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Assessing the Effect of Weed Management Practices on Yield of Maize in Chittagong Hill Tracts of Bangladesh

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***Abstract*— One of the most important stress factors for maize (*Zea mays* L.) production is the competition with weeds for growth resources, which reduces crop yields. A field study in randomized completely block design (RCBD) with three replications was directed during rabi season at farmer's field of Khagrachari hill district of Bangladesh to seek out the best eco-friendly weed management practice for maize production. The treatment combinations comprised of hand weeding, mulching, hand weeding + mulching, intercropping, herbicide and control (no weeding). In the practice of weed treatment in maize fields, compared with other treatments, hand weeding + mulching treatment had the lowest plant mortality (0.42%). Hand weeding + mulching also provided the highest plant height (282.97 cm), number of leaf plant^{-1} (14.07), number of plants^{-1} (2.17) of corn ears, length of corn ears (23.90 cm), and individual ears of corn Weight (289.48 g) compared with other treatments, corncob yield (9.29 t ha^{-1}), harvest index (27.41%). Through hand weeding + mulching treatment, the maximum weeding efficiency at development stages of corn was also obtained. While the control had the lowest growth and yield of maize compared to other treatments. So hand weeding + mulching treatment was recommended as a best eco-friendly effective weed management practice for maize production.**

***Keywords*— Harvest index, paraquat, hand weeding, mulching and weed control efficiency**

I. INTRODUCTION

Maize (Zea mays L.) belongs to the Gramineae family and is a staple food crops in the universe, second only to wheat and rice. Maize has become an important grain because of its huge production potential and adaptability to a wide range of environments. As a C4 plant, it can use solar radiation more effectively even at higher radiation intensity. In Bangladeshi agriculture, maize assumes a special significance on account of its utilization as food, feed, fodder and stalk besides several industrial uses. However, there are several stress factors that can reduce maize productivity, the most important of which is weeds, which cause approximately 13% of global losses [1]. Contrarily, Akobundu [2] observed that due to weed competition, global production lost 34% to 60%. Weeds also reduce the root system and leaf area of maize [3], thereby reducing yield [4]. Depending on weed plants type and the intensity and duration of crop weed competition, the yield loss of maize ranges from 28% to 93% [5]. The most likely explanation for this phenomenon is the competition between water, nutrients and sunlight. Corn is very vulnerable to competition from weeds, especially in the primary phases of growth. Therefore, effective control before and early after emergence is very important. Once the maize reaches a height of about 0.5 m, weed control will no longer affect yield [6]. The interference of weeds will not only cause crop loss, but also increase pest damage, difficult harvesting and crop pollution [7].

In order to minimize the loss of weeds, several methods can be used, such as mechanical, cultural, biological and chemical control methods. Crop rotation, tillage, cover crops, soil types, crop types, relative humidity, herbicide use and farming methods are related drivers that explain the abundance of weeds [8]. Current studies have exposed that human management factors, such as sowing date, seed type, crop rotation, etc., are more important than environmental factors [9].

Due to the exhaustion of cultural methods, farmers are turning to other weeding methods [10, 11]. Most farmers are using pre-germination herbicides to control weeds in corn, but their effectiveness will be reduced due to various climate and soil and water conservation factors. Therefore, the alternative is to use post-emergence herbicides. Glyphosate is a non-selective post-emergence herbicide that can suppress many different weed species. The ability to use glyphosate during the growing season allows producers to reduce the total number of herbicides used in crops and reduce the need for weeding prior to growing plants to restraint unwanted plant [12, 13].

Intercropping or intercropping crops is another weed management method in which cash crops are planted after or in the crop, and then usually terminated before or after planting the next major crop [14]. In addition to weed suppression, cover crops have many advantages over standard planting systems, including reducing soil corrosion, improving soil water retention, water infiltration, soil organic matter, soil tilt, soil nitrogen, and reducing farming requirements [15, 16, 17, 18, 19].

Mulching or covering the soil with plant residues/waste is considered as popular management measures to reduce weed problems [20]. The main purpose of using mulch is to suppress weeds in the crop to be grown. Mulch usually works by blocking light or creating environmental conditions that can prevent germination or obstruct the growth of weeds shortly after germination. The use of mulch can generally increase the yield and value of vegetable crops, thereby increasing the profitability of the grower. On the other hand, organic mulch can maintain soil and water conservation, enhance soil biological activity and improve soil chemical and physical properties [21, 22]. The more the mulch, the better the weed controls. In temperate region where water is a limiting factor for plant growth, chaff mulch was found to have a positive effect on crop growth and yield [23]. In the view of the above facts, a survey was conducted to study the effectiveness of farmers' manual weeding, straw mulching, post-emergence herbicides and corn field cropping/mulching crops (bush beans). Therefore, the experiment was designed to find out best eco-friendly weed management techniques for maize production.

II. MATERIALS AND METHODS

The experiment was executed during the Rabi season in a farmer's field in the Khagrachari hill area of the Chittagong hill tracts in Bangladesh. The maize variety BARI Hybrid Bhutta-9 was used as the variety. The experiment was carried out with a random repeated complete block design (RCBD) with three replications. Six different treatments for weed management were applied in the maize field viz. T1 (Hand weeding = Three hand weeding were done in 30 DAS, 60 DAS and 90 DAS), T2 (Mulching = Straw mulching were done in 30 DAS and continued up to harvesting), T3 (Hand weeding + Mulching = Two hand weeding were done in 30 DAS and 90 DAS and straw mulching were done in 30 DAS and continued up to harvesting), T4 (Intercropping= Bush bean seeds were dibbled at 15 cm apart from furrows in between the rows of maize crop),T5 (Herbicide= Apply paraquat in 30 DAS and 75 DAS @ 851 g a.i. ha^{-1}) and T6 (Control = no weeding). The unit plot size was (5m x 4m) = 20m2. Seeds were sown in the furrows opened at 60 cm and 30 cm apart and 2 seeds per hill were dibbled in furrows to a depth of 4 cm. After sowing, seeds were covered with thin layer of soil. Apply different nutrients at the recommended dose of 170:50:80:36 kg ha^{-1} N:P:K:S, one third of which is nitrogen (urea) and the full dose of phosphorus (TSP), potassium (MOP)), the sulfur-based gypsum (gypsum) and the remaining nitrogen at sowing are divided into two equal parts with 30 DAS (days after sowing) and 50 DAS rabi maize. For the proper growth and development of the crops four irrigations were provided at different growth phases which are 15 DAS (6-leaf stage), 30 DAS (12-leaf stage), 60 DAS (tasseling) and 85 DAS (50 % silking and dough stages). Complete gap filling within 8 DAS (a few days after sowing), and thin out by keeping the healthy and disease-free seedling on each hill on 15 DAS to maintain the desired plant population. Plant protection measures were taken when needed during the crop growth period. Apply Marshall 20 EC @ 2ml/L twice on 20 DAS and 40 DAS to control the corn stem borer. Tilt 250 EC @ 0.5ml/L and Ripcord 10 EC 1ml/L were applied simultaneously in 30 DAS and 60 DAS to control insects and diseases. The corn cobs of corn are harvested at the stage from milk to dough, which is done by hand. Green cobs were extracted from ten arbitrarily nominated plants for each treatment to record necessary observations.

Data collection parameters

For assessing the effects of weed treatments on the growth and development of maize, observations were recorded before and after harvest. In order to record data on growth and yield attributes, ten plants from each plot were randomly selected in the net plot area and marked for observation. At the early progress stage of 20 DAS and harvest, the plant population ha^{-1} was recorded on each plot with the help of squares (m-2), and then the value of the plant population was converted to ha^{-1}. Record the plant height (cm) of the maize at harvest, in centimeters from the ground to the fully opened leaves. Calculate the average height by dividing the sum by ten. Count and record the number of green and fully open leaves of leaf plant^{-1} at the time of harvest. Calculate the number of ear-grain plant^{-1} from ten labeled plants in each plot. After calculating the cob, calculate the average value to obtain the number of cob plant^{-1}. The lengths of ten cobs were randomly selected from each plot and measured from the root of the lowest primary shaft to the top of the cob, and the average value was recorded as the length of the cob in centimeters. To measure the weight of green cobs, fully filled green cobs were extracted from ten labeled plants of each treatment, and their fresh weight was recorded and expressed in grams. The cobs were removed from plants of all the treatment plot separately and weighted to noted the green cob yield which was then compiled as green cobs yield (t ha^{-1}) by multiply with conversion factor. Harvesting was done with the help of sickles manually at 10 cm above the ground level. After the harvesting of green cobs, the remaining stalks were tied into bundles and weighing was done. Weigh the feed output of each net map separately, and finally convert it to t ha^{-1} by multiplying by the conversion factor. The dry matter production of weeds was documented at 30 DAS, 60 DAS, 90 DAS and maize harvest. The weeds were uprooted from a randomly selected area of 1 square meter and exposed to the sun within 15 days. Finally, record the weight of weeds in each treatment and express it as g/m2.

Calculation of Harvest index

The harvest index is defined as the ratio of green cob yield to biological yield [24] and expressed in percent. The harvest index of maize was worked out as indicated below.

$$\text{Harvest index (\%)} = \frac{\text{Green cob yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

Calculation of Weed control efficiency (WCE)

The calculation of weed control efficiency is based on the reduction of the dry matter yield of the weeds in the treated plots compared with the weed control at 30 DAS, 60 DAS, 90 DAS and at harvest, and expressed as a percentage [25].

$$\text{Weed control efficiency (WCE \%)} = \frac{\text{DMC} - \text{DMT}}{\text{DMC}} \times 100$$

Where,

WCE = Weed control efficiency (%)

DMC = Dry matter of weeds in weedy check plot

DMT = Dry matter of weeds in treated plot

Statistical analysis

The data obtained on various parameters are tabulated and statistically analyzed. Using the computer software package R version (3.6.1) software (package="agricolae"), perform the analysis of variance according to RCBD [26]. The significance of the difference between a pair of means was tested by the least significant difference (LSD) test at a significance level of 5%.

III. Results and Discussions

Plant populations, plant height and number of leaves plant^{-1} of maize

The plant populations of maize at 20DAS and at harvest m^{-2} area under different weed management practices are presented in Table 1. At 20 DAS the highest number of plant populations (53576 plants ha-1) was observed at hand weeding + mulching treatment and the lowest number of plant populations (52433 plants ha^{-1}) was observed at unweeded control treatment. Contrarily, at harvest, the highest number of plant populations (53350 plants ha^{-1}) was observed at hand weeding + mulching treatment and the lowest number of plant populations (50520 plants ha^{-1}) was observed in unweeded control treatment. As a result, significantly the highest plant mortality rate (3.79%) was observed in the unweeded control treatment and the lowest plant mortality rate (0.42%) was observed in hand weeding + mulching treatment.

The data of plant height of maize at harvest are presented in Table 1. The maximum plant height (282.97 cm) was recorded under hand weeding + mulching treatment. The minimum plant height (251.52 cm) was recorded from unweeded control treatment indicating that weeds reduced the plant height due to competition for growth resources. A similar result was found by some other researchers [27].

Table 1 lists the observation data of the number of corn leaf plant^{-1}affected by different weed treatment methods. The highest number of leaf plant^{-1}obtained by artificial weeding + mulching treatment (14.07). The increase in the number of functional leaf plant^{-1} treated by hand weeding + mulching was due to the decrease in weed competition. Compared with other treatments, the lowest number of leaf plant^{-1} (9.37) recorded in the unweeded control treatment on each observation date. This shows that weeds have reduced the number of leaves due to competition for growth resources.

Number of cob plant^{-1}, cob length and cob weight of maize

The number of green cobs of corn cob plant^{-1} is significantly affected by different weed management practices and related data, as shown in Table 2. The maximum number of cobs (2.17 plant^{-1}) was produced by hand weeding + mulching treatment. Where significantly the minimum number of cobs (0.97 plant^{-1}) was recorded under unweeded control treatment. These findings were confirmed by other researchers [28, 29].

The data recorded in respect of cob length are presented in Table 2. Hand weeding + mulching was recorded significantly the highest length of cobs (23.90 cm) over all the weed management practices. Significantly the lowest length of cobs (16.12 cm) was recorded in the unweeded control treatment.

The different weed management practices significantly affected the weight of the green cobs as depicted in Table 2. Highest cob weight (289.48 g) was obtained from hand weeding + mulching treatment and lowest cob weight (233.12 g) in the unweeded control treatment. The reduction of green 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.

Green cob yield, fodder yield and harvest index of maize

The different weed management practices significantly affect green cob yield and data are presented in Table 3. Significantly the highest cob yield of maize (9.29 t ha^{-1}) was obtained under hand weeding + mulching treatment. The hand weeding + mulching treatment helps to weed suppression, as well as mulching helps to soil moisture conservation, soil temperature regulation and after decomposition in the soil add organic matter, which enhanced the growth and yield contributing characters of maize. On the other hand, the lowest cob yield (6.15 t ha^{-1}) was obtained under unweeded control treatment due to crop weed competition. Chopra and Angiras [29] and Mynavathi [30] observed similar results for these traits.

The data on the fodder yield of maize as affected by different weed management practices are presented in Table 3. Hand weeding + mulching treatment was recorded highest fodder yield (33.89 t ha^{-1}). The higher production of dry matter in plants might have improved the values of growth and yield attributes under hand weeding + mulching treatment which resulted in higher fodder yields of maize. The lowest fodder yield (26.36 t ha^{-1}) was recorded in unweeded control treatment due to crop weed competition for growth resources.

The harvest index (%) of maize was calculated and presented in Table 3. Significantly the highest harvest index was observed in T3 (27.41%) treatment followed by T5 (26.66%), T4 (26.63%), T2 (26.07%) and T1 (24.65%) respectively. The lowest harvest index was observed in T6 (23.34%) treatment due to lower cob yield and more crop weed competition.

Weed dry weight m^{-2} during different growth period of maize

The data of the dry weight of weeds is recorded in different time intervals of crop growth, see Table 4. The dry weight of weeds is greatly affected by different weed management practices. At 30 DAS, the lowest weed dry weight (44.53 gm^{-2}) of the hand weeding + mulching treatment was recorded. Similar trends were also observed at 60 DAS (56.00 gm^{-2}), 90 DAS (58.62 gm^{-2}) and at harvest (68.36 gm^{-2}) in hand weeding + mulching treatment. However, at 30 DAS the highest weed dry weight (52.50 g m^{-2}) was recorded in the unweeded control treatment. Similar trends were also observed at 60 DAS (96.37 gm^{-2}), 90 DAS (119.36 gm^{-2}) and at harvest (149.81 gm^{-2}) in the unweeded control treatment. Arvadia [27] and Sanodia [31] reported similar observations.

Weed control efficiency of maize

The data regarding weed control efficiency was recorded at 30 DAS, 60 DAS, 90 DAS, and at harvest which was presented in Table 5. At 30 DAS, the highest weed control efficiency (15.18 %) was recorded in hand weeding + mulching treatment. Similar trends were observed at 60 DAS (41.86 %), 90 DAS (50.88 %) and at harvest (54.36%) in hand weeding + mulching treatment. This may be due to the decrease of weed population and the decrease of weed dry matter yield under the condition of hand weeding + mulching. On the other hand, in the hand weeding treatment, when the DAS is 30, the weeding efficiency is the lowest (5.71%). Similar trends were observed at 60 DAS (17.69 %), 90 DAS (24.42 %) and at harvest (20.02 %) in hand weeding treatment.

IV. Conclusion

In this study, the production of rabi maize in the Khagrachari hill district was tested by different weed treatment methods. From the above results, it can be concluded that in maize, the observed plant height, leaf number, cob number, cob length, cob yield, harvest index and weed control efficiency are the highest, while the plant mortality is the lowest for hand weeding and mulching treatment compared with other treatments. Finally, compared with other treatments, hand weeding with mulching can be considered as most effective weeding method of maize. Further multilocational trials at different agroecological zones are also recommended for more precise findings.

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Table 1: Plant population ha^{-1}, plant height and number of leaves plant^{-1} of maize as influenced by different weed management practices

TREATMENTS	Plant populations ha^{-1}			Plant height (cm)	Number of leaves plant^{-1}
	20 DAS	At harvest	% Mortality		
T_1 (Hand weeding)	52789 c	51563 d	2.38 b	272.13 ab	11.05 e
T_2 (Mulching)	53047 bc	52045 c	1.92 bc	274.17 ab	11.76 d
T_3 (Hand weeding + Mulching)	53576 a	53350 a	0.42 d	282.97 a	14.07 a
T_4 (Intercropping)	53266 b	52523 b	1.41 bcd	278.88 a	12.15 c
T_5 (Herbicide)	53154 b	52687 b	0.88 cd	280.35 a	12.98 b
T_6 (Unweeded control)	52433 d	50520 e	3.79 a	251.52 b	9.37 f
CV (%)	**0.29**	**0.37**	**33.29**	**4.99**	**1.12**

Table 2: Number of cob plant^{-1}, cob length and cob weight of maize as influenced by different weed management practices

Treatments	No. of cob plant^{-1}	Cob length (cm)	Cob weight (g)
T_1 (Hand weeding)	1.62 e	18.60 d	265.89 e
T_2 (Mulching)	1.72 d	18.87 d	270.21 d
T_3 (Hand weeding + Mulching)	2.17 a	23.90 a	289.48 a
T_4 (Intercropping)	1.80 c	20.95 c	274.95 c
T_5 (Herbicide)	1.89 b	22.90 b	284.54 b
T_6 (Unweeded control)	0.97 f	16.12 e	233.12 f
CV (%)	**1.94**	**2.14**	**0.79**

Table 3: Green cob yield, fodder yield and harvest index of maize as influenced by different weed management practices

Treatments	Green cob yield (t ha^{-1})	Fodder yield (t ha^{-1})	Harvest index (%)
T_1 (Hand weeding)	7.17 e	29.09 e	24.65 c
T_2 (Mulching)	7.77 b	29.79 d	26.07 b
T_3 (Hand weeding + Mulching)	9.29 a	33.89 a	27.41 a
T_4 (Intercropping)	8.32 c	31.25 c	26.63 b
T_5 (Herbicide)	8.77 b	32.92 b	26.66 b
T_6 (Unweeded control)	6.15 f	26.36 f	23.34 d
CV (%)	**1.42**	**0.71**	**1.45**

Table 4: Weed dry weight m^{-2} during different growth period of maize as influenced by different weed management practices

Treatments	Weed dry weight (g m^{-2})			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
T_1 (Hand weeding)	49.50 b	79.31 b	90.21 b	119.81 b
T_2 (Mulching)	48.22 c	72.46 c	85.78 c	109.92 c
T_3 (Hand weeding + Mulching)	44.53 f	56.00 f	58.62 f	68.36 f
T_4 (Intercropping)	46.50 d	70.27 d	81.12 d	96.55 d
T_5 (Herbicide)	45.46 e	65.48 e	73.60 e	87.11 e
T_6 (Unweeded control)	52.50 a	96.37 a	119.36 a	149.81 a
CV (%)	**0.99**	**1.07**	**1.03**	**0.77**

Table 5: Weed control efficiency of maize as influenced by different weed management practices

A. ***Treatments***	**Weed control efficiency (%)**			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
T_1 (Hand weeding)	5.71 e	17.69 e	24.42 e	20.02 e
T_2 (Mulching)	8.15 d	24.79 d	28.13 d	26.62 d
T_3 (Hand weeding + Mulching)	15.18 a	41.86 a	50.88 a	54.36 a
T_4 (Intercropping)	11.43 c	27.07 c	32.04 c	35.55 c
T_5 (Herbicide)	13.41 b	32.06 b	38.34 b	41.85 b
T_6 (Unweeded control)	--	--	--	--
CV (%)	**12.88**	**3.36**	**2.42**	**1.67**