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Alteration of Soil Temperature and Moisture Through Mulching on the Morpho-physiological Differentiation in Maize

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Abstract
Mulching effects of sawdust, ash, rice straw and water hyacinth on the morpho-physiological differentation of maize (*Zea mays* L.) and to relate these with soil environment were described. Water hyacinth and rice straw mulches had significant promotive effects on shoot elongation, root penetration, LAI and DM accumulation. All mulches conserved soil moisture but water hyacinth and rice straw retained comparatively greater amount. Water hyacinth and rice straw mulches reduced soil temperature fluctuations in all soil depths (5 to 15 cm) and retained higher soil temperatures at the early hours of the day (02 to 06 hrs) which were considered to be the decisive factor for the rapid development of maize plants. Sawdust mulch due to the lower soil temperature had retardive effects on all morpho-physiological attributes. Ash mulch ranked intermediate between the rice straw or water hyacinth and the control.

Introduction
Mulches of various kinds have been used to modify soil temperature and moisture regimes in the root zone. The nature and magnitudes of their effects on soil properties and crop growth depend upon the nature of the mulches, the climatic conditions and the crop involved (Bansal *et al*., 1971). Both soil and air temperatures influence the early growth of plants (Burrows, 1963) and the soil temperature appear to be important determinant in the growth processes of maize (Larson *et al*., 1960). The prevailing soil temperature at the early growing period in maize is perpetuated during subsequent growth stages that regulate the final yield (Millerd and McWilliam, 1968). A 1°C difference in soil temperature within the range of 12 to 35°C at the seedling stage may have 30-40 percent growth enhancement in maize (Walker, 1969). Lower soil temperatures have retardive effects on shoot elongation and dry matter accumulation (Burrows and Larson, 1962) and the roots penetrate more deeply in association with warmer soil (Rosenberg *et al*., 1983). But very few attempts describing the indigenous mulching effects especially on maize-a promising crop, have ever been carried out under the agroecological conditions of Bangladesh. Therefore, the present experiment describes the morpho-physiological development in maize using different indigenous mulches.

Materials and Methods
Experiment on maize (cv. Popcorn) with four indigenous mulches viz. sawdust, ash, rice straw and water hyacinth was carried out at the Crop Botany Field Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh (24° 7' N and 90° 5' E), during the 1996-97 winter season. The Experimental site belongs to the Brahmaputra Alluvial Soil having sandy loam in texture, a 1.3 percent organic matter in top soil and a pH of 6.0. All mulches were applied immediately after seed sowing at 10 t/ha in randomized complete block design (RCBD) with 4 replications. The seeds were sown 75 cm apart from line to line and 25 cm from plant to plant. Recommended doses of fertilizers were applied together with the intercultural operations as and when required.

For data on morpho-physiological attributes plants of 1 m^2 from each plot were uprooted at 10 days interval, starting from 30 DAS and continued till maturity (130 DAS). The corresponding growth attributes like shoot elongation, root penetration, LAI, DM accumulation etc. were also determined using standard practices. Diurnal fluctuations of soil temperature at 5, 10 and 15 cm depths were measured on 30 and 90 DAS at 2 hours interval. Soil moisture contents (weight percentage) at root zone within sampling area at 0-10 cm and 10-20 cm depths starting from 30 DAS upto maturity were also measured at 10 days interval.

Results and Discussion
Soil temperature: Water hyacinth and rice straw mulches retained comparatively higher soil temperatures at the early hours of the day i.e. late night to the early morning (02-06 hrs) at all soil depths (Table 1). But the situation was reversal during the noon. Ash mulch generated the maximum soil temperature in the upper few centimeters (5 cm) during the period of maximum sunshine and was follwed by the control, water hyacinth, rice straw and the sawdust mulches. This trend of temporal variation was apparent at the early stages of plant growth under incomplete canopy cover (30 DAS). But when canopy cover was complete the temperature variations among the soil depths under different treatments appeared to be levelled-off (Table 2).

Mulch-induced night soil temperatures were also reported by Manrique and Meyer (1984). The under mulched minimum soil temperature fluctuations during the day and night time and a relatively higher soil temperatures under water hyacinth and rice straw agree well with the findings of Izquierdo and Menendez (1980) who obtained higher and stable soil temperatures during winter under corn and barley straw mulches. Identical views were also expressed by Manrique and Meyer (1984) in Peruvian at aridic isothermic environment.

Maintenance of maximum soil temperatures by the ash and the minimum by the sawdust mulched soils during the period of maximum sunshine was as obvious because of their highly absorbing and reflecting properties respectively. Maintenance of relatively higher soil

Table 1: Diurnal soil temperature (°C) fluctuations of a mulched maize crop as measured on 30 DAS

Treatments	Depth (cm)	Solar hours											
		02	04	06	08	10	12	14	16	18	20	22	24
Control	5	16.0	15.0	14.6	15.7	19.9	22.6	24.8	23.6	21.0	18.8	17.9	17.5
	10	17.4	16.7	16.3	16.2	19.3	20.8	22.7	22.2	21.0	19.5	18.6	18.0
	15	18.1	17.7	17.4	17.1	18.0	19.5	21.5	21.1	20.7	19.6	19.0	18.5
Sawdust	5	16.9	16.5	16.2	15.7	17.1	18.8	19.4	20.0	19.1	18.5	17.8	17.3
	10	17.5	16.9	16.5	16.2	17.3	18.2	18.7	19.2	18.8	18.5	18.2	18.0
	15	18.1	17.8	17.6	17.3	17.2	17.9	18.6	18.9	18.7	18.5	18.4	18.3
Ash	5	17.5	17.1	16.8	16.1	20.2	22.8	25.0	25.4	22.1	18.7	18.8	17.8
	10	17.8	17.5	17.0	16.5	17.0	18.2	21.7	22.0	20.7	18.8	18.0	18.0
	15	18.2	18.0	17.8	17.4	17.2	17.7	19.2	20.8	20.2	18.8	18.4	18.4
Rice straw	5	17.7	17.3	17.1	16.5	17.8	19.4	19.9	20.4	19.5	18.7	18.0	18.0
	10	17.9	17.7	17.5	17.0	17.5	18.5	19.0	19.5	19.1	18.7	18.2	18.2
	15	18.4	18.2	18.0	17.6	17.6	18.1	18.8	19.2	19.0	18.8	18.5	18.5
Water	5	17.9	17.6	17.4	17.0	18.2	19.7	20.1	20.7	19.6	19.0	18.2	18.2
hyacinth	10	18.1	17.9	17.7	17.3	17.8	19.0	19.4	19.7	19.3	18.8	18.3	18.3
	15	18.6	18.3	18.2	18.0	17.7	18.2	18.9	19.4	19.3	19.2	18.7	18.7

Table 2: Diurnal soil temperature (°C) fluctuations of a mulched maize crop as measured on 90 DAS

Treatments	Depth (cm)	Solar hours											
		02	04	06	08	10	12	14	16	18	20	22	24
Control	5	16.2	15.1	14.6	18.5	20.3	23.2	24.5	25.7	21.2	20.4	19.3	17.4
	10	16.0	15.8	15.5	17.0	19.0	21.6	22.4	23.8	20.5	19.4	18.5	17.4
	15	17.5	16.7	16.3	17.1	18.0	20.2	21.5	22.4	20.7	19.5	18.7	18.2
Sawdust	5	15.9	15.2	14.7	16.9	19.2	21.5	22.3	23.2	20.3	18.7	18.2	16.8
	10	17.0	16.2	15.5	16.2	18.5	20.8	21.4	22.1	18.7	18.1	17.7	17.3
	15	17.6	16.7	16.3	16.8	17.7	19.3	19.7	20.4	19.3	18.9	18.3	17.9
Ash	5	16.2	15.2	14.8	19.1	21.2	23.8	25.3	25.8	21.7	20.6	19.5	17.7
	10	16.9	16.3	15.5	17.3	19.7	22.5	23.7	24.0	20.8	19.7	18.8	17.5
	15	17.7	16.6	16.5	16.9	18.4	20.7	21.6	21.9	20.5	19.4	18.5	18.3
Rice straw	5	16.1	15.4	15.0	17.3	19.6	22.0	22.5	23.6	20.8	19.0	18.5	17.0
	10	17.3	16.4	15.8	16.5	18.8	21.1	21.7	22.5	19.0	18.5	18.1	17.6
	15	17.8	17.0	16.6	17.3	17.9	19.6	20.1	20.7	19.6	19.2	18.5	18.0
Water	5	16.3	15.5	15.0	17.3	19.6	22.2	22.6	23.6	20.9	19.2	18.4	17.3
hyacinth	10	17.3	16.5	15.7	16.5	19.0	21.2	21.9	22.6	19.9	18.5	18.2	17.5
	15	17.7	17.0	16.6	17.3	18.0	19.8	20.1	20.8	19.5	19.2	18.6	18.1

Table 3: Soil moisture contents (weight per cent) in maize as influenced by the different mulches

Treatments	Depth (cm)	Days after sowing (DAS)										
		30	40	50	60	70	80	90	100	110	120	130
Control	0-10	23.2c	22.3b	21.4b	20.4b	19.8c	18.0c	34.7b*	31.1	29.3	28.6	33.3
	10-20	29.6	29.2	28.7c*	28.1c*	27.5b	26.8c*	32.8	30.9	30.3	30.0	32.0
Sawdust	0-10	27.6a	27.2a	26.2a*	26.1a	24.4ab	23.2b	36.6ab*	31.7	31.1	30.7	34.6
	10-20	31.5	31.1	30.6ab*	29.9abc*	29.6ab*	28.7abc*	32.8	31.8	31.1	30.9	32.3
Ash	0-10	25.6ab	25.2ab	24.7ab	23.9a	23.1b	22.0b	36.0ab*	31.1	30.5	30.2	34.3
	10-20	30.6	30.3	29.7bc*	29.0bc*	28.6ab	27.9bc*	32.4	31.3	30.8	30.5	32.1
Rice straw	0-10	28.8a	28.5a	28.1a	27.4a	26.7a	25.5a	37.9a*	33.7	32.3	31.6	35.8
	10-20	32.4	32.2	32.0a*	31.5a*	31.1a	30.6a*	33.4	32.8	32.0	31.7	32.9
Water	0-10	27.1ab	26.7a	26.0a	25.4a	24.9ab	24.0ab	37.1a*	32.5	31.6	31.1	35.0
hyacinth	10-20	31.2	31.1	30.7ab*	30.3ab*	30.0ab	29.3ab*	33	32.2	31.4	31.1	32.6

In a column figures followed by no common letter (s) are significantly different at 1% (non steric) and 5% (steric*) level

temperature in the late night to early morning hours under the water hyacinth and rice straw mulches was greatly masked by their ability to create insulation over the soil surface, thereby restricting the temperature inversion from the soil. Reduction of mulch effects on the temperature fluxes during later stages of plant growth was mainly ascribable to the complete cover of the crop canopy that offered mutual shading to the soil surface.

Soil moisture: The water hyacinth and rice straw mulches effectively retained greater amount of water in the top soil and the least in the control followed by sawdust and ash mulches during the rainless period of plant growth (30 to 90 DAS) (Table 3). But a moderate shower after 90 DAS minimized the differences in the level of water contents among the mulch and unmulched plots.

Mulching materials reduced the quantity of energy consumed in evaporation by blocking the transport of water vapour out of the soil (Rosenberg *et al.*, 1983), thereby conserving the soil moisture contents. Retention of higher amount of moisture under mulches is a common feature (Larson *et al.*, 1960; Bansal *et al.*, 1971; Abrecht and Bristow, 1990) and the present finding is of no exception (Table 3).

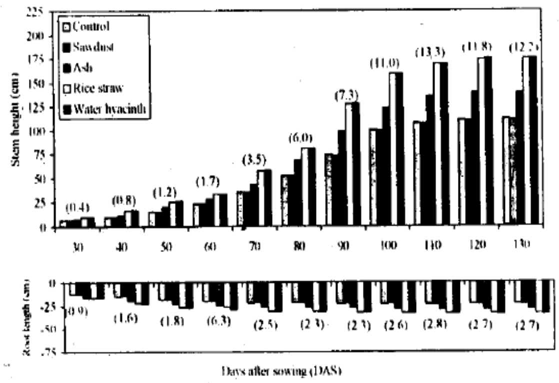

Fig. 1: Effect of different mulches on the shoot elongation and root penetration in maize with time. The values in the parentheses indicate $LSD_{0.01}$

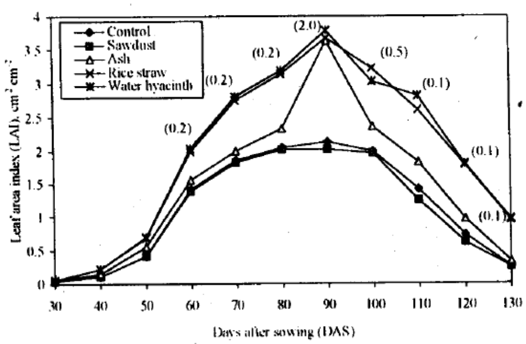

Fig. 2: Effect of different mulches on the leaf area index (LAI) in maize with time. The values in the parentheses indicate $LSD_{0.01}$

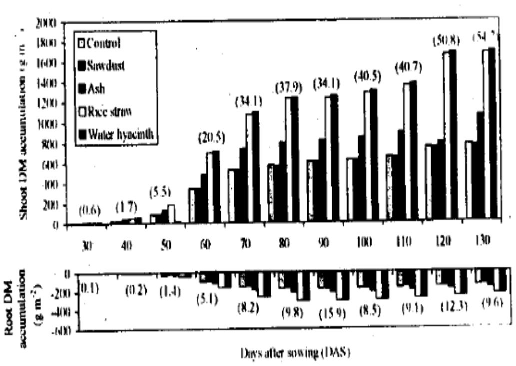

Fig. 3: Root and shoot dry matter (DM) accumulation in maize as influenced by different mulches. The values in the parentheses indicate $LSD_{0.01}$

Shoot elongation: The rate of shoot elongation was slow at the early stage of plant growth (Fig. 1). But beginning from 60 to about 100 DAS the shoot elongation had a linear phase. Thereafter, it remained almost static in all the treatments. However, the extent of shoot elongation was significantly higher under water hyacinth and rice straw mulches compared to the ash, sawdust and control. The initial slow rate of shoot elongation followed by a rapid growth and a subsequent retardation is a common pattern in many cereals (Khan, 1979) and was the consequence of phasic development (Khan and Madsen, 1995). Mulch induced higher shoot elongation in maize in association with higher night soil temperature was reported by Abrecht and Bristow (1990). Sawdust mulch had retardive effect in this trait which was related to cold edaphic environment (Burrows and Larson, 1962) (Table 1).

Root penetration: During most part of vegetative development (30 to 60 DAS) the root penetration, as assessed in terms of root length, was higher than that of the shoot elongation (Fig. 1). But at the subsequent stages of growth the shoot overtook the root penetration. However, the corresponding pattern of the root penetration appeared to be identical with that of the shoot growth during the entire course of development. Mulch induced deep root penetration was also reported by Choudhury and Prihar (1974) in relation to warmer soil (Rosenberg *et al.*, 1983).

Leaf are index (LAI): The initial low LAIs very rapidly increased until the attainment of their maxima at 90 DAS (Fig. 2). After attaining the maxima the LAIs very sharply declined with the subsequent growth stages. The mulched plants other than sawdust had significantly higher LAIs over the control. However, there was a dramatic increase in LAIs of the mulched plants during the period of tasseling to silking stages (80 to 100 DAS) when they attained their maxima.

A sharp increase in LAIs with time was the consequence of increased number of leaves and vigorous growth which corresponded well with the morpho-physiological events (Khan, 1981). From their maxima, the decrease in LAIs was due to increased senescence (Katiyar, 1980). Significantly increased LAI in potato due to water hyacinth and straw mulching at different stages of growth was observed by Gunadi (1988) and Roy *et al.* (1990). The result presented here is commensurate well with the obsrvations made by other inline workers.

Root and shoot dry matter (DM) accumulation: The initial slow rate of root and shoot DM accumulation at the vegetative stage had a dramatic enhancement with the transition of reproductive growth (50 to 60 DAS) in all the treatments (Fig. 3). Thereafter, the shoot DM`increment had a plateau until about 110 DAS (corresponding to the beginning of silking stage) and increased again during the grain filling stage (120 to 130 DAS). However, the root DM accumulation after attaining the maximum at 90 DAS had a slow but continual retardive trend for the rest of the growing period. All mulches except sawdust had the promotive effects both on root and shoot DM accumulation. Water hyacinth and rice straw mulches accumulated almost double the amount of both root and shoot DM compared to the control and the sawdust at all stages of growth and the ash mulch behaved intermediately. Mulch-influenced DM accumulation was also reported by Jadhav *et al*. (1993). But the sawdust mulch had the cooling effects on the soil (Table 1) and a depression on DM accumulation (Fig. 3). The result is in conformity with the finding of Burrows and Larson (1962) who obtained lower DM production in maize under chopped corn stalk mulch for creating the lower soil temperature.

From the initial slow rate at the early stages of growth a greater amount of DM accumulation, both in the root and shoot until about 90 DAS, was the expression of the plants ability to attract more mineral nutrients from the soil to meet the increasing damand of the plants. Subsequent reduction in DM accumulation in the root after, attaining the maximum was the consequence of shifting from tasseling to silking stage when greater proportion of DM was diverted to the growing cobs.

As the night temperature of the soil had the regulatory effect on the subsequent growth of maize plants (Duncan *et al*., 1973), the increased night soil temperature under water hyacinth and straw mulches (Table 1) together with greater availability of moisture (Table 3) had the promotive effects on the DM accumulation (Fig. 3). Thus the mulch induced DM accumulation was the reflection of the plants ability to exploit both aerial and underground environments resulting in greater DM. The inability of sawdust mulched plants to attract more biomass production is stemmed from the fact that the soil (root) environment under such mulch condition remained mostly at par the control during the night time. The present findings clearly demonstrate that the water hyacinth and rice straw can conveniently be used as mulching meterials for improvement of corn yield under the agroclimatic conditions of Bangladesh.

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