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YIELD POTENTIALITY OF MAIZE AS RELAY CROP WITH T. AMAN RICE UNDER DIFFERENT AGRONOMIC MANAGEMENT

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ABSTRACT. The experiment was conducted at the Regional Agricultural Research Station, BARI, Ishwardi, Pabna, Bangladesh, during 2013-2014 and 2014-2015 to introduce maize as relay crop with T. Aman rice under different agronomic practices for determine the production potentials. The experiment was design split plot with three replications. The agronomic management practices included four plant spacing viz. S_1=75 cm×20 cm (66666 plants/ha), S_2=60 cm×20 cm (83333 plants/ha), S_3=50 cm×20 cm (100000 plants/ha) and S_4=40 cm×20 cm (125000 plants/ha) and four soil management practices viz. M_1=soil mulching at 25 DAE, M_2=earthing up at 25 DAE, M_3=straw mulching at 25 DAE and M_4= without earthing up and mulching (control). Seeds were relayed by dibbling manually in 10 days before the harvest of T. Aman rice. Results showed that an increasing plant spacing increased leaf area Index (LAI), total dry matter (TDM), crop growth rate (CGR) and light energy interception (LEI). Grain yield was higher in S_3 spacing (8.44 t/ha) than others (S_4 8.11 t/ha, S_2 7.34 t/ha and S_1 6.89 t/ha). Among the soil management practices, M_2 increased LAI, TDM, CGR, LEI as well as grain yield. Moreover, M_2 and M_1 gave similar grain yield (8.22 t/ha and 8.02 t/ha), that were significantly greater than other two soil management practices (M_3 7.55 t/ha and M_4 6.98 t/ha). From the economic point of view, combination of S_3M_1 gave better performance with gross margin of Tk. 95000/ha and BCR of 2.17. On the basis of results, S_3M_1 combination was suitable for growing maize under relay sowing with T. Aman rice.

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Keywords: relay maize; plant spacing; soil management; light energy interception; growth.

INTRODUCTION

Most of the winter maize in Bangladesh has planted after harvested of T. Aman rice. Thus the planting of maize depends on the harvest time of T. Aman rice, the speed of drying of the soil just after rice harvest, and farmer priorities on planting other rabi season crops. In Bangladesh, the major maize based cropping pattern are maize-fallow-T. Aman rice, potato-maize-T. Aman rice, maize-relay jute/jute-T. Aman rice, maize-pre monsoon Aus rice-T. Aman rice, maize-vegetables-vegetables cropping patterns. However, main maize-based cropping patterns were found maize-fallow-T. Aman and major maize growing area was covered in Northern and western parts of Bangladesh (Yusuf Ali *et. al.,* 2009). These cropping systems disseminate day by day other maize growing area of Bangladesh. Moreover, farmers cultivate T. Aman rice varieties, particularly of Aromatic rice that have a long development cycle (145-150 days, seed to seed) and are harvested mid November to early December. This means that most maize farmers plant maize in the second or third week of December and/or after other Rabi crops.

Thus, sowing of maize is delayed due to late harvest of rice. Hence, maize yield in the rice tract are much lower compared to other irrigated areas. On the contrary, Temperature in mid December is often low (average max 23ºC and min 11ºC). Late planted maize takes around two weeks to germination due to cold winter weather and grows slowly. Late planting (from 20 December onwards) may cause yield losses of 12% - 22% (Ali, 2006). The later harvesting of the late-planted crops makes it vulnerable to early monsoon rain, when post harvest processing becomes difficult. This raises the moisture content of maize and the incidence of cob rot diseases resulting in poor quality grain and a low market price. Late planted maize has also an increased danger of lodging and water logging later in crop development because of pre-monsoon storms during March and April. Early planting within the optimum time period is important to achieve high yield with Rabi season hybrid maize. Also the turnaround period between the harvest of T. Aman rice and planting of maize is very narrow in Bangladesh. Thus, there is a need to develop a method, which would facilitate timely sowing of maize in rice fields, where the following cropping system is followed. Relay cropping technology (zero tillage) is one of the method where sowing a crop few days before harvesting of another crop. This cropping is generally adopted in areas where T. Aman harvesting delayed and/or land remains moist, which takes few to more days to become optimum condition for land preparation. Under this situation, farmers can grow the crop in optimum time by adopting relay cropping. Moreover, this practice makes the best use of the residual moisture of rice field. Relay cropping is beneficial in terms of utilize residual moisture from previous crop and reduced planting cost (Saleem *et al.,* 2000; Malik *et al.,* 2002; Jabbar *et al.,* 2005). It was mentioned that, if maize can be established as relay crop, easily obtained near about 75-80 days in between maize and T. Aman rice with maize-fallow-T. Aman cropping system. Thus, there is a great scope to utilize this period to produce some summer vegetables, like indian spinach, red amaranth, stem amaranth, leaf amaranth, jute (as vegetable), Ghima kalmi "Kangkong" (*Ipomoea aquatica*) and mungbean. It may be introduce maize-summer vegetables/ mungbean-T. Aman cropping pattern instead of the cropping system maize-fallow-T. Aman.

Agronomic management practices like planting density, tillage option may be changed due to differential agro-ecological condition. At present diverse planting patterns, such as narrow to wide plant spacing have been practiced in maize (*Zea mays* L.) to search of high grain yields under different growing conditions. Too close spacing interferes with normal plants development and increase competition resulting in yield reduction, while too wide spacing may result in excessive vegetative growth of plant (Maqbool *et al.,* 2006). United States has shown yield increases of up to 9.9% by growing maize in rows narrower than 76 cm (Paszkiewicz, 1998; Roth, 1997). Widdcombe and Thelen (2002) reported that plant density had a significant effect on grain yield and the highest plant density level evaluated (90000 plants/ha) resulting in the highest grain yield may have been too low to establish the true plant density for maximum yield. Porter *et al.* (1997) reported inconsistent optimal plant density levels ranging from 86000 to 101270 plants/ha for corn grain yield across three Minnesota locations. The need, therefore, arises to investigate the optimum plant density for maize production under relay sowing.

Soil management or tillage is a very important crop production activity, which may affect crop performance differently. As maize is a deep rooted crop, so zero/minimum soil tilth is enough to produce better yield. However, selection of an appropriate management practice after relaying for the production of maize is very important for optimum growth and yield. Considering the above points, this study was undertaken to introduce maize as relay crop with T. Aman rice, followed by different agronomic practices for determine the production potentials. Therefore, relaying maize with T. Aman rice by appropriate management practices may be diversified and highly profitable crop patterns should be promoted widely.

MATERIALS AND METHODS

The experiment was conducted at the Regional Agricultural Research Station, BARI, Ishwardi, Pabna, Bangladesh, during 2013-2014 and 2014-2015 to introduce maize as relay crop with T. Aman rice, followed different agronomic practices for determine the production potentials. The climate of the experimental site was subtropical in nature and it's belonging to Ishwardi series under the Agro-ecological Zone-11 (AEZ-11) in Bangladesh. The latitude and longitude of the experimental site was 24.03^0 S and 89.05^0 E, respectively. The soil was clay loam having 7.26 p^H, 1.07% organic matter, 0.055% total nitrogen, 11µg/ml available phosphorus, 0.12 meq/100g soil available potassium, 13 µg/ml sulphur, 0.20 µg/ml boron and 2.0 µg/ml zinc. During the relay sowing the initial soil moisture was 39.60% and 40.25% in both the years, respectively. Field capacity and bulk density of the soil were 29% and 1.40 g/cc, respectively; permanent wilting point was near about 14%. The experiment was laid out in a split plot design with three replications. The treatments comparison with two agronomic practices viz. four plant spacing {S_1= 75 cm×20 cm (66666 plants/ha), S_2= 60 cm×20cm (83333 plants/ha), S_3= 50 cm×20 cm (100000 plants/ha) and S_4= 40 cm×20 cm (125000 plants/ha) }were assign in the main plot and four soil management practices viz. M_1 = Soil mulching at 25 DAE, M_2= earthing up at 25 DAE, M_3= Straw mulching at 25 DAE and M_4 = Without earthing up and mulching (Control) were allotted in the sub plot. The unit plot size was 5 m×3 m. Selected maize and T. Aman rice variety were BARI Hybrid Maize-7 and BINA Dhan-7, respectively. The crop was relayed on 7 and 4 November 2013 and 2014 (10 days before the T. Aman rice harvest), respectively, and harvest on 15-20 April 2014 and 2015, respectively. Fertilizer was applied @ 254-52-110-47-5-1kg/ha of N-P-K-S-Zn-B. One third nitrogen and full amount of other fertilizer were applied as basal before relay in the standing rice field. Rest nitrogen will be top dressed in two equal split at 60 and 90 days after relay (DAR). Four irrigations were applied at 30, 60, 90 and 120 DAR, respectively. Two hand weeding were done at 55-60 and 85-90 days after emergence, respectively both the year. Soil mulching was done by spading (one time). As straw mulching, 9 t/ha straw was used for cover the soil surface (around 4-5 cm thickness). Data on yield and yield contributing characters were taken and analyzed statistically. The mean values were adjusted by LSD at 0.05 levels of probability. In order to determine the LAI, the length and width of the leaves on a plant were measured with a ruler. The LAI was calculated using following equation:

Leaf area index $(\mathrm{LAI}) = \mathrm{k}(\mathrm{L} \times \mathrm{W})$, where, k = 0.75, which is constant for all cereals, L = Leaf length and W = Leaf width.

Crop growth rate (CGR) was calculated by the formula given by Beadle (1987):

$$\mathrm{CGR} = \frac{W_2 - W_1}{T_2 - T_1},$$

where, W_2 = dry weight m^{-2} land area at second harvest, W_1 = dry weight m^{-2} land area at first harvest, t_2 = time corresponding to second harvest and t_1 = time corresponding to first harvest.

Light energy intercepted (LEI) by the crop was calculated according to Charles-Edwards (1982) was as follows:

$$\mathrm{LEI} = \frac{\sum_{n}^{1} \mathrm{DM}}{\mathrm{LUE}},$$

where, DM = daily dry matter production (g/m^2), LUE = Light use efficiency (g/MJ), which is constant (3.4 g dry matter/ MJ) for maize and LI = Light energy intercepted by the crop (MJ/m^2).

RESULTS AND DISCUSSION

Effect of plant spacing

LAI increased with increasing the plant spacing (*Fig. 1a*), which caused variation in plant population that greatly influenced LAI. The increasing LAI is a prime factor that increasing imprison of solar radiation within the canopy and production of dry matter. Hence, dry matter produced decreases with decreasing of LAI. Plant population was higher in closer spacing than those of wider spacing. LAI reached to a maximum level at 100 DAR and showed a declining trend at 120 DAR in all the plant spacing which due to increasing aging of leaves and shading. However, the higher LAI was computed in S_4 {40 cm×20 cm spacing (125000 plant/ha)}, which ranged 2.99 to 3.47 at all the growth stages and the lowest one was obtained in S_1 (75 cm×20 cm) spacing (1.86 to 2.18), where remain 66666 plants/ha. Flent *et al.* (1996) stated that increase in LAI because of the increase in plant density. However, a number of results have indicated that a LAI between 3 and 4 may be optimal for achieving maximum yield (Lindquist *et al.*, 1998).

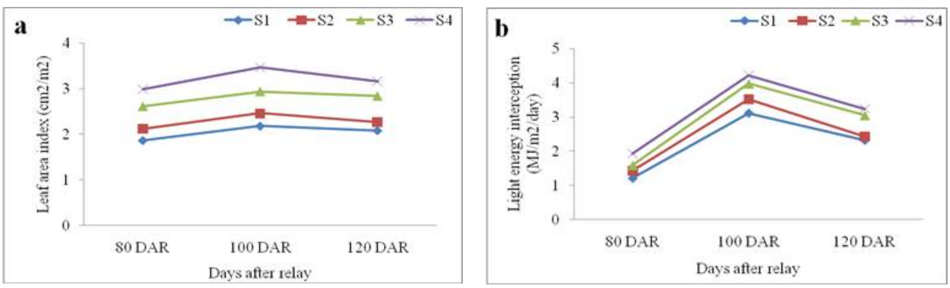

Figure 1 (a-b) - Variation in Leaf area index and Light energy interception as influenced by plant spacing at different growth stages

The LEI was increased with increasing plant spacing in different growth stages, respectively (*Fig. 1b*). The efficiency of LEI depends on the leaf area of the plant population, as well as leaf shape and inclination into the canopy (Ahmed *et al.*, 2010). However, it was increased with the decrease of plant spacing over the growing period. At 80 DAR, LEI was lower due to less canopy coverage, compared to other growth stages. LAI increased with the progress of canopy coverage, which leads to more LEI for photosynthesis. Closer spacing enhanced canopy coverage, which responsible for more LEI. In the present study, the maximum LEI (1.92- 4.22 MJ/m^2/day) was obtained with spacing S_4, followed by that with S_3 {50 cm×20 cm (100000 plants/ha)}, which ranged from 1.59-3.98 MJ/m^2/day, while the lowest was with S_1 (1.21-3.11 MJ/m^2/day). The results indicate that LEI has been significantly increased through the increase in plant spacing up to 40 cm×20 cm. Higher light interceptions with higher maize population were also reported by several workers (Andrade *et al.*, 2002; Maddonni and Otegui, 2004). Andrade *et al.* (2000) showed that radiation absorption will be increased by reducing the row space.

CGR was increased with increased plant spacing. It was gradually increased up to 100 DAR and thereafter it exhibited a declining trend at 120 DAR (*Fig. 2a*). Increasing the CGR with increasing of plant spacing may be due to accelerating the photosynthesis activity and the positive response of CGR to plant. The decrease in CGR after 100 DAR is due to cessation of vegetative growth, loss of leaves, senescence of leaves and decrease of LAI. However, higher CGR (6.53-63.48 g/m^2/day) occurred in S_4, followed by S_3 that ranged 5.40-54.86 g/m^2/day, while the lowest (4.12 2-44.66 g/m^2/day) was in S_1 at different growth stages, respectively. This might have been caused by higher plant population in S_4 spacing. Higher plant population showed higher CGR due to more dry matter accumulation per unit area (m^2).

Dry matter production by the plants depends on the amount of LEI by the leaves and its efficiency of conversion into chemical energy. Better dry matter production and its proper partitioning into reproductive organ are the prime requisite of higher productivity of a crop (Ahmed *et al.*, 2010). TDM increased with the advancement of plant maturity (*Fig. 2b*). After 100 DAR, accumulation of dry matter decreased due to decreasing CGR. The TDM in unit of area increased with increasing plant spacing indicates the favorable response of biomass produced by maize to plant population. It is possibly related to accelerating the photosynthesis activity that caused dry matter accumulation increase. As the TDM at S_4 spacing was higher (679.06 g -1968.75 g/m^2) at different growth stages (*Fig. 2b*), followed by that with S_3 spacing (561.07 g - 1837.51 g/m^2), while the lower (428.63 g - 1439.58 g/m^2) in S_1 spacing. It might be due to higher plant population increased the LAI, which had leaded more LEI that was transformed into higher TDM.

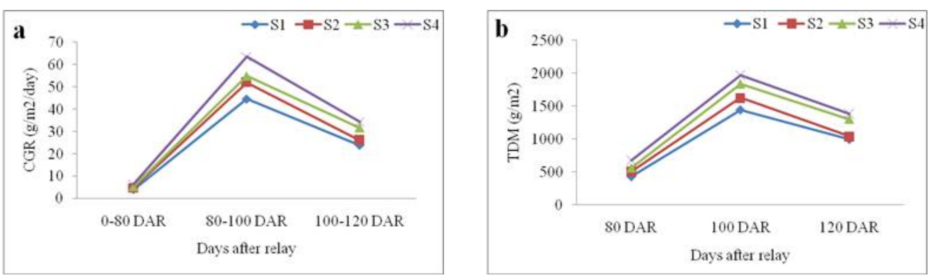

Figure 2 (a-b) - Variation in CGR and TDM as influenced by of plant spacing at different growth stages

Effects of plant spacing on the yield contributing characters were shown in *Table 1*. Plant spacing significantly affected plant height, ear height, cob length, cob breath, grains/cob, 1000-grain weight and grain yield. The plant height significantly influenced by the plant spacing. It ranged 154.49 cm to 167.63 cm in different spacing, while the tallest plants (167.63 cm) were measured at spacing S_3. Konuskan (2000) found that plant height increased with increased in plant density up to 10 plant/m^2 (100000 plants/ha). Ear height and cob length decreased from 71.96 to 61.33 and 16.96 to 14.77 cm, respectively, when plant spacing was maintained from 75 cm×20 cm to 40 cm×20 cm (66666 to 125000 plants/ha). Gokmen (2001) and Turgut (2000) reported that shorter ears were obtained at higher plant densities, as a consequence of interplant competitions. Cob breath increased with the increased of plant spacing and the thickest cob were obtained from S_1 with 5.11 cm, where the thinnest cobs were obtained from S_4 with 4.82 cm. These results are in agreement with the finding of Konusken (2000) and Turgut (2000). A significant difference was observed in number of grain/cob due to variation in spacing (*Table 1*). However, number of grains/cob decreased from 438.92 to 316.67 with increased plant spacing 75 cm×20 cm to 40 cm×20 cm (66666 to 125000 plants/ha). Significantly, the most number of grain/cob (438.92) was obtained in S_1, while the lowest was with S_4 (316.67). These results are consistent with the results of Tetio-Kagho and Gardner (1988). Among the spacing, there is not statistically a significant difference between 75 cm×20 cm to 60 cm×20 cm. The plant spacing significantly affected the 1000-grain weight of maize. Among the different plant spacing 1000-grain weight ranged from 315.34 g - 295.11g, while the wider plant spacing (S_1) produced heavier grain, compared to the narrower ones (S_4), which it show an increase of 6.42%. Stone *et al.* (2000) recorded a reduced 1000-grain weight in maize with higher plant population.

Grain yield was influenced due to changing plant spacing (*Table 1*). The highest grain yield (8.44 t/ha) was obtained in S_3 spacing, which show an increase grain yield of 22%, 15% and 4% rather than S_1, S_2 and S_4 spacing, respectively. Results of this study are in conformity with findings by Barbieri *et al.* (2000), who reported a 10% yield response to narrow rows. The lowest grain yield (6.89 t/ha) was occurred in plant spacing S_1. It happened due to lowest plant population. It was mention that although the highest plant population were in S_4 spacing but produced lower yield (8.11 t/ha) than S_3 spacing (8.44 t/ha) as a result of minimum grain/cob and 1000-seed weight. The result also raveled that grain yield significantly increased along with decreasing in plant spacing between rows up to 50 cm and thereafter decreased. Tollenaar and Wu (1999) and Mashingaidze (2004) reported that maize yield was known to increase with increased plant population until the increase in yield attributable to the addition of plants is less than the decline in mean yield per plant due to increased inter-plant competition. It was also revealed that very close spacing interferes with normal plants development and increase competition resulting in yield reduction, while too wide spacing may result in excessive vegetative growth of plant ultimately reduced per unit grain yield. Farnham (2001) determined that corn grain yield increased from 10.1 to 10.8 t/ha, as plant density increased from 59000 to 89000 plants/ha. Malik *et al.* (1993) mention that the most appropriate spacing is one, which enables the plants to make the best use of the conditions at their disposal. Bavec and Bavec (2002) reported under optimal water and nutrient supply, increased plant population results in smaller cobs, but the increased number of cobs per unit area usually results in higher grain yields.

Table 1 - Effect of spacing on yield contributing characters and yield of maize

Treatments	Plant height (cm)	Ear Height (cm)	Cob Length (cm)	Cob Breath (cm)	Grain/ Cob (no.)	1000-seed weight (g)	Grain Yield (t/ha)
S_1	159.25	71.96	16.96	5.11	438.92	315.34	6.89
S_2	163.33	69.98	16.50	5.03	433.29	310.64	7.34
S_3	167.63	66.89	15.51	4.94	403.41	306.04	8.44
S_4	154.49	61.33	14.77	4.82	316.67	295.11	8.11
LSD (0.05)	2.98	2.68	0.35	0.06	8.23	4.27	0.22
CV (%)	2.94	6.31	3.45	1.80	3.29	2.21	4.48

Plant spacing: S_1=75 cm × 20 cm (66666 plants/ha); S_2=60 cm × 20 cm (83333 plants/ha); S_3=50 cm × 20 cm (100000 plants/ha); S_4=40 cm × 20 cm (125000 plants/ha)

Effect of soil management practices

There was significant effect of soil management practices on LAI of maize. Leaf area is important factor for crop light interception and, therefore, has a large influence on crop yield (Dwyer and Stewart, 1986). LAI increased gradually with the advancement of the growth period and reached the maximum at 100 DAR and thereafter declined at 120 DAR (*Fig. 3a*). LAI decreased at 120 DAR reflecting the loss of some existing leaves through senescence. However, the treatment M_2 only produced the highest LAI (2.89 - 3.36), in comparison with the other treatments. The treatment M_1, followed by the M_2, gave the next highest LAI (2.51 - 2.81). The M_4 plots produced the smallest LAI.

LEI are a function of the LAI. As increasing, LAI resulted increasing LEI. As regards the data, LEI remained higher (1.87 - 4.33 $MJ/m^2/day$) in M_2, while the lowest (1.04 - 2.90 $MJ/m^2/day$) in M_4 (*Fig. 3b*). It can be attributed to a higher availability of nitrogen to plants in the plot of M_2 and M_1 due to incorporate of rice stalk as well as other debris's, which remain in soil surface after harvest of T. Aman rice that leading faster mineralization of the organic matter in the soil than in M_4. On the contrary, in M_4, there was a slow mineralization and availability of nitrogen to plants in order to poorly incorporated of rice stalk as well as other debris's. Hence, in M_1 and M_2 were enhanced to increase the LAI resulted increase LEI. Dreccer *et al.* (2000) observed a direct relation between the LAI and the N content in leaves, allowing to a highest interception of radiation, combined to high N content in leaves. Moreover, in M_4, the plant have more compact leaf architecture, with prevailing erect leaves, permitting a higher PAR transmission to soil surface, compared to those cultivated on M_2 and M_1, respectively. However, maize plants growing on M_2, as well as M_1 tend to have open leaf architecture, prevailing an horizontal shape on leaves, so taking a higher space into the canopy and getting higher amount of LEI than in M_4 and M_3.

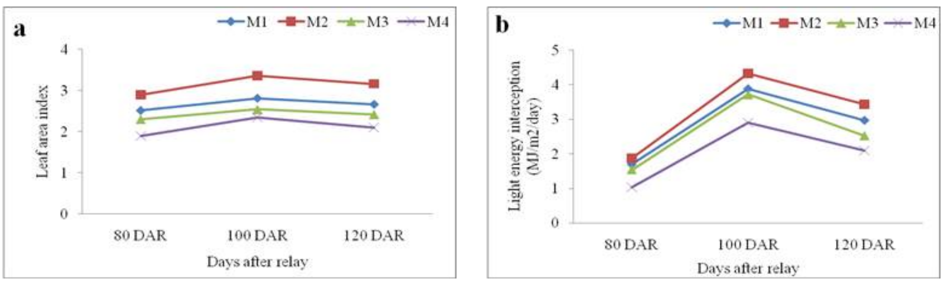

Figure 3 (a-b) - Variation in Leaf area index and Light energy interception as influenced by soil management practices at different growth stages

Different soil management practices affected the CGR of maize (*Fig. 4a*). The CGR was measured within the periods of 0 - 80, 80 - 100 and 100 - 120 DAR. The CGR progressively increased up to 100 DAR and afterwards it decline (*Fig. 4a*). However, the higher CGR (6.36-67.13 g/m^2/day) obtained from M_2, followed by M_1 (5.77 - 60.28 g/m^2/day), while the lowest (3.52 - 39.12 g/m^2/day) was in M_4. It might be due to in this system termination of vegetative growth and leaf senescence was earlier than others. Beside, plants of M_4 did not developed properly due to poorer root expansion, soil compactness, improper distribution of irrigation water, as well as soil moisture, improper nutrient uptake that inhibition poor growth and development. Beside, root expansion and nutrient uptake capacity may higher in M_2 and M_1 due to loosing of the soil surface, proper soil moisture and nutrient distribution that enhanced more nutrient uptake, which responsible for proper growth and development. Available soil moisture was poor in this treatment (M_4), compared to other soil management practices, which highly responsible for growth and development of the plants resulted lower CGR value.

The highest dry matter (661.76 g - 2002.80 g/m^2) was found in M_2, followed by M_1, which ranged 599.68 g - 808.50 g/m^2 in different growth stages, while the lowest maize dry matter (366.07 g - 340.96 g/m^2) was located in the M_4 (*Fig. 4b*). These results are similar to that of Díaz-Zorita (2000), who reported higher dry matter yield in conventional tillage plots, in comparison with that of the no tillage plots on a sandy loam Typic Hapludoll soil in Buenos Aires, Argentina. Higher DM accumulation in M_2 was, probably, attributed to more LAI, which leads to increase LEI within the canopy and production of dry matter of the plants, as compared to M_1, M_3 and M_4.

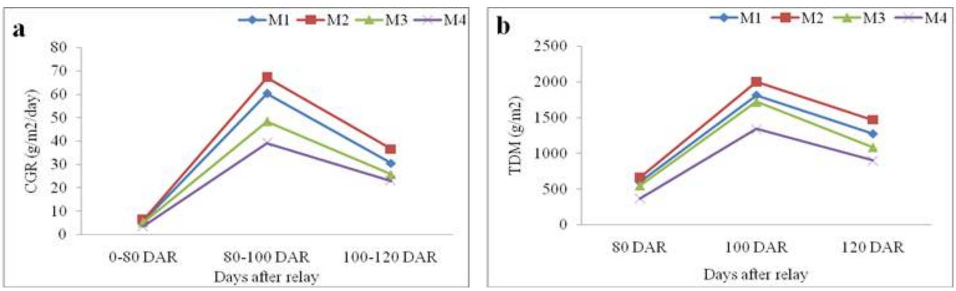

Figure 4 (a-b) - Variation in CGR and TDM as influenced by soil management practices at different growth stages

Table 2 - Effect of different soil management practices on yield contributing characters and yield of maize

Treatments	Plant height (cm)	Ear height (cm)	Cob Length (cm)	Cob Breath (cm)	Grain/ Cob (no.)	1000-seed weight (g)	Grain Yield (t/ha)
M_1	166.64	74.54	16.42	5.06	418.06	313.30	8.02
M_2	170.75	76.90	16.73	5.13	429.94	318.95	8.22
M_3	159.37	62.28	15.89	5.01	384.47	302.05	7.55
M_4	147.93	56.45	14.70	4.70	359.83	292.83	6.98
LSD (0.05)	2.94	1.37	0.34	0.13	9.77	5.27	0.16
CV (%)	3.14	3.48	3.72	4.53	4.23	2.96	3.63

M_1 = Soil mulching at 25 DAE; M_2= Earthing up at 25 DAE; M_3= Straw mulching at 25 DAE; M_4 = Without earthing up and mulching (Control)

Grain yield, plant height, ear height, cob length, cob breath, grains/cob and 1000-seed weight were significantly influenced by different soil management practices (*Table 2*). The treatment M_2 had higher plant height (170.75 cm), followed by M_1 (166.64 cm). The lowest plant height (147.93 cm) was recorded in M_4. These results are agreement with the finding of Kayode and Ademiluyi (2004), who observed the shortest maize plant in the no tillage plots, in comparison with that in the tilled plots on a sandy clay loam alfisol in Southwestern Nigeria. Khurshid *et al.* (2006) also reported taller plants in conventional tillage plots, in comparison with that of the minimum tillage plots. Grains/cob were significantly higher in treatments M_2 (429.94), rather than M_1 (418.06), M_3 (384.47) and in M_4 (359.83). There was significant effect on 1000-grain weight among the different soil management practices. The most 1000-grain weight (318.95 g) was recorded in M_2. The lowest 1000-grain weight (292.83 g) was obtained in M_4. It may be due to the lack of soil loosening for providing conditions favorable to crop growth and yield. These results are in agreement with that of Videnović *et al. (*2011), who observed higher maize yield in conventional tillage plots, in comparison with that of the no tillage plots on the chernozem soil type in Zemun Polje, Serbia. Similar trend were observed in case of ear height, cob length and cob breath.

Highest grain yield (8.22 t/ha) was obtained from M_2, but there were no significant difference with yield (8.02 t/ha) of M_1 treatment (*Table 2*). The M_4 treatment yielded significantly less (6.98 t/ha) than the others. Thus different soil management practices significantly improved the yield and yield contributing characters.

Combined effect of plant spacing and soil management practices

LAI, LEI, CGR as well as TDM varied comprehensively when maize was relay with different plant spacing under various soil management practices (*Figs. 5, 6 & 7*). However, maximum value was recorded at 80, 100 and 120 DAR in combination with S_4M_2, followed by S_4M_1, while minimum was recorded in S_1M_4 combination. In the 100 DAR, the value of above parameters were continued to increase while decreased towards maturity. The plant spacing with soil management practices greatly influenced on grain yield of maize shown in *Fig. 7*. The maximum grain yield (9.14 t/ha) was found in S_3M_2 combination, which was closely, followed by S_3M_1 (8.82 t/ha). The lowest grain yield (6.32 t/ha) took in S_1M_4 combination. Though higher value of LAI, LEI, CGR and TDM were recorded in S_4M_2 combination, but it fails to produce higher grain yield due to minimum cob length and cob breadth, which responsible for number of grain/cob resulted lower yield.

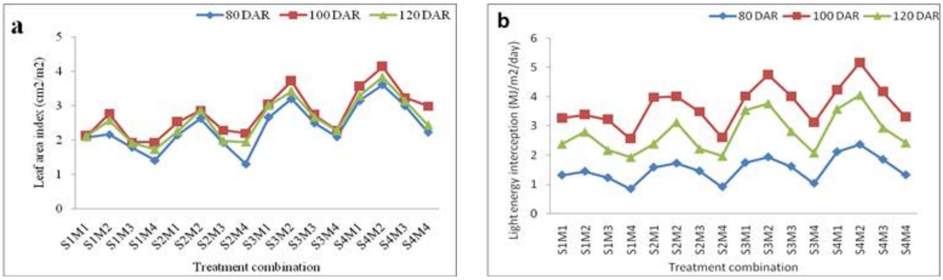

Figure 5 (a-b) - Combined effects of plant spacing and soil management practices on Leaf area index and Light energy interception at different growth stages

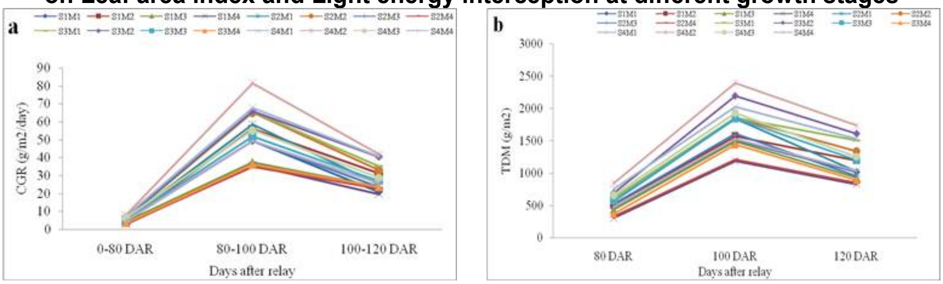

Figure 6 (a-b) - Combined effects of plant spacing and soil man agement practices on CGR and TDM at different growth stages

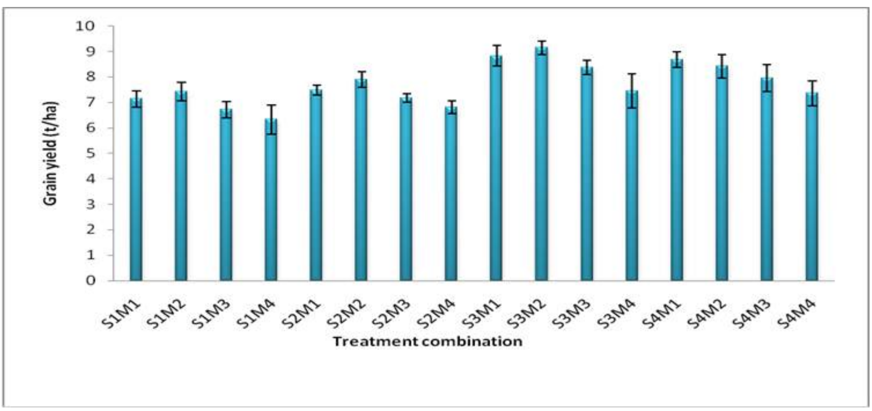

Figure 7 - Combined effects of plant spacing and soil management practices on grain yield of maize at different growth stages

Economics

Data regarding the *Table 3* showed that the treatment combination of S_3M_1 produced higher gross margin (Tk. 95000/ha) and BCR (2.17). Different plant spacing with earthing up at 25 DAE fail to produce higher economic benefit, compared to plant spacing with soil mulching at 25 DAE treatment combination, because after rice harvest in compact paddle soil earthing up need more labour than soil mulching. The seed rate also varies due increasing spacing, which responsible for varies total variable cost. Plant spacing with straw mulch treatment combinations produced lowest economic return than plant spacing with soil mulched/earthing up/control (without earthing up and mulching). This might be due to the prices of rice straw. It was mentioning that around 9 t rice straw needs to mulching one hectare of land. Hence, the BCR was lower in the combination where straw mulching used compared to other combinations. However, the lowest gross margin (Tk. 43400/ha) and BCR (1.48) were occurred in S_1M_3 combination.

Table 3 - Economic evaluation of the study

Treatments	Gross return (Tk./ha)	Total cost (Tk.)	Gross margin (Tk./ha)	BCR
S_1M_1	142600	75800	66800.00	1.88
S_1M_2	148400	85800	62600.00	1.73
S_1M_3	134200	90800	43400.00	1.48
S_1M_4	126400	73800	52600.00	1.71
S_2M_1	149400	78600	70800.00	1.90
S_2M_2	157800	88600	69200.00	1.78
S_2M_3	143400	93600	49800.00	1.53
S_2M_4	136200	76600	59600.00	1.78
S_3M_1	176400	84400	95000.00	2.17
S_3M_2	182800	91400	91400.00	2.00
S_3M_3	167400	96400	71000.00	1.74
S_3M_4	149000	79400	69600.00	1.88
S_4M_1	173600	84200	89400.00	2.06
S_4M_2	168400	94200	74200.00	1.79
S_4M_3	159000	99200	59800.00	1.60
S_4M_4	147200	82200	65000.00	1.79

Price: Maize seed: TK 20000/ton; Rice straw: Tk 2500/ton; Labour: Tk.250/day/capita

CONCLUSION

Regarding the results obtained this study, it can be concluded that maize may be cultivated as a relay with T. Aman rice. Results showed the physiological indices like LAI, CGR, TDM and LEI increased through the increase plant spacing. It was also revealed that after relay soil management practices was prime factor for getting higher productivity of maize. However, soil mulching at 25 DAE with plant spacing 50 cm× 20 cm was economically more beneficial in respect of produced yield of 8.82 t/ha, gross margin (Tk.95000/ha) and BCR (2.17).

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