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Effect of Mulch and Irrigation on Leaf Water Relation and Pod Yield of Common Bean in Dry Period of Bangladesh

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Abstract: Field study was carried out to understand the effects of three mulches (*Senna siamea* leaf, straw and water hyacinth) and five irrigation regimes {IW (irrigation water)/CPE (cumulative pan evaporation) 1.0, IW/CPE 0.75, IW/CPE 0.50, IW/CPE 0.25 and no irrigation} on leaf water status and pod yield of common bean during the dry season of Bangladesh. IW/CPE 1.0, 0.75, 0.50 received 40 mm irrigation when CPE reached 40, 53 and 80 mm. IW/CPE 0.25 did not receive any irrigation due to lower CPE than 160 mm during the study. Relative water content (RWC), water potential (Ψ_l) and stomatal conductance (g_s) did not vary significantly among the mulches. These parameters, however, varied with the change of irrigation regimes but the variations were not significant up to IW/CPE 0.50 with all mulches. Green pod size and yield did not change remarkably among the mulches. Irrigation played significant role in pod size and yield. Significantly higher yield was recorded in IW/CPE 1.0 with straw and water hyacinth mulches, while under *Senna* leaf mulch pod yield did not vary much up to IW/CPE 0.75. The better performance of *Senna* leaf might be due to favorable soil environment. Therefore, common bean for green pod can be grown successfully at IW/CPE 0.75 with *Senna* leaf mulch during the dry season in central Bangladesh.

Key words: Mulch, irrigation, common bean, relative water content, stomatal conductance, water potential, green pod yield

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is a newly cultivated crop in Bangladesh and it has the potential being cultivation throughout the winter (Rashid, 1993). Its cultivation has been attracting farmers because of its high market value and high export potential. The crop is grown during winter season in Bangladesh when there is general paucity of conserved moisture, thus its production is very much dependent on the availability of irrigation water (Anonymous, 2000). Conserved soil moisture is an important issue in rainfed agriculture in dry areas. Bangladesh has a distinct dry season (October to March) when little (about 10% of total) rainfall occurs (Begum *et al*., 2001). Mulching is a good technique, which conserves soil moisture and improves crop yield. In Bangladesh, rice straw and water hyacinth are two conventional mulches evaluated by researchers for crop production (Rahman *et al*., 2004; Haque *et al*., 2003) but because of different uses and other reasons, availability of these mulches are decreasing. Recently, agroforestry is being practiced in some places of Bangladesh and tree prunings, after management, could be used as alternative mulch. Performance of tree mulch on soil conservation, weed control and crop productivity had been examined (Kamara *et al*., 2000a, b; Budelman, 1989). *Senna siamea* is a potential agroforestry tree species with hard and waxy leaves that can remain on the soil surface for a long time.

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The increasing worldwide shortage of water and cost of irrigation are leading to an emphasis on developing methods of irrigation that minimize water use (Jones, 2004). Accurate estimation of water consumption by plant is important not only in directing irrigation and improving water use efficiency of crop, but also in studying the interactions between plant and atmosphere (Wang *et al*., 2006). Generally, irrigation scheduling is based either on soil water measurement or soil water balance calculations. Plant responses are based on physiological measurements and calculation of water requirements based on evapotranspiration. Weather conditions and soil water availability are primary factors affecting plant water status such as leaf water potential, stomatal resistance and transpiration (Lobo *et al*., 2004). It has been reported that leaf water potential can provide a sensitive index for irrigation control (Peretz *et al*., 1984). Changes in stomatal conductance are particularly sensitive to developing water deficits in many plants and therefore, potentially provide a good indicator of irrigation need in many species (Jones, 2004). Relative water content is a widely used measure of water status that does not require sophisticated equipment.

The effect of mulches and irrigation regimes on crop productivity had been evaluated separately by different researchers, however, little information exists regarding plant water status and crop yield in relation to different mulches combined with various irrigation regimes in Bangladesh. The present study was aimed at investing the effects of different mulches and irrigation regimes on leaf relative water content, stomatal conductance, water potential and pod yield of common bean during the dry period.

MATERIALS AND METHODS

Field experiment was conducted at the research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) (24°09′N, 90°26′E, 8.5 m above the sea level), Gazipur, Bangladesh during winter season of 2005-2006 in a silty clay loam soil. The top layer (0 to 15 cm) of the soil contained 1.48 g cm^{-3} average bulk density, 0.86% organic carbon, 0.070% total N and 12.6 meq 100 g $soil^{-1}$ CEC. The air temperature varied from 9.2 to 31.4°C during the experimentation (Fig. 1). The mean annual rainfall at the study area was about 2200 mm but no rainfall was recorded during the study period.

The experiment was laid out in a split-plot design with three replications where three mulches (*Senna* leaf, rice straw and water hyacinth) were assigned in the main plot and five irrigation regimes (IW/CPE 1.0 = 40 mm, IW/CPE 0.75 = 40 mm/0.75, IW/CPE 0.50 = 40 mm/0.50, IW/CPE

Fig. 1: Air maximum (O) and minimum (●) temperature at different days after emergence during the dry winter period of 2005-2006 in the central Bangladesh

0.25 = 40 mm/0.25 and IW/CPE 0 = no irrigation) were in the sub-plot. Fixed amount of irrigation (IW) of 40 mm was applied at four levels of depletion of cumulative pan evaporation (CPE), i.e., IW/CPE 1.0, IW/CPE 0.75, IW/CPE 0.50 and IW/CPE 0.25. The respective plot received water after 40, 53, 80 and 160 mm CPE. Thus, the frequency of irrigation varied depending on CPE and rainfall. IW/CPE 1.0, IW/CPE 0.75 and IW/CPE 0.50 plot had received 3, 2 and 1 irrigation, respectively (Table 1), while IW/CPE 0.25 treatment did not receive any irrigation because during the experiment total a 121.6 mm CPE was recorded (Fig. 2).

Land preparation was done by tractor driven disc plough and laddering until a good tilth was achieved. Drains were made around each plot and excavated soil was used for raising the plots about 10 cm high from the field level. Seeds of common bean (var. BARI Jhar Seem-1) were sown on 6 December 2005 maintaining 30×15 cm spacing. Unit plot size was 3×3 m and each plot was separated by 1 m distance from each other. After emergence, the seedlings were thinned leaving a single vigorous seedling. Decomposed cow dung, N, P_2O_5 and K_2O at the rate of 10000, 55, 100 and 36 kg ha^{-1}, respectively, were applied in all plots. All cow dung, P, K and half N were applied as basal dose, while the rest of the N was applied into two installments at 15 and 40 days after sowing. After seed sowing, common irrigation of 40 mm was applied to all the plots to ensure better germination and seedling establishment. *Senna* leaf and water hyacinth were sun dried for about 5 days on a threshing floor and sun dried rice straw was collected from the BSMRAU farm. All mulches were applied at the rate of 10 t ha^{-1} one week after seedling emergence.

Leaf relative water content (RWC), stomatal conductance (g_s) and water potential (Ψ_l) of common bean were measured at pod forming stage (49 DAE). All measurements were done at mid day from the

Table 1: Application of irrigation based on cumulative pan evaporation (CPE)

	IW/CPE 1.0		IW/CPE 0.75		IW/CPE 0.50		IW/CPE 0.25	
Irrigation frequency	Time (DAE)	CPE (mm)	Time (DAE)	CPE (mm)	Time (DAE)	CPE (mm)	Time (DAE)	CPE (mm)
1	30	40.0	37	54.6	47	81.6		
2	47	81.6	55	106.6				
3	60	121.6						

No rain recorded during the study therefore irrigation was applied based on CPE. IW/CPE 0.25 did not receive any irrigation because CPE was lower than 180 mm during the pod harvest

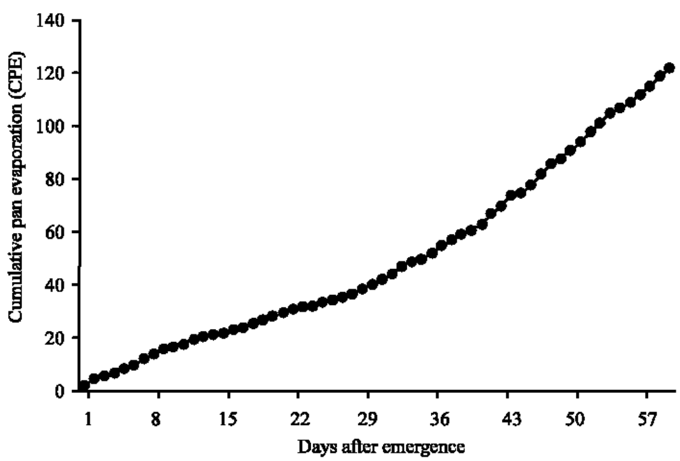

Fig. 2: Cumulative pan evaporation at different days after emergence during the dry winter period of 2005-2006 in the central Bangladesh

youngest fully expanded leaves. RWC of the uppermost fully expanded leaflets was measured following Lopez *et al.* (2002). The leaflets were detached and weighed (fresh weight, FW), floated on water for 2 h (assuming that complete hydration of leaflets occurred within 2 h) to allow turgidity to be regained and then re-weighted (turgid weight, TW) and dried overnight at 80°C to determine the dry weight (DW). The relative water content was calculated as follows:

$$\text{RWC}(\%) = \frac{\text{FW} - \text{DW}}{\text{TW} - \text{DW}} \times 100$$

g_s was measured with an LI-1600 steady state porometer (LiCOR Inc., Lincoln, NE), while Ψ_l was measured using a portable pressure chamber fitted with a rechargeable N_2 gas cylinder (model 600, PMS Instrument Company, USA).

Ten plants from each plot were selected to harvest green pod on 12-16 days after anthesis and harvesting was done four times during the crop season. Green pod yield of each plot was then converted to t ha^{-1}.

Data were subjected to analysis of variance (ANOVA) using the IRRISTAT computer program to compare the effects of mulches and irrigation regimes. The difference between means was compared by LSD at 5% level of significance.

RESULTS

Leaf Water Status

Leaf relative water content (RWC) of common bean decreased with the reduction of irrigation regime but up to IW/CPE 0.50, the variation was not significant ($p<0.05$) irrespective of mulches (Fig. 1). When the irrigation regime reduced to IW/CPE 0.25, RWC decreased sharply yielding a similar value to the no irrigation regime. No significant variation was noted among the mulches though comparatively higher RWC was obtained in *Senna* leaf mulch. However, the maximum (68.63%) and the minimum (54.25%) RWC were recorded in *Senna* leaf mulch with IW/CPE 1.0 and straw with IW/CPE 0.25 irrigation (IW/CPE 0), respectively. Leaf stomatal conductance (g_s) followed a similar trend where the highest (0.41 mol m^{-2} sec^{-1}) and the lowest (0.25 mol m^{-2} sec^{-1}) g_s were noted in *Senna* leaf mulch with IW/CPE 1.0 and straw mulch without irrigation treatments, respectively. Leaf water potential (Ψ_l) did not vary much among the mulches but varied significantly with the change of irrigation regimes. Relatively higher Ψ_l was recorded at maximum irrigation regime (IW/CPE 1.0) but did not change remarkably when irrigation regime reduced to IW/CPE 0.5 regardless of mulches. At higher irrigation regimes (up to IW/CPE 0.50), mulches had no effect on Ψ_l, but it changed distinctly when grown under water stressed conditions, where *Senna* leaf mulch gave higher values followed by water hyacinth and straw mulch. Among the treatment combinations, the highest (-0.60 MPa) and the lowest (-1.03 MPa) Ψ_l were noted at IW/CPE 1.0 with water hyacinth mulch and IW/CPE 0.25 with straw mulch, respectively.

Pod Size and Yield

Pod length and pod diameter showed similar trend of variations under the different mulches and irrigation regimes (Table 2). Mulch treatments produced almost similar number of pods regardless of irrigation regime. Pod size did not reduce significantly up to IW/CPE 0.75 when grown in straw and water hyacinth mulches while no significant differences were observed up to IW/CPE 0.50 in *Senna* leaf mulch. Irrigation regimes had significant effect on green pod yield of common bean (Table 3). Under straw and water hyacinth mulches, significantly the highest yield was noted in IW/CPE 1.0; while under *Senna* leaf mulch, IW/CPE 1.0 and IW/CPE 0.75 produced insignificant green pod yield.

Table 2: Effect of mulches and irrigation regimes on pod size of common bean during the dry season 2005-2006

	Irrigation regime (IW/CPE)				
Mulch	1.0	0.75	0.50	0.25	0
Pod length (cm)					
Senna leaf	12.97aA	12.55aA	12.21aA	10.19aB	10.18aB
Straw	12.83aA	12.37aAB	11.89aB	10.00aC	10.08aC
Water hyacinth	12.78aA	12.39aAB	11.78aB	10.02aC	9.98aC
Pod diameter (mm)					
Senna leaf	11.07aA	10.63aA	10.40aA	9.31aB	9.27aB
Straw	10.93aA	10.43aAB	10.17aB	9.24aC	9.16aC
Water hyacinth	10.91aA	10.52aAB	10.23aB	9.23aC	9.10aC

In a column, means followed by a common letter, an in a row, means followed by a common capital letter are not significantly different at $p<0.05$ according to LSD

Table 3: Effect of mulches and irrigation regimes on pod yield (ton ha^{-1}) of common bean during the dry season 2005-2006

	Irrigation regime (IW/CPE)				
Mulch	1.0	0.75	0.50	0.25	0
Senna leaf	7.39aA	6.90aA	6.28aB	4.98aC	4.89aC
Straw	7.32aA	6.60aB	6.19aB	4.81aC	4.75aC
Water hyacinth	7.20aA	6.64aB	6.07aB	4.90aC	4.78aC

In a column, means followed by a common letter, an in a row, means followed by a common capital letter are not significantly different at $p<0.05$ according to LSD

Intermediate yield was found in IW/CPE 0.50 whereas significantly lower yield was recorded in IW/CPE 0.25 and no irrigation regimes irrespective of mulches. Among the mulches, *Senna* leaf mulch gave the highest yield, which was insignificantly followed by straw and water hyacinth mulches.

DISCUSSION

The study was conducted during the dry season when no rain occurred, therefore, performance of plants and availability of soil water were entirely dependent on irrigation. Leaf relative water content (RWC), leaf stomatal conductance (g_s) and leaf water potential (Ψ_l) were not significantly influenced by the different mulches, though *Senna* leaf mulch showed relatively better performance over other mulches (Fig. 3). These parameters significantly varied with the variation of irrigation regimes. On the contrary, plant water status did not vary remarkably between maximum irrigation (IW/CPE 1.0) and 50% reduction of irrigation (IW/CPE 0.50). This might be due to the rapid recovery of water loss, because in this study, leaf water status was measured at the pod formation stage just two days after application of irrigation in IW/CPE 1.0 and 0.5, while IW/CPE 0.75 treatment was irrigated 11 days earlier. On the other hand, neither IW/CPE 0.25 nor IW/CPE 0 treatment received any irrigation before the measurements, therefore, plant water status of common bean grown in these treatments were distinctly lower and insignificant. Present result is in good agreement with Pallas *et al.* (1979) who reported that water status of peanut was completely recovered within 1-2 days of re-watering and stomata almost completely reopened. Duff *et al.* (1997) showed that g_s and Ψ_l of savanna species decline during the dry season in response to increasing vapor pressure deficit and declining soil water availability. Souza *et al.* (2005) showed significantly higher g_s of common bean leaf in irrigated treatment (0.34 mol H_2O m^{-2} sec^{-1}) compared to water deficit treatment (0.05 mol H_2O m^{-2} sec^{-1}). Begg and Turner (1976) found that values of Ψ_l between -0.75 and -0.90 MPa caused complete stomatal closure in common bean cultivars. Ike and Thurtell (1981) also reported that Ψ_l of cassava decreased when the rain or irrigation was intercepted and wilting of leaves occurred at Ψ_l between -9 and -11 bars. In the present experiment, however, wilting was not observed during the dry period. This might be due to application of mulches that conserved little soil moisture even in non-irrigated treatment.

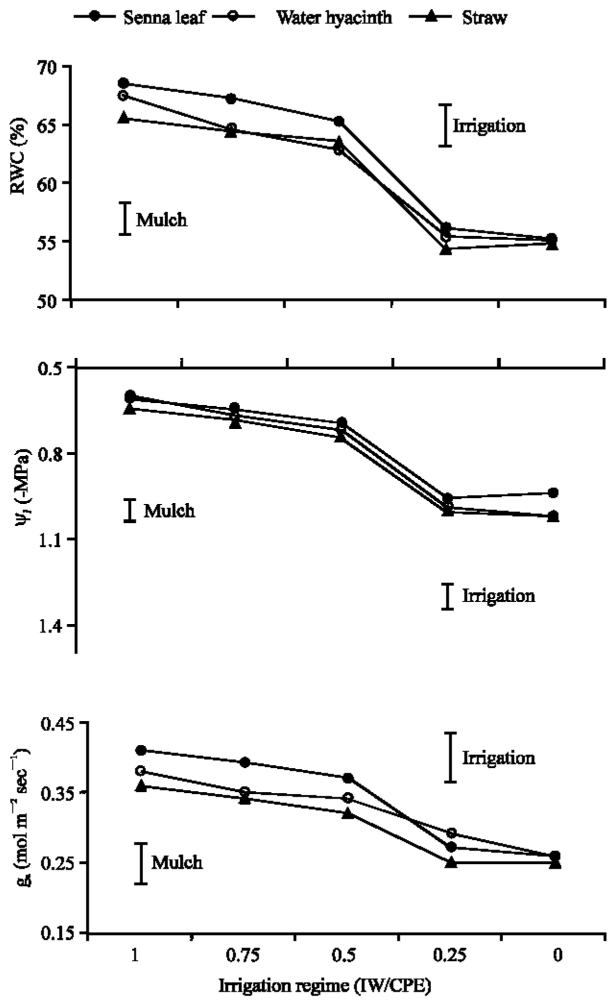

Fig. 3: Leaf relative water content (WRC), water potential (Ψ_l) and stomatal conductance (g_s) of common bean as influenced by mulch and irrigation at pod forming stage during the dry season of 2005-2006. Bars for mulch treatments indicate $LSD_{0.05}$ at the same irrigation regime; bars for irrigation treatments indicate $LSD_{0.05}$ with the same mulch treatment

Senna leaf mulch produced relatively higher pod size and yield than straw and water hyacinth mulch though not statistically different from each other (Table 2 and 3). On the other hand mean (average of three mulches) pod yield of common bean grown in maximum irrigation (IW/CPE 1.0) regime was about 15 and 34% higher that grown in moderate (IW/CPE 0.5) and severe stress (IW/CPE 0) conditions, respectively. Kamara *et al.* (2000a) recorded higher maize yield in tree leaf mulch treatment over open field. Better crop performance in tree leaf mulch treatment might be due to favorable soil environment (Budelman, 1989) and relative lower weed infestation (Kamara *et al.*, 2000b). Pod yield decreased significantly with the change of irrigation regime. No irrigation and IW/CPE 0.25 irrigation regimes produced almost similar yield because these two treatments did not receive any irrigation. Irrigation applied at pod forming stage (IW/CPE 0.50) produced substantial amount of pod yield but did not recover yield loss like plant water status as observed by Awal and

Ikeda (2002) in peanut. Lobo *et al.* (2004) noted higher yield of common bean when grown with more irrigation water. Ghuman and Lal (1983) observed significantly better performances of cassava and sweet potato with the application of straw mulch and irrigation. They explained that application of mulch and irrigation maintained a favorable soil environment. Abu-Awwad (1999) observed maximum onion root yield in mulched plot with higher irrigation regimes compared to open field with the same irrigation regimes.

The results show that leaf water status of common bean was higher up to IW/CPE 0.5 after that declined sharply. Among the mulch relatively better water status was observed in *Senna* leaf compared to other mulches. Pod size of common bean did not vary significantly up to IW/CPE 0.75 under straw and water hyacinth mulches, while green pod yield was reduced significantly with the change of irrigation regime. On the other hand, under *Senna* leaf mulch leaf water status was insignificant up to IW/CPE 0.50 and yield did not vary up to IW/CPE 0.75. Common bean for green pod, however, can be grown without significant yield reduction by applying irrigation when 53 mm CPE occurs if *Senna* leaf is used as mulch during the dry period of Bangladesh. Therefore tree leaf could be used as alternative mulch for better crop production.

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