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# Cultivation of French bean (*Phaseolus vulgaris* L.) with an effective Biofertilizer for sustainable farming

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## Abstract

The French bean (*Phaseolus vulgaris* L.), also utilized as tender young fruits and as a pulse, is a member of the Fabaceae family. This experiment was carried out in the BINA sub-station Sunamganj research field (25°03'02.2"N and 91°25'09.2"E) to determine the suitability of *Rhizobium* biofertilizer for French beans with regard to the yield of green fruits and vegetables. There were seven treatments with four French bean biofertilizer as control, FBR-1, FBR-2, FBR-3, FBR-4, $N_{15}$, and $N_{30}$. The design of the experiment was RCBD with three replications. The BARI French bean-3 was utilized as a test crop. With FBR treatment with $N_{30}$, there was an improved yield and yield parameters such as plant height, root length, nodule number, pod plant$^{-1}$, pod length, weight and yield. The highest number of nodule (2.67) was produced from FBR-1 treatment and treatment FBR-3 showed statistically similar nodule number with FBR-1 treatment and there were no nodule at all in control plots, $N_{15}$ and $N_{30}$ treatments, respectively. In case of effective nodule treatments FBR-3 produced highest effective nodule (1.33) and others were similar fashion observed as nodule number. The highest yield (4.94 t ha$^{-1}$) was produced from $N_{30}$ treatment followed by FBR-4 (4.56 t ha$^{-1}$) and FBR-1 (4.41 t ha$^{-1}$), FBR-2 (4.21 t ha$^{-1}$), and FBR-3 (4.48 t ha$^{-1}$) treatments, respectively. There was a significant effect of French bean *Rhizobium* (FBR) biofertilizer on growth and yield contributing characters in French bean production which is low cost and sustainable inputs for French bean cultivation.

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**Introduction**

French bean (*Phaseolus vulgaris*) commonly known as Forashisheem or Jharsheem in Bengali belongs to the family Fabaceae is an annual, diploid (2n=2x=22) species (Galvan *et al*., 2003). This crop serves two purposes: it is cultivated as a pulse and is also eaten as young, fragile fruits. It is found in Bangladesh's Jessore, Rangpur, Comilla, Chittagong, and Sylhet regions (Nazrul *et al*., 2016). It is very rich in protein, vitamins and minerals.As per the FAO estimates, it is grown in the world in an area of 28 million hectares with an annual production of 20 million tons and productivity of 729 kg/ha (Prakash and Ram, 2014). Foliage of the crop may also provide hay; silage and green manures and plants can be fed to cattle after harvest (Kakon *et al*., 2016).

French bean is a short duration crop and farmers get more profit in a short period. In these regions, it is cultivated in rice fallow during spring summer and on hill slopes during autumn winter season. In these areas where irrigation facilities are available throughout the dry season, it can be grown all year round. French bean (*Phaseolus vulgarris* L) is an important legume among others legume like Country bean, Mungbean, Chick pea, Lentil etc. Its dry seed contains 21.1 per cent protein, 69.9 percent carbohydrates, 381 mg calcium, 1.7 percent fat, 12.4 mg iron and 425 mg phosphorous per 100 g of edible part (Ali and Kushwaha, 1987). Additionally, common beans are said to provide a significant source of calories and protein in diets for humans (Smithson *et al*., 1993). French beans are gaining popularity because of their soft pods and shelled beans. In Chittagong Hill Tracts (Khagrachari), it has been cultivated as companion crop with Maize and Sugarcane. Bean legumes are capable of fixing atmospheric nitrogen by the presence of Rhizobium bacteria at their root nodules. Molybdenum is an essential element that acts as an essential cofactor in stimulating N- fixing activity of Phaseolus vulgaris (Reyes *et*. *al*., 2016). It maintains soil fertility through biological nitrogen fixation in association with symbiotic Rhizobium prevalent in their root nodules (Nazrul *et al*., 2016). Leguminous crops require a large amount of N for seed protein synthesis. The N is derived from symbiotic $N_2$ fixation with soil microorganisms in addition to soil mineralized N and fertilizer N. To boost the seed yield of leguminous crops, particularly in Asia, it is crucial to improve soil management, cropping practices, and the promotion of $N_2$ fixation through the inoculation of a highly effective rhizobium strain (Biofertilizer Manual, 2006).

Sustainable agriculture means an integrated system of plant and animal production practices having a site-specific application that over the long term will: Satisfy human food and fiber need, enhance environmental quality and the natural resource base upon which the agricultural economy depends, make the most efficient use ofnon-renewable resources and on-farm resources and integrate, where appropriate, natural biology cycles and controls, sustain the economic viability of farm operations, enhance the quality of life for farmers and society as a whole" (USDA Farm Bill, 1990). For this case Biofertilizer for French bean is developed and its use can be spread through these regions is time demanding. In Sylhet region, farmers are generally cultivating local French bean cultivars and they called Forash. In this region there are no indigenous Rhizobia which can enhance root nodulation and biological Nitrogen fixation in French bean. For this demand Biofertilizer for French bean developed by Bangladesh Institute of Nuclear Agriculture (BINA). A biofertilizer is thus defined as "a substance which contains living microorganisms which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant" (Vessey, 2003).Formulation of these beneficial microorganisms into microbial inoculants constituted an important component of integrated nutrient management to increase crop productivity (Chen, 2006). French bean is a legume; it supplies nitrogen to the soil by forming a symbiotic or mutually beneficial partnership with rhizobia through the biological nitrogen fixation process. Use of

biofertilizers can provide quality produce for human consumption by way of reduction of the chemical residues and also reduces the risk of environmental pollution. Biofertilizers are low-cost, environmentally-friendly and effective inputs with high agricultural benefits, which need to be more popularized within the farming community of the GMR (Nath and Das, 2018).

The main component causing soil deterioration, according to Kopittke *et al.* (2019), is soil fertility loss, which puts crop productivity at risk. Furthermore, Singh *et al.* (2020) pointed out that soil degradation, soil organic matter depletion, population growth, and climate change have been the key obstacles to the advancements in sustainable crop production. Crop production has been defined by the use of chemical fertilizers, large farm equipment, intensive tillage, high-yielding crop varieties, and pesticides that are resistant to biodegradation since the era of the green revolution. This present study was under taken to observe the performance of BINA developed different French bean biofertilizer for its effectiveness as well as to produce higher yield of French bean.

## Materials and methods

*Experimental site*

This study was carried out at BINA sub-station Sunamganj research field and the site is located at 25°03'02.2"N latitude and 91°25'09.2"E longitude with an elevation of 14.4 m from sea level. The experiment was conducted during Rabi season 2022-23. The experimental area experiences a subtropical climate. It is characterized by comparatively no rainfall, low humidity, low temperature, and a relatively short day period during December to April. This period is favorable for the growing for French bean. The study area is non-saline and belongs to the agro-ecological zone (AEZ#22) of Northern and Eastern Piedmont Plain soil.


**Fig. 1.** Experimental site.

*Experimental design and other operations*

The experiment was designed with randomized complete block design with three replications. The BARI French bean-3 (bari jharsheem-3) which is a modern high yielding French bean variety and four French bean *Rhizobium* (FBR) biofertilizer which

developed by BINA was used. Total numbers of treatments were seven i.e. control, FBR-1, FBR-2, FBR-3, FBR-4, $N_{15}$ and $N_{30}$. There was no nitrogen and French bean *Rhizobium* (FBR) biofertilizer in control treated. Experimental design was RCBD with three replications. Individual plot size was 4 $m^2$ (2m × 2m and total number of plots were 21. Irrigation and pesticide were as per needed.

*Harvesting and data collection*

Data were recorded on shoot length (cm), root length (cm), nodule number and effective nodule number at 18 days after sowing (DAS), 38 days after sowing (DAS), 60 days after sowing (DAS) respectively. Pod per plant, Pod length (cm), per pod weight (g), pod weight per plant (g), Pod weight per plot (g) and pod yield (ton/ha) at 60 days after sowing (DAS).

Statistical *analysis*

The collected data of experiment measured from crops were done using statistical program "R Studio" software and mean differences were compared by Duncan's Multiple Range Test (Gomez and Gomez, 1984). The means were separated by least significant difference (LSD (0.05).

**Results**

Recorded data from the field experiment of French bean with different treatments at BINA sub-station Sunamgonj research field has been shown Table 1(18 DAS) table 2 (38 DAS) and table 3 (60 DAS), respectively. In respect of time intervals detail descriptions were given below:

*Yield attribute at 18 DAS*

At18 days after sowing (DAS) it was observed that the plant height was significantly influenced by the different treatments where the highest plant height of French bean was recorded in $N_{30}$ that was 30 kg nitrogen per hectare (12.57cm) while the lowest plant height (10.47cm) in control (no FBR inoculant and no nitrogen dose) plot.

The others treatments showed statistically similar in respect of plant height. In case of root length, all treatments showed statistically similar.

**Table 1.** Effect of French bean biofertilizer on the growth parameter of French bean at 18 days.

| Treatments | Shoot length | Root length | Nodule | Effective Nodule |
|---|---|---|---|---|
| $T_1$(Control) | 10.47 b | 5.87 | 0.0 c | 0.0 d |
| $T_2$(FBR-1) | 11.2ab | 6.83 | 10.0 a | 2.33 a |
| $T_3$(FBR-2) | 11.7ab | 7.27 | 7.33 b | 1.00 c |
| $T_4$(FBR-3) | 10.97ab | 5.73 | 6.67 b | 1.67 b |
| $T_5$(FBR-4) | 11.77ab | 6.40 | 8.67ab | 2.00ab |
| $T_6$($N_{15}$) | 12.23ab | 6.00 | 0.0 c | 0.0 d |
| $T_7$($N_{30}$) | 12.57 a | 6.63 | 0.0 c | 0.0 d |
| CV% | 9.05 | 12.14 | 26.59 | 29.55 |
| LSD (0.05) | 1.86 | 1.38 | 2.21 | 0.53 |

The number of nodule, French bean *Rhizobia*-1 (FBR-1) treatment gave maximum nodules (10), FBR-2, FBR-3 FBR-4 treatments showed statistically similar nodule number and there were no nodule at all in control plots and also $N_{15}$ that was 15 kg nitrogen per hectare and $N_{30}$ treatment. In case of effective nodule there were similar fashion observed as nodule number but height effective nodule was found in FBR-1(2.33).

*Yield attributes at 38 DAS*

At 38 days after sowing (DAS) the plant height were showed statistically similar for all treatments (Table 2). The maximum root length (22.60 cm) was observed in FBR-2 treatment rest of the treatments showed statistically similar result. The highest number of nodule (23.00) obtained from FBR-1 treatment and treatments FBR-2, FBR-3 FBR-4 showed statistically similar nodule number and there

were no nodule at all in control plots and also $N_{15}$ and $N_{30}$ treatments.

*Yield and yield attributes at 60 DAS*

The yield parameters of French bean were matured at 60 days. At 60 days after sowing it was observed that the plant height was significantly influenced by the different treatments where the highest plant height of French bean was observed in $N_{30}$ (40.52 cm) while the lowest plant height (24.6 cm) in control (no FBR inoculant and no nitrogen dose) plot. FBR-2, FBR-3 FBR-4 treatments showed statistically similar considering the plant height. In case of root length, all treatments showed statistically similar results although the highest root length was found in FBR-4 and the lowest was produced from $N_{15}$ treatments.

**Table 2.** Effect of French bean biofertilizer on the growth parameter of French bean at 38 days.

| Treatment | Shoot length(cm) | Root length(cm) | Nodule No. | Effective Nodule |
|---|---|---|---|---|
| Control | 23.07a | 15.17b | 0.00c | 0.00b |
| FBR-1 | 24.47a | 15.17b | 23.00a | 8.00a |
| FBR-2 | 26.83a | 22.60a | 13.00b | 7.67a |
| FBR-3 | 24.27a | 14.57b | 14.33b | 8.33a |
| FBR-4 | 23.50a | 15.53b | 15.67b | 9.33a |
| $N_{15}$ | 23.17a | 14.67b | 0.00c | 0.00b |
| $N_{30}$ | 24.00a | 16.67b | 0.00c | 0.00b |
| CV% | 16.69 | 16.28 | 30.56 | 23.07 |
| $LSD_{(0.05)}$ | 7.18 | 4.73 | 5.13 | 1.95 |

The highest number of nodule (2.67) was produced from FBR-1 treatment and treatment FBR-3 showed statistically similar nodule number with FBR-1 treatment and there were no nodule at all in control plots, $N_{15}$ and $N_{30}$ treatments, respectively. In case of effective nodule treatments FBR-3 gave highest effective nodule (1.33) and others were similar fashion observed as nodule number. In pod plant$^{-1}$ maximum pod was found in $N_{30}$ treatment (6.00) followed by FBR-1 treatment (5.33) whereas FBR-2, FBR-3 FBR-4 treatments showed statistically similar in pod plant$^{-1}$. In case of pod length maximum pod length was observed in FBR-1 treatment (11.11cm) and FBR-2, FBR-3 FBR-4, $N_{30}$ treatments performed similar length where $N_{15}$ treatment showed lowest pod length. The highest weight pot$^{-1}$ was obtained from $N_{30}$ treatment (6.79 g) followed by FBR-1 treatment (6.51 g) and FBR-2, FBR-4 treatments showed statistically similar in per pod weight. The highest pod weight plant$^{-1}$ was observed in $N_{30}$ treatment (24.89 g), from treatments FBR-1 (24.48g), FBR-4 (24.33 g), FBR-3 (24.06 g), FBR-2 (21.18 g), were obtained and the lowest from control one (11.67 g) respectively.

The yield of French bean was influenced significantly with the treatments combination of biofertilizers. All the biofertilizer treated plot produced higher yield along with $N_{30}$ treatments. Although the highest yield was produced from $N_{30}$ treatment (4.94 ton ha$^{-1}$) but the biofertilizer treated plot produced statistically similar yield (Table 3). The lowest yield was found in control treatment (2.75 t ha$^{-1}$).

**Discussions**

Bio-fertilizers are helpful microorganisms that are crucial to agriculture and have the capacity to biologically convert nutritionally significant materials from an unusable to a useable state (Bahadur *et al.*, 2004). Since the plain land area where the experiment was conducted lacked native French bean Rhizobium, we created French bean Rhizobium (FBR) biofertilizer specifically for the cultivation of French beans. Leguminous plant species rely heavily on the delayed release of symbiotic nitrogen from root nodules during plant growth. According to Thakur *et al.* (1999), the rhizobium inoculation treatment may also be responsible for the bacteria's enhanced nodulation, nitrogen fixation, and generation of

secondary metabolites. After symbiotically interacting with legume species, rhizobium has the unique capacity to fix atmospheric $N_2$ through BNF (Sprent, 2001; Willems, 2006). The interaction between rhizobia and legumes is highly particular, although it is known to enhance plant N uptake, which leads to increased plant growth and yield (Pankievicz *et al.*, 2019).

*Yield attributes*

Different French bean *Rhizobium* (FBR) biofertilizer treatments with control and two different nitrogen fertilizers dose affect remarkably in yield and yield contributing characters of French bean. In case of nodule formation French bean *Rhizobium* (FBR) biofertilizer performed the best and also in case of effective nodule number, pod length and pod weight. This result was in conformity with Sharma and Verma (2011) who reported that rhizobium inoculation and application of FYM and chemical fertilizers had significantly increased the plant height, number of pods/ plant, number of seeds/pod, yield and net returns over controls. Singh and Chauhan (2009) also reported similar results in French bean.

**Table 3.** Effect of French bean biofertilizer on the growth parameter and yield of French bean at 60 days.

| Treatments | Shoot length (cm) | Root length (cm) | Nodule (no.) | Effective Nodule (no.) | Pod plant$^{-1}$ | Pod Length (cm) | Pod wt (g) | Pod Wt /per plant (g) | Yield (t ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| Control | 24.63 b | 17.23 | 0.0 c | 0.0 b | 2.67 c | 8.72 b | 4.36 d | 11.67b | 2.75 b |
| FBR-1 | 38.29a | 18.20 | 2.67a | 0.67 ab | 5.33a | 11.11a | 6.51ab | 24.48a | 4.41a |
| FBR-2 | 35.87a | 20.37 | 1.67b | 0.67ab | 5.0ab | 10.96a | 6.33ab | 21.18a | 4.21a |
| FBR-3 | 39.83a | 19.73 | 2.33ab | 1.33a | 4.67ab | 10.49a | 5.50bc | 24.057a | 4.48a |
| FBR-4 | 38.10a | 20.53 | 1.67b | 0.67ab | 5.00ab | 9.83 | 6.01ab | 24.33a | 4.56a |
| N15 | 30.40b | 16.47 | 0.0c | 0.0b | 3.33bc | 8.57b | 4.91cd | 16.83ab | 3.31 b |
| N30 | 40.52a | 18.80 | 0.0 | 0.0 | 6.0a | 10.24a | 6.80a | 24.89a | 4.94 a |
| CV% | 10.39 | 13.96 | 36.66 | 91.65 | 20.06 | 7.76 | 9.85 | 19.44 | 11.17 |
| LSD$_{(0.05)}$ | 6.43 | 4.66 | 0.78 | 0.78 | 1.63 | 1.38 | 1.01 | 7.28 | 0.81 |

The highest plant height was observed in $N_{30}$ (40.52 cm) followed by the Rhizobium treated plot. The plant height increased significantly with the combined application of urea, vermicompost and Rhizobium biofertilizer (Jan *et al.* 2019). Sayma Parween *et a*l. (2019) found that combination of urea, vermicompost and Bio-fertilizer (Rhizobium + PSB) resulted in maximum plant height.

*Nodule formation*

The highest number of nodule was produced from FBR-1 and FBR-3 treatments and there were no nodule at all in control plots, $N_{15}$ and $N_{30}$ treatments, respectively in the present study. Prabhakar *et al.* (2011) recorded that organic manure equivalent to recommend quantity of nitrogen gave the highest number of nodules. The maximum number of nodules per plant significantly influenced by the application of 100% RDF + Rhizobium culture + Humic Acid in French bean. Dutt *et al.* (2013) found that the maximum number of nodules was recorded in combination of farmyard manure, nitrogen fixer-A, phosphate solubilizer and chopped crop residues at flowering stage of French bean.

*Yield production*

The maximum pod was found in $N_{30}$ treatment (6.00) followed by FBR-1 treatment (5.33) whereas FBR-2, FBR-3 FBR-4 treatments showed statistically similar in pod plant$^{-1}$. The longest pod length was found from FBR-1 whereas the highest pod weight pot$^{-1}$ was obtained from $N_{30}$ treatment followed by FBR-1, FBR-2 and FBR-4 treatments in the present study. Thakur *et al.* (2018) conducted an experiment on French bean under dry temperate conditions and reported that the combination of Rhizobium + PSB + FYM treatment showed that the highest number of pods. They also reported that the combination of Rhizobium + PSB + FYM treatment showed the highest green pod yield production of French bean.Although the highest pod yield was produced from $N_{30}$ treatment in this study but the biofertilizer

treated plot produced significant yield without the use of chemical fertilizer urea which is very important. Ramana *et al.* (2011) conducted a field trial on French bean which were they found that 75 % RDF +VAM@ 2 kg/ha + PSB @ 2.5 kg/ha increased the pod yield. Thakur et al. (2018) conducted an experiment under dry temperate conditions and they reported that the combination of Rhizobium+ PSB + FYM treatment showed the maximum highest green pod yield per hectare in French bean.

French bean *Rhizobium* (FBR) biofertilizer has no harmful effect for legumes because there was sharply decrease of nodules in later period of cultivation and no over growth of vegetative parts. For this why French bean *Rhizobium* (FBR) biofertilizer can be very effective for French bean cultivation in farmer's field. They have the potential to reduce the negative impacts from chemical fertilizer use by playing a significant role in restoring soil fertility and improving crop health and yields (Patil and Solanki, 2016; Malusa and Vassilev, 2014). The development and commercialization of effective microbial products (biofertilizers, biostimulants, biopesticides, and plant growth promoting PGP) with proven success to improve crop yield and adaptation to environmental changes, as well as inputs of carbon and energy, are the result of advancements in genomic, post-genomic, biochemistry, ecology, and symbiotic interactions of beneficial microbial strains (Timmusk and Associates, 2017; Umesha and Associates, 2018).

**Conclusion**

The growth and yield-contributing characteristics of French bean production were significantly impacted by the use of French bean Rhizobium (FBR) biofertilizer. The experiment was conducted in plain terrain with no native Rhizobium for French beans. It is a sustainable, affordable, user-friendly, and environmentally favorable input for French bean farming. Sustainable farming refers to agricultural methods that satisfy society's current demands for food and textiles without endangering the ability of present or future generations to meet their needs from the same natural resources and without having an adverse impact on the environment. Biofertilizer is necessary for sustainable farming and the preservation of soil health.

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