

Short Communication

## Genetic variability and character association for yield and yield related traits in *Rajmah* (*Phaseolus vulgaris* L.) landraces of Barak valley of Assam

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### ABSTRACT

In the present study, the genetic diversity and the association among seventeen morphological and yield traits were assessed among 14 *Rajmah* (*Phaseolus vulgaris* L.) landraces collected from different places in the Barak Valley of Assam. The results revealed high estimates of the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for plant height, number of seeds per plant, and seed weight. Moderate estimates of GCV and PCV for number of pods per plant, seed weight per pod, average pod weight, seed breadth, 100-seed weight and seed yield. The analyses revealed that selection would be highly effective for the characters like plant height, number of seeds per plant and seed weight per plant, number of pods per plant, seed weight per pod, average pod weight, seed breadth, 100-seed weight, and seed yield as these traits showed high to moderate estimates of GCV and PCV along with high estimates of heritability coupled with moderate to high estimates of genetic advance as per cent of means. Correlation and path analysis revealed that besides seed yield, number of branches per plant, leaf length, leaf breadth, pod length, number of seeds per plant, seed yield per plant, number of pods per plant, number of seeds per pod, seed breadth, 100-seed weight, seed length, and days to 50% flowering are some of the important yield attributing traits in *Rajmah*.

**Key words:** *Rajmah*, Germplasm, Variability, Heritability, Genetic Advance, Path Analysis

French bean or common bean (*Phaseolus vulgaris* L.) is one of the most popular short-duration leguminous vegetable crops which is grown worldwide for its edible pods and dry seeds. The varieties used for dry seeds used as 'dal' or pulses are referred to as *Rajmah* or *Rajmash*. Dry seeds contain 21.1%, 69.9% carbohydrates, 1.7% fat, 381 mg calcium, 425 mg phosphorous and 12.4 mg iron per 100 g of edible part (Ali and Kushwaha 1987). It is considered an important protein source for the people of many developing countries (Chatterjee 2022) and hence often called poor man's meat (Beebe *et al.* 2000). French bean is becoming popular for its tender pods and shelled beans. Besides, it maintains soil fertility through biological nitrogen fixation in association with symbiotic *Rhizobium* prevalent in their root nodules. In India, it is mainly grown in Himachal Pradesh, Uttarakhand, Jammu and Kashmir, Punjab, Haryana, Uttar Pradesh, Bihar, Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu and north-eastern region of India (Chouhan *et al.* 2023).

In the Barak valley of Assam, comprising three districts, *viz.*, Cachar, Karimganj, and Hailakandi, *Rajmah* is considered one of the most important pulse crops. The region is situated in the southern part of Assam and geographically located between 24°15' and 25°9' N Latitudes and 90°16' and 93°15' E Longitudes. *Rajmah* or common bean is one of the oldest cultivated crops (Mathew *et al.* 2011). It is also one of the most popular short-duration leguminous vegetable crops which is grown worldwide for its edible pod and dried seeds. A native of Central and South America, *Rajmah* is widely cultivated in temperate and subtropical regions of the world (Zeven *et al.* 1999). The beans are also rich in minerals, particularly iron, potassium, manganese, and magnesium, and are widely consumed food legumes among the pulses. Several landraces of *Rajmah* are grown by the farmers of Barak Valley as a cash crop. These local varieties vary in seed morphology, growth pattern, shape, size, taste, coat color, maturity duration, and yield potential. The selection of landraces differed with farmers based

on their preferences. Many farmers cultivate the landraces based on taste, thus resulting in poor yield (Verma *et al.* 2014). The biodiversity of this crop in this region is rapidly decreasing due to urbanization, depleting soil nutrient status, the introduction of high-value vegetable crops, and climatic constraints. Efforts are necessary for the conservation and utilization of this rich genetic wealth of *Rajmah* beans. High resistance to pests and diseases, wider adaptability, and short duration are the major features for genetic improvement in this crop. To improve the existing germplasm in any crop, knowledge of genetic variability, and an association of different traits with yield and its heritability is necessary (Saifullah and Rabbani 2009). Seed yield is a complex quantitative trait, the development of superior varieties involves selection based on component traits. It is, therefore, imperative to know about the degree and direction of association of plant characters, which would be of great value in pinpointing the important component traits affecting seed yield directly or indirectly. To date, no work has so far been reported on the genetic diversity of *Rajmah* beans of Barak Valley region of Assam. Therefore, the present investigation has been undertaken to assess the genetic diversity and also to study the association among different characters in this crop.

The materials for the present investigation comprised fourteen *Rajmah* genotypes including 13 landraces collected from different places in the Karimganj district of Barak Valley and one check variety (Table 1). The experiment was conducted during *Rabi* (November-March) season over two years (2019-20 and 2020-2) using a randomized block design with three replications. The experiment was carried out at the Research Farm of the Regional Agricultural Research Station (RARS), AAU, Karimganj (24°50' N Latitude and 92°20' E Longitude at an elevation of 16m above MSL). Seeds were sown in plots consisting of five rows of 2 m in length at a spacing of 30cm row to row and 10cm within row. The crop was raised by following the recommended package of practices for Assam. Five randomly chosen plants from each plot were tagged for recording observations on fourteen morphological and yield traits. Days to fifty percent flowering, 100-seed weight, and seed yield were recorded on per plot basis. The observations recorded on different morphological and yield traits during both years were pooled together following standard statistical procedures (Gomez and Gomez 1984) for the biometrical analyses. Genotypic variance ( $\sigma_g^2$ ),

phenotypic variance ( $\sigma_p^2$ ), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability ( $h^2_{b.s.}$ ), genetic advance (GA) were calculated following Singh and Choudhury (1979). The GCV and PCV were categorized as low (<10%), moderate (10-20%) and high (>20%) according to Sivasubramanian and Madhavamenon (1973) and heritability was categorized as low (<30%), medium (30-60%) and high (>60%) according to Robinson *et al.* (1949). Genetic advance as a percent of the mean was categorized as low (<10%), moderate (10-20%) and high (>20%). Correlations between characters were worked out according to Johnson *et al.* (1955). Path coefficient analysis was carried out following the method of Dewey and Lu (1959).

The mean performance of all the accessions under investigation on seventeen morphological and yield traits are presented in Table 2. FB-08/17 recorded the highest seed yield (3019 kg/ha), followed by FB-02/19 (2906 kg/ha) and FB-17/19 (2872 kg/ha). Two accessions, FB-08/17 and FB-16/19 exhibited maximum 100-seed weight (60.83 g), while another accession (FB-06/19) produced the smallest seeds with 100-seed weight of 43.5 g. Similarly, FB-08/17 exhibited the highest seed weight per plant (25.93 g) with the highest number of seeds per pod (5.08), maximum seed weight per pod (2.93 g), heaviest pod (4.20 g) and longest seeds (18.60 mm). The results revealed high estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were recorded for plant height, number of seeds per plant, and seed weight per plant indicating that these traits are important in *Rajmah* breeding program (Table 3). Moderate estimates of GCV and PCV for number of pods per plant, seed weight per pod, average pod weight, seed breadth, 100-seed weight, and seed yield. The estimates for PCV were found to be slightly higher than their corresponding GCV values for all the traits under study indicating that the traits are slightly influenced by environment. Similar results were reported by Kamaludin (2011) and Devi *et al.* (2015), who reported higher estimates GCV and PCV for number of pods per plant and yield per plant. Basavaraja *et al.* (2022) also reported a wide range of variations for days to 50% flowering, days to maturity, pod length, the number of seeds per pod and 100-seed weight. On the other hand, Thirugnanavel *et al.* (2019) reported high GCV and PCV for plant height, number of pods per plant, number of seeds per plant and seed yield in this crop. Allard (1960) suggested that the selection of traits in improvement programs should

**Table 1.** Details of *Rajmah* bean landraces collected from different places in the Barak Valley region of Assam from 2016 to 2019.

Sl. No.	Collection No.	Place of collection		Seed shape	Seed coat colour
		Village	District		
1.	FB-04/16	Mokoi Bhanga	Karimganj	Kidney shaped, medium sized	Purple black
2.	FB-08/17	Mokoi Bhanga	Karimganj	Rectangular, big sized	Gulf red
3.	FB-01/19	Kholarputa	Karimganj	Kidney shaped, medium sized	Brown speckled
4.	FB-02/19	Kholarputa	Karimganj	Kidney shaped, big sized	White with brown streak
5.	FB-05/19	Kholarputa	Karimganj	Kidney shaped, medium sized	Black mottled
6.	FB-06/19	Kholarputa	Karimganj	Kidney shaped, medium sized	Purple speckled
7.	FB-07/19	Kholarputa	Karimganj	Kidney shaped, medium sized	Purple speckled
8.	FB-16/19	Sherong Dewpur	Karimganj	Rectangular, big sized	Blackish
9.	FB-17/19	Borshila	Karimganj	Rectangular, medium sized	Gulf red
10.	FB-18/19	Borshila	Karimganj	Rectangular, big sized	Blackish
11.	FB-19/19	Borshila	Karimganj	Kidney shaped, medium sized	Brown speckled
12.	FB20/19	Borshila	Karimganj	Oval shaped, small sized	Blackish
13.	FB-22/19	Brahmansa-shan	Karimganj	Rectangular, medium sized	Blackish
14.	Arun (C)	AAU-ZRS, Shillongani	Nagaon	Rectangular, medium sized	Gulf red

**Table 2.** Mean performance of all the accessions under investigation on seventeen morphological and yield traits pooled over two years, 2019-20 and 2020-21.

Collection No.	DF50%	LL	LB	PH	NBP	NPP	PL	PB	NS/ Pod	SW/ Pod	APW	NS/ Plant	SW/ Plant	SL	SB	100-SW	Yield (kg/ha)
FB-04/16	70.500	11.550	8.083	41.317	4.567	11.590	13.977	1.067	4.600	2.700	3.267	41.483	19.400	17.950	5.650	48.667	2,465
FB-08/17	71.167	12.767	9.250	42.233	4.633	13.283	14.347	1.037	5.083	2.933	4.200	41.250	25.933	18.600	6.867	60.833	3,019
FB-01/19	67.833	13.450	9.083	42.833	4.217	10.697	14.193	1.123	4.300	2.367	3.333	49.933	14.667	15.633	5.517	46.500	2,477
FB-02/19	70.333	12.483	8.367	43.233	5.083	13.647	13.857	1.060	4.400	2.500	2.933	59.417	22.283	17.733	6.683	56.167	2,906
FB-05/19	77.500	13.233	8.783	45.183	4.483	12.140	14.103	1.120	4.533	1.933	2.367	45.150	20.367	16.817	6.900	44.667	2,673
FB-06/19	68.667	11.600	7.833	44.767	3.967	10.783	13.280	1.063	4.500	1.933	2.650	62.583	12.067	16.833	6.350	43.500	2,075
FB-07/19	70.833	11.867	8.833	41.600	4.033	9.027	13.880	1.080	4.483	2.517	3.267	32.917	14.967	16.317	5.833	48.833	2,175
FB-16/19	67.833	11.850	7.700	45.650	3.733	10.690	12.843	1.033	4.233	2.617	3.717	35.883	18.550	17.267	6.133	60.833	2,169
FB-17/19	68.667	12.850	8.617	46.150	5.167	12.390	13.680	1.000	4.883	2.550	3.167	37.700	21.933	18.117	6.583	49.333	2,872
FB-18/19	70.333	12.283	8.900	45.050	4.150	12.023	12.797	1.043	4.517	2.533	3.167	29.733	20.983	13.567	7.400	55.333	1,979
FB-19/19	70.500	12.867	8.833	44.717	4.183	10.207	13.163	1.090	4.567	2.617	3.300	31.567	12.867	15.650	5.600	49.333	2,031
FB20/19	72.500	12.000	7.883	42.283	4.733	11.213	10.880	1.120	4.333	2.250	2.650	29.300	14.417	16.050	5.917	45.167	1,743
FB-22/19	71.500	12.517	8.650	47.567	4.167	10.067	13.347	1.077	4.617	2.300	3.067	54.800	13.850	15.833	5.467	38.333	2,098
Arun (C)	80.667	12.650	7.833	103.183	4.317	10.967	14.167	1.150	4.033	1.967	2.767	51.567	16.200	16.267	5.233	41.833	2,291

be based on GCV because it represents the heritable part of the total variability. But GCV alone will not be useful in selection and it could be better to select the traits based on GCV together with heritability (Burton 1952). Heritability plays an important role in determining the phenotypic changes observed for different traits due to genotype or environmental factors. Since only the heritable portion of the variability is transmitted to the offspring, the study on heritability is very much important in any plant breeding program. In the present study, high estimates of heritability (>60%) were observed for all the traits. Highest heritability was observed for plant height (98.68%), followed by 100-seed weight (98.01%), days to 50% flowering (96.07%), number of seeds per plant (94.21%), seed breadth (93.24%), seed yield per plant (90.50%) and seed weight per pod (90.17%). These characters also exhibited moderate to high estimates of genetic advance as

percent of means, indicating that these traits could be controlled by additive genes and not much influenced by the environment. Hence, selection based on these characters should be effective. The results obtained in this study conform with the results obtained earlier workers (Singh *et al.* 1994, Junaif *et al.* 2010, Rai *et al.* 2010, Sofi *et al.* 2011, Verma *et al.* 2014, Jyothi Devi *et al.* 2015, Basavaraj *et al.* 2022).

Table 4 is presented estimates of genotypic and phenotypic correlation coefficients indicating a strong inherent association among the characters. In the present study, pooled analysis of the results revealed that there were both positive and negative correlations between yield and its component traits. Seed yield exhibited significant positive correlations at both genotypic and phenotypic levels with seed yield per plant (0.826), seed length (0.795), pod length

(0.782), number of pods per plant (0.759), number of branches per plant (0.656), number of seeds per pod (0.558), leaf length (0.478), 100-seed weight (0.390), seed breadth (0.386), leaf breadth (0.358) and number of seeds per plant. On the other hand,

pod breadth (-0.339) showed a significant negative correlation with seed yield. Significant positive correlations were also observed between most of these component traits. Thus, these characteristics can be regarded as important yield attributes in

**Table 3.** Pooled estimates of variances and other related parameters for different characters in fourteen genotypes of *Rajmah* during 2019-20 and 2020-21.

Traits	Mean	Range	$\sigma_g^2$	$\sigma_p^2$	GCV	PCV	$h^2_{b.s.}$	GA
Days to 50% flowering	71.35	67.83-80.67	12.819	13.343	5.018	5.120	96.071	10.133
Plant height (cm)	48.27	41.32-103.18	252.123	255.485	32.896	5.690	98.684	67.318
Leaf length (cm)	12.43	11.55-13.45	0.275	0.500	4.219	6.623	54.991	6.445
Leaf breadth (cm)	8.48	7.70-9.25	0.245	0.315	5.847	33.114	77.928	10.632
No. of branches/plant	4.39	3.73-5.17	0.161	0.192	9.132	9.988	83.607	17.202
No. of pods/plant	11.34	9.03-13.65	1.509	1.813	10.833	11.876	83.206	20.356
Pod length (cm)	13.47	10.88-14.35	2.219	2.422	6.388	7.209	78.507	11.660
Pod breadth (cm)	1.08	1.00-1.15	0.001	0.002	3.446	4.596	56.227	5.324
No. of seeds/pod	4.51	4.03-5.08	0.055	0.093	5.220	6.773	59.396	8.287
Seed weight/pod (g)	2.41	1.93-2.93	0.088	0.098	12.331	12.986	90.174	24.122
Average pod weight (g)	3.13	2.37-4.20	0.208	0.235	14.557	15.457	88.692	28.242
No. of seeds/plant	43.09	29.30-62.58	120.484	127.894	25.473	26.244	94.206	50.931
Seed weight/plant (g)	17.75	12.07-25.93	16.931	18.708	23.183	24.370	90.501	45.433
Seed length (mm)	16.62	13.57-18.60	1.609	1.875	7.634	8.240	85.816	14.567
Seed breadth (mm)	6.15	5.23-7.40	0.418	0.448	10.510	10.884	93.237	20.905
100-seed weight (g)	49.24	38.33-60.83	46.317	47.259	13.822	13.962	98.007	28.188
Seed yield (kg/ha)	2355	1743-3019	132494	191429	15.455	18.577	69.213	26.487

**Table 4.** Estimates of correlation coefficients at genotypic (above diagonal) and phenotypic (below diagonal) levels for seventeen different growth and yield traits in the local germplasm of *Rajmah* during *Rabi* 2019-20 and 2020-21 (pooled)

	DF50%	LL	LB	PH	NBP	NPP	PL	PB	NS/ Pod	SW/ Pod	APW	NS/ Plant	SW/ Plant	SL	SB	100-SW	Yield/ ha
DF50%		0.262 <sup>NS</sup>	-0.158 <sup>NS</sup>	0.748 <sup>**</sup>	0.108 <sup>NS</sup>	0.056 <sup>NS</sup>	0.164 <sup>NS</sup>	0.735 <sup>**</sup>	-0.341 <sup>*</sup>	-0.559 <sup>**</sup>	-0.501 <sup>**</sup>	0.108 <sup>NS</sup>	0.026 <sup>NS</sup>	-0.073 <sup>NS</sup>	-0.154 <sup>NS</sup>	-0.426 <sup>**</sup>	0.001 <sup>NS</sup>
LL	0.223 <sup>NS</sup>		0.636 <sup>**</sup>	0.143 <sup>NS</sup>	0.326 <sup>*</sup>	0.270 <sup>NS</sup>	0.449 <sup>**</sup>	0.339 <sup>*</sup>	0.124 <sup>NS</sup>	-0.111 <sup>NS</sup>	0.005 <sup>NS</sup>	0.094 <sup>NS</sup>	0.212 <sup>NS</sup>	-0.111 <sup>NS</sup>	0.066 <sup>NS</sup>	-0.110 <sup>NS</sup>	0.478 <sup>**</sup>
LB	-0.113 <sup>NS</sup>	0.638 <sup>**</sup>		-0.380 <sup>*</sup>	0.121 <sup>NS</sup>	0.142 <sup>NS</sup>	0.441 <sup>**</sup>	-0.152 <sup>NS</sup>	0.646 <sup>**</sup>	0.409 <sup>**</sup>	0.399 <sup>**</sup>	-0.203 <sup>NS</sup>	0.317 <sup>*</sup>	-0.175 <sup>NS</sup>	0.311 <sup>*</sup>	0.182 <sup>NS</sup>	0.358 <sup>*</sup>
PH	0.721 <sup>**</sup>	0.128 <sup>NS</sup>	-0.326 <sup>*</sup>		-0.076 <sup>NS</sup>	-0.101 <sup>NS</sup>	0.225 <sup>NS</sup>	0.531 <sup>**</sup>	-0.580 <sup>**</sup>	-0.462 <sup>**</sup>	-0.251 <sup>NS</sup>	0.246 <sup>NS</sup>	-0.125 <sup>NS</sup>	-0.111 <sup>NS</sup>	-0.392 <sup>*</sup>	-0.337 <sup>*</sup>	-0.065 <sup>NS</sup>
NBP	0.085 <sup>NS</sup>	0.216 <sup>NS</sup>	0.142 <sup>NS</sup>	-0.060 <sup>NS</sup>		0.774 <sup>**</sup>	0.060 <sup>NS</sup>	-0.219 <sup>NS</sup>	0.453 <sup>**</sup>	0.184 <sup>NS</sup>	-0.134 <sup>NS</sup>	0.062 <sup>NS</sup>	0.576 <sup>**</sup>	0.508 <sup>**</sup>	0.280 <sup>NS</sup>	0.078 <sup>NS</sup>	0.656 <sup>**</sup>
NPP	0.036 <sup>NS</sup>	0.215 <sup>NS</sup>	0.128 <sup>NS</sup>	-0.077 <sup>NS</sup>	0.642 <sup>**</sup>		0.196 <sup>NS</sup>	-0.332 <sup>*</sup>	0.425 <sup>**</sup>	0.226 <sup>NS</sup>	0.071 <sup>NS</sup>	0.184 <sup>NS</sup>	0.850 <sup>**</sup>	0.467 <sup>**</sup>	0.711 <sup>**</sup>	0.496 <sup>**</sup>	0.759 <sup>**</sup>
PL	0.153 <sup>NS</sup>	0.323 <sup>*</sup>	0.380 <sup>*</sup>	0.193 <sup>NS</sup>	0.079 <sup>NS</sup>	0.153 <sup>NS</sup>		-0.031 <sup>NS</sup>	0.312 <sup>*</sup>	0.085 <sup>NS</sup>	0.238 <sup>NS</sup>	0.474 <sup>**</sup>	0.370 <sup>*</sup>	0.426 <sup>**</sup>	-0.012 <sup>NS</sup>	0.046 <sup>NS</sup>	0.782 <sup>**</sup>
PB	0.558 <sup>**</sup>	0.198 <sup>NS</sup>	-0.074 <sup>NS</sup>	0.416 <sup>**</sup>	-0.116 <sup>NS</sup>	-0.368 <sup>*</sup>	-0.023 <sup>NS</sup>		-0.805 <sup>**</sup>	-0.683 <sup>**</sup>	-0.570 <sup>**</sup>	0.170 <sup>NS</sup>	-0.561 <sup>**</sup>	-0.431 <sup>**</sup>	-0.628 <sup>**</sup>	-0.678 <sup>**</sup>	-0.339 <sup>*</sup>
NS/Pod	-0.283 <sup>NS</sup>	0.133 <sup>NS</sup>	0.491 <sup>**</sup>	-0.424 <sup>**</sup>	0.293 <sup>NS</sup>	0.347 <sup>*</sup>	0.120 <sup>NS</sup>	-0.438 <sup>**</sup>		0.593 <sup>**</sup>	0.495 <sup>**</sup>	-0.160 <sup>NS</sup>	0.561 <sup>**</sup>	0.441 <sup>**</sup>	0.535 <sup>**</sup>	0.308 <sup>*</sup>	0.558 <sup>**</sup>
SW/Pod	-0.519 <sup>**</sup>	-0.046 <sup>NS</sup>	0.364 <sup>*</sup>	-0.432 <sup>**</sup>	0.136 <sup>NS</sup>	0.239 <sup>NS</sup>	0.096 <sup>NS</sup>	-0.547 <sup>**</sup>	0.466 <sup>**</sup>		0.884 <sup>**</sup>	-0.491 <sup>**</sup>	0.516 <sup>**</sup>	0.285 <sup>NS</sup>	0.176 <sup>NS</sup>	0.755 <sup>**</sup>	0.298 <sup>NS</sup>
APW	-0.457 <sup>**</sup>	-0.000 <sup>NS</sup>	0.334 <sup>*</sup>	-0.239 <sup>NS</sup>	-0.127 <sup>NS</sup>	0.103 <sup>NS</sup>	0.243 <sup>NS</sup>	-0.470 <sup>**</sup>	0.376 <sup>*</sup>	0.844 <sup>**</sup>		-0.315 <sup>*</sup>	0.419 <sup>**</sup>	0.299 <sup>NS</sup>	0.050 <sup>NS</sup>	0.714 <sup>**</sup>	0.286 <sup>NS</sup>
NS/Plant	0.100 <sup>NS</sup>	0.081 <sup>NS</sup>	-0.165 <sup>NS</sup>	0.228 <sup>NS</sup>	0.036 <sup>NS</sup>	0.132 <sup>NS</sup>	0.411 <sup>**</sup>	0.154 <sup>NS</sup>	-0.123 <sup>NS</sup>	-0.447 <sup>**</sup>	-0.283 <sup>NS</sup>		-0.117 <sup>NS</sup>	0.264 <sup>NS</sup>	-0.141 <sup>NS</sup>	-0.354 <sup>*</sup>	0.330 <sup>*</sup>
SW/Plant	0.011 <sup>NS</sup>	0.172 <sup>NS</sup>	0.292 <sup>NS</sup>	-0.108 <sup>NS</sup>	0.508 <sup>**</sup>	0.824 <sup>**</sup>	0.303 <sup>NS</sup>	-0.462 <sup>**</sup>	0.432 <sup>**</sup>	0.476 <sup>**</sup>	0.366 <sup>*</sup>	-0.114 <sup>NS</sup>		0.493 <sup>**</sup>	0.703 <sup>**</sup>	0.687 <sup>**</sup>	0.826 <sup>**</sup>
SL	-0.088 <sup>NS</sup>	-0.067 <sup>NS</sup>	-0.135 <sup>NS</sup>	-0.088 <sup>NS</sup>	0.436 <sup>**</sup>	0.398 <sup>**</sup>	0.285 <sup>NS</sup>	-0.277 <sup>NS</sup>	0.386 <sup>*</sup>	0.272 <sup>NS</sup>	0.243 <sup>NS</sup>	0.243 <sup>NS</sup>	0.447 <sup>**</sup>		0.054 <sup>NS</sup>	0.303 <sup>NS</sup>	0.795 <sup>**</sup>
SB	-0.143 <sup>NS</sup>	0.044 <sup>NS</sup>	0.275 <sup>NS</sup>	-0.378 <sup>*</sup>	0.265 <sup>NS</sup>	0.619 <sup>**</sup>	-0.012 <sup>NS</sup>	-0.430 <sup>**</sup>	0.348 <sup>*</sup>	0.157 <sup>NS</sup>	0.051 <sup>NS</sup>	-0.119 <sup>NS</sup>	0.662 <sup>**</sup>	0.056 <sup>NS</sup>		0.561 <sup>**</sup>	0.386 <sup>*</sup>
100-SW	-0.406 <sup>**</sup>	-0.079 <sup>NS</sup>	0.150 <sup>NS</sup>	-0.333 <sup>*</sup>	0.066 <sup>NS</sup>	0.461 <sup>**</sup>	0.057 <sup>NS</sup>	-0.524 <sup>**</sup>	0.227 <sup>NS</sup>	0.710 <sup>**</sup>	0.678 <sup>**</sup>	-0.341 <sup>*</sup>	0.662 <sup>**</sup>	0.254 <sup>NS</sup>	0.540 <sup>**</sup>		0.390 <sup>*</sup>
Yield/ha	0.024 <sup>NS</sup>	0.407 <sup>**</sup>	0.413 <sup>**</sup>	-0.055 <sup>NS</sup>	0.552 <sup>**</sup>	0.627 <sup>**</sup>	0.624 <sup>**</sup>	-0.311 <sup>*</sup>	0.416 <sup>**</sup>	0.307 <sup>*</sup>	0.296 <sup>NS</sup>	0.290 <sup>NS</sup>	0.668 <sup>**</sup>	0.586 <sup>**</sup>	0.318 <sup>*</sup>	0.331 <sup>*</sup>	

<sup>NS</sup> Nonsignificant \* Significant at 5 percent probability level

\*\* Significant at 1 percent probability level

DF50%: Days to 50% flowering; LL: Leaf length; LB: Leaf breadth, PH: Plant height; NBP: Number of branches per plant; NPP: Number of pods per plant; PL: Pod length; PB: Pod breadth; NS/Pod: Number of seeds per pod; SW/Pod: Seed weight per pod; APW: Average pod weight; NS/Plant: Number of seeds per plant; SW/Plant: Seed weight per plant; SL: Seed length; SB: Seed breadth; 100-SW: 100 seed weight; Yield/ha: Seed yield in kg/ha

*Rajmah*. The analysis revealed significant positive and negative correlations among other characters also (Table 4) and supported by earlier studies (Rai *et al.* 2010, Kamaludin 2011, Makhdoomi and Dar 2011, Singh *et al.* 2011, Thirugnanavel *et al.* 2019, Shah *et al.* 2021). Hence, these traits can be directly considered for the yield improvement program in french bean.

Path coefficient analysis of yield and other yield attributes depicts the cause-and-effect relationship and accordingly measures the relative importance of each variable. Path coefficient analysis provides a more realistic picture of the relationship among the characters and reveals whether the association of each individual character with yield is due to its direct effect on yield or due to indirect effects via other component characters. Separation of total correlation into direct and indirect effects by path analysis aids in the selection of genotypes more effectively (Hasan *et al.* 2013). When a correlation study includes many variables, path analysis

becomes necessary to explain the true direct and indirect association among the traits (Mohammadi *et al.* 2003). In the present study, estimated the direct and indirect effects of sixteen component traits on seed yield at the phenotypic level is presented in Table 5. The analysis revealed that the number of branches per plant had the maximum positive direct effect (0.303) on seed yield followed by 100-seed weight (0.259), pod length (0.252), seed length (0.240), leaf breadth (0.230), number of seeds per plant (0.228) and days to 50% flowering (0.225). Some other characteristics like leaf length, number of pods per plant, average pod weight, and seed yield per plant showed low positive direct effects on seed yield. On the other hand, moderate to low negative direct effects on seed yield were recorded for pod breadth (-0.230), seed weight per pod (-0.106), plant height (-0.092), seed breadth (-0.078) and number of seeds per pod (-0.010). Some of the characters also showed low estimates of positive indirect effects on yield, *viz.*, leaf length via leaf breadth (0.147),

**Table 5.** Path coefficient analysis indicating direct (bold) and indirect effects of different traits on yield/ha in local *Rajmah* germplasm accessions of Barak valley region, Assam at phenotypic level during *Rabi* 2019-20 and 2020-21 (pooled).

Characters	DF50%	LL	LB	PH	NBP	NPP	PL	PB	NS/Pod	SW/Pod	APW	NS/Plant	SW/Plant	SL	SB	100-SW	r
DF50%	<b>0.225</b>	0.028	-0.026	-0.066	0.026	0.002	0.039	-0.128	0.003	0.055	-0.041	0.023	0.000	-0.021	0.011	-0.105	0.024 <sup>NS</sup>
LL	0.050	<b>0.126</b>	0.147	-0.012	0.065	0.012	0.081	-0.046	-0.001	0.005	0.000	0.018	0.001	-0.016	-0.003	-0.020	0.407 <sup>**</sup>
LB	-0.025	0.081	<b>0.230</b>	0.030	0.043	0.007	0.096	0.017	-0.005	-0.039	0.030	-0.038	0.002	-0.032	-0.022	0.039	0.413 <sup>**</sup>
PH	0.162	0.016	-0.075	<b>-0.092</b>	-0.018	-0.004	0.049	-0.095	0.004	0.046	-0.022	0.052	-0.001	-0.021	0.030	-0.086	-0.055 <sup>NS</sup>
NBP	0.019	0.027	0.033	0.005	<b>0.303</b>	0.036	0.020	0.027	-0.003	-0.014	-0.011	0.008	0.003	0.104	-0.021	0.017	0.552 <sup>**</sup>
NPP	0.008	0.027	0.029	0.007	0.194	<b>0.056</b>	0.038	0.085	-0.004	-0.025	0.009	0.030	0.005	0.095	-0.049	0.120	0.627 <sup>**</sup>
PL	0.035	0.041	0.087	-0.018	0.024	0.009	<b>0.252</b>	0.005	-0.001	-0.010	0.022	0.094	0.002	0.068	0.001	0.015	0.624 <sup>**</sup>
PB	0.126	0.025	-0.017	-0.038	-0.035	-0.021	-0.006	<b>-0.230</b>	0.005	0.058	-0.042	0.035	-0.003	-0.066	0.034	-0.136	-0.311 <sup>*</sup>
NS/Pod	-0.064	0.017	0.113	0.039	0.089	0.019	0.030	0.101	<b>-0.010</b>	-0.050	0.034	-0.028	0.002	0.093	-0.027	0.059	0.416 <sup>**</sup>
SW/Pod	-0.117	-0.006	0.084	0.040	0.041	0.013	0.024	0.125	-0.005	<b>-0.106</b>	0.076	-0.102	0.003	0.065	-0.012	0.184	0.307 <sup>*</sup>
APW	-0.103	0.000	0.077	0.022	-0.038	0.006	0.061	0.108	-0.004	-0.090	<b>0.090</b>	-0.064	0.002	0.058	-0.004	0.176	0.296 <sup>NS</sup>
NS/Plant	0.023	0.010	-0.038	-0.021	0.011	0.007	0.104	-0.035	0.001	0.048	-0.026	<b>0.228</b>	-0.001	0.058	0.009	-0.089	0.290 <sup>NS</sup>
SW/Plant	0.002	0.022	0.067	0.010	0.154	0.046	0.076	0.106	-0.004	-0.051	0.033	-0.026	<b>0.006</b>	0.107	-0.052	0.172	0.668 <sup>**</sup>
SL	-0.020	-0.009	-0.031	0.008	0.132	0.022	0.072	0.064	-0.004	-0.029	0.022	0.055	0.002	<b>0.240</b>	-0.004	0.066	0.586 <sup>**</sup>
SB	-0.032	0.006	0.063	0.035	0.080	0.035	-0.003	0.099	-0.004	-0.017	0.005	-0.027	0.004	0.014	<b>-0.078</b>	0.140	0.318 <sup>*</sup>
100-SW	-0.092	-0.010	0.034	0.031	0.020	0.026	0.014	0.120	-0.002	-0.076	0.061	-0.078	0.004	0.061	-0.042	<b>0.259</b>	0.331 <sup>*</sup>

Residual effect: 0.151

DF50%: Days to 50% flowering; LL: Leaf length; LB: Leaf breadth, PH: Plant height; NBP: Number of branches per plant; NPP: Number of pods per plant; PL: Pod length; PB: Pod breadth; NS/Pod: Number of seeds per pod; SW/Pod: Seed weight per pod; APW: Average pod weight; NS/Plant: Number of seeds per plant; SW/Plant: Seed weight per plant; SL: Seed length; SB: Seed breadth; 100-SW: 100 seed weight

plant height via days to 50% flowering (0.162), pod breadth via days to 50% flowering (0.126) and seed weight per pod via pod breadth (0.125) and via 100-seed weight (0.184). The residual effect was found to be low (0.151), indicating 85 percent of the variability in seed yield per plant could be explained by the independent variables included in path analysis. Similar results were also obtained by Thirugnanavel *et al.* (2019), Rai *et al.* (2010), Salehi *et al.* (2010), Kamaludin (2011), Praveen *et al.* (2011) and Jyothi Devi *et al.* (2015) who reported that characters like 100-seed weight, number of seeds per plant, number of pods per plant, seed length had high direct and positive effect on seed yield per plant in common bean. In conclusion, higher estimates of GCV and PCV coupled with higher estimates of heritability and genetic advance as percent of means for the traits like plant height, number of seeds per plant, and seed yield per plant, indicating that these traits are important in *Rajmah* breeding program. Correlation and path coefficient analyses revealed that seed length, pod length, number of branches per plant, 100-seed weight, leaf breadth, and number of seeds per plant are some of the important traits based on which simultaneous selection can be practiced for improvement of seed yield in *Rajmah*.

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