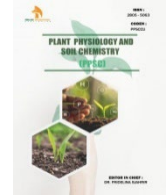




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RESEARCH ARTICLE

ASSESSING THE PATTERN OF SEED DEVELOPMENT AND PHYSIOLOGICAL MATURITY OF SUMMER COUNTRY BEAN (*LABLAB PURPUREUS* L.) IN ACID SOIL

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ABSTRACT

Country bean is a winter crop valued for seeds and young twigs for vegetable purpose, and now it also cultivated in summer season for the introduction of photo-insensitive genotypes. Seeds of country bean are high source of protein and the amount of protein is highest at physiological maturity stage. For this, the experiment was conducted to identify the physiological mature stage of seed in the summer season as this stage is indicated by the maximum deposition of dry matter and the proper time of harvest to gain maximum benefit. Four genotypes of country bean (Sikribi Sheem-1, Sikribi Sheem-2, IPSA-2 and SB-003) were investigated in the summer season. The field experiment was done in RCBD with three replications. Randomly 10 pods/replication were harvested at three days intervals from 12 DAF up to 30 DAF and data were collected. Statistical analysis have been done with the help of R software. It was found that SB-003 produced the highest fresh weight (67.57 g). Sikribi Sheem-1 was also good at pod production (65 g). Though Sikribi Sheem-1 and SB-003 showed better performance over Sikribi Sheem-2 and IPSA-2, all the genotypes showed better performance in pod production at 21 DAF. Highest seed weight (10.3 0.13) found at 27 DAF and seed dry weight increased gradually and maximum at 27 DAF. Seed dry weight of 10 seeds varied from 6.92 to 8.02 for different genotypes. Dry matter content of the seed was highest (34.46%) at 27 DAF after that it started to decrease. Cotyledon DM (38.32%) and shell DM (29.77%) were also highest at 27 DAF. Other seed growth parameters increased up to 27 DAF and for all the genotypes after that, it started to decrease. It is concluded that 27 DAF is considered as physiological maturity stage for country bean seed production in summer season in acid soil and 21 DAF is considered as the proper time of harvest for vegetative purpose.

KEYWORDS

Seed, Physiological maturity, pattern, bean, acid soil

1. INTRODUCTION

Country bean (*Lablab purpureus* L.) is a major vegetable of Bangladesh which belongs to the family "Fabaceae" under the sub-family Papilionaceae. It is a multi-purpose self-pollinated legume crop which is mostly cultivated in winter season and commonly known as "sheem" in our country. Cross-pollination also can see due to insect mediation. These multi-purpose legume crops are grown for vegetables and forage (Tefera et al., 2006). Green pods of this legume crop are used as a vegetable. Dry seeds of this legume crop are also used in various food properties (Sultana, 2001). It is distributed in the tropics and subtropics, but it is commonly found in Asia and Africa (Parmar et al., 2013; Pengally and Maass, 2001). In Ethiopia huge wild variations of lablab bean are present. Thus, some publications considered Ethiopia as the center of origin of the lablab bean (Maass, 2006). It is commonly cultivated in tropical countries in the world and is mainly cultivated in Egypt, Sudan, and India (Pratap and Kumar, 2011). In Bangladesh, it is cultivated in all districts and now it is commercially cultivated in Comilla, Noakhali, Sylhet, Kishorgonj, Tangail, Jessor, Pabna, and Dinajpur (Sharmin et al., 2018)

Lablab bean is a short-day crop and for this, its cultivation is limited in the winter season. The critical day length for lablab beans is not more than 12 hours (Anne Sennhenn et al., 2017). In our local market, it is only found in the winter season because of its photo sensitivity. In recent years some photo-insensitive varieties of lablab bean developed by the researcher of

Bangladesh Agricultural Research Institute, Sylhet Agricultural University, Bangabandhu Sheikh Mujibur Rahman Agricultural University and BRAC Agricultural Research and Development Centre (Biswas, 2016; Islam, 2016). For this nowadays it is widely cultivated through the year Bangladesh. Sikribi Sheem-1, Sikribi Sheem-2, IPSA Sheem-2, SB-3, BARI Sheem-7, Usha, Borsha, Maya, etc are some popular photo-insensitive genotypes of lablab bean which cultivated in all seasons of the year. April to May and August to October is considered as the off-season for vegetables production (FAO, 2014). Vegetable production in the summer season in Bangladesh is very low, therefore the varieties of lablab beans which are photo-insensitive can play a vital role to meet up with the demand for vegetables as well as protein demand. Moreover, the demand for lablab beans is high during the off-season and the price is 3-4 times higher than in winter. Lablab beans contain balance nutrition and a huge amount of health-promoting compounds like phytochemistry. Day by day the consumption of lablab beans is increasing internationally (Kader et al., 2004; Hounsoume et al., 2008).

The deposition of maximum dry matter in the seed indicates the physiological maturity stage (Das and Fakir, 2014). In mature seeds contents of Protein, carbohydrate, lipid, Crude fiber and ash varied from different ranges (Barnali Sarma et al., 2010). It also contains Carbohydrate, minerals, vitamins, fiber and essential fatty acids (Mortuza et al., 2009; Mohan et al., 2009). For the presence of all this property, it

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can play a significant role in food security and better nutrition. At present mature seeds are exporting many countries by air and ship (Haq et. al., 2016). A good number of researches on country beans were conducted in the past. Some research conducted focusing on physiological maturity in the winter season. But there is hardly any literature available on the physiological maturity of summer country beans in acid soil. However, adequate information on the proper harvesting time of summer country bean is essentially important for the growers. Therefore, this study was carried out to identify the proper time of harvest to obtain mature seeds for consumption and to assess the stage of physiological maturity (PM) in the summer season.

2. MATERIALS AND METHODS

2.1 Site selection

Year	Month	Average temperature (° C)		Average rainfall (mm)	Relative humidity (%)
		Maximum	minimum		
2022	January	24.28	13.6	8.6	69
	February	27.9	15.2	3.8	54
	March	32.1	18.3	22.4	52
	April	32.9	21.2	24.8	58
	May	32.3	25.4	27.6	78
	June	32.8	27.1	33.4	81
	July	34.6	24.9	24.9	82
	August	34.8	26.1	19.5	75
	September	31.2	24.1	14.2	78
	October	30.6	23.4	31.1	76
	November	29.8	21.2	3.2	71
	December	25.7	14.6	0.4	66

Source: Regional Meteorological Office, Sylhet-3100

2.1.4 The soil of the experimental site:

Detailed data about the soil of the experimental site was collected from Soil Resources Development Institute (SRDI), Sylhet which shown in Table 2.

Morphological features	Characteristics
Soil series	Khadimnagar
Soil tract	High land
Soil group/Type	Sandy loam
Soil color	
➤ Surface	Deep brown
➤ Sub-surface	Pale brown
➤ Lower surface	Pale/brown

Source: Soil Resource Development Institute (SRDI), Regional Laboratory, Sylhet-3100

2.2 Land preparation and seed sowing

2.2.1 Planting materials

In this study, four genotypes of lablab beans (Sikribi Sheem-1 (G1), Sikribi Sheem-2 (G2), IPSA Sheem-2 (G3) and SB-003 (G4)) were collected from the Department of Horticulture, Sylhet Agricultural University and used to identify the proper time of harvest and to assess the stage of physiological maturity.

2.2.2 Experimental design and layout

The field experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each block consists of four plots comprised of four genotypes, each one having one pit. The size of the block was 8 m² (8m×1m) and the size of each plot was 2 m² (2m×1m). About 0.5 m distance was laid out between block to block to drain out excess water. The treatment combination was presented in Table 3

2.1.1 Experimental site

The location of the experimental site is the north-east corner of Bangladesh (Sylhet district) and it laying between 23°57' to 25°13' North latitude and 90°57' to 92°21' East longitude. It falls under the AEZ-20 (Eastern Surma-Kusiyara Floodplain). The elevation of the site is 30m above sea level.

2.1.2 Duration of the experiment

The experiment was carried out during the period from March 2022 to June 2022.

2.1.3 The climate of the experimental site

Details of meteorological data for 2022 were collected from the weather station of Sylhet and presented in the Table 1.

S1G1	S1G4	S1G3
S1G2	S1G3	S1G1
S1G3	S1G2	S1G4
S1G4	S1G1	S1G2

Here, G groups means different genotypes and S means summer season.

2.2.3 Preparation of land

The experimental land was first opened by using a spade and subsequently spading to obtain desired tilth for a good crop stand. The land was prepared by trimming and by removing weeds, stubbles and crop residues to make the field free from a host of diseases and insects. As the land was acidic in nature, lime was applied in the field @ 4 kg per decimal. Cowdung was applied during final land preparation at the rate of 10 tons/ha. Then the surface of the land was leveled and the layout was done as per experimental design. Irrigation channels were made around each block to restrict the lateral run-off of irrigation water and the removal of excess water.

2.2.4 Pit preparation

About 50cm×50cm×50cm size pit was dug and left for sundry. The soil was pulverized well and mixed with the basal dose of fertilizers. The pit was prepared in such a way that the top level of the pit 10 cm above the ground level drains out excess water. Pits were prepared two weeks before the sowing of the seeds.

2.2.5 Sowing of seeds

For the experiment, five seeds of each genotype (Sikribi Sheem-1, Sikribi Sheem-2, IPSA Sheem-2, SB-003) were sown in each pit on 18 march 2022. The soil of the pit was well prepared mixing sandy loam soil with well-decomposed cow dung at a 50:50 ratio. Watering was done just after the sowing of seeds for proper germination of seeds.

2.3 Intercultural operation

All sorts of intercultural operations such as thinning and gap filling, manuring and fertilization, stacking, Weeding and mulching, Irrigation

and drainage and Pest and disease control were performed following standard protocol.

2.4 Tagging and harvesting

2.4.1 Tagging of flower

For the collection of data on various days after flowering (12,15,18,21,24,27,30 DAF) to identify the proper stage of harvesting and physiological maturity, the flowers were tagged on the days of blooming with different colors of woollen threads.

2.4.2 Harvesting

For estimation of pod and seed growth, 5 pods from each block randomly for one genotype that is 15 pods/genotype from three blocks were harvested. Pods were harvested by hand at 3 days intervals from 12 days after flowering (DAF). The harvested pods were brought to the laboratory for the collection of data.

3. DATA COLLECTION

3.1 Collection of data in laboratory

The harvested pods were brought to the laboratory and data in regard to different parameters were recorded.

3.1.1 Pod growth behavior

For estimation of pod growth behavior 10 pods from each replication which means 30 pods for each genotype were collected at 3 days intervals from 12 days after flowering (DAF) and taken into the laboratory and individual pod weight (g), pod length (cm), pod breadth (cm), beak length (mm), pericarp fresh weight (g) and pericarp dry weight (g) were measured.

3.1.2 Seed growth behaviour

The harvested pods were split open to obtain seed from them and no. of seed, seed length (mm), seed breadth (mm), seed thickness (mm), cotyledon fresh weight (g), cotyledon dry weight (g), shell fresh weight (g) and shell dry weight (g) were measured.

3.1.3 Dry matter (DM %)

Dry matter (DM%) of seed, seed cotyledon and seed shell were calculated using the following equation (AOAC, 2010)

$$DM (\%) = \frac{\text{Dry Weight (g)}}{\text{Fresh Weight (g)}} \times 100$$

3.2 Statistical analysis

The recorded data on different parameters were statistically analyzed with the help of R software (R Gui ×64 3.6.0) to get an analysis of variance (ANOVA). The mean differences were calculated by Duncan's Multiple Range Test. By paired sample test level of significance and t-value were measured.

4. RESULTS

4.1 Effect of genotypes

4.1.1 Pod growth behavior

Fresh weight was greatly associated with ultimate pod yield. G1 showed better performance in terms of pod length, beak length, pod fresh weight, pericarp fresh weight and pericarp dry weight production followed by G2 and G3 (Table 4.1). G4 was also showed similar performance as G1 except pod width production and in addition G4 genotype was showed better performance in pod length production (9.8±0.22) followed by other genotypes (Table 4). Highest pericarp dry matter (11.4±0.16) accumulation was found in G3 (Table 4).

Table 4: Effect of genotypes on pod growth

Genotypes	Pod length (cm)	Pod width (cm)	Beak length (cm)	Pod fresh weight (10 pods)	Pericarp fresh weight	Pericarp dry weight	Pericarp DM
G1	8.33b ± 0.1	2.86a ± 0.04	6.92 ± 0.36	65a ± 1.52	49.6a ± 1.08	5a ± 0.15	10.08c ± 0.21
G2	7.27c ± 0.12	2.41c ± 0.05	7.32 ± 0.41	53.99b ± 2.66	37.44b ± 1.38	4.09b ± 0.19	10.9b ± 0.21
G3	6.11d ± 0.06	1.98d ± 0.03	6.63 ± 0.36	48.7c ± 2.03	32.58c ± 0.8	3.71c ± 0.1	11.4a ± 0.16
G4	9.8a ± 0.22	2.52b ± 0.02	7.19 ± 0.33	67.57a ± 2.45	50.92a ± 1.58	5.19a ± 0.15	10.22c ± 0.13
Level of significance	***	***	NS	***	***	***	***
p-value	< 2e-16	< 2e-16	0.36	7.22e-14	< 2e-16	< 2e-16	1.79e-11

4.1.2 Seed growth behavior

G2 showed better performance in terms of no. of seed (41.67±0.63), seed width (8.72±0.35) and seed thickness (5.54±0.25) production followed by G1, G3 and G4 (Table -5). G1 showed almost similar performance with G2

in terms of no. of seed production and in seed width and seed thickness G3 showed almost similar performance with G2. In case of seed length production G4 (14.87±0.38) showed better performance followed by other genotypes (Table 5).

Table 5: Effect of genotypes on seed growth

Row labels	No. of seeds in 10 pods	Seed length (mm)	Seed width (mm)	Seed thickness (mm)
G1	40.11ab ± 0.44	14.32b ± 0.3	8.42b ± 0.33	4.88c ± 0.19
G2	41.67a ± 0.63	13.78c ± 0.28	8.72a ± 0.35	5.54a ± 0.25
G3	37.56c ± 0.66	13.34d ± 0.39	8.56ab ± 0.39	5.34ab ± 0.32
G4	38.67bc ± 0.9	14.87a ± 0.38	8.46b ± 0.36	5.14b ± 0.18
Level of significance	**	***	*	***
p-value	0.00122	1.66e-12	0.02256	1.27e-05

4.1.3 Seed weight production

In seed weight and seed dry matter production variations were found among genotypes (Table-6). G4 was showed better performance in seed fresh weight (17.08±1.32), cotyledon fresh weight (10.41±0.91) and shell fresh weight (6.15±0.38) production over genotypes G1, G2 and G3 (Table

4.3). G1 and G3 were showed almost similar performance in fresh weight (seed fresh weight, cotyledon fresh weight and shell fresh weight) production. But in case of dry weight and dry matter production G3 was showed better performance except shell dry weight and shell dry matter production (Table 6).

Table 6: Effect of genotypes on seed weight production

Row labels	Seed fresh weight (10 pods)	Seed dry weight	Total seed dry matter	Cotyledon fresh weight	Cotyledon dry weight	Cotyledon DM	Shell fresh weight	Shell dry weight	Shell DM
G1	15.11b ± 1.07	3.85c ± 0.49	23.87c ± .73	9.27b ± 0.76	2.6c ± 0.39	25.54b±2.14	5.44c±0.26	1.25b±0.11	22.39a±1.21
G2	16.47ab ± 1.45	4.27bc ± 0.55	24.35c ± 1.28	10.01ab±0.98	2.82bc±0.42	25.7b±1.69	5.94ab±0.44	1.45a±0.14	24.04a±1.04
G3	15.55b ± 1.4	4.75a ± 0.67	27.68a±2.12	9.42b±1.04	3.3a±0.55	30.38a±2.75	5.63bc±0.37	1.45a±0.13	23.6a±1.89
G4	17.08a±1.32	4.67ab±0.63	25.46b±1.76	10.41a±0.91	3.14ab±0.5	27.08b±2.28	6.15a±0.38	1.53a±0.13	24.3a±0.93
Level of significance	*	***	***	NS	**	***	*	***	NS
p-value	0.0276	0.000444	3.01e-08	0.0597	0.001147	1.06e-06	0.0241	1.67e-05	0.27

4.2 Effect of harvesting time

4.2.1 Pod growth behavior

Harvesting time had significant influence on pod growth behavior. Pod

growth behaviors except beak length were found highest at D21 (Table 7). Highest beak length (8.07±0.27) was found at D15, but no statistical significance was present between D12 and D15. Pod length and pericarp dry matter production were also showed similar performance at D21, D27 and D30 (Table 7).

Table 7: Effect of harvesting time on pod growth

Row labels	Pod length (cm)	Pod width (cm)	Beak length (mm)	Pod fresh weight (10 pods)	Pericarp fresh weight (10 pods)	Pericarp dry weight (10 pods)	Pericarp Dm
D12	7.23c ± 0.35	2.28d ± 0.1	7.12ab ± 0.41	44.72d ± 3.47	35.97d ± 2.85	3.75d ± 0.27	10.5bc ± 0.12
D15	7.72b ± 0.41	2.31d ± 0.1	8.07a ± 0.27	54.81c ± 2.86	43.06bc ± 2.82	4.29c ± 0.18	10.17c ± 0.34
D18	7.85b ± 0.42	2.5bc ± 0.09	8.02a ± 0.41	60.83b ± 2.56	45.99ab ± 2.65	4.64b ± 0.23	10.16c ± 0.15
D21	8.28a ± 0.44	2.58a ± 0.11	6.9b ± 0.56	66.3a ± 3.04	47.16a ± 2.81	5.15a ± 0.24	11.05a ± 0.27
D24	7.89b ± 0.44	2.45c ± 0.1	6.28bc ± 0.32	60.92b ± 2.65	41.15c ± 2.16	4.45bc ± 0.22	10.84ab ± 0.19
D27	8.31a ± 0.5	2.56ab ± 0.1	5.72c ± 0.28	65.3ab ± 2.42	42.48c ± 2.23	4.71b ± 0.2	11.2a ± 0.32
D30	8.29a ± 0.41	2.53ab ± 0.1	5.68c ± 0.27	64.73ab ± 2.73	43.26bc ± 2.19	4.83ab ± 0.29	11.17a ± 0.18
Level of significance	***	***	***	***	***	***	***
P value	2.91e-06	1.2e-12	7.26e-05	6.15e-12	3.18e-08	3.65e-11	3.34e-07

4.2.2 Seed growth behavior

Though highest no. of seed (40.67±0.93) was found at D27, harvesting

time had no significant influence on seed production (Table 8). Seed length and seed width production were found highest at D27 and D30. Highest seed thickness (6.13±0.12) was found at D24 (Table-8).

Table 8: Effect of harvesting time on seed growth

Row labels	No. of seeds in 10 pods	Seed length (mm)	Seed width (mm)	Seed thickness (mm)
D12	38.33a ± 0.92	11.95e ± 0.31	6.2f ± 0.09	3.93e ± 0.12
D15	39.5a ± 0.7	13.2d ± 0.14	7.65e ± 0.1	4.55d ± 0.13
D18	40.17a ± 0.52	13.58c ± 0.18	7.93d ± 0.11	4.9c ± 0.13
D21	39.17a ± 1.42	14.9b ± 0.31	9.17c ± 0.13	5.78b ± 0.35
D24	39.17a ± 0.87	15.13b ± 0.2	9.98b ± 0.11	6.13a ± 0.12
D27	40.67a ± 0.93	15.7a ± 0.25	10.3a ± 0.13	6.07ab ± 0.13
D30	40.38a ± 0.69	15.69a ± 0.29	10.28a ± 0.17	6.09ab ± 0.21
Level of significance	NS	***	***	***
P Value	0.49918	< 2e-16	< 2e-16	< 2e-16

4.2.3 Seed weight production

Harvesting time had significance influence on seed growth behavior (Table 9). Seed fresh weight and shell fresh weight were found highest and D27 and D30 cotyledon fresh weight was highest at D27. Cotyledon dry

weight and shell dry weight were found highest at D27 and D30 seed dry weight was found highest at D27. D24, D27 and D30 were showed almost similar performance in total seed dry matter and cotyledon dry matter production. Shell dry matter was highest (29.77±0.72) at D24 (Table 9).

Table 9: Effect of harvesting time on seed weight production

Row labels	Seed fresh weight (10 pods)	Seed dry weight	Total seed dry matter	Cotyledon fresh weight	Cotyledon dry weight	Cotyledon DM	Shell fresh weight	Shell dry weight	Shell DM
D12	8.31e±0.66	1.52e±0.13	18.11d±0.37	4.72f±0.42	0.84e±0.08	17.59d±0.18	3.5d±0.23	0.68f±0.05	19.32cd±0.69
D15	11.22d±0.48	2.03e±0.13	17.92d±0.65	6.13e±0.33	1.08e±0.09	17.45d±0.69	4.77c±0.15	0.94e±0.06	17.63d±1.83
D18	15.35c±0.44	3.31d±0.16	21.53c±0.78	8.88d±0.31	1.97d±0.11	22.33c±1.14	6.15b±0.21	1.33d±0.06	21.65c±0.51
D21	19.15b±0.73	5.01c±0.21	26.29b±0.97	11.47c±0.47	3.39c±0.18	29.71b±1.47	6.46b±0.27	1.62c±0.05	25.51b±1.15
D24	19.68b±0.95	6.84b±0.48	34.46a±1.37	12.96b±0.68	4.95b±0.41	37.65a±1.75	6.39b±0.35	1.89b±0.09	29.77a±0.72
D27	22.6a±0.75	7.61a±0.26	33.73a±0.63	14.5a±0.44	5.55a±0.21	38.32a±1	7.47a±0.25	2.06a±0.07	27.6ab±0.3
D30	21.59a±0.47	7.43ab±0.13	34.41a±0.89	14.29ab±0.31	5.48a±0.31	38.34a±0.82	7.39a±0.32	2a±0.08	27.06ab±0.54
Level of significance	***	***	***	***	***	***	***	***	***
P Value	<2e-16	< 2e-16	< 2e-16	<2e-16	< 2e-16	< 2e-16	<2e-16	< 2e-16	3.01e-13

4.3 Interaction effect of genotype and harvesting time

4.3.1 Pod growth behavior

G4 was produced highest pod fresh weight (74.83±3.37), highest pod length (3.06±0.03) at D27 and highest pericarp fresh weight (56.03±3.48),

highest pericarp dry weight (5.59±0.36) at D18 (Table 10). Dry matter accumulation was found highest (11.94±0.59) in G3 at d27. G1 genotype was produced highest pod width (3.06±0.03) at d 21 (Table-10). Combination interaction of genotype and harvesting time had no significant influence on beak length production.

Table 10: Interaction effects between genotype and harvesting time on pod growth

Row labels	Pod length (cm)	Pod width (cm)	Beak length (mm)	Pod fresh weight (10 pods)	Pericarp fresh weight (10 pods)	Pericarp dry weight (10 pods)	Pericarp DM
G1D12	8.17 ± 0.28	2.68ef ± 0.02	7.33 ± 0.33	57.61 ± 3.92	46.91 ± 2.64	4.78defgh ± 0.27	10.2defg ± 0.22
G1D15	8.34 ± 0.01	2.72de ± 0.06	8.6 ± 0.5	63.12 ± 3.49	52.78 ± 3.25	4.68fgh ± 0.2	8.89h ± 0.21
G1D18	8.11 ± 0.04	2.91bc ± 0.03	7.53 ± 0.48	66.75 ± 2.09	52.39 ± 0.91	5.07bcdef ± 0.02	9.69g ± 0.14
G1D21	8.64 ± 0.09	3.06a ± 0.03	6.47 ± 1.2	73.6 ± 0.38	53.51 ± 1.38	6.2a ± 0.08	11.59ab ± 0.15
G1D24	7.93 ± 0.13	2.82cd ± 0.06	6.6 ± 0.81	62.41 ± 1.98	45.86 ± 1.05	4.57fghi ± 0.04	9.98fg ± 0.15
G1D27	8.79 ± 0.39	2.96ab ± 0.1	5 ± 0.64	66.51 ± 3.16	46.13 ± 2.1	4.66fgh ± 0.06	10.14efg ± 0.35

Table 10 (cont): Interaction effects between genotype and harvesting time on pod growth

G1D30	8.61 ± 0.19	2.93bc ± 0.08	4.98 ± 0.53	64.86 ± 2.69	46.78 ± 1.95	4.71fgh ± 0.08	10.06efg ± 0.21
G2D12	6.54 ± 0.05	2.15j ± 0.04	7.87 ± 1.07	34.25 ± 0.69	27.53 ± 0.04	2.91i ± 0.04	10.58cdef ± 0.16
G2D15	6.91 ± 0.15	2.19j ± 0.01	7.47 ± 0.77	49.15 ± 1.73	35.9 ± 1.14	3.63k ± 0.02	10.14efg ± 0.27
G2D18	7.33 ± 0.17	2.53ghi ± 0.08	9.07 ± 1.14	53.61 ± 1.54	39.11 ± 0.45	3.93jk ± 0.01	10.06efg ± 0.1
G2D21	7.91 ± 0.18	2.63efgh ± 0.07	7 ± 1.44	66.22 ± 1.28	46.07 ± 0.63	5.05bcdef ± 0.01	10.97bc ± 0.14
G2D24	7.29 ± 0.04	2.47i ± 0.02	6.07 ± 0.7	56.39 ± 2.09	36.51 ± 0.81	4.25hij ± 0.18	11.64ab ± 0.24
G2D27	7.65 ± 0.24	2.52ghi ± 0.11	6.47 ± 0.52	64.32 ± 3.53	39.51 ± 1.79	4.77efgh ± 0.47	12.03a ± 0.65
G2D30	7.64 ± 0.27	2.43ij ± 0.13	6.38 ± 0.09	63.73 ± 2.81	37.84 ± 0.97	4.68efgh ± 0.29	12.01a ± 0.37
G3D12	5.72 ± 0.09	1.83m ± 0.03	5.4 ± 0.2	33.51 ± 1.01	26.41 ± 0.24	2.89l ± 0.08	10.95bc ± 0.27
G3D15	6.05 ± 0.08	1.87lm ± 0.02	8.6 ± 0.23	43.21 ± 1.25	32.59 ± 0.61	3.88jk ± 0.02	11.92a ± 0.17
G3D18	6.07 ± 0.07	2.07jk ± 0.03	8.27 ± 0.74	52.8 ± 1.1	36.41 ± 0.74	3.98jk ± 0.01	10.93bcd ± 0.2
G3D21	6.39 ± 0.21	2.07jk ± 0.01	5.33 ± 0.47	53.84 ± 4.11	33.88 ± 1.52	4.01ijk ± 0.07	11.87a ± 0.31
G3D24	6.23 ± 0.07	1.97kl ± 0.06	6.4 ± 0.58	53.29 ± 1.52	33.36 ± 0.36	3.6k ± 0.01	10.81cde ± 0.11
G3D27	6.18 ± 0.03	2.1jk ± 0.02	5.8 ± 0.31	55.54 ± 0.56	32.83 ± 1.13	3.91jk ± 0.07	11.94a ± 0.59
G3D30	6.13 ± 0.19	2.07jk ± 0.04	5.73 ± 0.28	54.31 ± 0.96	32.16 ± 1.23	3.80jk ± 0.08	11.83cde ± 0.21
G4D12	8.47 ± 0.21	2.44i ± 0.02	7.87 ± 0.55	53.52 ± 2.87	43.03 ± 2.34	4.41ghij ± 0.26	10.25cdefg ± 0.05
G4D15	9.56 ± 0.3	2.45i ± 0.05	7.6 ± 0.42	63.77 ± 2.16	50.97 ± 1.96	4.96cdefg ± 0.25	9.73g ± 0.13
G4D18	9.87 ± 0.23	2.51hi ± 0.04	7.2 ± 0.76	70.13 ± 4.19	56.03 ± 3.48	5.59b ± 0.36	9.97fg ± 0.08
G4D21	10.16 ± 0.77	2.54ghi ± 0.04	8.8 ± 0.2	71.55 ± 8.13	55.17 ± 5.3	5.33bcde ± 0.28	9.74g ± 0.42
G4D24	10.12 ± 0.51	2.56fghi ± 0.03	6.07 ± 0.84	71.58 ± 6.83	48.85 ± 4.37	5.35bcd ± 0.5	10.94bcd ± 0.05
G4D27	10.61 ± 0.24	2.65efg ± 0.01	5.6 ± 0.61	74.83 ± 3.37	51.46 ± 1.67	5.51bc ± 0.17	10.71cdef ± 0.1
G4D30	10.59 ± 0.28	2.63efg ± 0.02	5.7 ± 0.56	74.79 ± 3.61	49.96 ± 2.69	5.33bcd ± 0.13	10.68cdef ± 0.03
Level of significance	NS	*	NS	NS	NS	***	***
P value	0.133	0.0453	0.0758	0.222	0.152	0.00013	2.03e-06

4.3.2 Seed growth behavior

No. of seed was not influence by combined interaction of genotype and harvesting time and it was varied from 36.67 to 44.67 at different

combinations (Table 11). G4 showed better performance in seed length (16.93±0.18) and seed width (10.53±0.07) production at D27 and at D21 seed width (10.53±0.07) showed better performance (Table 11).

Table 11: Interaction effects between genotype and harvesting time on seed growth

Combination	No. of seeds in 10 pods	Seed length (mm)	Seed width (mm)	Seed thickness (mm)
G1D12	40 ± 2	12.87nop ± 0.07	6.33j ± 0.13	4.27hi ± 0.13
G1D15	40.67 ± 0.67	13lmno ± 0.12	7.33i ± 0.27	4.4fghi ± 0.12
G1D18	40 ± 1.15	13.67jklm ± 0.07	7.93gh ± 0.18	4.87efg ± 0.29
G1D21	40	15.87bc ± 0.18	9.53c ± 0.18	4.07ij ± 0.29
G1D24	40	14.93efg ± 0.27	9.47cd ± 0.13	5.73d ± 0.07
G1D27	40 ± 2	15.6bcde ± 0.23	9.93bc ± 0.29	5.93bcd ± 0.07
G1D30	40 ± 1.63	14.9efg ± 0.28	9.86bc ± 0.17	5.88bcd ± 0.09
G2D12	41.33 ± 0.67	12.2p ± 0.31	6.27j ± 0.07	3.67jk ± 0.07
G2D15	40.67 ± 1.76	13.13klmno ± 0.07	7.93gh ± 0.18	4.93ef ± 0.07
G2D18	42	13.33klmn ± 0.37	8.4fg ± 0.12	5.4de ± 0.23
G2D21	42.67 ± 1.76	13.87ijk ± 0.55	9de ± 0.12	6.53a ± 0.13
G2D24	38.67 ± 0.67	14.87efgh ± 0.24	10.13ab ± 0.07	6.33abc ± 0.07
G2D27	44.67 ± 1.76	15.27cdef ± 0.24	10.6a ± 0.12	6.4ab ± 0.12
G2D30	43.59 ± 1.21	15.13def ± 0.27	10.17ab ± 0.43	6.38abc ± 0.08

Table 11 (cont): Interaction effects between genotype and harvesting time on seed growth

G3D12	34.67 ± 0.67	10.27q ± 0.18	6j ± 0.2	3.47k ± 0.18
G3D15	38.67 ± 1.76	12.93mnop ± 0.37	7.67hi ± 0.07	4.07ij ± 0.24
G3D18	39.33 ± 1.33	13.13klmno ± 0.18	7.67hi ± 0.18	4.87efg ± 0.13
G3D21	36.67 ± 2.91	14.13hij ± 0.13	9.47cd ± 0.18	6.67a ± 0.33
G3D24	37.33 ± 0.67	14.6fghi ± 0.12	10.4ab ± 0.12	6.67a ± 0.13
G3D27	38.67 ± 0.67	15def ± 0.35	10.13ab ± 0.37	6.33abc ± 0.18
G3D30	37.06 ± 1.09	14.78defg ± 0.28	10.07ab ± 0.41	6.09bcd ± 0.37
G4D12	37.33 ± 0.67	12.47op ± 0.07	6.2j ± 0.31	4.33ghi ± 0.07
G4D15	38 ± 1.15	13.73jkl ± 0.29	7.67hi ± 0.18	4.8fgh ± 0.23
G4D18	39.33 ± 0.67	14.2ghij ± 0.5	7.73hi ± 0.07	4.47fghi ± 0.13
G4D21	37.33 ± 4.67	15.73bcd ± 0.24	8.67ef ± 0.13	5.87bcd ± 0.55
G4D24	40.67 ± 3.53	16.13b ± 0.07	9.93bc ± 0.07	5.8cd ± 0.12
G4D27	39.33 ± 0.67	16.93a ± 0.18	10.53a ± 0.07	5.6d ± 0.31
G4D30	37.93 ± 0.46	15.44cde ± 0.19	10.16ab ± 0.09	5.48de ± 0.27
Level of significance	NS	***	**	***
P value	0.80055	0.000161	0.00102	1.62e-08

4.3.3 Seed weight production

Combined interaction of genotype and harvesting time had significant influence on seed growth behavior (Table 12). G2 was produced highest seed fresh weight (24.52±1.65), cotyledon fresh weight (15.67±1.24) and shell fresh weight (8.18±0.5) at D27. But highest seed dry weight

(8.22±0.77) and cotyledon dry weight (6.03±0.57) found at D24 and shell dry weight was highest (2.24±0.15) in G2 at D27. Dry matter percentage is highest at D27 for total seed dry matter (36.47±1.24) in G4, cotyledon dry matter (44.37±0.3) in G3 and shell dry matter (30.7±2.77) in G2 (Table 12).

Table 12: Interaction effects between genotype and harvesting time on seed weight production

Combination	Seed fresh weight (10 pods)	Seed dry weight	Total seed DM	Cotyledon fresh weight	Cotyledon dry weight	Cotyledon DM	Shell fresh weight	Shell dry weight	Shell DM
G1D12	10.3j±1.14	1.93lmn±0.15	18.93ghi±0.75	5.97kl±0.7	1.08klmn±0.13	18.04hij±0.33	4.3jkl±0.29	0.86hi±0.03	19.97gh±0.72
G1D15	9.57jk±0.5	1.41mn±0.03	14.81j±0.45	5.29klm±0.29	0.82lmn±0.01	15.59j±0.67	4.13kl±0.25	0.59jk±0.02	14.4ij±0.36
G1D18	14.29ghi±0.87	2.67jkl±0.04	18.8ghi±0.81	8.55hij±0.64	1.63ijkl±0.02	19.24hij±1.15	5.43fghij±0.23	1.04hi±0.02	19.21ghi±0.38
G1D21	19.8bcde±1.51	5.18def±0.1	26.37d±1.38	11.97cde±1.22	3.52def±0.05	29.9e±2.41	6.55cdef±0.28	1.66def±0.05	25.32bcdef±0.25
G1D24	16.53efg±0.95	5efg±0.69	29.97c±2.56	10.66efgh±0.69	3.41ef±0.58	31.55de±3.56	5.62fghi±0.29	1.59efg±0.12	28.13abc±0.71
G1D27	20.16bcd±1.07	6.92bc±0.31	34.34b±0.28	13.19bcd±0.58	5.13bc±0.21	38.9bc±0.18	6.57cdef±0.47	1.79bcde±0.1	27.28abcd±0.4
G1D30	19.83bcde±0.74	6.72bcd±0.54	33.93bc±0.29	12.98bcde±0.57	4.94bc±0.23	38.06bc±0.25	6.23cdef±0.13	1.69cde±0.17	27.17abcd±0.47
G2D12	6.69k±0.76	1.24mn±0.13	18.66ghi±0.22	3.75lm±0.42	0.65mn±0.07	17.45ij±0.05	2.79m±0.3	0.59jk±0.06	21.23efg±0.69
G2D15	12.97hij±0.61	2.57jkl±0.04	19.89gh±0.79	7.4ijk±0.36	1.49jklm±0.04	20.22hi±1.06	5.25ghijk±0.25	1.08h±0.03	20.6fgh±0.49
G2D18	14.91ghi±1.29	3.09ijk±0.15	20.85fg±0.91	8.71ghij±0.98	1.73ijk±0.08	20.13hi±1.48	5.85efghi±0.37	1.36g±0.08	23.26cdefg±0.13

Table 12 (cont) : Interaction effects between genotype and harvesting time on seed weight production

G2D21	19.88bcde± 0.64	4.83efg±0. 16	24.32de±0. 65	11.81cde±0. 53	3.32efg±0.0 4	28.19ef±0.9	7.21abcd±0. 25	1.51fg±0.1 4	21.02efgh±2. 06
G2D24	19.86bcde± 1.28	6.25cd±0.4 9	31.42c±0.9 0	12.7bcde±0. 81	4.34cd±0.35	34.11d±1.0 7	6.37cdefg±0 .89	1.91bc±0.1 4	30.7a±2.77
G2D27	24.52a±1.65	7.63ab±0. 84	30.95c±1.3 4	15.67a±1.24	5.39ab±0.69	34.13d±1.6 4	8.18a±0.5	2.24a±0.15	27.4abcd±0.3
G2D30	22.64ab±0.6 3	6.78bc±0.3 7	29.98c±0.8 4	15.07a±1.08	5.13bc±0.55	34d±1.23	8.07ab±0.68	2.18ab±0.1 9	27.03bcd±0.2 1
G3D12	6.18k±0.26	1.02n±0.0 5	16.48ij±0.1 1	3.23m±0.18	0.55n±0.03	16.97ij±0.1 5	2.92m±0.15	0.47k±0.02	16.11hij±0.1
G3D15	10.39j±0.68	1.84lmn±0 .1	17.77hi±0. 55	5.21klm±0.5 1	0.8lmn±0.0 5	15.58j±0.72	4.74ijkl±0.0 6	1.04hi±0.0 5	13.97j±6.97
G3D18	16.05fgh±0. 66	4.08ghi±0. 16	25.42de±0. 52	8.89ghij±0.6 7	2.51ghi±0.1 6	28.23ef±0.3 7	6.88bcde±0. 25	1.57efg±0. 02	22.9defg±0.6
G3D21	18.35def±1. 52	5.66de±0. 27	31c±1.03	11.21def±1. 29	3.93de±0.18	35.54cd±2. 2	5.87efghi±0. 6	1.73cdef±0 .08	29.81ab±1.53
G3D24	19.7cde±1.4 2	7.89ab±0. 7	39.96a±0.7 7	13.53abc±1. 35	6.01a±0.64	44.37a±0.3	6.12defgh± 0.19	1.88bcd±0. 07	30.8a±0.73
G3D27	22.64abc±0. 6	8.02a±0.2 3	35.46b±0.8 9	14.44ab±0.4 3	6ab±0.2	41.62ab±2. 02	7.25abcd±0. 21	2.03ab±0.0 5	28.01abc±1.1 6
G3D30	21.58bc±0.5 9	7.47bc±.6	34.63bc±0. 47	13.93abc±0. 48	5.64ab±0.6	40.53ab±1. 6	7.03bcd±0.1 6	1.95bc±0.0 8	27.78bcd±0.6 9
G4D12	10.09j±0.76	1.86lmn±0 .22	18.38ghi±0 .71	5.92kl±0.42	1.06klmn±0. 11	17.91hij±0. 51	3.97lm±0.2 6	0.8ij±0.11	19.96gh±1.4
G4D15	11.93ij±0.71	2.28klm±0 .06	19.21gh±0. 67	6.63jk±0.47	1.22jklmn± 0.04	18.44hij±0. 75	4.95hijkl±0. 24	1.06h±0.02	21.56efg±0.6 6
G4D18	16.16fgh±0. 47	3.4hij±0.0 9	21.05fg±0. 02	9.37fghi±0.2 6	2.04hij±0.06	21.73gh±0. 05	6.43cdefg±0 .27	1.36g±0.04	21.23efg±0.3 3
G4D21	18.57def±2. 39	4.38fgh±0. 66	23.45ef±0. 48	10.89efg±0. 99	2.8fgh±0.58	25.21fg±2.7 5	6.21defg±0. 8	1.58efg±0. 09	25.88abcde± 1.74
G4D24	22.64abc±2. 43	8.22a±0.7 7	36.47b±1.2 4	14.93ab±1.5 5	6.03a±0.57	40.58ab±1. 46	7.46abc±0.8 9	2.19a±0.23	29.44ab±0.56
G4D27	23.11ab±1.7 6	7.89ab±0. 54	34.18b±0.5 9	14.72ab±0.8 1	5.7ab±0.43	38.64bc±0. 76	7.88ab±0.28	2.19a±0.11	27.69abcd±0. 42
G4D30	22.28bc±1.4 6	7.34bc±0.4 1	32.98bc±0. 46	14.53ab±0.6 8	5.05bc±0.46	37.89bcd±0 .67	7.41bc±0.68	1.9bcd±0.6 4	26.85bc±0.51
Level of significance	NS	***	***	*	***	***	*	***	*
P value	0.0525	0.000385	6.27e-08	0.0427	0.000266	8.36e-06	0.0156	7.83e-05	0.0204

5. DISCUSSION

Genotypes had a significant influence on pod weight. All genotypes showed variation in producing pod fresh weight. G4 (SB-003) produces the highest pod fresh weight (67.57±2.45) and G3 (IPSA-2) produces the lowest pod fresh weight (48.7±2.03). 249 genotypes in Australia and found that G4 produces the highest fresh weight (Pengelly and Maass 2001). From the result, it also found that G1 (Sikribi Sheem-1) showed almost similar performance in terms of pod fresh weight production. Statistically significant variations were observed in pod length in relation to genotype. G4 produced the highest pod length (9.8±0.22) and the lowest pod length found in G3 (6.11±0.06). G1 also showed better performance in terms of pod length. Pengelly and Maass (2001) also reported that pod length varied from 2.5 to 14 cm and seed length is a prominent character for G4. In this study, pod width varied from 1.6 to 3.2 cm (Pengelly and Maass 2001). Among the genotypes, G1 exhibit higher pod width (2.86±0.04) and it was an inherent character of the genotype. Other genotypes except G3 showed better performance in terms of pod

width. Variations were observed in pod weight production at different harvesting stages of country bean. It observed that at 21 DAF highest pod width was produced. Experiment on snap bean and stated the highest pod weight produced at 15 to 20 days after anthesis (S. Lee et. Al., 2001). It was measured by the observation of pod length, and pod width. From the result highest pod length was produced at 27 DAF. But no statistical significance was found between 21 DAF and 27 DAF. Pod width is also highest at 21. (DAF. K. K. Roy et. Al., 2014) stated that the highest pod weight production of G4 was observed at 12 to 15 days after anthesis in the winter season. In cowpea, 12 days after anthesis as the proper time of harvest for vegetative purposes because of the highest pod length production (K Krishnakmary 2012). From the result it can be stated that 21 DAF is the proper time of harvest. Pericarp dry matter accumulation is also highest at 21 DAF. The pod size of country bean was maximum at 34 DAF during the winter season. Pod length had no significant influence on the combined interaction of genotype and harvesting time (Das and Fakir 2014). But variations were observed in different genotypes. G4 produced the highest pod length at all interaction effects. But in all interactions, it found that at 21 DAF highest pod length was produced. On pod width combined

interaction of genotype and harvesting time had a significant influence. All genotypes showed better performance in terms of pod width at 21 DAF. G4 produced the highest pod width among the genotypes. G4 showed better performance in pod production (K. K. Roy et al., 2014). Although no significant influence was found in the interaction effect of genotype and harvesting time on pod length, but all genotypes produced the highest pod length at 21 DAF except G4. The number of seeds is greatly associated with seed production. Genotypes had a significant influence on seed production. The highest number of seeds was found in G2 (Sikribi Sheem-2) and the lowest number of seeds was found in G3. But total dry matter content was highest in G3. G4 showed better performance in cotyledon and shell dry matter production. But no statistical significance is present between G4 and G3 in terms of shell dry matter production. The highest dry matter accumulation indicates the physiological maturity of the seed (S.S. Das and M.S.A. Fakir 2014). And at this period nutrition content is high (S.S. Das and M.S.A. Fakir, 2014). Harvesting time had no significant influence on a seed number. But seed fresh weight was greatly influenced by harvesting time. Seed fresh weight gradually increased up to 27 ADF and after that, it started to decrease. Seed dry weight was also highest at 27 DAF and after that it started to decrease drastically. Cotyledon fresh weight and dry weight were also maximum at 27 DAF. Shell fresh weight and dry weight maximum at 27 DAF and after that, it decreases drastically. Cotyledon dry matter accumulation is highest at 27 DAF and shell dry matter accumulation is highest at 24 DAF. Experiment on country bean in the winter season and found that seed dry weight was maximum at 40 DAF (S.S. Das and M.S.A. Fakir 2014). At this time cotyledon and shell fresh weight were also maximum. They stated that at this time protein and other nutrient content was maximum and this period was considered as the physiological mature stage. 54 DAF seeds attain maximum dry matter in the winter season in acid soil (S Moonmoon and M M Ahmed 2020). Our result showed differences because of the seasonal variation. In the summer season temperature and relative humidity were higher than winter season which helps to accumulate dry matter faster. The combined interaction of genotype and harvesting time had no significant influence on the number of seeds. But seed dry weight is greatly influenced by the combined interaction of genotype and harvesting time. From the result, it was found that all the genotypes attain maximum seed dry weight at 27 DAF. Among the genotypes, G3 and G4 showed better performance in respect of seed dry weight production. Seed dry matter is also higher than other genotypes. Seed fresh weight production shows differences in genotypes. Variations among four country bean genotypes (Islam 2008). But in combination with harvesting time genotypes had no significant effect on seed fresh weight production.

6. CONCLUSION

All the genotypes had a significant influence on pod fresh weight, pod length, and pod width. G1 and G4 had better performance in pod production followed by G2 and G3. For this G1 and G4 can be considered for pod production for as vegetative purposes. The time of harvest also has a significant influence on pod production. Highest pod fresh weight was found at 21 DAF for all the genotypes. At this time pod length and pod width are also the highest which is related to ultimate pod production. For this 21 DAF can be considered as the proper time of harvest for vegetative purposes. G4 showed better performance in seed production but total dry matter accumulation and cotyledon and shell dry matter accumulation are highest in G3. At 27 DAF seed weight was highest and dry matter content was also highest. And maximum dry matter accumulation indicates the physiological maturity stage. For this 27 DAF can be considered as the physiological maturity stage for good-quality seed production. At the physiological maturity stage protein and other nutrient content are high.

The study may be repeated to identify more number of harvesting times to generate more prices recommendation for a green vegetable. It can be repeated in the different parts of our country to know the effect of soil and environmental condition on physiological maturity.

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AUTHORS' CONTRIBUTIONS

This research was conducted under the direct supervision of the two co-

author (Prof. Dr. Sharifunnessa Moonmoon and Prof. Dr. Md. Masudur Rahman) where they played role as Supervisor and Co-supervisor respectively of the MS research of the first author (Kamrul Hasan shafi). Prof. Dr. Sharifunnessa Moonmoon and Prof. Dr. Md. Masudur Rahman contributed to the enrichment of laboratory, project administration, resources, funding and experimental design. All authors discussed the results and contributed to the final manuscript. Kamrul Hasan shafi wrote the manuscript with support from Prof. Dr. Sharifunnessa Moonmoon and Prof. Dr. Md. Masudur Rahman

AVAILABILITY OF DATA AND MATERIAL

All data generated or analysed during this study are included in this published article as supplementary information files. Other data are available on request from corresponding author

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