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Contribution of morpho-physiological traits on yield of lentil (*Lens culinaris* Medik)

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Abstract

Experiments were performed under sub-tropical condition (24°8´ N 90°0´ E) with five promising lentil mutants, LM-149, LM-417, LM-504, LM-507, LM-1018 and a check, L-5 to evaluate some morpho-physiological features and its impact on seed yield. The growth rate was very slow during the vegetative phase in all the genotypes due to a relatively smaller portion of dry matter production before flower initiation and bulk of it after anthesis. The maximum growth rate was observed at late flowering stage (60-70 days after sowing) in most of the genotypes. Results indicated that genotype improvement efforts have achieved higher seed yield by higher growth rate at early growth stages and better assimilate partitioning to economic yield. The bushy plants are unlikely to improve harvest index in lentil. Two mutants, LM-507 and LM-1018 had medium plant stature with moderate biomass production capacity and improved harvest index and increased yield. This information may be used in future plant breeding programme.

Keywords: Growth, lentil, mutants, nitrate reductase, yield.
Abbreviations: AGR-absolute growth rate; CGR-crop growth rate**;** DAS- days after sowing; HI-harvest index; LA-leaf area; LAI-leaf area index; NAR-net assimilation rate; NR-nitrate reductase; Pn-photosynthesis; TDM-total dry mass.

Introduction

Lentil (*Lens culinaris* Medik), a pulse of global economic importance, has been long domesticated. Among the pulses, lentil is of special interest with 23.7% content of grain protein. In addition to protein, its seed is a rich source of minerals and vitamins as human food, while the straw serves as high-value animal feed (Rasheed et al., 2010). Not only that, its cultivation enriches soil nutrient status by adding nitrogen, carbon and organic matter, which promotes sustainable crop production system (Sarker et al., 2004). However, lentil yield potential far below than the other cereal crops.

International endeavours to improve lentil have been promising in some cases (Erskine, 1998), but it is not the case everywhere. In South Asia, the yield of lentil remains low and average seed yield on a country basis is below 1.0 t ha^{-1} (SAIC, 2009). Further, the area under lentil cultivation in South Asia has been decreasing at a faster rate because of increasing demand for staple grains like rice and wheat (Rahman and Ali, 2011). Lentil has been identified as a narrow adapted crop and the principal constraint of lentil production is its low yield potential because of undesirable plant type (Hanlan et al., 2006). Except for the response to sowing date, little is known about the morpho-physiological and biochemical characteristics in South Asia to explain the causes of low yield of lentil in this region. Several reports have been made about the contribution of various yield components towards yield (Dutta and Mondal, 1998; Samad et al., 2007; Mondal et al., 2012). The yield components depend on some physiological traits.

To understand the physiological basis of yield difference among the genotypes of lentil, it is essential to quantify the components of growth, and the variation, if any, may be utilized in crop improvement.

Important physiological attributes such as LAI, CGR, NAR and photo-assimilate production capacity and its efficient partitioning to economic yield etc. can address various constraints of a variety for increasing its productivity. A plant with optimum LAI and NAR may produce higher biological yield (Mondal et al., 2012). The dry matter accumulation may be the highest if the LAI attains its maximum value within the shortest possible time (Mondal et al., 2011). It is suggested that high partitioning efficiency (harvest index) would be advantageous for high yield. For lentil, all genotypes are indeterminate growth habit and branched (Erskine and Goodrich, 1991).

Table 1. Effect of genotypes on morphological and phenological characters in lentil.

Mutants/ Mother cultivar	Plant height (cm)	Branches plant^{-1} (no)	Leaf area plant^{-1} (cm^2)	Days to flowering			Days to maturity		
				2009-10	2010-11	Mean	2009-10	2010-11	Mean
L-5 (mother)	41.5 b	13.6 a	466 a	55.0 c	57.1 c	56.1 d	111 bc	116 b	113.5 b
LM-149	50.2 a	12.6 b	403 bc	63.3 a	64.0 a	63.7 a	120 a	124 a	122.0 a
LM-417	46.9 a	11.9 b	389 c	62.0 a	62.5 a	62.2 b	121 a	125 a	123.0 a
LM-504	43.1 b	13.1 ab	404 bc	59.7 b	60.0 b	59.9 c	119 a	123 a	121.0 a
LM-507	37.1 c	14.8 a	436 b	55.3 c	57.0 c	56.2 d	112 b	117 b	114.5 b
LM-1018	40.9 b	14.2 a	425 b	53.3 e	55.0 d	54.2 e	109 c	114 b	111.5
F-test	**	*	**	*	**	**	**	**	**

In a column, figures with same letter (s) do not differ significantly at $P \leq 0.05$; *, ** indicate significant at 5% and 1% level of probability, respectively.

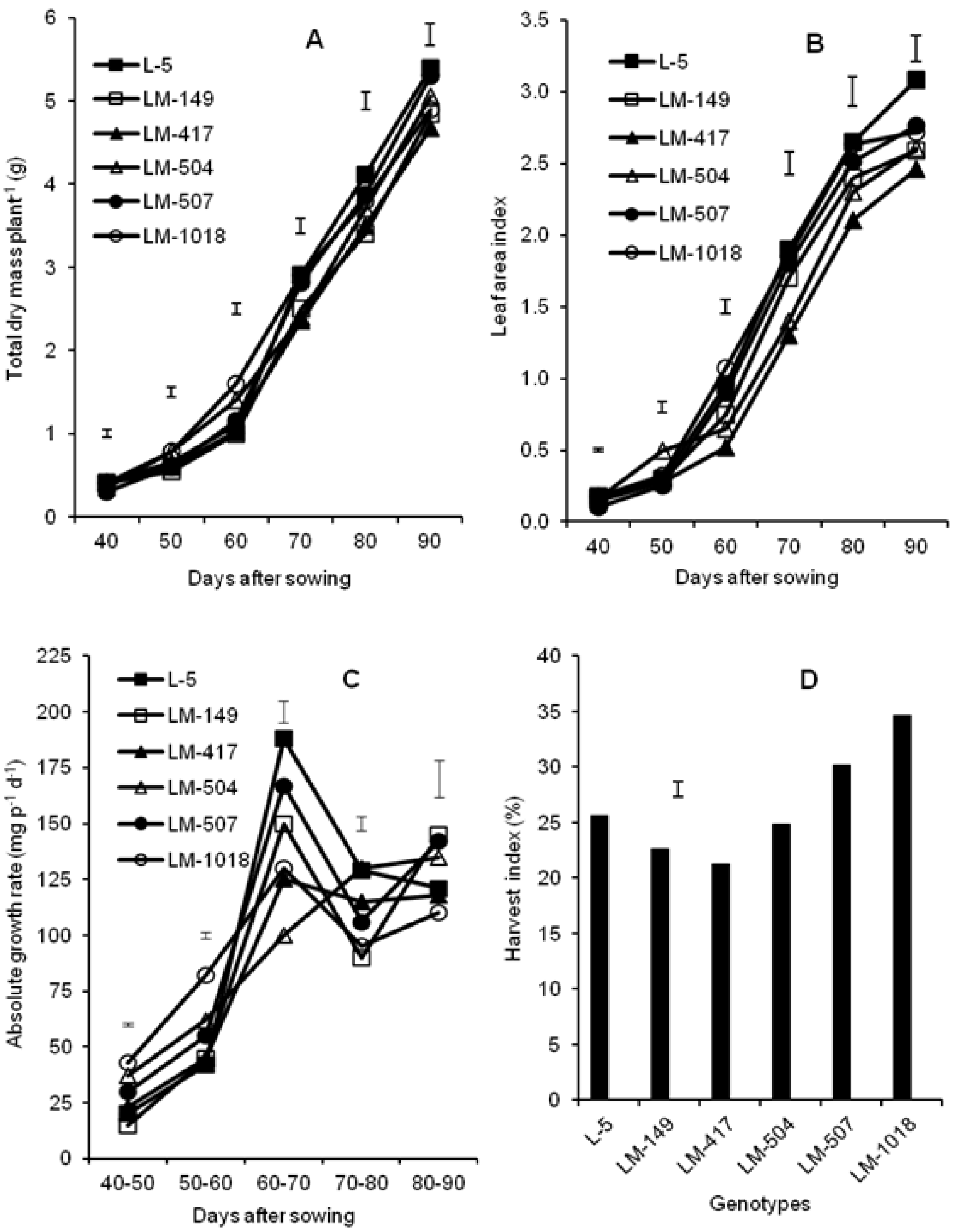

Fig 1. Changes in (A) total dry mass, (B) leaf area index and (C) absolute growth rate at different growth stages and (D) harvest index at harvest of six lentil genotypes. Vertical bars represent LSD (0.05).

As a result, competition between pods and vegetative parts for photosynthates causes a lower harvest index. In other words, lentil produces disproportionately large vegetative growth and support lesser grains. The ratio of grains to vegetative matter in lentil is roughly 1:3 (Whitehead et al., 2000). On the contrary, species domesticated for commercial purposes are expected to produce optimum vegetative growth to support maximum grains. Samad et al. (2007) suggested that the relationship between flower production and pod set in lentil is related to source (LA), in which higher seed yield could be achieved by increasing the source capacity. Since yield is the result of genotype by environment interaction, it has been suggested that by increasing photosynthetic efficiency, productivity could be increased (Shrestha et al., 2006).

It is known that photosynthetic efficiency depends on leaf area, chlorophyll content and the stomatal response/gas exchange. Therefore, it is worth determining these parameters and analyzing the correlation, if any, in newly developed genotypes. On the other hand, component characters for yield are interdependent on one another, while one character may express at the expense of others (Yadav et al., 2003). The importance of correlation study both at genotypic and phenotypic levels in any breeding programme is well documented for various crop species as it provides a basis for effective selection of characters contribution to yield (Singh et al., 2008). Some authors have reported that in lentil higher performance are achieved by contribution of various yield components (Anzam et al., 2005; Kakde et al., 2005; Tuba and Sakar, 2008; Younis et al., 2008; Karadavut, 2009). Information on identification of important source-sink characters and their correlation with yield is scanty in lentil.

Bangladesh Institute of Nuclear Agriculture has developed some promising lentil mutants through chemical mutagenesis of L-5, the local landrace popular cultivar. The special character of these developed mutants is synchronous in pod maturity, which is desirable trait for lentil cultivation in Bangladesh. These mutants need to be evaluated for their physiological and morphological manoeuvring that takes place compared to the existing lentil cultivar, L-5. The objective of the present research work was to study the physiological, biochemical and morphological relationship with seed yield in advanced lentil mutant lines.

Results and discussion

Growth parameters

The effect of lentil genotypes on ontogenetic growth characters like total dry mass (TDM), leaf area index (LAI) and absolute growth rate (AGR) was significant (Fig. 1). At the later growth stages (70-90 DAS), the highest TDM plant^{-1} and LAI was recorded in L-5. The mutant LM-417 produced the lowest TDM and LAI at most of the growth stages followed by LM-504. The mutant LM-1018 produced the highest TDM plant^{-1} at early growth stages (40-60 DAS) followed by second highest TDM at later growth stages (70-90 DAS). The mutants LM-507, LM-1018 and the variety L-5 showed higher LAI at 60-80 DAS with non-significant differences. The AGR increased with age until 60-70 DAS followed by a decline in all genotypes except LM-504. In LM-504, AGR increased with age till 90 DAS. At early growth stages (40-60 DAS), the AGR was greater in LM-1018 than the other genotypes and also showed higher grain yield. On the other hand, L-5 and LM-507 showed higher AGR at 60-70 DAS and also showed higher seed yield. This result indicates that higher growth rate at vegetative and flowering stage is desirable for getting higher grain yield in lentil. Plant growth and yield are represented by the crop's early ability to intercept solar radiation and its subsequent utilization for biomass production (Hanlan et al., 2006). In lentil, increase interception of solar radiation at early seedling stages enable plant to make rapid early growth, resulting in high yield (Purcell et al., 2002).

In the present experiment, the mutant LM-1018 showed early higher growth rate and also showed high yield potential. Similar result was also reported by Samad et al. (2007) who observed that the genotypes, which had capacity to early higher growth rate, also showed higher seed yield in lentil. The highest harvest index was recorded in LM-1018 (34.67%) followed by LM-507 (30.21%) and these two mutants also performed higher seed yield (Fig. 1). The lower harvest index was recorded in LM-417 and LM-149 with being the lowest in LM-417 (21.26%) and also showed the lowest seed yield (0.91 t ha^{-1}). Generally, high yielding genotypes produced higher TDM and LAI (Dutta and Mondal, 1998).

In the present experiment, the variety L-5 was the medium yielder with highest TDM and LAI producer variety. Furthermore, the TDM's negative response to HI in L-5 could be explained in way that high TDM producing capacity might have used assimilate for other vegetative sinks and that it deprived translocation of assimilates to economic sink. In other word, dry matter partitioning to economic yield was lower in L-5 which is not desirable character.

On the other hand, the high yielding mutants LM-507 produced higher TDM, whereas another high yielding mutant, LM-1018 produced intermediate TDM and LAI. This, in turn, indicated that TDM production is not obligatory for achieving higher seed yield in lentil. But dry matter partitioning to economic yield is more important than TDM production. However, the mutant LM-1018 produced intermediate TDM with highest dry matter partitioning to economic yield (34.67%) and results higher seed yield that is the desirable character. Greater biomass production is unlikely to improve harvest index in lentil (Hanlan et al., 2006). The authors also suggest that plants having moderate biomass with reduced branching would carry more pods, have a lesser tendency to lodge, and result in improved harvest index and yield in lentil. In the present experiment, the mutant LM-1018 had medium plant stature with moderate biomass production capacity and improved HI, thereby increased yield.

Morphological and phenological characters

Plant height, number of branches plant^{-1} and leaf area (LA) varied significantly among the mutants/ mother variety (Table 1). The tallest plant was recorded in LM-149 (50.2 cm) followed by LM-417 (46.9 cm) with the same statistical rank while the shortest plant was recorded in LM-507 (37.1 cm). Results showed that two mutants, LM-507 and LM-1018 were shorter than the mother plant (L-5) and other three mutants were taller than the mother.

There was no significant difference for branch production among the mutants/ mother variety (Table 1). However, two mutants, LM-507 and LM-1018 produced higher number of branches plant^{-1} with being the highest in LM-507 (14.8) and these two mutants also showed higher seed yield. In contrast, the lowest branch production was recorded in LM-417 (11.3 plant^{-1}) followed by LM-149 (12.6 plant^{-1}) with same statistical rank and these two mutants also showed lower yield performance, indicating branch production is more

Table 2. Genotypic variation in physiological parameters, protein content in grain, and isotope uptake in lentil.

Mutants/ cultivar	Chlorophyll (mg g^{-1} fw)	Leg- haemoglobin (mg g^{-1} fw)	Nitrate reductase (μ molNO_2^- g^{-1}fw h^{-1})	Photosynthesis (μmolCO_2 $m^{-2}s^{-1}$)	Protein content in grain (%)
L-5 (mother)	1.36	12.70	2.66 a	15.41 b	23.30 b
LM-149	1.33	12.24	2.14 c	13.34 d	24.34 ab
LM-417	1.33	12.34	2.33 bc	14.22 c	23.90 b
LM-504	1.28	12.15	2.39 ab	15.19 b	25.20 a
LM-507	1.32	13.24	2.62 a	16.01 a	23.63 b
LM-1018	1.35	13.13	2.46 ab	15.84 ab	23.97 ab
F-test	NS	NS	*	*	*

In a column, figures with same letter(s) do not differ significantly at $P \leq 0.05$; *, ** indicate significant at 5% and 1% level of probability, respectively; NS indicates not significant.

important than plant height in achieving higher seed yield in lentil. Similar result was also reported by many workers in lentil (Yadav et al., 2003; Anzam et al., 2005, Kakde et al., 2005; Karadavut, 2009) who reported that seed yield was positively and significantly correlated with branch number. On the other hand, Hanlan et al. (2006) suggested that short plant stature with less number of branches are desirable to achieve higher seed yield in lentil, which disagrees with the present findings.

The mutant LM-1018 flowered earlier (54.2 days) and also matured earliest (111.5 days). On the other hand, three mutants, LM-149, LM-417 and LM-504 took longer days to maturity with being the highest in LM-417 (123 days). This mutant (LM-417) also performed poor in yield. This result is disagreement with Tuba and Sakar (2008) who reported that days to flowering and maturity was positively correlated with seed yield in lentil.

Biochemical parameters

Genotypes had no significant influence on chlorophyll and leg-haemoglubin contents but significant genotypic influence on nitrate reductase (NR) activity and photosynthesis (Pn) in leaves and protein content in grains (Table 2). However, there was no high variation in NR, Pn and protein content in grains among the mutants/mother variety. The highest/higher NR and Pn was recorded in LM-507 and LM-1018 and these two mutants also showed higher seed yield which indicated seed yield is positively correlated with NR and Pn. On the other hand, two mutants, LM-149 and LM-417 showed inferior NR and Pn and also gave lower yield performance. These results are partially consistent with Dutta (2001) who reported Pn was positively correlated with yield and negatively correlated with NR in mungbean and lentil. Furthermore, the cultivar, L-5 shower superior in biochemical parameters with intermediate yield performance, which might be due to improper dry matter partitioning to economic yield (Fig. 1). The highest protein content in grains was recorded in LM-504 (25.20%) followed by LM-149 (24.34%) and LM-1018 (23.97%) with same statistical rank. In contrast, the lowest grain protein (23.63%) was recorded in LM-507. Result further revealed that grain protein content had no relation with seed yield in lentil. This result is in agreement with Erskine et al. (1985) who reported that seed yield was negatively correlated with grain protein and positively correlated with seed size. Sarker et al. (2004) reported that seed size and protein content in seed was negatively correlated. Gill and Singh, (2012) observed a positive relation between seed yield and protein content. However, most of scientists reported that seed yield was negatively correlated with seed protein content in lentil.

Correlation study

Pod number is the prime yield attributes in lentil and pod number showed significant and positive correlations with branch number (r = 0.56**), LA (r = 0.60**), LAI (r = 0.53**), TDM (r = 0.67**), AGR (r = 0.60**), HI (r = 0.77**), NR (r = 0.56**), Leg-haemoglubin (r = 0.42*) and Pn (r = 0.62**); thereby, strongly correlated to the seed yield (Table 3). In contrast, both seed yield and pod number had negative association with plant height and chlorophyll content in leaves. This suggests that increasing sink (pod number) production would increase seed yield and pod production depend on morpho-physiological characters except for the plant height. These results are in agreement with the result of many authors who also observed that seed yield increased with increased number of pods plant^{-1} in lentil (Yadav et al., 2003; Anzam et al., 2005; Tabu and Sakar, 2008; Younis et al., 2008; Karadavut, 2009).

Seed yield and yield attributes

Results revealed that the mutant LM-1018 produced the highest seed yield in both years (1.51 and 1.60 t ha^{-1} for 2009-10 and 2010-11, respectively) while LM-507 produced moderate yield in 2009-10 (1.39 t ha^{-1}) and the highest in 2010-11 (1.60 t ha^{-1}) (Table 4). The yield was higher in those two mutants (LM-507 and LM-1018) due to production of higher pods plant^{-1} and bolder seeds. In contrast, LM-417 produced the lowest seed yield (0.91 t ha^{-1}) due to lower yield attributes. Based on the superior morpho-physiological characters and yield, two mutants such as LM-507 and LM-1018 may be selected for further field trial at different agro-ecological zones of Bangladesh to confirm the results.

Materials and methods

Planting materials and experimental design

Two field experiments were conducted at the experimental field of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during winter (November-March) in two consecutive years of 2009-10 and 2010-11. Five elite lentil mutants were developed from the widely cultivated local landrace, L-5, through chemical mutagenesis using the chemical mutagen, sodium azide. The name of the mutants/ mother variety is presented in Table 1. The soil of the experimental area is silty loam having 0.06% nitrogen, 1.15% organic matter, 18.5 ppm available phosphorus, 0.28 meq/100g exchangeable potassium, 18 ppm sulphur and 6.8 pH. The experiments were laid out in a randomized complete

Table 3. Simple correlation coefficient among the different quantitative characters in lentil

Characters	Plant height	Branch number	Leaf area	Leaf area index	Total dry mass	Absolute growth rate	Harvest index
Seed yield	- 0.75**	0.84**	0.63**	0.60**	0.41*	0.58**	0.82**
Pod number	- 0.59**	0.575**	0.60**	0.53**	0.67**	0.60**	0.77**
1000-seed weight	- 0.40*	0.32*	0.54**	0.50*	0.21^{NS}	0.68**	0.48*

Table 3. Contd

Characters	Chlorophyll	Nitrate reductase	Leg- haemoglubin	Photo-synthesis
Seed yield	0.23^{NS}	0.67**	0.58**	0.47*
Pod number	-0.11^{NS}	0.56**	0.42*	0.62**
1000-seed weight	0.72**	0.47*	0.61**	0.33*

N = 18; *, ** indicate significant at 5% and 1% level of probability, respectively; NS indicates not significant.

Table 4. Effect of genotypes on some yield components and seed yield in lentil

Mutants/ cultivar	Number of pods plant^{-1}			1000-seed weight (g)			Seed yield (t ha^{-1})		
	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
L-5 (mother)	77.3 c	87.5 bc	82.4 c	18.73 a	18.90 a	18.82 a	1.26 b	1.29 b	1.28 b
LM-149	57.6 d	79.2 cd	68.4 d	15.93 c	17.00 b	16.47 d	0.86 d	1.20 bc	1.03 c
LM-417	62.0 d	71.4 d	66.7 d	16.57 b	17.02 b	16.79 c	0.80 d	1.01 c	0.91 d
LM-504	91.1 a	108.0 a	99.6 a	15.03 d	15.30 c	15.16 e	1.05 c	1.30 b	1.18 bc
LM-507	83.5 b	106.0 a	94.6 a	16.23bc	18.30 a	17.27 b	1.39 b	1.60 a	1.50 a
LM-1018	87.0 ab	95.2 b	91.1 b	18.27 a	19.00 a	18.64 a	1.51 a	1.60 a	1.56 a
F-test	**	**	**	**	**	**	**	**	**

In a column, figures with same letter(s) do not differ significantly at $P \leq 0.05$; ** indicates significant at 1% level of probability.

block design with three replicates. The unit plot size was 2.5 m × 2.0 m with plant spacing of 30 cm × 5-6 cm.

Crop establishment and cultural practices

Seeds were sown in lines, two weeks after germination. Plants were thinned to 5-6 cm distances. Recommended intercultural practices such as weeding, thinning, application of pesticides were followed for proper growth and development of the plants in both years. Nitrogen, phosphorus and potash were provided during final land preparation at the rate of 20, 45 and 30 kg ha^{-1} in the form of urea, triple superphosphate and muriate of potash, respectively. First weeding was done followed by thinning at about 25 days after sowing (DAS).

Parameters measured

The morpho-physiological parameters were recorded only from the second year experiment, and yield and yield components were recorded from both year experiments. To study ontogenetic growth characteristics, a total of six harvests were made in 2010-11. Ten plants were randomly sampled for growth parameters from 40 DAS and continued at an interval of 10 days up to 90 DAS. The second and third rows of each plot were used for sampling. Plants were separated into roots, stems, leaves and pods, and the corresponding dry weights were recorded after oven drying at 80 ± 2 ^{0}C for 72 hours. The growth analysis was carried out following the formulae of Hunt (1978). Leaf area index was measured by Canopy analyzer (Model: LAI 2000, LI-COR Biosciences, USA). Chlorophyll content and nitrate reductase activity in leaves, leg-haemoglubin content in nodule and photosynthesis rate in leaves were determined at 65-70 DAS (flowering and fruiting stages). Leaf area of each sample was measured at 90 DAS (flowering complete, pod growth and development stage) by automatic leaf area meter (Model: LI 3000, LI-COR Biosciences, USA). Leaf chlorophyll was determined following the method of Yoshida et al. (1976). Leaf photosynthesis was measured by photosynthesis meter (LI 6400XT, LI-COR Biosciences, USA). Nitrate reductase activity was determined following the methods of Stewart and Orebamjo (1979). Leg-haemoglubin was determined by the Cyanmethaemoglobin method (Schifftmann and Lobel, 1970). Grain protein percent was estimated by Micro-Kjeldhal method (AOAC, 1980). The yield contributing characters were recorded at harvest from ten competitive plants of each plot. The seed yield was recorded from five rows of each plot (1.5 m × 2.0 m) and converted into seed yield ha^{-1}.

Statistical analysis

All data were analyzed statistically as per the used design following the one way analysis of variance technique and the mean differences were adjusted with Duncan's Multiple Range Test using the statistical computer package programme, MSTAT-C (Russell, 1986). Microsoft excel was used for graphical presentation.

Conclusion

In addition to superior characters for yield components, a high yielding lentil genotype should possess a relatively higher growth rate at early growth stages and having capacity to better dry matter partitioning to economic yield. Among the mutants/cultivar, ML-1018 produced the highest seed yield ha^{-1} and HI with earliest maturity time, which may fit in the existing cropping pattern in Bangladesh.

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