IMPACT OF ORGANIC MULCHES ON WEED DYNAMICS AND PRODUCTIVITY OF RAINFED WHEAT (*Triticum aestivum*L.)

Ahsan Aziz[1*], Amna Khan[1], Muhammad Asif[1], Muhammad Ather Nadeem[1], Muhammad Ashraf[2], Ali Raza[1], Muhammad Mansoor Javaid[1], Tasawer Abbas[3], Naeem Akhtar[4], Saba Munir[3]

DOI: https://doi.org/10.28941/pjwsr.v28i1.942

ABSTRACT

Wheat is a widely grown cereal crop under rain-fed conditions of semi-arid areas of the world including Pakistan. Unfortunately, its yield remains low due to heavy weed infestation and scarce moisture supply in root zone from erratic rainfall. Therefore, a field experiment was conducted to observe the influence of different organic mulches on the soil moisture, weeds, growth and yield of wheat crop. Four organic mulches i.e. wheat straw, saw dust, rice straw and rice husk were applied up to 2 inches surface layer between the rows of wheat crop. Application of wheat straw mulch conserved maximum soil moisture (72.3%) at 0-15cm depth six weeks after sowing and caused maximum weed suppression with 81.17% weed control efficiency and 63.70% weed control index as compared to non-mulched (control). Maximum plant height (70.8cm), productive tillers (137.33 m^{-2}), grain weight per spike (2.37g), grains per spike (52.3), 1000-grain weight (50.66 g), biological yield (9393.9 kg ha^{-1}), grain yield (3665.6 kg ha^{-1}), harvest index (38.60%) and benefit cost ratio (1.69) were observed in rain-fed wheat crop treated with wheat straw mulch. Wheat crop total rainfall use efficiency followed the order of wheat straw > rice straw > saw dust> rice husk> control. The highest weed density and dry weight while lowest soil moisture and grain yield were recorded with no mulch and rice husk treatments.

Keywords: Organic mulches, rain-fed wheat, weeds, water conservation, economic return

Citation: Aziz, A., A. Khan, M.Asif, M.A. Nadeem, M. Ashraf, A. Raza, M.M. Javaid, T. Abbas, N. Akhtar, S. Munir. 2022. Impact of organic mulches on weed dynamics and productivity of rainfed wheat (T*riticum aestivum* L.). Pak. J. Weed Sci. Res., 28(1): 1-17.

[1]Department of Agronomy, College of Agriculture, University of Sargodha 40100, Sargodha, Pakistan
[2]Department of Soil Science, Bahauddin Zakariya University, Multan, Pakistan.
[3]Inservice Agricultural Training Institute, 5[th]Rasala Sargodha 40100, Sargodha, Pakistan
[4]Department of Plant Breeding and Genetics, College of Agriculture, University of Sargodha,Sargodha, Pakistan
[*]**Corresponding author's email:** ahsan.aziz@uos.edu.pk

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a one of the major cereal crop and primary food source of more than 35% of world population. It fulfils around 50% caloric and more than 20% protein requirement of people in poor nations (Shiferaw *et al.,* 2013). It is widely planted crop worldwide and ranked third after maize and rice with annual production of 600 million tonnes (MT) (Asseng *et al.,* 2011). In Pakistan, wheat is cultivated on 9.2 million hectares (Mha) including 2.2 Mha area grown under rain-fed conditions. Pakistan's annual wheat production is 25.49 MT with 10% contribution in value-added and 2.1% in gross domestic product (GDP) (Govt. of Pakistan, 2018). Considering the importance of wheat crop, it is crucial to enhance wheat production on sustainable basis under irrigated as well as rain-fed conditions to cope with issue of food security and to fulfil dietary requirements of fast-growing population.

In coming decades, change in rainfall pattern and intensity due to climate change are supposed to increase rain-fed areas in various countries worldwide including Pakistan (Borken and Matzner, 2009). Increase in drought periods in various locations is also expected (Field, 2012). In rain-fed areas, the temporal pattern of precipitation is much erratic, thus ensuring moisture availability is important factor to sustain successful crop production (Sun *et al.,* 2017). Among various strategies used to enhance water use efficiency in rain-fed conditions, use of organic mulches has supreme importance. Due to soil covering effect, mulches effectively reduce evaporation of water from soil surface (Ramakrishna *et al.,* 2006; Subhan *et al*., 2017). Hence, uniform and better supply of water reduces the need of irrigation and mitigates suppressive effects of water stress on crop plants. Alternatively, evaporation of water from bare soil surface may cause 25-50% loss of total available water (Hu *et al.,* 1995). Mulching with maize crop straw in wheat helped to reduce evaporation loses up to 40% (Chen *et al.,* 2007). Zhang *et al.* (2009) revealed that mulching with straw of wheat was effective in reducing water losses with positive effect on wheat grain yield.

In addition to reduction in evaporation losses, mulches also help to manage weeds. In recent decades, long term use of chemicals to control unwanted plants in crops has been challenged by fast development of herbicide resistance in weeds, environment issues and various hazards to human and livestock health. Herbicide resistance in *Phalaris minor* Retz. and *Avena fatua* L. are reported in wheat fields in various locations in the Punjab, Pakistan (Abbas *et al.,* 2017; Raza *et al.,* 2021). Therefore, identification, optimization and efficacy evaluation of organic weed control methods such as plant mulches is important to ensure sustainable weed control. Mulches control weeds through different ways, for example by providing physical cover, reducing light penetration, changing temperature and by releasing allelechemicals in the rhizosphere (Zhang *et al.,* 2009). Mulches act as physical obstacles in the emergence of weeds (Ahmad *et al.,* 2015); however, when the organic mulches decompose, they quickly come out the soil surface. Some organic mulch also acts as the allelopathic and releases some toxic chemicals which are helpful for the reduction of weeds (Ahmad *et al.,* 2020). The use of crop straws as mulch material is one of the natural ways to control weeds in field crops. Various studies documented that straw mulches were effective to control weeds efficiently with additional benefits of improved soil structure and fertility (Grassbaugh *et al.,* 2004; Khan *et al.,* 2012). Abbas *et al.* (2018a) and Afridi and Khan (2014) reported that straw mulches of various crops like rice were effective in order to suppress weeds in wheat fields.

Considering the importance of wheat and its extensive use as food source the sustainable wheat production is essential to ensure food security. In recent years, scientists have identified various problems that have been occurred due to extensive use of synthetic herbicides. Furthermore, significant decrease has been noticed in availability of irrigation water for crop production in various countries worldwide including Pakistan. Under current situation the identification, evaluation and optimization of natural alternatives to chemical weed control has prime importance. Organic mulches e.g. crop straw, have various benefits including weed control, soil moisture conservation, soil fertility enhancement and improvement of soil structure. Use of crop straw is also less costly and natural way to ensure the sustainability of wheat. Hence, the present study was undertaken to assess the weed control potential of various types of organic mulches in wheat and to check the effect of organic mulches on soil moisture conservation, wheat growth and yield under rain-fed conditions.

MATERIALS AND METHODS

Experimental site description

An experiment was accomplished in the Research area, College of Agriculture, University of Sargodha, Punjab, Pakistan to investigate the impact of natural mulches on soil moisture, weed sand wheat growth and yield under rain-fed conditions. The climate of experimental site was sub-tropical (32.08° N latitude, 72.67° E longitude) of the central Punjab, Pakistan. Daily rainfall, relative humidity, temperature during crop growth period is presented in Fig.1. Soil samples were collected from top 20cm layer of soil with soil auger. These samples were dried in warm air, sieved through 2mm mesh and examined for various physico-chemical properties. Soil was loamy in texture with pH 7.87, organic matter 0.57%, sodium adsorption ratio 6.13 $(mmolL^{-1})^{1/2}$, electrical conductivity 0.31 dS m^{-1}, $CaCO_3$ 11.26%, cation exchange capacity 16.2 Cmole (+) kg^{-1}, total nitrogen 0.37%, available phosphorous 9.45 mg kg^{-1} and extractable potassium 125 mg kg^{-1}.

Experimental details

The proposed experiment was performed using randomized complete block design (RCBD) repeating each treatment four times. Every experimental unit (subplot) was comprised of 4m×2m area. There were four different types of mulches (rice straw, wheat straw, saw dust and rice husk) and no mulch was used as control treatment. Soil was well prepared, with three cultivation and planking. Wheat variety "Faisalabad-2008" was used as a test crop. Single row hand drill was used to plant wheat at 23cm row to row distance using a seeding rate of 100 kg ha^{-1}. At sowing time N and P @ 55 kg ha^{-1} each was incorporated in soil in the form of urea and Di-ammonium Phosphate, respectively. Potassium was not applied at all due to its sufficient inherent amount in the soil.

The mulching materials were collected from different sources i.e. farmer's field, rice Sheller, sawmill and added up to 2 inches' surface layer between the rows of wheat crop. Uniform agronomic practices were carried out except those under study.

Weed density was recorded at fifteen weeks after start of weed emergence by using standard formula:

$$\text{Weed density} = \frac{\text{Number of weeds}}{\text{Area (m2)}}$$

The efficiency of mulching material to control weeds was computed with formula of Mani *et al.* (1973) as described below

$$\text{Weed control efficiency} = \frac{weed\ population\ in\ control\ - weed\ population\ in\ treated\ plot}{weed\ population\ in\ control} \times 100$$

The fresh and dry biomass of collected weeds samples were recorded by using their standard procedures and weed control index was calculated by adopting the formulae of Misra and Tosh (1979) as described below

$$\text{Weed control index (WCI)} = \frac{weed\ dry\ weight\ in\ control - weed\ dry\ weight\ in\ treated\ plot}{weed\ dry\ weight\ in\ control} \times 100$$

Similarly, wheat growth and yield parameters including plant height, productive and unproductive tillers, spike length, number of spikelets on each spike, grain numbers, average grain weight and 1000-grain weight were recorded by using their standard protocols.

The biological and grain yields of sundried samples were recorded for each experimental unit by weighing through electronic balance and changed into $Kgha^{-1}$. While, harvest index was calculated with formula of Beadle (1987):

$$\text{Harvest index} = \frac{Grain\ yield}{biological\ yield} \times 100$$

Total rainfall use efficiency was determined with formula by Devasenapathy *et al.* (2008):

$$\text{Total rainfall use efficiency} = \frac{Grain\ yield}{Total\ rainfall\ received\ during\ the\ cropping\ season\ (mm)}$$

Soil moisture contents were determined by using the formula of Burden (2005):

$$\text{Soil moisture content} = \frac{wet\ sample\ weight - dry\ sample\ weight}{dry\ sample\ weight} \times 100$$

Economic analysis was performed to determine the impact of various mulches on net income by using the formula (CIMMYT, 1988).

Net income = Gross benefit - Gross investment

Statistical analysis

The recorded data were analysed by using Fisher's Analysis of Variance (ANOVA) technique on MSTAT Statistical Package (Russel and Eisensmith, 1983). The treatment means were compared at 5% level of significance using Tukey's HSD (honestly significant difference) test (Steel *et al.,* 1997).

RESULTSAND DISCUSSION

Weed growth characteristics

Weed density (m^{-2})

Data analysis showed that the impact of mulching on weed density was significant (Table. 1). Maximum weed density was detected in control plots. Weed density in rice straw (12.33 m^{-2}) treated plots was statistically similar with wheat saw dust (10.66 m^{-2}) mulched plots. Least weed density (4.33 m^{-2}) was seen in plots wherever wheat straw mulching was applied. It was possibly because of allelopathic effect and blockage of sunlight which is necessary for the germination of weed seeds. Our outcomes are supported by the findings of previous researchers (Abbas *et al.,* 2018a; Farooq *et al.,* 2019) who found that mulches of various crops including wheat have strong suppressive effect on weed density in different field crops. Khan *et al.* (2007) also found that mulches release many allelochemicals which damage weeds. Maximum weeds present in un-mulched plots were probably due to bare soil. Sensitivity of weeds germination to allelochemicals have been confirmed by various researchers (Farooq *et al.,* 2019; Raza *et al.,* 2019).

Weed control efficiency(%)

Data regarding weed control efficiency (WCE) of various organic mulching materials in wheat crop cultivated under rain-fed conditions is presented in Table 1. Data exhibited that weed control efficiency of different organic mulches was significantly different. Maximum WCE (80.90%) was observed in those plots where rice husk mulching was applied. Among applied organic mulching materials, minimum WCE (46.46%) was recorded in rice straw treated plots which was statistically at par to saw dust (53.21%) treated plots. Maximum weed control efficiency recorded with rice husk was probably due to thorough coverage of soil which inhibited the germination of small seeds of weeds. Findings of this experiment are in line with Batish *et al.* (2007) who observed that weed can be suppressed by mulching. According to

Schonbeck, (1998) mulches have ability to block most of the weeds except few species which could emerge through mulch cover. In addition to physical hindrance mulches of allelopathic crops released phytotoxic compounds that suppress sprouting and seedling development of different weed species (Farooq *et al.,* 2019). Inhibitory effect of mulches was a major factor in providing better weed control efficiency. Previously, conducted related studies revealed that mulches of crops can be potentially used to enhance weed control efficiency as effective alternative of highly unsustainable chemical weed control (Abbas *et al.,* 2018a; Farooq *et al.,* 2019). Furthermore, Abbas *et al.* (2016) revealed that crop mulches were effective to control little seed canary grass, a major weed of wheat crop with positive effect on wheat crop.

Weed fresh biomass (gm^{-2})

Data regarding fresh biomass of weeds growing in rain-fed wheat crop was influenced by different organic mulching (Table. 1). It is obvious from the results that effect of various organic mulching on fresh biomass of weeds was significant. Un-mulched control plots produced more fresh biomass of weeds. Less weed fresh biomass was observed in plots where straw and saw dust mulch was applied. Both were statistically at par. It was followed by rice straw and rice husk mulching that were statistically at par with weed fresh biomass of 11.6gm^{-2} and 10.66 gm^{-2}, respectively. Reduction in weed biomass can be justified on the basis of strong inhibition of weed germination that leads to less weed density and ultimately less weed biomass. Our finding are in conformity with Ramakrishnan *et al.* (2006) who reported a decrease in weed fresh biomass as a result of mulching induced poor weed emergence and survival. Similarly, Abbas *et al.* (2016) revealed a strong reduction in weed biomass after application of crop mulches. Maximum weed fresh biomass noted from control plots was probably due to better weed seed emergence and seedling growth from uncovered as soil coverage by mulching that inhibit the germination of weeds. Current outcomes are reinforced by Abouziena *et al.* (2008) who found that mulching are effective by improving soil health, moisture conservation and weed suppression.

Dry biomass of weeds (gm^{-2})

Data analysis showed that dry biomass of weeds was significantly affected by different mulches (Table. 1). Maximum dry biomass of weeds (13.03 g m^{-2}) was obtained from plots where no mulch was added. Least weed dry biomass was seen from plots wherever wheat straw was applied as mulching treatment. A statistically similar weed dry biomass was achieved from plots wherever saw dust and rice husk were used as mulching material. Highest dry weigh of weed was noted in control that was perhaps due to more weed density as indicated by table 1 and hence produced greater biomass as compared to other mulched plots. The reduction in weed dry biomass was probably due to blockage of direct sunlight which inhibited germination and vegetative growth of weeds. The highest inhibitory influence of wheat straw mulch on dry biomass (gm^{-2}) of weeds found in our experiment are supported by outcomes of Aziz *et al.* (2019) who compared weed control efficiency of various organic mulching materials in lettuce crop. Our results are also supported by Chakra borty *et al.* (2008) who found that different organic residues improve soil moisture and suppresses weed growth. Similarly, our results are also in conformity with the observations of Abbas *et al.* (2018a) who stated that organic mulching decrease soil temperature and suppress weed growth. Our findings are also supported by Economou *et al.*(2002) who figured out that organic mulching is an effective weed control technique in organic agriculture. Less weed dry biomasses a result of allelopathic crop mulches application is justified by previous researchers as Farooq *et al.* (2019), reviewed that allelopathic mulches including mulches of rice and wheat are operative in supressing weeds due to their inhibitory impact on weed germination, density and growth. In line with this Abbas *et al.* (2016), reported that crop mulches can be effectively used to reduce biomass of *P. minor* in wheat crop.

Weed control index (%)

Data regarding weed control index showed that the impact of mulching materials on weed control index was statistically significant (Table 1). Wheat straw treated plots showed maximum weed control index (62.23%). It was probably due to low moisture contents in un-mulched bare soil because when moisture stress occur crops and weeds compete for it. As allelopathic mulches were found to reduce weed biomass they enhance the weed control index accordingly. Previous studies revealed that reduction in dry biomass after application of allelopathic crop mulches enhanced weed control index (Abbas *et al.,* 2018a). However, wise application of mulch at proper dose is essential to achieve required results as low doses of mulching materials were found to increase weed growth and biomass (Abbas *et al.,* 2018b). Farooq *et al.* (2019) also concluded that use of allelopathy through application of allelopathic crop mulches is potential alternative of non-sustainable chemical weed control.

Yield and yield traits of wheat

Plant height (cm)

Plant height of rain-fed wheat as influenced by the application of various mulching materials is given in Table. 2. It is clear from results that the influence of different mulching materials on plant height was significant at $p \leq 0.05$. The height of wheat plants grown in plants treated with wheat straw mulch was maximum (70.8 cm). It was followed by the plants treated with rice straw (60.3 cm) which was statistically similar with saw dust (57.3 cm) and rice husk (60.0 cm) treated plants. The minimum (53.76 cm) plant height was recorded from wheat plants grown without mulching. Maximum plant height in wheat straw treated plots was perhaps because of better weed suppression and moisture conservation as compared to other mulch treatments. High soil moisture contents and less weed infestation in wheat straw mulch treated plots enabled wheat plants to absorb more nutrients and water which in turn resulted in more dry matter production and taller plants. Different effect of organic mulches on wheat plant height found in our study is in conformity with Teame *et al.* (2017) who found that the application of sesame straw mulch caused a significant rise in sesame plant height than sorghum and sudan grass mulch. The minimum wheat plant height observed in control plots was probably due to poor soil moisture status and excessive weed growth due to absence of any coverage on soil surface. Teame *et al.* (2017) also recorded lowest crop plant height from untreated control plots.

Productive tillers (m^{-2})

The results about influence of different organic mulching on productive tillers of rain-fed wheat are shown in Table 2 which depicts that these were significantly varied. Maximum productive tillers per unit area were recorded in those plot where wheat residues mulching was applied. Least productive tillers were seen in plots with no mulch applied which was statistically similar to plot where rice husk was used as organic mulching material. Maximum productive tillers recorded from wheat straw treated plots were probably due to reduction of fluctuation in soil temperature, increased soil moisture and low weed density which promoted survival of more productive tillers. Our results are supported by Misra (1996) who stated that productive tillers were meaningfully increased due to mulching. The results of this study are also similar to findings of Aziz *et al.* (2009) they documented that number of spike containing tillers was meaningfully reduced by increasing weed (*Galium aparine*) density.

Unproductive tillers (m^{-2})

Data showed that effect of different organic mulching on sterile tillers of rain-fed wheat was significant (Table 2). Maximum unproductive tillers were observed in control. Minimum unproductive tillers (8.00 m^{-2}) were recorded from those plots where wheat straw was applied. It was followed by rice straw (17.00 m^{-2}), saw dust (20.66 m^{-2}) and rice husk (16.66 m^{-2}) that were statistically at par mutually. Maximum unproductive tillers observed in control were possibly due to less soil moisture content and high rate of evapotranspiration from bare soil. Minimum unproductive tillers recorded in wheat straw treated plots were probably due to more soil moisture retention capacity of wheat straw. These observations are in accordance with the reports of Mishra (1996) who stated that mulching cause reduction in unproductive tillers. Our findings are conformed by Ahmed *et al.* (2009) that mulching material have ability to increase productive tillers.

Spike length (cm)

Results regarding the impact of organic mulching materials on spike length of wheat are presented in Table 2. The effect of various mulching materials on spike length of rain-fed wheat was significant. Lengthy spikes were observed in plots treated with straw mulch of mature wheat crop. Shorter spikes were recorded from wheat plots grown without any mulching material. Medium and statistically similar spike lengths were from plots treated with rice straw, saw dust and rice husk mulch. It was because of optimum soil temperature, nutrients availability and moisture contents. Lowest spike length observed in un-mulched plots was perhaps due to excessive weed growth and low moisture contents which reduced resource use efficiency of wheat crop and hence poor spike growth. Maximum spike length recorded in plots receiving wheat straw mulch was perhaps due to better smothering of weed by this mulch and consequently more availability of resources for higher photosynthetic rate of rain-fed wheat plants. Previous study conducted by Aziz *et al.* (2009) confirmed that increase in weed density reduced wheat growth. This observed reduction in spike length in un-mulched plots could be due to stronger competitive effect of unrestricted weed growth. These outcomes are in settlement with the findings of Khan *et al.* (2007) who stated reduction in spike length with increase in weed density.

Grain weight per spike(g)

Data pertaining to grains weight per spike presented in Table 2 indicated that it was influenced significantly ($p \leq 0.05$) by the addition of organic mulches. Least grain weight per spike (1.35g) was recorded from wheat plants grown without any mulching. Wheat straw treated plots produced maximum grain weight per spike (2.37g). It was followed by rice straw, saw dust and rice husk treated plots, respectively. The significant variation in seed weight per capsule was also reported by Teame *et al.* (2017) when they compared the effect of different organic mulches in sesame crop. Most probably the favourable and modified root zone environment (Hage, 1993) in mulched plots resulted in more grain weight of each spike. Excessive grain weight of each spike produced in wheat straw treated plots may also be due to less weed density as a result of this treatment and this argument is supported by Khan *et al.* (2007) who observed reduction in grain weight per spike because of surge in weed density. According to Economou *et al.* (2002) some weeds are more competitive under moisture stress conditions and resultantly they reduce crop yield which in accordance with our results of lower grain weight per spike in un-mulched control plots having more weeds.

Grains per spike

Data pertaining to grain number per spike indicated that it was influenced significantly ($p \leq 0.05$) by the addition of different organic mulches in wheat grown under rain-fed condition (Table 2). Maximum number of grains per spike

(52.33) were obtained from wheat grown in wheat straw treated plots. It was followed by saw dust, rice husk and rice straw treated plots with 42, 42 and 39 grains per spike, respectively. Un-mulched control plots produced minimum number of grains on each spike (29). Highest number of grains produced in spikes obtained from wheat plants grown in wheat straw mulched plots was because of better weed control and lower loss of water through evapotranspiration due to mulch covered surface of soil. This argument is in harmony with the results of Misra (1996) who observed decrease in evapotranspiration and rise in available water contents in soil with use of mulches. Similar results were also obtained by Al-Amin *et al.* (2017) who recorded maximum no. of grains spike^{-1} (37.64) with straw mulch, although the least (27.37) number of grains spike^{-1} with control treatment. Mulching may have increased chlorophyll content of wheat leaves which resulted in more leave photosynthetic activity and consequently grains numbers on each spike was increased. This has also been reinforced by Al-Amin *et al.* (2017) who observed highest chlorophyll content in straw mulch treated plants.Our outcomes are sustained by Hu *et al.* (1995) who found that mulching can enhance the leaf area, no of grains per spike and no of spikelets per spike and have ability to speed up the life cycle of wheat plant. Control recorded poor results may be due to uncovered soil and soil moisture losses.

Number of spikelets per spike

Data showed that number of spikelets spike^{-1} differed significantly as type of mulching material was changed (Table 2). Maximum number of spikelets spike^{-1} was achieved from wheat straw mulch. It was followed by rice husk, saw dust and rice straw which were statistically similar. Minimum spikelet number spike^{-1} was recorded from wheat plants grown in un-mulched soil. This effect is in accordance with the observations of Wang and Wang (1998) who found that mulching enhanced chlorophyll contents and raised spikelet number spike^{-1}. Previous research conducted by Akter *et al.* (2018) partially support our results as they observed more spikelets spike^{-1} in rice residues mulch treated plots and the least number of average spikelets spike^{-1} in control.

1000-grain weight (g)

The highest 1000-grain weight (50.66 g) was seen in wheat straw mulching, however the least grain weight (38.81g) was noted in un-mulched control plots. A statistically similar grain weight was noted in case of rice husk, rice straw and saw dust mulching. Minimum grain weight noted in plots without mulch treatments was possibly due to less water availability to crop plants due to more evaporation from bare soil and excessive resource competition among weeds and crop plants due to unrestricted growth of weeds in mulch free plots (Table 2). Our results are confirmed by Al-Amin *et al.* (2017) who reported significant variation in 1000-grain weight of wheat due to mulch application and argued that it was due to variable moisture conservation potential of different mulching materials. Decrease in 1000-grain weight of wheat with more density of weeds has also been documented by many previous workers (Khan *et al.,* 2007; Aziz *et al.,* 2009) which corroborate our findings of rise in 1000-grain weight due to less weed density as a result of suppressive effects of mulching.

Biological yield (Kgha^{-1})

The recorded data about biological yield of wheat (straw plus grain) revealed that mulch treatments influenced this trait significantly (Table 2). Wheat straw treated plots provided maximum biological yield (9393.9 kg ha^{-1}) and control plots (5329.9 kg ha^{-1}). Rice straw treated plot produced more biological yield than control, however the response of saw dust and rice husk were statistically at par. Maximum biomass in wheat straw mulched plots was might be due to better moisture absorption, moisture conservation and limited weed seed germination. As these plots restricted the growth of weeds so there was less loss of available resources by weeds. Our results are parallel to Economou *et al.* (2002), who revealed that application of mulches reduce moisture loss and increases the straw and grain yield of wheat crop. The outcomes of our study are also confirmed by Abbas *et al.* (2018a) who found that all mulch treatments showed good results regarding rise in biological yield of wheat as than control.

Grain yield (Kgha^{-1})

Results regarding grain yield revealed that mulch treatments were very effective to enhance grain yield of wheat. It is depicted from data that the effect of different mulching material on grain yield of rain-fed wheat is statistically significant (Table 2). Wheat straw treated plot showed maximum grain yield (3665.8kg ha^{-1}) however less grain yield was noted in control plots (zero mulch) that was statistically similar with saw dust and rice husk. It was further noted that rice straw treated plots gave better grain yield as compared to control, saw dust and rice husk. Maximum grain yield observed in wheat straw treatment was probably due to the less moisture losses through evaporation and transpiration. Weed infestation was also reduced due to suppress of weed seed emergence by mulches. Our outcomes are supported by Nawaz *et al.,* (2017), who reported that rice residues mulch significantly reduced weed and evaporation losses and enhance wheat grain yield. Our findings are also similar with the investigation of Misra (1996) who found that mulching increase grain yield and moisture availability. Minimum grain yield observed in control may be due to more water losses and high weed density. Our findings are also similar to Abbas *et al.* (2018a) who found that mulching treatments produce maximum grain yield as compared to control where no mulch was added.

Harvest index (%)

The result about wheat crop harvest index as effected by application of various mulches have been given in table 2 which reveal that mulching material had a significant impact on harvest index of wheat. Highest harvest index value of 38.6% was obtained from plots mulched with wheat residues and it was followed by plots receiving saw dust, rice straw, rice husk and control with 35.2, 33.8, 29.1, and 27.1% values of harvest index, respectively. Maximum harvest index in wheat straw and rice husk treated plots was perhaps due to good weed control and moisture conservation in these plots. Additionally, the decomposition of these plant based mulches may have released nutrients and improved biological activities of soil micro flora. Moisture stress due to excessive evaporation loss from bare soil and heavy weed infestation may have negatively impacted dry matter partitioning ability of the crop. These observations are reinforced by the finding of Balwinder-Singh *et al.* (2011) who stated that maize harvest index was affected adversely with rise in weed density. Research results are also sustained by Abbas *et al.* (2018a) who found that as compared to control mulch treated plots showed greater harvest index.

Total rainfall use efficiency (Kgha^{-1}mm^{-1})

Total rainfall use efficiency of rain-fed wheat crop was significantly affected by various organic mulching materials (Fig.2). The maximum rainfall use efficiency was depicted by wheat crop grown in wheat straw treated plots, while least was recorded in plots without the use of mulch material. Total rainfall use efficiency of remaining organic mulches was intermediate and followed the order of rice straw > saw dust> rice husk. Higher rainfall use efficiency in wheat straw mulching may be accredited to good coverage of soil which reduced evapotranspiration of water and promoted moisture availability in crop root zone. Our observation of higher rain fall use efficiency of wheat crop because of mulching is in accordance with the conclusions of Balwinder-Singh *et al.*

(2011) they noted that straw mulching significantly reduced evapotranspiration rate ($P \leq 0.05$), soil moisture depletion ($P \leq 0.01$), and improved water-use efficiency ($P < 0.001$). Chakraborty *et al.* (2008) also support our experiment results by stating that mulch treatments improved the soil moisture status and water use efficiency of wheat crop under limited irrigation. Hen *et al.* (2015) reported a substantial rise in winter wheat water use efficiency because of the application of crop residues mulches. Yu *et al.* (2018) has also reported significant improvement in water use efficiency of cereals including wheat and corn crop as a result of straw mulching.

Soil moisture contents (%)

Results about soil moisture as influenced by the addition of various mulching is presented in table 2. It is depicted from the results that the effect of different mulches on soil moisture contents were significant. Maximum soil moisture contents (72.33%) were noted in wheat straw mulching plots. It was shadowed by plots treated with rice straw which was statistically similar with rice husk and saw dust treated plots. Minimum soil moisture contents (53.6) were observed in un-mulched control plots. Maximum soil moisture content observed in plots where wheat straw was applied may be due to better sunlight blocking ability of this mulching material which resulted in less evaporation of soil water. Our outcomes are sustained by Balwinder-Singh *et al.* (2011) who found that use of wheat straw mulch in wheat crop was more potent in reducing soil moisture losses. The outcomes of this experiment are also supported by Chen *et al.* (2007) who reported a 40% reduction in soil moisture evaporation due to the application of wheat straw mulch in wheat crop. Lowest moisture content recorded in plots under no mulch were probably due to bare soil surface which stimulated more water evaporation. Our findings are in conformity with Teame *et al.* (2017) who found lowest moisture content in plots without mulch application.

Economic analysis

The appropriateness of any crop management operation is ultimately determined by the monetary gain in any crop production system. Data regarding the economics of rain-fed wheat cultivation as influenced by mulching is given in Table 3. It is depicted from the data that there was a clear difference among different organic mulching in terms of net return per acre. The net income of organic mulching was recorded as Rs. 2379.69, 3605.72, 4958.44, 22.10 and -73.34 with control, rice straw, wheat straw, rice husk and saw dust, respectively (Table 3). Wheat straw mulch application resulted in maximum net return followed by rice straw. Net return from control plot was greater than rice husk and saw dust treatments. This more net return from control plots was perhaps due to no input cost in these plots whereas rice husk and saw dust were costly and less efficient in conserving moisture and controlling weeds. Highest net return and BCR recorded from wheat straw mulch treated rain-fed wheat plots was probably because of its less per unit price and better soil moisture conservation and weed control efficiency. Current findings are similar to the conclusions of Ehsanullah *et al.* (2014) who reported that some mulches are not economical due to high cost.

The benefit cots ratio depicts the benefit gained against each rupee invested in any entrepreneur. In the present experiment maximum (1.69) benefit cost ratio was attained in wheat straw which was followed by rice straw with 1.63 benefit cost ratio. Minimum benefit cost ratio (0.99) was recorded in saw dust treated plots. Our findings are in agreement with the observations of Aziz *et al.* (2019) who found minimum benefit cost ratio with the use of saw dust mulch in lettuce production.

CONCLUSION

The findings of this study revealed that among various organic mulching materials, wheat straw gives better economic return by improving growth and yield of rain-fed wheat through more soil moisture retention and weed suppression attributes.

REFERENCES CITED

Abbas, T., M.A. Nadeem,A. Tanveer,N. Farooq and A. Zohaib. 2016. Mulching with allelopathic crops to manage herbicide resistant littleseed canarygrass. Herbologia, 16: 31-39.

Abbas, T., M.A. Nadeem, A. Tanveer, H.H. Ali and N. Farooq. 2018a. Role of allelopathic crop mulches and reduced doses of tank-mixed herbicides in managing herbicide-resistant *Phalaris minor* in wheat. Crop Prot., 110:245-250.

Abbas, T., M.A. Nadeem, A. Tanveer, H.H. Ali and A. Matloob. 2017. Evaluation and management ACCase inhibitor resistant little seed canary grass (*Phalaris minor*) in Pakistan. Archives J. Agro. Soil Sci., 63:1613-1622.

Abbas, T., M.A. Nadeem, A. Tanveer, H.H. Ali, M.E. Safdar, A. Zohaib and N. Farooq. 2018b. Exploring the herbicidal and hormetic potential of allelopathic crops against fenoxaprop-resistant *Phalaris minor*. Planta Daninha., 36:1-8.

Abouziena, H.F., O.M. Hafez, M.I. El-Metwally, S.D. Sharma and M. Singh. 2008. Comparison of weed suppression and mandarin fruit yield and quality obtained with organic mulches, synthetic mulches, cultivation, and glyphosate. Hortsci., 43:795-799.

Afridi, R.A. and M.A. Khan. 2014. Reduced herbicide doses in combination with allelopathic plant extracts suppress weeds in wheat. Pak. J. Bot., 46: 2077-2082.

Ahmad, S., M.A.S. Raza, M.F. Saleem, M.S. Zaheer, R. Iqbal, I. Haider, M.U. Aslam, M. Ali and I.H. Khan. 2020. Significance of partial root zone drying and mulches for water saving and weed suppression in wheat. J. Anim. Plant. Sci., 30:154-162.

Ahmad, S., M.A.S. Raza, M.F. Saleem, S.S. Zahra, I.H. Khan, M. Ali, A.M. Shahid, R. Iqbal and M.S. Zaheer. 2015. Mulching strategies for weeds control and water conservation in cotton. J. Agric. Biol. Sci. 8:299-306.

Ahmad, 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 rain-fed conditions of Pothowar. Pak. J. Agric. Res., 22:3-4.

Akter, S., U.K. Sarker, A.K. Hasan, M.R. Uddin, M.M.I. Hoque and C.K. Mahapatra. 2018. Effects of mulching on growth and yield components of selected varieties of wheat (*Triticum aestivum* L.) under field condition. Archives Agri. Environ. Sci., 3:25-35.

AlAmin, M.A., A.K. Hasan, M.H. Ali, S. Nessa and M.N. Islam. 2017. Effect of mulching and organic manure on growth and yield performance of wheat. Archives Agri. Environ. Sci., 2:134-140.

Asseng, S., I.A.N. Foster and N.C. Turner. 2011.The impact of temperature variability on wheat yields. Global Change Bio. 17:997-1012.

Aziz, A., M. Ashraf,M. Asif, M.E. Safdar, S.M. Shahzad, M.M. Javaid, N. Akhtar, H. Waheed, M.A. Nadeem, S. Ali and M.S. Munir. 2019. Impact of mulching materials on weeds dynamics, soil biological properties and lettuce (*Lactuca sativa* L.) productivity. Int. J. Bot. Stu., 4:128-134.

Aziz, A., A. Tanveer, A. Ali and M. Yaseen. 2009. Density dependent interactions between cleavers (*Galium aparine*) and wheat (*Triticum aestivum*) planted at different times. Pak. J. Agri. Sci., 46: 258-265.

Balwinder-Singh, E. Humphreys, P.L. Eberbach, A. Katupitiya, S. Yadvinde rand S.S. Kukal. 2011. Growth, yield and water productivity of zero till wheat influenced by rice straw mulch and irrigation schedule. Field Crops Res., 121:209-225.

Batish, D.R., M. Kaura, H.P. Singh and R.K. Kohli. 2007. Phytotoxicity of a medicinal plant, *Anisomeles indica*, against *Phalaris minor* and its potential use as natural herbicide in wheat fields. Crop Prot., 26:948-952.

Beadle, C.L. 1987. Plant growth analysis. In:techniques in Bioproductivity andphotosynthesis. 2nd ed. J. Coombs, D.O. Hall,S.P. Long and J.M.O. Sacrlock (Eds.).Programon Press. Oxford New York. USA. 21-23.

Borken, W and E. Matzner. 2009. Reappraisal of drying and wetting effects on C and N mineralization and fluxes in soils. Global Change Bio., 15:808-824.

Burden, D. 2005. Sesame Profile. Organic Farming 2005, cited 2014 Jan 2; Available from: http://www.darcof.dk.

Chakraborty, D., S. Nagarajan, P. Aggarwal, V.K. Gupta, R.K. Tomar, R.N. Garg and N. Kalra. 2008. Effect of mulching on soil and plant water status, and the growth and yield of wheat (*Triticum aestivum* L.) in a semi-arid environment. Agri. water manage., 95:1323-1334.

Chen, S.Y., X.Y. Zhang,D. Pei, H.Y. Sun and S.L. Chen. 2007. Effects of straw mulching on soil temperature, evaporation and yield of winter wheat: field experiments on the North China Plain. Annals Appl. Bio., 150:261-268.

Chen, Y., T. Liu, X. Tian, X. Wang, M. Li, S. Wang and Z. Wang. 2015. Effects of plastic film combined with straw mulch on grain yield and water use efficiency of winter wheat in Loess Plateau. Field Crops Res., 172:53-58.

CIMMYT. 1988. Economics Program, International Maize, and Wheat Improvement Center. *From agronomic data to farmer recommendations: An economics training manual*: 27.

Devasenapathy, P. 2008. Efficiency indices for agriculture management research. *New India Publishing*.

Economou, G.O. Tzakou, A. Gani, A. Yannitsarosand D. Bilalis. 2002. Allelopathic effect of *Conyzaalbida* on *Avenasatyva* and *Spirodelapolyrhiz*. J. Agrono. Crop Sci., 188:248-253.

Ehsanullah, R.Q., M. Kalim, A. Rehman, Z. Iqbal, A. Ghaffarand G. Mustafa. 2014. Growth and economic assessment of mulches in aerobic rice (*Oryza sativa* L.). J. Agri. Res., 52.

Farooq, N., T. Abbas, A. Tanveer and K. Jabran. 2019. Allelopathy for Weed Management. Co-Evolution of Secondary Metabolites. 1-16.

Field, C.B. 2012. Managing the risks of extreme events and disasters to advance climate change adaptation: Special report of the intergovernmental panel on climate change.Cambridge University Press.

Govt. of Pakistan. 2018. Economic Survey of Pakistan 2014-15. Ministry of Food, Agriculture and Livestock, Federal Bureau of Statistics., 26.

Grassbaugh, E.M., E.E. Regnier and M.A. Bennett. 2004. Comparison of organic and inorganic mulches for heirloom tomato production. Acta Horti., 638:171-176.

Hage, H. 1993. Mulch treatments in potato production. Further development of ridges. Kartoffelbau., 44:277-279.

Hu, W., S. Duan and Q. Sui. 1995. High yield technology for groundnut. Int.Arachis New sletter., 15:1-22.

Khan, M.A., K. B. Marwat, A. Amin, A. Nawaz and H. Khan. 2012. Soil solarization: an organic weed management approach in cauliflower. Comm. Soil Sci. Plant Analy. 43 (13): 1847- 1860.

Khan, I.J.G. Hassan, Ihsanullah and I.A. Khatak. 2007. Effect of wild oats (*Avena fatua*) densities and proportions on yield and yield components of wheat. J. Agri. Bio. Sci. 1:26-31.

Mani, V.S.K., C. Gautam and Bhagvandas. 1973. Chemical weed control in sunflower. Proc. 3rd All India Weed Control Seminar, Hisar.,48.

Misra, A and G.C. Tosh. 1979. Chemical weed control studies on dwarf wheat. J Res., 1-6.

Misra, O.R. 1996. Influence of mulching and antitranspirants on water consumption, yield and yield contributing characters of different rainfed wheat varieties. Crop Res., 11:1-8.

Nawaz, A.,M. Farooq, R. Lal, A. Rehman, T. Hussain and A. Nadeem. 2017. Influence of sesbania brown manuring and rice residue mulch on soil health, weeds and system productivity of conservation rice-wheat systems. Land Degrade. Develop., 28:1078-1090.

Ramakrishnan, A., H.M. Tam, S.P. Wani and T.D. Long. 2006. Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. Field Crops Res. 95:115-125.

Raza, A., M. Kamran, M.E. Safdar, H.H. Ali, T. Abbas, M. Asif, L. Ali and A. Rehman. 2019. Management tactics for the handling of *Parthenium hysterophorus* L. in non-native environment through phytotoxic compounds of local species. Int. J. Agri. Bio., 21: 215-222.

Raza, A., H.H. Ali, M.A. Khan, M.A. Nadeem, M. Awais, M. Kamran, T. Abbas, M. Latif, N. Hamid and O.S. Uslu. 2021. Evaluation of clodinafop-propargyl resistant *Avena fatua* L. (wild oat) in Sargodha division of Punjab-Pakistan. Pak. J. Bot., 53: 1-7.

Russel, D.F. and S.P. Eisensmith. 1983. MSTAT-C. Crop and Soil Science Department, Michigan State University, USA.

Schonbeck, M.W.and G.K. Evanylo. 1998. Effects of mulches on soil properties and tomato production. Soil temperature, soil moisture and marketable yield. J. Sus. Agri., 13:55-81.

Shiferaw, B., M. Smale, H.J. Braun, E. Duveiller, M. Reynolds and G. Muricho. 2013. Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. Food Security., 5:291-317.

Steel, R.G.D., J.H. Torrie and D.A. Dicke. 1997. Principles and procedures of statistics. A biomatrical approach 3rd edition. The McGraw–Hill, companies,Inc,NY.USA.

Subhan, A., Q.U. Khan, M. Mansoor and M. J. Khan. 2017. Effect of organic and inorganic fertilizer on the water use efficiency and yield attributes of wheat under heavy textured soil. Sarhad Journal of Agric. 33(4): 582-590.

Sun, D., Q. Bi, H. Xu, K. Li, X. Liu, J. Zhu, Q. Zhang, C. Jin, L. Lu and X. Lin. 2017. Degree of short-term drying before rewetting regulates the bicarbonate-extractable and enzymatically hydrolyzable soil phosphorus fractions. Geoderma., 305:136-143.

Teame, G., A. Tsegay and B. Abrha. 2017. Effect of organic mulching on soil moisture, yield, and yield contributing components of sesame (*Sesamum indicum* L.). Int. J. Agrono., 1-6.

Wang, P.G. and P. Wang. 1998. Effect of sowing in furrows and covering with plastic film on overwintering and yield of winter wheat. J. Jilin Agri. Uni., 20:21-24.

Yu Y.Y., N.C. Turner, Y.H. Gong, F.M. Li, C. Fang, L.J. Ge and J.S. Ye. 2018. Benefits and limitations to straw-and plastic-film mulch on maize yield and water use efficiency: A meta-analysis across hydrothermal gradients. Europ. J. Agro., 99:138-147.

Zhang, S., L. Lövdahl, H. Grip, Y. Tong, X. Yang and Q. Wang. 2009. Effects of mulching and catch cropping on soil temperature, soil moisture and wheat yield on the Loess Plateau of China. Soil Tillage Res., 102:78-86.

Table1. Effect of organic mulches on weed parameters growing in wheat crop cultivated under rain-fed conditions.

Treatment	Weed density(m^{-2})	Weed control efficiency (%)	Fresh biomass (gm^{-2})	Dry biomass (gm^{-2})	Weed control index (%)
Control	23.00a	-	17.77a	13.03a	0.00c
Rice straw	12.33b	46.46c	11.66ab	8.13bc	35.86b
Wheat straw	4.33c	63.26b	7.59b	4.73c	62.23a
Saw dust	10.66b	53.21bc	10.00b	9.71ab	30.25b
Rice husk	8.33bc	80.90a	10.66ab	9.50ab	24.46b
HSD (0.05)	**5.35**	**16.38**	**7.54**	**3.97**	**24.34**

Means not sharing identical alphabet are statistically different at $p \leq 0.05$.

parameters under rain-fed conditions.

Treatment	Plant height (cm)	Productive tillers (m^{-2})	Unproductive tillers (m^{-2})	Spike length (cm)	Grain weight per spike(g)	No of grains per spike	No of spikelets $spike^{-1}$	1000-grain weight (g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)	Soil moisture contents (%)
Control	53.7c	76.67b	24.66a	6.46c	1.35c	29c	10c	30.667c	5329.9c	1541.6b	29.1ab	53.6c
Rice straw	60.3b	102.00ab	17.00b	8.10b	1.79b	39b	14b	41.66b	7413.3b	2497.3b	33.8ab	62.6b
Wheat straw	70.8a	137.33a	8.00c	10.05a	2.37a	52.3a	17a	50.66a	9393.9a	3665.8a	38.6a	72.3a
Saw dust	57.3bc	99.67ab	20.66ab	7.60bc	1.74b	42b	14b	37.66b	7124.8bc	2561.2ab	35.2ab	61.0bc
Rice husk	60.0bc	77.00b	16.66b	7.36bc	1.58bc	42b	14.7b	38.00b	6535.6bc	1871.9b	27.1b	61.6b
HSD (0.05)	**6.36**	**47.47**	**7.65**	**1.4514**	**0.3658**	**7.45**	**2.17**	**4.42**	**1945.9**	**1119.9**	**9.7**	**8.24**

Means not sharing identical alphabet are statistically different at $p \leq 0.05$.

Table3. Economic analysis influenced by different organic mulches in rain-fed wheat production.

Treatments	Yield (Tons ha^{-1})	Gross income (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit cost ratio (BCR)
Control	0.1804	6995.08	4615.38	2379.69	1.51
Rice straw	0.2385	9245.40	5639.67	3605.72	1.63
Wheat straw	0.3131	12134.55	7176.11	4958.44	1.69
Saw dust	0.2229	8639.21	8712.55	-73.34	0.99
Rice husk	**0.2122**	**8222.53**	**8200.40**	**22.10**	**1.0**

Wheat grain = Rs.1300/40 kg; Wheat straw = 250/40kg; Rice straw = 100/40kg; Sawdust = 400/40kg; Rice husk = 350/40kg

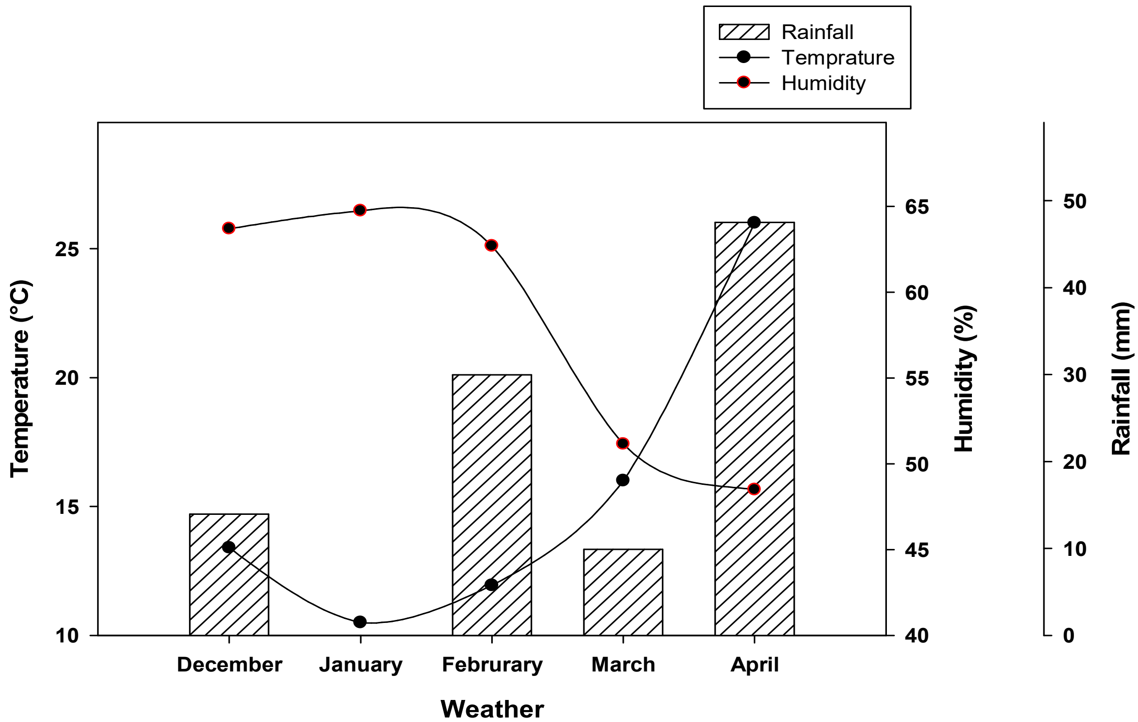

Figure1. Rainfall, temperature and relative humidity for the growing period of wheat during 2017-2018.

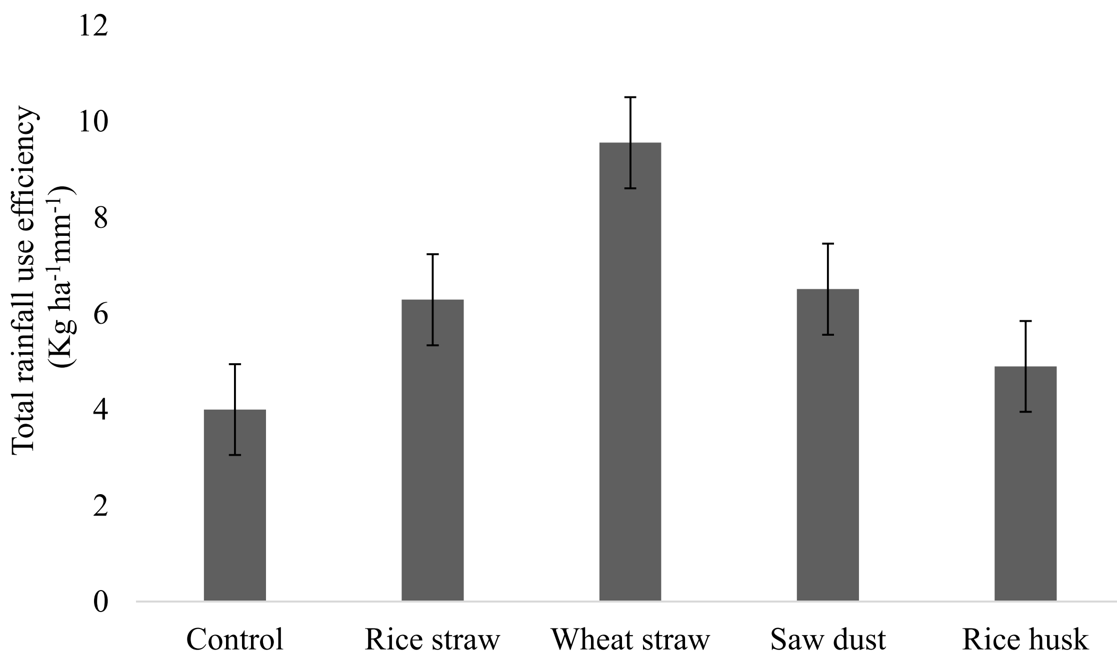

Figure2. Effect of different organic mulching materials on total rainfall use efficiency of rainfed wheat.