

**EFFECT OF ORGANIC MULCHING ON SOIL MOISTURE
CONSERVATION AND YIELD OF WHEAT
(*TRITICUM AESTIVUM* L.)**

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ABSTRACT

A field study was conducted at Nuclear Institute of Agriculture Experimental Farm, Tandojam, to evaluate the effect of different mulches on soil moisture and yield of wheat. Five types of organic materials such as wheat straw; mungbean straw, rice husk, farm yard manure and poultry litter were used for mulching. Different mulches were applied at 10 tons ha⁻¹ on 3rd day after 1st irrigation. A control without any mulch material was kept for comparison. The experiment was performed according to the split plot design keeping irrigation treatment in the main plots and mulching in subplots. Three main plots were comprised of three irrigation regimes such as four irrigations with mulches, three irrigations with mulches and two irrigations with mulches. Different mulches conserved the soil moisture content to 16-27% over control. Wheat straw retained maximum soil moisture of 27%, followed by the farm yard manure (24.0%), rice husk (20.0%), mungbean straw (19%) and poultry litter (16.0%), respectively. A non-significant relationship was observed between grain yield and irrigation regimes, but application of different mulches had significant effect on the grain yield. The highest wheat grain yield of 4.22 tons ha⁻¹ was observed in case of mulch with wheat straw, followed by poultry litter (3.92 tons ha⁻¹), farm yard manure (3.75 tons ha⁻¹), rice husk (3.61 tons ha⁻¹) and mungbean straw (3.38 tons ha⁻¹). These findings suggest that wheat straw could be used effectively for mulching to conserve soil moisture and increase crop productivity.

Keywords: Irrigations, organic mulches, soil moisture, wheat yield.

INTRODUCTION

Use of new crop varieties and the adoption of better production technologies have significantly improved agricultural production in the country. However, the increase in human population, changes in the global environment and depletion of land and water resources have created new challenges for the researchers and policy makers. The most alarming challenge is the shortfall in the water availability for irrigation purpose, where it is predicted to be cut off by 25% by

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2010 and 31-33% by the year 2025 (State of Environment Report, 2005; Rana, 2013). This shortfall of water availability would definitely affect the crop production. Irrigated agriculture uses about 97% of available water and provides average 90% of agriculture produce. Accumulative effect of these limiting factors is likely to cause a drastic shortfall of 28 million tons of different food crops in the Pakistan's crop production (PWP, 2001). With all prevailing limitations in crop production, sustainable yield could be achieved by effective and efficient management tactics of land and water resources.

Mulching is considered a comprehensive approach to reduce water loss and water use from soil surface. The Extension Department of Colorado State University reported that mulches can cut off water use by 25 to 50% on surface soil. Any material spread on the surface of soil to protect it from raindrops, solar radiation and evaporation could serve the purpose of mulch. Mulches are used to cover surface of soil nearby crop plants to develop eco-friendly and favorable conditions for maintenance of growth. They significantly affect the soil electrical conductivity, organic matter, nitrogen, phosphorus, potassium content (Khurshid *et al.*, 2006, Pakdel *et al.*, 2013), slower evaporation and reduce water requirement of crop plants (Chawla, 2006; Liu *et al.*, 2009; Collin, 2006; Concord, 2009). Mulching improves soil moisture status and structure of soil (Muhammad *et al.*, 2009), decreases salinity, controls weeds and soil erosion (Concord, 2009; Bu *et al.*, 2002; Kumar and Lal, 2012), and increase the number of fertile tillers, and biomass production of wheat crop (Ahmed *et al.*, 2009). There are various materials which are being used for mulches; these include plastic sheets/films, sawdust, sugarcane trash, rice straw, plant residues, poultry litter, paper pellets and city garbage, etc. However, the use of plastic sheets and rice straw have been more common (Bu *et al.*, 2002; Li, 2003; Berglund *et al.*, 2006). The wheat grain yield is generally increased by increase in soil moisture content due to reduction of surface evaporation. Mulching resulted in 17% increase in grain yield and 19% in above ground biomass (Tolk *et al.*, 1999).

The present study was designed to evaluate the effectiveness of different mulching materials and irrigation on wheat yield and soil moisture contents during the crop growth

MATERIALS AND METHODS

The study was carried out at Experimental Farm of Nuclear Institute of Agriculture, Tandojam, Sindh, Pakistan. This location is situated in a semi-arid to arid climatic area with long-term annual mean air temperature of 26 °C, annual mean precipitation of 30-40 mm. Precipitation during the wheat growth period was 50 mm. The texture of soil at 20 cm depth was clay loam with bulk density of 1.4g cm⁻³; soil EC of 1.2 dS m⁻¹ and pH of 7.7. The organic matter was determined by Black and Walkley method (Walkley, 1947), Kjeldhal N, available Olsen-P and AB-DTPA extractable K contents were 0.69%, 0.035%, 9.5 mg kg⁻¹ and 210 mg kg⁻¹, respectively (Jackson, 1973). Experiment was performed with six treatments including no mulching (control), and mulching with wheat straw, mungbean straw, rice husk, farm yard manure and poultry litter. Mulches were

applied at the rate of 10 tons ha⁻¹ after 3-4 days of 1st irrigation, this amount of mulches was enough to cover the surface area of soil. The treatments were arranged according to split plot design with irrigation forming the main plots and mulching, the subplots (3 m x 5 m). Main plots were used for the three irrigation regimes, i) normal irrigations (4) with mulches (common practice of irrigation), ii) 3 irrigations with mulches and 2 irrigations with mulches.

The soil was sodden before sowing of wheat crop. All the irrigations were applied at the interval of 21 days. The fertilizer phosphorus (TSP) at 90 kg P₂O₅ ha⁻¹ and potassium (SOP) 60 kg K₂O ha⁻¹ was applied as a basal dose while nitrogen (urea) 120 kg N ha⁻¹ into two splits one half at sowing and other half at tillering stage to fulfill the nutritional requirement of the crop. Wheat variety "Sarsabz" was sown at rate of 150 kg ha⁻¹. Weeds were manually removed twice from the experimental area. Soil sampling was carried out with soil auger when soil moisture was at field capacity level to crop use at an interval of 10 days of irrigation at 0-20 cm depths from each plot for moisture determination. Soil moisture was determined using the following formula:

$$\text{Soil moisture (\%)} = \frac{\text{Wet weight} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100$$

The meteorological data regarding rainfall (mm), humidity (%), temperature (°C) and evaporation (mm) were recorded.

Data analysis

The data recorded was analyzed for LSD after ANOVA by using statistical software, Statistix® Version 8.1, Analytical Software, Inc. Tallahassee, FL, USA.

RESULTS AND DISCUSSION

Temperature

The meteorological data regarding temperature during the growth period of wheat crop is presented in Fig. 1. The minimum temperature was 10°C in the month of December and 8°C in the month of January; whereas maximum temperature was documented in the months of October (36°C) and March (32°C). Environmental temperature is a key parameter to change the climatic and soil conditions for wheat crop. Generally, daytime changes in temperature have important consideration during Rabi season. Mostly, in cold season diurnal temperature fluctuation touched to 32°C to 35°C rests at 10°C to 15°C at night (Fig. 1). In many cases, daytime temperature changes check the crop growth. Therefore, mulches insulate and protect soil direct sunlight and prevent it from hard setting and toughness by controlling rate of evaporation (Tolk *et al.*, 1999). Therefore, the soil that is covered by mulch remains cooler as compared to non-mulched soil because of minimal temperature changes. The less evaporation and normal soil temperature develop more favorable conditions for the crop growth. (Wood *et al.*, 2008).

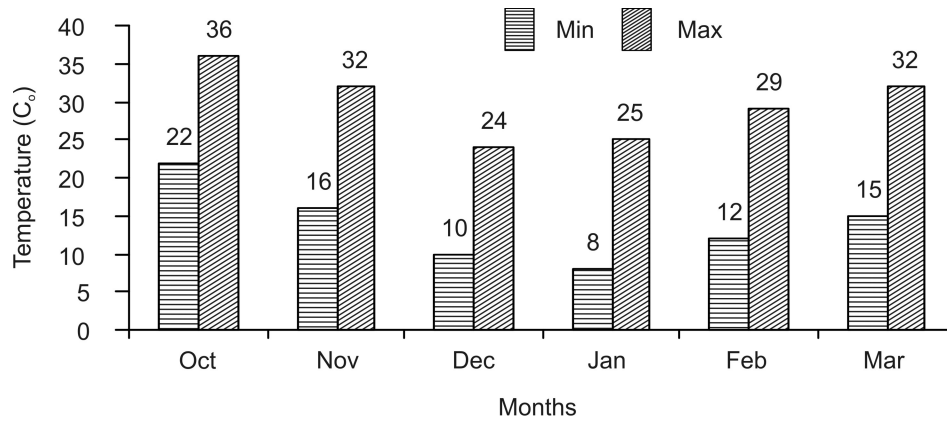


Figure 1. Mean Temperature (°C) recorded during the wheat growth period.

Relative humidity

Humidity (%) during the wheat growth period varied in different months (Fig. 2). Maximum humidity (74%) was recorded in the month of October and December while minimum in March (64%), respectively. The occurrence of humidity in the form of dew and mist is necessary for the survival and normal growth of wheat crop. The amount of water either stored on leaf surface in dew form can be utilized by crop plants by stomata or fall on soil surface which contributes to soil moisture. The soil water is evaporated into air when its concentration is higher than air. In contrast, the soil water is condensed and dew leads to maximization of humidity in air, which reduces the evaporation.

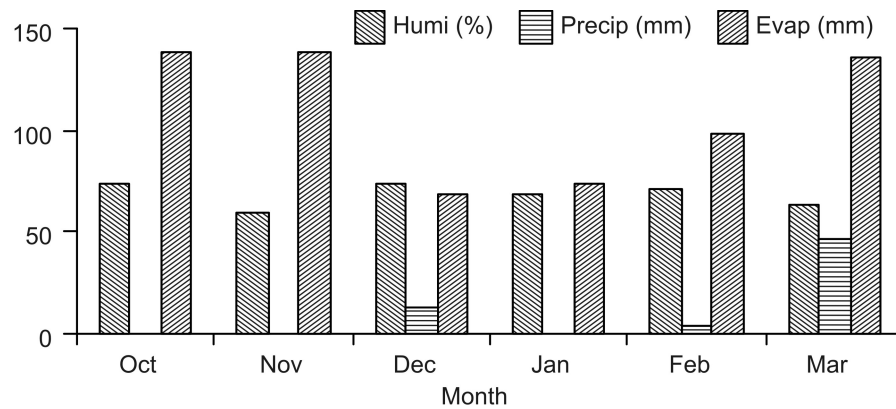


Figure 2. Mean Relative humidity (%), precipitation (mm) and evaporation (mm).

Precipitation

Precipitation (mm) during the winter wheat growing period was recorded very minimal as shown in Fig. 2. The recorded data indicates that slight rainfall (3.5

mm) was observed in February and relatively good rainfall (46 mm) in March. The rainfall (precipitation) that occurs in different locations which either intercepts on plant leaves or directly falls on soil surface moves downward into soil as subsurface or ground water flow. Tanner and Sinclair (1983) reported that the locations that have more tendencies for improving water use efficiency (WUE) are those where evapo-transpiration rate is small.

Evaporation

The meteorological data pertaining to evaporation (Fig. 2) depicted the maximum evaporation in the months of October (139 mm) and minimum in the month of December (68 mm), respectively. There is positive relationship between evaporation and soil moisture without intervention of time. The evaporation is chief factor for soil water balance that can be assumed by temperature and humidity. Mulches lower soil temperatures indirectly by evaporation (Wood *et al.*, 2008). Mulches used on soil surface can affect the severity of stormy exchange between environment and soil moisture, ultimately which reduce the evaporation and enhance the water utilization effectively (Dong and Qian, 2002; Li *et al.*, 2000b).

Soil moisture content (%)

Before 1st irrigation

Soil water content (%) of all mulches and irrigation regimes (three) was more or less similar and non-significant before application of 1st irrigation (Fig. 3).

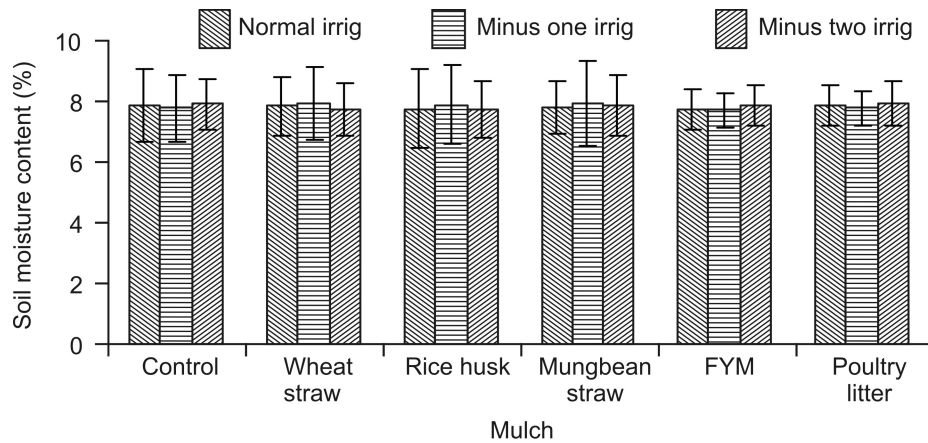


Figure 3. Moisture content (%) as influenced by different mulches under three irrigation regimes before 1st irrigation.

Before 2nd irrigation

The data regarding soil moisture content (%) in various sub-plots showed the variable impact in response to different mulches before the application of 2nd

irrigation. Wheat straw conserved the highest moisture content of 21.8%, followed by farm yard manure (20.8%), mungbean straw (19.2%), rice husk (19.1%) and poultry litter (18.3%), respectively. Normal irrigation illustrated the significant response as compared with minus one and minus two irrigations (Fig. 4).

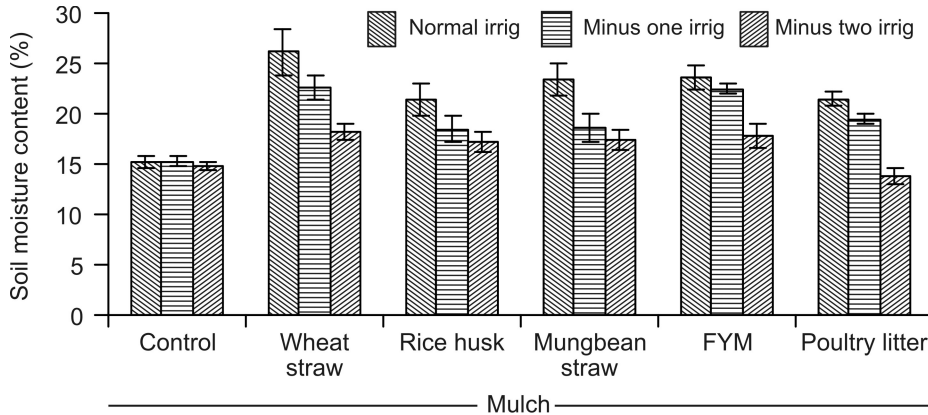


Figure 4. Moisture content (%) as influenced by different mulches under three irrigation regimes before 2nd irrigation.

Before 3rd irrigation

The data revealed that normal irrigation and the irrigation plot where single irrigation was reduced had parallel feed back for moisture conservation before 3rd irrigation but significantly varied from minus two irrigation plot (Fig. 5). Normal irrigation plot showed maximum moisture content of 27.5% and lowest of 18.5%. Wheat straw conserved average moisture content of 29.8% in all three irrigation regimes followed by farm yard manure (28.3%), mungbean straw (27.2%), rice husk (27.0%) and poultry litter (26.5%), respectively (Fig. 5).

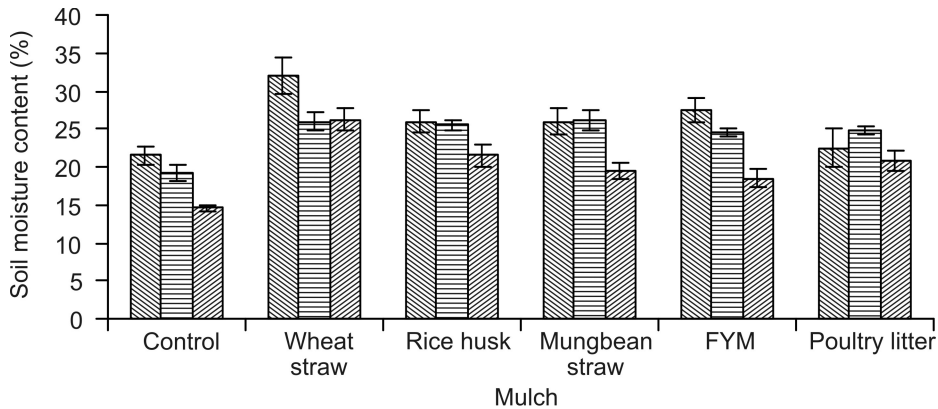


Figure 5. Moisture content (%) influenced by different mulches under three irrigation regimes before 3rd irrigation.

Before 4th irrigation

The data recorded to monitor the response of different mulches and irrigations demonstrated the variable impact for moisture conservation before application of 4th irrigation. The data further revealed that normal irrigation plot scrutinized the highest moisture content of 33.5% and lowest of 18.2% in irrigation regime where two irrigations were reduced. Wheat straw conserved average moisture content of 27.6% in all three irrigation regimes; followed by farm yard manure (26.4%), rice husk (25.6%) mungbean straw (24.3%), and poultry liter (22.7%), respectively (Fig. 6).

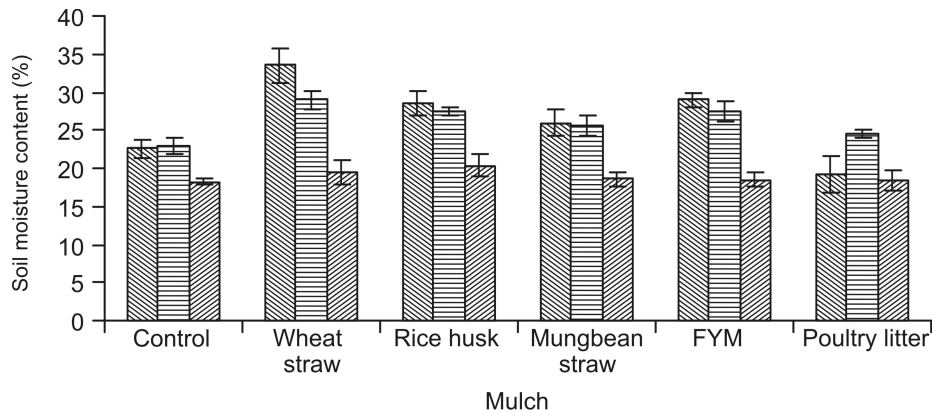


Figure 6. Moisture content (%) influenced by different mulches under three irrigation regimes before 4th irrigation.

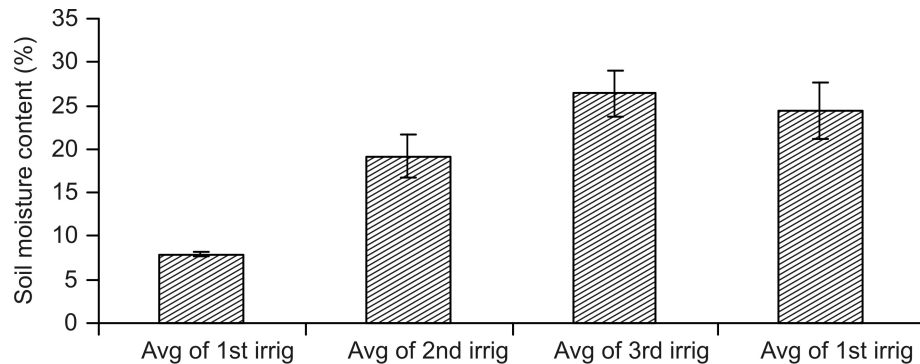


Figure 7. Overall moisture content (%) influenced by different mulches.

The data regarding overall performance of irrigation regimes (main plots) and different mulches (sub-plots) revealed that the maximum moisture content (average of four, before 1st, 2nd, 3rd and 4th irrigation) of 26.4% was monitored in irrigation plot, where soil samples were taken before 3rd irrigation. The differences significantly varied from other treatments, followed by before 4th irrigation (24.4%), before 2nd irrigation (19.2%) and before 1st irrigation (7.9%),

respectively (Fig. 7). Different mulches performed in diverse manner which conserved the soil moisture content showing 16-27% increase over control (Fig. 8). Wheat straw retained 27.0%; moisture followed by farm yard manure (24.0%), rice husk (20.0%), mungbean straw (19.0%) and poultry litter (16.0%), respectively.

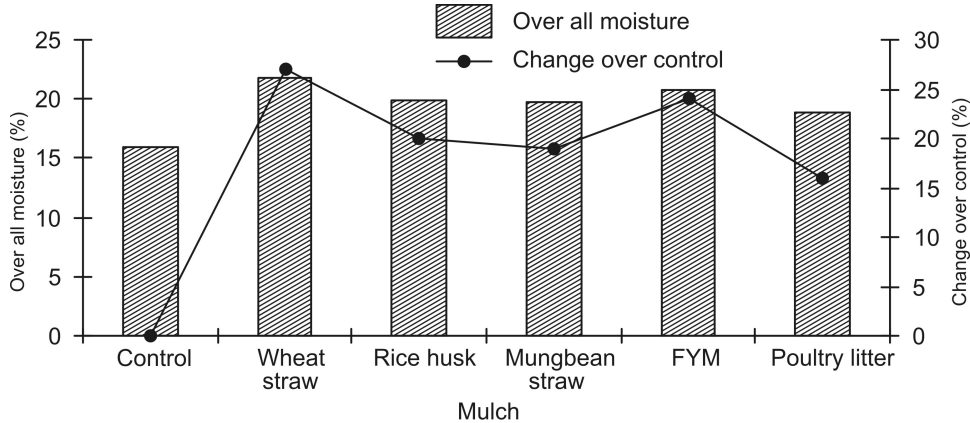


Figure 8. Change in moisture content (%) over control by different mulches under three irrigation regimes.

In this study different irrigation regimes showed the non-significant relationship with each other in response to application of various biological mulches. It may be due to mulches were used as a layer on soil surface which reduced the direct sun stroke on soil surface and rate of evaporation, hence, the soil moisture was retained for long time in soil. Similar results were observed by Gill (1979), who reported that the interaction between irrigation levels (regimes) was non-significant. The prime effect of mulching is reduction in soil temperature which varies by thickness and type of mulch. The results indicated the maximum moisture over control recorded in response to wheat straw mulch (10 tons ha⁻¹), which varied significantly than other mulches (Fig. 8). The results are in conformity with the findings of Chaudhry *et al.* (1994), who reported that soil moisture increased when straw mulch was applied at rate of 6 tons ha⁻¹. The experiment showed more soil moisture in mulch treated top soil than non-mulched soil at initial stage, which decreased as the plant canopy increased (Yaung *et al.*, 2006).

Crop harvest

Biological yield

The findings pertaining to biological yield of wheat showed the non-significant variation in all irrigation regimes (Fig. 9). Different mulches responded parallel to each other except control for biological harvests (Fig. 10). Poultry manure produced the highest biomass of 11.48 tons ha⁻¹, while mungbean straw lowest

one (10.30 tons ha⁻¹). The biological yield of wheat revealed the non-significant response of irrigation regimes. The biological yield represents the total biomass of wheat (vegetative + grain), so it doesn't change with little variation. The results are in conformity with the findings of Gill (1979), who reported that the interaction between irrigation levels (regimes) for biomass was non-significant.

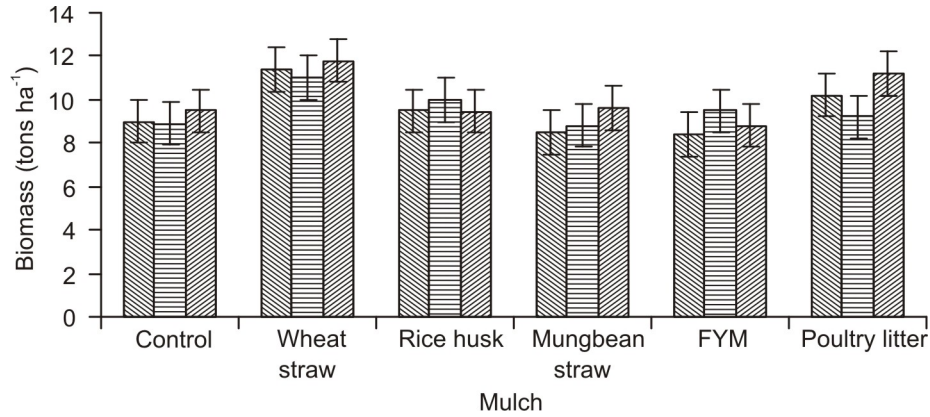


Figure 9. Biological yield of three irrigation regimes as influenced by different mulches.

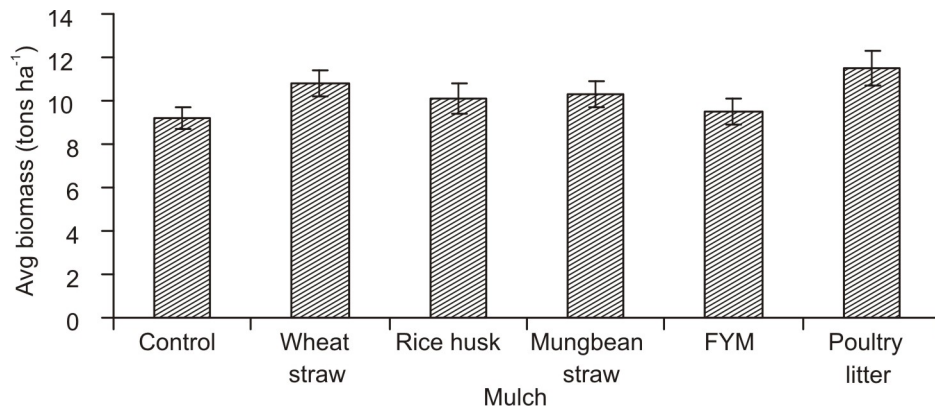


Figure 10. Average biological yield (tons/ha) of wheat as affected by different mulches.

Grain yield

The data regarding wheat grain yield depicted the non-significant relationship for all irrigations regimes under various sub-plots (Fig. 11), but significantly varied by application of different mulches (Fig. 12). Wheat straw mulch produced the highest wheat grain yield of 4.22 tons ha⁻¹ followed by poultry litter (3.92 tons ha⁻¹), farm yard manure (3.75 tons ha⁻¹), rice husk (3.61 tons ha⁻¹) and mungbean straw (3.38 tons ha⁻¹).

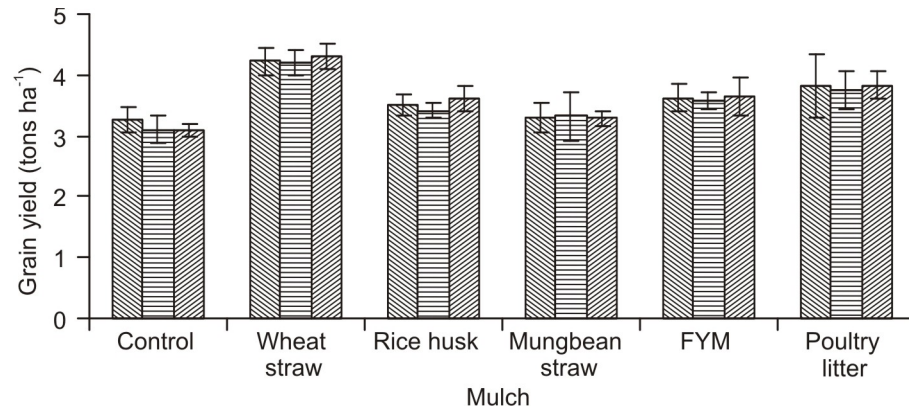


Figure 11. Wheat grain yield (tons ha⁻¹) of three irrigation regimes as affected by different mulches.

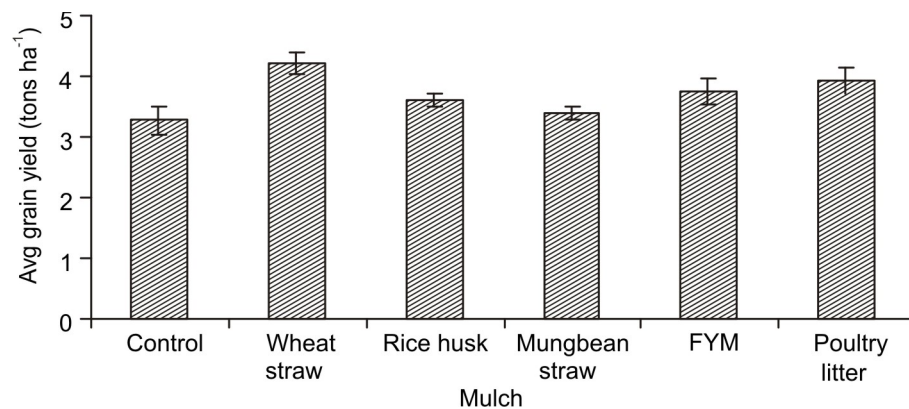


Figure 12. Average wheat grain yield (tons ha⁻¹) produced under by different mulches.

The wheat grain yield depicted the non-significant relationship for all irrigation regimes under various sub-plots (Fig. 11), but significantly varied by application of different mulches (Fig. 12). The results are in agreement with the findings of Sharma and Acharya (2000) and Singh *et al.* (2010) who stated that corresponding values of moisture conserved with different mulches produced significantly higher wheat grain yield (0.58-2.96 Mg ha⁻¹) than control (0.36-1.78 Mg ha⁻¹). Zamir *et al.* (2013) also reported similar findings and stated that the wheat straw mulch gave highest grain yield (6.33 t ha⁻¹), followed by sawdust (4.92 t ha⁻¹).

CONCLUSION

Different mulch materials showed variable effect on the conservation of soil moisture. Wheat straw could retain maximum soil moisture. Similarly, it was effective mulch material in improving wheat yield compared to other mulching

materials, suggesting its use for improving agricultural production by conserving soil moisture.

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REFERENCES

- Ahmed, Z. I., M. Ansar, M. Iqbal and N. M. Minhas. 2009. Effect of different planting geometry and wheat straw mulch on performance of wheat under rainfed conditions of Pothowar. *Pakistan J. Agric. Res.*, 22 (3.4): 112-115.
- Berglund, R., B. Svensson and U. Gertsson. 2006. Impact of plastic mulch and poultry manure on plant establishment in organic strawberry production. *J. Plant Nutr.*, 29 (1):103-112.
- Bu, Y. S., H. L., Shao and J. C. Wang. 2002. Effects of different mulch materials on corn seeding growth and soil nutrients' contents and distributions. *J. Soil Water Cons.*, 16 (3): 40-42 (Chinese).
- Chaudhry, M. A., S. Ali and I. Hussain. 1994. Effect of different rates of mulches on moisture conservation and yield of corn under rain-fed conditions in Rawalpindi. *Pakistan. J. Soil Sci.*, 9 (3-4).
- Chawla S. L. 2006. Effect of irrigation regimes and mulching on vegetative growth, quality and yield of flowers of African marigold. Ph.D. Thesis, Department of Horticulture, Maharana Pratap University of Agriculture and Technology, Udaipur.
- Collin, M. 2006. Mulch to conserve water. Daily Camera and Boulder Publishing, LLC.
- Concord, M. 2009. Concord Water Conservation - Mulch Coupons. California.
- Dong, Z. Y. and B. F. Qian. 2002. Field investigation on effects of wheat-straw/corn-stalk mulch on ecological environment of upland crop farmland. *J. Zhejiang Univ. Sci.*, 3 (2): 209-215.
- Gill, M. L. 1979. Irrigation efficiency of corn on high water table soil. M.Sc. Thesis, Deptt. of Agronomy Univ. of Agric. Faisalabad.
- Jackson, M. L. 1973. Soil Chemical Analysis. Prentice hall of India, New Delhi. pp.498.

Khurshid, K., M. Iqbal, M. S. Arif and A. Nawaz. 2006. Effect of tillage and mulch on soil physical properties and growth of maize. *Internat. J. Agric. and Biol.*, 8: 593-596.

Kumar, S. D. and B. R. Lal. 2012. Effect of mulching on crop production under rainfed condition: A Review. *Int. J. Res. Chemistry and Environ.*, 2 (2): 8-20.

Li, X.J., Z. G. Zhang and Y. C. Li. 2000b. Effects of straw mulch on water status in saline soil. *Chin. J. Soil Sci.*, 30 (4): 176-177.

Li, X.Y. 2003. Gravel-sand mulch for soil and water conservation in the semiarid loess region of northwest China. *Catena*, 52 (2):105-127.

Liu J., Xu S. A., Zhou G. Y. and Lu H. H., 2009. Effects of transplanting multi-cropping spring maize with plastic film mulching on the ecological effect, plant growth and grain yield. *J. Hubei Agric. Coll.*, 2: 100-102.

Muhammad, A. P., I. Muhammad, S. Khuram and Anwar-ul-Hassan. 2009. Effect of mulch on soil physical properties and NPK concentration in maize (*Zea mays*) shoots under two tillage system. *Int. J. Agric. and Biol.*, 11: 120-124.

Pakdel, P., A. Tehranifar, H. Nemati, A. Lakzian and M. Kharrazi., 2013. Effect of different mulching materials on soil properties under semi-arid conditions in northeastern Iran. *Wudpecker, J. Agric. Res.*, 2 (3): 080-085.

PWP. 2001. Supplement to the Framework For Action (FFA) For Achieving the Pakistan Water Vision 2025. Pakistan Water Partnership.

Rana, I. 2013. Water shortage in Pakistan will increase to 31% of people's needs by 2025 and this underlines the need for some tangible steps, including water usage charges and building of storages, to cope with the problem. *The express Tribune*, Saturday, April 26, 2014.

Sharma, P. K. and C. L. Acharya. 2000. Carry-over of residual soil moisture with mulching and conservation tillage practices for sowing of rainfed wheat (*Triticum aestivum* L.) in north-west India Agricultural Research Information Centre. *Soil Tillage Res.*, 57: 43-52.

Singh, B., E. Humphreys, P. L. Eberbach, A. Katupitiva, Y. Singh and S. S. Kukal, 2010. Growth, yield and water productivity of zero till wheat as affected by rice straw mulch and irrigation schedule. *Field Crops Res.*, 121 (2): 209-225

State of the Environment Report Draft. 2005. Ministry of Environment, Government of Pakistan.

Tanner, C. B., and T. R. Sinclair. 1983. Efficient water use in crop production: Research or research? p. 1-27. *In*: H.M. Taylor *et al.* (ed.) Limitations to efficient water use in crop production. ASA, Madison, WI.

Tolk, J. A., T. A. Hawell and S. R. Evett. 1999. Effect of mulch, irrigation and soil type on water use and yield of maize. *Soil Till. Res.*, 50: 137-147.

Walkley, A. 1947. A Critical examination of Rapid Method for Determining Organic Carbon in Soil: Effect of various digestion conditions of organic soil constituents. *Soil Sci.*, 63: 251-263.

Wood, C. W., H. Brenda Kipling, S. Balkcom, J. Kemble and D. Shannon, 2008. High biomass cover crops and organic mulch effects on soil moisture and weed distribution during collard production. Dept. of Agronomy and Soils, Auburn University.

Yaung, Y., L. Xiao-jing, L. I. Wei-qiang and L. I. Cun-zhen, 2006. Effect of different mulch materials on winter wheat production in desalinized soil in Heilonggang region of North China. Chinese Academy of Sciences, Beijing, 100039.

Zamir, M. S. I., H. M. R. Javeed, W. Ahmed, A. U. H. Ahmed, N. Sarwar, M. Shehzad, M. A. Sarwar and S. Iqbal..2013. Effect of tillage and organic mulches on growth, yield and quality of autumn planted maize (*Zea mays* L.) and soil physical properties. *Cercetări Agronomice în Moldova*, XLVI (2): 154.

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