IMPACT OF CONSERVATION TILLAGE UNDER ORGANIC MULCHES ON THE REPRODUCTIVE EFFICACY AND YIELD OF QUALITY PROTEIN MAIZE

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ABSTRACT

The present study was carried out to evaluate the efficacy of conservation tillage under organic mulches on the reproductive developments and production potentials of Quality Protein Maize (QPM) cv. Pozarica during the period from November 2007 to April 2008. The study included tillage and zero tillage conditions and four indigenous mulches viz. water hyacinth, rice straw, rice husk and ash. All the mulches significantly modified microclimatic parameters in both tillage and zero tillage conditions. However, under non-tilth condition water hyacinth and rice straw mulches reduced the maximum soil temperature at 5 cm depth by 3.5-4.2°C and 2.4-2.7°C, respectively at 14:00 hrs and raised the minimum temperature by 1.5-2.3°C and 1.2-1.4°C at 06:00 hrs. The water retentive capacity of the mulched soil under zero tillage condition was higher at all the stages of plant growth and ranked in the order of water hyacinth>rice straw>rice husk>ash>control. The reproductive developments in mulched plants were advanced by about 1 to 10 days. Mulching practices also enhanced the number of ears plant^{-1}, ear height, length and diameter, tassel length, number of seed rows ear^{-1} and seeds row^{-1}, 1000-grains weight, weight of rachis ear^{-1}, grain yield and higher harvest index (HI). The grain yield of mulched plants notably water hyacinth was nearly double (8.73 t ha^{-1}) than unmulched plants (4.93 t ha^{-1}) under non-tilth condition. The indigenous mulches especially water hyacinth and rice straw, irrespective of tilth or non-tilth conditions, appeared to be great suppressants of weed growth allowing to produce less than one third of the total biomass compared to that of control. The residual mulching effect had little or no influence on physical properties of the soil under both conditions. However, the chemical properties were favourably influenced for the follow-up crops.

Key words: *Conservation tillage, organic mulches, soil moisture conservation, yield, QPM.*

INTRODUCTION

Maize is the third most important cereal crop in the world after wheat and rice. Though quantitatively it is after wheat and rice, it yields the highest per unit area. The average global production of maize in 2003 was 4.47 t ha^{-1} as compared to 2.67 and 3.84 t ha^{-1} for wheat and rice, respectively (FAO, 2004). This cereal is mostly deficient in essential amino-acids; lysine and tryptophan and a vitamin, nyacin. CIMMYT has developed nutritionally improved maize containing high levels of aforesaid amino-acids and vitamin and termed as quality protein maize (QPM). Even different QPM lines have the potential to yield more than 8 t ha^{-1}, whereas the national average yield is only 1.06 t ha^{-1} (Rahman *et al*., 2002). Although the productivity of this crop is better during the dry winter season, it remains far below the world average because of the low moisture content and low atmospheric and soil temperature. During winter, rainfall is erratic and evapotranspiration is high, and only 40% of the cultivable land can be brought under irrigation (Islam and Kaul, 1986). In this situation, various types of mulching materials could be widely used as an effective cultural practice to bring a large

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area under maize cultivation.Mulching is a desirable management practice which regulates farm environment and thereby enhances crop production through regulating soil temperature (Khan, 2001), by reducing leaching and evapotranspiration (Liu *et al*., 2000), by increasing the soil organic matter content (Roldan *et al*., 2003) and by reducing nutrient loss due to run off (Smart and Bradford, 1999). On the other hand, land tilling is a common practice for crop cultivation. In Bangladesh most of the crops are usually grown after adequate soil tillage. However, with scientific bases, conservation tillage or zero-tillage techniques, as an alternative to conventional tillage is gaining popularity worldwide (Monneveux *et al*., 2006). Zero tillage increases the mechanical resistance and the apparent density of soil and curbs soil evaporation (Rivas *et al*., 1998). It has also been reported to increase total nitrogen and microbial biomass in various soils (McCarthy *et al*., 1995). Moreover, conservation tillage reduces the number of field operations by minimizing input costs for labour, fuel, tractors and other equipments and thus results in greater economic returns compared with conventional tillage system (Smart and Bradford, 1999).

Zero tillage system of cultivation could be more successful if other appropriate cultural practices such as mulching, crop rotations and fallow systems are applied (Franzen *et al*., 1993). Without any external field cover (i.e. mulching practices) zero tillage led to increase weed infestation, especially with perennial species. Conventional and continuous deep ploughing decreased soil strength, on the other hand zero tillage along with rice straw mulch (6 t ha^{-1}) decreased soil temperature and strengthened soil composition (Machul, 1993). Thus, zero tillage with adequate different organic mulches on the soil surface may produce yield comparable to or higher (especially in drier areas) than those of obtained from conventional tillage. However, the effectiveness of the indigenous mulches under zero tillage condition remains to be explored though the efficacy of these mulches on the growth and development of maize is well recognized. Therefore, the present study was undertaken to monitor mulch induced micro-environment and to identify effective organic mulch(es) suitable for production potentials of QPM and to observe their effects on physiochemical properties of soils under tilth and non-tilth conditions.

MATERIALS AND METHODS

Experimental site and planting materials

The present experiment was carried out at the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh during the period from November 2007 to April 2008. Seeds of Quality Protein Maize (QPM) cv. Pozarica (pedigree no. 8763) were used as planting material.

Experimental protocol

Land preparation for the research work was somewhat different from the traditional method. One field remained in zero tillage condition and in late October, rain water was deposited in other field by constructing ‘furrows’ around the field. After 3 days, weeds and stubble were removed by spade and hoe. Manures and fertilizers were applied to the plots as per recommendation of BARI (1993). The experiment was laid out in Randomized Complete Block Design (RCBD) with two different land conditions (tilth and non-tilth), each comprising of five treatments and four blocks, each representing a replication. Five plots each measuring 15m×10m were prepared in each block. The seeds were sown 25 cm apart in rows at a distance of 75 cm between the rows. After completion of seed germination, the indigenous mulches viz. water hyacinth, rice straw, rice husk and ash at the rate of

10 t ha^{-1} were uniformly spread immediately over the plots assigned for the definite mulch treatment. Weeding was done manually at 40 and 70 DAS. No irrigation was applied. Appropriate measures were taken against insect-pests and diseases as and when required.

Data collection

Data were collected on microclimatic parameters such as soil temperature and moisture and on reproductive attributes namely, days to tasseling, silking and maturity, yield and yield attributes like number of ears $plant^{-1}$, ear height, length and diameter, tassel length number of seed rows ear^{-1} and seeds row^{-1}, 1000-grains weight, weight of rachis ear^{-1}, grain yield, harvest index weed growth and physiochemical properties of soil. Morpho-physiological parameters were obtained from 20 randomly selected plants of each plot.

The diurnal variation of soil temperatures was recorded on a clear sunny day with ordinary thermometer cased in copper tubes with pointed tips at hourly intervals at the depth of 5 cm beginning from 06:00 hrs to 17:00 hrs on 22 DAS and 80 DAS. Moisture content at 0-5 cm depths of the soil layers was measured by electronic soil moisture and temperature meter (Delta devices, UK) at 10 day intervals starting from 40 DAS and continued to 120 DAS.
Weeds grown in 1 m^2 area of unit plot were collected from mulching treatments during the weeding at 40 and 70 DAS. The weeds were oven dried at 80±2°C for 48 hrs and measured by an electric balance to record the total weed biomass. After one month of final harvest the analysis of the soil particle of the experimental plots was carried out by hydrometer method described by Black (1965). The textural classes were determined by using the Marshall's Triangular Co-ordinates. The pH of the soil sample was determined with the help of a glass electrode pH meter. Organic C, total N, available P, K and S content of the soil sample was determined according to Walkley and Black (1935), Page *et al*. (1989), Olsen *et al*. (1954), Black (1965) and Page *et al*. (1989), respectively.

Statistical analysis

The collected data on different parameters under study were compiled and subjected to statistical analysis. Analysis of variance was calculated following the experimental design with the help of the computer package MSTAT-C (Russell, 1986). The means differences were evaluated by the Least Significant Difference (LSD) and Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Soil temperature

A remarkable variation in soil temperature was observed due to non-tilth condition and mulches throughout the day (Figure 1-4). The greatest influence was recorded in water hyacinth mulched plants, which reduced the maximum soil temperature at 22 and 80 DAS by 4.2 and 3.5°C and increased the minimum temperature by 1.5 and 2.3°C, respectively when compared to the control. The reduction of soil temperature of water hyacinth was followed by rice straw, rice husk and ash.
Mulches reduced the soil temperature by day because they reflect a considerable part of incidental solar radiation. Moreover, their lower thermal conductivity prevents and decreases the amount of downward transmission of heat (Giri and Singh, 1985). On the other hand, higher temperature under mulched condition at night might be due to trapping of out going long wave radiation released by the soil (Rahman *et al*., 2002). Increased soil temperature accelerated the rates of leaf tip appearance, full leaf expansion and enabling the crop canopy development, more biomass production with only minimal impact on air temperature (Stone *et al*., 1999).

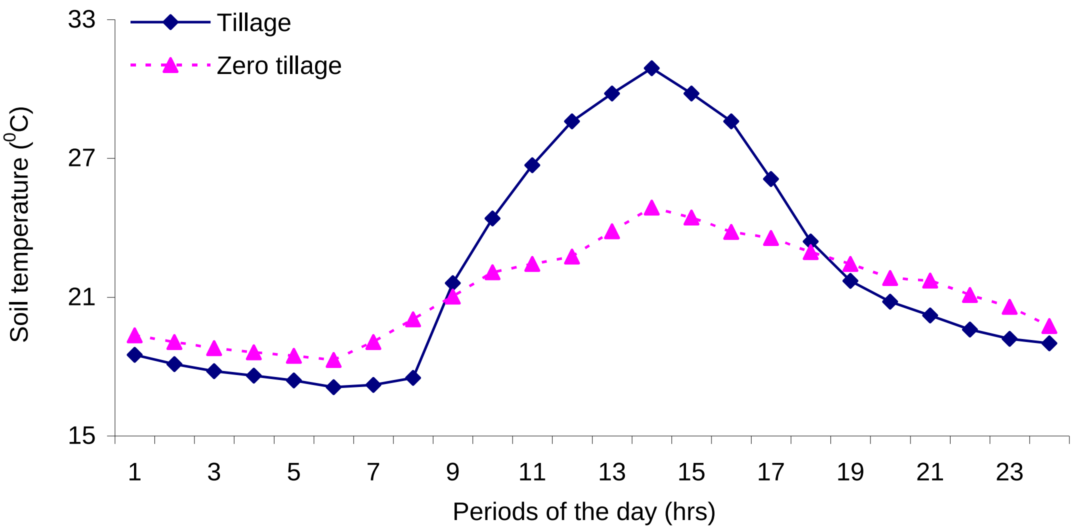

Figure 3. Diurnal fluctuation of soil temperature at 5 cm depth as influenced by tilth and non-tilth conditions on 20 February 2008 i.e. 80 DAS.

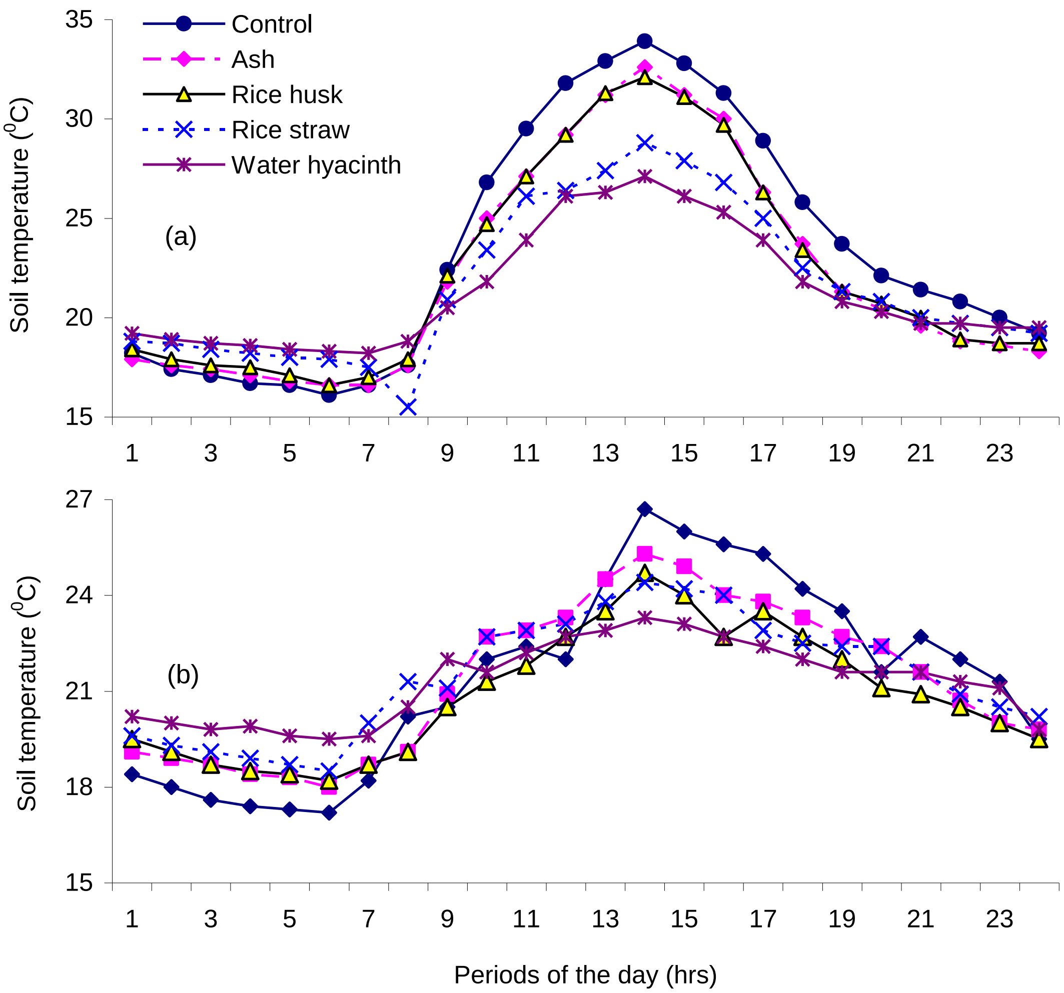

Figure 4. Diurnal fluctuation of soil temperature at 5 cm depth as influenced by indigenous mulches under tilth (a) and non-tilth (b) conditions on 20 February 2008 i.e. 80 DAS.

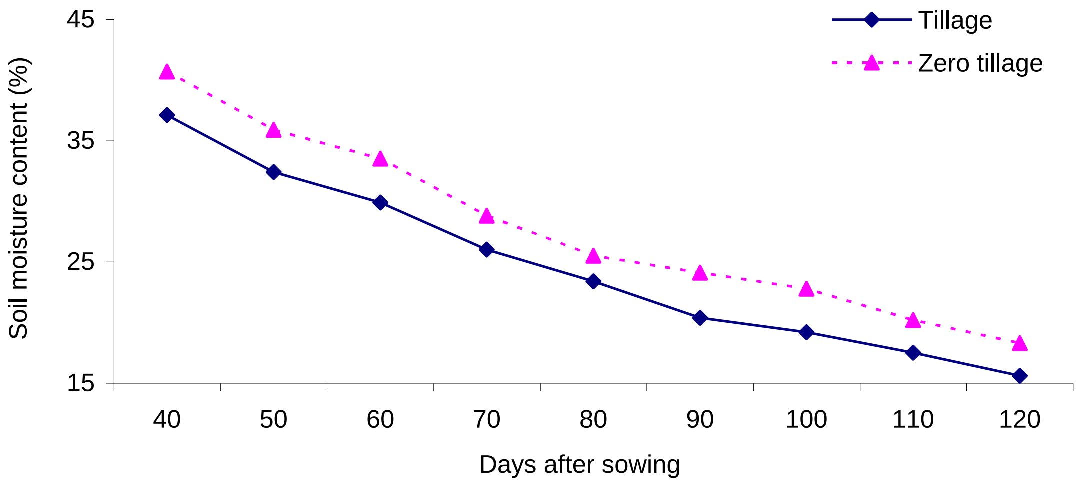

Figure 5. Soil moisture content (weight per cent) at different days after sowing as influenced by conventional and conservation tillage.

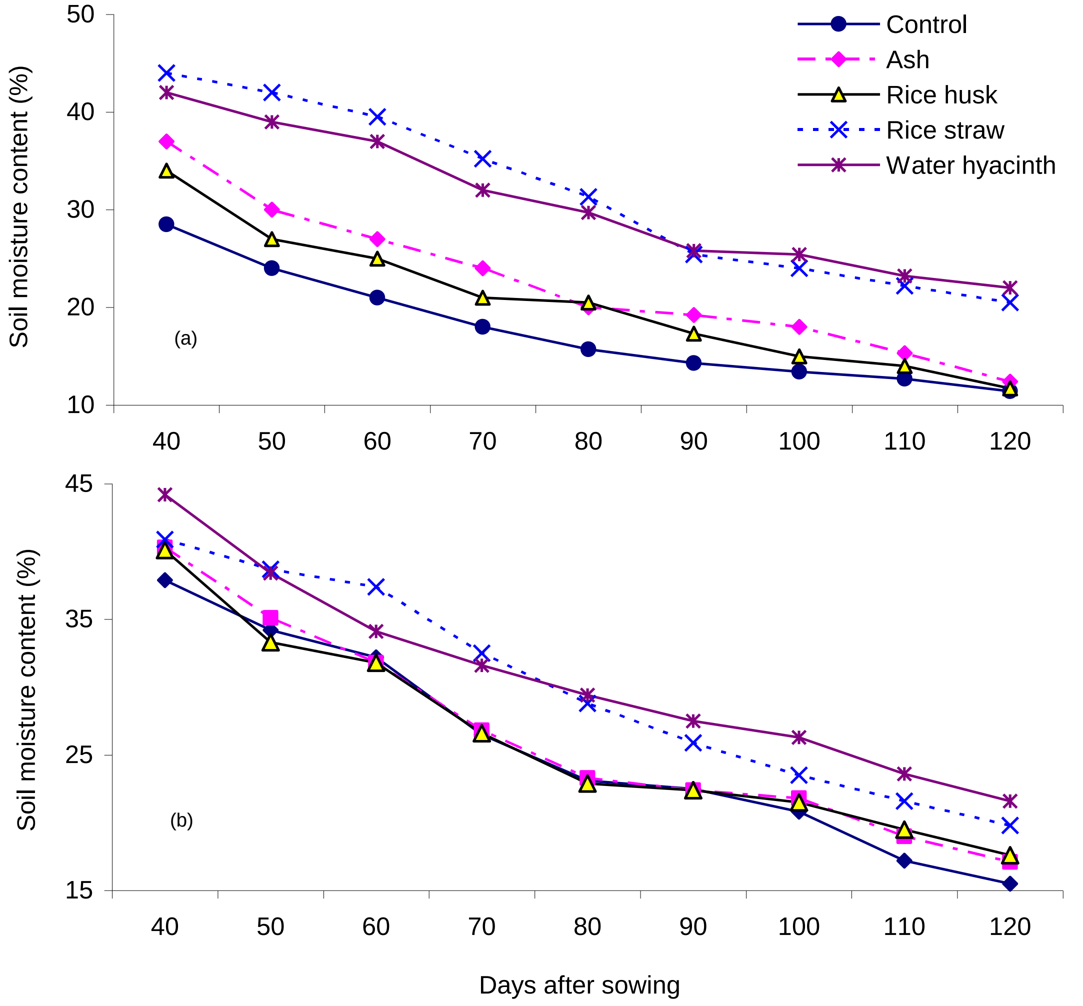

Figure 6. Soil moisture content (weight per cent) at different days after sowing as influenced by different indigenous mulches under tillage (a) and zero tillage (b) conditions.

Soil moisture content

There were significant changes in soil moisture content with time due to non-tilth condition and application of different indigenous mulches (Figure 5 and 6). The initial higher soil moisture content at 40 DAS decreased gradually up to crop maturity. It was always higher in non-tilth than the tilth conditions (Figure 5). Rice straw and water hyacinth mulches contained maximum soil moisture throughout the entire period of growth when compared to other mulches and control under both conditions (Figure 6). The performance of rice husk and ash in retaining soil moisture was intermediate. The effectiveness of mulches with regards to soil moisture content was in the order of rice straw>water hyacinth>rice husk>ash>control.

During the growth stages from 40 to 90 DAS soil moisture content decreased since there was no rainfall (Weather Yard, 2008). Rice straw and water hyacinth mulches retained maximum soil moisture in this period probably due to reduced evaporation (Cui *et al*., 1998), transmissivity (Mbagwu, 1990), plant transpiration (Shekour, *et al*., 1987) and increased hydrolic conductivity (Schoningh, 1985), water infiltration (Sutrisno *et al*., 1995) and water holding capacity (Xu *et al*., 1988). However, under zero tillage condition, the dry-land lost soil moisture due to higher evapotranspiraion. But no-tillage with adequate organic mulch on the soil surface conserved soil moisture which was comparable to or higher than the conventional tillage system (Gicheru *et al*., 1998). In addition, the accumulation of leaf litter on the surface layer of compacted soils caused a reduction of evapotranspiration and thus, soil moisture was conserved (Vidhana Arachchi and Liyanage, 2003).

Days to tasseling, silking and maturity

Zero tillage condition and all the mulches significantly decreased the number of days required to tasseling, silking and maturity as compared to control (Table 1). Irrespective of mulching, the date of tasseling, silking and maturity were advanced by about 4, 2 and 6 days, respectively under non-tilth condition. However, under tilth condition, advancing was more for silking, but lower for maturity and similar for tasseling in rice straw and water hyacinth mulched plants than under non-tilth condition. The influences of rice husk and ash mulches were intermediate in this respect. The interaction effects between tilth and non-tilth conditions were insignificant for all the reproductive characters.

The number of days to tasseling and silking of QPM was reduced possibly due to their earlier emergence and favourable soil temperature under water hyacinth and rice straw mulches (Madsen, 1992). Mulched treatments also maintained significantly greater plant available water (PAW) compared to the bare soil until near anthesis and after anthesis which helped earlier initiation of tassel and silk (Tolk *et al*., 1999). However, the earlier maturity in water hyacinth and rice straw treated plants was due to the higher minimum soil temperature caused by the mulches (Rahman *et al*., 2002).

Yield contributing attributes

Yield contributing attributes such as number of ears plant^{-1}, ear height, length and diameter, tassel length, number of seed rows ear^{-1} and seeds row^{-1}, 1000-grains weight and weight of rachis ear^{-1} were significantly affected by zero tillage and different mulches (Table 2). However, under zero tillage condition most yield attributes were significantly increased with the water hyacinth and rice straw mulches compared to rice husk, ash and control than tillage condition. There was no significant variation in number of ears plant^{-1} between tilth and non-tilth conditions. But tilth and non-tilth conditions were interacted insignificant for all the yield contributing characters.

Mulch induces yield improvements in maize plant (Ma and Han, 1995). Different researchers found that cultivation of maize under minimum tillage or zero tillage along with various mulches did not significantly reduce the yield and yield contributing attributes (Tolk *et al.*, 1999), which were similar to our findings.

Table 01: Effect of tilth conditions and indigenous mulches on reproductive characters of QPM

Treatments	Days to tasseling	Days to silking	Days to maturity
Tillage	73.64 b	82.46 b	131.94 b
Zero Tillage	76.05 a	83.96 a	138.30 a
$LSD_{(0.01)}$	0.88	0.67	1.23
Tillage × Mulches			
Control	78.2 a	87.0 a	136.1 a
Ash	75.6 b	85.3 b	132.8 b
Rice husk	75.3 b	85.1 b	132.3 b
Rice straw	69.8 c	77.8 c	129.6 c
Water hyacinth	69.3 c	77.1 d	128.9 d
$LSD_{(0.01)}$	0.85	0.67	0.60
Zero Tillage × Mulches			
Control	81.28 a	92.10 a	144.1 a
Ash	80.35 a	91.28 ab	142.0 b
Rice husk	75.20 b	86.07 c	141.4 b
Rice straw	72.28 c	85.07 c	133.1 c
Water hyacinth	71.52 c	83.30 c	132.3 c
$LSD_{(0.01)}$	0.97	0.68	1.05

Figures with same letter in a column are statistically similar at 1% level of significant

Table 02: Yield and yield contributing attributes of QPM as influenced by conservation tillage and indigenous mulches

Treatment	No. of ears plant^{-1}	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Tassel length (cm)	No. of seed rows ear^{-1}	No. of seeds row^{-1}	1000 seeds wt. (g)	Wt. of rachis ear^{-1}(g)	Grain yield (t ha^{-1})
Tillage	1.06	57.5b	15.1a	4.48a	46.24b	13.78a	28.15a	219.82a	19.88a	4.63a
Zero Tillage	1.09	65.63a	16.3b	5.24b	51.33a	14.40b	29.94b	335.75b	35.12b	7.10b
$LSD_{(0.01)}$	NS	4.20	1.19	0.76	4.39	1.06	1.06	18.6	8.05	2.38
Tillage × Mulches										
Control	1.0c	51.1c	12.0c	3.9 c	42.9 c	12.6b	22.5c	189.5c	14.9c	2.96e
Ash	1.0c	53.6c	13.8b	4.41b	45.2bc	13.0b	26.26b	221.9b	18.0b	3.76d
Rice husk	1.0c	54.6c	14.5b	4.39b	46.0bc	13.6b	27.5b	218.0b	19.4b	4.23c
Rice straw	1.1b	59.4b	17.1a	4.69ab	47.7ab	14.7a	31.5a	229.2ab	23.0a	5.54b
Water hyacinth	1.2a	68.8a	18.1a	4.94a	49.4a	15.0a	33.0a	240.5a	24.1a	6.67a
$LSD_{(0.01)}$	0.06	3.87	1.17	0.36	3.10	1.06	1.99	15.6	1.4	0.32
Zero Tillage × Mulches										
Control	1.0d	37.03d	14.50b	5.09d	43.30c	13.00b	25.25b	316.62c	28.6d	4.93d
Ash	1.0d	48.70c	15.05b	5.17c	46.80c	14.00b	27.50ab	332.97b	32.4c	6.55c
Rice husk	1.04c	70.55b	17.00a	5.27b	52.75b	14.50ab	30.25ab	340.25a	37.2b	7.46b
Rice straw	1.15b	86.70a	17.00a	5.32a	57.60a	15.00ab	32.70a	342.30a	38.2b	7.85b
Water hyacinth	1.25a	89.18a	17.97a	5.35a	58.20a	15.50a	34.00a	346.60a	39.3a	8.73a
$LSD_{(0.01)}$	0.07	3.92	1.21	0.42	3.24	1.18	2.95	7.38	1.01	0.48

Figures with same letter in a column are statistically similar at 1% level of significant

Grain yield

Zero tillage and all the mulching treatments had a positive effect on grain yield when compared to tillage conditions and the control, respectively (Table 2). Plants under non-tilth condition gave a higher grain yield (7.10 t ha^{-1}) when compared to plants in tilth plots (4.63 t ha^{-1}). The highest grain yield (8.73 t ha^{-1}) was obtained from water hyacinth mulched plants followed by rice straw, rice husk, ash and control under non-tilth condition while it was 6.67 t ha^{-1} under tilth condition. There was no significant difference between rice straw and rice husk in promoting the grain yield under non-tilth conditions (Table 2).Water hyacinth and rice straw mulches generated favourable soil temperature and soil moisture conditions which in turn increased the dry matter accumulation in plant (Rahman *et al*., 2002). Grain yield and total dry matter production in cereals were positively related. Straw mulch induced yield improvement in maize as stated by Crutchfield (1985).The different dry land crops like maize, sorghum, soyabeans and mung beans sown under no-tillage with adequate vegetative mulch produced grain yields comparable with or higher than (especially in drier season) those obtained from conventional tillage (Tolk *et al*., 1999).

Harvest index (HI)

Tilth conditions and different mulches had a significant effect on HI (Table 3). It was higher in non-tilth condition than in the tilth condition. The highest HI was obtained from water hyacinth mulched plants (0.618) under non-tilth condition while it was (0.478) under tilth conditions. However, the interaction between tilth and non-tilth conditions had insignificant influence on the HI.

The HI of cereals depends on grain yield (Bhatia, 1975) and biological yield (Kramer, 1979). The HI of water hyacinth and rice straw treated plants increased possibly as a consequence of their higher gain yield and biological yield. Grain yield increment was significantly correlated with HI. Increased HI resulted from increased crop yield was being probably because of improved partitioning of dry matter to the cob as stated by Planiappan (1985).

Weed growth

The impact of different indigenous mulches at 40 and 70 DAS under tillage and zero tillage condition was found to be significant in terms of weed biomass production (Table 3). Under tilth condition the maximum weed biomass was obtained (55.14 gm^{-2}) at 40 DAS and the lowest in non-tilth condition (41.32 gm^{-2}) at 70 DAS (Table 3). Besides, all the mulches controlled the weed growth at both stages compared to the bare plot. However, water hyacinth and rice straw mulches suppressed the weed growth greatly by inducing higher growth rate of maize plants. The interaction effects between tilth and non-tilth conditions were insignificant for weed growth.

Different indigenous mulches such as water hyacinth, rice straw, rice husk and ash reduce the emergence and survival of weeds in maize (Mohler and Calloway, 1992). The greater suppression of weed biomass was observed in water hyacinth and rice straw treated plots probably due to the little or no transmission of solar radiation through the mulches (Rahman *et al*., 2002). The present findings are in agreement with Machul (1993).

Aftermath mulching effects on physiochemical soil properties

Physical properties of soil:

Different mulch treatments did not play any significant role in changing the physical properties such as sand, silt and clay contents in soil. Generally the organic mulches are much slower than the chemical fertilizer in respect of nutrient release in soil. Even the organic mulches may leave residual effects for about 4-5 years (Tilander, 1993). This fact may be the probable cause for the non significant impact on physical properties of soil in the present investigation.

Chemical properties of soil:
Aftermath changes in chemical properties of soil due to application of different indigenous mulches on maize crop as presented in Table 4. Ash mulch increased soil pH significantly over all other mulch treatments, while the rice straw mulch decreased it when compared to the control. The highest organic carbon (1.19%) was observed under water hyacinth mulch followed by rice husk (1.08%) and rice straw (1.07%), due to high decomposition rate of water hyacinth. The accumulation of nitrogen from water hyacinth and straw mulches appeared to be 0.127% and 0.116%, respectively and they occupied superior position over rest of the mulches. Although, they were significantly different from each other, their accumulation rate over control treatment was recognizable. However, all the treatments showed more or less similar results in case of phosphorus accumulation but only the ash treatment differed significantly from the others. The result also indicated that rice straw and ash mulches significantly increased available potassium over control treatment, whereas the rice husk and water hyacinth mulches showed a decreasing effect. A significant variation was also found in case of sulphur contents due to mulching. Although, the water hyacinth mulch ranked first (19.15 ppm), the rice straw and ash mulches did not differ significantly from the rice husk in term of sulphur.

Table 03: Effect of tilth conditions and indigenous mulches on HI and weed growth

Treatments	Harvest index (HI)	Weed growth (gm^{-2})	
		40 DAS	70 DAS
Tillage	0.379b	55.14a	53.86a
Zero Tillage	0.522a	42.34b	41.32b
$LSD_{(0.01)}$	0.023	9.67	8.56
Tillage × Mulches			
Control	0.191d	90.4a	89.6a
Ash	0.350c	69.6b	67.5b
Rice husk	0.398b	58.5b	56.5b
Rice straw	0.478a	30.4c	29.3c
Water hyacinth	0.478a	26.8c	26.4c
$LSD_{(0.01)}$	0.011	15.86	11.49
Zero Tillage × Mulches			
Control	0.450d	70.3a	69.1a
Ash	0.467d	49.7b	49.1b
Rice husk	0.517c	45.8b	44.5b
Rice straw	0.557b	25.2c	24.5c
Water hyacinth	0.619a	20.7c	19.4c
$LSD_{(0.01)}$	0.032	6.30	6.90

Figures with same letter in a column are statistically similar at 1% level of significant

Table 04: Changes in chemical properties of soil due to the aftermath effect of different indigenous mulches

Treatments	pH	O.C (%)	N (%)	P (ppm)	K (ppm)	S (ppm)
Control	6.33 bc	1.01 b	0.100 c	26.31 a	58.42 c	15.69 b
Ash	6.66 a	1.04 b	0.100 c	16.30 b	63.52 a	16.57 b
Rice husk	6.28 bc	1.08 ab	0.100 c	24.80 a	56.51 d	15.16 b
Rice straw	6.18 c	1.07 ab	0.116 b	27.82 a	62.00 b	17.19 ab
Water hyacinth	6.42 b	1.19 a	0.127 a	23.03 a	56.67 d	19.15 a
$LSD_{(0.01)}$	0.22	0.13	0.01	6.22	4.75	2.22

Figures with same letter in a column are statistically similar at 1% level of significant

CONCLUSION

The research concluded that zero tillage condition with water hyacinth and rice straw mulches was more efficient than other mulches and the control in respect of developmental and yield contributing attributes, which ensured the higher grain yield of QPM cv. Pozarica under the agro-climatic conditions of Bangladesh. In addition, zero tillage did not bring about a decrease in yield of QPM cv. Pozarica, rather it provided an advantage of low labour requirement and prevented crop lodging. Moreover, improved physiochemical properties of soil due indigenous mulching had added advantages on the follow-up crops. This practice with QPM may supplement nutritional deficiency of the malnourished people and a good source of poultry feed in Bangladesh.

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