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Photosynthetic Gas Exchange Characteristics, Leaf Area and Dry Matter Accumulation of Two Blackgram Cultivars

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Abstract: A pot experiment was conducted to evaluate the gas exchange, leaf area dynamics and dry matter accumulation of blackgram varieties namely BARI mash 3 and BINA mash 1. The two blackgram varieties did not differ statistically in gas exchange characteristics, leaf area and dry matter accumulation over the growth stages. Blackgram showed highest photosynthesis rate at flowering stage, might be attributed due to higher leaf chlorophyll, higher stomatal and mesophyll conductance and lower intercellular CO_2 concentration, but the highest respiration rate was found at pod filling stage. Leaves of top canopy showed highest gas exchange characteristics followed by the leaves of middle canopy and then bottom canopy. Diurnally, photosynthesis increased gradually with increasing intensity of light and peaked at around noon then decreases. Photosynthesis showed strong correlation with leaf area and dry matter accumulation of blackgram.

Key words: Gas exchange, leaf area, dry matter, blackgram

Introduction

Crop productivity and yield depend on many physiological processes and environmental factors. But among them central to the physiological process is photosynthesis. Now, it is well established that photosynthesis contributes about 90% of total dry matter. As a result, crop production aims to maximise photosynthesis. A plant must processes an efficient photosynthetic mechanism to be highly productive biologically. Photosynthetic productivity depends on leaf area development, leaf age, growth stage and light intercepted by the foliage. As leaf of each segment of the crop canopy heterogeneous in leaf development and also light distribution, photosynthetic activity differs which determine canopy photosynthesis. Photosynthesis also varies time to time during day periods depending on the dynamics of light intensity, air temperature and relative humidity of the day.

Genotypic variability in photosynthesis rate has been identified within several crop species (Mahon, 1990; Babu *et al.*, 1985). However, there is little evidence that differences in photosynthetic rates are related to crop yield or even biomass production in the field (Lambers, 1987 and Chaudhury, 1992). Some have reported a negative correlation between leaf area and photosynthetic rate (Bhagasari and Brown, 1986), while other showed that such relationship was inconsistent (Watanabe and Tabuchi, 1972). Hesketh *et al.* (1981) demonstrated positive correlation between leaf photosynthesis rate and chlorophyll content. Information relating spatial and temporal photosynthetic activity of blackgram cultivars and effects on dry matter production are very scanty. Therefore, this study was undertaken to know the photosynthetic activity over the growth stages, gas exchange characteristics in leaves of different canopy layers and the time course of gas exchange characteristics of blackgram cultivars.

Materials and Methods

A pot experiment was conducted at experimental farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during summer season of 1999. The two blackgram varieties namely BARI mash 3 developed by Bangladesh Agricultural Research Institute (BARI) and another BINA mash 1 developed by Bangladesh Institute of Nuclear Agriculture (BINA) were selected as treatment variables for this experiment. The experiment was laid out in randomized complete block design. The plants were grown in 12 liter pots containing soils prepared by mixing silty-loam and cowdung in 3 : 1 ratio. Three well-soaked seeds were sown in each pot and at trifoliate stage only one healthy seedling per pot was retained. The plant received N, P and K @ 40-60-40 kg per ha^{-1}. Half of N and full dose of P and K were applied as basal dose and rest half of N was applied as top dressed at vegetative stage. Intercultural operations such as weeding, mulching, irrigation, plant protection measures etc. were done as needed.

Photosynthetic gas exchange was measured at six growth periods viz. vegetative stage (25 DAE), flowering stage (35 DAE), pod filling stage (45 DAE), early maturity stage (55 DAE), mid maturity stage (65 DAE) and late maturity stage (75 DAE) using a portable photosynthesis system (LICOR-6200). Measurement of gas exchange was done following the procedures described by Kubota and Hamid (1992). At each measurement, fully expanded young leaf from top of the canopy was selected and attached with the leaf chamber. Leaf chlorophyll, stomatal conductance, mesophyll conductance, intercellular CO_2 concentration and respiration were also recorded at each measurement. Measurements were performed from twelve individual plants at each growth period. For measurement of respiration, leaf chamber was covered with a thick black cloth in a way that no radiation was entered into sample leaf. The sample leaf was attached into the leaf chamber of the photosynthesis system and CO_2 evolution rates were recorded for respiration. Photosynthetic gas exchange characteristics were measured from leaves of top, middle and bottom layers of canopy of blackgram and also recorded diurnally. Leaf chlorophyll was measured by chlorophyll meter.

Fifteen plants were sampled at each vegetative, flowering, pod filling and maturity stage. Leaf area per plant was measured using a leaf area meter. Plant parts were oven dried at 70°C for 72 h for weighing the dry mass. Data on different parameters analyzed statistically and means were compared by using F-test and LSD test when necessary (Gomez and Gomez, 1984).

Results and Discussion

Photosynthesis: Photosynthesis rates of two blackgram varieties did not differ in all growth stages. The highest photosynthesis rate was recorded at flowering stage and then a gradual decrease with the increase of plant age (Fig. 1A). Similar findings also reported in mungbean by Srinivason *et al.* (1985) and Mitra and Ghildiyal (1988). The highest photosynthesis rate of blackgram was observed at flowering stage due to higher chlorophyll content, higher stomatal and mesophyll conductance and lower intercellular CO_2 concentration of blackgram.

Leaf chlorophyll: There was no difference in chlorophyll content of leaves between the varieties of blackgram. Blackgram showed sharp increase of chlorophyll content from vegetative stage and reached peak at flowering stage of blackgram (Fig. 1B). Afterwards it decreased gradually at later stages of growth due to remobilization of leaf nitrogen into the developing seeds of blackgram. A positive correlation (r = 0.94) was found between leaf chlorophyll and photosynthesis of blackgram. The result was similar with Ma *et al.* (1995) who reported a positive correlation (r = 0.75) between leaf photosynthesis and chlorophyll (SPAD-502 meter reading) in soybean.

Stomatal conductance: Both the blackgram varieties showed identical behaviour in stomatal conductance in all the growth stages. Stomatal conductance was resembled to the photosynthesis rates over growth periods of blackgram (Fig. 1C). A positive correlation (r = 0.97) was found between stomatal conductance and leaf photosynthesis of blackgram. Stomatal conductance was also positively correlated (r = 95) with mesophyll conductance of blackgram. Similar result also reported by Islam *et al.* (1993) in mungbean. Higher stomatal conductance was observed at flowering stage and then t declined sharply in other growth periods and continued till maturity. The decrease of stomatal conductance in the later part of growth periods was observed due to loss of integrity of chloroplast with the increase of plant age (Thornton and Wample, 1980).

Mesophyll conductance: There was no difference in mesophyll conductance between two blackgram varieties in all growth stages. Mesophyll conductance was lower at vegetative stage and peaked at flowering stage thereafter it decreased sharply with increased age of plant (Fig. 1D). Mesophyll conductance decreased at later stage of plant growth may be due to decrease of Rubisco activity. However, a strong positive correlation (r = 0.98) was found between mesophyll conductance and leaf photosynthesis of blackgram. Similar results also reported by Islam *et al.* (1993) in mungbean.

Intercellular CO_2 concentration: The two blackgram varieties showed identical intercellular CO_2 concentration in all growth stages except at maturity stage. BARImash 3 showed lower intercellular CO_2 concentration than that of BINA MASH 1 at maturity stage (Fig. 1E). A negative correlation (r = -0.94) was found between intercellular CO_2 concentration and photosynthesis at flowering and pod filling stages of blackgram. Similar results was also reported by Hassan (1993). The highest inter cellular CO_2 concentration was found at pod filling stage resulted from higher respiration rates might be responsible for lower photosynthesis rate of blackgram.

Dark respiration: Respiration rates did not differ due to varietal difference of blackgram in all growth stages except at vegetative stage. BARImash 3 showed higher respiration rate than that of BINA MASH 1 at vegetative stage. Highest respiration rate was recorded at pod filling stages of blackgram and thereafter it decreased with increased age of plant (Fig. 1F). Similar results also reported by Hassan (1993) in blackgram genotypes. Higher respiration rates at early part of growth of blackgram may be attributed to use of some energy for synthesis of new materials and development of structural organs of blackgram. In the later part of growth, only the maintenance respiration may accomplish with the decrease of respiration rate of blackgram.

Gas exchange at canopy layers: Variation in gas exchange characteristics of leaves of different canopy layers between the varieties was insignificant. The leaves of top canopy showed the highest gas exchange characteristics followed by middle canopy and lower canopy. The leaves of top canopy showed highest photosynthesis rate due to higher stomatal conductance, mesophyll conductance and higher chlorophyll content (Table 1). The highest intercellular CO_2 concentration was observed in the leaves of top canopy which was statistically similar with the leaves of middle canopy and the lowest (262 ppm) was recorded in the leaves of bottom canopy of blackgram. The highest intercellular CO_2 concentration was recorded in leaves of top canopy, it might be due to higher respiration rate in their leaves.

Time course of gas exchange characters: Varietal difference in diurnal gas exchange characteristics was very narrow and both the varieties showed almost similar trend at flowering stage of blackgram. Photosynthesis rates of blackgram were low in the morning and peaked around at noon and thereafter it tended to decline (Fig. 2A). Similar trend of diurnal gas exchange was reported by Islam *et al.* (1993) in mungbean.

Table 1. Variation in gas exchange characters in the leaves of different canopy layers of blackgram at pod filling stage.

Canopy layers	Pn (μ mol m^{-2} s^{-1})	Ci (ppm)	Cs (μ mol m^{-2} s^{-1})	Gm (μ mol m^{-2} s^{-1}) (μ mol m^{-2} s^{-1})	Respiration (μ mol m^{-2} s^{-1})	Chlorophyll (SPAD)
Top	25.977	279	5.400	0.093	5.803	47.783
Middle	16.591	237	2.717	0.070	2.879	38.467
Bottom	8.001	262	1.808	0.031	2.047	35.767
LSD (0.05)	1.577	29.10	0.667	0.014	0.835	2.964
C.V. (%)	10.14	12.14	21.85	8.49	25.29	5.79

Pn = Leaf photosynthesis
Ci = Intercellular CO_2 concentration
Cs = Stomatal conductance
Gm = Mesophyll conductance

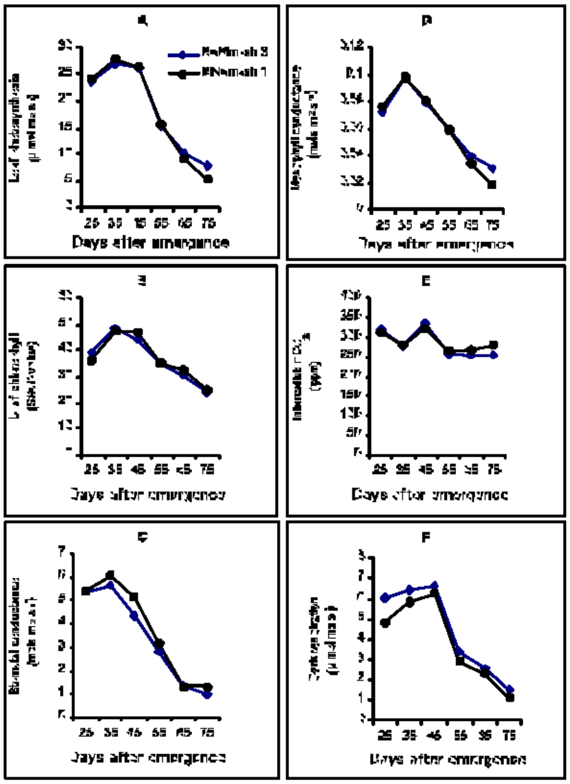

Fig. 1: Photosynthesis (A), stomatal conductance (B), mesophyll conductance (C), leaf chlorophyll (D), intercellular CO_2 concentration (E) and dark respiration (F) of two blackgram varieties at different growth stages

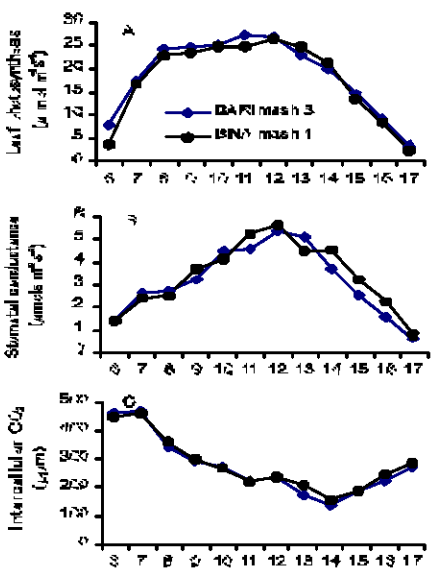

Fig. 2: Time course of photosynthesis (A), stomatal conductance (B) and intercellular CO_2 (C) of two blackgram varieties at flowering stage

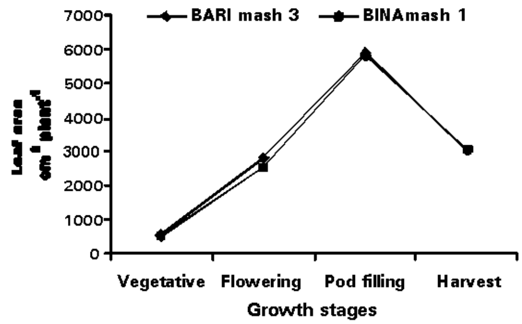

Fig. 3: Leaf area dynamics of two blackgram varieties at different growth periods

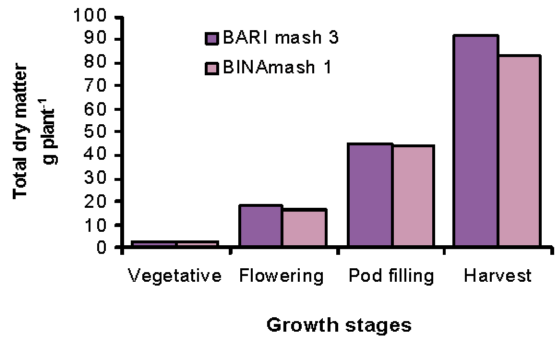

Fig. 4: Total dry matter production of two blackgram varieties at different growth stages

The highest photosynthesis rate of blackgram was observed at noon due to higher stomatal conductance because of higher light intensity and lower intercellular concentration. Stomatal conductance was also lower in morning which increased at around noon and lowest in the evening (Fig. 2B). Stomatal conductance is regulated to greater extent by the intensity of light (Grantz *et al.*, 1990) which may influenced the photosynthesis pattern of blackgram throughout the day periods. Intercellular CO_2 concentration further affected on photosynthesis rates of blackgram (Fig. 2C). Higher amount of CO_2 inhibited the rates of photosynthesis of blackgram in the morning. Occurrence of higher CO_2 in the morning might be due to accumulation of more CO_2 by the respiration during night and it could not release in atmosphere because of closing of stomata. The decrease of intercellular CO_2 with the advent of time happened because of more assimilation of CO_2 with the increase of light intensity. The slight increase in intercellular CO_2 concentration again in the evening may be due to closing of stomata and subsequent reduction of photosynthesis under low light intensity.

Leaf area and dry matter accumulation: The two varieties did not vary in leaf area per plant over the growth stages. Leaf area increased slowly during pre flowering but rapid increase in leaf area was found during post flowering stage of blackgram (Fig. 3). The highest leaf area was recorded in pod filling stage and thereafter it decreased sharply due to senescence of leaf. Similar trend of leaf area in blackgram also reported by Rahman *et al*. (1994). A positive correlation was found between photosynthesis and leaf area during flowering (r = 0.78) and pod filling (r = 0.97) stages. Similar results also reported by Mahon and Hobbs (1987).

There was no difference in total dry matter accumulation between the varieties of blackgram over the growth stages. Blackgram showed rapid increase of dry matter during post flowering than pre flowering stage and the highest accumulation of dry matter was recorded at harvest (Fig. 4). Blackgram showed significant correlation between leaf area and total dry matter accumulation at vegetative (r = 0.97), flowering (r = 0.96) and pod filling stage (r = 0.97). Total dry matter accumulation also strongly correlated with leaf photosynthesis both at flowering (r = 0.93) and pod filling (r = 0.91) stages of blackgram. Similar results also reported by Mahon (1982).

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