: 100 mg kg^{-1}). The experiment was laid out in Randomized Complete Block Design having four replications with a net plot size of 13.5 m x 13.5 m. Different combinations of tillage, integrated with glyphosate herbicide were used in this study. The experiment consisted of following treatment combinations viz. T_1 = Conventional Tillage (1MB Plowing + 8 Cultivations), T_2 = No-till + Glyphosate, T_3 = 1MB Plowing + Glyphosate, T_4 = 1MB Plowing + 4 Cultivations, T_5 = Disc Harrowing + Glyphosate, T_6 = Disc Harrowing + 4 Cultivations, T_7 = Chiseling + Glyphosate.

In T_1, deep tillage was done with moldboard plough at the onset of moon soon after that 8 shallow cultivations were applied with common cultivator including seed bed preparation according to the availability of rainfall. Finally sowing was done in this treatment with conventional seed-cum-fertilizer drill; whereas, in T_2, No-tillage was applied before sowing of crop, but the weeds germinated during fallow period of summer season were controlled with the two applications of (glyphosate) a non-selective herbicide. In case of T_3, one deep plowing was done with moldboard plow at the onset of monsoon and then the fallow period weeds were controlled by glyphosate spraying twice as per needed and then direct sowing was done with especially designed no-till rain fed drill. One moldboard plowing was practiced at the onset of monsoon in T_4, and then 4 cultivations were applied including preparatory tillage. Sowing was done in T_4 with conventional seed-cum-fertilizer drill. In T_5, one disc-harrowing was applied at the establishment of 1st flush of weeds during monsoon rains then the fallow period summer weeds were controlled with the use of glyphosate by two times as and when needed and the sowing of winter wheat was directly done with no-till drill. One disc-harrowing was done after the 1st flush of weeds in T_6, followed by four shallow cultivations with common cultivator including preparatory tillage and sowing of wheat was done with conventional seed-cum fertilizer drill. In T_7, one very deep tillage was done with chisel plow before the start of monsoon rains and then fallow period summer weeds were controlled with two applications of glyphosate as per requirement and wheat was sown directly by drilling with no-till drill. The glyphosate herbicide was sprayed at the rate of 2.5 liters per hectare (recommended dose) in each case.

Seed of wheat cultivar cv. Chakwal-50 (high yielding, drought tolerant and disease resistant) was obtained from Barani Agricultural Research Institute Chakwal and was sown on October 23rd, in 2012 and on October 28th, in 2013 in 22.5 cm apart rows using conventional and no-till drill for T_1-T_3 and T_4-T_7, respectively. Nitrogen, phosphorus and potash were applied at the rate of 90-60-60 kg ha^{-1} respectively using urea (46% N), di-ammonium phosphate (DAP) (18%N, 46% P_2O_5) and sulfate of potash (50% K_2O) fertilizers as sources of N-P-K, respectively. Whole Phosphorus and Potash was applied at the time of seed bed preparation but nitrogen was applied in two splits, first at sowing time and second at tillering stage (as per availability of rainfall).

To determine the biological yield, three samples per plot, each from unit area were harvested and tied into bundles and sundried for one week. Then the biological yield was recorded by using electronic weighing balance. The samples were then threshed and grain yield was recorded and the harvest index (HI) was computed according to the equation:

$$HI = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Data were analyzed statistically collected on all parameters by using MSTAT-C software (Crop and Soil Sciences Department of Michigan University of the United States). Least significance difference (LSD) test was applied at 5% probability level to compare the treatments means (Steel & Torrie, 1980). Regression and correlations were determined by using software "Statistix 8.1". The cluster analysis was made using "PAST" version 2.17c computer software (Hammer *et al.*, 2001).

The economic analysis of the data regarding different experimental treatments must be analyzed economically from the farmer's point of view as they are most likely interested in the benefits and costs effective new technologies and then they decide whether to adopt them or not; likewise, they are also interested to the risks attached with these new technologies. To determine the economic feasibility of tillage systems, economic analysis were done through partial budget analysis, dominance analysis and marginal rate of return analysis following (Anon., 1998). In the partial budget analysis, total cost that varied, gross benefits and net benefits were compared, but there was no any further comparison of these values in a systematic way to find out the most profitable tillage combination. So, the total costs that varied and net benefits were compared through dominance analysis in such a manner that the treatments were arranged in an ascending order of total costs that varied starting from minimum cost to maximum cost along with net benefits. A tillage system was dropped (dominated) if its variable costs were higher than the preceding systems, but its net benefits were lower than them. Such a tillage system was considered as dropped/dominated and denoted by "D". Marginal rate of return analysis is conducted after going through partial budget analysis and dominance analysis. This analysis is conducted to calculate the marginal rate of returns (%) between all non dropped treatments. The treatment is valued if its rate of return is higher than minimum acceptable rate of return otherwise it is dropped and the next treatment is compared with preceding treatment that was not dropped. The minimum acceptable marginal rate of return was set as 50 (%) for our agro-ecological zone.

Meteorological data are presented in Table 1.

Table 1. Meteorological data of the experimental site during study period.

Month	Rainfall mm/day	Mean Mini. Temp. (C°)	Mean Max. Temp. (C°)	R.H (%)	Sunshine hours/Day	Pan evap. mm/day
May-2012	3.3	18.9	36.0	35.1	10.8	8.2
Jun-2012	14.3	23.1	39.9	30.0	9.1	9.4
Jul-2012	61.4	25.5	36.8	55.4	9.3	7.3
Aug-2012	153.4	24.2	32.4	73.0	6.9	4.0
Sep-2012	84.3	20.6	30.5	74.2	7.5	3.5
Oct-2012	16.3	13.3	27.7	61.0	9.1	3.6
Nov-2012	1.0	6.4	23.6	58.9	8.5	1.8
Dec-2012	28.3	3.3	18.6	55.4	6.0	1.3
Jan-2013	0.0	1.5	15.9	62.0	6.5	1.6
Feb-2013	213.4	7.6	16.8	79.7	4.6	0.8
Mar-2013	17.9	10.8	24.0	65.3	7.9	3.0
Apr-2013	21.0	15.0	28.8	53.5	9.1	4.2
May-2013	29.7	18.7	37.3	33.4	10.5	7.5
Jun-2013	84.0	23.9	38.7	47.3	9.6	9.2
Jul-2013	169.9	24.7	34.6	67.2	6.7	5.5
Aug-2013	122.7	24.2	32.5	77.3	6.8	5.0
Sep-2013	126.1	22.4	33.9	71.0	8.4	4.5
Oct-2013	24.6	18.3	32.3	59.7	9.2	4.1
Nov-2013	14.4	7.7	23.5	64.5	7.9	2.2
Dec-2013	4.3	2.8	20.4	72.1	7.2	1.4
Jan-2014	0.0	0.6	17.0	69.3	3.9	1.6
Feb-2014	37.4	4.9	16.3	70.6	6.2	1.7
Mar-2014	94.1	7.4	21.5	70.8	5.8	3.7
Apr-2014	66.0	11.5	28.1	62.6	7.5	5.0
May-2014	67.5	18.3	32.1	50.3	9.2	9.9
Jun-2014	35.5	22.8	40.0	30.0	9.8	10.5

Source: Meteorological observatory, Soil and water conservation research institute, (SAWCRI) Chakwal

Results and Discussions

Wheat productivity: Data regarding yield of wheat showed that the maximum biological yield was found in T_1 followed by T_4, while minimum biological yield was found in T_5 which was statistically at par with T_7 (Table 2). Similarly, the maximum grain yield of wheat was obtained from T_1 that was at par with T_4 and T_3; while, it was minimum in T_7 having at par difference with T_5. Maximum grain yield in T_1 may be due to the good crop establishment under fine seed bed and efficient use of soil resources. When tillage systems were arranged in ascending order of tillage intensity, it was found that there was a positive correlation between tillage intensity, grain yield, biological yield, harvest index, gross benefit and net benefit (Table 3). The regression analysis showed that the grain yield was decreased by decreasing tillage intensity (Fig. 1). It negates the findings of Rusu *et al.* (2013), who investigated that by applying the minimum soil tillage system; one can obtain production comparable to the classical variant with plowing as for the wheat, maize and soybean. Likewise, the maximum harvest index was obtained (Table 2) from T_1 that was statistically not different from all other treatments; while, the minimum harvest index was obtained from T_7.

Economic analysis: The whole economic evaluation methodology was comprised partial budgeting, dominance analysis and marginal rate of return analysis.

Partial budget analysis: In partial budget analysis total cost that varied, gross benefits and net benefits are calculated for comparison. The partial budgets were prepared for each tillage system to compare the costs and benefits associated with each tillage system. The year wise and pooled data about partial budgets of different tillage systems are presented in Tables 4, 5 and 6.

Partial budget of different tillage systems (2012-13): The data about partial budget of 2012-13 regarding different tillage systems are presented in Table 4. The data of partial budget of tillage systems applied during 2012-13 revealed that the gross benefit was highest in T_1 followed by T_4 and T_7. Table 4 also reflected that T_1 gave maximum net benefits followed by T_4 and T_7. The minimum net benefits were reflected in T_3. The maximum net benefits under T_1 may be achieved due to maximum grain yield, biological yield and harvest index under this system. Because the T_1 had given the highest net benefit as compared to the rest of the tillage systems in 2012-13; therefore, there is no need of further analysis of the treatments through dominance analysis or marginal rate of return analysis. As T_1 is the farmers practice so, T_1 is still considered as the cost efficient and best productive treatment during 2012-13.

Table 2. Effect of tillage systems on wheat productivity parameters.

Treatment	Grain yield (t / ha)			Biological yield (t / ha)			Harvest index (%)		
	2012-13	2013-14	Average	2012-13	2013-14	Average	2012-13	2013-14	Average
T_1	4.01120 a*	3.7960 ab*	3.9036 a*	12.850 NS	8.553	10.701 a*	31.56 cd*	44.45 a*	38.00 NS
T_2	3.00840 bc	2.86750 bc	2.93795 bc	11.778	6.658	9.218 bc	25.50 de	41.55 ab	33.52
T_3	2.91020 bc	3.5940 ab	3.2521 abc	13.049	7.624	10.336 ab	22.35 e	47.38 a	34.87
T_4	3.39410 ab	3.54864 ab	3.47137 ab	12.258	7.959	10.109 ab	28.17 cde	44.61 a	36.39
T_5	3.04350 abc	2.09920 cd	2.57135 c	10.655	5.214	7.935 c	28.87 cde	39.77 ab	34.32
T_6	3.11360 ab	3.18464 ab	3.14912 bc	12.687	7.395	10.041 ab	24.23 de	43.34 a	33.79
T_7	3.35900 ab	1.76830 d	2.56365 c	11.692	4.862	8.277 c	28.71 cde	34.51 bc	31.61
Average	3.26286 NS	2.97975	3.1213	12.138 a*	6.895 b	9.517	27.05 b*	42.23 a	34.64

***=** Any two means in a column not sharing a common letter differ significantly at 5% level of probability

Table 3. Correlations.

	By	GB	GY	HI	NB
GB	0.9290				
P-Value	0.0025				
GY	0.9290	1.0000			
		0.0000			
HI	0.7068	0.8874	0.8875		
	0.0758	0.0077	0.0077		
NB	0.9348	0.9474	0.9474	0.8332	
	0.0020	0.0012	0.0012	0.0199	
TI	0.6149	0.7339	0.7339	0.6155	0.5529
	0.1417	0.0604	0.0604	0.1412	0.1980

GB = Gross benefit; BY = Biological yield; GY = Grain yield; NB = Net benefit; TI = Tillage intensity; HI = Harvest index

Table 4. Partial budget of rain-fed wheat as affected by different tillage systems during 2012-13.

Variables	Tillage systems						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Average yield (t ha^{-1})	4.011	3.008	2.910	3.394	3.043	3.114	3.359
Adjusted yield (t ha^{-1})	3.610	2.708	2.619	3.055	2.739	2.802	3.023
Gross benefits ($ ha^{-1})	1128.16	846.12	818.50	954.59	855.98	875.70	944.73
Costs that vary							
Total cost of tillage practices ($ ha^{-1})	209.00	0	65.00	137.00	22.50	94.50	75.00
Total cost of glyphosate herbicide ($ ha^{-1})	0	61.00	61.00	0	61.00	0	61.00
Total cost that vary ($* ha^{-1})	209.00	61.00	126.00	137.00	83.50	94.50	136.00
Net benefits ($ ha^{-1})	919.16	785.12	692.50	817.59	772.48	781.20	808.73

*1US$ = 100 Rupees (Local currency of Pakistan) T_1 = 1MB Plowing + 8 cultivations; T_2 = Zero-tillage + Glyphosate herbicide; T_3 = 1MB Plowing + Glyphosate herbicide; T_4 = 1MB Plowing + 4 Cultivations; T_5 = 1Disc Harrowing + Glyphosate; herbicide; T_6 = 1Disc Harrowing + 4 Cultivations; T_7 = 1Chiseling + Glyphosate herbicide

Table 5. Partial budget of rain-fed wheat as affected by different tillage systems during 2013-14.

Variables	Tillage systems						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Average yield (t ha^{-1})	3.796	2.8675	3.594	3.54864	2.0992	3.18464	1.7683
Adjusted yield (t ha^{-1})	3.416	2.581	3.235	3.194	1.889	2.866	1.591
Gross benefits ($ ha^{-1})	1067.66	806.51	1010.84	998.09	590.42	895.71	497.35
Costs that vary							
Total cost of tillage practices ($ ha^{-1})	209	0	65	137	22.5	94.5	75
Total cost of glyphosate herbicide ($ ha^{-1})	0	61	61	0	61	0	61
Total cost that vary ($* ha^{-1})	209	61	126	137	83.5	94.5	136
Net benefits ($ ha^{-1})	858.66	745.51	884.84	861.09	506.92	801.21	361.35

*1US$ = 100 Rupees (Local currency of Pakistan) T_1 = 1MB Plowing + 8 cultivations; T_2 = Zero-tillage + Glyphosate herbicide; T_3 = 1MB Plowing + Glyphosate herbicide; T_4 = 1MB Plowing + 4 Cultivations; T_5 = 1Disc Harrowing + Glyphosate; herbicide; T_6 = 1Disc Harrowing + 4 Cultivations; T_7 = 1Chiseling + Glyphosate herbicide

Table 6. Partial budget of rain-fed wheat as affected by different tillage systems (pooled for two years).

Variables	Tillage systems						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Average yield (t ha^{-1})	3.9036	2.9380	3.2521	3.4714	2.5714	3.1491	2.5637
Adjusted yield (t ha^{-1})	3.5132	2.6442	2.9269	3.1242	2.3142	2.8342	2.3073
Gross benefits ($ ha^{-1})	1097.92	826.32	914.68	976.35	723.21	885.72	721.05
Costs that vary							
Total cost of tillage practices ($ ha^{-1})	209	0	65	137	22.5	94.5	75
Total cost of glyphosate herbicide ($ ha^{-1})	0	61	61	0	61	0	61
Total cost that vary ($* ha^{-1})	209	61	126	137	83.5	94.5	136
Net benefits ($ ha^{-1})	888.92	765.32	788.68	839.35	639.71	791.22	585.05

*1US$ = 100 Rupees (Local currency of Pakistan) T_1 = 1MB Plowing + 8 cultivations; T_2 = Zero-tillage +Glyphosate herbicide; T_3 = 1MB Plowing + Glyphosate herbicide; T_4 = 1MB Plowing + 4 Cultivations; T_5 = 1Disc Harrowing + Glyphosate; herbicide; T_6 = 1Disc Harrowing + 4 Cultivations; T_7 = 1Chiseling + Glyphosate herbicide

Partial budget of different tillage systems (2013-14): The data about partial budget of 2013-14 regarding different tillage systems are presented in Table 5. The data of partial budget of tillage systems applied during 2013-14 revealed that the gross benefit was highest under T_1 followed by T_3 and T_4 in this season. The data also showed that T_3 gave maximum net benefits followed by T_1 and T_4. The minimum net benefits were reflected in T_7 followed by T_5 during 2013-14. The highest net benefits earned from T_3 were due to low costs involved in this tillage system as compared to T_1 as only one application of moldboard plowing was involved and maximum grain yield and harvest index was achieved under this system during 2013-14. As the farmers practice i.e. T_1 had not given maximum net benefit, therefore there was further requirement of analysis of the tillage systems data through dominance analysis for 2013-14.

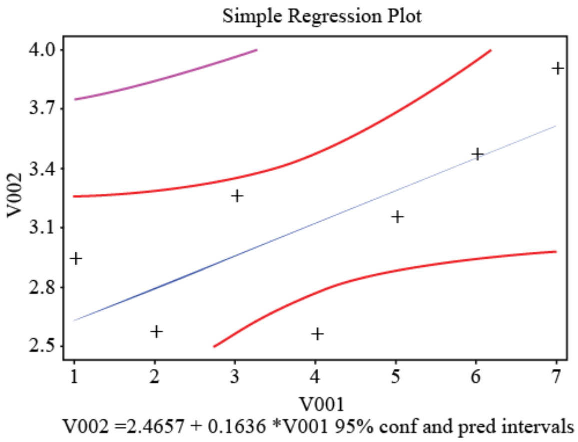
Partial budget of different tillage systems (pooled data for two years): The data about pooled partial budget of both sowing years i.e. 2012-13 and 2013-14 regarding different tillage systems are presented in Table 6. The data of pooled partial budget of tillage systems indicated that the gross benefit was highest in T_1 followed by T_4 and T_3. The data also reflected that T_1 gave maximum net benefits followed by T_4 and T_3. The minimum net benefits were reflected in T_7 treatment followed by T_5 and T_2 in pooled data of two years. The highest net benefits under T_1 may be due to maximum grain yield, biological yield and harvest index under this system as compared to other treatments. Since the T1 had given the highest net benefit as compared to the rest of the tillage systems in pooled data of two years; therefore, there was no need of further analysis of the treatments through dominance analysis or marginal rate of return analysis and T_1 was concluded as the cost efficient treatment for pooled data. These results are in agreement with the findings of Usman & Khan (2009) & Ali *et al.* (2014), who documented that deep tillage exhibited the best performance, with maximum net benefit than shallow or medium tillage. However, Rusu *et al.* (2013) found that by applying the minimum soil tillage systems one could obtain productions comparable to the classical variant with plowing as for the wheat, maize and soybean yield with more net profits than the conventional tillage.

Dominance analysis: As, the T_1 had given the highest net benefit as compared to the rest of the tillage systems in 2012-13; therefore, there was no need of further analysis of the treatments through dominance analysis or marginal rate of return analysis for this year, however, as the farmers practice i.e. T_1 had not given maximum net benefit in 2013-14, therefore there was further requirement of analysis of the tillage systems data through dominance analysis.

Dominance analysis of different tillage systems (2013-14): The results of dominance analysis of sowing year 2013-14 are presented in Table 7. It is clear from the data given in this table that T_5, T_7, T_4 and T_1 treatments were dropped in dominance analysis for sowing year of 2013-14 as their variable costs were higher than preceding tillage systems, but their net benefits were lower. So three tillage systems were again left back which demanded further analysis through marginal rate of return analysis for their adoption or rejection, as the farmers can adopt only that tillage system which is more economical and have net returns greater than minimum acceptable rate of return. For this purpose the marginal rate of return analysis was employed on the data of remaining 3 tillage systems for 2013-14.

Marginal rate of return analysis (%): As three tillage systems were again left back in 2013-14 which demanded further analysis through marginal rate of return analysis for their adoption or rejection. For this purpose the marginal rate of return analysis was employed on the data of remaining 3 tillage systems for 2013-14 that has been presented in next section 3 a).

Marginal rate of return analysis of different tillage systems (2013-14): Data regarding marginal rate of return analysis of different tillage systems during 2013-14 are presented in Table 8. The data indicated that there were only three tillage systems i.e. T_2, T_6 and T_3 that were not dropped in dominance analysis and were compared further through marginal rate of return analysis. The T_6 gave 719.138 (%) marginal rate of return in comparison to T_2 which was higher than minimum acceptable marginal rate of return; therefore it was not dropped and further compared with T_3. The comparison of T_3 and T_6 showed 379.319 (%) marginal rate of return which was greater than minimum acceptable marginal rate of return, therefore T_3 was recommended for the year 2013-14. The cluster analysis made on the base of pooled data of two years about biological yield, grain yield, harvest index, gross benefit and net benefit showed a big difference between T_1 and T_4 (Fig. 2).



R^2 = 0.5362 and r = 0.73225
V001= Tillage systems; V002 = Grain yield of wheat (t ha^{-1}); 1= No-till (T2); 2= 1DH + GH (T5); 3= 1MBP + GH (T3); 4= 1CP + GH (T7); 5= 1DH +4 Cult. (T6); 6= 1MBP + 4 Culti. (T4); 7= 1MBP + 8 Culti. (T1)

Fig. 1. Relationship between tillage intensity and grain yield of wheat.

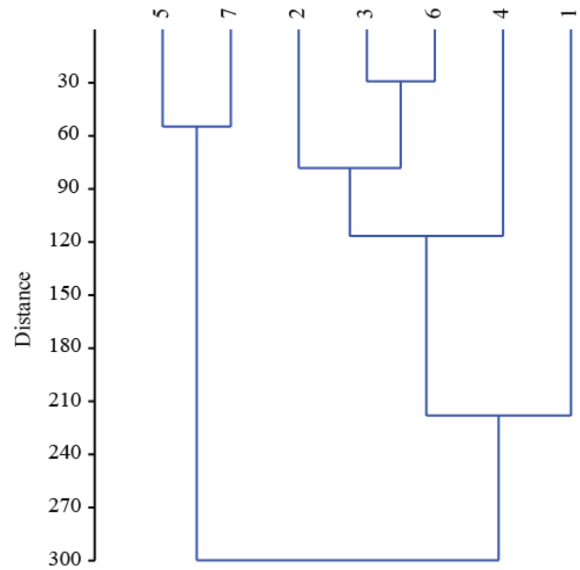


Fig. 2. Clustering of tillage systems on the base of two year data of biological yield, grain yield, harvest index of wheat, gross benefit and net benefit

Table 7. Dominance analysis of rain-fed wheat as affected by different tillage systems during 2013-14.

Tillage systems	Costs that vary ($* ha^{-1})	Net benefits ($ ha^{-1})
T_2	61	745.51
T_6	94.5	801.21
T_5	83.5	506.92 D
T_3	126	884.84
T_7	136	361.35 D
T_4	137	861.09 D
T_1	209	858.66 D

*1US$= 100 Rupees (Local currency of Pakistan) T_1 = 1MB Plowing + 8 cultivations; T_2 = Zero-tillage + Glyphosate herbicide; T_3 = 1MB Plowing + Glyphosate herbicide; T_4 = 1MB Plowing + 4 Cultivations; T_5 = 1Disc Harrowing + Glyphosate; herbicide; T_6 = 1Disc Harrowing + 4 Cultivations; T_7 = 1Chiseling + Glyphosate herbicide

Table 8. Marginal rate of return (%) of rain-fed wheat as affected by different tillage systems during 2013-14.

Tillage systems	Costs that vary ($* ha^{-1})	Net benefits ($ ha^{-1})	Marginal costs that varied (MC) ($ ha^{-1})	Marginal net benefits (MNB) ($ ha^{-1})	MRR (%)
T_2	61	745.51			
T_6	94.5	801.21	33.5	55.7	166.269
T_3	126	884.84	31.5	83.63	265.492

*1US$ = 100 Rupees (Local currency of Pakistan)

Conclusion

The highest yield (3.5132), (3.1242) t ha^{-1} and net benefit (888.92), (839.35) $ ha^{-1} were obtained in case of conventional tillage (T_1) followed by reduced tillage (T_4) according to partial budget analysis. The cluster analysis was made on the basis of pooled data of two years about biological yield, grain yield, harvest index, gross benefit and net benefit showed a big difference between T_1 and T_4. The yield was positively affected by tillage intensity. In crux, T_1 is still sustainable for the semi-arid rain-fed agro-ecological zones of Pakistan.

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