

RESEARCH ARTICLE

Effect of spacing and genotypes on physiological growth indices of french bean (*Phaseolus vulgaris* L.)

■ C. M. Kamble, A. P. Trivedi, A. S. Bhanvadia, J. J. Ghadiali and B. K. Patel

SUMMARY

A field experiment was conducted at the Regional Research Station, Anand Agricultural University, Anand to evaluate the effect of various spacing and genotypes on physiological growth indices of french bean (*Phaseolus vulgaris* L.) during *Rabi* seasons of 2019-20 and 2020-21. The experiment consisted of twenty-two treatment combinations comprised of two levels of spacing [S_1 : 30 x 10 cm and S_2 : 45 x 10 cm] and eleven levels of genotypes [G_1 : SKAUSJ-WB 185, S_2 : Tripura Rajma-1, G_3 : Phule Rajma, G_4 : Phule Suyash, G_5 : RKR 1011-1, G_6 : RKR 1033, G_7 : GR-1, G_8 : Varun, G_9 : HPR-35, G_{10} : IPR-98-3-1 and G_{11} : Swarna Safal (ICAR Ranchi)]. The results revealed that 45 x 10 cm spacing recorded significantly higher physiological growth indices in french bean. While among the various genotypes tested, the significantly higher physiological growth indices were obtained in Swarna Safal genotype of french bean and it also remained at par with Phule Rajma and GR-1 genotypes at 30 DAS, 60 DAS and at harvest.

Key Words : French bean, Spacing, Genotype

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The production of pulses however, does not commensurate with the demand in the country. The per capita availability of pulses in India has been continuously decreasing which is at present 55.90 g/day/capita against the minimum requirement of 85 g/day/capita for balanced diet as recommended by World Health Organization (WHO) and Food and Agricultural Organization (FAO). It is the high time to cultivate pulses crops scientifically with increasing area (Patel *et al.*, 2013).

French bean (*Phaseolus vulgaris* L.) is a leguminous crop and belongs to family Fabaceae. It is also known as *Snap bean*, *Kidney bean*, *Common*

bean, Rajma bean, Haircot bean, Dwarf bean, Pole bean, Navy bean, Pinto bean and String bean. French bean is the most important leguminous vegetable, mainly grown for the tender vegetable, shelled green beans (Rajma) and dry beans also. In India, it is being grown for tender vegetable, while in the USA, it is grown for processing. It is found in two major groups, bush beans and pole beans. Bush beans are short plants, grows approximately 2 feet height without support, reach maturity and produce all of their pods in a relatively short period of time (Heena *et al.*, 2015). Both pole and bush-type French beans are cultivated for green pods in the hills (500–1600 MSL) during summer to autumn.

The world's largest producer of french bean is India and also, the greatest producer and importer of french bean. The area of pea and beans in the agricultural year of 2020-21 was 0.637 M ha with the production of 0.876 MT and the productivity is 1375 kg/ha (Ministry of Agriculture and Farmers Welfare, Govt. of India). Punjab and Haryana having the highest area with higher productivity, western Uttar Pradesh, Andhra Pradesh, and the West Bengal are the major french bean growing areas and it is also grown in Kerala, Karnataka's eastern and coastal regions, Tamil Nadu, and some regions of Maharashtra.

The suitable variety and proper spacing are the two important factors for higher crop production. The performance evaluation of different french bean varieties varies under different agro-climatic conditions due to their specific climatic requirement. Therefore, an appraisal of varieties for their variability with respect to growth, yield and quality under different conditions is essential to improve the production. In this context it is very much necessary to evaluate these commercial varieties available, in order to identify high yielding types for increasing production and productivity.

Proper spacing is the most important non-monetary input in crop production, which affects the crop growth, yield and quality to a greater extent. Optimum plant population plays an important role to fully exploit all available resources for growth as it provides optimum growing conditions such as temperature, light, humidity and rainfall.

The improvement of french bean for any quantitative trait involves a proper selection criterion. The plant selected based on phenotype may not perform with the same magnitude in the next generation. Hence, the criteria like heritability, genetic advance and correlation co-efficient provides a measure of association among

characters and can serve to identify the character of high yielding ability while making selection from the base population.

MATERIAL AND METHODS

A field experiment was carried out at the Regional Research Station, Anand Agricultural University, Anand to elicit the effect of various spacing and genotypes on physiological growth indices of french bean (*Phaseolus vulgaris* L.) during *Rabi* seasons of 2019-20 and 2020-21. The experiment was laid out in Randomized Block design with factorial concept and replicated three times. There were 22 treatment combinations comprising 2 levels of spacing and 11 levels of genotypes. The soil of experimental field was loamy sand in texture, low in nitrogen, medium in available phosphorus and high in available potash. Urea and SSP were applied as a source of nitrogen and phosphorus prior to sowing at the rate of 25 kg N: 50 kg P₂O₅ per ha. Sowing was done under dry condition on 14th December, 2019 and 29th November, 2020.

Physiological growth indices were calculated by following formulas:

$$\text{Absolute growth rate (AGR)} = \frac{DW_2 - DW_1}{t_2 - t_1}$$

where, DW₁ and DW₂ are dry weight of plant at t₁ and t₂ times, respectively.

$$\text{Crop growth rate (CGR)} = \frac{1}{P} \times \frac{DW_2 - DW_1}{t_2 - t_1}$$

where, DW₁ and DW₂ were whole plant dry weight at time t₁ and t₂, respectively.

P is land area on which W₁ and W₂ were recorded.

$$\text{Relative growth rate (RGR)} = \frac{\log W_2 - \log W_1}{t_2 - t_1}$$

where, W₁ and W₂ were dry weight of plant at t₁ and t₂ times, respectively.

$$\text{Net assimilation rate (NAR)} = \frac{(W_2 - W_1)(\log L_2 - \log L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

where, W₁ and W₂ were dry weight of plant at t₁ and t₂ times, respectively.

L₁ and L₂ were leaf area of plant at t₁ and t₂ times, respectively.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized

under following heads :

Effect of spacing and genotypes on absolute growth rate (AGR) :

At 0 – 30 DAS :

The results (Table 1) revealed that spacing and genotypes exerted significant effect on absolute growth rate in french bean. In both the year (2019-20 and 2020-21) and in pooled analysis, spacing 45 × 10 cm recorded significantly higher absolute growth rate (0.070, 0.072 and 0.071 g/day) than 30 × 10 cm spacing (0.061, 0.063 and 0.062 g/day), respectively.

Among the genotype, Swarna Safal recorded highest absolute growth rate (g/day) and remained at par with Phule Rajma (0.079, 0.081 and 0.080 g/day). GR-1 (0.072 and 0.074 g/day), recorded similar absolute growth rate to Swarna Safal in both the year but found significant lower in pooled analysis (0.073 g/day). Conversely, Tripura Rajma – 1 listed lowest AGR (0.057,

0.059 and 0.058 g/day) at 0-30 DAS in both years and in pooled analysis, respectively.

Interaction effect between the spacing and genotype found non-significant at 0-30 DAS in absolute growth rate.

At 30 – 60 DAS :

The data pertaining to absolute growth rate (g/day) at 30 – 60 DAS in Table 1 showed the significant difference among the spacing and genotype of french bean. Among the spacing, 45 × 10 cm recorded significantly higher absolute growth rate both the year (2019-20 and 2020-21) and in pooled analysis (0.651, 0.665 and 0.658 g/day) than 30 × 10 cm spacing (0.397, 0.405 and 0.401 g/day), respectively.

Among the genotype, Swarna Safal documented highest absolute growth rate (0.641, 0.655 and 0.648 g/day) which was at par with Phule Rajma (0.611, 0.624 and 0.618 g/day) at 2019-20, 2020-21 and in pooled result.

Table 1 : Effect of various spacing and genotypes on absolute growth rate (AGR)

Treat.	Absolute growth rate [AGR] (g/day)								
	0-30 DAS			30 – 60 DAS			60 DAS – Harvest		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Spacing (S)									
S ₁	0.061	0.063	0.062	0.397	0.405	0.401	0.665	0.680	0.673
S ₂	0.070	0.072	0.071	0.651	0.665	0.658	0.773	0.791	0.782
S.E.±	0.001	0.001	0.001	0.007	0.007	0.005	0.010	0.010	0.007
C.D. (P=0.05)	0.003	0.003	0.002	0.021	0.020	0.014	0.027	0.030	0.020
Genotypes (G)									
G ₁	0.067	0.069	0.068	0.549	0.561	0.555	0.767	0.784	0.776
G ₂	0.057	0.059	0.058	0.445	0.454	0.449	0.601	0.615	0.608
G ₃	0.075	0.077	0.076	0.611	0.624	0.618	0.851	0.870	0.860
G ₄	0.066	0.067	0.067	0.540	0.552	0.546	0.756	0.774	0.765
G ₅	0.064	0.066	0.065	0.500	0.511	0.505	0.674	0.689	0.682
G ₆	0.063	0.065	0.064	0.495	0.505	0.500	0.667	0.682	0.674
G ₇	0.072	0.074	0.073	0.588	0.601	0.594	0.822	0.841	0.832
G ₈	0.060	0.061	0.060	0.463	0.473	0.468	0.626	0.641	0.633
G ₉	0.059	0.061	0.060	0.463	0.473	0.468	0.624	0.637	0.631
G ₁₀	0.060	0.062	0.061	0.466	0.477	0.472	0.631	0.646	0.639
G ₁₁	0.079	0.081	0.080	0.641	0.655	0.648	0.888	0.915	0.902
S.E.±	0.002	0.003	0.002	0.017	0.016	0.012	0.022	0.025	0.017
C.D. (P=0.05)	0.007	0.008	0.005	0.049	0.047	0.034	0.064	0.070	0.047
S × G interaction									
S.E.±	0.003	0.004	0.003	0.024	0.023	0.017	0.032	0.035	0.024
C.D. (P=0.05)	NS	NS	NS	0.070	0.066	0.048	0.090	0.099	0.067
CV%	8.518	9.772	9.209	8.058	7.540	7.829	7.592	8.192	7.981

NS= Non-significant

On the contrary, Tripura Rajma – 1 registered lowest AGR (0.445, 0.454 and 0.449 g/day) at 30-60 DAS in both years and in pooled analysis, respectively.

Absolute growth rate at 30 – 60 DAS was affected by the interaction effects of the factors spacing and genotype at 30 – 60 DAS. Accordingly, variety Swarna Safal showed the highest Absolute growth rate (g/plant) at 45 × 10 cm plant spacing which was at par with Phule Rajma and GR-1 at spacing 45 × 10 cm in 2019-20 and

2020-21 both the years. However, Phule Rajma found at par with Swarna Safal at 45 × 10 cm spacing in pooled analysis. Lowermost absolute growth rate recorded in Tripura Rajma-1 when sown on 30 × 10 cm spacing.

Wider spacing might be attributed to less competition for resources subsequently improved available soil moisture of the plant, nutrients, light and space for better development of these characters. The results corroborate with the findings of Patel *et al.* (2010) for moth bean.

Table 2 : Interaction effect of various spacing and genotypes on absolute growth rate (AGR) at 30 – 60 DAS

Treat.	Absolute growth rate [AGR] (g/day) at 30 – 60 DAS								
	2019-20			2020-21			Pooled		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁	0.405	0.693	0.549	0.414	0.708	0.561	0.410	0.701	0.555
G ₂	0.345	0.545	0.445	0.352	0.556	0.454	0.348	0.550	0.449
G ₃	0.454	0.768	0.611	0.464	0.785	0.624	0.459	0.776	0.618
G ₄	0.398	0.682	0.540	0.407	0.697	0.552	0.402	0.689	0.546
G ₅	0.388	0.612	0.500	0.397	0.625	0.511	0.393	0.618	0.505
G ₆	0.383	0.606	0.495	0.392	0.619	0.505	0.388	0.612	0.500
G ₇	0.435	0.741	0.588	0.445	0.757	0.601	0.440	0.749	0.594
G ₈	0.359	0.568	0.463	0.367	0.580	0.473	0.363	0.574	0.468
G ₉	0.358	0.568	0.463	0.366	0.580	0.473	0.362	0.574	0.468
G ₁₀	0.362	0.571	0.466	0.370	0.583	0.477	0.366	0.577	0.472
G ₁₁	0.477	0.806	0.641	0.487	0.823	0.655	0.482	0.815	0.648
Mean	0.397	0.651		0.405	0.665		0.401	0.658	
	S.E.±		0.024	S.E.±		0.023	S.E.±		0.017
	C.D. (P=0.05)		0.070	C.D. (P=0.05)		0.066	C.D. (P=0.05)		0.048

Table 3 : Interaction effect of various spacing and genotypes on absolute growth rate (AGR) at 60 DAS – Harvest

Treat.	Absolute growth rate [AGR] (g/day) at 60 DAS – harvest								
	2019-20			2020-21			Pooled		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁	0.679	0.855	0.767	0.695	0.873	0.784	0.687	0.864	0.776
G ₂	0.577	0.625	0.601	0.591	0.640	0.615	0.584	0.633	0.608
G ₃	0.761	0.942	0.851	0.776	0.964	0.870	0.768	0.953	0.860
G ₄	0.667	0.845	0.756	0.682	0.865	0.774	0.675	0.855	0.765
G ₅	0.650	0.698	0.674	0.666	0.712	0.689	0.658	0.705	0.682
G ₆	0.642	0.692	0.667	0.655	0.708	0.682	0.649	0.700	0.674
G ₇	0.732	0.912	0.822	0.749	0.933	0.841	0.740	0.923	0.832
G ₈	0.602	0.650	0.626	0.616	0.666	0.641	0.609	0.658	0.633
G ₉	0.602	0.647	0.624	0.614	0.660	0.637	0.608	0.654	0.631
G ₁₀	0.607	0.656	0.631	0.621	0.671	0.646	0.614	0.663	0.639
G ₁₁	0.798	0.978	0.888	0.817	1.013	0.915	0.808	0.995	0.902
Mean	0.665	0.773		0.680	0.791		0.673	0.782	
	S.E.±		0.032	S.E.±		0.035	S.E.±		0.024
	C.D. (P=0.05)		0.090	C.D. (P=0.05)		0.099	C.D. (P=0.05)		0.067

At 60 DAS to harvest :

The spacing 45 × 10 cm recorded significantly higher absolute growth rate at 60 DAS – at harvest (0.773, 0.791 and 0.782) than 30 × 10 cm spacing (0.665, 0.680 and 0.673 g/day) in year 2019-20, 2020-21 and in pooled result, respectively.

Among the different genotypes used in experiment, highest absolute growth rate (g/day) recorded in Swarna Safal (0.888, 0.915 and 0.902 g/day) which was at par with Phule Rajma (0.851, 0.870 and 0.860 g/day). While in contrary, Tripura Rajma-1 recorded lowest AGR value (0.601, 0.615 and 0.608 g/day) at 60 DAS – at harvest in both years and in pooled analysis, respectively.

Absolute growth rate was affected by the interaction effects of the factors spacing and genotype at 30 – 60 DAS (Table 3). Accordingly, variety Swarna Safal showed the highest Absolute growth rate (g/plant) at 45 × 10 cm plant spacing which was at par with Phule Rajma and GR-1 at spacing 45 × 10 cm and the lowest in Tripura

Rajma-1 (g/plant) when sown on 30 × 10 cm spacing. Vasava and Patel (2020) concluded same finding during their experiments.

Effect of spacing and genotypes on crop growth rate (CGR) :

At 0 – 30 DAS :

The data with regard to crop growth rate at 0 – 30 DAS as influenced by different spacing and genotype of French bean are furnished in Table 4. The spacing 45 × 10 cm recorded significantly higher crop growth rate at 0 – 30 DAS (1.565, 1.604 and 1.585 g/m²/day) than 30 × 10 cm spacing (2.038, 2.087 and 2.062 g/m²/day) in year 2019-20, 2020-21 and in pooled result, respectively.

Crop growth rate at 0 – 30 DAS significantly differed in different genotypes, among the genotypes Swarna Safal (2.16, 2.22 and 2.19 g/m²/day) recorded highest crop growth rate at 0-30 DAS which was at par with Phule Rajma (2.06, 2.11 and 2.08 g/m²/day) in 2019-

Table 4 : Effect of various spacing and genotypes on crop growth rate (CGR)

Treat.	Crop growth rate (g/m ² /day)								
	0-30 DAS			30 – 60 DAS			60 DAS – Harvest		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Spacing (S)									
S ₁	2.04	2.09	2.06	13.23	13.51	13.37	22.17	22.67	22.42
S ₂	1.57	1.60	1.59	14.46	14.77	14.61	17.17	17.59	17.38
S.E.±	0.03	0.03	0.02	0.20	0.19	0.14	0.28	0.29	0.20
C.D. (P=0.05)	0.07	0.09	0.06	0.56	0.53	0.38	0.79	0.82	0.57
Genotypes (G)									
G ₁	1.84	1.89	1.86	14.46	14.77	14.61	20.89	21.28	21.05
G ₂	1.57	1.60	1.58	11.79	12.05	11.92	16.57	16.96	16.76
G ₃	2.06	2.11	2.08	16.10	16.45	16.27	23.14	23.64	23.39
G ₄	1.80	1.85	1.82	14.21	14.52	14.36	20.50	20.99	20.74
G ₅	1.76	1.81	1.79	13.27	13.55	13.41	18.59	19.01	18.80
G ₆	1.74	1.78	1.76	13.12	13.41	13.26	18.39	18.80	18.59
G ₇	1.98	2.03	2.01	15.49	15.82	15.65	22.33	22.85	22.59
G ₈	1.63	1.67	1.65	12.29	12.56	12.42	17.25	17.66	17.45
G ₉	1.63	1.67	1.65	12.27	12.54	12.40	17.26	17.56	17.39
G ₁₀	1.65	1.69	1.67	12.38	12.65	12.51	17.40	17.81	17.60
G ₁₁	2.16	2.22	2.19	16.90	17.26	17.08	24.17	24.88	24.52
S.E.±	0.06	0.07	0.05	0.46	0.44	0.32	0.65	0.67	0.47
C.D. (P=0.05)	0.17	0.21	0.13	1.32	1.25	0.90	1.85	1.93	1.32
S × G interaction									
S.E.±	0.09	0.10	0.07	0.65	0.62	0.45	0.92	0.95	0.67
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	8.12	9.60	8.95	8.17	7.58	7.90	8.06	8.21	8.20

NS= Non-significant

20, 2020-21 years and in pooled analysis, respectively. However, GR-1 also found at par with Swarna Safal in the year of 2020-21 (2.03 g/m²/day). While in contrary, Tripura Rajma-1 registered lowest crop growth rate value (1.57, 1.60 and 1.58 g/m²/day) at 0 – 30 DAS in both years and in pooled analysis, respectively.

Interaction effect between the spacing and genotype found non significant at 0 – 30 DAS in crop growth rate in both the year and in pooled analysis.

At 30-60 DAS :

The data with respect to crop growth rate at 30 – 60 DAS presented in Table 4 clearly revealed that, the significant difference was found with respect to crop growth rate between the spacing and genotypes of french bean. The significantly higher crop growth rate at 30-60 DAS was recorded under 45 × 10 cm (14.46, 14.77 and 14.61 g/m²/day) spacing than 30 × 10 cm spacing (13.23, 13.5 and 13.37g/m²/day) in year 2019-20, 2020-21 and

in pooled result, respectively. The study of Rachaputi *et al.* (2015) supported these results. They proved that the narrow row spacing resulted in 22% higher shoot dry matter and 14% more yield compared to the wide rows.

Among the genotype, Swarna Safal registered highest crop growth rate at 30–60 DAS (16.90, 17.26 and 17.08 g/m²/day), which was at par with Phule Rajma (16.10, 16.45 and 16.27 g/m²/day) at 2019-20, 2020-21 and in pooled result. On the contrary, Tripura Rajma-1 registered lowest crop growth rate (11.79, 12.05 and 11.92 g/m²/day) in both years and in pooled result, respectively.

Interaction effect between the spacing and genotype observed non-significant at 30-60 DAS in crop growth rate in both the year and in pooled analysis.

At 60 DAS to harvest :

The data depicted in Table 4 clearly indicated that, the crop growth rate (CGR) at 60 DAS – at harvest

Table 5 : Effect of various spacing and genotypes on relative growth rate (RGR)

Treatments	Relative growth rate (g/g/day)				
	0-30 DAS			30 – 60 DAS	
	2019-20	2020-21	Pooled	2019-20	2020-21
Spacing (S)					
S ₁	0.0087	0.0090	0.0089	0.033	0.034
S ₂	0.0107	0.0111	0.0109	0.041	0.042
S.E.±	0.0002	0.0002	0.0002	0.001	0.001
C.D. (P=0.05)	0.0006	0.0007	0.0004	0.002	0.001
Genotypes (G)					
G ₁	0.0101	0.0104	0.0103	0.038	0.038
G ₂	0.0077	0.0081	0.0079	0.035	0.035
G ₃	0.0117	0.0121	0.0119	0.040	0.040
G ₄	0.0098	0.0101	0.0100	0.038	0.038
G ₅	0.0094	0.0098	0.0096	0.037	0.037
G ₆	0.0093	0.0096	0.0094	0.037	0.037
G ₇	0.0112	0.0115	0.0113	0.039	0.039
G ₈	0.0083	0.0087	0.0085	0.036	0.036
G ₉	0.0083	0.0086	0.0085	0.036	0.036
G ₁₀	0.0085	0.0088	0.0086	0.036	0.036
G ₁₁	0.0124	0.0128	0.0126	0.040	0.041
S.E.±	0.0005	0.0006	0.0004	0.001	0.001
C.D. (P=0.05)	0.0014	0.0016	0.0011	0.004	0.004
S × G interaction					
S.E.±	0.0007	0.0008	0.0005	0.002	0.002
C.D. (P=0.05)	NS	NS	NS	NS	NS
CV%	12.26	13.90	13.17	8.229	8.023

NS= Non-significant

was significantly differed among the plant spacing and genotype of french bean. The maximum crop growth rate (CGR) at 60 DAS – at harvest was registered under 45×10 cm (22.17, 22.67 and 22.42 g/m²/day) spacing which was significantly higher than 30×10 cm spacing (17.17, 17.59 and 17.38 g/m²/day) in year 2019-20, 2020-21 and in pooled result, respectively.

Among the genotype, Swarna Safal registered highest crop growth rate at 60 DAS – at harvest (24.17, 24.88 and 24.52 g/m²/day), which remained at par with Phule Rajma (23.14, 23.64 and 23.39 g/m²/day) at 2019-20, 2020-21 and in pooled result, respectively. However, GR-1 also found at par with Swarna Safal in 2019-20 year. On the dissimilar, Tripura Rajma registered lowest crop growth rate (16.57, 16.96 and 16.76 g/m²/day) in both years and in pooled result, respectively.

Wider spacing might be attributed to less competition for resources subsequently improved available soil moisture of the plant, nutrients, light and space for better

development of these characters. The results corroborate with the findings of Patel *et al.* (2010) for moth bean.

Effect of spacing and genotypes on relative growth rate (RGR) :

At 0 – 30 DAS :

The data with regard to relative growth rate at 0 – 30 DAS as influenced by different spacing and genotype of French bean are furnished in Table 5. The spacing 45×10 cm recorded significantly higher relative growth rate at 0-30 DAS (0.0107, 0.0111 and 0.0109 g/g/day) than 30×10 cm spacing (0.0087, 0.0090 and 0.0089 g/g/day) in year 2019-20, 2020-21 and in pooled result, respectively.

Among the various genotypes, Swarna Safal (0.0124 and 0.0128 g/g/day) recorded highest relative growth rate at 0-30 DAS and remained statistically at par with Phule Rajma (0.0117 and 0.0121 g/g/day) and GR-1 (0.0112 and 0.0115 g/g/day) in 2019-20 and 2020-21 years,

Table 6 : Effect of various spacing and genotypes on net assimilation rate (NAR)

Treatments	Net assimilation rate [NAR] (g/g/day)				
	0-30 DAS			30 – 60 DAS	
	2019-20	2020-21	Pooled	2019-20	2020-21
Spacing (S)					
S ₁	0.0059	0.0062	0.0061	0.054	0.054
S ₂	0.0076	0.0081	0.0079	0.105	0.107
S.E.±	0.0059	0.0062	0.0061	0.001	0.001
C.D. (P=0.05)	0.0076	0.0081	0.0079	0.004	0.004
Genotypes (G)					
G ₁	0.0070	0.0082	0.0076	0.094	0.095
G ₂	0.0054	0.0057	0.0055	0.075	0.076
G ₃	0.0069	0.0088	0.0078	0.085	0.086
G ₄	0.0075	0.0080	0.0078	0.089	0.087
G ₅	0.0070	0.0066	0.0068	0.076	0.077
G ₆	0.0060	0.0064	0.0062	0.072	0.071
G ₇	0.0073	0.0074	0.0073	0.075	0.076
G ₈	0.0055	0.0056	0.0055	0.071	0.070
G ₉	0.0058	0.0062	0.0060	0.077	0.079
G ₁₀	0.0048	0.0050	0.0049	0.061	0.061
G ₁₁	0.0112	0.0111	0.0111	0.103	0.108
S.E.±	0.0002	0.0002	0.0002	0.003	0.003
C.D. (P=0.05)	0.0006	0.0007	0.0006	0.009	0.009
S × G interaction					
S.E.±	0.0003	0.0003	0.0003	0.004	0.005
C.D. (P=0.05)	NS	NS	NS	0.012	0.013
CV%	7.5997	8.3233	11.3557	9.161	9.865

NS= Non-significant

respectively. However, Swarna Safal only found at par (0.0126 g/g/day) with Phule Rajma (0.0119 g/g/day) in the pooled result.

Interaction effect between the spacing and genotype found non-significant at 0–30 DAS in crop growth rate in both the year and in pooled analysis.

At 30-60 DAS :

The data with respect to on relative growth rate at 30-60 DAS presented in Table 5 clearly revealed that, the significant difference was found on relative growth rate due to the spacing and genotypes of french bean. The significantly higher on relative growth rate at 30-60 DAS was recorded under 45 × 10 cm (0.041, 0.042 and 0.041 g/g/day) spacing than 30 × 10 cm spacing (0.033, 0.034 and 0.033g/g/day) in year 2019-20, 2020-21 and in pooled result, respectively.

Among the different genotype, Swarna Safal reported highest relative growth rate at 30–60 DAS (0.040, 0.041 and 0.040 g/g/day), which was at par with remaining treatments except Tripura Rajma-1 in the year 2019-20. In the year 2020-21, Swarna Safal recorded highest relative growth rate and observed at par with Phule Rajma, GR-1. However in pooled analysis, Swarna Safal also recorded highest relative growth rate, but it was at par with Phule Rajma,. Among all the genotypes Tripura Rajma-1 recorded lowest relative growth rate in both the years and in pooled result. The same findings in french bean germplasm were also reported by Rania *et*

al. (2010), Noor *et al.* (2014) and Meena *et al.* (2018).

Effect of spacing and genotypes on net assimilation rate (NAR) :

At 0 – 30 DAS :

The data with regard to net assimilation rate at 0–30 DAS as influenced by different spacing and genotype of french bean are furnished in Table 6. The spacing 45 × 10 cm recorded significantly higher net assimilation rate at 0-30 DAS (0.0076, 0.0081 and 0.0079 g/g/day) than 30 × 10 cm spacing (0.0059, 0.0062 and 0.0061 g/g/day) in year 2019-20, 2020-21 and in pooled result, respectively.

Net assimilation rate at 0–30 DAS significantly differed in different genotypes. Swarna Safal (0.0112, 0.0111 and 0.0111 g/g/day) recorded significantly higher net assimilation rate at 0-30 DAS than the remaining genotypes in 2019-20, 2020-21 years and in pooled analysis, respectively. However, Tripura Rajma-1 registered lowest net assimilation rate (0.0054, 0.0057 and 0.0055 g/g/day) at 0–30 DAS in both years and in pooled analysis, respectively.

Interaction effect between the spacing and genotype reported non-significant variation at 0-30 DAS in net assimilation rate in both the year and in pooled analysis.

At 30 – 60 DAS :

The different spacing exerted significant differed on net assimilation rate at 30-60 DAS (Table 6). The

Table 7 : Interaction effect of various spacing and genotypes on net assimilation rate (NAR) at 30 – 60 DAS

Treat.	Net assimilation rate [NAR] (g/g/day) at 30 – 60 DAS								
	2019-20			2020-21			Pooled		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁	0.062	0.125	0.094	0.063	0.127	0.095	0.125	0.253	0.189
G ₂	0.053	0.098	0.075	0.053	0.098	0.076	0.106	0.196	0.151
G ₃	0.056	0.115	0.085	0.055	0.117	0.086	0.112	0.232	0.172
G ₄	0.061	0.118	0.089	0.059	0.116	0.087	0.119	0.234	0.177
G ₅	0.052	0.100	0.076	0.053	0.102	0.077	0.105	0.201	0.153
G ₆	0.051	0.094	0.072	0.049	0.094	0.071	0.099	0.188	0.144
G ₇	0.049	0.102	0.075	0.049	0.104	0.076	0.098	0.205	0.152
G ₈	0.051	0.092	0.071	0.048	0.092	0.070	0.099	0.184	0.142
G ₉	0.053	0.100	0.077	0.052	0.106	0.079	0.106	0.206	0.156
G ₁₀	0.042	0.079	0.061	0.043	0.078	0.061	0.086	0.157	0.121
G ₁₁	0.067	0.138	0.103	0.071	0.146	0.108	0.138	0.284	0.211
Mean	0.054	0.105		0.054	0.107		0.109	0.213	
	S.E.±		0.004	S.E.±		0.005	S.E.±		0.003
	C.D. (P=0.05)		0.012	C.D. (P=0.05)		0.013	C.D. (P=0.05)		0.009

spacing 45×10 cm recorded significantly higher net assimilation rate at 30-60 DAS (0.105, 0.107 and 0.106 g/g/day) than 30×10 cm spacing (0.054, 0.054 and 0.054 g/g/day) in year 2019-20, 2020-21 and in pooled result, respectively.

Net assimilation rate at 30–60 DAS significantly differed in different genotypes, among the genotypes Swarna Safal (0.103, 0.108 and 0.106 g/g/day) recorded significantly higher net assimilation rate at 30-60 DAS than the remaining genotypes in 2019-20, 2020-21 years and in pooled analysis, respectively. However, Tripura Rajma-1 registered lowest net assimilation rate (0.075, 0.076 and 0.075 g/g/day) at 30–60 DAS in both years and in pooled analysis, respectively.

The net assimilation rate (g/g/day) of french bean at 30-60 DAS was affected by the interaction effects of spacing and genotype (Table 7). Accordingly, variety Swarna Safal showed the highest net assimilation rate (g/g/day) at 45×10 cm plant spacing and the lower plant height was observed in Tripura Rajma-1 when sown on 30×10 cm spacing these results are in confirmation of findings of Malek *et al.* (2012).

Conclusion :

On the basis of the present results, it could be concluded that spacing of 45×10 cm recorded significantly higher physiological growth indices *viz.*, AGR, CGR, RGR and NAR in french bean during 2019-20; 2020-21 and pooled analysis, respectively. In case of genotypes, result revealed that significantly higher physiological growth parameters *viz.*, AGR, CGR, RGR and NAR was observed in Swarna Safal genotype during 2020, 2021 and in pooled analysis, respectively. This genotype was also found closely related to Phule Rajma during the years 2019-20, 2020-21 and in pooled analysis. This is concluded from interaction effect results that Swarna Safal (ICAR Ranchi) found significantly superior in various growth attributes at 45 × 10 cm spacing under middle Gujarat conditions.

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