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RESEARCH ARTICLE

Response of Zero Tilled Wheat Crop to Different Mulching Techniques in a Semiarid Environment

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Abstract

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Mulching plays an important role mainly in soil moisture conservation and in suppressing weeds growth. In order to determine the effect of various mulching techniques under zero tillage system, a field experiment was carried out during winter season 2009-10 at the Agronomic Research Area, University of Agriculture, Faisalabad. The experiment was laid out in randomized complete block design (RCBD) in triplicate run. The experiment comprised of six treatments, viz. no mulch (control), animal manure @ 4 t ha⁻¹, rice straw mulch @ 4 t ha⁻¹, maize straw mulch @ 4 t ha⁻¹, wheat straw mulch @ 4 t ha⁻¹, and burned rice straw after harvesting. Results showed that all mulching treatments under zero tillage technique have significant ($P \leq 0.05$) influence on moisture retention percentage at tillering, booting and grain formation stages. Maximum average moisture retention (21.33%; 13.07%; 17.41%) was recorded with rice straw mulch @ 4 t ha⁻¹ at tillering, booting and grain formation stages respectively, before each irrigation compared to no mulch. Maize straw mulch @ 4 t ha⁻¹ also provided better results in moisture retention percentage but not more than rice straw mulch. Higher weeds biomass reduction (41 g) was also attained in rice straw mulch @ 4 t ha⁻¹ treated plots parallel to other mulching treatments. Maximum grain yield (5.16 t ha⁻¹) was obtained in rice straw mulch treatment compared to all other treatments. Similarly, the plant height (105.00 cm), number of spike bearing tillers (385.66 m⁻²), spikelets per spike (18.62), grains spike⁻¹ (53.20), 1000-grain weight (52.20 g), straw yield (5.58 t ha⁻¹) and biological yield (13.74 t ha⁻¹) were the highest in rice straw mulch @ 4 t ha⁻¹ treated plots. Therefore, zero tilled rice straw mulch @ 4 t ha⁻¹ performed well in the entire crop data parameters and showed effectively higher grain yield in wheat.

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Introduction

Wheat (*Triticumaestivum* L.) is the most important cereal crop in the world and is a staple food of about one third of the world's population. Challenges to low wheat production in Pakistan are still considerable. Its grain yield is low because of increased moisture scarcity at the time of sowing throughout the growing season which adversely affects the plant growth and development (Ahmad *et al.*, 2009).

The problem is further underscored because of the heavy infestation of weeds which not only alleviate the soil moisture but also compete with the crop plants for light, carbon dioxide, space, nutrients and many other growth factors, resulting in direct loss to quantity and quality of the produce (Gupta, 2004). Crop losses due to weeds competition are greater than those resulting from the combined effect of insects and diseases. Weed infestation is one of the main causes of low wheat yield as it reduces wheat yield by 37-50% (Waheed *et al.*, 2009; Naseer *et al.*,

2011). However, moisture accessibility is one of the most important limiting factors, which directly affects the emergence, plant growth and establishment.

Mulches help in different ways to improve physical characteristics of soil like decrease in bulk density of soil, increase in infiltration rate, and maintenance of good conditions for plant growth and moderation of soil temperature (Ahmad *et al.*, 2009). Using crop residues as mulch proved effective in reducing evaporation and aid in conserving soil moisture in the rhizosphere. It offers a moist, shaded growing zone and protective soil cover which suppresses weeds growth without use of herbicides (Szwedo and Maszczyk, 2001). Surveys have shown that sowing of wheat after rice is often delayed because of the number of tillage operations needed for good seedbed preparation. As a result, costs escalate and farmer profit margins decrease (Hobbs *et al.*, 2002). Studies have shown that any delay in wheat planting after November results in a linear decline in yield potential (Pandey *et al.*, 2002). Finding ways to reduce the traditional practice of repeated tillage operations prior to wheat sowing is an important research area. The delay in wheat sowing may be reduced by using different practices such as use of early maturing rice varieties, harvesting of rice using combine and using zero tillage method and adopting such methods of wheat planting which facilitate early planting of wheat. Zero till wheat is being introduced to avoid late planting and poor land preparation. It ensures timely planting, better stand establishment and higher grain yield than conventional method. It also saves 30% irrigation and land preparation cost (Aslam *et al.*, 1999; Ghuman and Sur, 2001) described that it is necessary to use residue mulch in conjunction with minimum tillage in order to improve soil quality, conserve moisture which ultimately improve crop production.

Keeping in view the necessity of using different mulches in conjunction with zero tillage, the present study was designed to explore the effect of different types of mulches on soil water conservation, growth and yield of wheat.

Materials and Methods

The proposed study was conducted at Agronomic Research Area, Department of Agronomy, University of Agriculture; Faisalabad (30.35-31.47 °N latitude, 72.08-73 °E longitude, elevation 150m), where mean minimum and maximum temperature 17 °C; 39 °C respectively, to evaluate the effect of mulching on growth and yield of wheat under zero tillage system during Rabi 2009-10. Before sowing, soil samples were collected from the experimental site with the help of soil auger prior to fertilizer application and then air dried for physio-chemical analysis. Based on physio-chemical properties as described by Hommer and Pratt, (1961) analysis revealed that soil was sandy clay loam with pH 7.5, 0.78% organic matter, 0.058% total nitrogen, 15.1ppm phosphorus and 80 ppm potassium. Meteorological data regarding average minimum and maximum temperatures (°C), monthly rainfall (mm) and relative humidity (%) were recorded from meteorological observatory in the immediate locality of the field during the phase of crop development (Fig 1).

The soil was found to be normal but low in organic matter without any problem for crop husbandry. The experiment was planned in randomized complete block (RCB) design in triplicate run with a net plot size 2.6m × 5.0m. During 3rd week of November 2009, Seher-2006 was sown with single row hand drill in the residual moisture just after harvesting of rice using the seed rate 125 kg ha⁻¹. There were 13 lines in each plot with row spacing of 20 cm. Sources of different crop mulches were chopped with the help of chopper and then applied between rows after sowing of wheat crop (Table 1). The crop was fertilized @ 125 kg N, 100 kg P₂O₅ and 60 kg K₂O ha⁻¹ in the form of Urea and diammonium phosphate (DAP) and sulphate of potash (SOP) respectively in all the treatments. Whole of the phosphorous and half of the nitrogen was applied at the time of sowing while remaining half at first irrigation. All other agronomic practices were kept normal and uniform for all treatments.

During the course of study, a unit area of one square meter was taken at random for recording plant height, number of spike bearing tillers, number of spikelets per spike, grains per spike, 1000-grain weight, straw yield, grain yield and harvest index were recorded. A quadrat measuring (50 × 50 cm) was randomly placed in respective plots as weeds were harvested from the ground surface per unit area from each plot at 45 days after mulching and their dry biomass was recorded after oven-drying at 70°C till constant weight was achieved. Data regarding soil moisture retention (%) by different types of mulches was determined at tillering, booting and grain formation stage from a composite soil sample at the depth of 0-15 cm from each plot. The moisture percentage was calculated as

Moisture (%) = Fresh weight - Dry weight / Oven dry weight × 100

Statistical analysis:The data collected was analyzed statistically according to Fishers analysis of variance technique (Steel *et al.*, 1997) and least significant difference (LSD) test at 5% probability level was used to compare the differences among treatments' means.

Results and Discussion

Effect on moisture content (%): The data recorded for soil moisture content at different growth stages (tillering, booting and grain formation) described that mulching treatments with no till have significant effect on soil moisture content ($P \leq 0.05$) (Table 2; 3). At tillering stage maximum soil moisture (21.33%) was conserved with rice straw mulch @ 4 t ha⁻¹ followed by maize straw mulch @ 4 t ha⁻¹ (18.00%) application which was statistically similar with wheat straw mulch @ 4 t ha⁻¹ (17.33%) and animal manure mulch @ 4 t ha⁻¹ (15.33%) treatments. Minimum soil moisture (12.00%) was recorded in burning rice straw that was statistically non significant with no mulch (13.66%). Lower soil moisture content in case of burning rice straw as compared to control may be due to reason that heat generated due to burning dissipated the moisture content more than bare soil (Shafiqet *al.*, 1994; Misra, 1996). The statistics regarding soil moisture content at booting stage displayed that application of rice, wheat and maize straw mulches @ 4 t ha⁻¹ conserved statistically similar moisture content (13.07%; 12.05%; 10.85% respectively) but different from that of no mulch (8.43%) treatment. Almost similar date fashion was recorded for moisture conservation at grain formation stage, where maximum soil moisture (17.41%) was conserved in rice straw mulched plots tracked by wheat straw (15.60%) and maize straw mulch @ 4 t ha⁻¹ (14.41%) compared to minimum soil moisture content (11.27%) which was observed in no mulch treatment that was non-significant with burning rice straw @ 4 t ha⁻¹ treatment.

Soil moisture values showed a lot of fluctuations which were mainly because of variation in the weather parameters like rainfall, temperature and relative humidity. When the soil samples were collected after rain their values was high with the exception of few sample where almost all the mulch treatments showed the high moisture contents in the soil as compared to control. It was further revealed that higher rates of mulch conserved more soil moisture by providing better cover to the non-cropped area. It was manifest that mulches have double ha⁻¹ actions. One by controlling weeds and other by providing soil cover, both these effects reduced water loss through decreased transpiration and evaporation, respectively (Ahmad and Hanif, 1998; Tariq *et al.*, 2001).

Table 1. Mulches used at the experimental site during 2009-10

| Mulches | Rate (t ha ⁻¹) |
|---|----------------------------|
| T ₁ = Zero tillage with no mulch | -- |
| T ₂ = Zero tillage with animal manure | 4 |
| T ₃ = Zero tillage with rice straw mulch | 4 |
| T ₄ = Zero tillage with maize straw mulch | 4 |
| T ₅ = Zero tillage with wheat straw mulch | 4 |
| T ₆ = Zero tillage with burning rice straw | -- |

Table 2. Mean square values for mulching treatments on moisture content (%) at different stages of wheat

| Source of Variation | Df | Mean square | | |
|---------------------|----|---------------------|--------------------|---------------------|
| | | At tillering | At booting | At grain formation |
| Replication (R) | 2 | 14.38 ^{**} | 0.16 ^{**} | 0.08 ^{**} |
| Mulches (M) | 5 | 33.39 ^{**} | 9.49 ^{**} | 14.52 ^{**} |
| Error (R × M) | 10 | 4.38 ^{**} | 2.14 ^{**} | 1.16 ^{**} |
| Total | 17 | | | |

^{**} means significance at ($P \leq 0.05$) level of probability

Table 3. Effect of various mulching treatments on moisture content (%) at different stages of wheat

| Treatments | Moisture retention (%) | | |
|---|------------------------|------------|--------------------|
| | At tillering | At booting | At grain formation |
| T ₁ = Zero tillage with no mulch | 13.66 cd | 8.43 c | 11.27 d |
| T ₂ = Zero tillage with animal manure @ 4 t ha ⁻¹ | 15.33 bcd | 8.89 bc | 13.30 c |
| T ₃ = Zero tillage with rice straw mulch @ 4 t ha ⁻¹ | 21.33 a | 13.07 a | 17.41 a |
| T ₄ = Zero tillage with maize straw mulch @ 4 t ha ⁻¹ | 18.00 ab | 10.85 abc | 14.41 bc |
| T ₅ = Zero tillage with wheat straw mulch @ 4 t ha ⁻¹ | 17.33 bc | 12.05 ab | 15.60 ab |
| T ₆ = Zero tillage with burning rice straw | 12.00 d | 9.07 c | 12.61 cd |
| LSD ($P \leq 0.05$) | 3.81 | 2.66 | 1.96 |

Any two means not sharing a letter in common differ significantly at $P \leq 0.05$

Effect on weeds biomass (g): Statistical comparison of treatments' means showed significant ($P \leq 0.05$) effects of mulches on total weeds biomass under zero tillage system (Fig. 2). Mulch application with rice straw @ 4 t ha⁻¹ produced minimum total weeds biomass (41.00g) which was statistically different from all treatments. Maximum total weed biomass was observed in no mulch plots (99.00g) which was followed by burning rice straw and animal manure mulch @ 4 t ha⁻¹ application (90.33g; 84.66g) respectively. Maize straw mulch @ 4 t ha⁻¹ with zero till produced statistically similar weeds biomass (72.33g; 71.67g), respectively. It was evident from the statistical data that all straw mulch applications controlled weeds more effectively contrast to other mulching treatments including control (no mulch). Least weeds biomass in straw mulched plots was due to the fact that straw mulches covered the soil surface better in non cropped area, causing reduced light availability for photosynthesis and ultimately growth of weeds (Ahmed *et al.*, 2007).

Wheat yield attributes: Data regarding yield attributes of wheat crop as affected by different mulching techniques under zero tillage are presented in Table 4; 5. Statistical results depicted that plant height was significantly affected by different mulching techniques ($P \leq 0.05$). Maximum plant height (105.00 cm) was measured in rice straw mulch @ 4 t ha⁻¹ followed by wheat straw mulch @ 4 t ha⁻¹ attaining plant height (103.18 cm). Maize straw mulch @ 4 t ha⁻¹ was statistically non significant with animal manure mulch @ 4 t ha⁻¹ giving plant height (101.36 cm); (101.17 cm) respectively, compared to minimum plant height (97.58 cm) from those plots where no mulch was applied. Maximum plant height may be attributed to better weeds control and more moisture retaining capacity in mulched plots. These results are in accordance with Ullah *et al.*, (1998); Rehman *et al.*, (2005); Ramakarishna *et al.*, (2006); Ahmed *et al.*, (2007) as they found positive effect of straw mulching for plant height and weeds suppression.

Spike bearing tillers m⁻² were significantly influenced by different mulching techniques ($P \leq 0.05$). Statistical analysis of the treatments showed that rice straw mulch @ 4 t ha⁻¹ produced significantly higher spike bearing tillers (385.66) than all other mulching treatments which was followed by wheat straw mulch @ 4 t ha⁻¹ (367.00) as compared to minimum number of spike bearing tillers (311.66) that was recorded in zero mulch. Less spike bearing tillers in zero mulch may be due to more evaporation losses resulting in low availability of moisture to crop plants. The availability of moisture was low due to the fact that soil had no cover on it to preserve moisture fully. Shafiq *et al.*, (1994) also reported that productive tillers m⁻² was increased in mulched plots than unmulched plots which was attributed to increase in soil moisture contents and reduction in evaporation from soil due to application of mulch but these results are in contrast with the findings of Dao and Nguyen, (1989) Who reported the maximum number of productive tillers m⁻² in sowing of wheat by no-tillage without straw mulch.

Table 4. Mean square values for treatments on weeds biomass and yield components of wheat

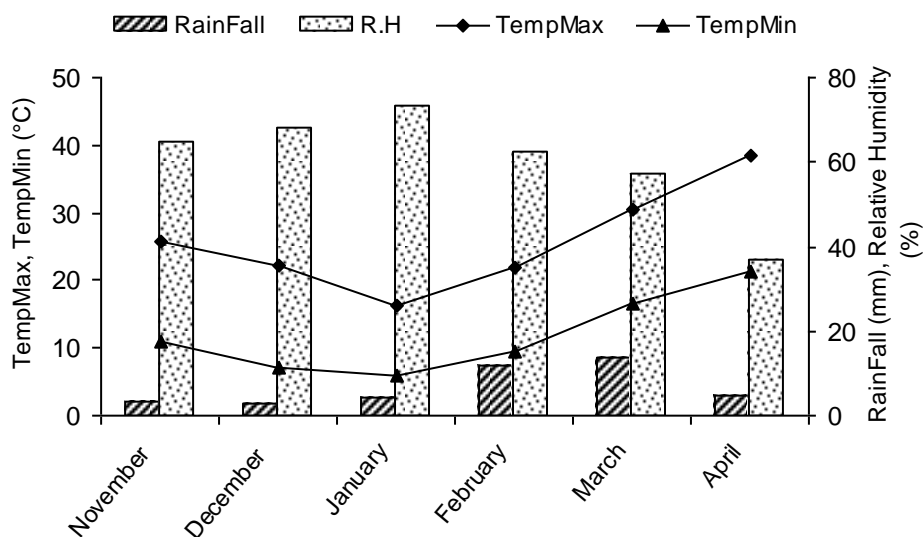
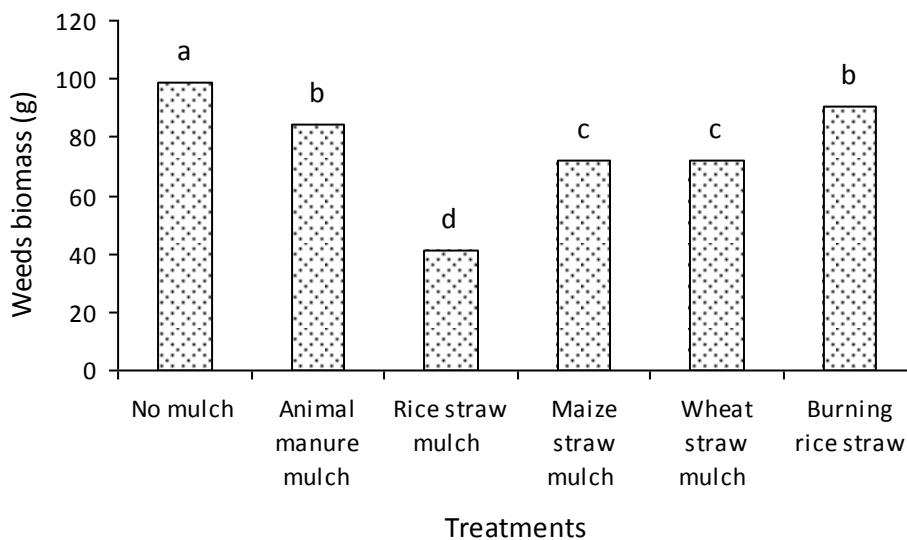
| Source of Variation | Df | Mean square | | | | | | | | |
|---------------------|----|-------------|-----------|------|---------|---------|------|-------|------|------|
| | | PH | SBT | SPS | GPS | TGW | SY | GY | BY | HI |
| Replication (R) | 2 | 1.48 | 10.50 | 0.07 | 0.47 | 0.005 | 0.12 | 0.001 | 0.09 | 0.87 |
| Mulches (M) | 5 | 20.89** | 2281.01** | 0.96 | 19.70** | 21.67** | 0.74 | 0.41 | 2.09 | 1.84 |
| Error (R × M) | 10 | 0.66 | 9.77 | 0.03 | 0.13 | 0.17 | 0.02 | 0.01 | 0.02 | 0.47 |
| Total | 17 | | | | | | | | | |

** means significance at $P \leq 0.05$ level of probability

Table 5. Effect of various mulching treatments on weeds biomass and yield components of wheat

| Treatments | Parameters | | | | | | | | |
|---|------------|----------|---------|---------|---------|---------|--------|---------|----------|
| | PH | SBT | SPS | GPS | TGW | SY | GY | BY | HI |
| T ₁ = No mulch | 97.58 e | 311.66 f | 16.99 d | 46.67 d | 45.45 e | 7.27 e | 4.17 e | 11.51 f | 36.25 c |
| T ₂ = Animal manure @ 4 t ha ⁻¹ | 101.17c | 344.00 b | 17.65 c | 50.51 c | 48.35 c | 7.70 cd | 4.66 c | 12.32 d | 37.70 ab |
| T ₃ = Rice straw mulch @ 4 t ha ⁻¹ | 105.00 a | 385.66 a | 18.62 a | 53.20 a | 52.20 a | 5.58 a | 5.16 a | 13.74 a | 37.55 ab |
| T ₄ = Maize straw mulch @ 4 t ha ⁻¹ | 101.36 c | 359.33 c | 18.11 b | 50.76 c | 50.63 b | 7.79 c | 4.89 b | 12.69 c | 38.55 a |
| T ₅ = Wheat straw mulch @ 4 t ha ⁻¹ | 103.18 b | 367.00 b | 18.00 b | 52.05 b | 50.71 b | 8.36 b | 4.96 b | 13.32 b | 37.24 bc |
| T ₆ = Burning rice straw after harvesting | 99.37 d | 342.33 e | 17.43 c | 47.44 e | 46.30 d | 7.55 d | 4.41 d | 11.96 e | 36.87 bc |
| LSD ($P \leq 0.05$) | 1.47 | 5.68 | 0.34 | 0.66 | 0.76 | 0.19 | 0.18 | 0.27 | 1.25 |

Abbreviations: PH= Plant height, SBT= Spike bearing tillers, SPS= Spikelets per spike, GPS= Grains per spike, TGW= Thousand grain weight, SY= Straw yield, GY= Grain yield, BY= Biological yield, HI= Harvest index; Any two means not sharing a letter in common differ significantly at $P \leq 0.05$

Fig 1. Average minimum and maximum temperatures ($^{\circ}\text{C}$), monthly rainfall (mm) and relative humidity (%)**Fig 2. Effect of zero tilled mulching techniques on weeds biomass reduction**

Statistical comparison of zero tilled mulching treatments means showed higher number of spikelets per spike was resulted in straw mulched treatments ($P \leq 0.05$). Rice straw mulch @ 4 t ha^{-1} resulted in maximum number of spikelets (18.62) per spike followed by maize straw @ 4 t ha^{-1} and wheat straw mulch @ 4 t ha^{-1} producing (18.11; 18.00) spikelets per spike respectively, and remained statistically non significant with each other. Minimum number of spikelets per spike was produced by zero mulch. The results seem to be comparable with Shahid, (2009) who reported more branches per panicle for straw mulches as compared with control.

The individual comparison of treatments' means elucidated that highest number of grains per spike (53.20) were recorded in rice straw mulch @ 4 t ha^{-1} followed by wheat straw mulch @ 4 t ha^{-1} having (52.05) grains per spike ($P \leq 0.05$). However, maize straw mulch @ 4 t ha^{-1} and animal manure mulch @ 4 t ha^{-1} were statistically at par with each other, while lowest number of grains per spike (46.67) was produced by no mulch (control). These results are in contrast with findings of Dao and Nguyen, (1989) as they reported that zero tillage without straw had no effect on number of grains per spike. Statistically analyzed data on 1000-grain weight showed highly significant differences

among various zero tilled mulching techniques ($P \leq 0.05$). The data evidenced that the treatment, mulched with rice straw @ 4 t ha⁻¹ fashioned the maximum 1000-grain weight (52.20 g). It was trailed by wheat straw mulch @ 4 t ha⁻¹ that was statistically at par with maize straw mulch @ 4 t ha⁻¹ by producing (50.71 g; 50.63 g) respectively, while minimum 1000-grain weight was found in no mulch with 45.45 g weight. Maximum 1000-grain weight in rice straw mulch @ 4 t ha⁻¹ may be attributed to the fact that plants involve in successive uptake of moisture and nutrients due to better soil moisture and nutrient conservation as compared to other treatments. Mulched treatments generally showed significantly greater total uptake of N, P and K than corresponding unmulched ones (Acharya & Sharma, 1994). These results are also in strong line of Bhatt and Khera, (2005); Lopez-Bellido, (1996) who reported maximum moisture retaining with rice straw and minimum 1000-grain weight under zero tillage un-mulch treatment respectively.

Mulches also showed significant difference ($P \leq 0.05$) in case of straw yield as maximum straw yield (8.58 t ha⁻¹) was obtained where rice straw mulch @ 4 t ha⁻¹ was used followed by wheat straw mulch @ 4 t ha⁻¹ treatment with straw yield of 8.36 t ha⁻¹. However maize straw mulch @ 4 t ha⁻¹ statistically similar with animal manure mulch @ 4 t ha⁻¹ and with burning rice straw mulch treatments. While minimum straw yield (7.27 t ha⁻¹) was recorded in no mulch. The straw yield increase in rice mulch treatment might be attributed to increased leaf area index, plant height and higher plant population. These results supported the work of Awal and Khan, (1999) as they reported improved straw yield in rice straw mulch as compared to control treatment. Statistical comparison of treatments showed that maximum grain yield (5.16 t ha⁻¹) was observed in rice straw mulch @ 4 t ha⁻¹ but different from wheat and maize straw mulch @ 4 t ha⁻¹ which were statistically at par with each other whereas minimum grain yield (4.17 t ha⁻¹) was recorded from no mulch treatment. The highest grain yield obtained in straw mulches @ 4 t ha⁻¹ compared to un-mulched treatment seems to be due to improved moisture retention, more spike bearing tillers, longer flag leaf lamina (Ahmed *et al.*, 2009) and more 1000-grain weight ($P \leq 0.05$). Similar findings were also been described by Bhatt and Khera, (2005).

Biological yield data revealed a significant ($P \leq 0.05$) effect of different type of mulches. In case of biological yield maximum yield (13.74 t ha⁻¹) was obtained from those plots which were grown under rice straw mulch @ 4 t ha⁻¹ lagged by wheat straw mulch @ 4 t ha⁻¹ that produced total biomass of 13.32 t ha⁻¹. However, minimum biological yield (11.51 t ha⁻¹) was recorded in no mulch plots. In fact straw mulching had different soil thermal properties under diverse temperatures from that of exposed soil; colder weather had higher soil temperatures under straw mulching than in non-mulched soils and lesser during hot weather (Fabrizzi *et al.*, 2005; Sarkar *et al.*, 2007). Adequate moisture contents, appropriate temperature of soil, weed suppression, enhanced availability of nutrients and improved soil physical, biological and chemical conditions due to mulching resulted in overall better crop performance (Al-Rawahy *et al.*, 2011; Christopher *et al.*, 2011). The results also showed a similarity to the work done by Su *et al.*, (2007) and (Acharya and Sharma, 1994), as they found that no-tillage with mulching gave higher yields than no mulch.

Data pertaining to harvest index (HI) revealed maximum value of HI (38.55%) in maize straw mulch @ 4 t ha⁻¹, though it was statistically similar with animal manure @ 4 t ha⁻¹ and rice straw mulch @ 4 t ha⁻¹ by documenting (37.70%; 37.55%) harvest index respectively. while minimum HI (36.25%) was recorded where no-mulch was applied. Maize straw and wheat straw mulches @ 4 t ha⁻¹ remained statistically similar with 37.24% and 36.87% values of HI. These results are in contrast with findings of Tao *et al.*, (2006) who reported that harvest index remained almost unaffected between, straw mulch and zero mulch applied treatments.

Conclusions: The results regarding this study revealed that mulches were beneficial in altering the temperature of soil, provided favorable soil conditions for plant growth, conserved moisture, suppressed weeds growth and reduced the loss of nutrients which is apparent from better plant performance in the considered parameters. However, straw mulch @ 4 t ha⁻¹ was proved to be more suitable for improving soil environment than other mulches. Conclusively, straw mulch in combination with zero tillage is recommended for higher wheat production based on better overall performance and also for being organic in nature.

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