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Effect of different tillage methods on the growth, development, yield and yield components of bread wheat

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Abstract

A two years field study was conducted to investigate the effect of three tillage methods (T_1: Conventional tillage (CT), T_2: Reduced tillage (RT) and T_3: No tillage (NT)) on the growth, development, yield and yield components of bread wheat (*Triticum aestivum* L. *cv*. TD-1). Results shown that when compared to RT (T_2) and NT (T_3) methods, the CT (T_1) method caused substantial improvement in almost all the growth, yield and yield component traits of bread wheat in both the years, particularly it improved seedling emergence percentage, plant height, root system, number of main-stem leaves per plant, number of productive tillers per plant, number of spike-lets per spike, spike length, number of grains per spike and grain and straw yields per hectare. However, the marginal return from reduced tillage treatment (T_2) was greater for both the years as compared to other treatments.

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Introduction

Bread wheat (*Triticum aestivum* L.) is an important cereal crop, as it contributes a major portion of staple food for the world's rising population. It contributes about 14.4 percent to the value added in agriculture and 3 percent to the GDP (GoP, 2014). Although, Pakistan ranks among top ten wheat producing countries in the world, its wheat production has not been exceeded yet from 1 to 1.5 tons per acre. The production of wheat can be improved and enhanced by using better inputs, proper production technology and appropriate tillage methods. Important factors like soil tillage and manure application can improve soil physical properties and enhance wheat yields. Selection of an appropriate tillage method can enhance wheat production by about 20 percent (Ahmed *et al.,* 1996). Several types of conservation tillage methods such as minimum tillage, incomplete tillage, reduced tillage, no tillage, etc. are being practiced across the world. The data collected by the Conservation Technology Information Center (2004) reveals that about 40.7 percent of the total crop land in USA is under conservation tillage system, of that, zero tillage and strip tillage are being used on about 23.6 percent. However, the implementation of this practice is based on many factors which include type of soil, compaction, retention power of moisture and other factors.The conventional tillage is being practiced all over Pakistan which transforms physical, chemical, biological and electrochemical properties of soil that in turn conserves soil moisture (Putte *et al.*, 2010; Jin *et al.*, 2011). Conventional tillage has also been reported (Babujia *et al.*, 2010) to increase the amount of carbon and microbial biomass in the top soil. In addition to that conventional tillage has been found to decrease and maintain soil heat in tropical and other regions. Improvement in biodiversity of soils has also been credited to conventional tillage (Adl *et al.*, 2005). Likewise, it increases organic contents and soil fertility in top layer that in turn results in greater yields (Chandio *et al.*, 2012). Significant emphasis is being given on reduced and zero tillage methods; that increase water use efficiency of summer crops, control erosion and increase crop production (Dawelbeit and Babiker, 1997). Wheat grown after rice is generally delayed up to 2-3 weeks. Due to delay in wheat sowing (after 25th November) an economical loss (1percent per day) in yield occurs (Randhawa *et al.,* 1979; Hobbs, 1988). Zero tillage technology facilitates sowing of wheat at proper time. It also saves cost of water and preparation of seedbed up to 30 percent (Aslam, 1999). Similarly, reduced tillage often affects the immobile soil phosphorous and it induces higher root length distribution in the top-most soil layer. In general, the root length distribution is higher at the outer side of a row than at the mid portion of the same (Rubino and Franchi, 1990).

Due to indifferent findings, there is still dire need to investigate the impact of tillage methods on plant growth, root development and yield components of wheat crop. Hence, this study was designed to investigate the effect of three tillage (Conventional, reduced and zero tillage) methods on some physiological parameters of bread wheat.

Materials and methods

Experimental details

Two field experiments were conducted at the Latif Experimental Farm of Sindh Agriculture University Tandojam. Experiment-1 was conducted in the Year 2008 and the Experiment 2 was conducted during 2009. The experimental site lies at 25.42^{o} latitude and 68.53^{o}longitude, while the elevation of land is about 12 m above the sea level. Both experiments were identical in all cases and laid-out in a randomized complete block design (RCBD) with three tillage treatments (T_1: Conventional tillage, T_2: Reduced tillage and T_3: No tillage) on same experimental plot (0.54 hectares (5400 m^2)). The main plot (60 m × 90 m) was divided into three blocks each of size 60 m × 30 m. Each block, separated by a two meter buffer was further divided into three sub-plots each measuring 30 m × 20 m. The conventional tillage (T1) was performed using a combination of moldboard plow and cultivator. The reduced tillage (T2) was comprised of regular double action disc harrow operated twice, and zero tillage treatment (T3) was included none tillage operation except drilling/ planting of seeds. In the conventional tillage treatment, plots were plowed down to a depth of 25 cm and crop was sown using a mechanical drill. In the reduced tillage treatment plots, a disc harrow was used twice to a depth of 15 cm. In no tillage treatment plots, direct seeding was done. The weeds were eradicated manually. The wheat variety TD-1 was sown at the row spacing of 0.15 m with a seed rate of 125 kg ha^{-1}. This allowed 40 rows in each unit under each replication. The outer five rows in each replication were used as buffer between treatment plots. At physiological maturity harvesting was done manually.

For both the experiments, soil sampling was done before sowing at 0-15, 15-30, 30-45 and 45-60 cm depths using a composite sampling method. After harvesting of crop, soil samples from each treatment plot were taken using a core sampler at three randomly selected locations under each replication for each 0-15, 15-30, 30-45 and 45-60 cm depth. The soil samples were processed by air-drying and passing through a 2 mm sieve. Physical properties such as soil texture (before sowing only), hydraulic conductivity (cm/hr), field capacity, saturation percentage and wilting points were determined. In addition to that some basic chemical properties such as pHs, ECs (dS m^{-1}), $CaCO_3$ and organic matter contents were determined using standard procedures (Rowell, 1994; Ryan *et al.*, 2000) adapted by the Department of Soil Science, Sindh Agriculture University, Tandojam. Measurements on various morphological and yield traits of wheat were taken during the study years. The traits included were: seedling emergence percentage, number of productive tillers per plant, number of main-stem leaves per plant, plant height at maturity (cm), spike length (cm), number of spike-lets per spike, number of grains per spike, number of roots per plant, root length (cm), root dry weight per plant, 1000-grain weight (g) and grain and biological yields (t ha^{-1}). For recording seedling emergence percentage one square meter area was selected and total number of seeds sown and number of plants emerged were counted. The process was repeated at three different places for each replication. This combination provided a total of nine measurements for a treatment. The emergence percent was then calculated from each replication according to the formula:

$$\text{Seedling emergence, \%} = \frac{\text{Nnumber of seedlings emerged}}{\text{Number of seeds sown}} \times 100$$

Number of roots per plant, root length and root dry weight was measured at maturity at three locations for each replicated plot. A total of nine plants for root measurements in a treatment were used. The root length was measured from the base of stem to the tip of root. The number and length of roots were determined by digging hole to 120 and 180 cm depth in each plot. The soil block with plant was soaked in water for 24 hr. Roots were carefully separated from adhering organic matter and soil particles. After cleaning, root length was measured and roots were counted carefully. The dry weight of roots (g) was taken by separating the roots from the base of the stem. After oven drying, the roots of three plants taken from each plot were weighed and average was determined.

Economic analysis

Economic analyses were performed on the basis of cost which varied in different treatments following the procedures given by Byerlee (1988). For each individual treatment, efforts were made to work out the contribution of gross income of the crop. The cost of wheat and maize production during 2009 were calculated for factors which were kept uniform such as watch and ward, harvesting, threshing and land rent. Then expenditure for tillage treatments was calculated separately. The gross income was calculated on the basis of wheat and maize yield per hectare according to present market value. The benefit cost ratio (BCR) and marginal rate of return were calculated by the following formulas:

$$\text{BCR} = \frac{\text{Gross income}}{\text{Total cost}}$$

$$\text{Marginal rate of return(\%)} = \frac{\text{Change in net benefit}}{\text{Change in cost}} X 100$$

Results and discussion

Soil properties

Results of some basic soil properties are presented in Table 1. The data indicate that the soil was clay loam in texture with 19 percent sand, 42.9 percent silt and 38.2 percent clay. The soils having such type of textural class are generally suitable for wheat cultivation. The hydraulic conductivity of the soil was 0.296 cm hr^{-1}. The soil moisture content at saturation, field capacity and wilting points was determined before sowing and after harvesting of both experiments (2008 and 2009). The soil moisture content at saturation and field capacity before sowing were 43 percent and 23 percent during 2008, respectively, while moisture content increased by 1percent and it was recorded as 44 percent and 24 percent, respectively after crop harvest, while it did not show remarkable change before sowing and after harvesting during 2009. The wilting point followed an increasing trend during experimental years. During 2008 the moisture content at wilting point was recorded as 9.1percent before sowing, whereas it slightly increased to 9.2 percent after harvest, while in 2009, the moisture content at wilting point was increased to 9.5 percent before sowing and it further increased to 10.2 percent after harvest during 2009. The results on soil chemical properties such as: ECs (dS m^{-1}), pHs, SAR, organic matter, total N, extractable K^+, Na^+, Ca^{2+} and Mg^{2+}–contents are given in Table 1. During 2008, the soil ECs before wheat sowing was 1.6 dS m^{-1}, which was increased to 1.7 dS m^{-1} after the crop was harvested; while during the year 2009, the soil EC before wheat sowing was 1.71 dS m^{-1} which was increased to 1.74 dS m^{-1}. These results suggest that the soil EC level remained within the permissible limits suitable for agricultural crops. The soil pH before sowing of wheat and after harvest was 7.9 and 7.85, respectively during 2008 and 7.96 and 7.97, respectively during 2009. The soil pH results indicate that pH was within the considerable limits suitable for agriculture. These results are comparable with the findings of other workers (Osunbitiana, 2004; Mathew *et al.,* 2012) who also found that soil management influences the soil physico-chemical properties and brings changes in the soil microbial activities. Alvarez and Steinbach (2009) found that tillage practices improve the soil moisture content in the cropped field. Similarly, Putte *et al.* (2010) and Jin *et al.* (2011) noticed and reported that the conventional tillage transforms the soil physical properties, particularly ensures better soil moisture retention.

Table 1. Physical and chemical properties of experimental soil.

Determination	Experiment-1		Experiment-2
	Before sowing	After Harvest	After Harvest
Soil physical properties			
Sand (percent)	19.0	-	-
Silt (percent)	42.8	-	-
Clay (percent)	38.2	-	-
Textural class	Clay loam (USDA)		
Saturation (percent)	43	44	44
Field capacity (percent)	23	24	24
Wilting point (percent)	9.1	9.2	10.2
Hydraulic Conductivity (cm hr^{-1})	0.296		
Soil chemical properties			
ECs (dS m^{-1})	1.65	1.70	1.74
pHs (H_2O)	7.90	7.85	7.97
Organic Matter (percent)	0.69	0.72	0.70
Total Nitrogen (percent)	0.56	0.57	0.58
Available P (mg kg^{-1})	5.58	5.62	5.64
Extractable K^+(mg kg^{-1})	170	175	178
Exchangeable Sodium Percentage	12.29	11.83	11.54

Effect of different tillage treatments on seedling emergence, growth, yield and yield components of wheat

Seeding emergence

The data related to emergence of wheat seedlings influenced by different tillage treatments during 2008 and 2009 are given in Table 2. The results show that the seedling emergence was not affected by the tillage treatments during both the wheat growing seasons. Maximum seedling emergence percentage (i.e. 93 and 95 percent) was noticed under conventional tillage. The seedling emergence percent remained comparatively lower under reduced tillage (92 and 92 percent) and no tillage treatments (87 and 89 percent) during 2008 and 2009, respectively. There was non-significant linear and quadratic response in seedling emergence under various tillage treatments during both the study years. The comparison between two years data suggests that slightly higher seedling emergence was observed during 2009 as compared to 2008. Lithourgidisa *et al.* (2006) reported that number of wheat plants reduced by 11 to 17 percent under minimum tillage compared to conventional and reduced tillage and suggested that wheat may be grown under conventional tillage systems.

Table 2. Effect of tillage treatments on seedling emergence, number of tillers plant^{-1} and the number of leaves plant^{-1} in wheat crop grown during 2008 and 2009.

Tillage Treatments	Seedling emergence (percent)		Tillers plant^{-1}		Leaves plant^{-1}	
	Year		Year		Year	
	2008	2009	2008	2008	2009	2008
	n = 9	n = 9	n = 9	n = 9	n = 9	n = 9
T_1 (Conventional tillage)	93	95	17.0 a	18.3a	12 a	14 a
T_2 (Reduced tillage)	92	92	12.7 b	14.3b	10 ab	11b
T_3 (No-tillage)	87	89	10.7 b	12.0c	8 b	10b
LSD	NS	NS	1.8	2.0	2.6	1.9
Significance	NS	NS	**	**	*	**

*, ** = Significant at 5percent and 1percent, respectively, NS= Non-significant

Within columns, means followed by the same letter are not significantly different.

Tiller production

The number of tillers plant^{-1} under various tillage treatments was investigated during 2008 and 2009 and the data are given in Table 2. The data indicated that the number of tillers plant per hectare was significantly affected by tillage treatments during both the years. During 2008, the highest number of tillers plant^{-1}(17.0) was noted under conventional tillage, and the number of tillers plant^{-1} declined under reduced tillage (12.7) and no tillage (10.7). Almost similar trends were observed during 2009, the highest number of tillers plant^{-1} (18.3) was noted under conventional tillage, and it decreased under reduced tillage (14.3) and no tillage (12.0) plant^{-1}. During 2008, the differences in number of tillers plant^{-1} between reduced and no tillage treatments were statistically non-significant. The number of tillers plant^{-1} during 2009 tended to be greater than that observed during 2008.

Leaves

The number of main-stem leaves plant^{-1} under different tillage treatments was counted for the 2008 and 2009 wheat growing seasons and results are presented in Table 2. Results reveal that the number of main-stem leaves plant^{-1} was significantly influenced by tillage treatments during both the study years. During 2008 and 2009, the maximum number of leaves was 12 and 14 plant^{-1} under conventional tillage, whereas, this number decreased under reduced tillage (10 and 11 plant^{-1}) and no tillage (8 and 10 plant^{-1}), respectively. During 2009, the differences in the number of leaves between conventional and reduced tillage treatments were statistically non-significant. The year wise comparison suggests that the total number of leaves plant^{-1} tended to be greater in 2009 as compared to 2008.

Table 3. Effect of tillage treatments on number of roots, root length and root dry weight.

Tillage Treatments	No of roots counted at 0-10 cm depth		No of roots counted at 11-20 cm depth		Root length (cm)		Root dry weight (g $plant^{-1}$)	
	Year		Year		Year		Year	
	2008	2009	2008	2009	2008	2009	2008	2009
	n = 9	n = 9	n = 9	n = 9	n = 9	n = 9	n = 9	n = 9
T_1 (Conventional tillage)	41 a	44 a	8.0 a	9.3 a	16 a	17 a	6.1 a	6.9 a
T_2 (Reduced tillage)	37 a	40 a	7.2 ab	8.0 ab	14 ab	15 a	5.4 b	5.6 b
T_3 (No-tillage)	31 b	34 b	5.8 b	5.7 b	11 b	11 b	5.0 b	5.1 b
LSD	5.00	4.90	1.50	2.60	3.02	2.40	0.70	0.60
Significance	**	**	*	*	*	**	*	**

*, ** = Significant at 5percent and 1percent, respectively, NS= Non-significant

Within columns, means followed by the same letter are not significantly differ.

Roots

The number of roots per plant (Table 3) was significantly affected by tillage treatments during both the years. During 2008 and 2009, the maximum number of roots (41 and 40 $plant^{-1}$) was observed under conventional tillage, and a consecutive reduction in the number of roots $plant^{-1}$ was recorded under reduced tillage (37 and 40 $plant^{-1}$) and no tillage treatments (31and 34 $plant^{-1}$), respectively. The year wise comparison indicated that during 2009 the number of roots $plant^{-1}$ was relatively greater than the number of roots $plant^{-1}$ recorded during 2008. The number of roots $plant^{-1}$ counted at 11-20 cm soil depth was also examined for the 2008 and 2009 wheat cropping seasons and the results are presented in Table 2. The number of roots $plant^{-1}$ was significantly affected by the tillage treatments during both the years. During 2008 and 2009, the maximum number of roots (8.0 and 9.3 $plant^{-1}$) observed was under conventional tillage, and 7.2 and 8.0 $plant^{-1}$for the reduced tillage treatment and 5.8 and 5.7 $plant^{-1}$ for the no tillage treatments in 2008 and 2009, respectively. The year wise comparison indicates that during 2009 the number of roots $plant^{-1}$ was slightly higher than the number of roots $plant^{-1}$ during year 2008.These findings are in agreement with those of Feng *et al.* (2010) who reported that conventional tillage significantly increased the number of roots $plant^{-1}$ in wheat. The root length of wheat plants as influenced by various tillage treatments was measured for two cropping seasons (2008 and 2009) and the data are given in Table 2. Results indicated that tillage treatments significantly affected the root length during both the seasons. The maximum root length of 16 and 17 cm was recorded under conventional tillage, whereas, a reduction in root length was recorded under reduced tillage (14 and 15 cm), while only 11 cm root length was measured under no tillage treatment during 2008 and 2009, respectively. The seasonal comparison between two years indicates that the roots were relatively longer during 2009 than those measured during 2008.The roots of selected wheat plants under various tillage treatments were collected, oven-dried weighed and the results are presented in Table 3. Results indicate that the root dry weight was significantly affected by the tillage treatments. The maximum root dry weight (6.1 and 6.9 g $plant^{-1}$) was observed under conventional tillage, whereas, the root dry weight $plant^{-1}$ was decreased considerably under reduced tillage (5.4 and 5.6 g) and no tillage treatments (5.0 and 5.1 g) during 2008 and 2009, respectively. Root's dry weight during 2009 was slightly higher as compared to 2008.

Spike-lets per spike

The results (Table 4) indicate that the number of spikelet $spike^{-1}$ was significantly affected by tillage treatments during both the years. The great number of spike-lets $spike^{-1}$ (17.7 and 18.3) was observed under conventional tillage, and the number of spikelet $spike^{-1}$ declined under reduced tillage (14.3 and 15.7 $spike^{-1}$) and no tillage (13.7 and 14.3 $spike^{-1}$) during 2008 and 2009, respectively. During 2008 the differences in the number of spikelet spike^{-1} between reduced and no tillage treatments were statistically non-significant. The comparison between two study years reveals that the number of spikelet spike^{-1} during 2009 tended to be greater than 2008.

Spike length

The spike length of wheat plants sown under different tillage treatments was measured for two study years and the results are presented in Table 4. The data reveal that the spike length was significantly affected by tillage treatments. The maximum spike length (12.4 and 13.0 cm) was measured under conventional tillage, whereas the spike length declined under reduced tillage (10.7 and 11.0 cm) and no tillage (9.9 and 10.1 cm) during 2008 and 2009, respectively. The comparison between study years showed that the spike length during 2009 tended to be greater than 2008.

Table 4. Effect of different tillage treatments on number of spike-lets per spike, spike length and number of grains per spike.

Tillage Treatments	Number of spikelet spike^{-1}		Spike length (cm)		Number of grains spike^{-1}	
	Year		Year		Year	
	2008	2009	2008	2009	2008	2009
	n = 9	n = 9	n = 9	n = 9	n = 9	n = 9
T_1 (Conventional tillage)	17.8 a	18.3 a	12.4 a	13.0 a	48.3 a	50.0 a
T_2 (Reduced tillage)	14.3 b	15.7 ab	10.7 ab	11.0 b	42.1 b	46.0 b
T_3 (No-tillage)	13.8 b	14.3 b	9.9 b	10.1 c	40.0 b	43.0 b
LSD	2.4	3.0	1.7	0.7	4.5	3.6
Significance	*	*	*	**	**	**

*, ** = Significant at 5percent and 1percent, respectively, NS= Non-significant

Within columns, means followed by the same letter are not significantly different.

Number of grains per spike

The number of grains spike^{-1}observed under different tillage treatments for 2008 and 2009 is shown in Table 4. The results showed that the number of grains spike^{-1} was markedly influenced by tillage treatments during both the study years. Maximum number of grains spike^{-1} was noted under conventional tillage, while this number declined under reduced tillage and no tillage. During both the years, the differences in the number of grains spike^{-1} between reduced and no tillage treatments were statistically non-significant. The comparison between two study years shows that the number of grains spike^{-1} during 2009 was greater than 2008. Almost similar results were reported by Bahrani *et al.* (2002). The number of spikes per square meter, grains per spike, 1000-grain weight increased under conventional tillage. Jug *et al.* (2011) found that number of grains per spike and plant population in wheat was greater under conventional tillage than under other tillage methods.

1000-grain weight

The 1000-grain weights observed under different tillage treatments for 2008 and 2009 are shown in Table 5. The results indicate that the weight of 1000-grain was markedly influenced by tillage treatments during both study years. The maximum 1000 grains weight (38 and 40 g) was observed under conventional tillage, and it decreased under reduced tillage (36.3 and 38.0 g) and no tillage (32.0 and 34.0 g) during 2008 and 2009, respectively. The comparison between two study years shows that the number of grains was greatin 2008; this ultimately resulted in great 1000-garin weight during 2009.

Grain and dry matter yields

The grain and dry matter yields ha^{-1} under different tillage treatments during two wheat growing seasons were recorded and the results are also given in Table 5. The grain yield ha^{-1} was significantly influenced by tillage treatments during both study years. Maximum grain yield ha^{-1} (4.7 and 5.1 tons) was recorded under conventional tillage, followed by reduced tillage (4.3 and 4.5 tons) and no tillage (3.8 and 3.8 tons) during 2008 and 2009, respectively. In a similar manner, dry matter yields were significantly affected by tillage treatments. The dry matter yield ha^{-1} (12.7 and 12.9 tons) was recorded under conventional tillage, followed by reduced tillage (11.0and 11.1tons) and no tillage (9.8and 10.0tons) during 2008 and 2009.The comparison between two study years showed that grain and dry matter yields ha^{-1} during 2009 tended to be greater than 2008. Similar results were reported (Bahrani *et al.*, 2002). They found that conventional tillage produced greater wheat grain yields as compared to other tillage methods. Sainju *et al.* (2006) and Busscher *et al.* (2005) harvested higher yields from various trials on different major crops under conventional tillage as compared to no tillage or reduced tillage, probably due to greater inorganic N and N uptake can be optimized and potentials for soil erosion and N leaching can be reduced by this treatment. De Vita *et al.* (2007) achieved maximum grain yield in wheat, thousand kernel weight, test weight and protein content under conventional tillage, while the minimum soil water contents were present under this tillage treatments. Machado *et al.* (2008) reported that conventional tillage resulted in higher wheat yields as compared to rest of the tillage treatments.

Table 5. Effect of different tillage treatments on 1000-grain weight, grain yield and dry matter yield.

Tillage Treatments	1000-grain weight (g)		Grain yield (t ha^{-1})		Dry matter yield (t ha^{-1})	
	Year		Year		Year	
	2008	2009	2008	2008	2009	2008
	n = 9	n = 9	n = 9	n = 9	n = 9	n = 9
T_1 (Conventional tillage)	38.3 a	40.0 a	4.7 a	5.1 a	12.7 a	12.9 a
T_2 (Reduced tillage)	36.3 ab	38.0 a	4.3 ab	4.5 b	11.0 b	11.1 b
T_3 (No-tillage)	32.0 b	34.0 b	3.8 b	3.8 c	9.8b	10.0 b
LSD	4.5	2.1	0.6	0.5	1.5	1.1
Significance	*	**	**	**	**	**

*, ** = Significant at 5percent and 1percent, respectively, NS= Non-significant

Within columns, means followed by the same letter are not significantly different.

Table 6. Economic analysis of tillage treatments based on wheat grain yield during 2008.

Tillage treatments	Conventional tillage	Reduce tillage	Zero tillage	Remarks
Grain yield	4.7	4.3	3.8	t ha^{-1}
Adjusted yield	4.2	3.9	3.5	To bring at farmer's level (10percent decrease)
Gross income	100676	92126	81866	Rs. 25000 t^{-1}
Conventional tillage	5400			Expenses of mould bold P low + cultivator + seed drill
Reduced tillage		3350		Expenses of disk harrow + cultivator + seed drill
Zero tillage			950	Expenses of seed drill
Total cost	5400	3350	950	Rs. ha^{-1}
Net benefit	95,276	88,776	80,916	Rs. ha^{-1}

Net benefit = gross income - variable cost

All prices of inputs and outs were considered of June, 2008 in Pakistan.

Economic analysis

Economic analysis during 2008

The economic analysis of experimental treatments on the basis of grain yield was calculated in terms of net benefit and marginal rate of return and results are tabulated in Table 6. The expenses on fertilizer, seed and inter-culturing etc. were similar for each treatment. Therefore the expenses occurred on tillage charges were deducted from the total gross income and the net benefit was calculated. Results reveal that the maximum net benefit (Rs. 95,276 ha^{-1}) was recorded under conventional tillage while, it was Rs. 88,776 ha^{-1} under reduce tillage whereas, zero tillage produced Rs. 80,916 ha^{-1} as net benefit. The marginal analysis (Table 7) revealed that reduced tillage had the maximum marginal rate of return (327percent) as compared to the conventional treatment where the marginal rate of return was 319percent.

Table 7. Marginal analysis of tillage treatments based on wheat grain yield during2008.

Tillage treatments	Net benefit (Rs ha^{-1})	Cost that vary (Rs ha^{-1})	Change in cost (Rs ha^{-1})	Change in net benefit (Rs ha^{-1})	Marginal rate of return (percent)
Zero tillage	80,866	950			
Reduced tillage	88,726	3350	2400	7860	327
Conventional tillage	95,276	5400	2050	6550	319

Variable cost = Cost of inputs, ha^{-1} that varied among the experimental treatments

D=Dominated due to a smaller amount of benefits than earlier investigation

Marginal rate of return (percent) = (Change in net benefit ÷ Change in cost) × 100.

Table 8. Economic analysis of tillage treatments based on wheat grain yield during 2009.

Tillage treatments	Conventional tillage	Reduce tillage	Zero tillage	Remarks
Grain yield	5.1	4.5	3.8	t ha^{-1}
Adjusted yield	4.6	4.1	3.4	To bring at farmer's level (10percent decrease)
Gross income	10,9654	97,043	81,653	Rs. 25000 t^{-1}
Conventional tillage	5600			Expenses of mouldboldPlow + cultivator + seed drill
Reduced tillage		3400		Expenses of disk harrow + cultivator + seed drill
Zero tillage			1000	Expenses of seed drill
Total cost	5600	3400	1000	Rs. ha^{-1}
Net benefit	104,054	93,643	80,653	Rs. ha^{-1}

Net benefit = gross income - variable cost

All prices of inputs and outs were considered of June, 2009 in Pakistan.

Economic analysis during 2009

The economic analysis for the year 2009 was based on grain yield and the net benefit and marginal rate of return were calculated (Table 8). The expenses on fertilizer, seed and inter-culturing etc. were similar for each treatment. Therefore the expenses occurred on tillage charges were deducted from the total gross income and the net benefit was calculated. Results shown in Table 8 reveal that the maximum net benefit (i.e. Rs. 10,4054 ha^{-1}) was recorded under conventional tillage while, it was Rs. 93,643 ha^{-1}under reduce tillage whereas, zero tillage produced the minimum net benefit (Rs. 80,653 ha^{-1}). The marginal analysis (Table 9) revealed that reduced tillage had the maximum marginal rate of return (541percent) as compared to the conventional treatment where the marginal rate of return was 473percent.

Table 9. Marginal analysis of tillage treatments based on wheat grain yield during 2009.

Tillage treatments	Net benefit (Rs ha^{-1})	Cost that vary (Rs ha^{-1})	Change in cost (Rs ha^{-1})	Change in net benefit (Rs ha^{-1})	Marginal rate of return (percent)
Zero tillage	80,653	1000			
Reduced tillage	93,643	3400	2400	12,990	541
Conventional tillage	104,054	5600	2200	10,411	473

Variable cost = Cost of inputs, ha^{-1} that varied among the experimental treatments

D = Dominated due to a smaller amount of profit than previous investigation

Marginal rate of return (percent) = (Change in net benefit ÷ Change in cost) × 100.

Conclusion

It can be concluded from the study when we had compared the effect of tillage practices e.g. reduced (RT) no tillage (NT) and conventional tillage (CT) treatments we found that in conventional tillage treatments almost all the growth and yield parameters of bread wheat in both the years were higher. However, the marginal return (economic benefits) in both the years was greater for reduced treatment (RT) than conventional and no tillage treatments. Therefore the RT is recommended for bread wheat cultivation

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