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Effect of Nutrient Management Options on Production and Profitability of French Bean (*Phaseolus vulgaris* L.) in Acid Soil of Arunachal Pradesh

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ABSTRACT

The present study was designed for the standardization of soil nutrient management in increasing the production and profitability of French bean (*Phaseolus vulgaris* L.) in acid soils of Arunachal Pradesh. A field experiment was carried out in randomized block design with three replications during the *rabi* season (October–January 2018–2021). The treatment consisted of two French bean cultivars (selection-9 and changlabi local) and 10 nutrient levels [control, vermicompost (Vc), vermicompost+lime (Vc+lime), 50% RDF (Recommended dose of fertilizer), 50% RDF+lime, 50% RDF+Vc, 75% RDF, 75% RDF+lime, 75% RDF+Vc, 100% RDF]. The doses of vermicompost, lime and RDF were 2.5 t ha^{-1}, 400 kg ha^{-1} and 50-50-50 NPK kg ha^{-1}. The results observed among the soil nutrient management, treatment 75% RDF+Vc recorded minimum values of 50% days to flowering (41.7 DOS) and maximum values of pod length (14.8 cm), the number of pod $plant^{-1}$ (7.17) and yield (4,654 kg ha^{-1}). This treatment also recorded maximum gross and production efficiency. The B:C ratio of 75% RDF+Vc and 75% RDF+lime treatment was recorded above 1.50, irrespective of the cultivar. Between the cultivar, selection-9 obtained higher values of yield attributes, yield, gross return, production efficiency and B:C ratio than changlabi local. Thus, based on French bean crop yield and yield attributes, 75% RDF along with Vc @ 2.5 t ha^{-1} was superior, irrespective of cultivar and between the cultivars, selection-9 was superior.

KEYWORDS: French bean, lime, management, nutrient, production, soil

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1. INTRODUCTION

French bean (*Phaseolus vulgaris* L.) a legume crop belonging to the family Fabaceae is a native crop of Central and South America, until the arrival of Spanish and Portuguese explorers in the 16th century. French bean is used for green pod vegetables or dry seeds. Besides the use as vegetable into regular diet, French bean encompasses a plethora of essential nutrient and vitamins (Chaurasia, 2020, Panda et al., 2016). In India, the French bean was introduced as a non-traditional winter crop (Kumar et al., 2020) and is commonly known as rajmash. In Arunachal Pradesh, the French bean is a popular *kharif* and *rabi* crop of Subtropical and Tropical agro-climate zones. The local French bean cultivar has low production. French bean yield ranges from 0.96–4.5 t ha^{-1} in Arunachal Pradesh (Sarangi and De, 2010) and 7–9 t ha^{-1} in India (Saikia et al., 2018, Datt et al., 2013). The low French bean production and productivity route from poor soil fertility due to acidic soil pH (Tasung et al., 2017), shallow soil depth (Maji et al., 2001), erratic rainfall (Gupta et al., 1998), and unavailability of high yielding French bean cultivar.

Most farmers of Arunachal Pradesh are resource-poor and do not use chemicals for crop production (Lobsang, 2022). Thus, the state is organic by default. However, with the bulging population and increasing demand for vegetables there may be a change in the scenario, enforcing the application of chemical fertilizer to increase crop yield (Sachan and Krishna, 2021). The use of sole organic fertilizer may not have a profitable return while, the use of sole inorganic fertilizer may degrade the soil fertility. Thus, alternate methods like integrated soil nutrient management (ISNM) will be agronomically, economically, and environmentally beneficial for French bean production (Mahanta et al., 2013; Kadam and Pathade, 2014; Shahid et al., 2015; Barcchiya and Kushwah, 2016; Pogula et al., 2016; Bordoloi et al., 2019; Sachan and Krishna, 2021). Vermicompost enhances soil fertility physically, chemically, and biologically by mineralization of organic matter through microbial action and due to the presence of biologically active plant growth-stimulating substances (Ayyobi et al., 2014; Kadam and Pathade, 2014; Lim et al., 2015; Soobhany et al., 2017; Mahmoud and Gad, 2020). However, the sole application of vermicompost is detrimental to French bean growth and yield potential (Kadam and Pathade, 201; Sachan and Krishna, 2021). Reports showed integration of chemical fertilizer and organic manure increased French bean productivity and profitability in Northeast of India, (Paul et al., 2017; Saikia et al., 2018; Kumar et al., 2020). Krishna (1996) identified the French bean as an acid-sensitive crop of the Himalayan region and suggested liming for optimum growth. Liming increases soil pH to near neutrality where most soil nutrients are present in available form (Widdowson, 1965; Krishna, 1996; Lynrah and Nongmaithem, 2017; Sharma et al., 2018; Effa et al., 2019; Kipngetich et al., 2021,). In an alluvium soil of pH 5.6 liming [10 me. % Ca $(OH)_2$] increased French bean yield by 199% (Widdowson, 1966). In strong to slightly acid soil, liming increases the growth and yield of French bean (Mugai et al., 2008; Kumar et al., 2016; Kumar et al., 2021).

French bean is a locally demanded vegetable in the Mid hills of Arunachal Pradesh. The demands, however, are not met by local production. In this regard, a three-year field experiment was conducted to investigate the effects of chemical fertilizer, vermicompost and lime on yield and profitability of French bean with aim of standardizing soil nutrient management in acid soil of Arunachal Pradesh during the dry *rabi* season (2018–2021).

2. MATERIALS AND METHODS

A three-year field experiment was conducted in ICAR-RC-NEH Region, Arunachal Pradesh Centre, Basar, Arunachal Pradesh, India during the *rabi* season (October–January) of 2018–19, 2019–20, and 2020–2021. The longitude and latitude of the experimental site is 94.703432^0E and 27.994355^0N. The soil of the experimental site falls under Ultisol and Alfisol (Maji et al., 2001) with $pH_{(1:2)}$ 4.88, $EC_{(1:2)}$ 0.10 dS m^{-1}, soil organic carbon of 0.45%, low available nitrogen (204 kg ha^{-1}), phosphorus (15.1 kg ha^{-1}) and potassium (158 kg ha^{-1}), respectively. The total rainfall received during cropping seasons was 47.8, 68.7, and 50.8 mm in 2018–19, 2019–20, and 2020–21, respectively (Table 1). Maximum and minimum temperatures during 2018–19, 2019–20, and 2020–21 was 22.4°C, 22.4°C, 23.3°C, and 9.02°C, 10.2°C, 10.3°C, respectively (Table 1). Two levels of French bean cultivar (changlabi local and selection-9) and 10 nutrient levels, viz. control, vermicompost (Vc), vermicompost + lime (Vc + lime), 50% Recommended dose of fertilizer (RDF), 50% RDF+lime, 50% RDF+Vc, 75% RDF, 75% RDF+lime, 75% RDF+Vc, 100% RDF were laid out in randomized block design (RBD) and replicated thrice. Decomposed vermicompost and lime were purchased and applied before the sowing of seeds. Vermicompost and lime were applied at rates 2.5 t ha^{-1} in rows and 400 kg ha^{-1} in furrows. The recommended dose of fertilizer (50:50:50 NPK kg ha^{-1}) was applied through Urea, SSP (Single super phosphate), and MOP (Murate of potash). The total

Table 1: Weather data of three cropping seasons from October–January (2018–2021)

Year	Mean Temperature (0C)		Mean Relative humidity (%)		Total Rainfall (mm)
	Maximum	Minimum	RH1	RH2	
2018–19	22.4	9.02	98.6	61.3	47.8
2019–20	22.4	10.3	98.2	66.2	68.7
2020–21	23.3	10.4	97.8	66.2	50.8

amount of phosphorous and potassium and half of the nitrogen were applied as basal dressing before sowing the seeds in the rows. The 22 days after sowing (DOS), half of the nitrogen was applied as top-dressing during hoeing as per the treatment schedule. French bean cultivars were sown with a seed rate of 70 kg ha^{-1} at 30×30 cm^2 spacing. During three years (2018–21) French bean cultivars were sown on the 15th, 10th, and 15th of October 2018, 2019, and 2020 and harvested after an average of 77 and 86 DOS for selection-9 and changlabi local, respectively. The yield attributes (50% days to flowering, pods $plant^{-1}$, and pod length) and green pod yield of French bean were recorded from randomly selected 10 plants at crop harvesting. Recorded data were statistically analysed by applying Anova by SAS9.1. Critical difference (5% level of probability) was computed for comparing means between the treatments.

3. RESULTS AND DISCUSSION

3.1. Yield attributes and yield of french bean

Improvement in yield attributes is a prerequisite to increase the yield of any crop. The combination of NPK fertilizer with vermicompost and lime had a significant effect on yield attributes and green pod yield of French bean than sole NPK fertilizer combination or sole vermicompost, irrespective of the cultivar. Application of 75% RDF+Vc recorded maximum pod length (14.8 cm) and the number of pod $plant^{-1}$ (7.17) followed by 100% RDF, 75% RDF+lime, 50% RDF+VC, 75% RDF, 50% RDF+lime, Vc+lime, 50% RDF, Vc and control (Table 2). The pod length and the number of pod $plant^{-1}$ in 75% RDF+Vc treatment was higher than control, 75% RDF+lime, and 100% RDF by 28.1, 5.70, 3.50 and 52.5, 6.20, 3.20%, respectively. Application of 75% RDF+Vc (4654 kg ha^{-1}) recorded maximum french bean yield followed by 100% RDF, 75% RDF+lime, 50% RDF+Vc, 75% RDF, 50% RDF+lime, Vc+lime, 50% RDF, Vc, and control. The French bean yield in 75% RDF+Vc and 75% RDF+lime treatment was higher than the control by a magnitude of 98.1 and 88.4% (Figure 1). This finding emphasizes the importance of vermicompost and lime in improving soil nutrient availability in acid soil for plant uptake. Thereby, increasing the plant's metabolic activity. The combination of fertilizer with vermicompost recorded superior yield attributes and yield of French bean compared to a combination of fertilizer with lime because apart from releasing growth promoting substance (Sachan and Krishna, 2021), decomposed vermicompost release nutrients, organic compounds that bind soil Al^{3+}, $Fe^{2+/3+}$ and H^+ ions whereas, liming only releases cations (Lehmann and Kleber, 2015; Possinger et al., 2020). Thus, in the acid soil of Arunachal Pradesh, optimum yield attributes and yield of French bean

Table 2: Effect of integrated nutrient management on the yield attributes of two French bean cultivars in mid hills of Arunachal Pradesh, India (pooled data of 3 years)

Treatments (T)	Days to flowering (50%)			Pod length (cm)			Number of pods $plant^{-1}$		
	French bean variety (V)			French bean variety (V)			French bean variety (V)		
	LC	PC	Mean (T)	LC	PC	Mean (T)	LC	PC	Mean (T)
Control	47.7	45.7	46.7	10.5	12.6	11.6^{j}	4.00	5.40	4.70^{f}
Vc	46.7	44.7	45.7	11.3	12.9	12.1^{i}	4.80	5.90	5.35^{ef}
Vc + lime	45.7	43.7	44.7	11.9	13.7	12.8^{g}	5.00	6.40	5.70^{e}
50% RDF	46.7	44.7	45.7	11.7	13.4	12.6^{h}	5.13	6.10	5.62^{e}
50% RDF + lime	45.7	43.7	44.7	12.2	13.9	13.0^{f}	5.43	6.60	6.02^{cd}
50% RDF + Vc	44.7	43.7	44.2	12.9	14.6	13.8^{d}	5.90	7.20	6.55^{bc}
75% RDF	44.7	42.7	43.7	12.5	14.3	13.4^{e}	5.80	6.80	6.30^{c}
75% RDF + lime	43.7	41.7	42.7	13.2	14.8	14.0^{c}	6.10	7.40	6.75^{b}
75% RDF + Vc	42.7	40.7	41.7	13.8	15.7	14.8^{a}	6.43	7.90	7.17^{a}
100% RDF	43.7	41.7	42.7	13.5	15.1	14.3^{b}	6.20	7.67	6.93^{ab}
Mean (V)	45.2	43.3		12.3^{B}	14.1^{A}		5.48^{B}	6.74^{A}	
	V	T		V	T		V	T	
CD (p=0.05)	NS	NS		0.001	0.012		0.016	0.037	

*The treatment details are 100% RDF is 50-50-50 kg NPK ha^{-1}, lime application in furrow is 0.4 t ha^{-1} lime and vermicompost application is 2.5 t ha^{-1}. The abbreviation LC, PC, V, T, VC, and CD stand for local variety, popular variety, variety, treatment, vermicompost, and critical difference. The superscript in the capital letter indicates significance at a 5% level between French bean variety and the small letter indicate significant difference among soil nutrient management treatments; *The data is pooled over three years (2018–2021)

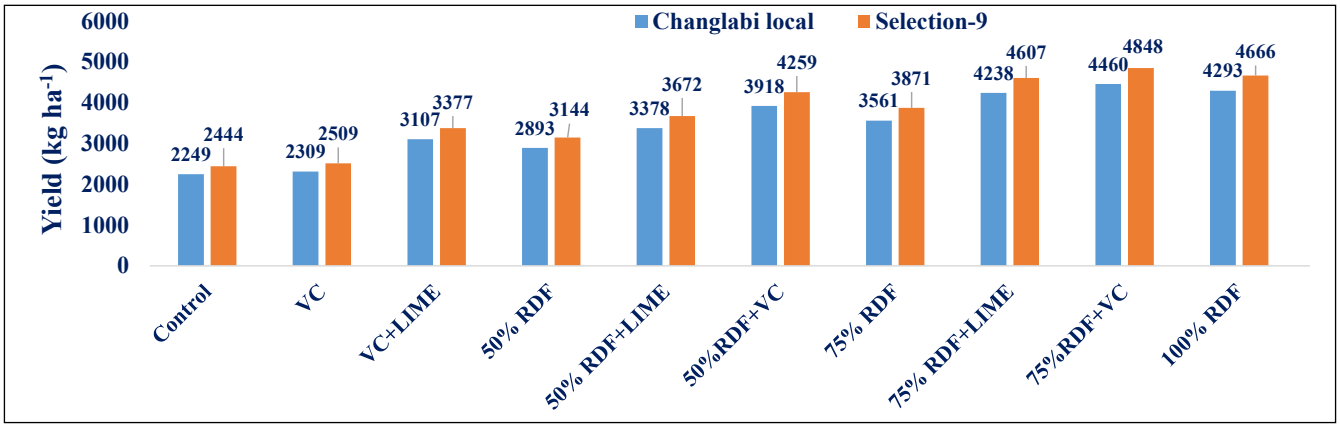

Figure 1: Effect of fertilizer combinations and the variety on the yield of French bean in acid soil of Arunachal Pradesh, India *The data given are significant at a 0.05 level of significance; *The treatment details are 100% RDF is 50-50-50 kg NPK ha^{-1}; lime application in furrow is 0.4 t ha^{-1} lime and vermicompost application is 2.5 t ha^{-1}; *The data is pooled over three years (2018–2021)

were recorded in 37.5–37.5–37.5 NPK kg ha^{-1} combined with 2.5 t ha^{-1} vermicompost, irrespective of the cultivar. This finding confirms the findings of Widdowson (1965), Krishna (1996), Cifu et al. (2004), Singh et al. (2011), Kadam and Pathade (2014), Elka and Laekemaria (2020) and Sachan and Krishna (2021).

The French bean cultivar selection-9 was significantly superior in pod length (14.1 cm), the number of pods plant^{-1} (6.74), and yield (3,740 kg ha^{-1}) by the magnitude of 14.1, 22.9, and 8.69% than changlabi local. This finding indicates that French cultivar selection-9 performance was better (Sarangi and De, 2010) than Changlabi local, irrespective of soil nutrient management.

3.2. Economics and profitability of french bean production

The maximum gross and production efficiency in French bean production was recorded at 75% RDF+Vc (₹ 185,657 and 57.6 kg ha^{-1}day^{-1}) while, the maximum net gross return was recorded at 100% RDF (₹ 136388) and the minimum was recorded in control, irrespective of French bean cultivar. The maximum B:C ratio was recorded in 100% RDF (4.19) followed by 75% RDF+lime (3.72) and 75% RDF (3.58) by a magnitude of 12.4 and 16.9% and was significantly higher than the rest of the treatments (Table 3). The high gross and production efficiency in treatment 75% RDF+Vc

Table 3: Economics of integrated nutrient management on the production of French bean in mid hills of Arunachal Pradesh, India (pooled data over 3 years)

Treatments (T)	Gross returns (₹ ha^{-1})			Net returns (₹ ha^{-1})		
	French bean variety (V)			French bean variety (V)		
	LC	PC	Mean (T)	LC	PC	Mean (T)
Control	89,709	97,509	93,609^{j}	59,780	52,758	5,626^{i}
Vc	92,102	100,111	96,106^{i}	24,888	17,658	21,273^{j}
Vc + lime	123,942	134,720	129,331^{g}	53,590	43,584	48,587^{h}
50% RDF	115,394	125,429	120,412^{h}	85,174	75,913	80,544^{g}
50% RDF+lime	134,755	146,473	140,614^{f}	100,275	89,325	94,800^{e}
50% RDF+Vc	156,295	169,886	163,091^{d}	92,251	79,423	85,837^{f}
75% RDF	142,063	154,417	148,240^{e}	112,940	101,353	107,146^{d}
75% RDF+lime	169,074	183,776	176,425^{c}	136,378	122,436	129,407^{b}
75% RDF+Vc	177,921	193,393	185,657^{a}	114,520	99,807	107,163^{c}
100% RDF	171,254	186,146	178,700^{b}	143,453	129,322	136,388^{a}
Mean (V)	137,251^{B}	149,186^{A}		92,325^{A}	81,158^{B}	
	V	T		V	T	
CD (p=0.05)	111	249		121	270	

Table 3: Continue...

Treatments (T)	Production efficiency (kg ha^{-1} day^{-1})			B:C (ratio)		
	French bean variety (V)			French bean variety (V)		
	LC	PC	Mean (T)	LC	PC	Mean (T)
Control	26.3	31.8	29.0^{i}	2.42	2.57	2.50^{f}
Vc	27.0	32.6	29.8^{i}	1.24	1.33	1.28^{i}
Vc+lime	36.3	43.9	40.1^{g}	1.54	1.66	1.60^{j}
50% RDF	33.8	40.9	37.3^{h}	2.91	3.10	3.00^{e}
50% RDF+lime	39.5	47.7	43.6^{f}	2.95	3.15	3.05^{d}
50% RDF+Vc	45.8	55.3	50.6^{d}	2.03	2.18	2.10^{h}
75% RDF	41.6	50.3	46.0^{e}	3.47	3.70	3.58^{c}
75% RDF+lime	49.5	59.9	54.7^{c}	3.60	3.85	3.72^{b}
75% RDF+Vc	52.1	63.0	57.6^{a}	2.27	2.44	2.36^{g}
100% RDF	50.2	60.6	55.4^{b}	4.05	4.32	4.19^{a}
Mean (V)	40.2^{B}	48.6^{A}		2.65^{B}	2.83^{A}	
	V	T		V	T	
CD (p=0.05)	0.36	0.82		0.031	0.41	

*The treatment details are 100% RDF is 50-50-50 kg NPK ha^{-1}, lime application in furrow is 0.4 t ha^{-1} lime and vermicompost application is 2.5 t ha^{-1}. The abbreviation LC, PC, V, T, VC, and CD stand for local variety, popular variety, variety, treatment, vermicompost, and critical difference. The superscript in the capital letter indicates significance at a 5% level between French bean variety and the small letter indicate significant difference among soil nutrient management treatments; *The data is pooled over three years (2018–2021)

in French bean production was due to the high French bean pod yield while the lower net return in the former treatment was due to the high cost of vermicompost and fertilizer. The maximum B:C ratio in 100% RDF compared to fertilizer (75% RDF) combination with lime (400 kg ha^{-1}) or vermicompost (2.50 t ha^{-1}) was due to the additional cost of vermicompost and lime apart from the inorganic fertilizer. However, when 75% RDF was applied along with lime or vermicompost B:C ratio was recorded above 1.50. These results indicate application of 75% RDF along with vermicompost and lime increases the production and profitability of French bean. An experiment reported that the application of NPK fertilizer integrated with FYM had higher gross and net return, production efficiency, and B:C ratio than sole fertilizer application in the production of dry seed of French bean (Kumar et al., 2020).

Between the French bean cultivar, the maximum gross return, production efficiency, and B:C ratio were significant and higher in selection-9 (₹ 149,486, 48.6 kg ha^{-1} day^{-1} and 2.83) compared to changlabi local due to higher green pod yield attained in selection-9.

4. CONCLUSION

Based on the findings of the present study it could be concluded that the application of NPK fertilizer (75% RDF) along with vermicompost (2.5 t ha^{-1}) or lime (400 kg ha^{-1}) for French bean production in acid soil of Arunachal Pradesh was found profitable as B:C ratio was above 1.50. However, the application of NPK fertilizer 75% RDF (37.5-37.5-37.5 kg ha^{-1} NPK) along with vermicompost (2.5 t ha^{-1}) was significantly more effective in increasing the production of French bean, irrespective of the cultivar.

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