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Research Article

Physiological causes of yield variation in similar durated mungbean genotypes

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ABSTRACT

The experiment was conducted during February to May, 2019 at the research farm of Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202. The objective of the study was to evaluate the growth, reproductive characteristics, yield and yield components of four similar durated mungbean genotypes, namely BARI Mung-2, Binamoog-2, MB-29, and MB-43. At most of the growth stages, the mutant MB-29 showed superiority in terms of growth parameters such as total dry matter, leaf area index, absolute growth rate, relative growth rate, and net assimilation rate whilst MB-43 showed the inferiority. Furthermore, MB-29 outperformed the other three genotypes in yield attributing features, resulting in a higher seed yield than the other three genotypes. In comparison, the MB-43 mutant showed the lowest value for the yield parameters. The seed yield correlated positively and significantly with leaf area, total dry matter, absolute growth rate, and number of pods plant^{-1}.

Introduction

Mungbean [*Vigna radiata* (L.) Wilzsek] is a superior supplementary source of protein for a rice-based diet. Mungbean contains more protein than cereals do. 51% of mungbean is made up of carbohydrates, 26% of it is protein, 4% is mineral, and 3% is vitamin (Mwangi et al., 2021). In addition to adding important protein to the diet, mungbean has the impressive property of assisting the symbiotic root rhizobia in fixing atmospheric nitrogen, thus improving the soil (Bam et al., 2022). It is typically grown in the dry season after winter crops, though it can also be grown in the Kharif-II season. The largest barrier to the production of mungbean is its low yield potential (average 960 kg ha^{-1}; BBS, 2020). There are numerous causes for the low yield (Mondal et al., 2011a). The cultivars used have a low genetic yield potential and are vulnerable to disease and pests. According to Mondal et al. (2011b), between 70 and 85 percent of mungbean flowers do not mature into mature pods, indicating that the number of potential fruits or seeds is typically much higher than the number that the plant vegetation actually generates. After growth stage R1 (fruit setting stage), the number of fruits with working to develop seeds rises, and it reaches its maximum after growth period R5 (maximum seed growth stages) (Mondal et al., 2012). However, during this time, the plant is still growing vegetatively. As a result, generating reproductive sinks is in competition with vegetative sinks for nutrients. It is evident that the number of seeds per unit area influences canopy photosynthesis during flowering and pod development. Additionally, canopy photosynthesis rate determines through leaf area index and crop growth rate.

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Significant physiological characteristics such as leaf area index (LAI), relative growth rate (RGR), crop growth rate (CGR), specific leaf weight (SLW), and net assimilation rate (NAR) could indeed discuss a variety's productivity limitations. A plant with best LAI and NAR may have a greater biological yield. The ability to efficiently partition between vegetative and reproductive parts may result in high yield potential (Mondal et al., 2011c). For optimum yield in mungbean, the LAI should be ranged from 3.5 to 4.5 (Ali et al., 2021). Any reduction in leaf area or light amount or intensity may have a negative impact on yield (Mondal et al., 2011d). If the LAI reaches its maximum value in the shortest time, the dry matter accumulation may be the greatest (Mondal et al., 2012).

Several research institutes in Bangladesh, including BARI, BINA, and BSMRAU, have developed a couple of summer mungbean varieties that are higher yielding than local landraces, with yield variation ranging from 1100 to 1600 kg ha^{-1} (Mondal et al., 2015). The yield variation of similar durated mungbean genotypes need to be assessed for its physiological growth and morphological maneuvering that takes place yield variation

The current study has been designed to study various growth and reproductive characteristics that contribute to higher biological and grain yields. Thus, the research work was carried out to evaluate the growth and development of similar durated (duration 69–72 days) two elite summer mungbean mutants (MB-29 and MB-43) compared to the existing two varieties (BARI Mung-2 and Binamoog-2), and to find out the physiological reason for yield variation in similar durated mungbean genotypes.

Materials and Methods

The experiment was conducted during February to May, 2019 at the research farm of Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202. Similar duration (69-72 days) of two high yielding promising mutants namely MB-29 and MB-43 and two released varieties viz., BARI Mung-2 and Binamoog-2 were used as planting material. At first, the seeds of the mungbean genotypes were sown 05 March 2019. The experiment was conducted with randomized complete design with three replications. Each unit plot size and plant spacing were 3 m × 3 m and 30 cm × 10 cm, respectively. The dose of fertilizers (N-P-K-S) were 20, 60, 40 and 15 kg ha^{-1} respectively (BARC, 2018). The total fertilizer except nitrogen was applied at the time of land preparation as basal dose. Twenty days after sowing the first weeding was performed. The irrigation was supplied at 21 days after sowing. For controlling shoot and fruit borer, Ripcord 50 EC insecticide was sprayed at 0.025% at the stage of flowering and grain filling.

To study ontogenetic growth characteristics, a total of five harvests were made. The second and third rows of each plot were used for sampling (Hunt, 1978). A first plant sample was taken at 20 DAS, and it was taken every ten days interval until the crop reached fruit physiological maturity maturity at 70 DAS. From each sampling, five plants were randomly selected from second and third rows of each plot and uprooted to collect necessary parameters. The plant's parts (roots, stems, leaves and pods) were separated. Then the separated plant parts were oven-dried at 80°C for 72 hours, and their oven-dry weight was taken. A leaf area meter (Model: LICOR 3000, automatic, USA) was used to measure the leaf area. The Hunt formulae (1978) was applied to analyze the growth characters such as absolute growth rate and relative growth rate. The opened flowers per plant were counted from fifteen plants, five plants from each plot. The opened flowers per plant were counted daily. The opening flower counting was done following the method of Fakir et al. (2011). The flowering duration was 12 to 18 days depending on genotypes. Reproductive efficiency was calculated using following formulae: % pod set = (Number of pods plant^{-1} ÷ Number of opened flowers plant^{-1}) ×100. The yield contributing characters were recorded at the time of harvest from ten plants. Five rows from each plot (1.50 m × 3.0 m) were used to measure the seed yield, which was then converted into seed yield per hectare. The seed weight per plant was calculated by seed weight of 10 plants divided by 10. Harvest index was calculated from the collected data using formula: (economic yield/plot ÷biological yield/plot)×100. The computer package program MSTAT-C was used to analyze the collected data. The LSD test was also performed to investigate the pairwise difference between the treatments means.

Results and Discussion

Growth parameters

Fig. 1 depicts the evolution of leaf area (LA) and leaf area index (LAI) in mungbean genotypes over time. The results showed that LA and LAI

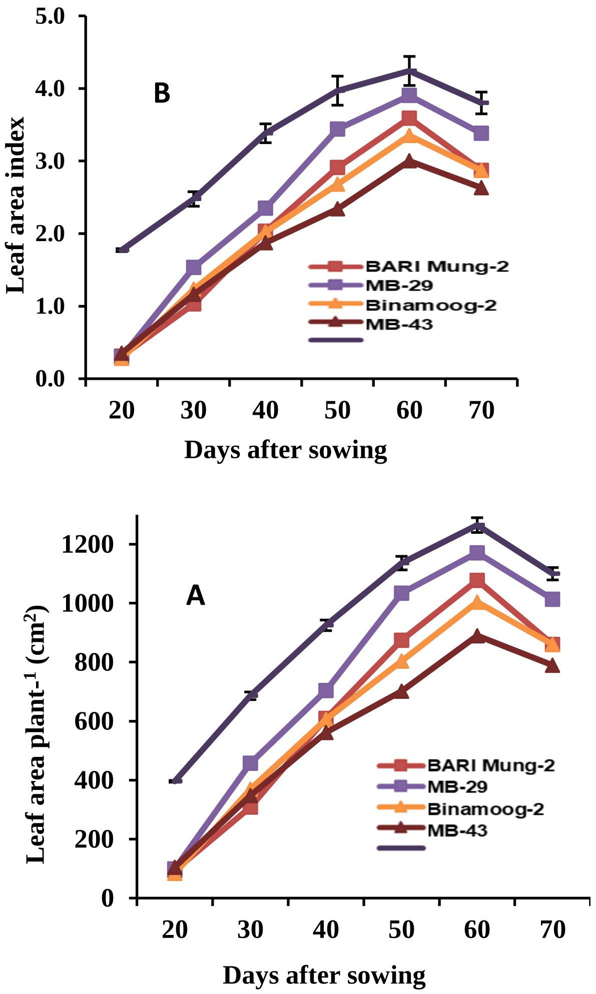

Fig. 1. Showing (A) leaf area and (B) leaf area index of similar durated four mungbean genotypes at different growth stages.

increased until 60 days after sowing (DAS), then decreased due to leaf shedding. At all growth stages except 20 DAS, the increasing levels of LA and LAI differed widely due to genotype. At all growth stages, the mutant MB-29 had the highest LA and LAI, followed by BARI Mung-2. MB-43, on the other hand, had the lowest LA and LAI during its growth period. The variation in LA and LAI might occur due to the variation in leaf number and the expansion of leaves. The result obtained from the present study was consistent with the result obtained by Lema et al. (2018) in mungbean, who stated that variation in LA and LAI could be attributed to changes in the number of leaves and rate of leaf expansion and abscission.

At all growth stages, mungbean genotypes showed considerable ontogenetic differences in total dry matter (TDM) production and absolute growth rate (AGR) (Fig. 2). TDM was gradually increased in all genotypes up to 40 DAS before increasing quickly until maturity. Comparing the mutant MB-29 to other genotypes, it produced more TDM at all growth stages, whereas MB-43 produced less TDM at all growth stages. TDM may have been increased in the MB-29 due to higher AGR and LAI (Fig. 1B) (Fig. 2B). The finding was corroborated by research from Mondal et al. (2012), who found that TDM increased as plant age increased up to physiological maturity.

The AGR increased gradually until 40 DAS, then increased quickly until 60 DAS, and then decreased as maturity progressed. Over the course of the growth period, MB-29, the high yielding mutant, consistently maintained the highest AGR value. The low yielding genotype MB-43, on the other hand, had the lowest AGR throughout the majority of the growth stages. Additionally, for all genotypes, the highest AGR was seen during the development of the pod and the grain filling stage (50–60 DAS). AGR and LAI have a positive correlation (Hamid et al., 1991). Along with the LAI growth, the AGR also

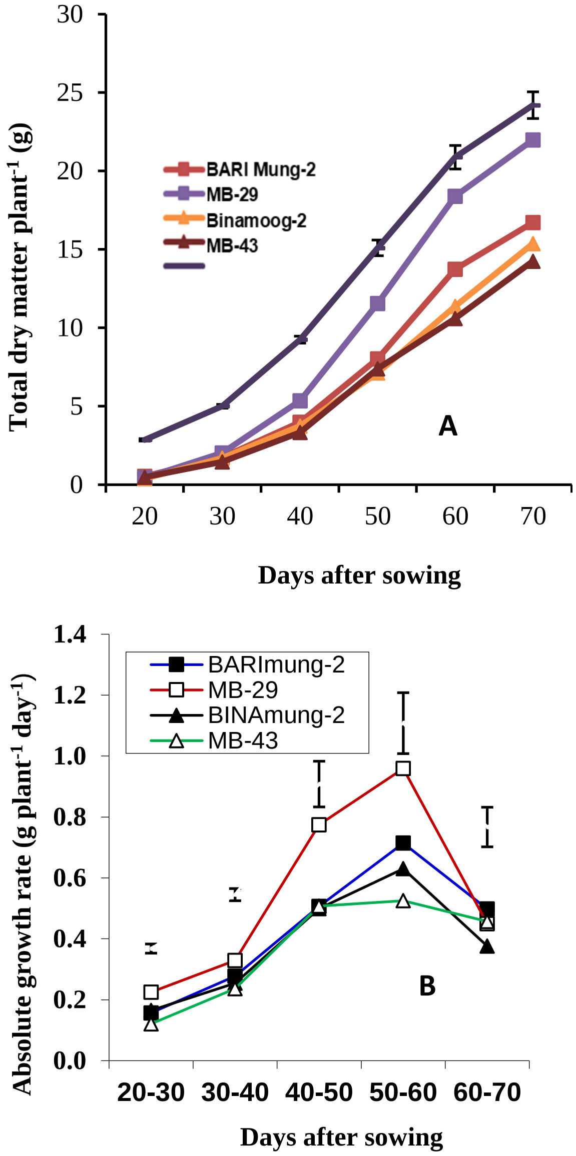

Fig. 2. Pattern of (A) total dry mass production and (B) absolute growth rate of similar durated four mungbean genotypes during their growth period.

increased. Lower LAI caused the lower AGR value during the early growth stages (Fig. 1B). The AGR value was found to be at its maximum at 50–60 DAS, indicating that the plant had increased its ability to assimilate for the growth of leaf area and feeding of pods. The abscission of leaves may have caused the AGR to decline after reaching its peak in all genotypes. These outcomes were in line with those of Mondal (2012) and Dutta and Mondal (1998) for mungbean and lentil, respectively.

At all growth stages, mungbean genotypes showed significant variation in their relative growth rates (RGR) and net assimilation rates (NAR) (Fig. 3). Initially, the RGR and NAR values were high and decreasing with age until maturity. RGR decreased substantially in the majority of field crops as plant age increased (Mondal et al., 2011c; Malek et al., 2012; Mondal et al., 2015). The genotypes' RGR and NAR values peaked between 20 and 30 DAS and then began to decline, reaching their lowest points at maturity (60–70 DAS). The mutant MB-29 showed superiority in AGR, RGR and NAR at most of the growth stages compared to other

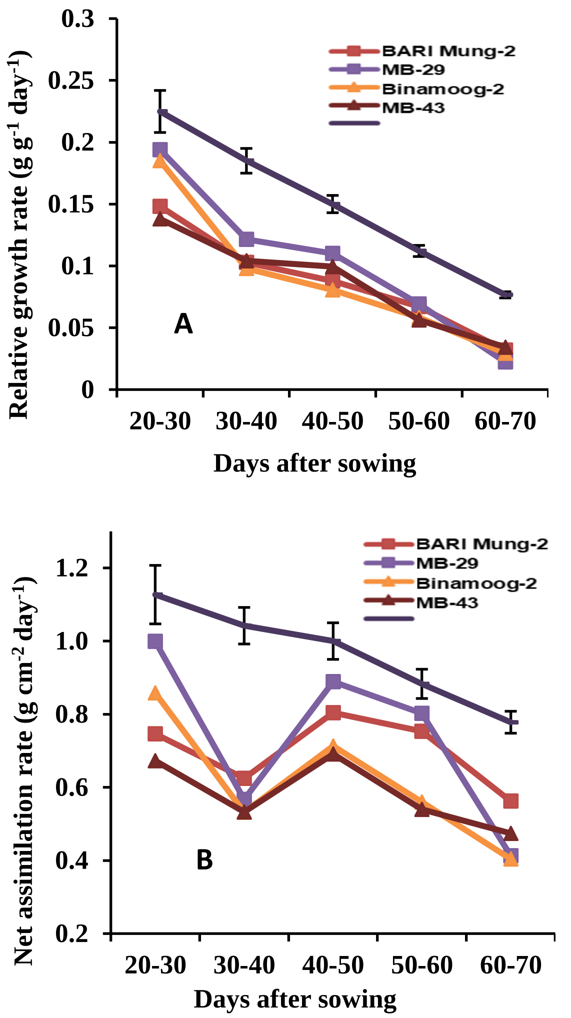

Fig. 3. Changes in (A) relative growth rate and (B) Net assimilation rate of similar durated four mungbean genotypes during their growth period.

three genotypes whilst MB-43 showed inferiority. A higher growth rate was positively correlated with seed yield (Mondal et al., 2013; Lema et al., 2018). In the current experiment, the mutant MB-29 demonstrated superiority in growth characters at all stages of growth resulting the maximum seed yield, and vice versa for the mutant, MB-43.

Morphological and reproductive characters

Considerable genotypic variation was also found in the mungbean genotypes in terms of plant height, number of branches, flowers, and racemes, as well as reproductive effectiveness, days to flowering, and maturity (Table 1). Out of all the genotypes, the MB-29 genotype had the tallest plant height (57.67 cm), most branches (3.17), racemes (17.67), and flowers (43.2). The mutant, MB-29 required the longest days to maturity (72 DAS) than the other genotypes. The MB-43 genotype, on the other hand, had the fewest branches (1.83 plant^{-1}), racemes (10.97 plant^{-1}), and flowers (26.2 plant^{-1}). MB-43 also had the shortest flowering and maturation times (37.3 and 68.5 DAS, respectively). The results also showed that, compared to low yielding genotypes, high yielding genotypes (Binamoog-2 and MB-29) produced more branches, racemes, and flowers (plant^{-1}) (Table 1). This finding suggests that the number of racemes and flowers is one of the key factors influencing seed yield. The association between high yielding and an increase in racemes and flowers could be explained by the possibility that high yielding genotypes have more raceme-bearing nodes that are borne on more branches, which would result in the production of more flowers (sink size). In other words, genotypes with higher flower production had lower RE, and vice versa, and the number of flowers showed a negative association with RE (Table 1). This result might be explained in a way that less competition for assimilates amongst the flowers/pods in the low yielding genotypes by being their fewer flowers. These results are corroborated with the results of Mondal (2012) who also reported that reproductive abscission (abortion) had inverse relationships with flower number and seed yield. MB-43 had the highest RE (52.4%), despite producing fewer flowers plant^{-1} (26.2). The genotypes with the lowest RE were in Binamoog-2 (47.1%) and MB-29 (49.5%), both of which had the same statistical rank and produced more flowers plant^{-1}.

Table 1. Some morphological and reproductive parameters and days required to maturity of similar durated four mungbean genotypes conducted during Kharif-I season, 2019

Mutants/ cultivars	Morphological parameters		Reproductive parameters			Phenological parameters	
	Plant height (cm)	Branches plant^{-1} (no.)	Racemes plant^{-1} (no.)	Opened flowers plant^{-1}	Repro-ductive efficiency (%)	Days to flowering	Days to maturity
BARI Mung-2	37.77 c	2.67 ab	13.47 b	35.5 b	50.7 ab	38.3 ab	69.8 b
Binamoog-2	49.43 b	3.00 a	16.07 a	41.4 a	47.1 b	39.0 a	70.0 b
MB-29	57.67 a	3.17 a	17.67 a	43.2 ab	49.5 b	40.0 a	71.9 a
MB-43	53.57ab	2.23 b	10.97 c	26.2 c	54.2 a	37.3 b	68.5 b
F-test	**	*	**	**	**	**	*
CV (%)	6.92	10.98	8.24	9.44	14.12	2.83	2.20

In a column, the figure having similar letter (s) do not differ significantly at $p \leq 0.05$; *, ** indicates significant at 5% and 1% levels of probability, respectively.

Yield attributes and seed yield

Genotypes had a significant impact on yield-contributing traits and seed yield (Table 2). MB-29 produced the highest pods plant^{-1} (21.6) and seeds pod^{-1} (11.7), whereas MB-43 showed the least amount of each (14.2 and 10.7 for pod plant^{-1} and seeds pod^{-1}, respectively). According to the findings, high yielding genotypes (MB-29 and Binamoog-2) had smaller pod and seed sizes (pod length, single pod, and 100-seed weight). In contrast, low-yielding genotypes (MB-43 and BARI Mung-2) had larger pod and seed sizes. The longest pod (8.66 cm), larger single pod (756 mg), and heaviest 100-seed weight (4.99 g) were found in MB-43. This outcome was consistent with that of Mondal et al. (2011a), who investigated the effects of pod number plant^{-1} and seed size on seed yield in 45 mungbean genotypes. The main objective of any agronomic or varietal development scheme is yield. The mutant MB-29 produced the highest total dry mass and seed weight (21.99 and 8.85 g, respectively) as well as seed yield (1328 kg ha^{-1}),while MB-43 produced the least(14.26 and 7.01 g plant^{-1} for TDM and seed weight plant^{-1}, respectively, and 1050 kg ha^{-1}). The genotypes, MB-29 and BINAmung-2 produced higher seed yield due to higher number of pods plant^{-1}.

This finding supported by numero us researchers who found that in legumes, seed yield was positively associated with TDM and pods plant^{-1} (Singh et al., 2008; Mondal et al., 2015; Mwangi et al., 2021). Harvest index was greater in varieties than in mutants indicating assimilates partitioning to economic yield is better in released varieties than the mutants. The highest yielder genotypes MB-29 showed the lowest HI (28.70%). This result indicates that selection of higher yielding genotype on the basis of HI may be deceiving. It agreed with Poehlman's (1991) who found that a high harvest index alone did not result in a high yield. Rather he had the opinion that many physiological process particularly efficient photoassimilation and it's partitioning into plant and seed determines high yield. The current study has also taken this viewpoint into consideration.

Conclusion

It is concluded that high-yielding mungbean cultivars have a greater number of branches and leaves, in addition to LAI, TDM, and AGR, resulting in higher pods number per plant than low yielding mungbeans genotypes. Among the similar durated mungbean genotypes, MB-29 performed the best with respect to growth, yield attributes and seed yield. The knowledge about the study of growth and yield of mungbeans could be useful in future breeding programs.

Table 2. Some yield contributing characters and yield in four mungbean genotypes conducted during Kharif-I season, 2019

Mutants/ cultivars	Pods plant^{-1} (no.)	Pod length (cm)	Single pod weight (mg)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seed weight plant^{-1} (g)	Seed yield (kg ha^{-1})	Total dry mass plant^{-1} (g)	Harvest index (%)
BARI Mung-2	18.0 b	7.90 b	704 b	10.9 ab	4.65 b	7.67 c	1180 bc	16.72 b	33.45 a
Binamoog-2	19.5 b	7.22 c	640 d	11.2 ab	4.30 b	8.33 b	1250 ab	17.38 b	36.68 a
MB-29	21.6 a	7.78 b	680 c	11.7 a	4.56 b	8.85 a	1328 a	21.99 a	28.70 b
MB-43	14.2 c	8.66 a	756 a	10.7 b	4.99 a	7.01 d	1050 c	14.26 c	28.92 b
F-test	**	**	**	*	*	**	**	**	*
CV (%)	4.73	2.60	1.45	3.08	7.45	4.30	5.05	6.31	7.45

In a column, the figure having similar letter (s) do not differ significantly at P ≤ 0.05 as per LSD; *, ** indicates significant at 5% and 1% levels of probability, respectively.

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Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this article.

Author's Contribution

M. Monjurul Alam Mondal: Concepts, literature review, conduct experiment, data collection, simulation, analysis, manuscript writing and revision.

Md. Azadul Haque: literature review, formatting, ,manuscript writing and revision.

Md. Mohimenul Islam: Literature review, formatting, manuscript writing and revision.

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