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ORIGINAL RESEARCH ARTICLE



Agro-morphological characterization of flax (*Linum usitatissimum* L.) accessions at north-western part of Bangladesh

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ABSTRACT

Flax (*Linum usitatissimum* L.), grown throughout the world for millennia. It is a multipurpose agricultural crop that can provide food, fuel and fibre. An agro-morphological characterization based on 13 traits of 26 flax accessions was carried out during the Rabi season 2017-2018 at the Agricultural Research Station, Bangladesh Agricultural Research Institute, Rangpur. The field experiment was laid out in a randomized completed block design having four replications. Flax seeds were sown in 3.0 m × 0.6 m plot with continuous line sowing (two lines). The seed germination (%) and vigour indices of all flax accessions varied from 44.1 – 77.7 and 44.1 – 119.4, respectively. A significant variation in all growth and yield attributing descriptors was observed except 1000-seed weight of flax. Among the accessions, BD-10708 possessed the highest seed yield (182.9 g plant⁻¹) and yield attributing descriptors viz., number of capsules plant⁻¹ (142) and seeds plant⁻¹ (513) of flax. The performance of the local accession Ulipur was observed poor compared to some of the test accessions of flax. Some of these flax accessions could be used as breeding materials in varietal developmental and improvement programmes with higher yield potentials of flax in Bangladesh.

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INTRODUCTION

Flax (*Linum usitatissimum* L.; Family Linaceae) is probably one of the most ancient plants among industrial crops cultivated for either its seeds or fibres (Deyholos, 2006). Depending on the aim of its cultivation, flax is separated in two types, i) oleaginous flax, for the production of oil and ii) fibre (or textile) flax (Goudenhooff et al., 2017; Patial et al., 2019). Flaxseeds (also called as linseeds) are a rich source of micronutrients, dietary fibre, manganese, vitamin B₁ and the essential fatty acid viz. alpha-linolenic acid (ALA) or omega-3 (Nôžková, 2016; You et al., 2019). Flax is the source of products (fibres) for existing high-value markets in the textile, composites, paper/pulp and industrial/nutritional oil sectors (Hamilton, 1986; Sharma and Van Sumere, 1992; You et al., 2019); is the source of industrial fibres and as currently processed, results in the long line (fibres) and short (i.e., tow) fibres (Van Sumere, 1992). Long fibre is used

in linen apparel, linen fabrics, damasks, lace, sheeting and banknote printing industries, while short fibre is used for manufacturing lower value products like twine, rope, canvas and webbing equipment, etc. (Dhirhi et al., 2015). Another popular use of flaxseeds oil is an ingredient in many wood finishing products, paint, varnish, finished leather and printing ink; flax is also grown as an ornamental plant in gardens.

Despite the huge benefits of flaxseed, it is grown in only 3.26 m ha with an annual production of 3.18 m tonnes in the world (<http://www.fao.org/faostat/en/#data/QC/visualize>). Although 41% of the total production was grown in Asia, flax is one of the most neglected crops of developing countries like Bangladesh and is grown on marginal land with poor management. The average productivity is also very low as compared to other countries; hence, there is an urgent need to increase productivity by breaking the present yield barrier and developing high yielding varieties through the introduction of new germplasm,

collection of local ecotypes and adopting interspecific hybridization (Patial et al., 2019). In Bangladesh, flax was cultivated in only 5,700 ha of land, producing 4,000-ton seed in the year 2017-2018; on the contrary, it has imported flax tow waste of Tk. 270.45 million (BBS 2019). Low productivity of the crop, sensitivity to fungal diseases, damage by pests, poor response to chemical fertilizers and competition with weeds are major constraints on cultivation of the flaxseed crop. A poor yield of this crop is attributed to the unavailability of improved cultivars, the only recommended cultivar BARI Tishi-1, to suit the diverse agro-climatic conditions. Moreover, flax cultivation is also getting less importance due to competition of other high-valued rabi (winter) crops, although some farmers are still cultivating it with less attention to meet up only their family uses. It is now being cultivated in limited areas in char lands as border crop or as a mixed crop with onion, coriander, etc. The limitation of lands under flax cultivation challenges researchers and farmers to produce more fibre and seed yield per unit area by planting high yielding varieties and through improved agricultural practices. Hence, the development of cultivars with high yielding potential becomes the top priority to overcome the poor yield levels (You et al., 2019). The agro-morphological characterization and selection is one of the oldest methods for varietal improvement of any crop. The availability and knowledge about the extent of genetic diversity of existing resources play a major role in identifying parental lines and developing new varieties with desirable traits (Mohammed et al., 2017; You et al., 2019). The present study, therefore, aimed to characterize and evaluate yield performances of 26 flax accessions in the north-western region of Bangladesh.

MATERIALS AND METHODS

The experiment was conducted at Agricultural Research Station, On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Alamnagar, Rangpur during November 2017 to March 2018. The experimental site was under agro-ecological zone (AEZ)-3. Out of Twenty-six flax accessions, twenty-five were collected from Plant Genetic Resource Centre, BARI, Gazipur and one was collected from a farmer's field in Ulipur (Kurigram), Bangladesh.

A seed germination experiment was laid out in a completely randomized design with four replications. Seeds of accession number BD-10708 and BD-10709 were not included (discern) in germination test due to little amount of seeds available. From each genotype, 50 healthy flaxseeds were spread uniformly on each Petri-dish using (kitchen) tissue paper as a medium of growth. The observations like germination percentage, vigour index, shoot and root length were recorded. The cumulative germination (CG) percentage of flaxseeds was counted daily up to 10 days (Bewley and Black, 1994).

$$CG (\%) = \left(\frac{\sum n}{N} \right) \times 100$$

Where n is the number of seeds germinated at each day and N is the total number of seeds sown.

Vigour index (VI) was calculated based on the percentage of seed germination and the mean length of shoot and root (Shreelalitha et al., 2015).

VI= (Mean shoot length + Mean root length) × germination percentage.

The field trial was laid out in a randomized completed block design having three replications. Individual plot size was 3.0 m × 0.6 m (two lines) with continuous line sowing. Seeds were sown with a depth of 2 cm with the help of hand tine. The recommended doses of fertilizer and manures for flax cultivation were applied (BARC, 2012). Intercultural operations were done as and when necessary. Seeds of all flax accessions were sown on 26 November 2017 and were harvested from 10–23 March 2018. The maximum and the minimum temperature (prevailing in the study area) were presented in Figure 1. The growth and yield attributing descriptors, viz. plant height (cm), number of branches plant⁻¹, number of capsules plant⁻¹, number of unfilled and effective capsules plant⁻¹, number of seeds capsule⁻¹, number of seeds plant⁻¹, 1000-seed weight (g) and seed yield (g plant⁻¹) of flax were recorded.

Data were analyzed statistically following the analysis of variance (ANOVA) technique, using Statistix 10 software package and means were separated by Duncan's new multiple range test (DMRT) at 5% level of significance.

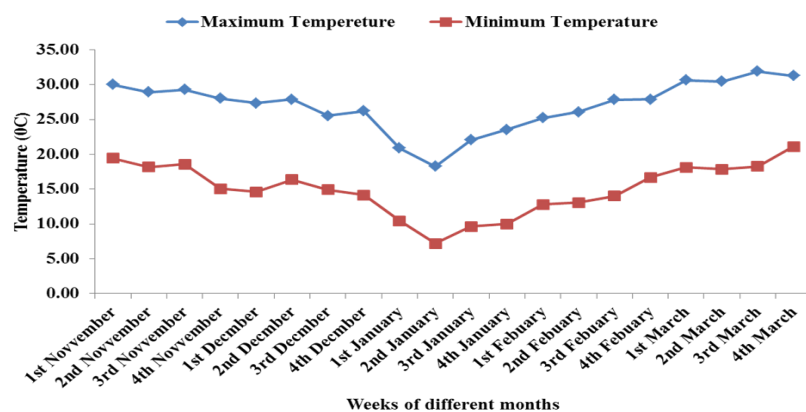


Figure 1. Weekly average maximum and minimum temperature (°C) during the flax growing Rabi season of 2017-2018 at Rangpur. (Source: Regional Meteorological Station, Rangpur).

RESULTS AND DISCUSSION

All growth and yield attributing descriptors were significantly varied among the all flax accessions. Germination percentage of flaxseed varied from 44.1% (#BD-9944) to 77.0% (#BD-10707) (Table 1). A similar report of significant variation in germination percentage of flaxseed due to the genotype was also mentioned by Kurt (2010). The seeds were stored in long-term storage; this may one of the causes for low germination count in this study. Kurt (2010) reported that the flax seed germination was influenced by seed coat colour and location. However, seed coat colour has a little or no influence in the seed germination percentage in this study. Shoot and root lengths were also significantly varied among the flax accessions; the vigour indices varied from 44.1 (#BD-9944) to 119.4 (#BD-10707) shown in Table 1. It indicated that the germination percentage of flax has a pronounced effect on vigour indices. High variation in seedling vigour may be formed from heterogeneity in collected accessions (Mezghani *et al.*, 2014).

All the parameters studied varied significantly among the accessions under trial except the number of seeds capsule⁻¹, capsules plant⁻¹ and 1000-seed weight of flax (Table 2). The longest plant was recorded in the accessions BD-10709 (70.33 cm) which was statistically similar with BD-7140 (65.67 cm). Statistically lowest identical plant height was obtained in BD-7145 and BD-10704 (55.33 and 55.67 cm) which were statistically similar to that of accessions Ulipur (56.33 cm). Plant height of flax was negatively associated with seed yield and oil content, but it was positively associated with straw and fibre yield (Fila *et al.*, 2018). However, the plant's height of accessions studied was relatively lower than standard fibre yielding cultivars (Goudenhooff *et al.*, 2019). The fibre yielding flax cultivars are commonly tall (100-125 cm) and erect (straight growing) with fewer secondary branches. The accession BD-10702 produced significantly the highest (7.33) number of branches plant⁻¹ which was statistically similar to that of the BD-10697 (6.67) and identically lowest number of branches plant⁻¹ was recorded in BD-7141 (3.67) and BD-7147 (4.0). The number of branches plant⁻¹ possesses significant correlation with seed yield of flax (Savita *et al.*, 2011).

Table 1. Seed and seedling descriptors of 26 flax accessions at 10 days after sowing.

Accession	Seed-coat colour	Cumulative germination (%)	Shoot length (cm)	Root length (cm)	Vigour index
BD-10696	Brown/Dark Brown	67.9 a-c	3.17 a-c	2.86 a-e	75.3
BD-10697	Brown/Dark Brown	73.0 ab	3.38 a-c	3.67 a-d	67.2
BD-10698	Brown/Dark Brown	69.0 a-c	3.62 a-c	2.78 b-e	89.8
BD-10699	Brown/Dark Brown	66.9 a-c	3.29 a-c	2.79 b-e	78.9
BD-10700	Brown/Dark Brown	62.8 a-d	3.61 a-c	3.10 a-e	73.1
BD-10701	Brown/Dark Brown	67.9 a-c	3.88 a-c	2.77 c-e	95.1
BD-10702	Brown/Dark Brown	64.9 a-d	3.64 a-c	2.71 de	87.2
BD-10703	Brown/Dark Brown	62.9 a-d	3.45 a-c	3.16 a-e	68.7
BD-10704	Brown/Dark Brown	68.0 a-c	3.86 a-c	3.17 a-e	82.8
BD-10705	Brown/Dark Brown	68.9 a-c	3.49 a-c	2.69 de	89.4
BD-10706	Brown/Dark Brown	72.0 ab	3.34 a-c	3.27 a-e	73.5
BD-10707	Brown/Dark Brown	77.0 a	4.03 a-c	2.61 e	119.4
BD-10708	Blackish	n.d.	n.d.	n.d.	n.d.
BD-10709	Brown/Dark Brown	n.d.	n.d.	n.d.	n.d.
BD-10710	Brown/Dark Brown	72.0 ab	3.39 a-c	2.91 a-e	83.9
BD-10711	Brown/Dark Brown	60.8 a-e	3.48 a-c	3.17 a-e	66.7
BD-7140	Brown/Dark Brown	73.9 ab	3.98 a-c	2.88 a-e	102.1
BD-7141	Brown/Dark Brown	52.9 c-e	3.79 a-c	3.29 a-e	60.9
BD-7142	Brown/Dark Brown	62.8 a-d	3.81 a-c	3.23 a-e	74.1
BD-7143	Brown/Dark Brown	52.8 c-e	3.50 a-c	2.94 a-e	62.9
BD-7144	Brown/Dark Brown	61.0 a-e	3.39 a-c	3.04 a-e	68.0
BD-7145	Brown/Dark Brown	48.1de	3.25 a-c	3.30 a-e	47.4
BD-7146	Brown/Dark Brown	60.2 a-e	3.12 c	2.86 a-e	65.7
BD-7147	Brown/Dark Brown	57.0 b-e	3.27 a-c	2.94 a-e	63.4
BD-9944	Brown/Dark Brown	44.1 ef	3.90 a-c	3.90 a	44.1
Ulipur	Brown/Dark Brown	51.0 c-e	4.18 a	3.82 ab	63.1
LSD		18.62	1.01	1.05	n.d.
CV		18.14	17.1	20.51	n.d.

n.d. not discern; In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT at 5% level).

Table 2. Yield and yield contributing attributes of 26 flax accessions.

Name of accessions	Plant height (cm)	Branch plant ⁻¹ (no.)	Capsules plant ⁻¹ (no.)	Filled capsules plant ⁻¹ (no.)	Unfilled capsules plant ⁻¹ (no.)	Seeds capsule ⁻¹ (no.)	Seeds plant ⁻¹ (no.)	1000-seed weight (g)	Seed yield (g plant ⁻¹)
BD-10696	61.67 b-f	4.33 e-g	49.00 fg	42.33 e-h	6.67 c-e	7.00 a-c	256.7 g-i	3.20	80.58 j
BD-10697	65.67 ab	6.67 ab	53.33 e-g	46.00 e-h	7.33 c-e	5.67 a-e	217.0 kl	3.25	68.66 o
BD-10698	70.33 a	4.33 e-g	47.67 fg	40.67 e-h	7.00 c-e	6.33 a-e	206.7 lm	3.29	63.70 q
BD-10699	62.33 b-f	5.67 b-e	38.00 g	26.33 h	11.7 a	7.33 ab	152.3 n	3.22	49.79 s
BD-10700	63.33 a-e	5.00 c-g	53.33 e-g	46.33 e-h	7.00 c-e	6.33 a-e	248.3 g-k	3.37	81.58 i
BD-10701	60.00 b-f	4.33 e-g	50.33 fg	40.00 f-h	10.3 ab	6.67 a-d	226.0 i-l	3.23	70.65 mn
BD-10702	63.00 b-e	7.33 a	45.33 fg	38.33 f-h	7.00 c-e	6.33 a-e	198.7 lm	3.22	63.20 q
BD-10703	61.67 b-f	4.33 e-g	43.67 fg	37.67 f-h	6.00 de	7.00 a-c	230.0 h-l	3.23	70.15 n
BD-10704	55.67 f	5.67 b-e	61.00 d-g	49.33 e-h	11.7 a	5.67 a-e	223.0 j-l	3.22	71.15 m
BD-10705	63.33 a-e	6.00 a-d	48.67 fg	41.33 e-h	7.33 c-e	6.33 a-e	216.0 kl	3.37	72.14 l
BD-10706	61.00 b-f	4.67 d-g	78.00 c-e	66.33 b-e	11.7 a	6.33 a-e	349.0 bc	3.23	108.9 c
BD-10707	59.00 b-f	4.67 d-g	94.33 b	86.67 b	7.67 cd	4.67 c-e	375.7 b	3.22	119.8 b
BD-10708	63.00 b-e	4.67 d-g	142.0 a	135.0 a	7.00 c-e	4.67 c-e	513.0 a	3.23	182.9 a
BD-10709	70.33 a	4.67 d-g	90.33 bc	84.67 bc	5.67 de	4.33 de	311.0 de	3.22	99.95 e
BD-10710	65.00 a-c	6.33 a-c	58.33 e-g	51.00 e-h	7.33 c-e	7.00 a-c	300.3 ef	3.37	97.47 f
BD-10711	60.33 b-f	5.00 c-g	43.33 fg	36.33 f-h	7.00 c-e	6.00 a-e	183.0 mn	3.23	58.73 r
BD-7140	65.67 ab	4.67 d-g	46.33 fg	36.00 f-h	10.3 ab	7.33 ab	227.3 i-l	3.22	69.16 o
BD-7141	58.33 c-f	3.67 g	39.00 g	34.00 gh	5.00 e	7.00 a-c	201.3 lm	3.23	64.69 p
BD-7142	57.67 d-f	5.33 b-f	62.67 d-g	55.00 d-g	7.67 cd	5.33 a-e	254.3 g-j	3.22	81.08 ij
BD-7143	63.00 b-e	6.00 a-d	84.00 b-d	79.00 b-d	5.00 e	4.00 e	250.3 g-j	3.37	81.08 ij
BD-7144	58.67 b-f	4.00 fg	55.00 e-g	49.33 e-h	5.67 de	5.0b c-e	214.0 lm	3.23	68.66 o
BD-7145	55.33 f	4.67 d-g	48.30 fg	39.33 f-h	9.00 bc	7.67 a	261.3 gh	3.22	79.59 k
BD-7146	62.00 b-f	5.00 c-g	56.00 e-g	48.00 e-h	8.09 b-d	6.33 a-e	268.0 fg	3.23	86.05 h
BD-7147	57.00 d-f	4.00 fg	67.33 c-f	60.67 c-f	6.67 c-e	6.33 a-e	342.0 cd	3.22	103.4 d
BD-9944	64.00 a-d	6.00 a-d	56.33 e-g	47.67 e-h	8.67 bc	6.67 a-d	275.3 fg	3.37	92.01 g
Ulipur	56.33 ef	5.00 c-g	50.33 fg	40.00 f-h	10.3 ab	7.33 ab	250.7 g-j	3.27	81.58 i
LSD	7.16	1.63	25.35	25.88	2.40	2.46	32.88	0.26	0.49
CV	7.08	19.60	25.74	30.23	18.66	24.36	7.72	4.98	0.36

In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT at 5% level).

The number of capsules plant⁻¹ was counted highest in BD-10708 (142.0) and the lowest was found in BD-10699 (38.0) which showed no significant variations with that of BD-7141, BD-10711, BD-10703, BD-10702, BD-7140, BD-7154, BD-10696, Ulipur, BD-10698 and BD-10701. Badwal *et al.* (1971) reported that capsules number and 1000-seed weight were the most important yield components and the best criteria for selecting high yielding linseed lines. The number of seeds capsule⁻¹ was found highest in BD-7145 (7.67) which varied non-significantly with the identical value (7.33) in BD-10699, BD-7140 and Ulipur. The lowest number of seeds capsule⁻¹ was counted in BD-7143 (4.0). The identical and highest unfilled capsules plant⁻¹ (11.67) was counted in BD-10699 and BD-10704 having no significant variations with that of BD-10701, BD-7140 and Ulipur (Table 2). In contrast, the lowest and identical unfilled capsules plant⁻¹ (5.0) was found in BD-7141 and BD-7143 followed by BD-7144 and BD-10709 both produced the identical value 5.67. The accessions BD-107089 gave the highest (135.0) number of effective capsules plant⁻¹ while the lowest was observed in BD-10699 (26.33). In case of the number of seeds plant⁻¹, accession BD-10708 produced the statistically highest (513) number of seeds while it was found lowest in BD-10699 (152.3). 1000-seed weight of the studied accessions didn't vary significantly which ranged from 3.20 g to 3.37 g. The 1000-seed weight of these accessions are

comparatively lower than accessions of other countries (Worku *et al.*, 2015); that may be one of the major causes of lower flaxseed yield in Bangladesh. Considering the seed yield, BD-10708 produced significantly the highest seed yield (182.9 g plant⁻¹) whereas the lowest was measured in BD-10699 (49.79 g plant⁻¹). In flax, yield and its components such as 1000-seed weight, the number of seeds capsule⁻¹, and capsules plant⁻¹, are quantitatively inherited and controlled by many genes affected by multiple genes interactions and the environment (Guo *et al.*, 2020).

Conclusion

This investigation concluded that the flax accession BD-10707 performed better at the seed germination stage of flax with higher vigour compared to other accessions. Moreover, BD-10708 was found to be the highest seed yielding accession under field trial. The performance of the local flax collection Ulipur was observed poor compared to some of the test accessions. Hence, there is an ample scope to introduce high yielding accession/genotype(s) for the increment of productivity at extrapolation areas in the country. As it was based on one year trial, the experiment should be repeated to another year for more confirmation including BARI Tishi-1 as a check.

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Conflict of interest

We do not have any conflict of interest.

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