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Evaluation of Mulching as an Integrated Weed Management Strategies in Maize

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Abstract

The experiment was conducted at the Agronomy Field of Bangladesh Agricultural University, Mymensingh to evaluate the efficacy of mulching as part of integrated weed management strategies in maize. Randomized Complete Block Design (RCBD) was employed with three replications comprising fifteen treatments that combined various mulches, pre-emergence (Panida 33EC) and post-emergence (Affinity 50.75WP) herbicides, as well as manual weeding. These treatments encompassed rice husk mulch, rice straw mulch, water hyacinth mulch, black plastic mulch, transparent plastic mulch, and different herbicide applications.The experimental maize crops were infested by 15 weed species from 9 families with prominent species including Cynodon dactylon, Echinochloa cruss-galli, Eleusine indica, Digitaria sanguinalis, Cyperus rotundus, Mimosa pudica, Polygonum hydropiper and Eclipta prostrate. Results indicated that the integration of mulching with herbicideapplications significantly influenced crop characteristics and yields. Particularly the combination of straw mulching with post-emergence herbicide exhibited the most favourable outcomes consisting the highest grain yield (13.65 t ha^{-1}) and stover yield (15.19 t ha^{-1}). Notably, the treatment involving post-emergence herbicide and rice straw mulch (T_{12}) displayed the lowest weed density and weed dry matter. Crucial yield-contributing factors such as plant height, cob length, cob diameter, number of grains per row and column, total grain count, total cob weight, dry weight of 100

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seeds, and overall grain and stover yield were maximized when post-emergence herbicide was coupled with rice straw mulch. This study concluded that the combination of post-emergence herbicide and rice straw mulch standed out as the most efficient weed control practice for maize cultivation.

Keywords: Mulching, weed, maize, herbicide, management

INTRODUCTION

Bangladesh, a developing nation, relies heavily on agriculture as its primary economic sector. The agriculture industry not only contributes to the country's socioeconomic progress but also supports sustainable economic development by enhancing rural conditions, ensuring food security, and reducing poverty. In the fiscal year 2019-20, agriculture accounted for 13.35% of Bangladesh's GDP (GoB, 2020).Among the major cereal crops, maize (*Zea mays*) holds a significant position. It is cultivated both in irrigated and rain-fed areas and ranks as the world's third-largest cereal crop. (CIMMYT, 2009) notes that maize thrives in Bangladesh's fertile alluvial soil and can be grown almost year-round excluding the rainy season. Starting from 2000, maize transformed into a profitable cash crop for farmers in the northern and western regions of Bangladesh due to surging demand, especially from the poultry industry. The establishment of the Bangladesh Agricultural Research Institute in 1976 catalyzed research and government interest in maize production (Ali et al., 2008). The annual maize demand now stands at around 1.2 million metric tons. Numerous organizations are actively engaged in increasing maize production in Bangladesh, leading to a steady rise in maize cultivation due to its high productivity and diverse applications (Islam and Kaul, 1986).Covering approximately 1,165,594 acres, maize yields around 4,015,306 metric tons of grains annually (BBS, 2020). Maize offers advantages such as higher yields and profitability compared to major cereal crops like rice and wheat. Despite ranking third in terms of human consumption after rice and wheat, Bangladesh imports a considerable quantity of maize to satisfy the burgeoning demand from poultry and feed industries. Maize's versatile applications range from human consumption to serving as a source of protein, carbohydrates, and lipids for malnourished populations. Consequently, the government is increasingly prioritizing maize production. Maize finds utility as food, poultry and livestock feed (Memon et al., 2011) and industrial raw material, with applications in producing corn oil, starch, flakes, syrups, and various other products. It's also commonly roasted for consumption (Romney et al., 2003).However, challenges such as substantial weed infestation in rain-fed areas lead to significant yield losses (Hussain et al., 2011). Weeds compete with crops for essential resources like light, water and nutrients, impacting crop quality and yield. Effective weed management practices are crucial for profitable agriculture. The sensitivity of maize to climatic conditions and poor management including inadequate weed control, heightens the risks and diminishes yields (Munsif et al., 2009). Weeds are reported to cause up to 58% grain yield loss in maize, surpassing the impact of other pests (Ihsan et al., 2015).Various integrated weed management (IWM) approaches encompass biological, cultural, mechanical, chemical, and genetic methods for effective weed control (Mahmoodi and Rahimi, 2009). Manual weeding and cultivation are important physical methods for weed control (Ulloa et al., 2011), but not always the most efficient. Legume cover crops enhance soil nutrient status (Kaizzi et al., 2006) and mixing legumes with cereals improves soil fertility and yield (Abdullah and Chaudhry, 1996).

Mulching, another cultural method, effectively suppresses weeds in maize fields. It involves covering soil to hinder weed growth while supporting crop growth. Mulching conserves soil and water, improves soil quality, regulates temperature, and restores degraded land's productivity (Shah et al., 2014). Plastic mulches, transparent or black, impact soil temperature especially for soil solarization (Stapleton, 2000; Ham and Kluitenberg, 1994).Considering the challenges, a study was conducted to assess the impact of mulching on weed suppression and maize yield. Bangladesh's agricultural landscape heavily relies on maize, a major cereal crop. Despite challenges posed by weed infestation, efforts through integrated weed management and innovative practices like mulching are being explored to enhance maize yield. These efforts are essential for addressing food security concerns and achieving sustainable economic development in the country. Therefore the study aimed to identify suitable mulches for weed control, evaluate mulch efficacy, and determine their influence on maize yield and yield-contributing factors.

MATERIALS AND METHODS

The study was executed at the Agronomy Field situated within the premises of Bangladesh Agricultural University in Mymensingh. This section provides a concise overview of the experimental site and soil, prevailing climatic conditions, applied treatments, specifics concerning the herbicide employed, the adopted experimental design and layout, as well as meticulous details pertaining to crop management, data collection procedures and the subsequent statistical analyses conducted.

Experimental site

The experimental site was located precisely at 24.75° N latitude and 90.5° longitude, standing at an elevation of 18 meters above mean sea level. It featured within the realm of non-calcereous dark gry floodplain soil, nestled in the ambit of the Old Brahmaputra Floodplain denoted as "AEZ-9" as per the delineation by UNDP and FAO in 1988. The sites terrain was elevated with well drained clay loam soil exhibiting a pH of 6.5.

Experimental material and design

A hybrid maize (*Zea mays*. L) cultivar namely Pioneer (imported by Petrochem BD Limited from India) was used for the experiment. The experiment was laid out in a randomized complete block design with 3 replications. The whole experimental area was divided into three blocks each representing a replication. Each block was then subdivided into 15 unit plots. There was a total of 45 unit plots (15 mulch treatments x 3 replications). The size of each unit plot was 4.0 m x 2.5 m. The treatments were T_1(Unweeded and no mulch), T_2(rice husk mulch), T_3(Rice straw mulch), T_4(Water hyacinth mulch), T_5(Black plastic mulch), T_6(Transparent plastic mulch), T_7(Pre-emergence herbicide), T_8(Pre-emergence herbicide + Rice straw mulch), T_9(Pre-emergence herbicide + Rice husk mulch), T_{10}(Pre-emergence herbicide + Water hyacinth mulch), T_{11}(Post emergence herbicide), T_{12} (Post emergence herbicide + Rice straw mulch), T_{13}(Post emergence herbicide +Rice husk mulch), T_{14}(Post emergence herbicide + Water hyacinth mulch), T_{15}(Hand weeding at 30 DAS and 45 DAS).

Description of herbicides

Trade Name	Generic Name	Mode of action	Target Weeds	Recomended dose	Time of application
Panida 33EC	Pendimethalin	Inhibitor of micro-tubule assembly	Annual weeds, Broad leaved weeds, eg. Bathua	2.5L/ha	At 1-5 DAS before emergence
Affinity 50.75 WP	Carphentrazone ethyl	Inhibitor of enzyme protoporphyrinogen oxidase	Grass and sedge type weeds	1.5kg/ha	At 30-40 DAS as post -emergence herbicides

Land preparation and Fertilization

The experimental land was initially prepared using a mechanized cultivator, subsequent ploughing and cross-ploughing with the mechanized cultivator, followed by harrowing to attain the desired soil texture. Peripheral sections were worked on manually, breaking down larger clods into smaller fragments with a wooden mallet. The eradication of weeds and residual plant matter was comprehensive after which the land was evened out and partitioned into sections with prescribed interplot spacing. These sections received fertilization with urea, triple super phosphate (TSP), muriate of potash (MoP), and Zinc Sulphate dosed at 525, 250, 200, and 15 kg ha^{-1} correspondingly. With the exception of gypsum, all fertilizers were applied a day prior to sowing, while urea was dispensed in three splits following the endorsed guidelines of the Bangladesh Agricultural Research Institute (Krishi Projukti Hat Boi). The application of gypsum was tailored to the treatment requirements.

Sowing of seeds

Seeds were sown in rows maintaining 75 cm×25 cm respectively. In each point 2-3 seeds were sown at the depth of 5 cm.

Intercultural Operation

Required space replenishment was conducted at 14 days after sowing (DAS), adhering to the targeted plant count. Mulching treatment were implemented using diverse mulch materials in accordance with the experimental design, when plant height ranged between 20 to 25 centimeters.. The mulch layers were upheld at a thickness of 6 to 8 centimeters. Thinning and weed removal activities were executed in accordance with necessity. Different crop protection for the crop were instituted whenever the situation demanded.

Making of the sample plants

Five plants were randomly selected and marked with polythene rope from each plot for collecting data on plant growth, yield and yield components.

Harvesting and processing

The crop was harvested plot wise at full maturity. The harvested crop of each plot was bundled separately, tagged and taken to the threshing floor and dried for three days. Grains and stovers were thoroughly dried plot by plot to record dry weight and then converted to ton per hectare.

Collection of data

The data on crop characters were recorded at harvest. The yield contributing characters were recorded from 5 randomly selected plants in each plot and their mean values were determined. The yield were taken plot-wise in gram basis by a digital weighing machine and then it was converted to hectare basis. Data were collected on the following crop parameters: plant height(cm), cob length (cm), cob diameter(cm), number of grains row^{-1}, number of grains column^{-1}, total no. of grains cob^{-1} , total cob weight per plant (g), 100-seed weight (g), stover yield (t ha^{-1}), grain yield (t ha^{-1}), biological yield (t ha^{-1}), harvest index (%), weed density,weed dry weight(g), weed control efficiency(%).

Harvest index (%)

Harvest index was determined as follows:

Harvest index (%) = Grain yield / Biological yield × 100.

Weed density

A quadrate of 0.50 m-0.50 m sizes was randomly placed at three places in each plot, all the weeds within the quadrate were collected in species wise.

Weed dry weight

After counting the weed density the weeds inside each quadrate were uprooted, cleaned and separated-wise. The collected weeds were dried in the sun and in an electrical oven for 72 hours maintaining a constant temperature of 80°C. After drying, weight of each species was taken.

Weed control efficiency (%)

Weed control efficiency (WCE) was calculated using the following formuladeveloped by Sawant and Jadhav (1985):

$$WCE = \frac{DWC - DWT}{DWC} \times 100$$

Where,
WCE = Weed control efficiency
DWC = Dry weight of weeds in weedy check (control)
DWT = Dry weight of weeds in each treatment

The extent of weed control by different weed control treatments and susceptibility of different weed species were graded on the basis of weed control efficiency by the following scale as suggested by Mian and Gaffer (1968):

Degree of weed susceptibility	Weed control efficiency	Grades of weed control
Completely susceptible (CS)	100	Completely control (CC)
Very highly susceptible (VHS)	90-99	Excellent control (EC)
Highly Susceptible (HS)	70-89	Good control (GC)
Moderately Susceptible (MS)	40-69	Fair control (FC)
Poorly Susceptible (PS)	20-39	Poor control (PC)
Slightly Susceptible (SS)	1-19	Slightly control(SC)
Completely resistant (CR)	0	No control(NC)

Statistical analysis

Data on yield and yield parameters were compiled, tabulated and analyzed statistically using the analysis of variance technique.Analysis of variance was doneand mean differences were adjusted by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984) with 5% probability level.

RESULTS AND DISCUSSION

Effect of mulching on weed density,weed dry weight and weed control efficiency (%)

Eleven weed species belonging to five families infested the experimental field (Table 1). Among eleven weed species most of them were grasses, broad leaves and sedges. A study was conducted by Hossain et al. (2019) found similar weed species*(Cyperus difformis, Eleusine indica, Echinochloa cruss-galli, Oldenlandia aquatic, Cynodon dactylon, Chenopodium arvensis, Cyperus rotundus, Solanum nigrum, Hydrocotyle ranunculoides, Ageratum conyzoides, Medicago denticulate, Avena ludoviciana)* in Maize field.

Table 1: Infesting weed species found in the experimental plots in maize

Sl no	Local name	Scientific name	Family	Morpho-logical type	Life cycle
1	Biskathali	*Polygonum hydropiper*	Polygonaceae	Sedge	Annual
2	Holud nakful	*Spilanthes iabadicensis A.*	Asteraceae	Sedge	Annual
3	Bothua	*Chenopodium album*	Chenopodiaceae	Grass	Annual
4	Mutha	*Cyperus rotundus*	Cyperaceae	Grass	Perennial
5	Durba	*Cynodon dactylon L.*	Graminae	Grass	Perennial
6	Foska begun	*Physalis heterophylla*	Solanaceae	Sedge	Perennial
7	Cela ghas	*Dactylis glomerata*	Poaceae	Grass	Principal
8	Bon morich	*Fimbristylis diphylla*	Cyperaceae	Sedge	Annual
9	Anguli ghash	*Digitaria sanguinalis L.*	Gramineae	Grass	Annual
10	Anguli ghash	*Digitaria sanguinalis L.*	Graminae	Grass	Annual
11	Shaknote	*Amaranthus viridis*	Amaranthaceae	Sedge	Annual

Weed population (m^{-2}) was significantly affected by different weed management practices as an integration of mulching. The maximum weed density (315.7) was found in treatment T_1 (Unweeded and no mulch) while the lowest weed density (29.33) was found in T_{12} (Application of post emergence herbicide + Rice straw mulch) treatment (Figure 1). Samtani *et al.* (2007) compared herbicides alone with herbicide-treated leaf pellets, rice straw, and pine bark and found similar result.The highest weed dry weight (528.8 gm^{-2}) was recorded in treatment T_1 (application unweeded and no mulch) and the lowest weed density (20.33 gm^{-2}) was found in T_{12} (application of post emergence herbicide + Rice straw mulch) treatment which was statistically identical to T_{11} (Post emergence herbicide), T_{14} (Post emergence herbicide + Water hyacinth mulch) (Figure 1). Similar result was reported from the findings of Mehmood *et al.* (2018).

The grading of weed control efficiency varied with different weed control practices (Figure 1). It is important to mention here that the treatments included T_6, T_8, T_{11}, T_{12} ,T_{13}, T_{14} at 90 DAS gave the best result as "excellent control" (90-99%), treatment T_3, T_4, T_5 T_{10} at 90 DAS gave the result as good control (70-89%) and treatment T_2, T_7, T_9 gave the result as fair control (40-69%). From the result it is showed that weed control efficiency at weed management practice with pre-emergence + rice straw mulch is higher than pre-emergence herbicide. This is due to emergence is weed throughout the growing season when pre-emergence herbicide used singly. Whereas when pre-emergence + rice straw mulch used as weed management practice, its increased weed control efficiency. On the other hand, post-emergence herbicide with or without combination with other weed management practice can increase weed control efficiency due to control of weed throughout the growing season.

In agronomic crop production systems, the seed bank in the soil is the primary source of new infestations of annual weeds each year and represents the majority of weed pests (Cavers, 1983). Herbicides are very effective at reducing weed populations and at the same time the number of seeds added to the soil seed bank (Hossain *et al.,* 2015). But excessive application of herbicide is harmful for the environment as well as for living organism including human, domestic animal and beneficial microorganism. So, we should replace herbicide or reduce its use by other weed management practices. The result of our study reveals that different mulching specially the straw mulch with the combination with herbicide can reduce the application of herbicide as well as can control weed with high efficiency level. So, it can be said that integrated weed management practice can control efficiently as well as can conserve environment. This result was in the agreement with the findings of Kebede *et al.* (2020).

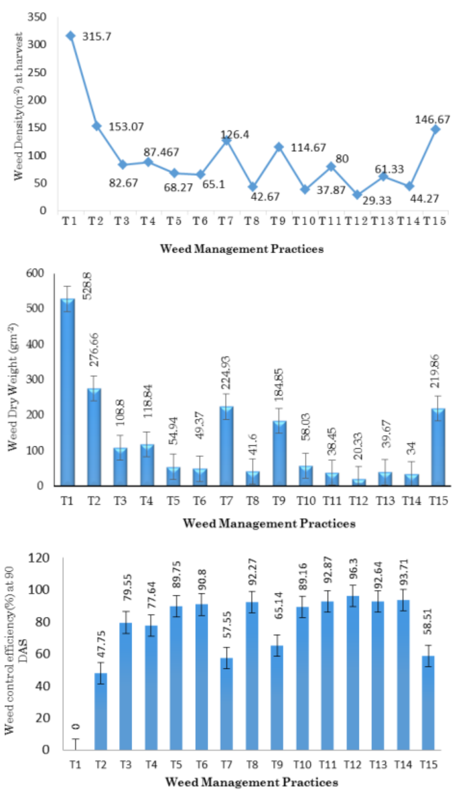


Fig 1:

Effect of mulching on weed density, weed dry weight and weed control efficiency (%)

Effect of mulching on the morphological and yield contributing characters of maize

Plant height (cm), Cob length, Cob diameter, number of grains per row, number of grains per column, total number of grains per cob, total cob weight per plant, dry weight of 100 grains(g) was significantly affected by different weed management practices as an integration of mulching (Table 2).Results revealed that the tallest plant (295.58 cm) was noted in T_{12} treatment and the shortest plant (239.27 cm) was noted in T_1 treatment (Table 2). Weed offer competition for the light, space and nutrient to the plant that why where plant show significance difference in plant height (in same variety/line) between weedy check and weed free plot. (Khan *et al.* (2020) discovered that if weed was controlled,significantly increase plant height which is similar to our findings.The longest cob (23.70 cm) was recorded in T_{12} treatment and the shortest cob (17.00 cm) in T_1 treatment(Table 2). These conclusions are in close immediacy with the work of Ihsanullah *et al.* (2002) who reported cob length in less weeds infected plots.

The wider cob diameter (18.20 cm) was observed in T_{12} treatment which was statistically identical to T_4 and T_8 treatment. The narrow cob diameter (17.00 cm) was found in T_1 treatment(Table 2). These conclusions are in close immediacy with the work of Amare *et al.* (2015) who reported cob diameter increased where weed control efficiency is higher.

The highest number of grains (16.00) per row of a cob was found in T_{12} treatment which was similar to T_{14}, T_{11}, T_3, T_{13} and T_4 treatment and the lowest number of grains was found in (13.33) per row in T_1 treatment(Table 2). Comparable findings were observed by Uddin *et al.* (2020), wherein a noteworthy rise in the number of grains per row was correlated with the reduction in weed densities in maize. The treatmentT_{12}exhibited the highest number of grains per column (38.00), on the other hand the lowest no. of grains was found in (27.00) per row in T_4 treatment (Table 2).

The maximum number of grains (608.00) per cob of was found in T_{12} treatment and the minimum numberof grains per cob in (409.3) was found T_1treatment(Table 2). Similar results were also reported by Ihsanullah *et al.* (2002) who stated that there was significant increase in number of grains cob^{-1} with decreasing weed populations in maize.Numerically the maximum cob weight per plant (260.09 g) was found in T_{12}treatment and the minimum cob weight per plant (194.28 g) was found in T_1 treatment (Table 2). Similar result was describe in the work of Uddin *et al.* (2020) and he cloncluded that cobs weight in maize under unweeded control was due to the high density of weed infestation, which increased interplant competition for space, light, nutrients and moisture, as well as responded to smaller cobs having the lower weight of cob.

The maximum grain weight (40.40 g) was found in T_{12} treatment which was statistically identical to t_{13}, t_{14} treatment and the minimum grain weight (35.87g) was found in t_1 treatment(Table 2). Similar result found at the work of Ihsanullah *et al.* (2002) and reported that the reason of decreased in 1000 seed weight in weedy check plots is attributed to the increasing weed per crop competition.

Table 2. Effect of mulching on morphological and yield contributing characters of maize

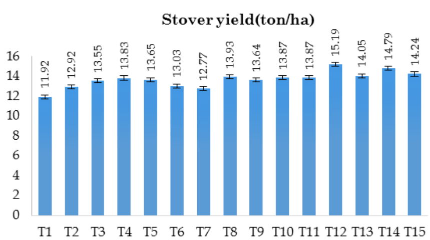
Treatment	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	No. of grains per row	No. of grains per column	Total no. of grains per cob	Total cob weight plant^{-1} (g)	Dry wt. of 100 seed (g)
T_1	239.27i	17d	15.8c	13.333c	30.66ab	409.3e	194.28d	35.873f
T_2	254.22gh	19.6c	16.6bc	14bc	34.66ab	485.33d	230.33c	37.90 bcd
T_3	265.17efg	21.9b	17.8ab	16a	34.33ab	449.3abcd	238.8bc	37.74cde
T_4	285.2abc	22.6ab	18.1a	15.667a	27b	443.3abcd	235.62bc	36.96e
T_5	279.89bcd	22.86ab	17.367ab	15ab	35.33ab	530bcd	244.7abc	38.03bc
T_6	251.95h	22.66ab	16.567bc	14bc	35.33ab	494.67cd	245.18abc	37.82cde
T_7	258.59fgh	22.9ab	17.63ab	15.333ab	35.33ab	541.3abcd	236.81bc	37e
T_8	270.23def	22.74ab	18.1a	15.333ab	36.33ab	557.3abc	243.82abc	37.82cde
T_9	277.7cd	22.56ab	17.12ab	15ab	35.67ab	535bcd	240.77bc	38.767b
T_{10}	290.57ab	22.97ab	17.737ab	15.333ab	36ab	552abcd	247.51ab	37.013e

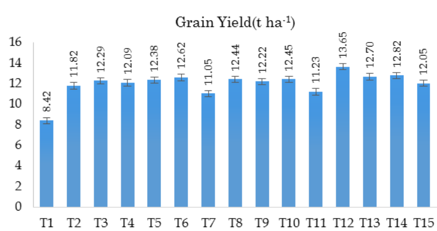
T_{11}	278.54bcd	23.03ab	17.33a	16a	36ab	576ab	246.14abc	38.04bc
T_{12}	295.58a	23.7a	18.20ab	16a	38a	608a	260.09a	40.403a
T_{13}	277.05cde	22.53ab	17abc	15.66a	36.66ab	574.7ab	248.91ab	39.693a
T_{14}	278.84bcd	22.96ab	17.64ab	16a	37ab	592ab	250.59ab	39.88a
T_{15}	280.46bcd	22.91ab	17.13ab	15ab	36ab	540bcd	243.26abc	37.15d
$LSD_{(0.05)}$	3.54	0.59	0.52	0.60	4.01	26.67	3.71	0.27
Significance level	**	**	**	**	*	**	**	**
CV(%)	1.5	2.210	2.499	3.402	9.771	4.217	2.337	0.758

Performance of different weed management strategies on yield of maize

Stover yield was significantly varied by different weed management practices as an integration of mulching. The highest stover yield (15.19 t ha^{-1}) was found in T_{12} treatment (Figure 2). The minimum cob weight (11.92 t ha^{-1}) was found in T_1 treatment (Figure 2). Similar result was found by Uddin *et al.* (2020) who reported that utmost stover yield found in less weeds infected plots.

Grain yield was significantly varied by different weed management practices as an integration of mulching. The highest grain yield (13.65 t ha^{-1}) was found in T_{12} treatment and the lowest cob weight (8.42 t ha^{-1}) was found in T_1 treatment (Figure 2). The results in the present study are similar to the findings of Kawsar *et al.* (2013) who reported increase in grain yield of maize crop with the use of herbicides and mulch as the herbicide suppresses the germination of weeds providing a competition free environment for the crop plants Biological yield was significantly influenced by different weed management practices as an integration of mulching. The highest biological yield (28.849 t ha^{-1}) was found in T_{12} treatment. The lowest biological yield (20.347 t ha^{-1}) was found in T_1 treatment (Figure 2). Harvest index was significantly influenced by different weed management practices as an integration of mulching. Numerically the highest harvest index (49.21%) was found in T_6 treatment and the lowest harvest index (41.42%) was found in T_1 treatment level (figure 2). The results revealed that mulching and herbicides positively enhanced the harvest index which was due to the fact that these practices effectively control the weeds and increased the grain yield due to lower weed crop competition as compared to control. These conclusions are in close immediacy with the work of Saeed *et al.* (2010) who reported utmost harvest index (HI) in less weeds infected plots.





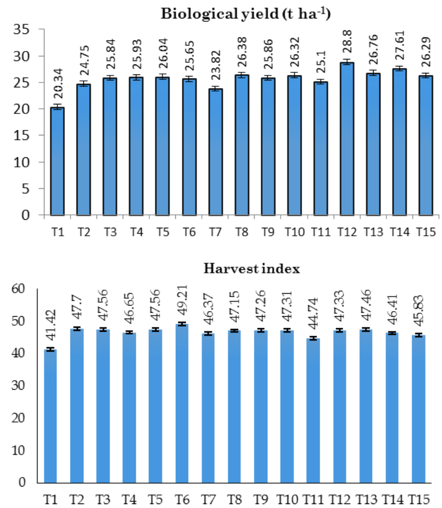


Fig. 2: Effect of mulching on the stover yield, grain yield, biological yield and harvest index of maize

CONCLUSIONS

Based on the present study, the results showed that various weed management strategies significantly affected the weed control efficiency, morphological, yield contributing characters and yield of maize. Weed control efficiency with pre-emergence + rice straw mulch is higher than pre-emergence herbicide, this is due to emergence of weed throughout the growing season when pre-emergence herbicide used singly. Whereas when pre-emergence + rice straw mulch used as weed management practice, it increased weed control efficiency. On the other hand post-emergence herbicide with or without combination with other weed management practice can increase weed control efficiency due to control of weed throughout the growing season.It may be concluded that application of Post emergence herbicide + Rice straw mulch as integration of mulching could be used as the best weed control practice in maize. Due to lower emergence of weed, crop weed competition in maize field is lower and so maize alone uptake higher rate of nutrients and increase the yield.

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