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Article

Evaluation of Organic and Inorganic Mulching as an Integrated Weed Management Strategy in Maize Under Rainfed Conditions

Avaliação de Coberturas Vegetais Orgânicas e Inorgânicas como Estratégia Integrada de Manejo de Plantas Daninhas no Cultivo de Milho de Sequeiro

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ABSTRACT - Weeds affect crop growth, health and yield by competing for resources, and they serve as refuge for insect pests. Mulches of different materials have been found to control weeds and insect pests. A field study was conducted at the village of Mang, Haripur, Khyber Pakhtunkhwa, Pakistan, to explore the effect of various mulch materials on weed suppression in maize fields under rain-fed conditions in 2013. Eight mulch materials treatments were used: control (no mulching), wheat straw mulch, dry leaves of eucalyptus, rice straw mulch, grass clippings, living mulch (soybean crop), black plastic mulch and the herbicide Primextra were investigated under a randomized complete block design with four replications. Statistical analysis of data showed maximum reduction in weed density, relative weed density, fresh biomass and dry biomass in all the test species at 25, 50 and 75 days after sowing (DAS) where Primextra and black plastic mulch were used, and this was statistically similar to where rice straw and wheat straw were used. Maximum weed density, relative weed density, fresh and dry biomass of all weed species were recorded where soybean was intercropped with maize and grass clippings were used. Based on these results, it was inferred that the mulch material of eucalyptus and rice straw can effectively be used for controlling weeds in maize fields under rain-fed conditions.

Keywords: *Zea mays*, mulch materials, net benefits, weed density, weed biomass.

RESUMO - As plantas daninhas afetam o crescimento, a saúde e a produtividade das culturas, competindo por recursos e servindo de refúgio para pragas de insetos. Descobriu-se que coberturas do solo com diferentes materiais promovem o controle de plantas daninhas e pragas de insetos. Foi conduzido um estudo de campo no vilarejo de Mang, Haripur, Khyber Pakhtunkhwa, Paquistão, para explorar o efeito de tipos variados de cobertura sobre a supressão de plantas daninhas em sistema de sequeiro, em 2013. Foram investigados, sob delineamento em blocos ao acaso com quatro repetições, oito tratamentos de cobertura do solo: controle (sem cobertura), cobertura de palha de trigo, folhas secas de eucalipto, cobertura de palha de arroz, resíduos de gramíneas, cobertura viva (soja), lona plástica preta e o herbicida Primextra. A análise estatística dos dados revelou redução máxima na densidade de plantas daninhas, na densidade relativa de plantas daninhas, na biomassa fresca e na biomassa seca em todas as espécies testadas aos 25, 50 e 75 dias após a semeadura (DAS) com o uso do Primextra e da cobertura de lona plástica preta, tendo sido registrados resultados estatisticamente semelhantes com o uso de palha de arroz e palha de trigo. Foram registradas densidade máxima de plantas daninhas, densidade relativa de plantas daninhas, biomassa fresca e seca

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para todas as espécies de plantas daninhas onde a soja foi consorciada com milho e foram utilizados resíduos de gramíneas. A partir desses resultados, inferiu-se que material de cobertura oriundo de eucalipto e palha de arroz pode ser utilizado com eficácia no controle de plantas daninhas no campo de milho sob condições de sequeiro.

Palavras-chave: *Zea mays*, materiais de cobertura, benefícios líquidos, densidade de plantas daninhas, biomassa de plantas daninhas.

INTRODUCTION

Maize (*Zea mays*) is an important major cereal crop which is grown both in irrigated and rain-fed areas. In Pakistan, an area 1.19 million hectares is under maize cultivation and has average annual production of 5.27 million tonnes (Pakistan, 2016-17). Currently, average maize yield in Pakistan is very low as compared to the world's potential yield (12 ton ha^{-1}). This gap in yield is due to various management and environmental dynamics/factors. Weed invasion is one of the main yield decreasing factors in maize (Fahad et al., 2014). It is reported that weeds cause about 58% grain yield losses in maize as a result of inadequate weed control. Such losses are higher than those caused by other pests in crops (Ihsan et al., 2015). Crop yield reduction arising from weed invasion depends on type of weed species, time of germination/emergence, density, weed-crop competition duration. Weeds not only compete for moisture, nutrients, light and air but also produce toxic allelochemicals in the plant rhizosphere through root exudation (Hussain et al., 2015). Among major weeds of maize crops, *Cyprus rotundus*, *Sorghum halepense*, *Digeria arvensis*, *Alternanthera pungens*, *Amaranthus hybridus*, *Echinochloa colona* and *Tribulus terrestris* account for 23-89% (Mahmood et al., 2015) invasion under field conditions.

Weeds are a veiled enemy of crop plants, impairing their functions and restraining their growth and development. They belong to the most ubiquitous class of pests which compete with crop plants not only for nutrients, water, space and light but also give refuge to pests and diseases and significantly reduce crop productivity. Weeds are troublesome in agroecosystems; productivity, quantity and quality of produce of agricultural crops are at risk because of weed-crop competition. Among various biological and agronomic constraints, weeds are the most destructive, upsetting, aggressive and unwanted pests of the maize and wheat fields. In fact, weeds interfere with agricultural crop plants via allelopathy and competition (Gupta, 2004). Weeds turn down yields and quality of crop plants and increase food production costs (Pandya et al., 2005). Therefore, control and management of weeds are important characteristics of crop production in agricultural systems. Different weed species in different crops require different control measures, including traditional to improved weed control methods. Every weed control method depends upon climatic conditions, technology in use, economic status of farmers, cropping pattern and crop growing area. Weed control methods consist of chemical, mechanical, cultural, biological, and integrated weed management practices. With the advent of novel chemistry and herbicides, the use of chemical weed control has increased to a great extent because of its efficacy, usefulness and usage simplicity, greater effectiveness and small labor force (Gianessi and Reigner, 2007). Herbicides provide good crop yield as a result of efficient weed control (Kahramanoglu and Uygur, 2010) but there are some drawbacks with the use of herbicides, including health and environmental issues. Typically, non-selective herbicides are applied at post-emergence, while selective herbicides are applied at pre- or post-emergence. Indiscriminate and non-random uses of herbicides for weed control develop resistance in weeds against herbicides and contaminate the food chain, exert toxic effects on non-target organisms. Foliar application of herbicides badly affects human health, damages foods crop and destroys fish and livestock farms (Kudsk and Streibig, 2003). Thus, because of all these problems, a great deal of effort is being made to unearth substitute cost effective approaches to handle or diminish weed infestation in maize and wheat crops (Triple..., 2009). In this regard, allelopathy offers a great prospect to resolve this critical issue and it can be used in different ways, e.g., as residues in the form of surface mulch (Jung et al., 2004). Keeping in mind the reductions caused by weeds to maize yield, an experiment was designed to select appropriate mulch under rain-fed conditions. This could reduce maize yield losses by minimizing weed infestation and, hence, increase yield.

MATERIALS AND METHODS

Site, soil and design: The proposed study was carried out on a farm in the village of Mang, Tehsil and District Haripur Khyber Pakhtunkhwa, Pakistan (31.25° N, 73.06° E and 183 m asl) during the first week of July, 2013. The experiment was laid out in randomized complete block design (RCBD) with four replications. Plot size was 5 m × 3 m. Before crop sowing, the soil was analyzed for physio-chemical properties as described by Chapman and Pratt (1961). The analysis revealed that soil was silt loam with pH 7.2, 0.93% organic matter, 0.051% total nitrogen, 8.5 ppm phosphorus and 1.20 ppm potassium. Meteorological data on average minimum and maximum temperatures (°C), monthly rainfall (mm) and relative humidity (%) were recorded and are shown in Figure 1.

Details of treatments: The weed management strategies that were investigated consisted of seven treatments, namely, T1: Control; T2: Wheat straw mulch at 4 ton ha^{-1}; T3: Dry leaves of Eucalyptus at 3.5 ton ha^{-1}; T4: Rice straw mulch at 4 ton ha^{-1}; T5: Grass clippings at 4 ton ha^{-1}; T6: Living mulch (soybean crop); T7: Black plastic mulch; T8: Herbicide (Primextra gold was purchased from Syngenta Global and applied at 400 mL $acre^{-1}$) as spray.

Wheat straw, dry leaves of eucalyptus, rice straw, grass clippings and black plastic mulch were chopped and applied just after sowing of the crop while living mulch (soybean crop) was planted in between the rows of the main (maize) crop just after sowing. Herbicide was applied as pre-emergence just after sowing of the maize crop. The experiment consisted of two factors: maize cultivar was allotted to main plot whereas mulching treatments were subjected to subplots.

Sowing of crop: Seeds of the maize cultivar Azam (basic) were obtained from the Cereal Crops Research Institute Pirsabak, Nowshera, Pakistan and sown on well-prepared soil during the first week of July, 2013 using a seed rate of 25 kg ha^{-1}. Line sowing was performed for the crop with the help of a hand drill.

Crop husbandry: All the phosphorus (100 kg ha^{-1}), potash (100 kg ha^{-1}) and half rate of nitrogen (150 kg ha^{-1}) were applied at the time of sowing and the remaining nitrogen was applied after intercultivation i.e., at the 1st tillage stage. Fertilizer sources were Urea (46% N) and Diammonium phosphate (46% P and 18% N) and Sulphate of Potash (50% K and 18% S).

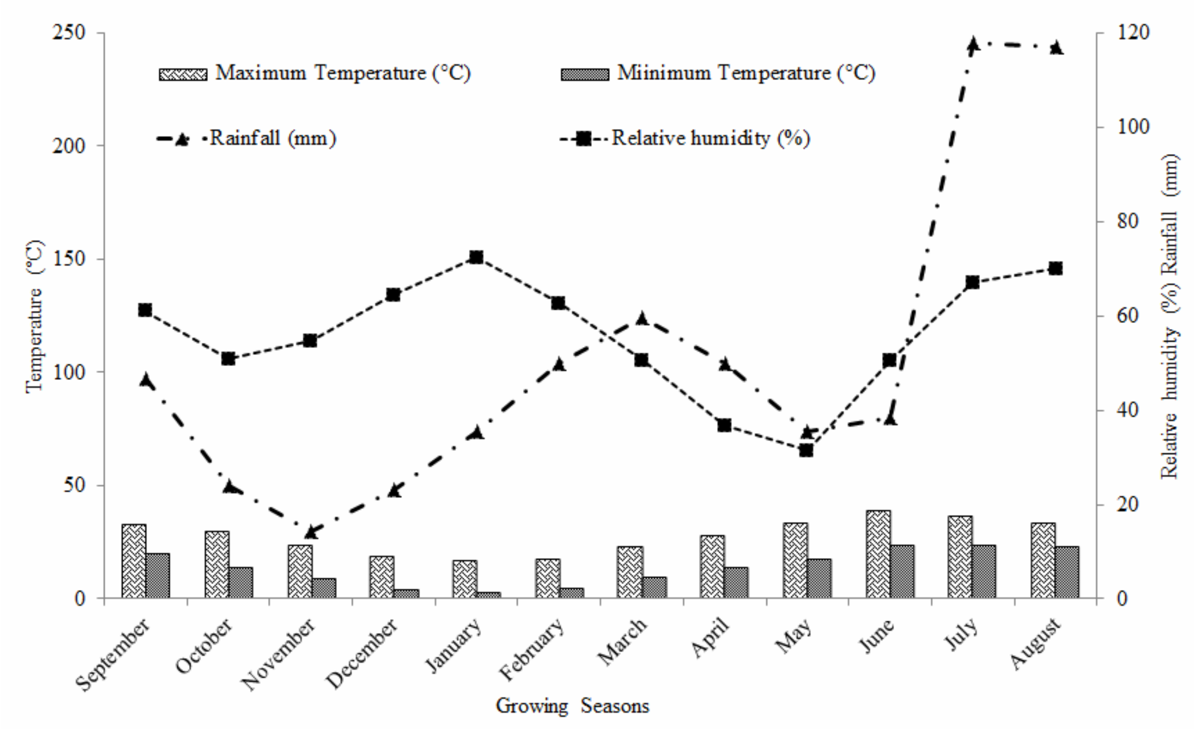


Figure 1 - Meteorological data on average minimum and maximum temperatures (°C), monthly rainfall (mm) and relative humidity (%).

The crop was harvested manually. After harvesting, the plants were left in the field for sun drying. Sun dried plants were weighed to record biological yield with the help of a spring balance. Each plot was threshed separately and grain yield was recorded using an electrical balance. The data were recorded for the different treatments on weed density, relative weed density, weed fresh and dry biomass, 1000 kernel weight (g), and grain yield (kg ha^{-1}).

Weed density (m^2) at 25, 50 and 75 days after sowing (DAS): Data on weed density was recorded from two randomly selected quadrats of 50 × 50 cm (0.25 m^{-2}) from each plot at 25, 50 and 75 DAS. Weeds within the quadrat were identified, counted and clipped off above the soil surface.

Relative weed density (m^2) at 25, 50 and 75 days after sowing (DAS): Relative density and dry weight were worked out by using the following formulae:

Relative weed density (RD) = (Density of a given weed species / Density of total weeds) × 100

Dry biomass (g m^{-2}) of weeds at 25, 50 and 5 days after sowing (DAS): Data on weed dry biomass was recorded from two randomly selected quadrats of 50 × 50 cm (0.25 m^{-2}) from each plot at 30, 45 and 90 DAS. Weeds within the quadrat were clipped off and kept separately in respective kraft paper bags. Weeds packed in kraft paper bags were oven dried at 70 ^{o}C for 72 h and their dry weight was recorded by using a digital balance (TX323L, Shimadzu, Japan).

Economic analysis of treatments: The experimental data was economically analyzed by using the methodology described in CIMMYT (1988). The cost of maize production was found and net income was calculated to find the most profitable treatment.

Data analysis: The data collected were analyzed statistically by applying analysis of variance (ANOVA), where differences were detected; means were compared by employing Tukey's HSD (Honest significance difference) test at 5% probability with the software Statistix 8.1.

RESULTS AND DISCUSSION

Effect of various mulch materials on weed density of different maize weeds at 25, 50 and 75 days after sowing (DAS):

***Cyperus rotundus* density:** Effect of various mulch materials on *C. rotundus* weed density was significant ($p \leq 0.05$) at 25, 50 and 75 DAS (Tables 1 and 3). At 25 DAS, minimum weed density of *C. rotundus* was noted where rice straw was used, which was statistically similar to herbicide, black plastic mulch, dry leaves of eucalyptus and wheat straw. Maximum weed density was recorded where soybean was intercropped with maize (Table 1). At 50 and 75 DAS, minimum *C. rotundus* weed density was recorded where the herbicide Primextra at 400 mL $acre^{-1}$ was sprayed and black plastic mulch was used (Tables 2 and 3).

***Sorghum halepense* density:** At 25, 50 and 75 DAS, higher density of *S. halepense* was recorded where soybean was intercropped with maize, which was statistically equal to grass clippings and control. Lower *S. halepense* density was noted where black plastic mulch was applied (Tables 1 and 3). Maximum weed density was recorded where living mulch was used, which was statistically similar to grass clippings and control (Tables 1 and 3).

***Digeria arvensis* density:** At 25 and 75 DAS, higher density of *D. arvensis* was recorded where soybean was intercropped with maize which was statistically equal to grass clippings and control. Lower *D. arvensis* density was noted where rice straw was used (Tables 1 and 3). However, at 50 DAS, there was no significant effect of various mulch materials on *D. arvensis* density (Table 2).

***Alternanthera pungens* density:** At, 25, 50 and 75 DAS, lower *A. pungens* density was recorded where the herbicide Primextra at 400 mL $acre^{-1}$ was sprayed however; it was statistically similar to plastic mulch, rice straw, dry leaves of eucalyptus and wheat straw mulch (Tables 1 and 3). Higher *A. pungens* density was recorded when no mulch was used (Tables 1 and 3).

***Amaranthus hybrids* density:** At 25 DAS, maximum *A. hybrids* density was noted where no mulch was used, which was statistically similar to grass clippings and living mulch (Table 1). Lower weed density was noted where the herbicide Primextra was sprayed (Table 1). At 50 and

Table 1 - Effect of various mulch materials on weed density of different maize weeds at 25 days after sowing (DAS)

Treatment	*Cyprus rotundus*	*Sorghum halepense*	*Digera arvensis*	*Alternanthera pungens*	*Amaranthus hybridus*	*Echinocloa colonum*	*Tribulus terrestris*
Control	13.25 a	11.00 a	10.00 a	7.10 a	6.00 abc	15.00 a	7.37 a
Wheat straw mulch	3.25 b	3.00 b	2.50 b	2.50 b	2.25 bcd	3.50 b	1.75 b
Dry leaves of Eucalyptus	2.50 b	3.00 b	1.50 b	2.00 b	1.75 cd	2.00 b	0.75 bc
Rice straw mulch	1.50 b	2.35 b	1.00 b	1.00 b	1.75 cd	1.75 b	0.00 c
Grass clippings	10.80 a	9.62 a	7.75 a	5.92 a	4.62 a	12.37 a	5.50 a
Living mulch (Soybean crop)	10.87 a	9.67 a	8.30 a	5.75 a	4.37 ab	12.50 a	5.25 a
Black plastic mulch	1.50 b	1.75 b	1.25 b	1.50 b	1.25 d	1.75 b	0.50 bc
Herbicide spray	1.75 b	2.00 b	1.50 b	1.00 b	1.00 d	1.00 b	1.00 bc
HSD at 0.05 P	2.29	2.24	2.08	1.74	2.36	2.81	1.70

Means not sharing a letter in common in the column differ significantly at 5% probability level by Tukey's HSD test.

Table 2 - Effect of various mulch materials on weed density of different maize weeds at 50 DAS

Treatment	*Cyprus rotundus*	*Sorghum halepense*	*Digera arvensis*	*Alternanthera pungens*	*Amaranthus hybridus*	*Echinocloa colonum*	*Tribulus terrestris*
Control	10.50 a	11.87 a	10.85 a	9.00 a	8.00 a	13.25 a	7.37 a
Wheat straw mulch	1.50 b	1.25 b	1.25 c	1.50 b	1.25 b	2.00 b	1.75 b
Dry leaves of Eucalyptus	1.25 b	1.50 b	1.75 c	1.25 b	1.25 b	2.25 b	0.75 bc
Rice straw mulch	1.00 b	1.00 b	0.75 c	0.75 b	0.75 b	1.25 b	0.00 c
Grass clippings	9.12 a	9.82 a	7.75 b	7.52 a	6.95 a	11.70 a	5.50 a
Living mulch (Soybean crop)	9.20 a	9.92 a	9.20 ab	7.32 a	6.77 a	12.32 a	5.25 a
Black plastic mulch	0.75 b	1.00 b	0.00 c	1.00 b	1.25 b	1.25 b	0.50 bc
Herbicide spray	0.75 b	1.25 b	1.25 c	1.00 b	1.25 b	1.75 b	1.00 bc
HSD at 0.05 P	1.66	1.60	2.01	1.78	1.62	2.21	1.70

Means not sharing a letter in common in the column differ significantly at 5% probability level by Tukey's HSD test.

Table 3 - Effect of various mulch materials on weed density of different maize weeds at 75 DAS

Treatment	*Cyprus rotundus*	*Sorghum halepense*	*Digera arvensis*	*Alternanthera pungens*	*Amaranthus hybridus*	*Echinocloa colonum*	*Tribulus terrestris*
Control	11.87a	10.12 a	9.62 a	9.80 a	8.62 a	10.45 a	8.00 a
Wheat straw mulch	1.50 b	1.75 b	1.00 b	1.00 b	1.50 b	2.00 b	1.25 b
Dry leaves of Eucalyptus	2.00 b	1.50 b	1.00 b	1.50 b	1.50 b	2.00 b	1.25 b
Rice straw mulch	1.25 b	1.00 b	2.50 b	0.50 b	1.25 b	1.50 b	0.25 b
Grass clippings	10.00 a	8.12 a	6.72 a	6.50 a	7.00 a	8.47 a	6.50 a
Living mulch (Soybean crop)	10.10 a	8.27 a	7.40 a	7.25 a	7.20 a	8.12 a	6.50 a
Black plastic mulch	1.25 b	1.00 b	0.50 b	0.25 b	1.25 b	1.00 b	0.50 b
Herbicide spray	1.00 b	0.52 b	0.50 b	0.25 b	0.25 b	0.50 b	0.50 b
HSD at 0.05 P	1.54	1.51	1.91	2.46	1.83	1.74	1.46

Means not sharing a letter in common in the column differ significantly at 5% probability level by Tukey's HSD test.

75 DAS, there was maximum reduction in *A. hybrids* density where rice straw was used (Tables 2 and 3), while maximum *A. hybrids* density was recorded in the control where no mulch was used (Tables 2 and 3).

***Echinochloa colona* density:** At 25, 50 and 75 DAS, more reduction in *E. colona* density was observed where the herbicide Primextra was sprayed, which was statistically similar to black plastic mulch, rice straw, wheat straw and dry leaves of eucalyptus (Tables 1 and 3). Maximum *E. colona* density was recorded where no mulch was used and soybean was intercropped with maize (Tables 1 and 3).

***Tribulus terrestris* density:** At 25 DAS, minimum *T. terrestris* density was recorded where the herbicide Primextra was sprayed, which was statistically similar to black plastic, rice straw and dry leaves of eucalyptus, followed by wheat straw. Higher *T. terrestris* density was noted where no mulch was used (Table 1). However; at 50 and 75 DAS, minimum *T. terrestris* density was observed where rice straw was used. Higher *T. terrestris* density was recorded where no mulch was used (Tables 2 and 3).

Effect of various mulch materials on relative weed density of different maize weeds at 25, 50 and 75 days after sowing (DAS): The effect of various mulch materials on relative weed density of different weeds was significant ($p \leq 0.05$) at 25, 50 and 75 DAS during the course of the study (Tables 4 and 6).

Table 4 - Effect of various mulch materials on relative weed density of different maize weeds at 25 DAS

Treatment	*Cyprus rotundus*	*Sorghum halepense*	*Digera arvensis*	*Alternanthera pungens*	*Amaranthus hybridus*	*Echinocloa colonum*	*Tribulus terrestris*
Control	29.47abc	33.62 a	15.77 a	14.72 a	20.12 a	22.05 a	20.60 a
Wheat straw mulch	13.35 bc	14.10 b	7.05 a	11.67 a	11.82 a	13.67 a	8.22 a
Dry leaves of Eucalyptus	13.75 bc	18.22 b	9.25 a	11.42 a	11.20 a	16.15 a	7.62 a
Rice straw mulch	12.30 c	18.40 b	9.95 a	8.07 a	18.55 a	18.97 a	5.82 a
Grass clippings	21.32 ab	10.00 b	9.40 a	13.60 a	8.65 a	19.07 a	15.75 a
Living mulch (Soybean crop)	22.35 a	9.40 b	11.37 a	12.07 a	13.02 a	19.25 a	14.12 a
Black plastic mulch	12.85 c	14.75 b	10.57 a	12.85 a	9.35 a	18.75 a	13.62 a
Herbicide spray	16.62 abc	18.72 b	11.22 a	7.47 a	10.80 a	15.40 a	19.55 a
HSD at 0.05 P	8.21	14.40	15.05	9.36	12.68	13.88	15.79

Means not sharing a letter in common in the column differ significantly at 5% probability level by Tukey's HSD test.

Table 5 - Effect of various mulch materials on relative weed density of different maize weeds at 50 DAS

Treatment	*Cyprus rotundus*	*Sorghum halepense*	*Digera arvensis*	*Alternanthera pungens*	*Amaranthus hybridus*	*Echinocloa colonum*	*Tribulus terrestris*
Control	22.5 a	21.05 a	16.55 a	17.75 a	15.45 a	26.50 a	21.57 a
Wheat straw mulch	15.85 a	15.00 a	10.75ab	15.00 a	13.32 a	20.00 a	13.30 a
Dry leaves of Eucalyptus	16.77 a	17.55 a	7.80 ab	14.15 a	12.57 a	23.45 a	19.57 a
Rice straw mulch	19.40 a	15.82 a	2.00 b	6.32 a	11.40 a	23.75 a	10.82 a
Grass clippings	18.17 a	17.65 a	11.45 ab	12.12 a	12.05 a	23.12 a	13.80 a
Living mulch (Soybean crop)	18.07 a	17.42 a	16.02 a	11.95 a	13.67 a	18.55 a	12.15 a
Black plastic mulch	16.00 a	11.50 a	2.00 b	3.55 a	13.27 a	23.12 a	8.37 a
Herbicide spray	16.00 a	16.67 a	2.00 b	6.25 a	4.15 a	11.25 a	8.37 a
HSD at 0.05 P	8.56	12.08	15.44	23.72	14.04	17.80	17.91

Means not sharing a letter in common in the column differ significantly at 5% probability level by Tukey's HSD test.

Table 6 - Effect of various mulch materials on relative weed density of different maize weeds at 75 DAS

Treatment	*Cyprus rotundus*	*Sorghum halepense*	*Digera arvensis*	*Alternanthera pungens*	*Amaranthus hybridus*	*Echinocloa colonum*	*Tribulus terrestris*
Control	23.15 a	22.07 a	18.25 a	17.00 a	16.62 a	23.25 a	16.50 ab
Wheat straw mulch	14.90 a	12.52 a	12.32 a	15.30 a	12.52 a	14.82 a	17.87 a
Dry leaves of Eucalyptus	11.82 a	14.37 a	16.95 a	13.12 a	10.82 a	13.77 a	6.80 ab
Rice straw mulch	9.55a	19.55 a	14.15a	14.50 a	13.32 a	20.65 a	5.00 b
Grass clippings	19.90 a	16.27 a	12.57 a	15.45 a	13.85 a	19.15 a	12.97 ab
Living mulch (Soybean crop)	19.92 a	16.75 a	13.82 a	14.52 a	15.20 a	19.10 a	14.05 ab
Black plastic mulch	9.80 a	19.17 a	5.000 a	13.37 a	15.42 a	22.75 a	9.375 ab
Herbicide spray	14.55 a	16.75 a	12.55 a	9.77 a	16.02 a	20.85a	13.25 ab
HSD at 0.05 P	17.03	9.63	24.20	27.26	24.19	19.08	16.89

Means not sharing a letter in common in the column differ significantly at 5% probability level by Tukey's HSD test.

Relative weed density of *Cyperus rotundus:* At 25 DAS, lower relative weed density of *C. rotundus* was noted where black plastic mulch was used and it was statistically similar to all other treatments except living mulch and grass clippings (Table 4). However; at 50 and 75 DAS, there was no significant statistical difference among treatments but a lower value was recorded where black plastic mulch, herbicide, rice, wheat straw and dry leaves of eucalyptus were used (Tables 5 and 6).

Relative weed density of *Sorghum halepense:* At 25 DAS, lower relative weed density of *S. halepense* was recorded where soybean intercropped with maize was used (Table 4). However; at 50 and 75 DAS, there was no significant statistical difference among treatments but a lower value was recorded where black plastic mulch was used (Tables 5 and 6).

Relative weed density of *Digeria arvensis:* At 25 and 50 DAS, there was non-significant statistical difference among treatments (Table 5). However; at 75 DAS, lower relative weed density was recorded where rice straw was used; it was statistically similar to all other treatments except for the control (Table 6).

Relative weed density of *Alternanthera pungens and Amaranthus hybridus:* Effect of various mulch materials on relative weed density of *A. pungens and A. hybridus* was non-significant at 25, 50 and 75 DAS (Tables 4 and 6).

Relative weed density of *Echinochloa colona:* The effect of different mulch materials on relative weed density of *E. colona* was non-significant at 25, 50 and 75 DAS during the course of the experiment (Tables 4 and 6).

Relative weed density of *Tribulus terrestris:* There was a non-significant effect of various mulch materials on relative weed density of *T. terrestris* at 25 and 75 DAS but significant ($p \leq 0.05$) at 50 DAS during the course of the study (Tables 4 and 6). At 50 DAS, minimum relative weed density of *T. terrestris* was recorded where rice straw was used (Table 5).

Effect of various mulch materials on fresh biomass of different maize weeds at 25, 50 and 75 days after sowing (DAS):

Fresh biomass of *Cyperus rotundus:* At 25 DAS, minimum fresh biomass of *C. rotundus* was noted where black plastic mulch was used, which was statistically similar to the remaining treatments (Table 7). However; at 50 and 75 DAS, minimum *C. rotundus* fresh biomass was recorded where the herbicide Primextra was sprayed (Tables 8 and 9). Maximum fresh biomass was also recorded where living mulch was used (Tables 7and 9).

Fresh biomass of *Sorghum halepense:* The effect of various mulch materials on *S. halepense* fresh biomass was non-significant at 25 DAS but significant at 50 and 75 DAS (Tables 7 and 9). At 50 and 75 DAS, maximum fresh biomass was found where no mulch was used (Tables 8 and 9). Minimum *S. halepense* fresh biomass was recorded where black plastic mulch was used (Tables 8 and 9).

Fresh biomass of *Digeria arvensis:* At 25 DAS, higher fresh biomass of *D. arvensis* was recorded where no mulch was used, which was at par with grass clippings and living mulch. Lower fresh biomass of *D. arvensis* was noted where the herbicide Primextra was sprayed (Table 7). However; at 50 DAS, minimum *D. arvensis* fresh biomass was recorded where black plastic mulch was used (Table 8). At 75 DAS, higher significant fresh biomass recorded in *D. arvensis* under control whereas lowest significant fresh biomass was recorded where black plastic mulch was used (Tables 7 and 9).

Fresh biomass of *Alternanthera:* At, 25 and 50 DAS, lower fresh biomass of *A. pungens* was recorded where rice straw was used (Tables 7 and 8). However; at 75 DAS, lower fresh biomass of *A. pungens* was measured where primextra herbicide was used (Table 9). Higher fresh biomass of *A. pungens* was recorded where no mulch was used (Tables 7and 9).

Fresh biomass of *Amaranthus* hybrids: At 25, 50 and 75 DAS, maximum *A. hybrids* fresh biomass was noted where no mulch was used, which was statistically similar to grass clippings and living mulch (Tables 7 and 9). Lower fresh biomass was noted where the herbicide Primextra was sprayed (Tables 7 and 9).

Table 7 - Effect of various mulch materials on fresh biomass different maize weeds at 25 DAS

Treatment	*Cyprus rotundus*	*Sorghum halepense*	*Digera arvensis*	*Alternanthera pungens*	*Amaranthus hybridus*	*Echinocloa colonum*	*Tribulus terrestris*
Control	6.12 a	8.07 ab	5.57 a	9.45 a	5.60 a	5.50 a	4.27 a
Wheat straw mulch	3.92 b	3.47 b	2.05 bc	3.35 b	1.62 b	3.70 abc	1.62 a
Dry leaves of Eucalyptus	2.55 bc	2.92 b	1.27 c	2.50 bc	1.30 b	2.05 bc	1.32 a
Rice straw mulch	2.10 bc	2.87 b	1.10 c	1.12 c	1.77 b	2.25 bc	1.02 a
Grass clippings	6.17 a	6.32 a	4.00 a	7.52 a	4.02 a	4.45 ab	3.02 a
Living mulch (Soybean crop)	6.95 a	6.67 a	3.82 ab	7.47 a	3.92 a	4.40 abc	3.05 a
Black plastic mulch	1.65 c	2.42 b	1.82 c	1.87 bc	1.10 b	1.92 c	1.50 a
Herbicide spray	2.02 bc	2.97 b	1.02 c	1.60 bc	0.95 b	1.97 bc	1.72 a
HSD at 0.05 P	2.16	2.71	1.82	2.17	1.78	2.50	2.27

Means not sharing a letter in common in the column differ significantly at 5% probability level by Tukey's HSD test.

Table 8 - Effect of various mulch materials on fresh biomass of different maize weeds at 50 DAS

Treatment	*Cyprus rotundus*	*Sorghum halepense*	*Digera arvensis*	*Alternanthera pungens*	*Amaranthus hybridus*	*Echinocloa colonum*	*Tribulus terrestris*
Control	5.10 a	4.22 a	2.77 a	2.92 a	2.60 a	3.10 a	2.40 a
Wheat straw mulch	0.57 b	0.52 b	0.35 b	0.40 b	0.35 b	0.60 b	0.47 b
Dry leaves of Eucalyptus	0.50 b	0.62 b	0.50 b	0.40 b	0.35 b	0.57 b	0.27 b
Rice straw mulch	0.42 b	0.42 b	0.25 b	0.22 b	0.20 b	0.42 b	0.23 b
Grass clippings	3.62 a	3.92 a	1.70 a	1.92 a	1.90 a	2.45 a	1.60 a
Living mulch (Soybean crop)	3.60 a	3.87 a	1.75 a	1.75 a	1.80 a	2.35 a	1.67 a
Black plastic mulch	0.32 b	0.40 b	0.30 b	0.27 b	0.40 b	0.40 b	0.17 b
Herbicide spray	0.30 b	0.60 b	0.40 b	0.32 b	0.40 b	0.50 b	0.32 b
HSD at 0.05 P	0.73	0.61	0.61	0.56	0.69	0.69	0.91

Means not sharing a letter in common in the column differ significantly at 5% probability level by Tukey's HSD test.

Table 9 - Effect of various mulch materials on fresh biomass of different maize weeds at 75 DAS

Treatment	*Cyprus rotundus*	*Sorghum halepense*	*Digera arvensis*	*Alternanthera pungens*	*Amaranthus hybridus*	*Echinocloa colonum*	*Tribulus terrestris*
Control	39.62 a	54.77 a	31.45 a	39.80 a	28.00 a	60.07 a	28.22 a
Wheat straw mulch	8.05 b	10.90 b	5.15 b	4.20 b	5.25 b	11.50 b	8.22 b
Dry leaves of Eucalyptus	8.75 b	8.80 b	5.22 b	7.07 b	7.35 b	8.87 b	5.85 b
Rice straw mulch	5.45 b	6.45 b	4.00 b	3.87 b	7.45 b	8.22 b	3.65 b
Grass clippings	37.50 a	50.00 a	28.75 a	37.70 a	24.25 a	54.25 a	26.75 a
Living mulch (Soybean crop)	35.12 a	49.62 a	28.50 a	38.00 a	25.50 a	57.50 a	25.17 a
Black plastic mulch	5.70 b	5.65 b	1.87 b	1.15 b	5.27 b	9.90 b	2.37 b
Herbicide spray	4.40 b	7.50 b	3.00 b	2.90 b	1.20 b	2.87 b	2.85 b
HSD at 0.05 P	10.86	13.17	10.44	14.62	10.27	11.22	7.72

Means not sharing a letter in common in the column differ significantly at 5% probability level by Tukey's HSD test.

Fresh biomass of *Echinochloa colona:* At 25 and 50 DAS, there was greater reduction in *E. colona* fresh biomass where black plastic mulch was used, which was statistically similar to herbicide spray, rice straw, wheat straw and dry leaves of eucalyptus (Tables 7 and 8). However; at 75 DAS, lower fresh biomass was noted where the herbicide Primextra was sprayed (Table 9). Maximum *E. colona* fresh biomass was recorded where no mulch was used (Tables 7 and 9).

Fresh biomass of *Tribulus terrestris:* There was a non-significant effect of various mulch materials on fresh biomass of *T. terrestris* at 25 DAS but a significant effect at 50 and 75 DAS (Tables 7 and 9). At 50 and 75 DAS, minimum *T. terrestris* fresh biomass was recorded where black plastic mulch was used. Higher *T. terrestris* fresh biomass was noted where no mulch was used (Tables 8 and 9).

Effect of various mulch materials on dry biomass of different maize weeds at 25, 50 and 75 days after sowing (DAS):

Dry biomass of *Cyperus rotundus:* At 25, 50 and 75 DAS, lower dry biomass of *C. rotundus* was recorded for black plastic, which was statistically similar to other mulch treatments (Tables 10 and 12). However, maximum dry biomass of *C. rotundus* at 25 DAS was recorded where wheat straw mulch was used (Table 10). At 50 DAS, maximum dry biomass was recorded where no mulch was used (Table 11). At 75 DAS, maximum dry biomass was found where living mulch was used (Table 12).

Table 10 - Effect of various mulch materials on dry biomass of different maize weeds at 25 DAS

Treatment	*Cyprus rotundus*	*Sorghum halepense*	*Digera arvensis*	*Alternanthera pungens*	*Amaranthus hybridus*	*Echinocloa colonum*	*Tribulus terrestris*
Control	2.52 bc	1.50 a	2.25 a	1.87 a	1.55 a	1.75 a	1.57 abc
Wheat straw mulch	1.17 a	0.85 a	0.47 b	0.85 abcd	0.35 b	0.95 ab	0.30 bc
Dry leaves of Eucalyptus	0.52 bc	0.72 a	0.30 b	0.60 bcd	0.30 b	0.47 b	0.27 bc
Rice straw mulch	0.52 bc	0.65 a	0.57 b	0.20 d	0.30 b	0.50 b	0.08 c
Grass clippings	0.82 abc	0.92 a	1.30 ab	1.52 ab	1.05 a	1.37 a	0.67 ab
Living mulch (Soybean crop)	1.02 ab	0.95 a	1.32 ab	1.25 abc	1.02 a	1.35 a	0.90 a
Black plastic mulch	0.30 c	0.52 a	0.20 b	0.37 cd	0.17 b	0.27 b	0.22 bc
Herbicide spray	0.35 c	0.62 a	0.15 b	0.47cd	0.12 b	0.25 b	0.27 bc
HSD at 0.05 P	0.64	0.98	1.44	0.95	0.55	0.81	0.49

Means not sharing a letter in common in the column differ significantly at 5% probability level by Tukey's HSD test.

Table 11 - Effect of various mulch materials on dry biomass of different maize weeds at 50 DAS

Treatment	*Cyprus rotundus*	*Sorghum halepense*	*Digera arvensis*	*Alternanthera pungens*	*Amaranthus hybridus*	*Echinocloa colonum*	*Tribulus terrestris*
Control	5.10 a	4.22 a	2.77 a	2.92 a	2.60 a	3.10 a	2.40 a
Wheat straw mulch	0.57 b	0.52 b	0.35 b	0.40 b	0.35 b	0.60 b	0.47 b
Dry leaves of Eucalyptus	0.50 b	0.62 b	0.50 b	0.40 b	0.35 b	0.57 b	0.27 b
Rice straw mulch	0.42 b	0.42 b	0.25 b	0.22 b	0.20 b	0.42 b	0.23 b
Grass clippings	3.62 a	3.92 a	1.70 a	1.92 a	1.90 a	2.45 a	1.60 a
Living mulch (Soybean crop)	3.60 a	3.87 a	1.75 a	1.75 a	1.80 a	2.35 a	1.67 a
Black plastic mulch	0.32 b	0.40 b	0.30 b	0.27 b	0.40 b	0.40 b	0.17 b
Herbicide spray	0.30 b	0.60 b	0.40 b	0.32 b	0.40 b	0.50 b	0.32 b
HSD at 0.05 P	0.73	0.61	0.61	0.56	0.69	0.69	0.91

Means not sharing a letter in common in the column differ significantly at 5% probability level by Tukey's HSD test.

Table 12 - Effect of various mulch materials on dry biomass of different maize weeds at 75 DAS

Treatment	*Cyprus rotundus*	*Sorghum halepense*	*Digera arvensis*	*Alternanthera pungens*	*Amaranthus hybridus*	*Echinocloa colonum*	*Tribulus terrestris*
Control	5.47 a	9.50 a	8.12 a	7.15 a	8.00 a	9.50 a	6.75 a
Wheat straw mulch	1.00 b	1.10 b	0.90 c	0.52 b	0.62 b	1.42 b	1.05 b
Dry leaves of Eucalyptus	1.15 b	1.10 b	0.67 c	0.87 b	0.92 b	1.10 b	0.72 b
Rice straw mulch	0.70 b	0.80 b	0.20 c	0.50 b	0.95 b	1.05 b	0.37 b
Grass clippings	4.62 a	7.62 a	5.12 b	5.00 a	5.62 a	8.50 a	4.87 a
Living mulch (Soybean crop)	4.82 a	7.00 a	6.65ab	5.50 a	4.62 a	7.20 a	5.50 a
Black plastic mulch	0.70 b	0.70 b	0.22 c	0.15 b	0.75 b	1.22 b	0.40 b
Herbicide spray	0.52 b	0.92 b	0.10 c	0.10 b	0.15 b	0.35 b	0.35 b
HSD at 0.05 P	1.61	1.60	1.90	1.92	1.71	1.99	1.61

Means not sharing a letter in common in the column differ significantly at 5% probability level by Tukey's HSD test.

Dry biomass of *Sorghum halepense:* The effect of various mulch materials on *S. halepense* dry biomass was non-significant at 25 DAS but significant at 50 and 75 DAS (Tables 10 and 12). At 50 and 75 DAS, maximum dry biomass was found where no mulch was used (Table 11). Minimum *C. halepense* dry biomass was recorded where black plastic mulch was used (Tables 11 and 12). Maximum dry biomass was recorded where no mulch was used (Tables 11 and 12).

Dry biomass of *Digeria arvensis:* At 25 and 50 DAS, higher dry biomass of *D. arvensis* was recorded where no mulch was used, which was at par with grass clippings and living mulch. Lower *D. arvensis* dry biomass was noted where the herbicide Primextra and black plastic mulch were used (Tables 10 and 11). However; at 75 DAS, higher dry biomass was found where no mulch was used (Table 12). There lowest *D. arvensis* dry biomass was recorded where rice straw was used (Table 12).

Dry biomass of *Alternanthera pungens:* At, 25 and 50 DAS, lower dry biomass of *A. pungens* was recorded where rice straw was used, which was statistically similar to other mulch treatments (Tables 10 and 11). However; at 75 DAS, lower dry biomass of *A. pungens* was measured where the herbicide was used (Table 12). Higher dry biomass of *A. pungens* was recorded where no mulch was used (Tables 10 and 12).

D**ry biomass of *Amaranthus hybrids:*** At 25 DAS, lower dry biomass was noted where herbicide was sprayed; however, it was statistically similar to other treatments (Table 10). But at 50 DAS, maximum reduction in *A. hybrids* dry biomass was observed where rice straw was used which was statistically similar to other treatments (Table 11). At 75 DAS, lower dry biomass was noted where the herbicide Primextra was sprayed (Table 12). Maximum *A. hybrids* dry biomass was recorded in the control, where no mulch was used (Tables 10 and 12).

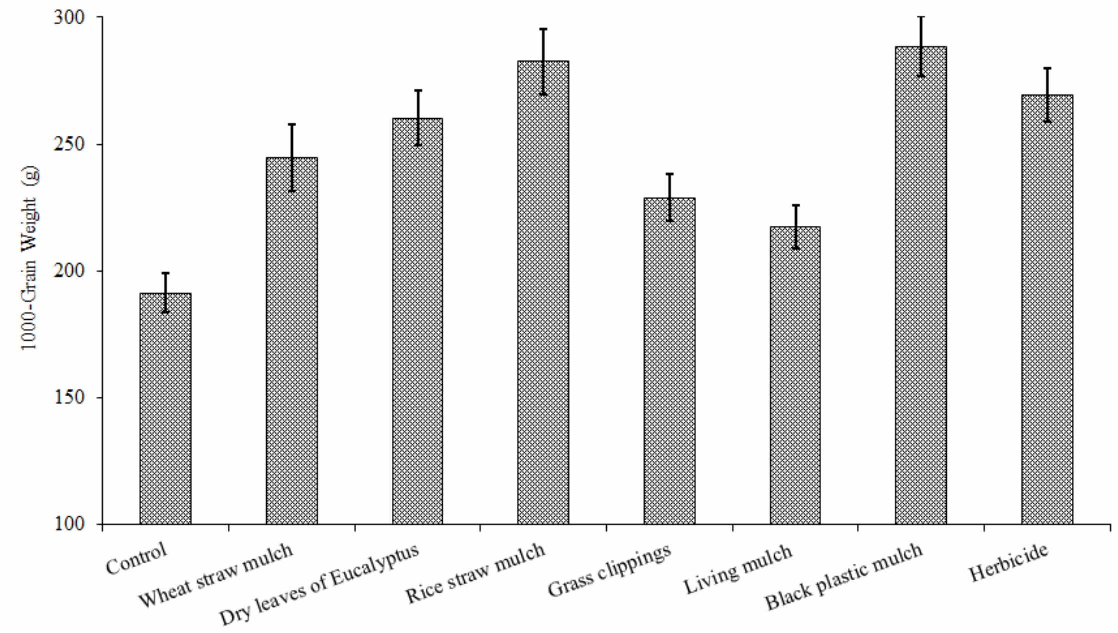
Dry biomass of *Echinochloa colona:* At 25 and 50 DAS, there was greater reduction in dry biomass of *E. colona* where black plastic mulch was used, which was statistically similar to the herbicide Primextra, rice straw, wheat straw and dry leaves of eucalyptus (Tables 10 and 11). However; at 75 DAS, lower dry biomass was noted where Primextra was sprayed (Table 12). Maximum *E. colona* dry biomass was recorded in the control, where no mulch was used (Tables 10 and 12)

Dry biomass of *Tribulus terrestris:* At 25 DAS, minimum *T. terrestris* dry biomass was recorded where black plastic mulch was used, which was statistically similar to Primextra, rice and wheat straw and dry leaves of eucalyptus and control. Higher *T. terrestris* dry biomass was noted where living mulch was used, which was equal to grass clippings and control (Tables 10). But at 50 DAS, minimum dry biomass of *T. terrestris* was found where rice straw was used (Table 11). At 75 DAS, minimum dry biomass of *T. terrestris* was found where the herbicide Primextra was sprayed. More *T. terrestris* dry biomass was recorded where no mulch was used (Tables 11 and 12).

1000 grain weight: There was a significant effect of various mulch materials on 1000 kernel weight of maize (Figure 2). More 1000 kernel weight was recorded where black plastic mulch was used followed by rice straw mulch. Lower 1000 grains weight was observed where no any mulch was used followed by living mulch (soybean intercropped with maize).

Grain yield: There was a significant effect of various mulch materials on grain yield of maize (Table 13). Higher grain yield was found where black plastic mulch was used; however, it was statistically similar to herbicide, living mulch, grass clipping, rice straw, dry leaves of eucalyptus and wheat straw mulching. Minimum grain yield was recorded where no mulch was used (control) but it was also at par with where wheat straw, grass clippings and soybean were intercropped with maize (Table 13).

Various mulch materials wielded suppressive effects on weed density, relative weed density, fresh and dry biomass of different weed species, and they had favorable effects on 1000 kernel weight and grain yield of maize plants. There was maximum reduction in fresh biomass, relative fresh biomass, fresh and dry biomass in all weed species where the herbicide Primextra at 400 mL acre^{-1} and black plastic mulch, rice straw and wheat straw were used (Tables 1 and 12). There was maximum weed density, relative weed density, fresh and dry biomass in all weed species where soybean was intercropped with maize and grass clippings were used (Tables 1



The bars indicate standard error (± SE) of mean (n = 3). All means are significantly different at $p \leq 0.05$.

Figure 2 - Effect of various mulch materials on 1000 grain weight of maize.

Table 13 - Economic analysis of maize as affected by various mulch materials in year 2013

Parameter	T1	T2	T3	T4	T5	T6	T7	T8	Remarks
Grain yield	14.46	15.46	15.72	15.62	15.31	15.31	15.87	15.81	t ha^{-1}
Adjusted yield	13.01	13.91	14.14	14.05	13.79	13.79	14.28	14.22	Less than 10% from actual yield
Value	4657.76	4979.88	5063.63	5031.42	493.15	493.15	5111.94	5092.61	USD 357.90/1000 kg
Value of stalk	389.78	407.15	4232.62	408.87	410.01	402.19	412.88	413.64	USD 19.09/1000 kg
Gross benefits	5047.55	5387.03	5478.61	5440.29	5341.57	5333.74	5524.82	5506.25	USD
Cost of wheat straw mulch	-	38.18	-	-	-	-	-		USD ha^{-1}
Cost of dry leaves of Eucalyptus	-	-	19.09	-	-	-	-	-	USD ha^{-1}
Cost of rice straw mulch	-	-	-	28.63	-	-	-	-	USD ha^{-1}
Cost of grass clippings	-	-	-	-	21	-	-	-	USD ha^{-1}
Cost of living mulch	-	-	-	-	-	95.44	-	-	USD ha^{-1}
Cost of black plastic mulch	-	-	-	-	-	-	42.95	-	USD ha^{-1}
Cost of herbicide								171.79	USD ha^{-1}
Variable costs	-	4000	2000	3000	2200	10000	4500	18000	USD ha^{-1}
Permanent cost	520.90	520.90	520.90	54578	520.90	520.90	520.90	520.90	USD ha^{-1}
Total expenditures	520.90	559.07	539.99	549.53	541.90	616.34	563.85	692.89	USD ha^{-1}
Net benefits	4526.65	4827.95	4938.62	4890.76	4799.68	4717.41	4960.97	4813.56	USD ha^{-1}
BCR	9.69	9.64	10.15	9.90	9.86	8.65	9.80	7.95	

T1 = Control, T2 = Wheat straw mulch, T3 = Dry leaves of eucalyptus, T4 = Rice straw mulch, T5 = Grass clippings, T6 = Living mulch (soybean crop), T7 = Black plastic mulch, T8 = Herbicide (primextra at 400 mL $acre^{-1}$), BCR = Benefit cost ratio, USD = United states dollar.

and 12). The possible reason of reduction in weed density, relative weed density, fresh and dry biomass in herbicide sprayed plots is the phytotoxic effect of herbicides. Herbicides enter the cell walls of weeds and interrupt different biochemical processes/pathways. When herbicides are sprayed, they interact with weeds and disrupt various biochemical processes such as inhibition of photosynthesis, chlorophyll bleaching and as a result weeds are killed (Yang et al., 2010; El-Hadary and Chung, 2013). In line with results of the current research where Primextra herbicide reduced weed density, relative weed density and fresh and dry biomass of maize weeds, Ugwunna et al., (2015) and Khan et al., (2013) found that Primextra gold significantly reduced weeds of cucumber, maize and wheat and hence improved their yield.

Black plastic mulch progressively reduced weed density, relative weed density, fresh and dry biomass of weeds (Tables 1 and 12). The possible reason of low weed density, relative weed density, fresh and dry biomass of weeds under influence of plastic mulch might be due to the lower percentage of sunlight transmission, which is necessary for photosynthesis, through black plastic mulch. Weeds also require sunlight for photosynthesis. But black plastic mulch significantly reduces light transmission to very low levels, and limits the process of photosynthesis, hence weeds grow poorly. Black plastic mulch inhibits/stops weeds, except for those which emerge through the planting holes or damaged portion of the plastic mulch. The results of reduction in weed density, relative weed density and fresh and dry biomass of weeds in maize under black plastic mulch are in line with Ashrafuzzaman et al., (2011) who reported that using black plastic film mulch resulted in 100% control of all the weeds in maize. Also, plastic mulches are expected to reduce field management costs, e.g., costs of weed control (Xu et al., 2015). Plastic mulches not only reduced evaporation, field management costs and soil erosion but also reduced weed infestation and increased yields of crops such as okra (Qin et al., 2013; Kareem et al., 2015; Xu et al., 2015). Furthermore, rice straw significantly decreased weed density, relative weed density and fresh and dry biomass of weeds in maize. This reduction might be due to release of allelochemicals from rice straw decomposition, which is more phytotoxic to weed plants. Allelopathic mulches such as rice, while in decomposition, produce a number of phytotoxins that suppress growth and development of subsequent crops and weeds (Khaliq et al., 2014).

Maximum weed density, relative weed density, fresh and dry biomass of all weeds species were found where soybean (living mulch) was intercropped with maize. This may be due to the fact that the soybean genotype used in this study might be a poor competitor for essential resources such as nutrients, moisture and light, because each crop cultivar has its specific ability to compete with weeds (Balbinot Jr., 2003). Another reason of higher weed density, relative weed density and fresh biomass of weeds in soybean mulch is that soybean belongs to the C3 category of plants while almost all weeds belong to the C4 group. C4 plants are more efficient at capturing CO_2 from the atmosphere and absorbing nutrients. Some weeds have high photosynthetic flexibility, and grow and reproduce even at low light levels. They have a deep root system and uptake moisture and nutrients more deeply than other C3 plants, e.g., soybean. It is also likely that soybean was affected by the allelopathic effects of weeds because each plant species has the potential to release allelopathic substances. Weeds inhibit or stimulate the growth of crop plants by releasing allelochemicals into the growing environment (Tanveer et al., 2010). Thus, it is likely that allelopathic chemicals present in weeds might have caused allelopathic effects on soybean crop, and soybean did not suppress weed density, relative weed density, fresh and dry biomass of weeds.

Improvement in 1000 grain weight and grain yield of the maize crop by application of herbicides, plastic mulch and rice, wheat straw and eucalyptus leaves is likely to be due to the ability of these inorganic and organic mulches to efficiently reduce weed density and growth. Better resource utilization (e.g., soil moisture by evaporation reduction, radiation interception, nutrient availability and soil temperature moderation caused by crop residue decomposition) probably contributed to prompt growth, greater dry matter accumulation and consequently higher 1000 grain weight and grain yield by maize plants. Qin et al. (2015) reported an increase in grain yield of maize and wheat by crop residue mulching. Rice straw possesses allelochemicals which are toxic to weeds and reduce weed growth and their densities, hence maize yield was increased. Furthermore, there may be an increase in the available water content of soil upon addition of various crop straw mulches (Murungu et al., 2011). Khurshid et al., (2006) ascribed positive yield response in maize as a result of increased water contents in soils after application of straw mulch, which reduced evaporation. Straw decomposition produces organic acids, which mobilize the insoluble phosphorus from soil to soil solution in plant available forms. Earlier research has shown that mulching with crop residues at the rate of 4 and 6 ton ha^{-1} not only affected the physical and chemical properties of the soil but also maintained good grain yield (Khurshid et al., 2006). Another study showed that the frequency of weeds was higher in unmulched than in mulched plots since mulches have the ability to smother weeds depending on their thickness (Essien et al., 2009). The lowest weed biomass in straw mulched maize plots was due to the fact that straw mulches shielded the soil surface better in the non-cropped area, providing reduced light availability for photosynthesis and ultimately reducing the growth of weeds (Ahmed et al., 2007).

Based on results of weed density, relative weed density, fresh biomass and dry biomass of different maize weeds, increased 1000 grain weight and higher grain yield after application of mulching materials, it was concluded that eucalyptus or rice straw mulching at 4 ton ha^{-1} proved to be the most effective for suppressing maize weeds with higher net income than other mulches. Conclusively, eucalyptus or straw mulch at 4 ton ha^{-1} is recommended for weed management in maize under local rain-fed conditions because of their effective weed suppression ability and also because they are organic in nature.

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