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Mulching improves weeds management, soil carbon and productivity of spring planted maize (*Zea mays* L.)

Muhammad Asif[1], Muhammad Ather Nadeem[2], Ahsan Aziz[3], Muhammad Ehsan Safdar[4], Muhammad Adnan[5*], Amjed Ali[6], Naeem Ullah[7], Naeem Akhtar[8], Basharat Abbas[9]
[1-7, 9] Department of Agronomy, College of Agriculture, University of Sargodha, Pakistan
[8] Department of Plant Breeding and Genetics, College of Agriculture, University of Sargodha, Pakistan

Abstract
Weeds and low soil organic matter contents significantly reduced maize yield. Chemical control of weeds creates environmental hazards and residual effects in crops and soil. Weed management through mulches is suitable alternative to chemical weed control. A trial was planned to ascertain the influence of mulches on carbon contents of soil, weeds dynamics and productivity of maize. Experimental treatments were comprised of control (weedy check), manual hoeing, plastic mulch, rice straw mulch, saw dust mulch and wheat straw mulch @ 4 tons ha^{-1} each. Results showed that all mulching treatments significantly affected weed growth, soil carbon and yield components of maize. Application of plastic and wheat straw mulch increased 30.76 and 26.06% plant height, 7.16 and 3.41% grains per cob, 33.13 and 14.57% grain yield, 19.0 and 9.29% biological yield, 3.29 and 4.84% harvest index respectively over weedy check (control). Maximum soil organic matter and carbon contents were observed in wheat straw mulch. Lowest weeds density and dry weight was observed in manual hoeing, transparent mulch and rice straw mulch, respectively. Results suggested that application of wheat straw mulch not only increase yield, soil organic matter contents but also improve yield of maize.

Keywords: Mulching, soil carbon, dynamics, Experimenta

1. Introduction

Maize is a member of family poaceae. In Pakistan it is an important cereal crop (Bukhsh *et al*., 2011) [4]. The cultivated area of maize is 159 m ha in all over the world with 796.46 m tones yield (USDA. 2010) [23]. In Pakistan, maize grain yield is low than other countries due to following problems such as low plant density, unsatisfactory level of fertilizer application, insufficient water supply, weeds infestation, low soil organic matter, poor inputs management, poor selection of varieties and insect pest attack (Tahir *et al*., 2008) [19]. Among all yield limiting factors of maize, weeds cause serious problems in the production of maize. Weeds compete with main crop, suppress the crop plant and ultimately influence their yield and quality (Webster, 2003) [25]. A number of weed species (*Cyprus rotundus*, *Parthenium hysterophorus*, *Convolvulus arvensis*, *Chenopodium album*, *Cynodon dactylon*, *Euphorbia hirta* etc.) compete with corn plant. Weeds cause 12.8% losses in yield of maize crop (Oerke and Steiner, 1996) [14]. These losses may increase up to 70% (Teasdale, 1995) [20]. Weeds can be controlled through following methods such as physical, chemical, mechanical, cultural and biological. The practice of high use of herbicide in agriculture is discouraged due to its un-desirable effects on the surrounding environment and other organisms (Diaz *et al*., 2004) [6]. In sustainable agriculture crop rotations, use of cover crops, mulching and good crop husbandry are very useful measures to suppress weeds (Kabambe, 2003) [8]. Therefore, environment friendly weed control methods are required to be used for weed management in maize crop in order to avoid the incidence of undesirable effects. Mulching may be a good Strategy for management of weeds. Mulching also helps in retention of soil moisture contents and suppresses weeds without herbicide application (Szwedo and Maszezyk, 2001) [10]. Mulch is a material that may be organic or inorganic in nature which spread on surface of soil and provides shelter from raindrop damage, evaporation and solar radiation. Mulches help to preserve moisture, suppress weeds and improve soil stability and avoid insect pest attack. Organic mulches help to moderate soil temperature, provide efficient control of weeds, decrease rate of evaporation and add nutrients and humus in the soil (Kluepfel, 2010) [11]. Mulching prevent soil erosion and has the ability to reduce the soil born-diseases.

Physical mulch improves soil particle aggregation and enhances the water infiltration rate. Chemical mulch offers a slow release of humic acids, nitrogen, phosphorus and potassium in the soil which facilitate to increase their uptake and utilization. Biological mulch is the component of integrated management of pest which provides control to phytophthora root rot, against dual competitive and aggressive microbes (Matava, 2009) [13]. Mulching materials contribute in modification of soil properties that results in attaining better germination and increase maize yield (Bansal *et al*., 2004) [2]. Wang *et al*. (2008) [24] described that application of straw mulch show positive effects on crop production, biological yield and water utilization efficiency of field crops. Keeping in mind the importance and role of mulches in weed control, improving soil chemical, physical and fertility properties, a trial was planned with the aims; to check the impact of different mulching on weed control and maize yield improvement, to check the role of different mulching materials on soil carbon and organic matter.

2. Materials and Methods

2.1 Site and Soil

Trial was laid in field at experimental area of Research Farm, College of Agriculture, University of Sargodha, Pakistan during spring 2017. Soil analysis was carried out before sowing and after harvesting of maize crop for NPK, soil organic matter and organic carbon contents. Properties of soil are present in table 1.

Table 1: Physicochemical analysis of soil

Depth cm	E.C mS cm^{-1}	pH	Organic matter %	Saturation %	Available Phosphorus mg kg^{-1}	Available Potassium mg kg^{-1}	Texture
0 - 10	1.05	7.9	0.56	37	6.8	173	Loam

2.2. Experimental design and treatments

The experimental design was randomized complete block design (RCBD) with three replications. Experimental treatments comprised of control (No treatment), manual hoeing, wheat straw mulch, plastic mulch, saw dust mulch and rice straw mulch @ 4 tons ha^{-1} each. Seeds were sown with dibbler on ridges, keeping 25 cm (P X P) distance and 75cm (R X R) distance. Nitrogen, phosphorus and potassium were incorporated @ 160, 80 and 60 kg/ha, respectively. All other operations were similar in all treatments.

2.3. Crop husbandry

Maize seeds were sown on fine and well prepared ridges on March 14, 2017. Before sowing seed bed was prepared with cultivator and planker. Then soil was made fine by rotavator. Finally, ridges were made through soil ridger. Fungicide "Confidor" was used to treat the maize seed @ 5g/kg to evade any fungal attack and seed deterioration. To ensure maximum and uniform maize population 10 kg/ha seed was used. At early stages of crop development thinning was carried out leaving 25 cm P X P distance for the purpose of providing maximum space to the plants for growth. NPK fertilizer was applied @ 160:80:60 kg/ha. Fertilizer was incorporated in soil (P, K) at sowing time. Nitrogen in three doses i.e. one-third before sowing, second dose with first irrigation and third dose at tasseling. Urea, DAP and MOP were used as sources of nitrogen (N), phosphorus (P) and potassium (k), respectively. To protect the maize crop against the attack of shoot fly, the crop was sprayed at 2-3 leaf stage with Imidacloprid through hand sprayer. To save the crop from the attack of stem borer Furadan was used @ 8 kg/acre at 4-5 leaf stage. After sowing of seed first irrigation was applied. Irrigation scheduling was maintained properly according to the requirement of the crop to provide optimum growth conditions to the crop plants. Observations recorded during the study were:

2.4. Observations

The crop was observed for different parameters including plant height, grains per cob, grain weight per cob, 100-grains weight (g), grain yield (tons ha^{-1}), biological yield (tons ha^{-1}), stalk yield (tons ha^{-1}), harvest index %, soil organic matter, organic carbon, weeds dry weight (gm^{-2}), weeds count m^{-2} by using the standard procedures. Ten plants were selected randomly and individual plant height, grains per cob and grain weight per cob was determined, and after that average was calculated. For 100- Grains weight, 100-grains were taken from every plot dried in oven and then weighed by electric balance. For biological yield (tons ha^{-1}) all plots were harvested separately weighed and converted into tons ha^{-1}. Then all cobs were removed and sun dried. After drying all the grains were removed from cobs, weighed and yield was converted in to tons/ha. Stalk yield was determined by weighing the stalks of the plants after the removal of cobs and leaves.

Soil organic carbon contents were determined by using dry combustion method. Induction or resistance furnace was used to carry out the dry combustion of carbon. Soil sample was mixed with catalyst and combusted in combustion chamber at a very high temperature along with oxygen to convert all the carbon present in soil in to CO_2. Thermal conductivity was used in gas chromatographic method to determine total CO_2 production. Total carbon was measured through Perkin-Elmer CHN analyzers.

For determination of soil organic matter 1g soil was placed in a flask and 10 mL dichromate-sulfuric acid was added for digestion. After addition of reagent, flask was covered with glass marble to reduce the loss of chromic acid. Then flask was placed in digestion oven heated for 90 minutes for 90ºC. After heating the sample was allowed to cool at room temperature for some time and then it was diluted by mixing water. Sample was mixed thoroughly by mechanical shaking and then it was allowed to stand for three hours. 10 mL solution was placed into a colorimeter tube. Intensity of supernatant was read at 645 nm on a colorimeter with blank reagent. Finally, the instrument was calibrated and percent organic matter was calculated comparing it with standard curve that was prepared from samples of known organic matter content. To record the data for weeds parameters, randomly 1 m^2 quadrate was used in each plot and weeds number was counted.

2.5. Statistical analysis

Statistically program 8.1 was used for data analysis and treatment means were separated by using tukey's honestly significant difference test at 5% probability level.

3. Results and Discussion

3.1 Plant height (cm)

Mean comparison for plant height under different treatments is given in Table 2 which showed significant difference among treatments. Maximum plant height (215.67 cm) was recorded by transparent plastic mulch which was statistically similar as manual hoeing (214.00 cm), wheat straw mulch (208 cm) and rice straw mulch (205 cm). The minimum height (165.00 cm) was observed under control treatment. Results are supported by the research findings of Buerkert *et al*. (2000) [3] who described that application of polythene sheet saved irrigation water. It was also observed that maximum height was attained by the plants under mulching by polythene sheet followed by rice straw. It was concluded from above results that reason for increase in plant height by transparent plastic mulch application may reduce population of seasonal weeds which germinate in the specific season and limits maize growth and when weeds suppressed and maize plants get advantage for space and nutrition that may resulted in improved plant height of maize.

3.2 Number of grains cob^{-1}
Mean comparison for grains/cob in maize influenced by mulching treatments is presented in Table 2 and significant difference was observed for grains/cob under different treatments. Number of grain per cob ranged from 415.47 to 465.15. Highest number of grains/cob (465.15) was observed in manual hoeing and minimum grains cob^{-1} (415.45) was observed in weedy check (control). These research findings are according Panday *et al*. (2000) [15] who described that total grains cob^{-1} significantly influenced by mulching. It was concluded from above results that number of grains per cob was less in control due to increased population of seasonal weeds which germinate in the specific season and limits maize growth.

3.3 Grain weight/cob (g)
It is the main component which contributes in the final yield. Mean comparison for grain weight per cob of maize among different treatments is presented in Table 2. Grain weight per cob ranged from 95.73 to 111.76 g cob^{-1}. Maximum grain weight (111.76 g cob^{-1}) was recorded under transparent plastic mulch application and minimum grain weight was recorded under weedy check/control (95.73 g cob^{-1}). Our research findings are similar with the findings of Mahajan *et al*. (2007) [12] who described that plastic mulch contributes in maintaining the high yield of plants by increasing the grain weight/cob and provides effective weed control without any herbicide application. The increased grain weight under plastic mulch application may be due to the reduced seasonal weeds population which germinates in the specific season and limits maize growth and when the germination of weeds is suppressed, maize plants took full advantage of space and nutrition that may resulted in improved grain weight per cob of maize.

3.4 100-Grain weight (g)
Data showed (Table 2) significant differences for 100-grain weight under different mulching treatments. 100-grain weight (g) ranged from 28.38 to 39.55 g. Maximum 100-grains weight (39.55 g) was observed by the application of saw dust mulch which was at par with rice straw mulch (36.35 g), wheat straw mulch (34.67 g), and manual hoeing (33.63 g). The lowest 100-grain weight (28.38 g) was observed under weedy check condition. Results of 100 grain weight are in accordance with Shah *et al*. (2013) [17] who described that organic mulches increase the moisture contents of soil, 1000-grain weight, LAI and final yield of wheat and maize crop.

3.5 Grain yield (tons ha^{-1})
The main purpose for which the maize crop is cultivated by the farming community is grain yield. Grain yield ranged from 5.01 to 6.67 t ha^{-1} (table 2). Maximum grain yield (6.67 t ha^{-1}) was observed under transparent plastic mulch application while weedy check/control gave minimum grain yield (5.01 t ha^{-1}). Results are supported by the Tolk *et al*. (1999) [22] who described that transparent plastic mulch efficiently enhanced grain yield up to 17% and 14 % and also increased water utilization efficiency over bare soil. Tian *et al*., (1993) [21] also found that application of mulching significantly improved maize production over the weedy check (control) treatment. These results are also observed by Xu *et al*. (2007) [27], who found that practice of plastic mulch produced higher grain yield and more dry mass than the other treatments. The increased grain yield under the application of transparent plastic mulch might be due increased moisture availability to plants which ensure healthy growth and ultimately enhanced the grain production.

3.6 Biological yield (tons ha^{-1})
Biological yield ranged from 15.92 to 18.96 t ha^{-1} (table 2). Highest biological yield (18.96 t ha^{-1}) was observed under transparent plastic mulch and lowest biological yield (15.92 t ha^{-1}) was observed in weedy check/control. Observed results are in accordance with the findings of Khurshid *et al*. (2006) [10] who described that maize yield and soil physical health improved significantly by the application of mulches. Biological yield and other plant components increased when mulch was practiced @ 12 tons/ha. Wick *et al*. (1994) [26] also found that dry matter yield was improved by mulch application. It may be concluded from the above results that minimum biological yield in the weedy check treatment was due to high weed population in un-mulched than in mulch treatments, because mulches suppress weeds density and decrease nutrient losses.

3.7 Stalk yield (tons ha^{-1})
Stalk yield is a vital attribute of maize as it shows the potential for green biomass and fodder yield. Mean comparison for stalk yield in maize under different mulching treatments is presented in Table 2. Stalk yield ranged from 12.50 to 16.23 t ha^{-1}. Maximum stalk yield (16.23 t ha^{-1}) was observed under manual hoeing (15.80 t ha^{-1}) and minimum stalk yield (12.50 tha^{-1}) was recorded under weedy check/control. Findings are quite similar with Wicks *et al*. (1994) [26] who found that kernel moisture, soil water content, dry matter yield increased with increasing mulching level. It may be concluded from above results that increased in stalk yield under manual hoeing was due to better weeds control so competition was minimized while availability of more organic matter and plant nutrients seems to be the reasons for more stalk yield in wheat as compare to control treatment (weedy check).

3.8 Harvest index (%)
The physiological capability of plant is determined in term of harvest index. Harvest index ranged from 30.98 to 33.0% (Table 2). Highest harvest index (33.0%) was observed in rice straw mulch and minimum harvest index was observed in weedy check (control) (30.98 %) and it was statistically similar with saw dust mulch (31.23%). The similar results are reported by Awal and Khan (1999) [1] who reported that rice straw mulch improved tasseling, milking and maturity stages of maize crop and significantly improved biological and economic yield over the control and saw dust. Higher harvest index value was also recorded under the rice straw mulch. Tian *et al*. (1993) [21] reported that mulching increased harvest index and maize grain yield over control treatments. Increased grain yield in all mulch treatments over control may be the reason for good harvest index.

Table 2: Effect of different mulching on maize yield and yield components

Treatments	Plant height (cm)	Number of grains/cob	Grain weight per cob (g)	100-grain weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Stalk yield (t ha^{-1})	Harvest Index (%)
Weed check	165.0 c	415.47 e	95.73 e	28.38 c	5.01 f	15.917 f	12.50 e	30.98 d
Manual hoeing	214.0 a	465.15 a	106.87 b	33.63 abc	5.79 b	18. 697 b	16.23 a	31.49 e
Transparent plastic mulch	215.7 a	445.23 b	111.76 a	30.33 bc	6.67 a	18.957 a	15.67 b	32.00 c
Wheat straw mulch	208.0 ab	429.65 c	104.75 bc	34.67 abc	5.74 c	17.400 c	15.35 b	32.48b
Rice straw mulch	205.0 ab	426.75 cd	102.12 c	36.35 ab	5.50 d	16.933 d	14.33 c	33.00a
Saw dust mulch	199.3 b	419.12 de	99.12 d	39.55 a	5.22 e	16.713 e	13.80 d	31.23 de
Tukey's HSD	11.91	8.46	2.74	7.15	0.040	0.597	0.404	0.48

3.9 Weed density per m^2
Weeds mostly compete with crop for space, sunlight, water, and nutrient uptake and significantly influence crop yield. Mean comparison for weed density of maize under different treatments are showed in Table 3. Weed density ranged from 44.85 plants to 243.83 plants m^{-2}. Maximum weed density (243.83 plants m^{-2}) was observed under control treatment (weedy check) and minimum weed density (44.85 plants m^{-2}) was recorded under manual hoeing. These findings are according to the findings Mahajan *et al*. (2007) [12] who reported that plastic mulch helps in maintaining soil temperature, early growth, plant height, yield and provide effective weed control. Diaz *et al*. (2004) [6] reported significant differences for weed density in maize due to mulching.

3.10 Weeds dry weight (g m^{-2})
Mean comparison for weeds dry weight in maize under different mulching treatments is presented in Table 3. Highest dry weight of weed (62.77 g m^{-2}) was observed under weedy check/control and minimum weeds dry weight (41.93 g m^{-2}) was observed by the application of transparent plastic mulch. These findings are same as observed by Rakha, (1999) [16] who described that dry weight of all weeds recorded 55 days after sowing (DAS) was suppressed by 38.6% and 47.2% as compared to control when sorghum mulch @ 10 and 15 t ha^{-1} was applied and yield was also increased with the ratio of 7.2% and 12.8% over control respectively. Rice residues suppress the broad-leave weeds and *Echinochloa colonum* with reduction in density of 56, 40% and biomass by 64, 39% respectively (Khan and Vaishya, 1992) [9].

3.11 Soil organic matter
Organic matter content at harvest differed among the treatments (Table 3). Organic matter ranged from 5.18 to 9.38 mg per Kg of soil. Maximum organic matter (9.38 mg per Kg of soil) was recorded by the application of wheat straw mulch which showed 73.70 % increase than pre sowing organic matter contents of soil and minimum organic matter (5.18 mg per kg soil) was recorded under manual weeds hoeing. Results are quite parallel to the findings of Dukiker and Iai (1999) [7] who reported the advantages of mulching on soil organic matter.

3.12 Soil organic carbon
Soil organic carbon contents varied among the mulching treatments and given in table 3. Soil organic carbon contents were increased almost in all treatment. Organic carbon ranged from 3.19 to 5.45 mg kg of soil. Maximum soil organic carbon (5.45 mg per kg of soil) was observed under the application of wheat straw mulch and minimum soil organic carbon (3.19 mg per kg soil) was recorded under weedy check control which is only 1.59 % higher as determined in pre-sowing soil sample. Almost similar findings are described by Canqui and Lai. (2007) [5] who observed that soil organic carbon significantly increased by the application of mulch.

3.13 Soil NPK contents after harvest.
Data regarding NPK contents of soil analyzed after crop harvest are presented in Table 3. Mulching treatments added the nutrients in soil. Data showed that maximum increase in NPK contents was observed in wheat straw mulch with 364.80, 8.7, 216.34 mg kg^{-1} of soil, respectively. Wheat straw mulch was followed by rice straw, transparent plastic mulch and saw dust, respectively after each other. Minimum NPK (335.09, 8.38, 204.82 mg kg^{-1} soil) was observed under control treatment, where weeds are allowed to freely grow with maize crop. These differences in NPK contents of soil may be due to release of nutrients from added mulches after mineralization and build up these nutrient reserves in soil. These research findings are in line with the findings of Pervez *et al.* (2009) [15] who described that mulching material significantly affect soil health and NPK concentration in maize shoot. It was reported that mulching increase soil moisture regime, plant height, grain yield, biological yield and NPK contents of soil.

Table 3: Effect of different mulching on weed parameters, organic matter, organic carbon and soil NPK contents

Treatments	Weed density	Weeds dry weight (g)	Organic Matter (mg Kg^{-1})	Organic carbon (mg kg^{-1})	Nitrogen (mg kg^{-1})	Available Phosphorus (mg kg^{-1})	Extractable K (mg kg^{-1})
Weed Check (control)	243.83a	62.77 a	6.52	3.19	335.09	8.38	204.82
Manual Hoeing	44.85d	48.62 e	5.18	3.79	343.66	8.44	209.16
Transparent Plastic Mulch	73.20c	41.93 f	6.01	3.49	348.75	8.54	212.24
Wheat Straw Mulch	84.30bc	53.78c	9.38	5.45	364.80	8.70	216.34
Rice Straw Mulch	89.08bc	51.95 d	8.21	4.77	352.70	8.67	213.72
Saw Dust Mulch	95.82b	59.62 b	6.97	4.05	338.90	8.51	206.06
Tukey's HSD	21.47	0.734	--	--	----	-----	----

4. Conclusion

Mulching is proved to be a good technique for weed control, building organic matter and increasing maize yield. So it is concluded that all mulching treatments effect positively on maize yield and yield parameters also improve soil organic matter with better weed control. While keeping in view the sustainable agriculture approach it is suggested that application of wheat straw mulch @ 4 t ha^{-1} is useful for obtaining high maize yield, controlling weeds without any herbicide application, improving soil organic matter and organic carbon contents.

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