ORGANIC MULCHES AND CONSERVATION TILLAGE: GROUND RESOURCES EXPLOITATION BY QUALITY PROTEIN MAIZE (QPM)

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Abstract

Production of Quality Protein Maize (QPM) through manipulating microclimate by mulch covers with conservation tillage are the realities for the non-irrigated riverine char lands in Bangladesh. Experiments were conducted in Char Sirajabad of Jamalpur district in the rabi season of 2012-2013. The indigenous mulches like water hyacinth and rice straw had the potentiality to enhance 2-3^{0}C night time soil temperature and water retention capacity to augment near about 2-fold yield improvement over the control. The mulches significantly influenced the nutrient uptake, root dry matter (RDM), total dry matter (TDM) production and finally the grain yield. The grain yield of mulched plants notably water hyacinth was nearly doubled. The average grain yield was 8.0, 7.2 t ha^{-1} under water hyacinth and rice straw mulches, respectively as against 4.5 t ha^{-1} for control. Mulching slightly improved the soil nutrient contents compared to control plots without much affecting the soil nutrient status.

Key words**:** mulches, microclimate, conservation, resource exploitation, QPM, DM.

INTRODUCTION

Mulching is a desirable management practice which regulates farm environment and thereby enhances crop production through regulating soil temperature (Khan 2001), reducing leaching and evapotranspiration (Liu *et al*. 2000), increasing the content of soil organic matter (Roldan *et al*. 2003) and reducing nutrient loss due to run off (Smart and Bradford 1999). The importance of surface mulch and conservation tillage in ameliorating soil temperature, moisture and fertility, and reducing soil erosion and loss in crop production in the semi-arid tropics are now evidenced firmly (Balaswamy *et al.* 1986, Xu *et al.*1988, Adeoye 1990, Bhatt *et al.* 2004, Xie *et al.* 2007). The efficacy of water hyacinth and rice straw mulches on QPM production under the agro-climatic conditions of Bangladesh are also well documented (Awal and Khan 1999, Khan 2001and 2008, Rahman and Khan 2002, Khan and Parvej 2010). Conservation tillage or zero-tillage technique as an alternative to conventional tillage, is gaining popularity worldwide (Monneveux *et al.* 2006).

Conservation tillage generally results in greater economic returns compared to the conventional tillage system due to both greater yields in dry years and smaller production costs in all other years (Smart and Bradford 1999). The conservation tillage system in the riverine *char* areas where irrigation facilities are quite scanty, would be more successful if it is accomplished with mulching to reduce weed infestation and to conserve soil moisture and temperature.

Rice straw and water hyacinth mulches appeared to enhance the growth and development of QPM resulting in about 2-fold yield improvement over the control (Khan 2001 and 2008, Awal and Khan 1999, Khan and Parvej 2010). But, the effectiveness of these mulches to exploit the ground resources in relation to the growth and development of QPM under conservation tillage in the riverine *chars* of Bangladesh remains undisclosed. The present study was, therefore, undertaken to assess the nature and extent of exploitation of ground resources under conservation tillage and organic mulch covers.

MATERIAL AND METHODS

The experiment was conducted in the 'Rabi' season (November - March) of 2012-13 in Char Sirajabad (25^{0}04′59.95″ N, 89^{0}47′59.49″ E) under Jamalpur district of Bangladesh involving the farmers of this riverine *char* of Brahmaputra. Five contact farmers were selected to form a composite block of five acres land where three representative farmers' plots for each treatment was considered as replication. Data was analyzed following Randomized Complete Block Design (RCBD). The treatments comprised two mulch covers (rice straw and water hyacinth) along with no mulch cover (control).

Conservation tillage technique was followed after harvesting Aman rice. The land was scratched by a handtine/plough to open the minimum soil to sow the maize seeds by line in it. Selected QPM accessions, collected form CIMMYT, multiplied at the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University (BAU), Mymensingh were used as planting materials. Fertilizers were applied following (BARC 2005) recommended doses. Maize seeds were sown in the 2^{nd} week of November. The seeds were placed in lines maintaining a distance of 75 cm row to row and 25 cm plant to plant. Maize seeds require 5-6 days for germination. After completion of germination water hyacinth and rice straw mulches @ 10 t ha^{-1} were uniformly spread over the plots assigned for the respective mulch treatment. No irrigation was applied. The land was weeded twice, once at 40 and the other at 70 days after sowing (DAS). Cutworm and ant attacks were controlled by applying 'Dersban' @ 1 L ha^{-1}.

Parameters studied

The diurnal variation of soil temperatures was recorded on a clear sunny day with an ordinary thermometer cased in copper tubes with pointed tips at hourly intervals at the depths of 7cm, 14 cm and 21cm on 60 DAS. Soil moisture content at 7cm, 14 cm and 21cm were measured by a soil moisture meter (Theta probe, Delta T ML 2x) at 20 days interval starting from 30 DAS. Plant samples for root growth analysis were collected for each replication at 20 days intervals starting from 30 DAS. Six plants from 1.125 m^2 (1.5 m× 0.75 m) $plot^{-1}$ were harvested. Root samples were collected by digging the soil around the base of the maize plant up to 100 cm depth and 25cm diameter. Root dry matter (RDM) was recorded after oven-drying at 80^{0}C for 24 hours. After shelling the cobs of harvested area (1.125 m^2), the moisture level of grains was determined by a grain moisture meter (Wile 55). The weight of grains was measured by an electrical top balance and yield was calculated in t ha^{-1} at 14% moisture content. Harvest index (HI) was calculated using the formula:

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Composite soil samples from three different depths (7, 14 and 21 cm) were collected from mulched and unmulched plots in the experimental field for the determination of soil nutrient status before and after QPM cultivation. The total soil nitrogen content was determined by micro-Kjeldhal method (Page *et al*. 1989). Available P and exchangeable K content of the soil samples were extracted by $NaHCO_3$ and $CaCl_2$; and then determined according to Olsen *et al*. (1954) and Black (1965), respectively.

The oven dry samples of QPM plants were analyzed for the determination of N, P, K by using standard methods of Page *et al*. (1989), Olsen and Sommers (1982), and Black (1965), respectively.

The collected data were compiled and subjected to statistical analysis by using the computer package MSTAT-C (Russell 1986). The mean differences were evaluated by the Duncan's New Multiple Range Test (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Variation in soil temperature

Rice straw and water hyacinth had significant regulatory effects on soil temperature (Fig. 1). The greatest influence was found in water hyacinth mulched plots and minimum in control plots.

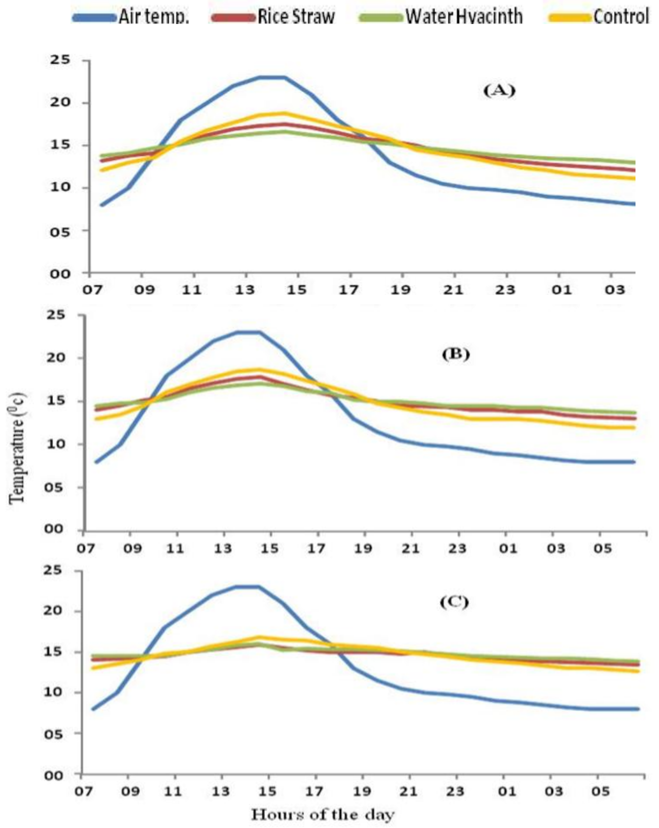

Fig. 1. Diurnal changes in air and soil temperatures at different depths [7 cm (A), 14 cm (B) and 21 cm (C)] under different mulches.

During day time all mulches had a retardative effect on soil temperature while reversal was the effect during night time resulting in 2-3°C higher temperature compared to unmulched plots. Mulches reduced the soil temperature during day because of the reflection of considerable amount of incident radiation. Moreover, their lower thermal conductivity prevented and decreased 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 the trapping of outgoing long wave radiation released by the soil (Rahman *et al*. 2002).

This night time higher soil temperature appeared to have most promising effect on leaf tip appearance, full leaf expansion, more biomass production and higher yield of maize.

Soil moisture

The water hyacinth and rice straw mulches effectively conserved the greater amount of soil water contents during the early stages of plant growth (30-70 DAS) and the least amount by the control (Fig. 2). However, all mulches significantly retained higher amount of water until about 90 DAS in all soil depths compared to the control. Two moderate showers at 90 and 110 DAS enhanced the water content of the soil in all depths, thereby reducing the effectiveness of different mulches in retaining the soil moisture in the subsequent stages of plant growth.

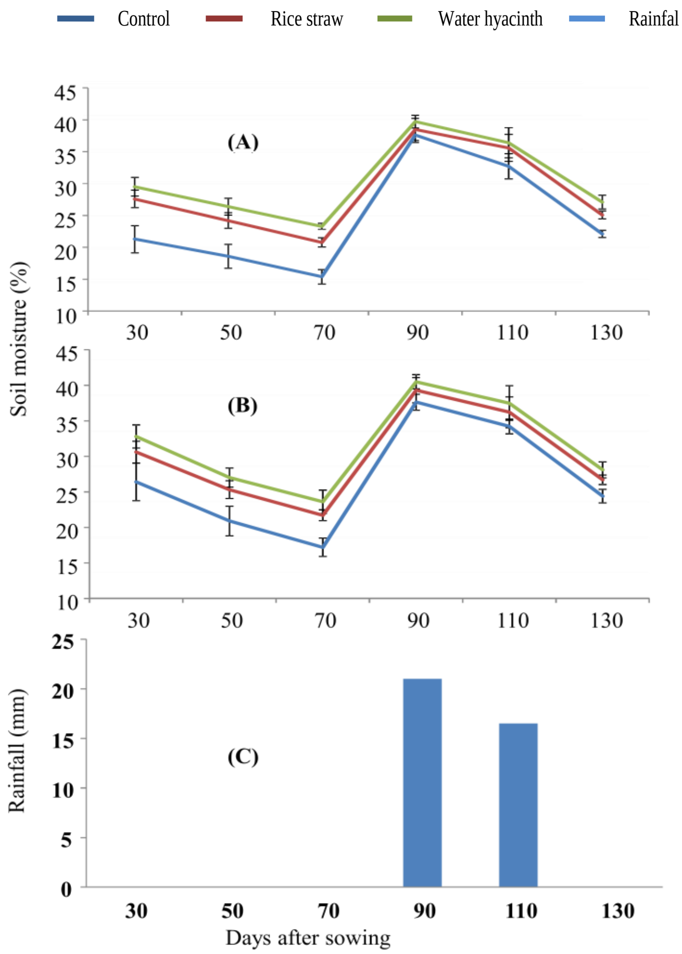

Fig. 2. Soil moisture contents under different mulches at different soil depths [0-7 cm (A) &8-14 cm (B)] with time. The amount of precipitation occurred during the growing season is also shown (C).Vertical bars represent standard deviation (SD) of means.

The water hyacinth and rice straw mulches retained maximum soil moisture probably due to reduced evapotranspiration (Shekour *et al*. 1987) and transmissivity (Mbagwu 1990) and increased hydraulic conductivity (Schoningh 1985), water infiltration (Sutrisno *et al*. 1995) and water holding capacity (Khan and Parvej 2010).

Soil nutrients

Substantial variation existed in total N content, available P and exchangeable K in initial and post harvest soil at different depths due to the effects of organic mulches (Table 1). The water hyacinth and rice straw mulched plots had slight enhancement of N content in postharvest soil and the control plot had a little negative balance in N content. These indicated that indigenous mulches had positive impact on N addition, N uptake and N balance in soil (Table 2). The trend of available P content of soil was always positive irrespective of mulched or unmulched plot, but mulched plot had a greater balance of P than that of control plot. This is due to the stability of P in the soil surface. In case of K, mulched plot had positive balance but control plot had negative balance. This is due to the huge uptake of K by maize plant as well as the leaching loss of K from sandy char soils. Total N, available P and exchangeable K contents in the upper soil (0-7 cm) were higher than that of subsequent soil depths (8-14 cm and 15-21 cm). This was in agreement with the findings of Jobbagy and Jackson (2001) that nutrients strongly cycled by plants, such as P and K, were more concentrated in the top soil (upper 20 cm). Anderson *et al*. (2010) showed that the surface application of P and K without tillage increases the concentration of these nutrients at the soil surface. If these nutrients are applied to the soil surface without tillage, they will remain in the top 2 to 5 cm.

Table 1. Effect of organic mulches and conservation tillage on soil N, P, K status.

Treatments	**Soil Depths (cm)**	**Total N content (%)**			**Available P (ppm)**			**Exchangeable K (meq/100 g soil)**		
		Initial status	Post harvest	Balance	Initial status	Post harvest	Balance	Initial status	Post harvest	Balance
Control	7	0.110	0.105	-0.005	10.96	11.07	0.11	0.105	0.103	-0.002
	14	0.104	0.102	-0.002	9.48	9.54	0.06	0.102	0.101	-0.001
	21	0.102	0.101	-0.001	8.11	8.15	0.04	0.099	0.099	0.000
Rice straw	7	0.110	0.115	0.005	10.96	11.26	0.30	0.105	0.109	0.004
	14	0.104	0.108	0.004	9.48	9.63	0.15	0.102	0.103	0.001
	21	0.102	0.105	0.003	8.11	8.22	0.11	0.099	0.100	0.001
Water hyacinth	7	0.110	0.118	0.008	10.96	11.34	0.38	0.105	0.111	0.006
	14	0.104	0.111	0.007	9.48	9.71	0.23	0.102	0.104	0.002
	21	0.102	0.106	0.004	8.11	8.28	0.17	0.099	0.100	0.001

Plant nutrient uptake

N, P and K uptake by stover and grain were significantly greater in mulched plots than unmulched (Table 2). These might be associated with higher amount of stover and grain yields of mulched plots compared to control. These findings are in agreement with Acharya and Sharma (1994) that mulched treatments show significantly greater total uptake of N, P and K than corresponding unmulched one. Moreover, N and P contents in maize grain were greater than stover, whereas K content was less in grain than stover. These might be due to the fact that N in the vegetative organs of a plant is largely a component of functional rather than structural compound and is readily translocated to younger metabolically active tissue, such as developing kernels as the plant matures (Gardner *et al*. 1985). K does not form part of plant or organic compounds and present as ion in the cell sap of plant tissue and crop residue (Mallarino*et al*. 2011). Thus, there is a small amount of K as measured in grain compared to stover.

Table 2. Uptake of plant nutrients by QPM under mulch cover at char Sirajabad.

Treatments	N (Kg/ha)			P (Kg/ha)			K (Kg/ha)		
	Stover	Grain	Total	Stover	Grain	Total	Stover	Grain	Total
Control	55.30c	64.80c	120.10c	6.64c	8.62c	15.26c	58.88c	13.43c	72.31c
Rice straw	74.45b	117.81b	192.25b	9.36b	17.57b	26.94b	82.06b	25.39b	107.44b
W. hyacinth	83.03a	135.07a	218.10a	11.03a	20.67a	31.69a	98.09a	29.62a	127.71a

Figures with same letter in a column are statistically similar at 5 % level of significant.

Root DM investment in relation to top growth

An important and unique structural aspect that regulates productivity and mineral cycling functions, is the investment of assimilation to the heterotrophic stratum beneath the soil. The effectiveness of organic mulches on root biomass production and its relations to the top growth have been evaluated in two parameters, viz. the RDM accumulation and R:S ratio (Fig. 3). The initial high RDM investment culminated at 90 DAS that commensurated with the transition of reproductive development in all the treatments.

The pattern of RDM accumulation was almost in phase with that of the top growth (Fig. 3). The maximum RDM accumulation was, however, found in the water hyacinth mulch, followed by the rice straw and the least in the control plants in all stages of growth. With the advancement of reproductive development the total RDM investment was either static or slightly retardative (Fig. 3A), while the R:S ratio continually declined with the approach of maturity (Fig. 3B). During the entire ontogeny of QPM plants organic mulches induced quantitatively higher amount of DM investments in the roots (Fig. 3A), the proportionate distribution was, however, inversely related to the unmulched plants (Fig. 3B).

The growth of the shoot is dependent on root for the uptake of water, mineral nutrients and mechanical support, while the roots derive most of the organic nourishments for their subsistence from the shoot. A co-ordination, therefore, must exist between the top and the root growth. The changing pattern of the root biomass with the R:S ratio is, thus, followed by a ‘source-sink’ relation. During the early growth period much of the photosynthate produced in the top was spent for the establishment of a sound root mass. With the transition of reproductive development (90 DAS) an appreciable amount of photosynthate produced in the leaves was consumed by rapidly developing cobs; thus the balance appeared to be in favour of the top growth with a concomitant reduction in the R:S ratios (Fig. 3B). However, the relative distribution still remaining high in mulched plants compared to the control indicating their potentiality to divert more photosynthate towards the upper ‘sink’ than the heterotrophic roots. It has been evidenced that any treatment that affects the top growth of cereals is likely to be reflected through the growth in the roots (Brouwer 1962, Davidson 1969). The increased rooting ability and suppression of R:S ratio (Fig. 3) in mulched plants are indicative to better adaptability of QPM under adverse edaphic conditions for the efficient utilization of soil resources.

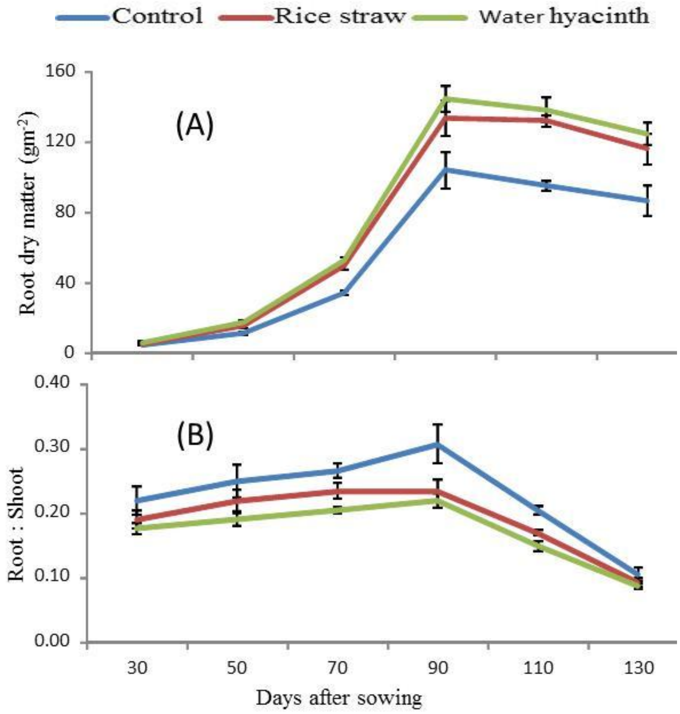

Fig. 3. Accumulation and distribution of RDM (A) and R:S ratio (B) in QPM grown at under organic mulches and conservation tillage. Vertical bars represent SD of means.

Harvest scenario

The interrelatinship among TDM, grain yield and HI in response to mulch covers and conservation tillage has been summerized in (Fig. 4). The organic mulches positively influenced the production of TDM, grain yield and HI compared to the unmulched. The water hyacinth and rice straw mulches generated fovourable soil temperature (Fig. 1) and soil moisture conditions (Fig. 2) which in turn increased the DM accumulation in plant (Fig. 4).

Grain yield and HI are generally improved from two underline principles: (i) an increase in TDM per unit area keeping distribution pattern between grain and straw constant and (ii) without change in TDM, but with more efficient distribution between the two. The improved HI of mulch treated plants was the consequence of favourable micro-climate (Fig. 1), improved mineral uptake (Table 2), better DM partioning and exploitation of underground esources (Fig. 3 and Fig. 4). Thus, mulching and conservation tillage could be useful tools for incrasing productivity of QPM in otherwise vulnerable *char* lands in Bangladesh where irrigation facilities can hardly be provided. Grain yield and HI are generally improved from two underline principles: (i) an increase in TDM per unit area keeping distribution pattern between grain and straw constant and (ii) without change in TDM, but with more efficient distribution between the two. The improved HI of mulch treated plants was the consequence of favourable micro-climate (Fig. 1), improved mineral uptake (Table 2), better DM partioning and exploitation of underground esources (Fig. 3 and Fig. 4). Thus, mulching and conservation tillage could be useful tools for incrasing productivity of QPM in otherwise vulnerable *char* lands in Bangladesh where irrigation facilities can hardly be provided.

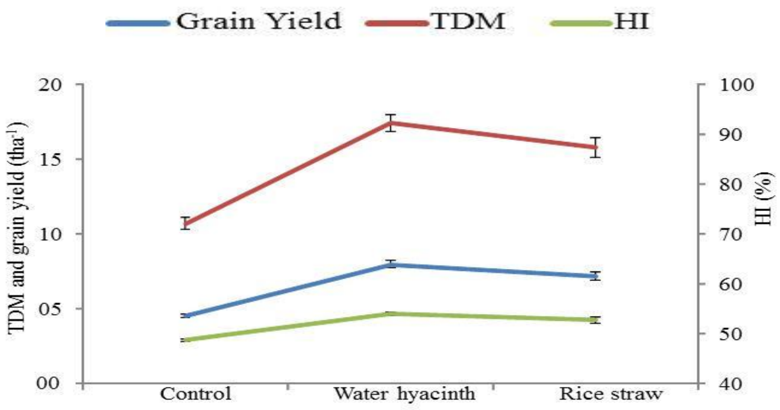

Fig. 4. Response of QPM plants grown under indigenous mulches and conservation tillage to the TDM, grain yield and HI. Vertical bars represent SD of means.

The water hyacinth and rice straw mulches effectively maintain favourable soil temperature and soil moisture in the riverine *char*, where irrigation facility is limited, thus ensuring the higher nutrient uptake, higher TDM production and higher yield of QPM plants. Moreover, these indigenous mulches retain soil nutrient for sustaining the soil fertility and productivity. This practice of QPM cultivation and dissemination may have supplementary effect in combating nutritional deficiency of the malnourished *char* people in Bangladesh.

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