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IMPACT OF HARVEST STAGE ON SEED YIELD QUALITY AND STORABILITY OF FRENCH BEAN

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Abstract

Good quality seeds are one of the least expensive but vital factors influencing yield potential and key to agriculture progress. Studies were conducted both in the field and laboratory with the objective to observe the impact of harvest stage on the seed, quality and storability of French bean. Five harvest stages viz. H_1-deep green with light yellow colours of pod, H_2-50% green and 50% yellowing of pods, H_3-light brown with few yellow colour pods, H_4-90% brown colour of pods and H_5-100% brown colour and dried pods were considered as treatments for field trial. Harvested seeds were then stored in both cool room and ambient conditions up to 16 months and performed seed quality studies in every 4 months. The treatments combination of laboratory studies were T_1: H_1 seed storage in cool room (SSCR), T_2: H_1 seed storage in ambient (SSAB), T_3: H_2 SSCR, T_4: H_2 SSAB; T_5: H_3 SSCR; T_6: H_3 SSAB; T_7: H_4 SSCR; T_8: H_4 SSAB; T_9: H_5 SSCR and T_{10}: H_5 SSAB. Experiments were laid out in a RCBD and CRD in the field and laboratory, respectively. Results revealed that the highest seed yield and quality of French bean was observed in H_3. On the contrary, seed harvested in H_4 and stored in cool room (with the mean temperature 18-20^{o}C and relative humidity around 60-70%) recorded the highest storability compared to ambient condition. However, seeds harvested in H_3 and H_5 were also showed better storability in cool room as well as ambient conditions. To sum up, all the seed quality parameters were satisfactorily well up to 12 months of storage then it declined in quality.

Keywords: Harvest stage, French bean, seed yield, seed storage, seed quality

Introduction

French bean (*Phaseolus vulgaris* L.) is a pulse crop but used as vegetable in Bangladesh. It is ranked high as cheap sources of nourishing food, rich in protein, carbohydrates, vitamins, calcium, iron etc. The immature pod and tender and also dry beans of French bean has a possibility to meet up a good share of vegetables demand in Bangladesh (BARI, 2011). The crop is generally cultivated in Chittagong hill tracts districts, Sylhet and also some parts of northern region in Bangladesh. The requirement of quality seeds of French bean was 10.5 t ha^{-1} in

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the country but the supply was only 6.2 t ha^{-1} (Rakhi, 2000). There are many factors that can narrow down the gap between potential and farm level yield. Among them, use of quality seed is the most important one (Ahmad, 2001), as quality seeds ensure better germination and increase yield as high as 30% keeping the other factors of production as constant (BARI, 1993). Huda (2001) reported that ten to fifteen percent production could be reduced due to use of poor quality seed. Kumar *et al*. (2002) asserted that seed yield and quality largely depends on the stage of maturity of crops. Results from the study of Mehta *et al.* (1993) found that chickpea seed attained maximum dry matter when most pods are appeared as light brown with a few yellow green colour stages.

Greven *et al*. (2004) reported that later sowing, higher plant populations, desiccation and earlier harvesting reduced seed size of dwarf French beans, but significant differences were found in seed vigour. Seed storability depends on storage conditions (humidity and temperature), moisture content and physical state of seeds, stage of seed maturity, external factors (temperature, relative humidity and micro flora) and genetic factors (Ayyub *et al*., 2007). Although, Mahesha *et al*. (2001) alluded that storability of seed is mainly a genetical character and is influenced by pre-storage history of seed, seed maturation and environmental factors during pre and post-harvest stages. There is hardly any literature available on appropriate harvest stage of French bean in Bangladesh condition where seed quality will be maximized and that will affects on subsequent viability and storability. Considering the above points of view, the present experiments were undertaken to find out the impact of harvest stage on seed, quality and storability of French bean.

Materials and Method

Experimental site, design and management

Studies were conducted at the research field and laboratory of Seed Technology Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh during *rabi* season from 2008 to 2011. Five harvest stages viz. H_1-characterized by deep green with light yellow colours of pod, H_2-50% green and 50% yellowing of pods, H_3-light brown with few yellow colour pods, H_4-90% brown colour of pods and H_5-100% brown colour and dried pods were considered as treatments for field trial. Harvested seeds were then stored in both cool room and ambient conditions up to 16 months and conducted seed quality studies in every 4, 8, 12 and 16 Month in the laboratory. Thus, the combination of treatments for laboratory studies were T_1: H_1 seed storage in cool room (SSCR), T_2: H_1 seed storage in ambient (SSAB), T_3: H_2 SSCR, T_4: H_2 SSAB; T_5: H_3 SSCR; T_6: H_3 SSAB; T_7: H_4 SSCR; T_8: H_4 SSAB; T_9: H_5 SSCR and T_{10}: H_5

SSAB. Experiments were laid out in a RCBD and CRD in the field and laboratory, respectively. The unit plot size was 12 m^2. The land was fertilized with 23-75-75-20 kg ha^{-1} of NPKS in the form of Urea, TSP, MoP and Gypsum, respectively. Half of N and all other fertilizers were applied at the time of final land preparation. The rest of N was applied at 30 days after sowing. Seeds of French bean (cv. BARI Jharsheem-I) were sown in furrows @ 60 kg ha^{-1} in 30 cm apart from lines on 22 and 24 November in the year 2008 and 2009, respectively. Before sowing, all seeds were treated with Bavistene @ 0.2 ml kg^{-1} of seed. Field emergences were recorded at 7 and 10 days after sowing of seed and approximately more than 90% seeds germination were recorded. Intercultural operations like weeding viz. two times each at 15 and 40 days after emergence (DAE), thinning at 30 DAE, irrigation two times, each at 30 and 50 DAE, respectively were accomplished. Fungicides Ridomil Gold and Diathene M 45 @ 2 ml l^{-1} of water were sprayed 4 times alternatively at 7-10 days interval for controlling of damping of disease. Pods were then harvested based on the specified treatments. The collected pods were then threshed and seeds were sun dried until the moisture content reach at 10-12%.

Weather recording

The average maximum and minimum air temperatures and total rainfall data were collected from the weather station BRRI, Gazipur in every week during the experimentation. Temperatures and relative humidity data were also recorded daily during storability study trial in the laboratory by using wall thermometer and moisture meter.

Data recording

Data on seed yield was recorded from individual plot and converted into t ha^{-1}. Dried seeds of different harvest stages were stored in air tied tin container at moisture content 11.50% in cool room and ambient conditions up to sixteen months. In every four month, seeds stored in cool room and ambient conditions were sun dried and cooled at normal temperature under shade and then again stored in the same way. The following quality parameters and seed vigour contributing characters of seed were recorded:

Determination of moisture content

Moisture content of seed sample was determined according to ISTA (1999). Moisture content data were taken before storage and every four months of storage of French bean seed. Ground seed samples harvested at different stage were taken into moisture cup and put into a pre heated oven at temperature of 103 ± 2^0C for one hour according to Morshed *et al.* (2003). After cooling, the weight of the container with its cover and contents were taken. The seed samples

were cooled in desiccators and weighted to work out the percent moisture content of the grains. The seed moisture content was determined by dry weight basis and was calculated by the following formula:

$$\text{Seed moisture content} = \frac{M_2 - M_3}{M_2 - M_1} \times 100 \quad \text{..... (A)}$$

Here,

M_1 is the weight in 'g' of the container and its cover, M_2 is the weight in 'g' of the container, its cover and its contents before drying and M_3 is the weight in 'g' of the container, its cover and contents after drying.

Determination of germination percentage

The data on seed germination (%) was carried out by the following formula (ISTA, 1999). For each treatment, 100 seeds were put into large petridishes and then put at room temperature (25 ± 2^0C). After eight days, normal, abnormal and diseased seeds were counted.

$$\text{Seed germination} = \frac{\text{Number of seed germinated}}{\text{Total seed}} \times 100 \quad \text{..... (B)}$$

Measurement of root and shoot length

From the eight days of seedlings, 10 plants were randomly selected. Seedlings were then cut and root and shoot parts were separated and their lengths were measured in each replication of each treatments using centimeter scale.

Determination of fresh and dry weight of seedling

After measurement of root and shoot length, fresh weight and dry weight of seedlings were recorded. Then the roots and shoots were put into paper packet and placed into the preheated oven (70^0C$\pm$ 2^0C) for 48 hours. After cooling in desiccators, the dry weights were taken.

Determination of vigour index

Seed vigour index is calculated and determined by multiplying germination (%) and seedling length (Reddy and Khan, 2001).

Vigour index (VI)=(MRL+MSL)×PG…….(C)

Here,

VI, MRL, MSL and PG are for Vigour index, Mean root length (mm), Mean shoot length (mm) and Percentage germination, respectively.

The collected data were analyzed statistically following the ANOVA technique with the help of MSTAT-C software. The mean differences among the treatments were adjudged by LSD (Gomez and Gomez, 1984). The correlation co-efficient was done for different variables wherever needed.

Results and Discussion

Weather data and results of experiments are presented in Fig.1-5 and Tables 1-5. These are furnished below:

Weather conditions

The air temperature and rainfall regime experienced at the site in 2008-2010 were considered normal for this region and are presented in Fig.1. It was found that average maximum air temperature (34^{o}C) was in the month of April in both the years while the lowest minimum air temperature (just above 9^{o}C) was recorded in middle of January. There was almost no rainfall observed during the growing period (November to February) of French bean both the years except in the last week of February where a very little amount of precipitation (5 mm) was recorded. However, total rainfall was recorded more or less in all rest of the months ranging from 5 mm to well above 160 mm. Average temperature and relative humidity (RH) data during storability study in the laboratory are also presented in Fig. 2 and 3. Fig. 2 shows that in 2009-10, the temperatures in cool room were ranged between 17-19^{o}C from March 2009 to August 2010. While at ambient condition these were varied between 25-32^{o}C except in mid December 2009 to January 2010 where it was remained almost 20-22^{o}C. The RH in cool room was recorded 78-84% up to October 2009 with some minor fluctuations then it increased and peaked (90%) at early December and remained static up to last week of January 2010. From this point, it decreased dramatically to about 68% RH in mid February 2010. After that the RH was 5-12% increasing in trend with some fluctuations up to August 2010, where it was just above 78% in RH. At ambient condition, the RH was just above 35% in March 2009 and after that it was got an increasing in trend having the mean 60-65% RH and reached at apex 78% with some fluctuations in mid July 2009. From this point, there was a decrement of RH (about 45%) up to last week of September then increased up to mid October 2010. After that it turned slightly down up to 1st week of March 2010 with fluctuations. There was a slightly ceiling trend of RH (50%) from mid March to August 2010 (just below 80%) with some fluctuations (Fig. 2).

Similarly, in 2010-11, it was remarked that temperatures in cool room were fluctuated between 18-20^{o}C from March 2010 to August 2011 (Fig. 3). But, ambient temperatures were recorded higher (22-31^{o}C) than cool room during study periods. The cool room temperature ranged from 25-34^{o}C from 3rd week of March to mid May 2010. After that the temperatures were remained within 30-35^{o}C up to mid October 2010 with some fluctuations. The temperature decrement started from end of October and touched the lowest mark about19^{o}C in January 2011. From this point, temperatures rose with some oscillation and reached at peak (35^{o}C) at end of April 2011 and almost unchanged up to August 2011. Observations of RH in cool room during 2010-11 showed that it was just above 80% in early of March and remained static up to August 2010 having the range 65-82% in RH. The RH trend line turned upward and touched the highest mark

88% in November 2010 and then remained the same up to early February 2011. After that it decreased to 68% in RH in mid March 2011 then an upward tendency was observed up to mid June 2011 amounting about 86% RH. After remaining almost the static up to mid August 2011, it was observed decreasing in trend in RH. While in ambient condition, the RH was recorded about 60% in 1st week of March 2010 then deliberately decreased to just above 40% in mid March 2010. From this point there was an increasing in trend of RH with some fluctuations by touching the highest mark around 80% in mid June 2010. After that the RH became static up to mid September 2010 (around 75%) then there was a decrement of RH with some oscillations up to mid December 2010 (around 45%). It was noted that from December 2010 to mid April 2011, the RH was remained around 55% and from this point there was an upward trend of RH up to August 2011 and onward (Fig. 3).

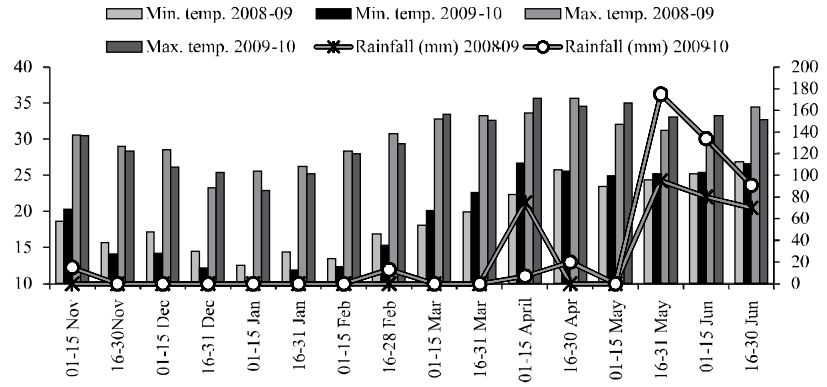

Fig. 1. Average maximum and minimum air temperatures (ºC) and total rainfall (mm) data from November to June in the year 2008-09 and 2009-10 at Joydebpur, Gazipur

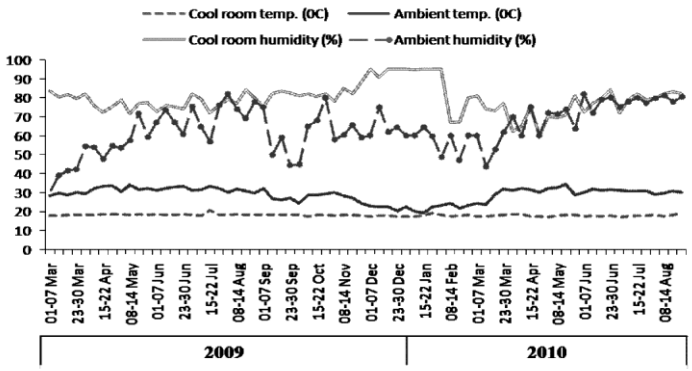

Fig. 2. Temperatures and relative humidity in cool room and ambient storage of French bean during March 2009 to August 2010 (Source: Weather data register book, Seed Technology laboratory, Seed Technology Division, BARI, Gazipur).

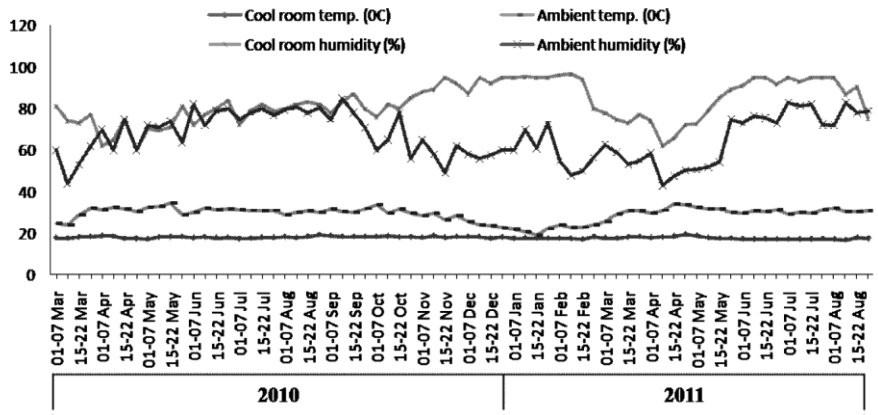

Fig. 3. Temperatures and relative humidity in cool room and ambient storage of French bean during March 2010 to August 2011(Source: Weather data register book, Seed Technology laboratory, Seed Technology Division, BARI, Gazipur).

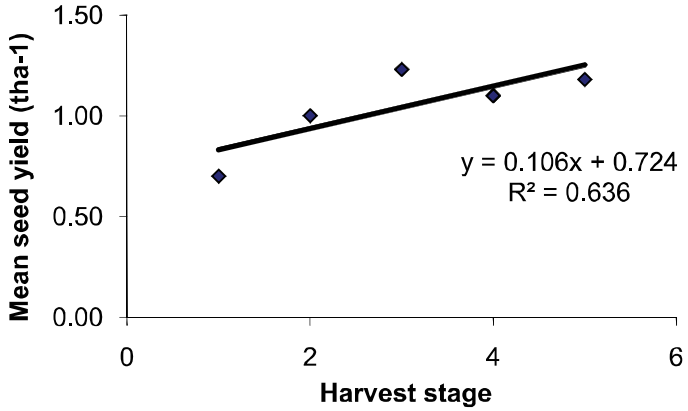

Fig. 4. Relationship between harvest stages on the seed yield of French bean (Pooled of two years).

Seed yield of French bean

Result from the pooled data revealed that seed yield of French bean was significantly influenced due to different harvest stages (Fig. 4). The highest seed yield 1.23 t ha^{-1} was recorded in H_3 and the lowest seed yield (0.69 t ha^{-1}) was obtained in H_1. Pooled of two years regression co-efficient study revealed that associations between harvest stage and with seed yield (r^2 =0.63) showed highly significant positive correlations. The present findings are in agreement with the findings of Khatun *et al.* (2010) who observed that highest seed yield of chickpea was recorded from the pods harvested at light brown with a few yellow green

colour stages. Kavak *et al.* (2012) observed that early and late harvests not only decrease physical quality of seed lots but also decrease seed quality**.** Thus, maximum seed quality of French bean may be ascertained during harvest at physiological maturity (H_3 stage).

Moisture content percentage (MC)

Before storage, the MC of French bean harvested seed was brought at 11.50% (Table 1). Results observed that MC of French bean during storage was significantly influenced by the harvest stage, storage conditions and periods (Table 2). The lowest MC at 4 months (M) storage was recorded in T_9 (12.20%) and T_7 (12.28%) while the maximum MC was observed in T_8 and T_4, respectively. At 8 M storage, the MC was the lowest in T_7 (12.62%) and the maximum was in T_{10} (13.38%). Similar results were also observed in the seed stored after 12 M. However, the minimum MC was recorded in T_7 (12.51%) that was statistically similar to T_5 (12.82%) and T_9 (12.83%). On the contrary, the MC at 16 M storage was the lowest in T_7 (12.59%) and the maximum was in T_8 (14.44%). But, at end of 16 M storage, the MC was increased in trend specially those who had stored in ambient condition (Table 2). Results revealed that moisture content of seeds of all harvest stages found comparatively lower up to 12 M of storage then it increased onwards. Temperature and relative humidity (RH) data both in cool room and ambient storage showed that seeds stored in cool room got cooler temperatures 18-20^{o}C that was much lower than ambient storage in both the years (Fig. 2 and 3). RH was higher all the time in cool room storage compared to ambient one. Therefore, RH around 60-70% and 18-20^{o}C temperature in cool room storage might be favoured to maintain lower MC in the seed that might be played an important role to higher seed storability of French bean. The findings are partially agreed with Ayyub *et al*. (2007) who reported that good storage conditions, low MC of seed, stage of seed maturity etc. are significantly influenced seed storability. The results of this study are also in conformity with the findings of Coolbear (1995).

Germination percentage (GP)

Significant variations were found among seeds of different harvest stage on GP of French bean both at before and during storage (Table 1 and 2). It was revealed that the maximum GP (93.78 and 94.12%) were found in H_3 in the year 2008-09 and 2009-10, respectively which was also similar to H_4 and H_5 for both the years. The lowest GPs (62.7 and 64.11%) were recorded in H_1 for both the years, respectively. On the other hand, the highest GP of French bean seed at 4 M storage was recorded in T_9 (90.22%) while the lowest GP was found in T_1 (58.33%). Similar results were also recorded at 8 and 12 M storage that were statistically similar to T_7 and T_5, respectively. But the lowest GPs were observed

Table 1. Effect of harvest time on the seed quality parameters of French bean before storage.

Treatments*	Moisture content (%)	Germination (%)		Root length (cm)		Shoot length (cm)		Seedling dry weight (g)		Vigour index (VI)	
		Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
H_1	11.50	62.67	64.11	8.39	7.98	18.57	19.60	0.11	0.11	1687	1769
H_2	11.50	74.89	73.11	8.52	8.17	19.42	21.25	0.12	0.11	2092	2153
H_3	11.50	93.78	94.12	9.59	10.01	21.25	22.59	0.14	0.13	2891	3069
H_4	11.50	92.89	90.56	9.58	8.97	20.81	20.96	0.14	0.13	2823	2711
H_5	11.50	92.56	92.00	9.26	8.55	21.26	20.91	0.12	0.12	2825	2712
LSD (0.05)	-	5.121	5.218	0.3859	0.7531	0.812	1.131	0.019	NS	118.4	183.8
CV (%)	-	3.26	3.35	2.5	4.58	2.13	2.85	9.88	4.32	2.25	3.93

* H_1-deep green with light yellow colours of pod, H_2-50% green and 50% yellowing of pods, H_3-light brown with few yellow colour pods, H_4-90% brown colour of pods and H_5-100% brown colour and dried pods and Y_1-2008-09 and Y_2-2009-2010.

Table 2. Effect of harvest time, storage condition and periods on the seed moisture content and seed germination of French bean (pooled of two years).

Treatments*	Seed moisture content (%)				Seed germination (%)			
	4 M	8 M	12 M	16 M	4 M	8 M	12 M	16 M
T_1: H_1 SSCR	12.42	12.76	12.81	12.89	58.33	74.11	78.61	75.43
T_2: H_1 SSAB	12.67	12.93	13.59	13.94	60.00	76.67	78.33	75.00
T_3: H_2 SSCR	12.76	13.03	12.85	12.66	73.22	78.17	84.33	87.23
T_4: H_2 SSAB	13.15	12.99	13.40	13.81	72.33	80.67	81.33	79.63
T_5: H_3 SSCR	12.32	12.79	12.82	12.76	88.78	86.22	93.28	87.83
T_6: H_3 SSAB	12.84	13.04	13.67	14.03	83.67	85.00	83.33	84.07
T_7: H_4 SSCR	12.28	12.62	12.51	12.59	85.22	86.61	91.29	87.73
T_8: H_4 SSAB	13.17	13.26	12.68	14.44	82.50	84.50	90.50	85.25
T_9: H_5 SSCR	12.20	12.80	12.83	12.51	90.22	87.89	93.65	87.33
T_{10}: H_5 SSAB	12.74	13.38	13.37	14.00	84.89	86.00	89.50	83.50
LSD(0.05)	0.60	0.15	0.44	0.45	5.92	4.75	5.93	6.94
CV (%)	2.78	2.02	1.95	1.97	4.46	3.37	4.03	4.89

* SSCR-Seed Storage in Cool Room, SSAB-Seed Storage in ambient and M-Month

Table 3. Effect of harvest time, storage period and storage conditions on the seedling root and shoot length of French bean (pooled of two years).

Treatments*	Seedling root length (cm)				Seedling shoot length (cm)			
	4 M	8 M	12 M	16 M	4 M	8 M	12 M	16 M
T_1: H_1 SSCR	8.24	9.68	9.62	9.57	18.93	16.12	16.45	16.83
T_2: H_1 SSAB	8.17	8.88	9.43	9.42	18.42	17.12	15.42	15.93
T_3: H_2 SSCR	8.36	9.51	8.39	9.18	19.26	16.99	15.94	17.46
T_4: H_2 SSAB	8.77	9.24	9.53	9.24	19.33	17.19	16.36	16.39
T_5: H_3 SSCR	9.61	11.47	12.41	11.37	21.46	20.19	19.42	17.98
T_6: H_3 SSAB	9.10	10.52	10.86	10.82	21.03	17.17	18.40	17.07
T_7: H_4 SSCR	9.27	10.87	12.20	11.73	21.53	20.56	18.64	18.83
T_8: H_4 SSAB	8.77	10.28	10.46	10.83	20.77	19.17	17.67	17.02
T_9: H_5 SSCR	9.24	10.71	12.60	11.97	21.07	19.83	19.11	17.42
T_{10}: H_5 SSAB	8.90	10.16	10.57	10.62	20.43	17.49	17.85	16.77
LSD(0.05)	0.42	0.55	0.90	0.65	0.68	1.73	1.21	1.38
CV (%)	2.81	3.22	4.98	3.63	1.99	5.58	4.06	4.74

* SSCR-Seed Storage in Cool Room, SSAB-Seed Storage in ambient and M-Month

in T_1 (74.11%) and T_2 (78.33%) at an end of 8 and 12 M storage, respectively. In case of 16 M storage, the maximum GP of seed was recorded in T_5 (87.33%) that was statistically identical with T_7 (87.73). The lowest GP was recorded in T_2 treatment (75%) (Table 2). Results of this study are in conformity with the findings of Seshu and Dadlani (1989) who reported that higher in seed quality indicated by high seed germination % and vigour of the seed. Poor storage conditions have been reported to cause 10% loss in seed quality (Genchev, 1997). However, Eliud *et al.* (2010) asserted that longevity of bean seeds depends on the ambient temperature and relative humidity at the stockiest stores**.**

Seedlings root length (SRL)

Results observed that harvest stage and storage conditions affected the SRL of French bean both at pre-storage and during storage (Table 1 & 3). The longest SRLs of French bean (9.59 and 10.01 cm) were found in H_3 while the shortest SRLs (8.39 and 7.98 cm) were recorded in H_1 in the year 2008-09 and 2009-10, respectively (Table 1). But, the longest SRL at 4 M storage of French bean was recorded in T_5 (9.61cm) and the shortest SRL was found in T_2 (8.17 cm). Similar results were also recorded at 8 M storage of French bean seed where, the maximum SRL was found at T_5 (11.47 cm) followed by T_7 (1087 cm). It was indicated that the longest SRL of French bean at 12 M storage was obtained in T_9 (12.60 cm) and the shortest SRL was observed in T_2 (9.43 cm). Statistically similar result was also recorded in 16 M storage, where the longest SRL was observed in T_9 (11.97 cm) (Table 3).

Seedlings shoot length (SSL)

It was noted that harvest stage and storage conditions influenced significantly to the SSL of French bean (Table 1 and 3). Similar to SRL, the longest SSLs of French bean before storage (21.26 and 22.59 cm) were remarked in H_5 and H_3 in the year 2008-09 and 2009-10, respectively while the shortest SSLs (18.57 and 19.60 cm) were recorded in H_1 stage in both the years, respectively (Table 1). Results from the storage of French bean seed at different storage conditions showed that the longest SSL at 4 M storage was recorded in T_7 (21.53 cm) while the shortest SSL was found in T_2 (18.42 cm). Similar results were also recorded at 8 M storage of French bean seed. Result indicated that the maximum SSL of French bean at 12 M storage was obtained in T_5 (19.42 cm) that was statistically similar with T_9 (19.11cm) while the shortest SSL was observed in T_2 (15.42cm). Relevant results were also gained in 16 M storage, where the longest SSL was observed in T_7 (18.83 cm) and the shortest SSL was found in T_2 (15.93 cm) (Table 3).

Seedling dry weight (SDW)

SDW of French bean both at before (except in 2nd year) and during storage were significantly influenced by different harvest stage and storage conditions (Table 1 and 4). It was revealed that the highest SDW (0.14 g) was recorded in both H_3 and H_4 while the lowest SDW (0.11g) was found in H_1 and H_2. SDW of French bean at 4 M storage was recorded the maximum (0.134 g) in T_8 followed by T_7 and T_5 (0.132 g) while the lowest SDW (0.111 g) was found T_1. Significantly, the maximum SDW of French bean at 8 M storage was recorded in T_7 (0.144 g) that was followed by T_9 (0.143 g) and the lowest SDW (0.119 g) was gained in T_2. Results found that the highest SDW of French bean at 12 M storage was remarked in T_5 (0.159g) that was statistically similar with T_7 (0.158 g). Furthermore, at 16 M storage, the highest SDW was observed in T_9 (0.148 g) while the lowest SDW was confirmed in T_2 (0.127 g) (Table 4).

Vigour index (VI)

It was observed that VI of before and during storage of French bean was significantly varied due to different harvest stages, storage conditions and periods (Table 1 and 4). It was indicated that the maximum VI of French bean (2891) before storage was recorded in H_3 that was statistically similar with H_5 (2825) and H_4 (2823). Similar trends of VI were also observed in the year 2009-10 (Table 1). Results showed that the highest VI at 4 M storage was recorded in T_5 (2759) while the lowest VI was found in T_1 (1584). The same trends of result were also recorded in VI of French bean at 8 M storage. But, at 12 M storage, significantly higher VI (2972) of French bean was found in T_9 that was statistically similar with T_5 (2971) and T_7 (2814). However, VI of French bean at 16 M storage was found the maximum in T_7 (2681) that was statistically similar with T_5 (2577) and T_9 (2566) while the lowest VI was observed in T_2 (1901) (Table 7). The findings of the present investigation are agreed with Seshu and Dadlani (1989) who reported that higher seed germination % and vigour resulted in better seed quality. The results are also partially agreed with that of Bailly *et el*. (2002) and Ayyub *et al*. (2007).

Correlation

Correlation matrix among the seed quality characters of French bean during storage has been shown in Table 5. A positive and significant correlation was observed between germination percentage and seedling root and shoot length of French bean stored in all 4, 8, 12 and 16 months of storage. Similar results were also observed in case of germination percentage and seedling dry weight and vigour index in all the months of storage. Significantly, a positive and strong correlation was also observed between seedling root and shoot length and seedling dry weight; vigour index and seedling root length and shoot length and

Table 4. Effect of harvest time, storage period and storage condition on the seedling dry weight of French bean (pooled of two years).

Treatments*	Seedling dry weight (g)				Vigour index (VI)			
	4 M	8 M	12 M	16 M	4 M	8 M	12 M	16 M
T_1: H_1 SSCR	0.111	0.124	0.129	0.127	1584	1912	2050	1992
T_2: H_1 SSAB	0.122	0.119	0.148	0.132	1597	1994	1947	1901
T_3: H_2 SSCR	0.119	0.131	0.137	0.136	2023	2071	2052	2324
T_4: H_2 SSAB	0.125	0.128	0.158	0.141	2032	2131	2105	2041
T_5: H_3 SSCR	0.132	0.138	0.159	0.136	2759	2728	2971	2577
T_6: H_3 SSAB	0.130	0.130	0.148	0.144	2521	2352	2438	2346
T_7: H_4 SSCR	0.132	0.144	0.158	0.143	2624	2723	2814	2681
T_8: H_4 SSAB	0.134	0.135	0.147	0.136	2437	2488	2546	2376
T_9: H_5 SSCR	0.131	0.143	0.165	0.148	2735	2683	2972	2566
T_{10}: H_5 SSAB	0.125	0.138	0.159	0.139	2489	2379	2543	2285
LSD(0.05)	0.12	0.12	0.12	0.12	178.4	179.3	239.3	234.8
CV (%)	5.69	5.53	7.79	6.67	4.59	4.49	5.75	5.97

* SSCR-Seed Storage in Cool Room, SSAB-Seed Storage in ambient and M-Month

Table 5. Correlation matrix among different parameters of French bean during storage.

Characters	Months	Correlation coefficient (r value)				
		Moisture content	Germination percentage	Seedling root length	Seedling shoot length	Seedling dry weight
GP	4	-0.010ns				
	8	0.123ns				
	12	-0.264ns				
	16	-0.306ns				
SRL	4	-0.206ns	0.796**			
	8	-0.087ns	0.696**			
	12	-0.280ns	0.731**			
	16	-0.215ns	0.564**			
SSL	4	-0.095ns	0.862**	0.780**		
	8	-0.377*	0.053*	0.660**		
	12	-0.219ns	0.683**	0.812**		
	16	-0.483**	0.454*	0.491**		
SDW	4	0.031ns	0.660**	0.608**	0.527*	
	8	0.154ns	0.709**	0.669**	0.436*	
	12	-0.083ns	0.453*	0.453*	0.400*	
	16	-0.077ns	0.499**	0.371*	0.117ns	
VI	4	-0.060ns	0.490**	0.848**	0.915**	0.655**
	8	-0.149ns	0.869**	0.851**	0.875**	0.678**
	12	-0.290ns	0.912**	0.919**	0.890**	0.508*
	16	-0.397*	0.893**	0.802**	0.733**	0.446*

*Significant at 5% level and ** Significant at 1% level, ns-Not significant

vigour index and seedling dry weight of French bean in all the months of storage. But a negative correlation was found between moisture content and germination percentage of French bean except in the 8 months of storage; seedling root and shoot length, seedling dry weight except in the months of 4 and 8 months of storage and vigour index in all the months of storage. A positive correlation (r=0.596) between germination and dry matter was also found by Mehta *et al.* (1993). They also observed that germination showed negative correlations (r=0.856) with moisture content of seed and (r=0.573) with fresh weight of pod wall. Reddy and Khan (2001) recorded a positive and significant correlation between germination and seedling dry weight (0.68*), vigour index I (0.91**) and vigour index II (0.97**). Similar results were also reported by Khatun *et al.* (2009).

Conclusion

Present investigations revealed that the highest seed yield and seed quality in respect to seed vigour and higher seed germination of French bean was obtained in H_3 (while pods were shown light brown with few yellow in colour). On the contrary, seeds stored in cool room up to 16 month, H_3 (pods appeared 90% of brown in colour) observed the highest storability in terms of higher germination percentage and vigour index. It was also indicated that all the seeds stored in cool room were found better in seed quality compared to ambient condition. However, seeds harvested in H_3 and H_4 also showed better seed quality and storability in cool room as well as ambient conditions. In addition, it was remarked that all the seed quality parameters were satisfactorily well up to 12 months of storage then declined in quality onwards. The findings of present investigations will help researchers to formulate further study of seed preservation of French bean as these seeds lose their germinability rapidly due to poor storage and shorter periods.

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