Journal of AgriSearch 3(3):136-141
Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
http://dx.doi.org/10.21921/jas.v3i3.11373

Assessment of Soil Fertility Augmenting Potential of Faba Bean (*Vicia Faba L.*) Germplasm and their Performance

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ARTICLE INFO		
Received on	:	01.08.2016
Accepted on	:	19.08.2016
Published online	:	10.09.2016

ABSTRACT

Faba bean (*Vicia faba L.*) maintain third place with respect to area and production among legume. Its unique ability to excel under all most all type of climatic conditions, it is one of the best performing crops under changing climate scenario. Its soil fertility augmenting potential and their performance was evaluated for two years with 73 accessions collected from Bihar. This study provides glimpses of scope and magnitude of soil fertility improving potential of faba bean (*Vicia faba* L.)

Keywords: Nitrogen fixing ability, Organic Carbon content, Agro-morphology, Bihar, germplasm, faba bean, Diversity index

INTRODUCTION

Faba bean (*Vicia faba L.*) is among the oldest crops in the world. Globally, it is third most important feed grain legume after soybean (*Glycine max*) and pea (*Pisum sativum* L.) (FAO, 2009 and Singh *et al*., 2013). Faba bean is assigned to the Central Asian, Mediterranean, and South American centres of diversity and believes to be a native of North Africa and southwest Asia (Harlan, 1969). Worldwide presently faba beans are grown in 58 countries (FAO, 2009). Probably one of the best performing crops under global warming and climate change scenario because of its unique ability to excel under all most all type of climatic conditions (Singh *et al*., 2013).It is such a wonderful legume which can be grown in profitable manner in pH ranging 5.5 to 9.0., being one of the most potential crops to serve humanity, unfortunately in India it is still treated as a minor legume / unutilized / underutilized crop (Singh *et al*., 2010 and Singh & Bhatt, 2012).Ability to excel under all most all type of climatic conditions coupled with its wide adoptability to range of soil environment make it strongest contender to be a "King of crop" and it is seen as an agronomically viable alternative to cereal grains (Alghamdi ,20102 and Singh *et al*., 2012b). It is mainly *rabi* pulses/legume in plains of India, though it is successfully grown during *kharif* (rainy season) in hilly and mountainous regions (Singh & Bhatt, 2012). It is good source of lysine rich protein (20-40 %) and less anti-nutritional substance than soybean. This crop can be taken as sole crop and as intercropped/mixed crops with variety of combination even as border / guard crop especially in Bihar and eastern Uttar Pradesh (Singh *et al*., 2013). There is a need to diversify the gene pool base of this crop by various means and sources. Exploration for collection of germplasm is quickest and sometime easiest method of enriching genetic resources of any crops (Brush, 1995 and Brown and Spillane, 1999) Characterization and evaluation of germplasm (73 accessions) collected from Bihar was carried out with an objective to enhance our understanding on extent and pattern of diversity in faba bean germplasm and to establish relationships among them (Arbaoui & Link , 2006 & Singh *et al*., 2011). Most landraces identified were medium to long-duration types. The recorded plant and seed traits varied considerably, but the frequency of landraces with relatively large white or cream seeds and large pods was high in all regions. Faba bean is an excellent nitrogen-fixing plant, capable of fixing atmospheric nitrogen through symbiosis which results in increased residual soil nitrogen for use by subsequent crops and can be used as green manure having potential of fixing free nitrogen (150-300 kg N/ ha). It is also equally good for phosphorus solubilising and potassium mobilization (Singh *et al*., 2012b and Stutzel & Aufhammer, 1992). With an objective to assess soil fertility augmenting potential of faba bean (*Vicia faba* L.) germplasm and their performance this study was undertaken.

MATERIALS AND METHODS

Plant exploration and collection of germplasm is quickest way to collect modest variability (Singh *et al*., 2012 a; Brush 1995; Brown and Spillane 1999). Two exploration trips was planned and executed to collect and conserve (*In-situ*) faba bean (*Vicia faba L.*) germplasm available in the Bihar. The geographical areas surveyed for diversity collection are Samastipur, Sitamadhi, Muzaffarpur, and Vaishali and total 73 accessions were collected during the designated exploration. A field evaluation experiment was undertaken for collected faba bean *(Vicia faba L.)* germplasm to assess its potential for soil fertility augmentation and their performance. All the accessions, which were collected, were planted at Main campus research farm ICAR Research Complex for Eastern Region Patna (25°35'N latitude and 85° 05'E longitude) Bihar. November planted crop generally flowers in January- February and complete its life cycle in the month of March. The field experiment was conducted during Rabi seasons of 2008-09 and 2009-10 in randomized block design (RBD) and replicated thrice. The experimental plot size was 2.0 m X 1.0 m. The surface soil up to 30 cm depth were sampled and collected

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from the experimental field, air dried, mixed and passed through 2 mm sieves and analysed for various physical and chemical prosperities. The soil of experimental site was sandy loam in texture, neutral in soil reaction (7.11 pH), Electrical Conductivity (dSm^{-1}) (0.27) having 0.67% organic carbon content, medium in fertility status (available N 244.5 kg, P 25.6 kg and exchangeable K 145.7 kg). Sowing operation was carried out during first week of November during both the years. Seeds were sown on well prepared flat bed at 30 cm row to row and 20 cm plant to pant spacing respectively, putting three seeds in each hole. After fortnight of sowing operation plant were thin out keeping two healthy plants per hole to maintain optimum plant population. Crop was fertilized with NPK @ 20:50:40 Kg/ha respectively. Three numbers irrigation was given at grand growth phase, pre-flowering and pod filling stage during both seasons. One hand weeding was carried out at initial stages of crop growth. No major incidence of pests and disease were noticed during the course of experimentation, however, prophylactic plant protection measures were taken care to manage the biotic stress if any. Germination of seeds were satisfactory during the both the season hence crop stand was normal. Agro-meteorological condition of Research Station is very much conducive for faba bean cultivation. The mean monthly minimum and maximum temperature (^{0}C), rainfall (mm), and was recorded (Table 1).

Table 1: Agro-meteorological data during crop season

Std. week No	1st Year (2008-09)						2nd Year (2009-10)					
	Temp.(ºC)		Rain	RH	Evpo	Wind Speed	Temp.(ºC)		Rain	RH	Evpo	Wind Speed
	Min	Max	(mm)	(%)	(mm)	(Km/hr)	Min	Max	(mm)	(%)	(mm)	(Km/hr)
46	17.1	28.3	0	72.5	2	1.2	14.2	28	0	67	1.6	1.5
47	14.1	27.6	0	64.5	1.9	1.5	16.1	26.7	0	76	1.5	1.5
48	11.5	25.9	0	63	1.5	1.1	13.6	25	0	63	1.4	1.9
49	12.2	23.4	0	76.5	0.9	1.3	11.8	27	0	65.5	1.9	1.4
50	13.1	27.1	0	68	1.2	1.3	13.2	26.8	0	70.5	1.6	1.5
51	10.4	24.4	0	66.5	1.4	1.7	13.1	21	0	85	0.2	2
52	8.7	20	8	76.5	1.2	2.8	8.5	22.9	8	72.5	1.2	2.6
1	8.6	15.2	0	75.5	0.7	3.2	9.6	22.7	0	71	1.6	2.1
2	9	16.8	0	82.5	0.8	4	7.8	21.8	0	68	1.5	2.2
3	9.5	20.2	0	79.5	0.6	2.3	9.2	22.3	0	70	1.1	2.8
4	11.3	20.2	40	76	0.8	2.3	10.1	20.7	0	75.5	1.3	3.2
5	8.2	20.4	3	73	1.5	2.9	11.9	21.2	7	75.5	1.4	3.1
6	8.3	23.2	0	68	1.4	2.2	10.4	24.8	5	70	2	2.4
7	11.9	27	0	67.5	1.9	1.9	14.4	28.2	0	61.5	3.8	5.9
8	13	27.1	0	60.5	2.3	2.5	14.8	27.1	8	73	2.3	3.9
9	14.2	28.6	0	64	2.8	3.7	13.3	28.4	9.5	60	3.5	3.9
10	14	29.2	0	66	3.1	4.1	18.9	31.1	0	59.5	4.3	5.8
11	19	31.9	0	70.5	2.7	2.2	16.7	31.2	0	61	3.6	2.9
12	21.4	33.9	0	70.5	3.9	4.5	19.3	30.8	0	64.5	4.6	4.8

10 representative plants were uprooted carefully along with the roots from each plot marked for sampling. Utmost care was taken to uproot the plant intact with full root systems. A light watering is done for easy uprooting of plants with maximum belowground portions root. After uprooting the plant root portion were separated carefully and washed with tape water gently to remove the soil particles. After proper sampling, above ground and below ground portion (roots and shoot) were separated. Data on the plant height was recorded from base to top of plant. After recording plant height, fresh weight of above ground portion was recorded and samples were kept in oven for drying till constant weight. Dry weights were recorded by drying samples in an oven at 60°C for 72 hours. Study on belowground portion (Roots) consists of recording of fresh weight of roots and nodule. After recording fresh observation samples were puts in the oven for dry weight purpose. Same procedure were followed as it was in case of shoot (above ground) portion. At harvest 10 representative samples of each plot were collected and biometrical data were recorded and computed for seed yield (g per plant). Uniform and representative soil sampling was done from each plot before the onset of experiment and after completion of each crop cycle, as per standard procedure described by AOAC (1980). Physical and chemical parameter of soils were recorded with reference to pH, EC (dS/m), OC (%), available P(ppm) and exchangeable K(ppp) before sowing and after harvest crop and converted in kg/ha.

All the data generated during course if study was subjected to

statistical analysis to have minimum, mean, maximum, coefficient of variance (CV), frequency distribution and correlation (R^2) etc. Coefficient of variance (CVs) is useful in estimating diversity, high CV (%) indicate presence of more diverse germplasm as suggested (Bond,1966 and Duc *et al.*,1999). Diversity index of faba bean germplasm was also workout with help of Shannon-Weaver Diversity Index (SDI) for individual accessions, location wise as well as for total collection by using formula (Poole, 1974) based upon frequency distribution.

$$H = -\sum_{i=1}^{n=1} Pi.\log pi$$

$$SDI = \frac{H}{Nln}$$

Where,
n is the number of phenotype class (for n vended for each trait and for quantitative traits qualitative characters)
N= equaled to the no of frequency classes
p_i is the proportion of total number of the accessions in the I^{th} class of the n- class character The indices are standardized by dividing each value of H1 by large (SDI= H / N l_n to keep the value in the range in between 0-1 in order to estimate the importance of phenotypic diversity. SDI was calculated based upon the frequency distribution.

RESULTS AND DISCUSSION

A total of four locations were explored and 73 accessions were collected, out of maximum 26 accessions were from Muzaffarpur area and minimum 1 from Sitamadhi District. Observation recorded during the experimentation as per schedules; data were analyses statistically to draw some valid inference. The result obtained is being discussed as under

Influence of faba bean germplasm on soil fertility status

Status of fertility of a soil is basically governed by its pH, EC, OC and nutrient supplying capacity. Effects of faba bean germplasm on the soil physiochemical properties especially nutrient dynamics were studied and results were summarized in table 2. Soil pH is the one of the crucial factor which influences the nutrients availability by and large as their reaction with soil clay complex are highly pH dependent. Perusal of data revealed that this parameter (soil pH) was very less influenced by the faba bean in two seasons. Soil pH was ranged from 6.83 to 7.18 with mean value of 6.91. The SD and CV (%) was 0.24 and 3.5, suggested slow pace of change during experimentation period. The initial soil pH was recorded 7.11(Alghamdi, 2002 and Singh *et al.*, 2009a). Electrical conductivity (EC) of soil was the one of parameter which was influenced most than other parameter under study with SD and CV (%) was 0.11 and 25.6. Though the range of variability was noted 0.25 to 0.59 with mean value of 0.43.This is the one of the soil fertility parameters which influenced inherent soil fertility due to its role in nutrient mobility in soil solution and to the root zone (Alghamdi, 2002 and Singh *et al.*, 2009a). Organic carbon content of soil is the barometer of the soil system to gauge bio-physico-chemical parameters (Singh *et al.*, 2010). Faba bean capacity to improve organic matter content of the soil is significant than as compare to other annual crop in short span of time. Data parented in table 2 indicate that OC content varied from 0.69 to 0.78 with mean value of 0.73. The Estimated SD and CV (%) was recorded 0.10 and 13.3. Germplasm collected form Bihar showed considerable variability in which traits which is crucial for soil fertility dynamics (l-Gizawy, *et al.*, 2009 and Singh *et al.*, 2009a). Nitrogen supplying ability of any soil is mainly governed by soil reaction, organic carbon content and electrical conductivity. All nitrogen supply parameter were significantly influenced by faba bean germplasm, hence, dynamic of inherent nitrogen availability was noticed accordingly (Arbaoui & Link, 2006 & Singh *et al.*, 2009b). Results depicted in table 2 revealed that inherent nitrogen availability (kg/ha) was minimum 257.1 to maximum 445.3 with average value of 343.2. Estimated SD was 39.22 with 11.4% CV (Singh *et al.*, 2009a). This improvement was might be due to symbiotic nitrogen fixed by faba bean, as it was evident by rhizospher /root activities. Availability of phosphorus in soil solution is mainly governed by pH and rhizoshpher temperature. It was noted that pH of soil has been positively influenced due to presence of faba bean. Availability of P (kg/ha) was varied 24.41 to 75.36 with mean value 49.75. Regarding diversity in this parameter, it was noticed that presence of estimated SD (12.09) and 24.3 % CV indicate good amount of variability exists in this trait (l-Gizawy, *et al.*, 2009 and Singh *et al.*, 2009a). Exchangeable potassium (kg/ha) was also influenced significantly due to variability in germplasm. Though the availability of potassium is mainly governed by parent material and soil pH and OC content plays a great role to make them available in exchangeable form. It was recorded that exchangeable potassium (kg/ha) was ranged from 156.80 to 372.40 with an average of 215.54. Good amount of variability was recorded with 39.80estimated SD and CV 18.5(%) (Alghamdi, 2002 and Singh *et al.*, 2009a).

Table 2: Changes in soil fertility due to faba bean germplasm

Parameters	Initial Value	Min	Max	Mean	Est. SD	CV (%)
pH	7.11	6.83	7.18	6.91	0.24	3.5
EC(mS/m)	0.27	0.25	0.59	0.43	0.11	25.6
OC (%)	0.67	0.69	0.78	0.73	0.10	13.3
N (kg/ha)	244.5	257.1	445.3	343.2	39.22	11.4
P (kg/ha)	22.6	24.41	75.36	49.75	12.09	24.3
K (kg/ha)	145.7	156.80	372.40	215.54	39.80	18.5

Est. = Estimated

Influence of faba bean germplasm on its performance

In order to understand and establishing the relationship among 73 accessions, agronomical characterization and evaluation was carried out. Faba bean employs a high degree of plasticity (Arbaoui and Link, 2006). Height of faba bean plant by and large governed by types its genetic makeup, their growing environment and agronomic management practices including input (Stutzel & Aufhammer 1992 and Singh *et al.*, 2009a). Plant height is base material for biomass production and other dependent and interdependent traits which is discussed here one by one (Alan & Geren 2007 and Singh *et al.*, 2011). Faba bean are highly influenced with its growing condition having high plasticity can accommodate in any situation to complete life cycle successfully. In this study plant height of faba bean germplasm ranged between 63.4 cm to 94.3 cm with mean of 78.4 cm with SD (6.1) and CV (7.8). In general there is every possibility that taller plant could bear more pods and consequently produce more seeds per plant. This trait can also use efficiently for evolving new genotype for this crop (Alan and Green, 2007 and Bora *et al.*, 1998). Root growth and development is the indicator of efficacy of any plant species. Plant takes their nutrients and water from soil through root only hence root play a crucial and important role in this regard (l-Gizawy, *et al.*, 2009 and Duc *at el.*, 1999).

More uptakes of water and nutrient is good sign for optimum performance and consequently more economic produce. More root dry weight is good for successful completion of life cycle. If root weight is more the number and length is supposed to be more. Data recorded in this aspect revealed existence of considerable diversity with 0.6 SD and 21.2 % CV. Range of root dry weight was recorded 1.81 g to 4.42 g with an average value of 2.98g (Duc *at el.*, 1999 and Singh & Bhatt,2012). Improvement in root dry weight influences the nodules dry wt. / plant but also directed to better and efficient symbiotic nitrogen fixed by faba bean germplasm (Alan & Geren, 2007 and Singh *et al.*,2012b).

Being a legume crop, faba bean actively involved in free nitrogen fixation through symbiosis with *rhizobia*. Number of effective nodules on root is more if plants have effective symbiosis in the root zone (Stutzel & Aufhammer. 1992 and Singh *et al.*, 2009b). If root zone is more, number of root and their length are also more. If rhizosphere environment is conducive then effective nodulation is increased along with their size. This is good sign towards the contribution in nitrogen nutrient management and maintenance of soil fertility and productive status. The tested germplasm exhibits presence of very good amount of variability. It is in general believe that there is direct and positive correlation between root and nodules dry weight, and by and large in normal condition it is found true. Range of nodule dry weight (g) varies from 0.57 to 1.48 with mean value of 0.96. The SD and CV of the tested lot were 0.2 and 20.08 (Singh &Bhatt, 2012 and Vesey *et al.*, 1999). This improvement attributed leads to better and efficient symbiotic nitrogen fixed by faba bean germplasm (Duc *at el.*, 1999 and Singh *et al.*, 2011). Biomass production is at least indicator of the ability of plant to adopt well under certain agro climatic condition up to vegetative or certain reproductive stage if not for whole lifecycle (Arbaoui and Link, 2006 and Singh *et al.*, 2009b). It is partial true when plant unable to bear seeds in pod or pod itself; and fully if successfully complete it seed to seed cycle (Singh *et al.*, 20011). The collected lot has very good amount of variability with 21.8 % CV and 36.5 SD. The range was 96.8 to 259.6 with mean value of 167.6. This data shows that there is ample scope of improvement in this very important traits having direct and positive bearing on seed yield. This trait indicates that the crop has great potential to improve its performance in leap. In protein yielding crops seeds are store house hence, most economical part (Singh *et al.*, 2012b and Weber *et al.*, 2005). Seed yield is resultant of series of successful event and governed multiple factors including its heredity characters, (being a polygenic trait) and agro-climatic conditions and agronomic management practice (Duc *at el.*, 1999 and Singh *et al.*, 2011). Faba bean seed yield per plant is determine by numerous factor but basically governed by its varietal characters and its management practices under prevailing agro climatic condition (Bora *et al.*, 1998 and Singh *et al.*, 2009b).

Faba bean poses high degree of plasticity which enables this crop to complete his life cycle (seed to seed) under adverse circumstance and perform best with conducive and congenial situation with efficient agronomic management conditions (Vesey *et al.*, 1999). Very good amount of diversity was recorded with SD (24.3) and CV 11(%). This variability was supported by minimum seed yield per plant (g) 21.9 and maximum 73.1 corresponding mean value of 45.1. Extent and pattern of diversity presence in this trait confirm that there is great scope of improving seed yield /plant and per unit area (Weber *et al.*, 2005). Harvest Index (HI) is the nothing but the ratio between economic yield and total biomass produced by unit and it is indicator of effective economic production (Singh *et al.*, 2009b and Singh *et al.*, 2013). If Hi is more the crop/plant is more efficient in terms of producing more economic matter. Harvest Index is effective indicator of source to sink relation and translocation of photosynthesis. Since it is ratio of two produce, there is itself no diversity but presence of variability

Table 3: Agro-morphological diversity in faba bean germplasm

Parameters	Min	Max	Mean	SD	CV (%)
Pant height (cm)	63.38	94.28	78.41	6.10	7.78
Root dry wt/plant(g)	1.81	4.42	2.98	0.63	21.19
Nodules dry wt/plant (g)	0.57	1.48	0.96	0.21	21.86
Biomass (g/plant)	96.80	259.65	167.64	36.49	21.77
Seed yield (g/plant)	21.89	73.09	45.12	10.97	24.31
Harvest Index	0.19	0.37	0.28	0.04	13.49

among the collected landraces (Singh *et al.*, 2010).The range in HI was 0.19 to 0.37 with mean value of 0.28. Data presented in table 3 shows good amount of diversity with SD and CV 0.04 and 14.5 respectively (Alan & Geren, 2007 and Veasey *et al.*, 1999).

Shannon Weaver Diversity Indices (SDI):

Shannon Weaver Diversity Indices (SDI) revealed the story of existence of very good amount of diversity for soil fertility capability of faba (*Vicia faba L.*) germplasm and its own up scaling of current productivity levels realized in India (Arbaoui & Link, 2006 and Singh & Bhatt, 2012). This is only because of genetic base developed through the passing of time. This genetic base is further multiplied by its nature of multiplication (being often cross-pollinated) and responsiveness to the added inputs (Bora *et al.*, 1998 and Singh *et al.*, 2010). Diversity index was worked out for all the four collection location i.e. Samastipur, Muzaffarpur, Vaishali, Sitamadhi and for total collections. Parameter which contributes soil fertility understudy viz., pH, EC, OC (%), N (kg/ha), P (kg/ha) and K (kg/ha), were subjected to Diversity Indices analysis. Results revealed that in case of soil pH diversity index was ranged from 0.07 to 0.11. Maximum diversity was noticed in case of germplasm explored and collected from Vaishali district (Table 4). Likewise, in case of electrical conductivity (EC) of soil SDI was ranged from 0.28 to 0.37. In case of Organic carbon content SDI was ranged0.23 to 0.27 with mean value of 0.25. Further, major nutrient (NP&K) supplying capability was also shown considerable amount of SDI among the locations and for total collections as well (Table 4). Similar experience was also noticed by while working at different places by Alan & Geren, 2007. Singh *et al*., 2012 .The agro-morphological data Shannon Weaver Diversity Indices (SDI) used to estimate the heterogenity present in the population under studies (Table 4). The observations were made to know the existing diversity on different quantitative parameters. This study showed that by adopting only traditional method of selection of best among available provides very limited scope for further crop improvement rapidly. On the other hand it's also providing a unique opportunity for selecting parent for distant hybridization programme. The data on diversity indices are looking encouraging; taking consideration of its nature of pollination (Arbaoui & Link, 2006 and Singh & Bhatt, 2012).The corresponding values of Shannon-Weaver Diversity Index (SDI) for all parameters are ranged from 0.05 to 0.26. Yield attributes viz., pod/plant, seed/pod, biomass production, seed yield/plant and harvest index. Growth and development parameters also exhibited good amount of diversity (Bora *et al.*, 1998 and Singh *et al*., 2011).

Table 4: Shannon-Weaver diversity indices (SDI) for soil fertility and faba bean (*Vicia faba L.)* germplasm

Parameters	Samastipur	Muzaffarpur	Vaishali	Sitamadhi	Total collection
Soil fertility					
pH	0.09	0.07	0.11	0.10	0.09
EC	0.32	0.28	0.37	0.34	0.34
OC (%)	0.27	0.23	0.27	0.24	0.25
N (kg/ha)	0.17	0.19	0.14	0.12	0.13
P kg/ha)	0.22	0.21	0.22	0.21	0.21
K kg/ha)	0.19	0.15	0.13	0.15	0.16
Faba bean					
Pant height (cm)	0.16	0.15	0.17	0.25	0.17
Root dry wt/plant(g)	0.20	0.21	0.14	0.25	0.13
Nodules dry wt/plant (g)	017	0.17	0.20	0.15	0.17
Biomass (g/plant)	0.21	0.23	0.19	0.22	0.21
Seed yield (g/plant)	0.22	0.22	0.21	0.23	0.22
Harvest Index	0.09	0.11	0.08	0.11	0.10

CONCLUSION

Agronomic evaluation and characterization provide tool for potential, scope and magnitude of faba bean (*Vicia faba* L.) improvement. This study not only proved that soil fertility can be improved with the inclusion of faba bean in cropping system in sustainable manner. Diversity analysis suggest that faba bean (*Vicia faba* L.) productivity can be improved through effective selection of elite germplasm or lines as well as through cross breeding with its close relatives, which is existing in cultivated, wild or weedy form.

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Citation:

Singh AK, Meena MK, Yadav R and Khan YJ . 2016. Assessment of soil fertility augmenting potential of faba bean (*Vicia faba L.)*germplasm and their performance. *Journal of AgriSearch* **3**(3): 136-141