Original Research Article

Effects of mulching on soil water content, maize performance and weed growth in dry land area of Bangladesh

ABSTRACT

Aims: The objectives of the research work were to evaluate the effects of mulching on soil water content, maize performance and weed growth in dry land area of Bangladesh

Study Design: The experiment was laid out in a randomized complete block design (RCBD) with three replications

Place and Duration of Study: Central research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during November 2019 to April 2020.

Methodology: The experimental field is divided into 3 blocks to represent 3 replications. There are 6 unit plots (each unit plot consists of 3m × 2m area) in the experimental farm. Distances of 1 m and 0.5 m are maintained between replication to replication and plots to plots, respectively. Plant to plant and row to row distances are considered to be 0.25 m and 0.75 m, respectively. The treatments are assigned in random plots. The land is ploughed four times followed by laddering to have fine tilth of the soil. The maize cultivars Shuvra and KS-510 are used as plant materials. Figure 2 represents the six mulch treatments are imposed on the plants: Control (without mulch, CK), water hyacinth dry (10 t/ha, WH), rice straw dry (10 t/ha, RS), black polythene (4m × 3m, BP), white polythene (4m × 3m, WP), and transparent polythene (4m × 3m, TP) (S2). The mulches are applied as per treatment in each plot just after sowing to maintaining an equal thickness throughout the plot. Dried and cleaned mulches are used before applying to the experiment. The significance of the difference among the treatment means were estimated by the MSTAT-C package programme at 5% level of probability.

Results: It is found in the experimental results that the soil water content of the no-mulching treatment is lower as compared to that of the other treatments from 0-10 cm, 10-20 cm and 20-30 cm soil depths. It is also observed that the RS mulching provides the highest soil water content, leaf area index (LAI), chlorophyll contents, and total biomass. Significant enhancement of maize yield (20.55 ton/ha) is recorded for the rice straw mulching. In contrast, the weed dry weight of 7.45g/m^2 is observed in the RS mulching, which is lower than the other treatments.

Conclusions: Therefore, it can be concluded that the RS mulching, compared to other mulching, would be more efficient for maximum utilization of limited water resources, weed suppression as well as to increase the maize yield. The present research approach would be applicable to manage the soil water for enhancing the maize production in dry land area.

Keywords: Bangladesh, growth, maize, Mulching, soil water content, yield

1. INTRODUCTION

The scarcity of water resources is the most significant constraint to crop production (Rockström et al., 2007). The burden on finite freshwater resources grows as the world's population grows. The agricultural sector faces the challenge to produce more food with less water by increasing Crop Water Productivity (Kijne et al., 2003). During crop growing stages, proper water utilisation is a critical aspect that can considerably boost production.

Maize (*Zea mays* L.) has long been seen to be one of the world's most promising cereal grains for human consumption (Tandzi and Mutengwa, 2020). However, the maize yields are remarkably limited by the water shortage, suboptimal field managements, and nutrients. Therefore, it is essential to increase the maize yield and to meet the rising food demand in world by maintaining suitable farming environments. Mulch is defined as a coating material spread over the soil surface (Kasirajan and Ngouajio, 2012). Among various water saving technologies, mulching has been considered as an effective way to improve crop growth by maintaining the soil water content and soil temperature in dry land agriculture (Cook et al., 2006). Mulching with different materials reduced water evaporation (Li et al., 2013), and increase the amount of stored soil water available for plant use (Wang et al., 2001). Mulching adds organic matter to the soil thus improving soil physical conditions and topsoil stability (De Silva and Cook, 2003). Studies have demonstrated that the mulching can significantly increase the yield (as well as WUE) of maize by 60% (Qin et al., 2015).

In addition, the maize is affected importantly by mulching regarding growth and yield characters. The enhancement in maize yield is generally accumulated to increase the soil moisture content by diminishing evaporation. Among different mulch materials, water hyacinth mulching increased soil C, total N, available P and K (Balasubramanian et al., 2013). The rice straw is an effective practice for improving the soil organic matter, fertility, and moisture of upland soils (Liu et al. 2014; Zhu et al. 2010). Nowadays, polythene mulch has gradually become an important discovery in agricultural production (Guo and Gu, 2000). The use of polythene mulch can be viewed as a positive step toward a more sustainable model of large-scale agriculture in a number of ways. First, polythene mulch limited soil erosion, as rain cannot fall directly onto soil, and wind cannot carry it away (Scarascia-Mugnozza et al., 2004). Second, the use of polythene mulch reduces the requirement for irrigation because evapotranspiration is reduced (Ramalan and Nwokeocha, 2000). Third, black polythene mulch and transparent polythene mulch films can partially or completely block sunlight and thus prevent any plants from growing that are not planted in holes punched or cut in the films. Thus, the use of agricultural mulch film reduces competition for soil nutrients without the use of herbicides (Greer and Dole, 2003).

To optimize water management and improve maize yield, it is necessary to understand how mulching practices affect soil conditions, crop growth, and resource utilization. Unfortunately, little is known about the impacts of various mulching techniques on maize. The purpose of this study was to assess the effectiveness of mulches on maize field growth, water management measures, yield, and weed growth in Bangladesh.

2. Materials and Methods

2.1. Time and place

Field experiment has been conducted during the period from November 2019 to April 2020 at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka City, Bangladesh. The soil of the experimental field belongs to the Modhupur Tract (UNDP, 1988) corresponding AEZ no. 28 and is shallow red brown terrace soil.

2.2. Tools and materials

The experiment is arranged in a randomized complete block design. The experimental field is divided into 3 blocks to represent 3 replications. There are 6 unit plots (each unit plot consists of 3m × 2m area) in the experiment farm. Distances of 1 m and 0.5 m are maintained between replication to replication and plots to plots, respectively. Plant to plant and row to row distances are considered to be 0.25 m and 0.75 m, respectively. The treatments are assigned in random plot. The land is ploughed four times followed by laddering to have fine tilth of the soil. The maize cultivars Shuvra and KS-510 are used as plant materials. Six mulch treatments are imposed on the plants: Control (without mulch, CK), water hyacinth dry (10 t/ha, WH), rice straw dry (10 t/ha, RS), black polythene (4m × 3m, BP), white polythene (4m × 3m, WP), and transparent polythene (4m × 3m, TP) (S2). The mulches are applied as per treatment in each plot just after sowing to maintaining an equal thickness throughout the plot. Dried and cleaned mulches are used before applying to the experiment.

The soil samples from 0-10cm, 10-20cm, and 20-30cm soil depths are collected at different days after sowing (DAS) such as 45 DAS, 75 DAS, and 115 DAS, respectively, to measure the soil moisture content gravimetrically by a soil screw auger. The soil samples are dried in oven at 105°C for 48 hours and are weighed to find out the differences between the initial and final moisture contents.

Leaf Area Index (LAI) is measured by leaf area meter (LICOR 3000, USA) at the time of 30 DAS, 60 DAS, 90 DAS, and 120 DAS. Data are recorded from 5 randomly selected plants in each plot. The LAI can be calculated as

$$\text{LAI}=\frac{\text{Surface area of leaf sample } m^2 \times \text{correction factor}}{\text{Ground area from where the leaves were colllected}}$$

The sun-dried plant is further dried in an oven at 70°C temperatures for 72 hours and is weighed in electronic digital balance. Soil Plant Analysis Development (SPAD) meter has been used to determine the chlorophyll content of a leaf (Model SPAD -502). The third, fifth and flag leaf from the top are selected. Three readings from each of the leaf are taken to have an average value of chlorophyll. Time (DAS) required for 50% and 100% of seedling emergence, tasseling, cob appearance, and silking is recorded. Time (DAS) required for harvesting of maize is also recorded.

Grains from the plants/ha area are collected and sun dried to achieve the required moisture level of the grains. The moisture percentage is tested by using grain moisture meter or tester (Grain moisture tester, model PM-400).

Weeds from $1m^2$ area of different treatment are collected at 30 DAS and are dried in oven at 70°C for 72 hours. Then, the dry weeds are weighed and recorded.

2.3. Data analysis

The results are interpreted via MSTAT-C package programme to obtain the level of significance. For all analyses, least significant difference (LSD) test at 0.05 level of probability was used to detect mean differences between the treatments.

3. Results and Discussion

3.1. Soil water content

Figure 3 manifests the effect of mulch materials on soil water content at different depth of soil. Water content in soil is notably incremented by mulch treatments. It reveals that the soil water content (0-10 cm, 10-20 cm, 20-30 cm) in CK treatment is lower than that in WH, RS, BP, WP, and TP treatments throughout the growing season. The highest soil water contents (38.55%, 45.57%, and 53.33%) are recorded in RS treatment from 0-10 cm soil depth and BP treatment (38.55%, 44.65%, and 51.28%) at 45 DAS. The plots with RS mulches have higher soil water content throughout the growing season than the plots with other mulch and no-mulch treatments at 0-10 cm, 10-20 cm, and 20-30 cm depths. Soil water content in WH mulch treatment was closely followed by the RS mulch treatments at 0-10 cm, 10-20 cm and 20-30 cm. TP mulch treatments showed low water content than other mulch treatments throughout the growing season.

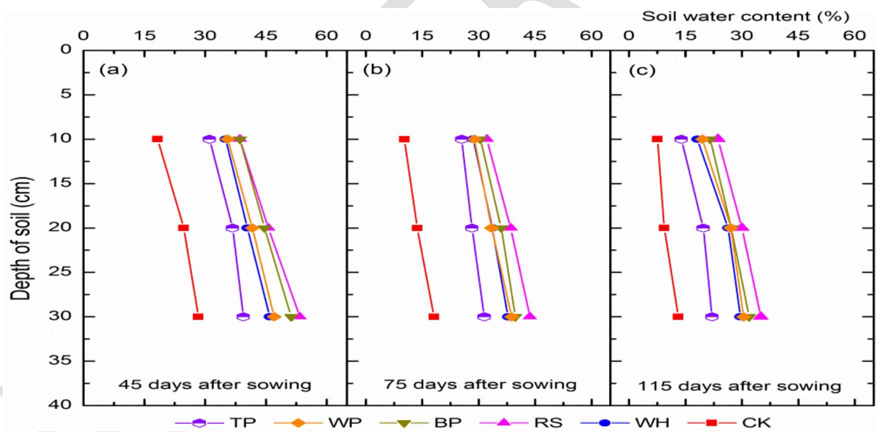

Fig. 3. Effect of mulch materials on soil water content at different depth of soil.

The extensive soil water content in the RS mulch treatment than the other treatments at the 0-10 cm depth of soil is obtained throughout the growing season of maize (Fig. 3). From the field experimental results, the RS mulch treatment has shown to reduce evaporation and to increase the soil moisture available for plant use. The RS mulch has also been found to have significant effects on soil moisture and greatly improve the soil moisture at the depth of 0-40 cm (Deng et. al., 2006).The plots with mulch materials have higher soil water content throughout the growing season than the plots with no-mulch, as exhibited in Fig. 3. Mulch application can greatly minimize soil moisture loss and extend the life of plants over time. Surface mulching helps to retain moisture by shading the soil and preventing water loss through evaporation (Mulumba and Lal, 2008).

3.2. Leaf area index (LAI)

The LAI is substantially influenced between-treatment variations in different growth stages. The effect of mulch materials on LAI of maize at different DAS is demonstrated in Fig. 4. It can be seen that the mulch treatments induce a rapid enhancement in the LAI throughout the growth stages than the no-mulch treatment. The RS treatment results the highest LAI values of 0.85, 2.57, 4.81, and 4.47 during 30, 60, 90, and 120 DAS, respectively, than the LAI values obtained in the other treatments. Similar results are observed in BP and WP treatments at 30, 90, and 120 DAS. WH treatment induces similar increases in LAI (4.25) at 120 DAS. As can be also seen in Fig. 4, the TP mulch is less effective on LAI throughout the growth stages. In addition, the plots with CK treatment reduced the LAI after the development stage of 90 DAS, respectively, which was lower level than in the mulch treatments.

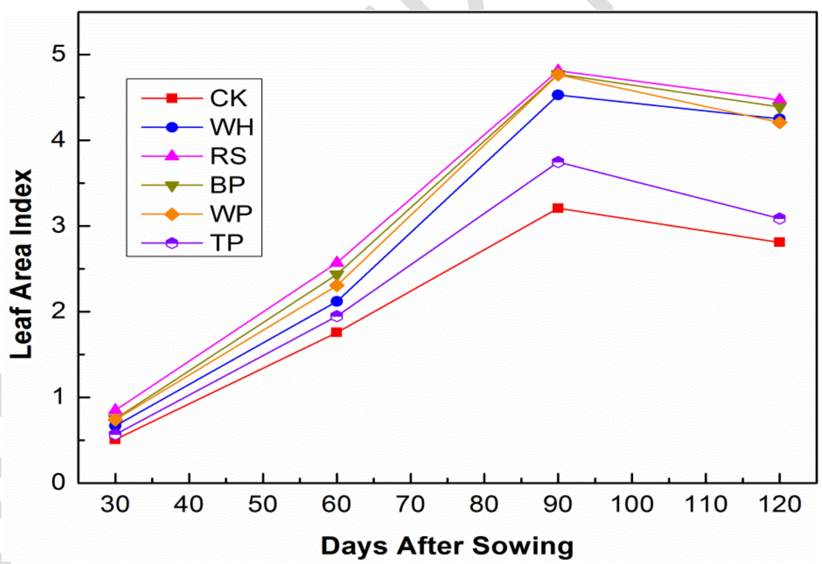

Fig. 4. Effect of mulch materials on leaf area index of maize at different DAS.

RS mulch is substantially enlarged the LAI of maize throughout the development stages than other mulch treatments (Fig. 4). RS and WP mulches increase the LAI of maize with their maximum at 90 days after sowing as compared to CK. Significant increase in LAI is observed with mulching from 90 and 100 days after sowing (Li et. al., 2013).

3.3. Days to seedling emergence, tasseling, cob appearance, silking, and harvesting

Figure 5 shows that the plots with mulches considerably promote 50% and 100% seedling emergence, tasseling, cob appearance, and silking. The RS treatment produces earlier 50% and 100% seedling emergence at 4.4 DAS and 7.3 DAS (Fig. 5(a)), tasseling at 67.8 DAS and 79.0 DAS (Fig. 5(b)), cob appearance at 69.7 DAS and 79.7 DAS (Fig. 5(c)), silking at 73.8 DAS and 88.3 DAS (Fig. 5(d)) as compared to that in the CK treatment. In addition, the plot with TP treatment produces almost similar 50% and 100% seedling emergence, tasseling, cob appearance silking as determined in the CK treatment. In case of the WH, BP, and WP mulch treatments, the values for 50% and 100% tasseling, cob appearance, and silking closely followed the TP treatment.

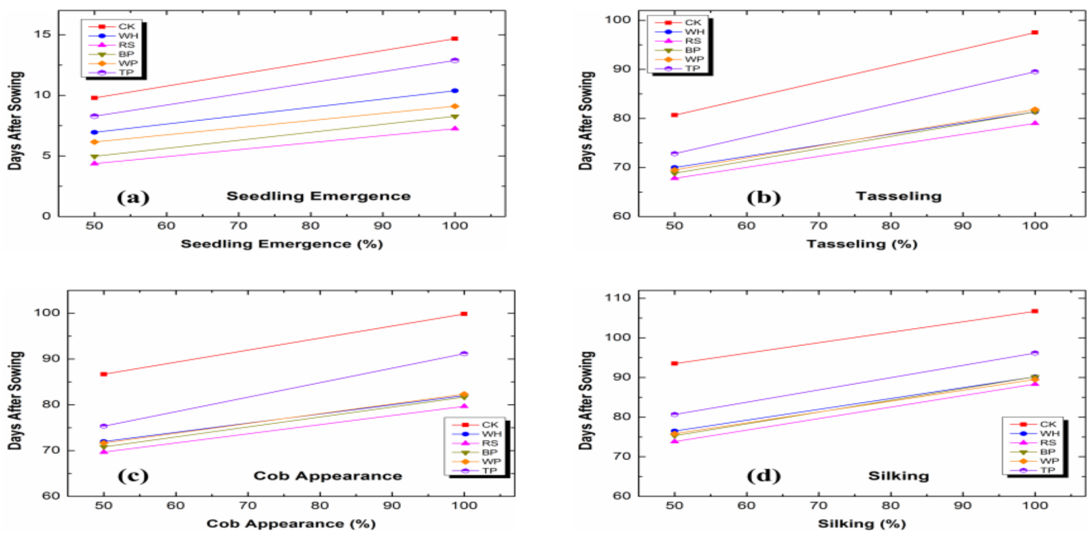

Fig. 5. Effect of mulch materials on (a) seedling emergence, (b) tasseling, (c) cob appearance, and (d) silking of maize at different DAS

The initiation of 50% and 100% seedling emergence, tasseling, cob appearance, and silking is significantly advanced due to the application of RS and BP mulches over the plot with no-mulch (CK), as observed in Fig. 5. The speedy emergence under mulch treatments may be attributed to the role of mulch application in moderation of soil temperature, which might have favorably influenced the physiological process of seed germination. Rice straw mulch treatments has taken lowest time to reach the maximum or constant maize seedling emergence and higher emergence percentage and emergence velocity compared to other mulches and no-mulch (Rahman, 1999). Mulches immensely influence tasseling and silking date of maize. The earliness of tasseling and silking time in the rice straw mulched plants might have been initiated due to the increased metabolic activities accompanied by higher soil temperature (Liakatas, 1981).

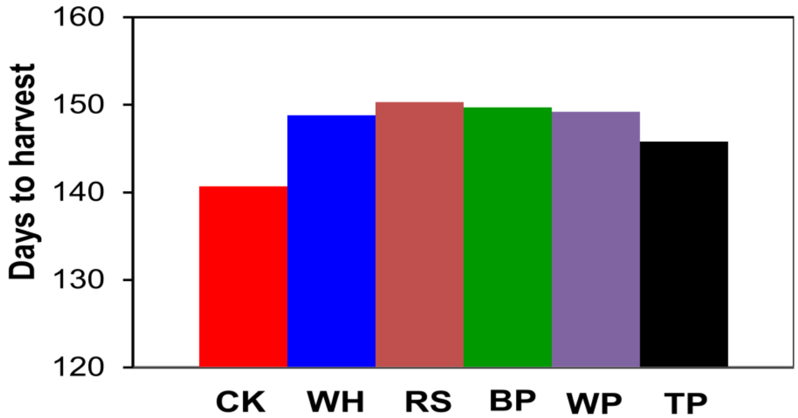

Fig.6. Effect of mulch materials on days to harvest of maize

The effect of mulch materials on days to harvest of maize is depicted in Fig. 6. It can be obtained that the RS treatment produced harvesting (by 150.3 days), which was closely followed by the BP (by 149.7 days) and WP (by 149.2 days) mulch treatments. The earlier harvesting produced by CK (by 140.7 days) treatment. Statistically, similar results are observed in TP (by 145.8 days). In WH mulch treatment produced harvesting (by 148.8 days). The days to harvesting varied considerably between the different mulch and no-mulch treatments (Fig. 6). The maximum time to harvest was required for rice straw mulch treatment and lowest time required for no-mulch treatment which was closely followed by transparent polythene mulch. The early flowering and maturity of maize was found with transparent photodegradable polythene film (Duhr and Dubas, 1990).

3.4. Chlorophyll content of leaf

In this research work, the effect of different mulch materials treatments in maize varieties on relative chlorophyll content of leaf is analyzed during growth periods at 40, 60, 80, 100, and 120 DAS. Figure 7 illustrates the effect of mulch materials on chlorophyll content of maize at different development stages DAS. The maximum chlorophyll values of 41.4, 46.67, 50.27, 50.87 and 44.77, respectively, are obtained in RS treatment, while the lowest chlorophyll values in the CK treatment are evaluated to be 35.33, 36.34, 37.83, 38.19 and 22.17 during 40, 60, 80, 100, and 120 DAS, respectively. In Fig. 7, the chlorophyll value

(42.76, 45.53 and 48.98) obtained in BP treatment, is nearly equal to the RS treatments at 40, 60, and 80 DAS. Moreover, the chlorophyll contents of 42.73, 42.15, and 39.44 are found in WH, WP, and TP treatments, which are substantially close to RS treatments during 40 DAS.

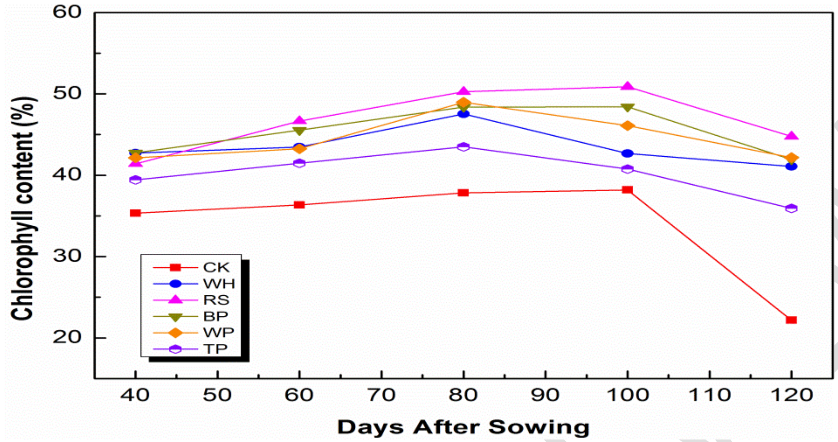

Fig. 7. Effect of mulch materials on chlorophyll content of maize at different DAS

From the experimental results in Fig. 7 the plots with RS and WH treatments significantly improve the photosynthetic characteristics of maize. Higher chlorophyll stability index (CSI) of maize is obtained in RS and WH mulch treatments than the other mulches and non-mulch (CK) treatments (Rahman et al, 2002).

3.5. Total biomass (g/plant) and grain yield (ton/ha)

Compared to the CK, the plots with mulch treatments significantly increase the total biomass and grain yield as summarized in Table 1. The total biomass of 427.8 g/plant, 554.2 g/plant, 490.0 g/plant, 446.6 g/plant and 353.0 g/plant are determined for WH, RS, BP, WP, and TP treatments, respectively. The grain yields are obtained to be15.31 ton/ha, 20.55 ton/ha, 18.02 ton/ha, 16.53 ton/ha, and 12.96 ton/ha for WH, RS, BP, WP, and TP treatments, respectively. It is clearly seen that the RS treatment gives the greatest significant increase in maize biomass and grain yield. On the other hand, the lowest biomass and grain yield of 208.8 g/plant and 6.37 ton/ha are measured in the CK treatment.

Table 1: Effect of mulch materials on total biomass (g/plant) and grain yield (ton/ha) of maize

Mulch materials	Total biomass g/plant	Grain yield ton/ha
CK	208.8 f	6.37 f

WH	427.8 d	15.31 d
RS	554.2 a	20.55 a
BP	490.0 b	18.02 b
WP	446.6 c	16.53 c
TP	353.0 e	12.96 e

In addition, the RS induces higher soil moisture retention and increases root density which may result in higher nutrient-use efficiency from the surface soil, thus enhances the total biomass and grain yield. A field experiment at Punjab Agriculture University, Ludhiana on maize reports that dry matter production with RS mulch is higher by 138% than the dry matter production from bare plots (Bhatt et al., 2004). Moreover, a similar result of enhancing the maize productivity by applying straw mulching is found in the previous work (Govaerts et al., 2007).

3.6. Weed dry weight (g/m^2)

The influence of mulch materials on weed dry weight is further investigated in this study, as shown in Fig. 8. The plot with CK treatment results the highest weed dry weight of 35.45 g/m^2, while the RS treated plots experience the lowest weed dry weight of 7.45 g/m^2. The weed dry weight of WH, BP, and WP treatments are measured to be10.82 g/m^2, 11.16 g/m^2, and 11.18 g/m^2, respectively, which are statistically similar but significantly lower than the CK treatment. In TP treated plots, weed dry weight 17.0 g/m^{2}which was higher than other mulch treated plots is found.

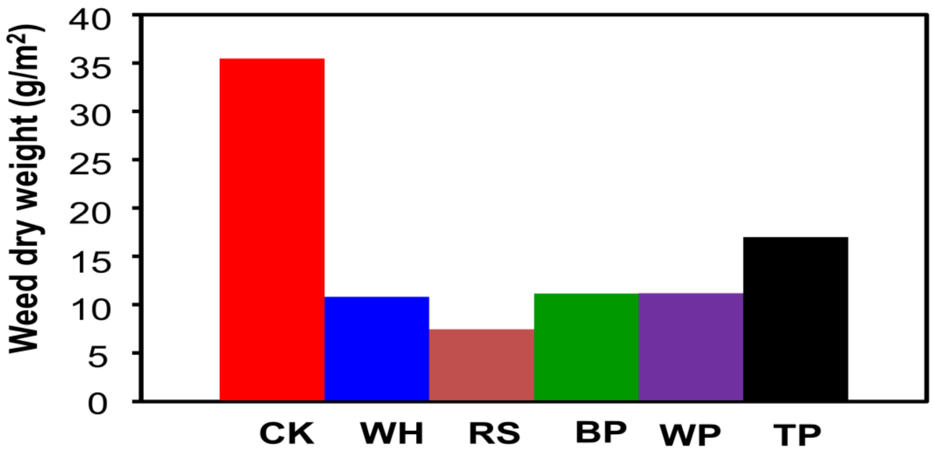

Fig. 8. Effect of mulch materials on weed dry weight.

As can be seen from the results of the average weed infestation in maize plots in Fig. 8, the weed growth can be suppressed effectively by the RS and WH mulches than other treatments. It is suggested that RS and WH mulches efficiently prevent the weed growth by blocking the radiant energy into the soil surface, thereby reducing the cost of weeding notably in maize field (Khan, 2001).The average weed infestation in maize plots show that mulches of different materials may also be useful to control weeds and insect pests. The frequency of weeding is more in the plot with no-mulch than in the plots with mulches. This is because, depending on their thickness, mulches have the power to suffocate weeds (Essien et al., 2009). Weeds compete for resources, reducing crop growth and productivity, and providing a safe haven for insect pests. Weed invasion has been identified as one of the key reasons reducing maize yields (Fahad et al., 2014).

5. Conclusions

In this work, the mulching effects on soil water content, maize performance, and weed growth in dry land area of Bangladesh have been evaluated experimentally. The overall performances of the maize growth are compared among six treatments consisting of no-mulch (CK), water hyacinth (WH), rice straw (RS), black polythene (BP), white polythene (WP), and transparent polythene (TP) mulches. The present experimental report reveals that the rice straw mulch practices can be significantly applied to improve soil moisture, LAI, and greater chlorophyll content with earlier development and rapid plant growth. In addition, these rice straw mulching practices are effective at improving the amounts of accumulated dry matter, thus leading to greater final biomass, grain yield and weed control in maize as compared the plots with other mulch treatments. These results lead to suggest that the rice straw mulch would be effective approach to improve the maize yield in dry land area of Bangladesh.

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