

Effect of Bio Fertilizers on the Growth, Productivity and Nutrient Absorption of Fenugreek (*Trigonella foenum graecum* L.)

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Abstract – To evaluate effect of bio fertilizers on growth, productivity and element uptake of fenugreek, a pot experiment was arranged based on completely randomized design with four replications at Research Greenhouse of College of Agriculture, University of Tehran, Iran. Treatments comprised of different kinds of bio fertilizers (*Azotobacter chroococum* (A), *Bacillus subtilis* (B), *Rhizobium meliloti* (R), *Pseudomonas fluorescence* (S), their double (AB), (AR), (AS), (BR), (BS), (RS), triple (ABR), (ABS), (ARS) (BRS), and quaternary combinations (ABRS) along with *Arbuscular mycorrhizal* fungi (from *Glomus* sp. genus) (M) and Control (C). Results indicated that application of bio-fertilizers (single and integrated) significantly improved vegetative and generative growth as well as nutrient uptake in fenugreek. Application of the integrated fertilizer treatment of AS (*Azotobacter chroococum*+*Pseudomonas fluorescence*) had the best positive effect on fenugreek growth characteristics compared to the other treatments and control.

Keywords – Bio Fertilizer, Fenugreek, Vegetative Growth, Generative Growth, Nutrient Uptake.

Abbreviation – A- *Azotobacter Chroococum*, B- *Bacillus Subtilis*, R-*Rhizobium Meliloti*, S-*Pseudomonas Fluorescence*, PGPR- Plant Growth Promoting Rhizobacteria.

I. INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is a flowering annual plant, with autogamous flowers. This crop is native to an area extending from Iran to northern India and is widely cultivated in China, India, Egypt, Ethiopia, Morocco, Ukraine, Greece, Turkey, etc. (Petropoulos, 2002). In Tunisia, it is especially cultivated in the regions of the North (Marzougui et al., 2007) and it is commonly used as a condiment in food preparation for its nutritive and restorative properties and has been used in folk medicine for centuries for a wide range of diseases including diabetes (Eidi et al., 2007). The seed is produced as a spice, as a vegetable for humans, as forage for cattle, and for

medicinal purposes. Fenugreek is incorporated into short-term rotation for hay and silage (livestock feed), and for soil fertility (fixation of nitrogen) (Sadeghzade et al., 2009). Fenugreek grown under modern production techniques, resulted in an increased yielding ability. The yield potential of fenugreek can be defined as the total biomass produced or agricultural important part of the crop. The total biomass is a result of the integration of metabolic reactions in the plant. Consequently, any factor influencing the metabolic activity of the plant at any period of its growth can affect the yield (Ahmad et al., 2010). To provide economically sustainable yields, essential nutrients like nitrogen and phosphorous must be present in sufficient available quantities in soil for root to uptake (Blaise et al., 2005, Zandvakili et al., 2012, Jahanzad et al., 2014). Organic fertilizers are excellent sources of nutrients for crop production and improving physical and chemical properties of soil (Ewulo, 2005). Microorganisms are important attributes in agriculture to promote the circulation of plant nutrients and reduce the need for chemical fertilizers (Pouryousef et al., 2007). Bio fertilizer is most commonly referred to as soil micro-organisms to increase the availability and uptake of mineral nutrients by plants. Bio fertilizers are organic products containing living cells of different types of microorganisms, which have the ability to convert nutritionally important elements from unavailable to available form through biological processes (Vessey, 2003). In recent years, bio fertilizers have emerged as an important component of the integrated nutrient supply system and hold a great promise to improve crop yields through environmentally better nutrient supplies. P-solubilizing bacteria may be important for plant nutrition by increasing P uptake and play a significant role as PGPR in the bio fertilization system (Hosseini et al., 2013). Trials with rhizosphere-associated plant growth-promoting P-solubilizing *Bacillus* species indicated that yield increased in sugar beet (Akmakc et al., 2006), wheat (De Freitas, 2000), sugar

beet and barley (Ahin et al., 2004).

Great attentions have been paid to studies and application of new combinations of phosphate-solubilizing bacteria with other probiotics. Thus, the use of combined bio-fertilizers is advocated for excellent growth performance of plants (Ibiene et al., 2012). Application of bio-fertilizers such as *Azotobacter* and *Azospirillum* bacteria had a positive effect on sorghum yield (Van Oosterom et al., 2010). In other study, inoculation of seeds by *Azotobacter* and *Azospirillum* increased forage yield of sorghum (Singh et al., 2005). According to Dobbelaere et al., (2002), inoculation of seeds by *Azotobacter* increased the yield of cereal up to 30 percentages.

More recently, a real challenge which faces the workers in the agricultural research fields is to stop using the high rates of agro-chemicals which negatively affect human health and environment (El-Kholy et al. 2005). Efforts to produce inoculants from Mycorrhiza fungi and to use it in proper environmental conditions, is a significant environmental friendly way to help plant growth and development through the enhancement of this natural phenomenon (Mehrvarez et al., 2008). Application of mycorrhiza and nonsymbiotic nitrogen-fixing bacteria have been shown to enhance soil fertility and availability of nutrients for plants (Cardoso et al. 2006).

To determine the most efficient sole or integrated biological fertilizer the present experiment was conducted to study, the effect of biological fertilizers on growth, yield and nutrient uptake of fenugreek in sustainable agricultural systems.

II. MATERIALS AND METHODS

The experiment was conducted in pots at Research Greenhouse of College of Agriculture, University of Tehran, Iran in 2012. The soil texture in pots was clay loam with pH = 7.7.

The treatments were arranged based on a completely randomized design with four replications. The treatments were different kinds of biological fertilizers (*Azetobacter chroococum* (A), *Bacillus subtilis* (B), *Rhizobium meliloti* (R), *Pseudomonas fluorescense* (S), their double (AB), (AR), (AS), (BR), (BS), (RS), triple (ABR), (ABS), (ARS) (BRS), and quaternary combinations (ABRS) along with

Arbuscular mycorrhizal fungi (*Glomus* sp.) (M) and Control (C). Soil was provided from the Agricultural research farm, College of Agriculture, University of Tehran in Karaj. The soil was collected from 0-30 cm top layer and was sieved twice with 5 mm sieve mesh and sterilized before being filled in the pots. Pots were sterilized by 70% ethylic alcohol before being filled by the soil. Nitrogen, phosphor and potassium fertilizers were added to each pot according to the soil test analysis. Each empty pot weighed 300g which had a capacity for 7000g of soil. Seeds were sterilized with sodium hypochlorite %5 for three minutes then rinsed 10 times with distilled water. Seeds were inoculated with Arabic gum and were put in a polyethylene sac then enough amounts of bacteria were added to prepare the treatments and shacked for five minutes. Ten fenugreek seeds (native cultivar) were planted in each pot on February 9th, 2012 and then the established seedlings were thinned to 4 in each pot at 3-leaf growth stage. The greenhouse received natural light during the day time and mean day time temperature was 25 +- 2 and during the night time was 15+ - 2. After planting the seeds, all the pots were immediately irrigated, since then irrigation was based on the water requirements during the growth stage (no water stress was applied on plants). Weeds were controlled by hand.

Measurements:

The vegetative growth parameters measured were: plant height, dry weight for leaf and stem, leaf/stem ratio and element content in the shoot at 10% flowering growth stage. The generative growth parameters were: number of pods per plant, number of seeds per pod, 1000 seed weight, seed yield, biological yield, and harvest index at the end of physiological maturity. To determine dry weight (DW), plant parts dried in an oven at 75°C for 48 hours. Shoot elements content, were analyzed in University of Tehran, College of Agriculture, Plant Nutrition Laboratory.

Data analysis:

Results were analyzed statistically by analysis of variance using the Statistical Analysis System computer (SAS 9.1). When analysis of variance showed significant treatment effects, the Duncan test was applied to make comparisons among the means at p< 0.05 level of significance.

Table 1: The results of soil analysis

| pH | OC (%) | Ca | Mg (mg/kg ⁻¹) | So ₄ ²⁻ | K | P (ppm) | N |
|-----|--------|----|---------------------------|-------------------------------|-----|---------|------|
| 8.1 | 0.33 | 37 | 23 | 6.1 | 6.5 | 10 | 0.04 |

III. RESULTS AND DISCUSSIONS

Bio fertilizer treatments significantly (p<0.05) increased all measured characters including plant height, root length, shoot dry weight, root dry weight, number of pods per plant, seed weight, grain yield, number of seeds per plant, biological yield and element uptake compared to control (Table 2 & 3).

Vegetative growth

The results in table 1 indicate that, there are significant

differences among application of bio fertilizers and control. In AS and RS treatments, the plant height was 21.4 cm and 23.3 cm, respectively (Table 2). Our results showed that sole application of the bacteria was less effective on plant height while their integrated application led to a significant increase in plant height. The least plant height was observed in control (15.5cm) (Table 2). Positive effects of bio-fertilizers on improving crop growth might be due to increase in nitrogenase activity and

synthesis of growth-promoting substances by phosphate solubilizing (S) and N fixing bacteria. Phosphorus-solubilizing bacteria play a strong role in phosphorus nutrition by enhancing its availability to plants through release from inorganic and organic soil P pools through solubilization and mineralization processes (De et al., 2012). It is the reason why adding bio fertilizer to the soil increases plant height and other characteristics of plant growth. Plant dry weight, height, leaf area index, leaf area ratio and specific leaf weight of grain sorghum were increased by using of bio-fertilizers such as *Azotobacter* and *Pseudomonas* Bacteria. Alnoaim and Hamad (2004) reported that by bio-fertilizers along with chemical N fertilizer (180 kg.ha⁻¹) application, the highest plant height, number of tillers and grain yield of rice (*Oryza sativa*) were achieved.

The highest fenugreek dry leaf weight of 1.47g/plant was observed in AS treatment when P solubilizing bacteria and N fixing bacteria was applied. The higher leaf weight might be due to early and abundant availability of nitrogen. Increased availability of phosphorus by Phosphorus-solubilizing bacteria improved nutrient availability which increased nitrogenase activity of roots creating congenial environment for plant rhizosphere that resulted in higher physiological growth parameters. The lowest dry leaf weight of 1.18 g/plant was obtained with RB treatment (Table 2). Almost the same results were observed in stem dry weight, shoot dry weight and leaf/stem ratio (Table 2). The integrated application of P

solubilizing bacteria (S) and N fixing bacteria (A) had synergistic effect to increase the shoot dry weight. Shaharoon et al. (2006) reported that *P. fluorescens* increased shoot dry weight.

Root length and dry weight were both positively affected by integrated bio-fertilizer application. Application of AS and RBS treatment increased root length and root dry weight, respectively (Table 3). This might be due to the fact that bacteria inoculation increased root growth, root development, caused better nodulation. More nutrient availability could result in vigorous plant growth and dry matter production leading to a better flowering and pod information (Mehtal et al., 2012). The higher bacteria population due to seed inoculation by bio-fertilizers leads to a better symbiosis activities in rhizosphere which result in increased amount of N fixed (Mehtal et al., 2012). Our results are also in conformity with those reported by Purbey (2004).

The higher content of macro-nutrients taken in by plant roots belonged to nitrogen, phosphorus and potassium which are the main ingredients of store-bought, non-organic, conventional, commercial, and artificial fertilizers (De et al., 2012). Benefits of plant inoculation with plant growth promoting rhizobacteria includes increasing of different indexes such as germination rate, root, dry matter production, disease control, leaf area, chlorophyll content, drought resistance, radicle and shoot weight and microbial activities (Lucy et al., 2004).

Table 2: The effects of different kinds of bio-fertilizers on growth and nutrient uptake of fenugreek at 10% flowering stage

| Treatments | Plant height (cm) | leaf dry matter (g/plant) | stem dry matter (g/plant) | Plant Dry matter (g/plant) | leaf /stem ratio | N % | K % | P % | Fe (mg/kg) | Zn (mg/kg) | Mn (mg/kg) | Cu (mg/kg) |
|------------|----------------------|---------------------------|---------------------------|----------------------------|---------------------|--------------------|-------------------|--------------------|---------------------|---------------------|-----------------------|----------------------|
| A | 18.62 ^{bcd} | 1.45 ^b | 1.23 ^{abc} | 2.68 ^{bc} | 1.17 ^{abc} | 3.29 ^{ab} | 1.75 ^a | 0.17 ^{bc} | 330 ^{bc} | 35.20 ^a | 59.20 ^{abc} | 34.20 ^{cd} |
| B | 19.12 ^{bcd} | 1.43 ^b | 1.19 ^{cde} | 2.62 ^{bcd} | 1.19 ^{ab} | 1.45 ^{de} | 1.60 ^a | 0.20 ^b | 286 ^{cd} | 31.95 ^{ab} | 39.75 ^e | 31.50 ^{cde} |
| R | 20 ^{bc} | 1.37 ^{bc} | 1.26 ^{ab} | 2.63 ^{bcd} | 1.08 ^{cde} | 2.79 ^c | 1.88 ^a | 0.14 ^c | 187 ^d | 25.75 ^b | 50.76 ^{de} | 29 ^{cde} |
| S | 17.07 ^{cde} | 1.38 ^{bc} | 1.20 ^{cd} | 2.58 ^{cde} | 1.15 ^{bc} | 1.19 ^{fc} | 1.50 ^a | 0.20 ^b | 348.5 ^{bc} | 30 ^{ab} | 56.25 ^{bcd} | 31 ^{cde} |
| RB | 17.42 ^{cde} | 1.18 ^f | 1.12 ^f | 2.31 ^e | 1.05 ^{de} | 0.85 ^{fg} | 1.85 ^a | 0.17 ^{bc} | 284 ^{dc} | 31.25 ^{ab} | 49.95 ^{ef} | 29 ^{cde} |
| RBS | 18.60 ^{bcd} | 1.45 ^b | 1.27 ^{ab} | 2.72 ^b | 1.13 ^{bcd} | 1.46 ^{de} | 1.71 ^a | 0.20 ^b | 233.5 ^{cd} | 30 ^{ab} | 38.75 ^{gh} | 28.95 ^{cde} |
| BS | 18.82 ^{bcd} | 1.32 ^{dc} | 1.19 ^{cde} | 2.52 ^{def} | 1.10 ^{bcd} | 1.69 ^d | 1.78 ^a | 0.24 ^a | 342.5 ^{bc} | 29.65 ^{ab} | 51.60 ^{cde} | 36.40 ^c |
| ABS | 16.42 ^{de} | 1.40 ^{bc} | 1.22 ^{bcd} | 2.62 ^{bcd} | 1.14 ^{bcd} | 2.95 ^{bc} | 1.76 ^a | 0.20 ^b | 333 ^{bc} | 29.50 ^{ab} | 58.50 ^{abcd} | 29.70 ^{cde} |
| AR | 20.12 ^{bc} | 1.43 ^b | 1.28 ^{ab} | 2.71 ^{bc} | 1.11 ^{cde} | 3.35 ^{ab} | 1.71 ^a | 0.16 ^{bc} | 280 ^{cd} | 29.70 ^{ab} | 50 ^{ef} | 26.70 ^{cd} |
| RAB | 17.45 ^{cde} | 1.22 ^{ef} | 1.16 ^{def} | 2.39 ^{fg} | 1.05 ^{de} | 2.81 ^c | 1.50 ^a | 0.14 ^c | 285 ^{dc} | 29.45 ^{ab} | 54.50 ^{cde} | 34.85 ^{cd} |
| RAS | 18.60 ^{bcd} | 1.45 ^b | 1.27 ^{ab} | 2.72 ^b | 1.13 ^{bcd} | 2.76 ^c | 1.75 ^a | 0.16 ^{bc} | 304.5 ^c | 32.05 ^{ab} | 43 ^{fg} | 33.80 ^{cd} |
| RABS | 18.67 ^{bcd} | 1.39 ^{bc} | 1.20 ^{cd} | 2.60 ^{bcd} | 1.15 ^{abc} | 2.93 ^{bc} | 1.69 ^a | 0.20 ^b | 285 ^{cd} | 26.65 ^b | 49.55 ^{ef} | 27 ^{cd} |
| RS | 23.27 ^a | 1.32 ^{dc} | 1.27 ^{ab} | 2.59 ^{bcd} | 1.02 ^e | 2.76 ^c | 1.64 ^a | 0.16 ^{bc} | 324.5 ^{bc} | 25.35 ^b | 55.55 ^{bcd} | 27.20 ^{de} |
| AS | 21.42 ^{ab} | 1.57 ^a | 1.29 ^a | 2.86 ^a | 1.21 ^a | 3.40 ^a | 1.78 ^a | 0.17 ^{bc} | 424 ^{ab} | 28.40 ^b | 64.50 ^a | 55.45 ^a |
| AB | 16.42 ^{de} | 1.40 ^{bc} | 1.22 ^{bcd} | 2.62 ^{bcd} | 1.14 ^{bcd} | 1.80 ^d | 1.73 ^a | 0.17 ^{bc} | 478 ^a | 30.85 ^{ab} | 63.35 ^{ab} | 29 ^{cde} |
| M | 17.95 ^{dcc} | 1.27 ^{def} | 1.20 ^{cd} | 2.47 ^{ef} | 1.05 ^{de} | 1.63 ^{de} | 1.72 ^a | 0.16 ^{bc} | 305 ^c | 33.35 ^{ab} | 56.45 ^{bcd} | 45 ^b |

Means with the same letter at each column are not significantly different (p<0.05).

A: *Azotobacter chroococum*, B: *Bacillus subtilis*, R: *Rhizobium meliloti*, S: *Pseudomonas fluorescens* and M: arbuscular mycorrhizal fungi from the genus of *Glomus*, the double combination (A+B), (A+R), (A+S), (B+R), (B+S) & (R+S), the triple combination (A+B+R), (A+B+S), (A+R+S) & (B+R+S), the quaternary combination (A+B+R+S) and C: Control.

Nutrient uptake

The AS fertilizing treatment enhanced N uptake (Table 3) in fenugreek. Improving effects of integrated application of *Pseudomonas* strains on dry weight of potato and sugar beet and higher accumulation of P, N was reported by Pouryousef (2007). The increased availability of N might lead to better root development as well as uptake and transportation of water and mineral nutrients (Rizvil et al., 2013). The increased plant vegetative and generative growth due to nutrients like N may be attributed to its role in enhancing chlorophyll content as nitrogen is one of the main components of chlorophyll, which increases synthesis of food material and their distribution towards the pods (Jain et al., 2003). The *Rhizobium* inoculation increased the N and P content in grain and straw and total uptake N and P. This was probably due to more nitrogen fixation by the bacteria resulting in better utilization of all other nutrients by crop. These findings support those of (Dubey et al., 2012).

It seems that application of bio fertilizers did not have any advantageous effect on K absorption in fenugreek. However, Khiriya and Singh (2003) reported that bio-fertilizer application on K uptake is mainly positive and therefore with increase in crop growth there has been improvement in potassium uptake by fenugreek. Potassium is considered as one of the nutrients which not only improves yield but also is involved in many metabolic processes (Basseto et al., 2007).

Application of BS treatment recorded significantly

higher phosphorus content (0.24%) than the other treatments in fenugreek shoot (Table 3). This could be explained by an increase in P availability to plant due to application of phosphate bacteria. Higher phosphorus content in plants is also expected due to better buffering capacity of bio fertilizers for incipient moisture stress and improving phosphorus availability to plant (Rizvil et al., 2013). The nitrogen fertilization of fenugreek increases the cation exchange capacity (CEC) of roots, enabling them to absorb more nitrogen from the soil, thus N and, subsequently, P might have been utilized in greater quantities due to their abundant availability (Nadeem et al., 2004).

Significantly higher Fe uptake was recorded with AB treatment (Table 3). Probably, Fe concentration increases with microbial activities and release of siderophores (Rengel et al, 1999).

There was not any significant difference between bio fertilizers and control on Zn content. (Table 3).

Integrated bio-fertilizers, especially AS treatment resulted in significantly higher Mn and Cu in fenugreek shoots than the other treatments and control plants (Table 3). Improvement in nutrient content could be attributed to the increased vegetative growth possibly as a result of effective utilization of nutrients absorbed through extensive root system developed under phosphate fertilization (Kumar and Kushwaha, 2006) and their efficient translocation towards sink components such as plant produce (Havlin et al., 2003).

Table 3: The effects of different kinds of bio-fertilizers on growth, yield and yield components of fenugreek at the end of physiological rippling stage

| Treatments | Root length | Root dry matter | biological yield (g/plant) | Number of pod/plant | Number of seed/pod | 1000 seed weight (g/plant) | seed yield (g/plant) | Harvest index (%) |
|------------|-----------------------|---------------------|----------------------------|---------------------|------------------------|----------------------------|----------------------|---------------------|
| A | 36 ^{bc} | 3.17 ^b | 62.23 ^c | 6.75 ^a | 8.25 ^h | 8.93 ^{cde} | 15.87 ^{bc} | 25.50 ^b |
| B | 21 ^{ih} | 2.25 ^{dc} | 54.35 ^g | 6 ^{ab} | 11.75 ^{defg} | 6.84 ^{defg} | 12.50 ^{de} | 22.99 ^c |
| R | 25.25 ^{fgh} | 1.80 ^{de} | 58.41 ^e | 3.25 ^c | 8.25 ^h | 6.52 ^{efg} | 10.92 ^{fg} | 18.70 ^{de} |
| S | 31 ^{cde} | 1.40 ^e | 53.96 ^g | 3 ^c | 12 ^{cdef} | 6.37 ^{fg} | 11.12 ^{fg} | 20.61 ^d |
| RB | 13.50 ^j | 1.40 ^e | 54.21 ^g | 2.5 ^c | 10.75 ^{efgh} | 5.66 ^g | 10.69 ^g | 19.73 ^{de} |
| RBS | 28.75 ^{defg} | 4.02 ^a | 59.50 ^{de} | 7.5 ^a | 14 ^{abcd} | 8.69 ^{def} | 15.67 ^{bc} | 26.34 ^b |
| BS | 34 ^{bcd} | 2.05 ^{cde} | 56.76 ^f | 4.25 ^{bc} | 13.25 ^{bcde} | 8.87 ^{cde} | 13.25 ^d | 23.34 ^c |
| ABS | 38.25 ^{ab} | 3.20 ^b | 58.72 ^e | 7 ^a | 16.50 ^a | 9.09 ^{cd} | 16.97 ^{ab} | 28.90 ^a |
| AR | 29 ^{def} | 2.72 ^{bc} | 60.83 ^d | 5.75 ^{ab} | 15.50 ^{ab} | 8.45 ^{def} | 14.65 ^c | 24.08 ^{bc} |
| RAB | 20 ^{ih} | 1.65 ^{de} | 54.74 ^g | 3.50 ^c | 12.75 ^{bcdef} | 7.86 ^{defg} | 12.15 ^{def} | 22.19 ^{cd} |
| RAS | 23.25 ^{ghi} | 1.72 ^{de} | 69.20 ^a | 6.50 ^a | 8.75 ^h | 7.53 ^{defg} | 12.45 ^{de} | 17.99 ^e |
| RABS | 28.25 ^{efg} | 1.92 ^{de} | 55.42 ^{fg} | 6.75 ^a | 14.50 ^{abcd} | 8.08 ^{def} | 14.67 ^c | 26.47 ^b |
| RS | 34.50 ^{bc} | 3.02 ^b | 59.20 ^{cd} | 6.25 ^a | 14.75 ^{abc} | 11/ 69 ^b | 15.67 ^{bc} | 26.46 ^b |
| AS | 42.75 ^a | 3.37 ^{ab} | 61.24 ^{cd} | 6.75 ^a | 15 ^{ab} | 13/ 83 ^a | 17.77 ^a | 29.01 ^a |
| AB | 24.50 ^{fghi} | 2.25 ^{cd} | 64.43 ^b | 3 ^c | 10 ^{fgh} | 11/ 12 ^{bc} | 12.22 ^{def} | 18.97 ^{de} |
| M | 19 ^j | 3.02 ^b | 69.20 ^a | 3.50 ^c | 13 ^{bcde} | 8/ 47 ^{def} | 12.25 ^{def} | 18.97 ^{de} |
| C | 9.50 ^j | 1.32 ^e | 53.86 ^g | 4.25 ^{bc} | 9 ^{gh} | 6/ 36 ^{fg} | 11.19 ^{efg} | 20.77 ^d |

Means with the same letter at each column are not significantly different ($p < 0.05$).

A: *Azotobacter chroocum*, B: *Bacillus subtilis*, R: *Rhizobium meliloti*, S: *Pseudomonas fluorescence* and M: *arbuscular mycorrhizal* fungi from the genus of *Glomus*, the double combination (A+B), (A+R), (A+S), (B+R), (B+S) & (R+S), the triple combination (A+B+R), (A+B+S), (A+R+S) & (B+R+S), the quaternary combination (A+B+R+S) and C: Control.

Generative Growth

Application of integrated bio-fertilizer (combination of different bacteria) showed the highest biological yield (Table 3). This might be due to the fact that bacteria inoculation increased root development, nodulation and more nutrient availability resulting in vigorous plant growth and dry matter production leading to better flowering and pod formation. These results correspond to the findings of Dubey et al., (2012) in fenugreek. The maximum biological yield obtained with RAS treatment while the minimum biological yield was obtained from RAB, RB, S, B and C. *Azotobacter* sp. Performed the best positive effects on biological yield.

It seems that most of the sole and integrated bio fertilizers like AS had positive effect on yield components of fenugreek. These results supports finding by Ghosh and Mohluddln (2000).

Seed yield of a crop is a function of yield attributes such as number of pods per plant, number of seeds per pod, seed yield per plant and 1000-seed weight. Increase in growth and yield attributes due to enhanced nutrient uptake will have direct and positive effect on seed, straw and biological yields of fenugreek (Godara et al., 2012). Integrated application of bio-fertilizers resulted in significantly higher seed yield than control (Table 3). Application of AS treatment produced the maximum amount of seed yield (17.77 g/plant). Higher seed yield of fenugreek seems to be due to cumulative effect of yield attributes and growth parameters. These results correspond with the finding of those of Godara et al., (2012). In the present study, it was observed that significant increase in seed yield was recorded due to integrated bio-fertilizer treatments (Table 3). Increase in seed yield was due to increase in plant growth and seed components attribute especially significant increase in the number of branches and pods per plants. Total plant dry matter also increased with integrated nutrient management which by no doubt provided basic source for yield and seed yield attributes (Dubey et al., 2012).

The highest harvest index of 29.01% and 28.90% was obtained by AS and ABS treatments, respectively (Table 3). It seems that integrated bio-fertilizers help better sink-source relations in to allocate more nutrients to seed and increase the harvest index in fenugreek plants. The reproductive growth depends on vegetative growth which increase leaf area and supply photosynthates for the formation of flowers and other seed yield attributes. Therefore, bio physiochemical properties of soil- plant system will buildup yield attributes and the seed yield (Dubey et al., 2012).

IV. CONCLUSION

Application of bio-fertilizers significantly improved vegetative and generative growth as well as nutrient uptake in fenugreek. Thus, fertilization of fenugreek plant with bio-fertilizer can be recommended. Bio-fertilizers improved root system and created deeper and more abundant roots and caused better nutrient absorption. Integrated application of Phosphorus-solubilizing and N fixing

bacteria increased the availability of nitrogen and phosphorus in the soil, which led to higher crop production. In this study, application of AS treatment (*Azetobacter chroococum*+*Pseudomonas fluorescence*) best performed in enhancing fenugreek vegetative and generative growth as well as nutrient uptake in fenugreek.

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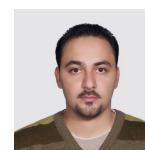


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