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# GROWTH AND YIELD OF RAIN FED WHEAT AS AFFECTED BY DIFFERENT TILLAGE SYSTEMS INTEGRATED WITH GLYPHOSATE HERBICIDE

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**Abstract**

In rainfed areas, tillage is primarily done for moisture conservation and weed control. However, excessive tilling not only harms the soil health but also increases the cost of production. To find out the sustainable and economical tillage combination, response of wheat was studied under different tillage systems integrated with glyphosate herbicide through field experiments conducted at University Research Farm of Pir Mehr Ali Shah, Arid Agriculture University Rawalpindi, Pakistan during 2012-2014 for two consecutive seasons. Principal component analysis proved that the plant height, biological yield, grain yield and harvest index of wheat were highest in treatment where one moldboard plowing was done followed by eight cultivations without using glyphosate in fallow period, which might be due to vigorous growth of wheat in this tillage system having enhanced root proliferation and moisture conservation, thus allowing plants to extract more nutrients and water from the deeper soil layers; whereas, the number of tillers per square meter, number of spikelets per spike, 1000 grain weight and number of grains per spike of wheat were maximum where one moldboard plowing was done followed by two applications of glyphosate herbicide in fallow period, which might be due to vigorous growth of wheat in this tillage system during 1st year of experiment when unexpected high rainfall was occurred during crop growth stage. Cluster analysis also categorized these two treatments into same category on the base of all agronomic parameters studied. The highest yield (3.5132 t $ha^{-1}$) and (3.1242 t $ha^{-1}$) was obtained from where one moldboard plowing was done following eight cultivations without using glyphosate followed by the treatment where one moldboard plowing was done following four cultivations without using glyphosate, respectively and were statistically at par with each other. Therefore one moldboard plowing following four cultivations is recommended for taking higher and economical yield in Pothwar Region of Pakistan.

**Key words:** Tillage combinations; Glyphosate; Principal components; Yield; Wheat.

## Introduction

Rainfed area has a high potential for crop production and it contributes 17 percent to the total cropped area of Pakistan and 10 percent to total agricultural production. Wheat (*Triticum aestivum* L.) a major winter crop contributes 2.2% to total GDP of country and 10.1% to the value added in agriculture (Anon., 2014). In rainfed tract of Punjab, wheat is grown on 549.1 thousand hectares area in Punjab producing 431.3 thousand tons and yielding average yield of 1005 kilogram per hectare (Anon., 2014). According to an estimate, more than 1200 kg per acre of wheat yield has been reported as produced on the rainfed land revealing a high potential of these areas. Unfortunately, potential of this land has often been under estimated (Adnan *et al.,* 2009). This large gap in potential and average wheat yield under rainfed conditions may be due to inadequate water availability or at the time of need, poor nutrients management, low fertility of soil, pest and diseases attack and high weeds infestation etc.

Conservation tillage is spreading in developed countries of the world, but in most of the developing countries, the old conventional tillage methods are being practiced due to lack of efficient awareness regarding conservation tillage methods, despite they have lower energy requirement, decrease soil erosion and lower soil moisture losses, which ultimately lead to more a biotic stress impacts on the crops productivity. Therefore, experimentation of appropriate tillage methods under rain fed condition for sustaining soil moisture according to climatic and soil characteristics of our region is too much important, because, the tillage methods affect on soil properties variedly from region to region. In crux, proper tillage practices that reduce surface runoff and increase infiltration rate can lead to more stored soil moisture. However, many researchers reported higher water holding capacity in low and no-tillage methods as compared with conventional methods (Abdipur *et al.,* 2012). The conventional tillage method in our agro-ecological region generally consists of once moldboard plowing followed by 4-8 shallow cultivations with common cultivator which has higher energy consumptions, increases water losses and degrades soil in the long run.

In view of this fact, the objectives of this study were to assess the growth and yield of wheat under different tillage combinations integrated with glyphosate (a non-selective herbicide) applied at fallow period and to find out the principal components that are responsible for this higher yield in productive tillage system.

## Materials and Methods

**1. Site description:** The study was conducted at University Research Farm of Arid Agriculture University Rawalpindi falling at the coordinates (latitude 33°N, longitude 73° and altitude 500 masl) in Pakistan on a sandy loam soil having Kahuta soil series and Udic Haplustalfs great group. The experimental soil possessed following properties i.e., pH= 7.20; EC= 0.92 $dscm^{-1}$; saturation percentage= 36%; organic matter= 0.63%; available phosphorus= 5.32 mg $kg^{-1}$; available potassium= 100 mg $kg^{-1}$.

**2. Experimental design and treatments:** The experiment was conducted through Randomized Complete Block Design laid out in four replications having 13.5 m x 13.5 m net plot size. 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.

**3. Experimental procedure:** The experiments were carried out for two years during the summer and winter seasons of 2012-13 and 2013-14. The tillage treatments integrated with glyphosate were applied in summer seasons while; crops were grown in winter seasons of both years as per the methods followed by (Ali *et al.,* 2014; Ali *et al.,* 2016). Fertilizers and all other inputs were used as per (Ali *et al.,* 2014).

**4. Data collection:** Plant height was measured by taking ten randomly selected mature plants and measuring from their ground level to the tip of each spike with the help of measuring tape and then average was calculated. Similarly a quadrate of 1 m x 1 m was placed randomly to record number of tillers per square meter in each plot from three places and then average was determined. The total number of fertile tillers from each quadrate was counted manually and average value was calculated later on per meter square. The spike length was determined through measuring the length of ten randomly selected spikes per plot. Measurement of length was made from base of first spikelet to tip of spike excluding awns. Average spike length was recorded as an observation. In the same way the number of spikelets per spike was calculated by counting the number of spikelets from ten randomly selected spikes per plot and then average was calculated. The number of kernels per spike were obtained by counting number of kernels from ten randomly selected spikes per plot at maturity and averaged to get number of grains spike$^{-1}$. For taking thousand grain weight a random sample of grains was taken from produce of each plot and 1000- kernel weight was recorded by electric balance. To determine the biological yield, three samples per plot, each from an area of 1m$^2$ were harvested and tied into bundles and sundried for one week. Then the biological yield was recorded by weighing these samples on an electric balance individually and then converted into t ha$^{-1}$. Then these samples were threshed and grains were separated and the gain yield was recorded using an electric balance and then was converted into t ha$^{-1}$. Harvest index was recorded by dividing the grain yield with biological yield and then multiplied by 100 (Ali *et al.,* 2014; Boutraa *et al.,* 2015). The meteorological data was collected from nearest authentic meteorological observatory of Soil and Water Conservation Research Institute (SAWCRI) Chakwal, located about 10 kilometers away from the studied site (Table 1; Ali *et al.,* 2016).

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

| Month | Rainfall mm/day | Mean Mini. Temp. (C$^o$) | Mean Max. Temp. (C$^o$) | 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

**5. Statistical tools used:** Data collected on all parameters were analyzed statistically by using MSTAT-C software on computer (Crop and Soil Sciences Department of Michigan University of the United States). Least significance difference test (LSD) was applied at 5% probability level to compare the treatments means (Steel *et al*., 1997). Regressions and correlations were determined using Statistix 8.1 version software. Principal component analysis and cluster analysis were done using computer software PAST version 2.17c (Hammer *et al.,* 2001).

## Results and Discussions

**1. Meteorological observations:** In summer season (fallow period), comparatively the rainfall was received highest during 2nd year of study viz. 2013-14; whereas, the rainfall was highest during crop growth period (February) in 1st year of study viz. 2012-13 that was probably attributed to good crop germination and finally good establishment in 1st year i. e. 2012-13 (Table 1; Ali *et al.,* 2016). Similarly the relative humidity was accordingly higher with reference to rainfall in respective seasons.

**2. Yield and yield components of wheat:** In pooled data of two years, the plant height, grain yield, biological yield and harvest index of wheat were highest in $T_1$ followed by $T_4$ and $T_3$ that were not significantly different statistically from each other (Table 2; Figs. 2, 7, 8 and 9). It strongly suggests that deep ploughing might have improved the infiltration rate, total porosity of soil and soil aeration, which ultimately conserved the soil moisture for longer period of time that extended root proliferation, movement of soil nutrients and resulted in good crop establishment (Ali *et al.,* 2014; David *et al*., 2006; Khurshid *et al.,* 2006; Barzegar *et al.,* 2003); whereas, the number of tillers per square meter, number of spikelets per spike, 1000 grain weight and number of grains per spike of wheat were maximum under $T_3$ that were at par with $T_1$ and $T_4$; while, these parameters were minimum under $T_2$, $T_7$ and $T_5$ (Table 2; Figs. 1, 4, 5 and 6). These traits might be improved in $T_3$ due to deep tillage and ultimately good crop growth in first year of study where exceptional higher rainfall was occurred during crop growth period of this growing year (Abdipur *et al.,* 2012; El-Titi, 2003). The cluster analysis also grouped $T_1$ and $T_3$ into same category on the base of agronomic parameters (Fig. 15). The maximum economic yields i.e., (3.5132) and (3.1242) t ha$^{-1}$ were obtained in case of conventional tillage $T_1$ and reduced tillage $T_4$, respectively which were statistically at par with each other (Table 3). Maximum grain yield in $T_1$ may be due to good crop establishment under fine seed bed, maximum root proliferation and efficient use of soil resources from deeper layers of soil (Ali *et al.,* 2014; David *et al*., 2006; Khurshid *et al.,* 2006; Barzegar *et al.,* 2003). When tillage systems were arranged in ascending order of tillage intensity, positive correlations between tillage intensity, grain yield, biological yield and harvest index were apparent (Table 4). The regression analysis showed that the grain yield decreased by decreasing tillage intensity (Fig. 10; Ali *et al.,* 2014). It negates the findings of Rusu *et al.* (2013), who investigated similar productions under conventional and conservation tillage system in wheat and maize that may be attributed to the difference in soil physical and chemical properties, pattern of rainfall, soil topography, prevailing environmental conditions and other management practices (Holland, 2004).

**3. Principal component analysis:** The principal component analysis (PCA) is used to compress and classify the data. The PCA reduces the dimensionality of the data to take it in a more momentous form. So, the quantity of variables is condensed to a little and more easily interpretable linear blends of records. This each new linear blend is known as principal component.

**Table 2. Yield and yield components of rainfed wheat as affected by different tillage systems and sowing years.**

| Tillage systems | No. of tillers (m$^{-2}$) | | Plant height (cm) | | Spike length (cm) | | No. of spikelets spike$^{-1}$ | | No. of grains spike$^{-1}$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2012-13 | 2013-14 | 2012-13 | 2013-14 | 2012-13 | 2013-14 | 2012-13 | 2013-14 | 2012-13 | 2013-14 |
| 1 MBP + 8 Cult. | 345.18 ab | 319.17 bc | 98.85 a | 89.44 bcd | 9.89 ns | 8.56 ns | 17.50 ns | 15.75 ns | 53.98 ns | 38.29 ns |
| NT + GH | 318.5 bc | 249.17 def | 91.18 bc | 75.00 e | 9.53 | 8.51 | 18.33 | 16.3 | 50.43 | 39.25 |
| 1 MBP + GH | 379.45 a | 290.42 bcd | 91.23 bc | 84.46 d | 10.66 | 8.69 | 18.6 | 17.04 | 55 | 43.5 |
| 1 MBP + 4Cult. | 336.85 ab | 300.83 bcd | 94.82 ab | 89.11 bcd | 9.91 | 8.57 | 17.83 | 16.46 | 51.33 | 40.96 |
| 1 DH + GH | 340.18 ab | 221.67 ef | 94.82 ab | 75.12 e | 10.04 | 9.49 | 17.7 | 16.54 | 52.2 | 38.34 |
| 1 DH + 4Cult. | 377.58 a | 275 cde | 92.61 b | 86.56 cd | 10.01 | 8.37 | 18.18 | 15.84 | 43.98 | 40.79 |
| 1 CP + GH | 310.92 bc | 216.83 f | 93.46 ab | 73.89 e | 10.38 | 8.67 | 18.43 | 16.71 | 54.75 | 41.71 |

| Tillage systems | 1000 Grain Weight (g) | | Biological Yield (t ha$^{-1}$) | | Grain Yield (t ha$^{-1}$) | | Harvest index (%) | |
|---|---|---|---|---|---|---|---|---|
| | 2012-13 | 2013-14 | 2012-13 | 2013-14 | 2012-13 | 2013-14 | 2012-13 | 2013-14 |
| 1 MBP + 8 Cult. | 48.28 ns | 49.79 ns | 12.850 ns | 8.553 ns | 4.011 a | 3.796 ab | 31.56 cd | 44.45 a |
| NT + GH | 44.56 | 41.53 | 11.778 | 6.658 | 3.008 bc | 2.868 bc | 25.50 de | 41.55 ab |
| 1 MBP + GH | 44.45 | 55.5 | 13.049 | 7.624 | 2.910 bc | 3.594 ab | 22.35 e | 47.38 a |
| 1 MBP + 4Cult. | 50.66 | 48.35 | 12.258 | 7.959 | 3.394 ab | 3.549 ab | 28.17 cde | 44.61 a |
| 1 DH + GH | 49.39 | 40.92 | 10.655 | 5.214 | 3.044 abc | 2.099 cd | 28.87 cde | 39.77 ab |
| 1 DH + 4Cult. | 41.86 | 47.91 | 12.687 | 7.395 | 3.114 ab | 3.185 ab | 24.23 de | 43.34 a |
| 1 CP + GH | 48.61 | 36.83 | 11.692 | 4.862 | 3.359 ab | 1.768 d | 28.71 cde | 34.51 bc |

Note: Any two means in a column showing an alphabetical letter in common do not differ significantly from each other; NS = Non-significant; MBP = Mouldboard ploughing; DH = Disc harrowing; CP = Chisel ploughing; GH = Glyphosate herbicide; NT = No tillage; Cult. = Cultivations

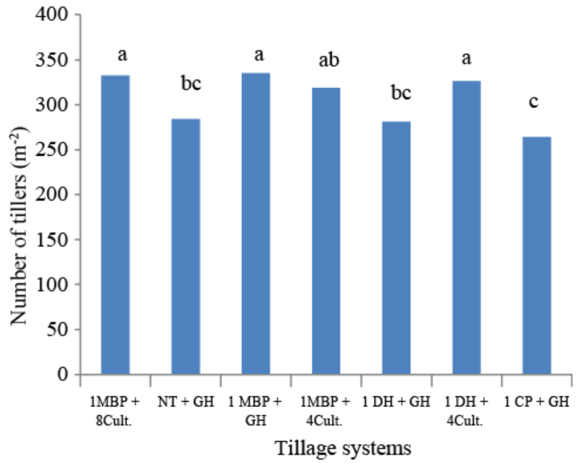



Fig. 1. Number of tillers ($m^{-2}$) of rainfed wheat as affected by different tillage systems integrated with glyphosate (Pooled for two years).

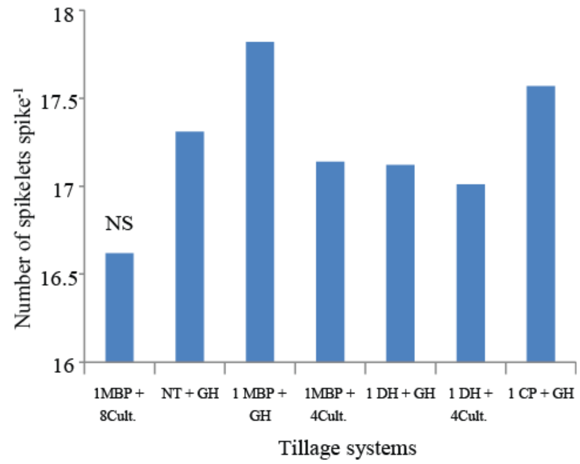



Fig. 4. Number of spikelets spike$^{-1}$ of rainfed wheat as affected by different tillage systems integrated with glyphosate (Pooled for two years).

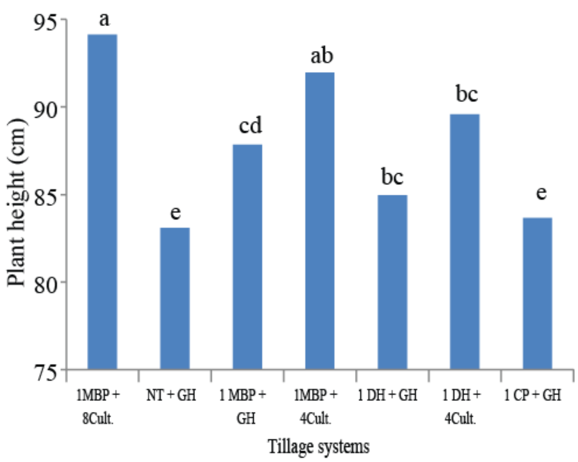



Fig. 2. Plant height (cm) of rainfed wheat as affected by different tillage systems integrated with glyphosate (Pooled for two years).

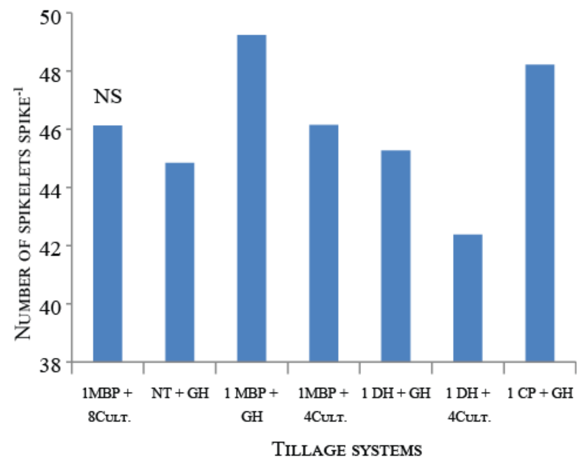



Fig. 5. Number of grains spike$^{-1}$ of rainfed wheat as affected by different tillage systems integrated with glyphosate (Pooled for two years).

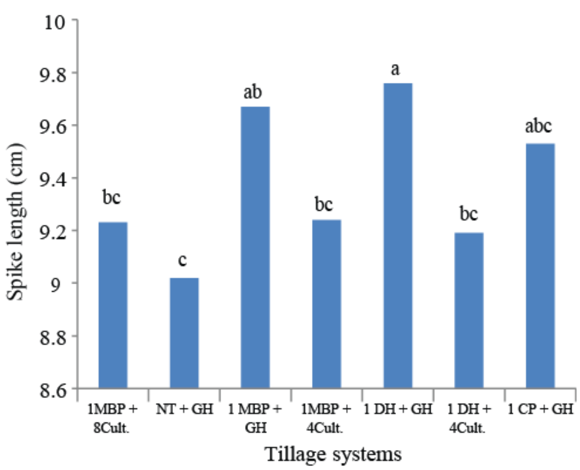



Fig. 3. Spike length (cm) of rainfed wheat as affected by different tillage systems integrated with glyphosate (Pooled for two years).

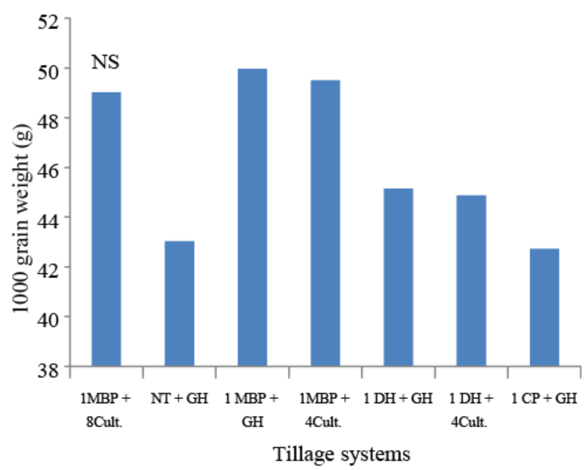



Fig. 6. 1000 grain weight (g) of rainfed wheat as affected by different tillage systems integrated with glyphosate (Pooled for two years).

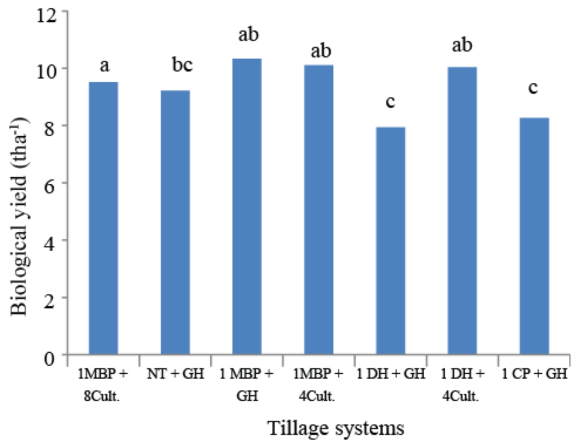



Fig. 7. Biological yield (t $ha^{-1}$) of rainfed wheat as affected by different tillage systems integrated with glyphosate (Pooled for two years).

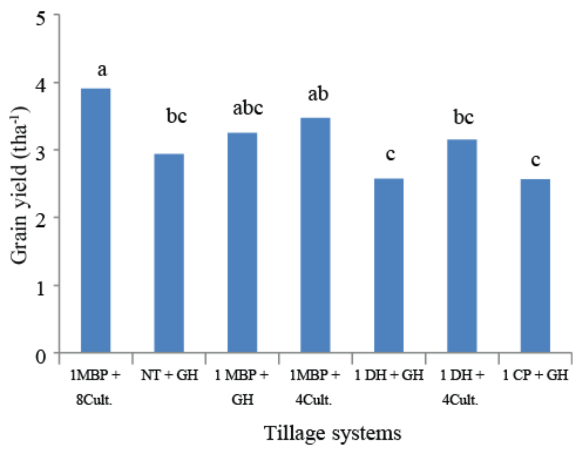



Fig. 8. Grain yield (t $ha^{-1}$) of rainfed wheat as affected by different tillage systems integrated with glyphosate (Pooled for two years).

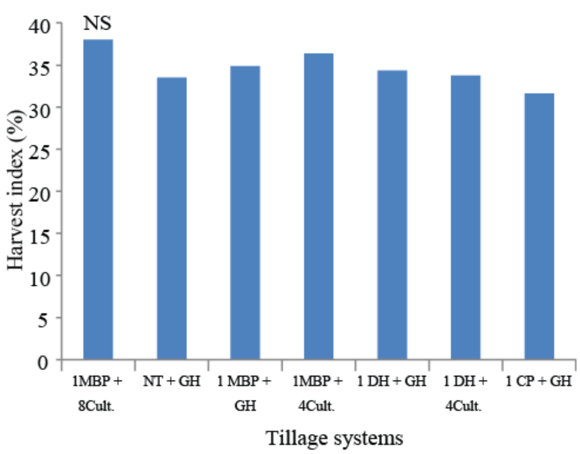


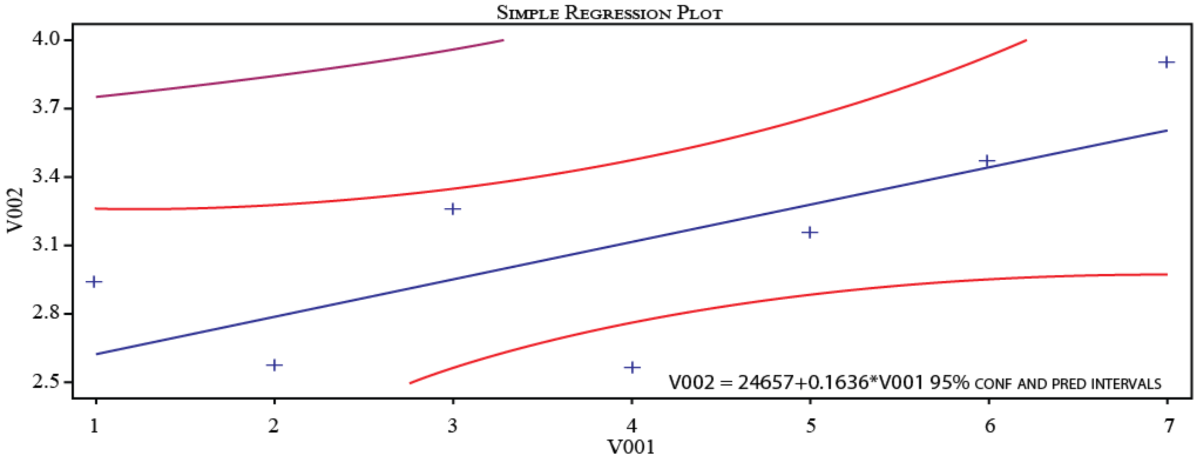

Fig. 9. Harvest index (%) of rainfed wheat as affected by different tillage systems integrated with glyphosate (Pooled for two years).

**a. Number of principal components for nine agronomic traits under seven tillage systems:** The Eigen values and variance percentage about principal components for nine agronomic traits and seven tillage systems are shown in Table 5. The Joliffe cut-off value was observed (1.05) hence it is obvious that the major contributing components were only first two out of six principal components. Maximum Eigen value was showed by $PC_1$ (5.47) while $PC_6$ showed minimum Eigen value (.064). First two components contributed maximum variance (84.08 %) for 9 agronomic traits and 7 tillage systems, therefore, these two factors are responsible for major variation in the experimental treatments and agronomic traits which has also been confirmed by Joliffe cut off value (Table 5). Similar results were reported by Mohamed (1999), who found two factors that for explained relationship of characters in bread wheat genotypes. These factors contributed 80.8% difference between characters and exposed as seed yield and spike density, respectively. Likewise, Leilah and Al-Khateeb (2005) considered bread wheat genotypes under drought stress state using diverse multivariate techniques and found three factors that contributed 74.4% to total variation. El-Hendawy *et al.* (2015) also reported similar findings.

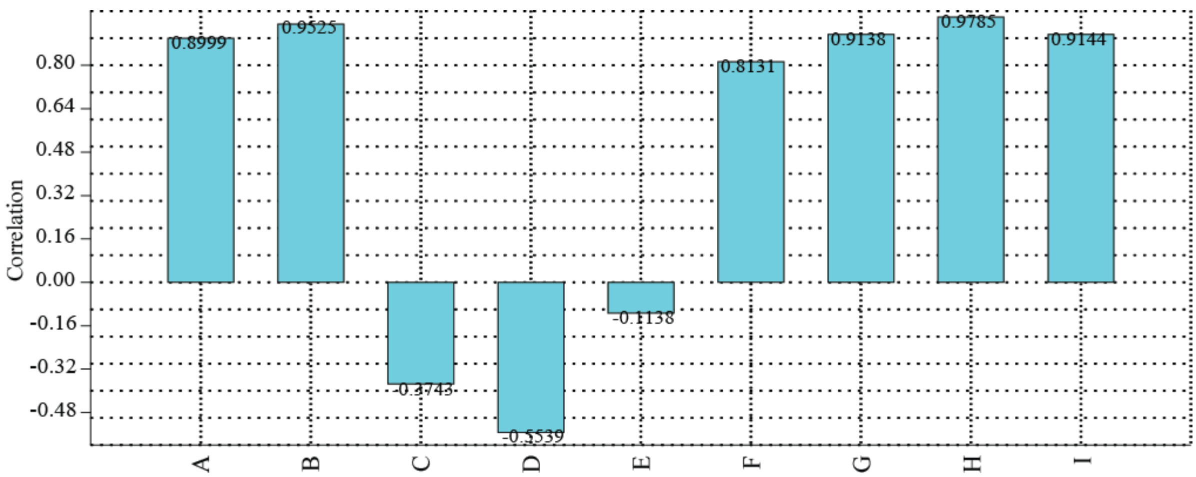
**b. Loadings for principal components:** Following are the loadings for principal components.

**i. Loadings for principal component 1 (PCA-1):** In Fig. 11 and Table 5, loadings for factor-1 are displayed. The first principal component is strongly correlated with five of the original variables. Maximum positive load was observed for grain yield agronomic trait (0.978) followed by plant height (0.9525), harvest index (0.914), biological yield (0.913) and number of tillers per square meter (0.899), respectively. Minimum positive load was observed for 1000 grain weight (0.813). Thus, this principal component increases with increasing grain yield, plant height, 1000 grain weight, harvest index, biological yield and number of tillers per square meter. This means that these five traits vary together, if one increases the other four also increase. This factor can be considered as the measure of grain yield, plant height, 1000 grain weight harvest index, biological yield and number of tillers per square meter. For loading factor-1, maximum negative load was recorded for number of spikelets per spike (-0.553) followed by spike length (-0.374) while minimum negative load was showed by number of grains per spike (-0.113). Factor-1 revealed that number of spikelets per spike was negatively correlated with grain yield and plant height. The correlation studies had also confirmed these findings (Table 4). For this factor, maximum positive load was contributed by grain yield, so grain yield may be considered as the effective factor for this component.

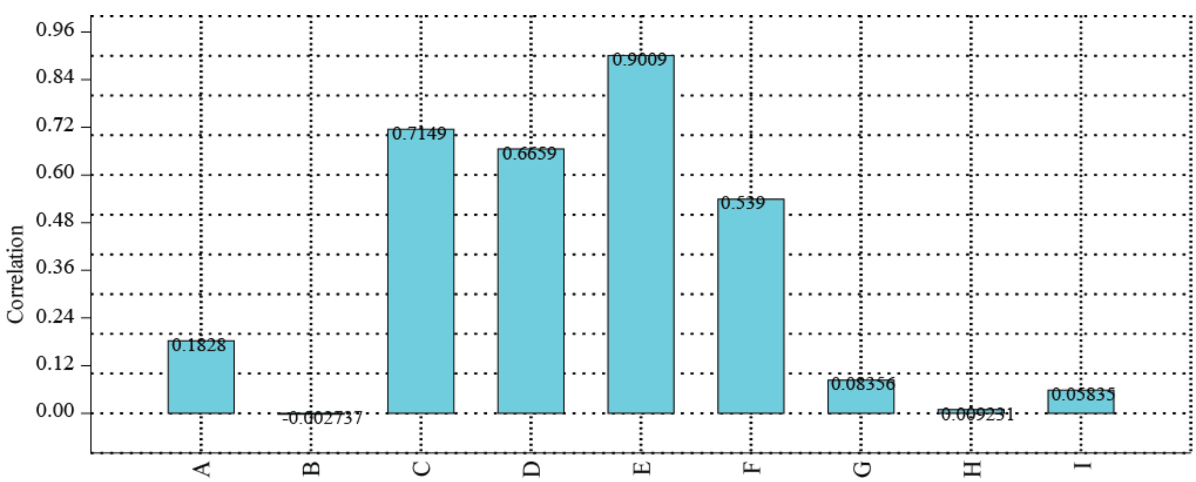
**ii. Loadings for principal component 2 (PCA-2):** Loadings for factor two presented in Fig. 12, Table 5 showed that maximum positive load was accounted for number of grains per spike (0.900) following spike length (0.714), number of spikelts per spike (0.665), 1000 grain weight (0.539) and number of tillers per square meter (0.182). Positive load was found minimum for grain yield (0.009). It means that all these above mentioned traits vary together according to the strength of correlation in this principal component. While, maximum negative load was displayed for plant height (-0.003) in this component. Current factor explored that number of grains per spike was negatively coorrelated with plant height. Correlation studies also justified this association (Table 4). As number of grains per spike added maximum positive load for this factor (0.900). Therefore, number of grains per spike trait is considered as effective factor for $2^{nd}$ principal component.




$R^2$ = 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. 10. Relationship between tillage intensity and grain yield of wheat




A= Number of tillers ($m^{-2}$); B= Plant height; C= Spike length; D= Number of spikelets per spike; E= Number of grains per spike; F= 1000 grain weight; G= Biological yield of wheat; H= Grain yield of wheat; I= Harvest index of wheat
Fig. 11. Loadings for principal component-1.




A= Number of tillers ($m^{-2}$); B= Plant height; C= Spike length; D= Number of spikelets per spike; E= Number of grains per spike; F= 1000 grain weight; G= Biological yield of wheat; H= Grain yield of wheat; I= Harvest index of wheat
Fig. 12. Loadings for principal component-2.

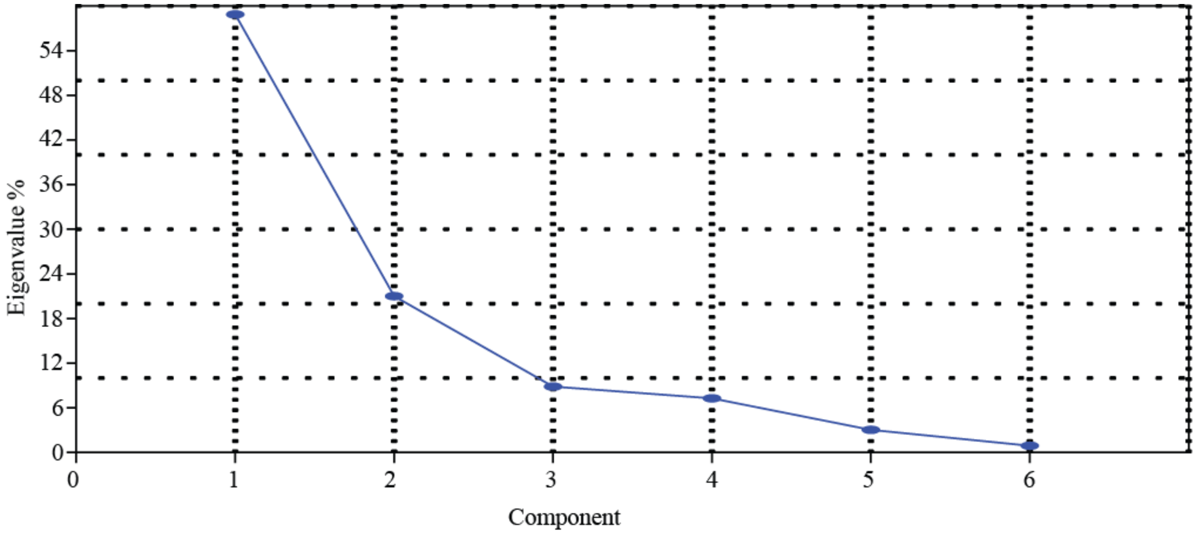
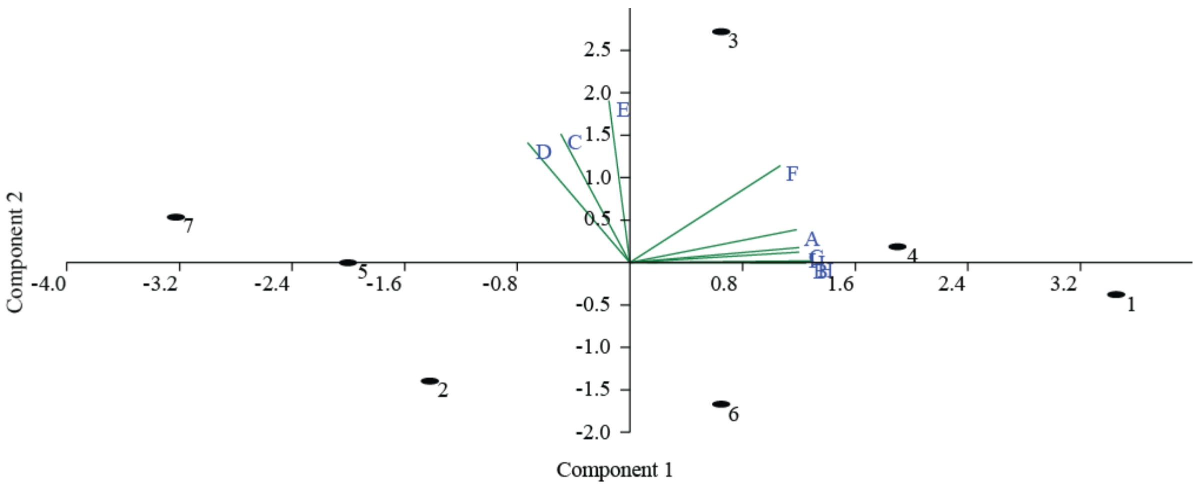



Fig. 13. Scree plot for principal component analysis.




A= Number of tillers ($m^{-2}$); B= Plant height; C= Spike length; D= Number of spikelets per spike; E= Number of grains per spike; F= 1000 grain weight; G= Biological yield of wheat; H= Grain yield of wheat; I= Harvest index of wheat; 1 = 1MB Plowing + 8 cultivations; 2= Zero-tillage + Glyphosate herbicide; 3 = 1MB Plowing + Glyphosate herbicide; 4 = 1MB Plowing + 4 Cultivations; 5 = 1Disc Harrowing + Glyphosate herbicide; $T_6$= 1Disc Harrowing + 4 Cultivations; 7 = 1Chiseling + Glyphosate herbicide

Fig. 14. Biplot scatter diagram for 9 agronomic traits under 7 tillage treatments.

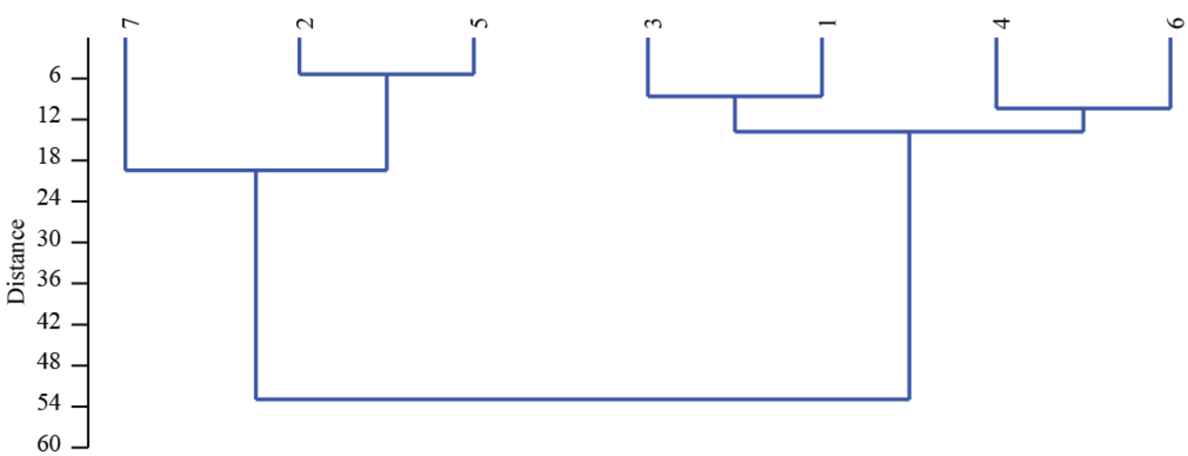



Fig. 15. Clustering of tillage systems on the base of two years average data of studied parameters.

**Table 3. Partial budget of rainfed 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

**Table 4. Correlations between yield and different yield components of wheat.**

| | V001 | V002 | V003 | V004 | V005 | V006 | V007 | V008 |
|---|---|---|---|---|---|---|---|---|
| V002 | 0.8258 | | | | | | | |
| P-VALUE | 0.0221 | | | | | | | |
| V003 | -0.1892 | -0.2641 | | | | | | |
| | 0.6844 | 0.5672 | | | | | | |
| V004 | 0.2648 | -0.6132 | 0.4600 | | | | | |
| | 0.5661 | 0.1431 | 0.2990 | | | | | |
| V005 | 0.0617 | -0.1152 | 0.5521 | 0.6386 | | | | |
| | 0.8955 | 0.8058 | 0.1988 | 0.1226 | | | | |
| V006 | 0.8215 | 0.7794 | 0.1313 | -0.1138 | 0.3447 | | | |
| | 0.0234 | 0.0388 | 0.7791 | 0.8081 | 0.4489 | | | |
| V007 | 0.9286 | 0.8086 | -0.4532 | -0.2723 | -0.0181 | 0.7352 | | |
| | 0.0025 | 0.0277 | 0.3071 | 0.5546 | 0.9692 | 0.0598 | | |
| V008 | 0.8454 | 0.9111 | -0.4497 | -0.5150 | -0.0236 | 0.7688 | 0.9290 | |
| | 0.0166 | 0.0043 | 0.3113 | 0.2369 | 0.9599 | 0.0434 | 0.0025 | |
| V009 | 0.7272 | 0.8699 | -0.2022 | -0.6141 | -0.0257 | 0.8218 | 0.7068 | 0.8875 |
| | 0.0640 | 0.0109 | 0.6638 | 0.1424 | 0.9565 | 0.0233 | 0.0758 | 0.0077 |

V001= Number of tillers ($m^{-2}$); V002= Plant height; V003= Spike length; V004= Number of spikelets per spike; V005= Number of grains per spike; V006= 1000 grain weight; V007= Biological yield of wheat; V008= Grain yield of wheat; V009= Harvest index of wheat

**Table 5. Principal components for nine agronomic traits under seven tillage systems.**

| PC | Eigen value | % variance | Cumulative variance % |
|---|---|---|---|
| 1. | 5.46654 | 60.739 | 60.74 |
| 2. | 2.10053 | 23.339 | 84.08 |
| 3. | 0.806193 | 8.9577 | 93.04 |
| 4. | 0.431089 | 4.7899 | 97.83 |
| 5. | 0.131415 | 1.4602 | 99.29 |
| 6. | 0.0642338 | 0.71371 | 99.99 |

Jolliffe cut-off value = 1.05

**1. Scree plot for principal components:** Scree plot is considered to be other selection criteria for significant principal component selection. For selected nine agronomic traits scree plot was drawn for seven tillage systems which showed that most of the contribution to the total variance percentage was attained by first two principal components for agronomic traits and tillage systems. Fig. 13 illustrated that first two principal components were main contributor to total variance. The line of scree plot was going in steep mode up to about $PC_3$ and after that line became flattened showing no major contribution towards the total variance, and is in line with the results presented in Table 5, which are based on the Eigen value and total variance of principal components for nine agronomic traits in seven tillage systems.

**2. Biplot scatter diagram for principal components:** A biplot is a modified scatter plot diagram that utilizes both points and vectors to represent structure in which both the length and dimension can be interpreted. Here biplot diagram is constructed for nine agronomic traits in seven tillage treatments of wheat (Fig. 14). First two principal components contributed maximum proportion of variance (84.08%) which was used to develop a scatter biplot diagram for nine agronomic traits in seven tillage systems. In biplot it is evident that three agronomic traits i.e., spike length, number of grains per spike and number of spikelets per spike were found at a long distance from the starting point as the vector lines joining these traits to the point of origin were longer thus contributing more variation in data of principal components while other traits like number of tillers plant$^{-1}$, plant height, biological yield and grain yield have showed less variance as the lines joining these traits were smaller in length and showing strong association. At the same time number of tillers plant$^{-1}$, plant height, biological yield and grain yield showed strong correlation with each other but negatively with spike length, number of grains per spike and number of spikelets spike$^{-1}$. These results can also be confirmed from correlation data (Table 4). Similarly the distribution of points of tillage systems in biplot diagram depicts that the $T_1$ followed by $T_4$ has high value for principal component-1 but $T_7$ followed by $T_5$ has minimum value for PC-1. It means that the traits like number of tillers plant$^{-1}$, plant height, biological yield, 1000 grain weight and grain yield are high in $T_1$ and $T_4$, but they were low in case of $T_7$ and $T_5$. Similarly the position of $T_3$ shows that it has high value for PC-2 but the position of $T_6$ followed by $T_2$ has minimum value for PC-2. It means that number of grains per spike, spike length, number of spikelts per spike, 1000 grain weight and number of tillers per square meter were high in $T_3$ but they were low in case of $T_6$ and $T_2$. These results also have been confirmed through the relevant values given in table i.e., (Table 4). Walton (1971) also found four components that accounted for 98.4% of variability between characters. Likewise, Mohamed (1999) reported two factors that were responsible for variation of characters in bread wheat genotypes. These factors contributed 80.8% to explaining relation between traits and exposed as seed yield and spike density, respectively. Whereas, Leilah and Al-Khateeb (2005) considered bread wheat genotypes under drought stress state using diverse multivariate techniques and found three factors that contributed 74.4% to total variation.

## Conclusion

Tillage intensity positively affected wheat yield. Principal component analysis proved that effective factors of principal component-1 were best under $T_1$ and the effective factors of principal component-2 were best under $T_3$, the cluster analysis also grouped $T_1$ and $T_3$ into same category. The highest yields (3.5132 t ha$^{-1}$) and (3.1242 t ha$^{-1}$) were obtained through conventional tillage ($T_1$) followed by reduced tillage ($T_4$), respectively that were statistically same. In conclusion, deep tillage is still sustainable for the semi-arid rainfed agro-ecological regions of Pakistan.

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