EVALUATION OF GERMPLASM AND INFLUENCE OF BIOINOCULANTS ON FENUGREEK

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By
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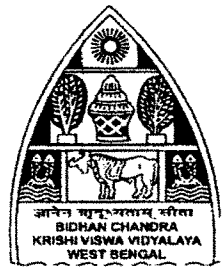

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APPROVAL OF EXAMINERS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (HORTICULTURE) IN SPICES AND PLANTATION CROPS

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Certificate

This is to certify that the work recorded in the thesis entitled **"Evaluation of germplasm and influence of bioinoculants on fenugreek"** submitted by **Ms. Majji Anitha** in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy (Horticulture)** in Spices and Plantation Crops, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, is a faithful and bonafide research work carried out under my personal supervision and guidance. The results of the investigation reported in the thesis have not so far been submitted for any other degree or diploma. The assistance and help received from various sources during the course of this investigation have been duly acknowledged.

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Place: Mohanpur, Nadia, W.B.
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Anitha

(Majji Anitha)

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Introduction

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is one of the most important seed spice crop cultivated throughout the world for seed, green leafy vegetable and forage purpose. The crop belongs to family *Fabaceae* of sub family *Papilionaceae* and the order *Fabales* (Petropoulos, 2002). It is popularly known by its vernacular name *Methi*, as a leguminous leafy vegetable. It has light to dark green leaves with or without pink margin. Its leaves are rich source of protein, minerals, vitamin A and C.

The chromosome number is 2n=16. It is a self-pollinated dicotyledonous plant with branched stem, trifoliate leaves, which bears white to yellow flowers and produces golden yellow to brown seeds. The seeds are widely used as spice in various oriental and occidental cuisines (Giridhar *et al.,* 2016). The seeds are small, hard, brownish yellow in colour and have pleasant taste, odour and flavour. The pods are slender, straw coloured when ripe, beak shaped and about 8-10 cm long containing 8-15 brownish yellow coloured seeds with smooth surface. Each seed is about 0.3-0.5 cm long, rich in vitamins like thiamine, riboflavin, niacin, vitamin A and minerals. Fenugreek seed contains 20% seed protein, 50% carbohydrate, 5% fat and 25% dietary fibres, lipid, cellulose, starch, ash, calcium, iron and ß-carotene and seed with 75% testa and 25% albumen (USDA, 2001).

Fig. 1 Morphology of fenugreek plant

Source: *http://fr.wikipedia.org/wiki/Utilisateur*

Apart from its spice value, fenugreek is a valuable source of several highly desirable biologically active compounds such as galactomannan (Brummer *et al.*, 2003), diosgenin (Fazli and Hardman, 1968), 4-hydroxy isoleucine (Fowden *et al.*, 1973) and trigonelline (Antony *et al.*, 1975) that have specific health benefits. These compounds have been demonstrated to exert beneficial effects on several physiological markers including glucose tolerance, inflammation, insulin action, liver function, blood lipids, anti cancer and cardiovascular health (Sharma, 1990; Smith, 2003 and Fuller and Stephens, 2015). In Ayurvedic and Unani systems of medicine, fenugreek is known to treat many chronic diseases. It is also having hypoglycaemic and hypocholesterolaemic properties.

The medicinal use of fenugreek was documented in ancient Egypt in curing incense human behaviour and embalming mummies. In India, it is used medicinally as lactation stimulant in mothers, curing ailments such as allergies, coughs, colds, flu, inflammation, fevers, dyspepsia, flatulence, headaches, pellagra, stomachic ulcers, bronchitis, dropsy, infections of mucous membranes etc. There are numerous other folkloric uses of fenugreek including treatments of indigestion and baldness (Naeem, 2012). Seeds are also used in ameliorating the bad effects of diabetes and rickets (Chevalier, 1996).

In addition to high medicinal and pharmaceutical values fenugreek can be used as a high quality forage legume, a nitrogen fixing cover crop and green manure in agricultural plantation (Sadeghzade *et al.*, 2009 and Zandi *et al.*, 2015). So, integration of fenugreek into the cropping system will have the routine advantages as other legume crops, especially improvement of soil fertility *via* biological fixation of nitrogen.

Due to these unique nutritional, aromatic, flavour, medicinal and nutraceutical properties, the crop has attained industrial status. The plant was known to be under cultivation since 4,000 B.C. and the exact origin is still unclear (Acharya *et al.*, 2008). It is probably indigenous to eastern Mediterranean, West Asia and India (Lim, 2012). Ethiopia is also known to be the original homeland for fenugreek (Sinskaya, 1950). The major fenugreek producing countries are India, Pakistan, Bangladesh, Argentina, Egypt, France, Spain, Turkey, Morocco, Iran, Nepal, Ukraine and China (Sastry and Anandraj, 2013).

India is the largest producer of fenugreek. The crop coverage in India was 227,960 ha with production of 248,350 metric tonnes and the average productivity of the

country was 1089 kg ha^{-1} (Spice Board, 2015). Rajasthan, Gujarat, Haryana, Uttar Pradesh and Uttarakhand are important states that produce fenugreek for spice purpose under irrigated conditions. It is also cultivated in the states of West Bengal, Madhya Pradesh, Bihar, Odisha, Karnataka and Andhra Pradesh to a limited extent mostly under supplementary or without irrigation (Sastry and Anandraj, 2013).

The productivity of the crop in India is considered low, mainly due to the paucity of good high yielding varieties and inadequate access of available HYV to growers (Giridhar *et al.,* 2016). For any crop improvement programme presence of genetic variability in the population is very important as it provides chance to select the genotype having desirable traits for improvement and it also gives wide range of options to improve the traits of interest. The knowledge of genetic variation is important for selection in crop improvement programme. McCormick *et al.* (2009) found a significant variation for flowering time and duration, growth habit and seed yield. Yield is a complex character governed by several other yield attributing characters. Since most of the yield attributing characters are quantitatively inherited and highly affected by environment, it is difficult to judge whether the observed variability is heritable or not. The genetic gain expected from selection depends on the amount of variability available in the quantitative trait in germplasm of a crop. A successful selection programme depends on the information on genetic variability and association of yield components with seed yield. Information owing to genetic and non-genetic causes is a prerequisite for initiating a crop improvement programme. So evaluation is important for further crop improvement programme.

Optimum supply of nutrients is of paramount importance not only for the higher yield but also for an improvement in quality of fenugreek. Injudicious use of chemical fertilizers not only harms the soil health but also increases the cost of production in other ways. Judicious combination of organic manure, bio-fertilizers and chemical fertilizers facilitate profitable and sustainable production (Singh and Sinsinwar, 2006). In recent years, application of natural and biological fertilizers has drawn researcher's attention due to their successful performance in crop production and their less ecological foot print compared with chemical fertilizers. A large group of soil inhabiting microorganisms known as plant growth promoting rhizobacteria (PGPR) is able to fix atmospheric nitrogen and or convert the non-absorbable mineral soil P to a usable form for plants (Vessey, 2003).

For quite some time bio-fertilizers have been noted as eco-friendly potential fertilizer sources for maintenance of soil health and sustainable crop production system (Gehlot and Bohra, 2001).

Free living nitrogen fixing bacteria *Azotobacter* has been considered as low cost bio-fertilizer in agricultural production. Worldwide inoculation experiments carried out with strains of *Azotobacter chroococcum* have demonstrated the potential of the bacteria to promote plant growth and enhance the yield of crops in different soils and in different climatological conditions (Pandey and Kumar, 1998). The beneficial effects of *Azotobacter* are attributed to production of plant growth hormones, improved nutrient uptake and antagonistic effects on plant pathogens (Parmar and Dadarwal, 1997).

Azospirillum assimilates atmospheric nitrogen, fixes it in soil and helps to save nitrogen. It also secretes phytohormones in the plant root region which in turn enhance the root growth (Govindan *et al.*, 2009)

Phosphorous solubilising bacteria play a strong role in phosphorous nutrition by enhancing its availability to plants through release from inorganic and organic soil pools by solubilising and mineralizing (De *et al.*, 2012).

Phosphorous solubilising bacteria improves nutrient availability which increases nitrogenous activity of roots creating congenial environment in plant rhizosphere and resulted in higher physiological growth parameters.

Biofertilizer application on K-uptake is mainly positive and therefore with increase in crop growth there has been improvement in potassium uptake by fenugreek (Khiriya and Singh, 2003). Potassium solubilising microorganisms play a vital role in making available insoluble forms of potassium by mineralization (Shanware *et al.*, 2014). Supanjani *et al.* (2006) reported that integration of phosphate and potassium solubilising bacteria increased P availability from 12 to 21% and K availability from 13 to 15% and increased yield of capsicum green pod by 23 to 30%.

Keeping the importance in view and lack of consorted work under West Bengal conditions, the present investigation has been framed with the following objectives.

1. To evaluate different genotypes for seed yield, yield contributing characters and quality under alluvial plains of West Bengal.
2. To study the efficacy of different bioinoculants along with inorganic nutrition in fenugreek.

Chapter-II

Review of Literature

REVIEW OF LITERATURE

India is the largest producer of fenugreek in the world. The productivity of the crop in India is considered low, mainly due to the paucity of good available high yielding varieties (HYV) and also inadequate access of the seed of available HYVs to the growers and imbalanced or inadequate use of nutrients. Use of improved varieties/cultivars is one of the important factors for increasing the area and production of the crop. The productivity can be increased if a proper combination of varieties and management practices are available to the growers. The research work done so far on related aspects of the present investigation have been reviewed and presented hereunder.

EVALUATION OF FENUGREEK GERMPLASM

Malik and Tehlan (2009) investigated the performance of 16 genotypes for growth and seed yield and recorded plant height with range of 74.8 to 84.5 cm, number of branches plant^{-1} with range of 5.5 to 6.3 among genotypes. Yield related parameters like number of pods varied from 57.7 to 71.8, pod length from 9.1 to 10.2 cm and number of seeds with range of 15.3 to 16.3 pod^{-1}. The maximum seed yield of 18.95 q ha^{-1} was recorded in Hissar Sonali as compared to other genotypes. Tamgadge *et al.* (2010) also carried out a germplasm evaluation experiment and observed that yield characters like number of pods plant^{-1}(36.48), pod length (13.84 cm), number of seed pod^{-1}(18.55), seed yield plant^{-1} (6.51 g) and seed yield ha^{-1} (16.64 q) were found highest in variety Pusa Early Bunching.

Singh *et al.* (2012) observed wide variation in both vegetative and yield attributes like plant height (49.07 to 69.20 cm), primary branches plant^{-1} (3.20 to 4.80), number of pods plant^{-1} (21.27 to 38.00), pod length (10.87 to 13.33 cm), number of seed pod^{-1} (12.18 to 17.47), test weight (7.47 to 7.96 g) and seed yield plant^{-1} (4.62 to 6.03 g) in 31 varieties. As per results of the study, Hissar Sonali, NDM-2, NDM-18, NDM-14 and NDM-20 are most suitable germplasm and out of them Hissar Sonali is expressed as best performing variety in Uttar Pradesh.

From an evaluation trial Jain *et al.* (2014) recorded maximum plant height (75.8 cm), number of pods plant^{-1} (36.4), pod length (9.89 cm), number of seeds pod^{-1} (14.8), seed yield (20.44 q ha^{-1}) and straw yield (47.89 q ha^{-1}) in genotype PRM 45 which was *at par* with another genotype RMt 143 except in straw yield. Genotype PRM 45 also fetched maximum net returns (₹ 28, 906 ha^{-1}) and benefit cost ratio of 3.01.

Santosha *et al.* (2014) noticed significant differences among 24 genotypes in respect of both growth and yield parameters. Maximum seed yield (25.13q ha^{-1}) was recorded in UM-8. Morphological parameters like plant height ranged between 39.67 cm (LFC-76) to 43.48 cm (UM-4), number of branches ranged from 5.67 (Pant Ragini) to 7.80 (LFC-83), number of pods $plant^{-1}$ varied from 25.73 (Ghataprabha Local) to 54.93 (UM-4), pod length from 8.17 cm (LFC-83) to 11.05 cm (Johar) and seeds pod^{-1} varied from 11.63 cm (Johar) to 15.24 (LFC-81).

Singh *et al.* (2015) carried an experiment with 102 genotypes of fenugreek at Jabalpur, Madhya Pradesh for two years and recorded wide variations among genotypes in different parameters like plant height with range of 60.5 to 109.0 cm at maturity, number of primary branches varied from 1.5 to 8.5 and secondary branches varied from 0.0 to 6.6 $plant^{-1}$. Number of nodules $plant^{-1}$ is in a range of 8.1 to 27.6. Yield related parameters like pods $plant^{-1}$ was recorded in between 5.3 and 47.0, pod length varied from 8.9 to 14.6 cm. Flowering time was recorded with range of 61 to 72 days and days to 75% maturity was recorded in between 111.8 days to 123.6 days. Number of seed pod^{-1} was recorded in between 7.3 to 22.1, 1000 seed weight varied from 12.5 to 14.9 g and seed yield $plant^{-1}$ was recorded with range of 1.0 to 6.6 g

Giridhar *et al.* (2016) evaluated 13 promising genotypes of fenugreek for yield in rainfed vertisols of Andhra Pradesh and observed that highest seed yield was recorded in genotype LFC-103 (584.1 kg ha^{-1}) followed by HM-348 (542.8 kg ha^{-1}). Mamatha *et al.* (2017) evaluated 150 fenugreek genotypes of different agro-climatic zones and observed a wide range of variability in yield and yield attributing traits. Maximum plant height (121.23 cm) and highest number of primary (6.07) and secondary (12.53) branches $plant^{-1}$ were recorded in variety HM-242. For yield attributing characters, maximum number of pods and number of seed pod^{-1} were recorded in variety HM-555 (164.40) and HM-509 (12.60) respectively. Highest seed yield $plant^{-1}$ (26.2 g) and test weight (14.53 g) were recorded in genotype HM-242.

The experiment was conducted with 20 accessions of fenugreek evaluated during *rabi* 2016-17 and observed highest mean for plant height (88.16 cm) at 90 DAS, highest number of pods (51.80), seed pod^{-1} (16.60), test weight (13.60 g) and maximum seed yield $plant^{-1}$ (12.12 g) in UM-410 and also noticed that UM-410 took minimum number of days (61.33) to reach 50% flowering stage (Meena *et al.*, 2017)

EVALUATION OF GERMPLASM OF OTHER SEED SPICES

Coriander

Nima and Korla (2003) evaluated 43 genotypes of coriander in Solan and observed maximum plant height in DH-41 (80.43 cm). Number of branches plant^{-1} was highest in DH-129 (9.27). Maximum number of days taken for flowering was recorded in local Solan check (116.00). Among yield related attributes, maximum test weight was recorded in Rajendra Swathi (14.64 g) and seed yield plot^{-1} (2.25 m^{-2}) was highest in DH-218 (31.67 g) genotype.

Integrated nutrient management

Nitrogen, phosphorous and potassium are major nutrients that limit plant growth and development. Application of chemical fertilizers is essential to achieve an optimum yield. But excessive application not only increases production cost, but also contributes to environmental pollution, mainly through nitrogen leaching, ammonia volatilization and phosphorous runoff. In recent years, application of bio fertilizers have drawn the attention of researchers due to successful performance in crop production and their less ecological footprint compared with chemical fertilizers (Dadrasan *et al.,* 2015). Microorganisms called as biofertilizers which contain living cells of different types are PGPR able to fix atmospheric nitrogen and or convert non-absorbable mineral soil phosphorous to a usable form for plants (Vessey, 2003).

Bio-fertilizers are gaining importance in sustainable agriculture used in the form of plant growth promoting rhizobacteria including nitrogen, phosphorous and potassium solubilizing bacteria. Because of low cost and the usage of combination of microbial inoculants for supplementing the major nutrients such as nitrogen, phosphorous and potassium which are necessary for sustainability. They are major essential macronutrients for plant growth and development and hence they are commonly added as fertilizers to optimize the yield.

A great portion of phosphorous applied through chemical fertilizer becomes insoluble turning into calcium or magnesium salts in calcareous soils and iron or aluminium salts in acid environment, all of which are unavailable to plants. PSB have been used to convert insoluble rock P material into soluble forms available for plant growth (Illmer *et al.,* 1995). Potassium solubilizing bacteria (KSB) are able to solubilize rock minerals such as mica, illite and orthoclases through production and excretion of

organic acids (Friedrich *et al.*, 1991). *Pseudomonas*, *Rhizobium* and *Bacillus* show high degree of tricalcium phosphate solubilization, while *Azospirillum* produces exopolysaccarides and IAA.Microbes like *Bacillus extroquens*, *Aspergillus niger* and *Clostridium pasteurianum* are involved in solubilization of rock potassium (Muentz, 1890).

In the present day of agriculture, intensive farming practices that achieve high yield require fertilizers. However, inappropriate agricultural intensification coupled with reckless use of fertilizers has deteriorated soil quality. Therefore, there is growing awareness on the use of environment friendly sustainable nutrient management practices that lay emphasis on restoration and maintenance of soil quality both in short and long term. Thus, effective biological technologies like the use of plant growth promoting rhizobacteria (PGPR) are being exploited for enhancing crop yields. PGPR represent a wide variety of rhizosphere inhabiting bacteria which colonize the root systems of plants and can stimulate plant growth by direct or indirect mechanisms. Direct mechanisms of plant growth promotion include biofertilization, stimulation of root growth, rhizoremediation and plant stress control, while mechanisms of biological control include reducing the level of disease, antibiosis, induction of systemic resistance and competition for nutrients and niches (Lugtenberg and Kamilova, 2009). Common PGPR include genera *Azospirillum*, *Azotobacter*, *Bacillus*, *Beijerenckia*, *Burkholderia*, *Enterobacter*, *Rhizobium* and *Serratia* (Anandraj and Dinesh, 2008). At present, PGPR are being increasingly used in combination with fertilizers for improving crop yields and contribute to the development of sustainable agricultural systems. Studies showing that PGPR had positive effect on spices (Anandraj and Sarma, 2003) their application found to improve plant uptake of nutrients and there by increases the fertilizer use efficiency of applied manures and fertilizers thus allowing reduced application rates of fertilizers. Very little information was available on effects of PGPR applied alone or in combination with graded doses of fertilizers on biochemical and microbial indices of soil.

Indiscriminate use of inorganic fertilizers for nourishment of plant has caused the contamination of soil, polluted water basins and destroyed micro-organisms making soil less fertile. Application of biofertilizers is one of the environmental friendly approach for supplementation of nutrient to plant. These microbial inoculants are able to dissolve fixed nutrients from mineral and rocks and influence plant growth and development. Among the different biofertilizers, nitrogen fixers like *Azotobacter sp.*,

Rhizobium sp. and phosphate solubilisers like *Bacillus megatherium* and *Aspergillus sp.* are most prominent. Application of VAM and arbuscular mycorrhizal fungi is primarily responsible for transfer and solubilization of nutrients, especially microbial diversity in rhizosphere. Bioinoculant is a good platform to supply one of the macronutrient *i.e.* potassium by assistance of potassium solubilizing microorganisms.

Bioinoculants: an overview

The production process of mineral fertilizers uses fuel energy and these are made available to farmers in India through imports and subsidies from government. This makes these fertilizers available at high cost, scarcity during cropping season and also further soil pollution. So, there is a renewed focus on organic recycling and biological nitrogen fixation to maintain soil fertility and increased productivity (Mazid and Khan, 2014). These biofertilizers are long term environmental implications negating the adverse effect of chemicals. These microbial inoculants are artificially cultured for improving soil fertility. Latent cells of efficient strains of nitrogen fixing, phosphate solubilizing and mobilizing cellulolytic microorganisms, potassic mobilizing etc. may be used as treatment to seed or seedling dipping or soil application along with manure or compost the areas with the objective of increasing the microbes in soil rhizosphere and to accelerate the microbial processes which augment the availability of nutrients that can be easily assimilated by plants (Mazid *et al.,* 2011). Biofertilizers are cost effective, eco-friendly and renewable energy sources of plant nutrients. Biofertilizers have following benefits.

- Low cost technology with a high benefit-cost ratio.
- Improve soil fertility through their sustained activities in the soil.
- Increase plant growth and crop yield through increased nutrient availability and soil fertility.
- Do not cause environmental pollution.
- Maintain soil health and conditioning.

Nitrogenous bioinoculants

Free living aerobic nitrogen fixing bacteria *Azotobacter* has been considered as low cost biofertilizer and considered as potential bacteria to promote plant growth and yield under different agroclimatological conditions (Pandey and Kumar, 1998). The

beneficial effect is due to ability to produce plant growth hormones such as gibberellins and vitamins and further enhance nutrient uptake by efficiently converting the atmospheric nitrogen to usable form for plant (Kizilkaya, 2008).

Azospirillum a diazotroph capable of fixing atmospheric nitrogen in soil and also secreting phytohormones such as auxins in rhizosphere helps in development of better root system. So, it can be used in cultivation of both extensive and intensive agriculture. Thus both *Azotobacter* and *Azospirillum* are potential biofertilizers capable to contribute in nitrogen metabolism to both leguminous and non-leguminous crops as well.

Phosphatic bioinoculants

Phosphorous is an important macronutrient required for plant growth and development. It plays a vital role in development of root, stem and flower and seed formation and early seed maturity. Therefore, demand can be met through supply of organic form or microbial inoculants. Soil microorganisms play a key role in soil phosphorous dynamics and subsequent availability of phosphate to plants (Richardson, 2001).

Arbuscular mycorrhizal fungi (*Glomus sp.*) namely *Glomus fasciculatum* most efficiently colonized the roots of *Trigonella foenum-graecum* and produced maximum number of spores in the rhizosphere (Mehaboob and Vyas, 2013). Soils of India are low to medium in available phosphorous. The fertilizer use efficiency of phosphatic fertilizer is very low (20-25%) due to fixation in soil. Phosphorous deficiency is the main factor which is responsible for poor yield in legume crops in all types of soils. Several strains of phosphate solubilizing bacteria (PSB) and fungi which are isolated have shown the ability to solubilise sparingly soluble phosphate, promote growth and uptake of P by plants (Whitelaw, 2000). Phosphatic biofertilizers are some heterotypic bacteria and fungi which are known to have the ability to solubilise inorganic phosphorous from insoluble sources by the production of organic acid. The mechanism is that secretion of organic acid, lowers the pH and increases the availability of sparingly soluble phosphorous sources.

Potash solubilising or mobilizing biofertilizer

Bacterial strains like *Bacillus edphicus*, *B.mucilaginious* and *Frateuria aurantia* are found most effective and widely used for inoculation. All the strains are reported to produce organic acids, siderophores, organic ligands and exo-polysacharides are known

to decompose or solubilise natural silicate and help in removal of metallic ions from rocks and soils (Yadav and Chandra, 2012). All microorganisms producing organic acids are good P-solubilisers but all P-solubilizers are not K-solubilisers. K-solubilisation in such a way that combination of organic acids, organic ligands and exo-polysachrides collectively act on fixed particles and release metallic ions from silicate particles.

EFFECT OF BIOINOCULANTS ON GROWTH AND YIELD OF FENUGREEK

Jat *et al.* (2003) recorded the highest grain yield in fenugreek on treatment with 80 kg P_2O_5 ha^{-1}, 100 kg S ha^{-1} along with *Rhizobium* + PSB inoculation. Response of fenugreek to bioinoculants (*Rhizobium* + PSB) was studied by Purbey and Sen (2005) who recorded the higher plant height (75 cm), dry matter production (21 g $plant^{-1}$) and seed yield (17q ha^{-1}). Neeraj and Chauhan (2006) concluded that application of inorganic form of phosphorous along with the arbuscular mycorrhizal fungi (AMF) was found effective in increasing the dry matter of root, shoot and leaves of fenugreek. From another experiment Jain *et al.* (2007) further reported that application of inorganic nitrogen (100 %) + *Azospirillllm* @ 1.5 kg ha^{-1} + 5 tonnes FYM ha^{-1} to fenugreek recorded the maximum net returns (₹ 22,728 ha^{-1}) and benefit: cost ratio (2.28: 1). Combined inoculation of *Rhizobium* + phosphate solubilizing bacteria (PSB) recorded higher values of growth and yield attributes in fenugreek cultivars RMt 1 and RMt 303 (Kumar *et al.*, 2009).

Sammauria and Yadav (2009) reported that attributes like plant height, branches $plant^{-1}$, dry matter accumulation, number of root nodule and their weight, pods $plant^{-1}$ and seed yield increased significantly in fenugreek with the combined inoculation of *Rhizobium* and phosphate solubilizing bacteria (PSB). Fenugreek cv. Giza 30 responded well to phosphatic biofertilizer along with mineral fertilizer in respect of increased plant height (81.87 cm), number of branches $plant^{-1}$ (9.90), number of pods $plant^{-1}$ (38.50) and dry weight $plant^{-1}$ (18.65 g) in Egypt (Ahmed *et al.*, 2010). Patel *et al.* (2010) reported that the application of recommended dose through inorganic form (20 kg N and 40 kg P_2O_5 ha^{-1}) and PSB @ 5 kg ha^{-1} to fenugreek resulted in highest plant height (63.75 cm), seed yield (2,164 kg ha^{-1}), straw yield (4,495 kg ha^{-1}). The same treatment also recorded maximum net returns and benefit:cost ratio.

Mehta and Patel (2011) reported that fenugreek seeds inoculated with *Rhizobium* and PSB resulted in the higher pod length (12.2 cm), number of pods $plant^{-1}$ (27.95),

number of seeds pod^{-1} (14.27), 1000 seed weight (12.02 g), seed yield (1,366 kg ha^{-1}) and straw yield (2,802 kg ha^{-1}). Bairava *et al.* (2012) concluded that superiority of dual inoculation of fenugreek seed with *Rhizobium* + PSB recorded significantly higher plant height at maturity (89.91 cm), primary branches plant^{-1}(6.68) and number of nodules plant^{-1} (24.35), number of pods plant^{-1} (89.62), pod length (12.05 cm), number of seed pod^{-1} (17.81), seed yield (17.43 q ha^{-1}) and straw yield (46.88 q ha^{-1}).

Biswas and Anasuya (2012) inoculated the compost with *Frateuria aurantia* (KMB), *Trichoderma viridae* (biocontrol agent), *Rhizobium sp.* (nitrogen fixer), *Aspergillus awamori* (PSM), *Pseudomonas fluorescens* (PGPR) in different combinations and evaluated them. Results concluded that inoculation with rock phosphate, biocontrol agent, KMB and PSM recorded maximum fresh weight (189 g) and dry weight (27.7 g) plant^{-1} of fenugreek.

Mehta *et al.* (2012) reported that application of 20 kg N and 40 kg P_2O_5 ha^{-1} gave significantly higher plant height at all growth stages *i.e.* 9.0, 45.0, 59.18 and 68.66 cm respectively at 30, 60, 90 DAS and at maturity, maximum number of branches plant^{-1}, maximum seed yield (14.90 q ha^{-1}) and straw yield (30.02 q ha^{-1}). Co-inoculation of seed with *Rhizobium*+ PSB and their sole application significantly gave higher plant height over control. Soyam *et al.,* (2012) recorded maximum plant height (16.13 cm), number of branches plant^{-1} (2.88) at 30 DAS and fresh weight of plants plot^{-1} (14.06 g) with seed inoculation and soil application of *Rhizobium* + PSB in fenugreek. Rizvi *et al.* (2013) reported that the application of phosphorous solubilising bacteria (*Pseudomonas fluorescens*) alone significantly improved fresh as well as dry weight of plants and number of pods plant^{-1} in fenugreek.

Jain *et al.* (2014) reported that among 75, 100 and 125% of increased recommended dose of N and P (20 kg N and 40 kg P_2O_5 ha^{-1}), successive increase in fertility levels up to 125% of recommended dose of N and P significantly increased plant height (74.0 cm), number of pods plant^{-1} (36.0), pod length (9.50 cm), number of seed pod^{-1}(14.5), seed and straw yield (20.18 and 46.49 q ha^{-1} respectively) over other fertility levels in fenugreek. It also recorded maximum net returns (₹ 28,005 ha^{-1}) and benefit: cost (2.91) over 75 and 100% RDF.

EFFECT OF BIOFERTILIZERS ON OTHER SEED SPICES

Coriander

Abou and Gomaa (2002) observed that inoculation of coriander seed with *Azotobacter chroococcum* , *Azospirillum brasiliense* combined with *Glomus mossae* (VAM), gave significantly higher vegetative growth. Kumar *et al.* (2002) observed the positive effect of nitrogen fertilizer application up to 60 kg N ha^{-1} along with inoculation of bio-fertilizers (*i.e., Azotobacter, Azospirillum* and *Azotobacter + Azospirillum*) on the yield of coriander cv. RCr-435. Darzi *et al.* (2012) stated that the highest plant height (69.2 cm), umbel number per plant (71.5), weight of 1000 seeds (5.04 g), dry weight of plant (32.31 g) and seed yield (630.2 kg ha^{-1}) were obtained by using nitrogen fixing bacteria (mixture of *Azotobacter chroococcum* and *Azospirillum lipoferum*) twice as inoculated to the seeds and foliar spray.

Cumin

In cumin, highest seed yield of 320 kg ha^{-1} was recorded with application of inorganic nitrogen (100%) with *Azospirillum* and FYM @ 5 t ha^{-1} (Anon., 2003). Patel *et al.,* (2004) reported that application of recommended dose of nitrogen (30kg ha^{-1} in inorganic form) through both mustard cake and inorganic fertilizer in 1:1 ratio recorded maximum growth attributes like plant height (33.2 cm), branch number $plant^{-1}$(5.3) and yield attributes like test weight (5.05 g) and seed yield (869 kg ha^{-1}) in cumin. Also, maximum net returns (₹ 70,765 ha^{-1}) and benefit: cost (4.39) was recorded by same treatment. Mehta *et al.* (2012) recorded highest plant height (33.20 cm), dry matter accumulation $plant^{-1}$ (5.8 g), number of branches $plant^{-1}$ (4.0) in cumin with application of *Azotobacter* in combination with sheep manure (7.5 t ha^{-1})

Ajowan

Meena *et al.* (2009) reported that *Azotobacter sp.* in combination with sheep manure (10 t ha^{-1}) in ajowain recorded higher plant height (103.37 cm) during maturity, yield attributing characters *viz.,* umbels $plant^{-1}$ (195), umbellets $umbel^{-1}$ (13.5), seeds $umbellet^{-1}$ (14.15) and seed yield (16.35 q ha^{-1}), stover yield (33.14 q ha^{-1}) and biological yield (49.49 q ha^{-1}).

Fennel

A combined application of 50% inorganic N + *Azospirillum* + organic manures proved better in yield attributing characters of fennel (Chaudhary, 2004). Yadav and Khurana (2005) reported that fennel seed treated with *Azotobacter* recorded significantly higher test weight.

QUALITY PARAMETERS OF FENUGREEK

Fenugreek, a representative member of leguminosae family, is a rich source of protein. In addition, it is endowed with a number of secondary phytochemicals with medicinal property (Petropoulos, 2002) which include galactomannans (Petropolous, 2002), diosgenin (Fazli and Hardman, 1968) trigonelline (Petropolous, 2002) and phenolic compounds (Huang and Liang, 2000 and Petropolous (2002). These phytochemicals vary considerably depending on genotype, environment and their interaction (Taylor *et al.*,2002; Acharya *et al.*, 2006 and Lee, 2006) and also different cultural practices especially application of manures and fertilizers (Shams *et al.*, 2013). The remarkable variability in the content of these phytochemicals is most often either overlooked or underestimated but pharmacological industries rely on the contents of these phytochemicals because of their pharmacological significance. The review of literature pertaining to the present study was discussed under as follows.

Galactomannans in fenugreek.

Protein in fenugreek.

Phenolic compounds in fenugreek.

Diosgenin in fenugreek.

Galactomannans in fenugreek

Galactomannans, a major polysaccharide of fenugreek seeds, constitutes nearly 50% of the seed weight (Raghuram *et al.* 1994). They form an integral component of the cell walls in the seed endosperm (Meier and Reid, 1977). Galactomannans generally consist of ß,1-4-linked linear mannan backbone, to which single galactose grafts are linked randomly by α, 1-6 glycoside bond (Fig. 2). Galactomannans in fenugreek, in contrast to other legume seed contain highest galactose (~48%; G:M, 1.02:1).

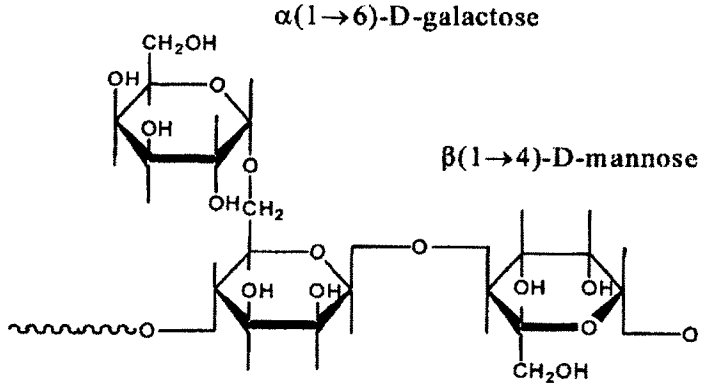


Fig.2 Structure of galactomannan

The substitution of the mannan backbone with high ratio of galactose is associated with hydrophilic properties of galactomannans in fenugreek seed and is important in determining the overall biological value of the galactomannans in fenugreek (Srichamroen *et al.,* 2005). Fully extended polysaccharide molecules are deposited on emulsified oil droplet in water protecting them against coalescence and flocculation. This property coupled with its moisture holding capacity opens up interesting possibility of using of fenugreek gum in cosmetics. Additionally, fenugreek galactomannans are also effective in controlling type-2 diabetes in animals and humans (Raghuram *et al.,* 1994). Several workers (Acharya *et al.,* 2006; Harish *et al.,* 2011 and Rathore *et al.,* 2013) analysed galactomannan content across the globe that varied between 16.1 and 28.2 % depending on genotypes and environment.

Protein in fenugreek

Amino acids, the product of N-assimilation are deposited as storage proteins in different parts including seeds and tubers. Globally about 70% of human demand for protein is met by the consumption of seeds directly or indirectly. Food proteins are not only as source of constructive and energetic compounds such as amino acids but also play an important role in several biological functions through formation of peptides (Rubio *et al.,* 2013). One of the resourceful means for characterizing protein in the seeds involves fractionation based on solubility that determines the molecular nature of protein. Solubility in water, dilute salt solution, dilute alkai solution and aqueous ethanol is represented by albumin, globulin, glutelin and prolamine respectively (Osborne, 1924).

Protein content in fenugreek ranges between 25 and 30%, which are primarily (90%) located in cotyledons plus embryo. Over 70% of these proteins are albumins, 5% proteins are globulins and 7% are glutelins (Sauvaire *et al.,* 1984). In contrast, legumes storage proteins are of the globulin type (Rubio *et al.,* 2013). In fenugreek, considering the high level of albumins, these proteins might have the role of storage proteins. With regard to biological value, legume proteins are deficient in S-containing amino acids. The lysine content of fenugreek seed is comparable to that of soybean. Belitz *et al.* (2009) reported the distribution of protein fraction in some selected legumes (Table 1.) According to the report of Rafik El-Mahdy and El-Sebaiy (1982), fenugreek seeds contain 6.3% prolamins. The glutelin content in fenugreek is similar that of soyabean (Hu and Esen, 1981) and pea (Boulter, 1977) and lower than that of beans (Marquez and Lajolo, 1981)

Table 1. Protein fraction distribution in some legumes

Fraction	Name of the crops		
	Soybean	Peas	Broadbean
Albumin	10	21	20
Globulin	90	66	60
Glutelins	0	12	15

Source: Belitz *et al.* (2009)

Among different fractions of protein, albumin constitutes the maximum percentage of storage protein (69.7%) in gila bean (Sidddhuraju *et al.* 2001). Protein fractions with albumin content of 18.1 % in lima bean, globulin content of 10.8 % in cow pea and pigeon pea, prolamine content of 2.3 % and acid-glutelin content of 1.4 % were obtained (Arogundade *et al.,* 2008). A preliminary study on protein fractionation of leucaena seed by Sethi and Kulkarni (1993) showed that the ethanol-soluble protein fraction (prolamin) constituted a very small percentage (1.2%). Furthermore they identified the major protein fraction is sodium-chloride soluble type (globulins, 43.5%), followed by the water soluble (albumin, 28-4%), and sodium hydroxide-soluble (glutelins, 25.0%) proteins. Protein concentrates were prepared from fenugreek seeds by extraction with distilled water, salt solution and alkaline solution. Alkaline solution (NaOH, 0.1 N) resulted in the highest extraction yield of about 82% (Osmon and Simon, 1991). Mehta *et al.*(2012) observed that combination of *Rhizobium*+PSB inoculation to fenugreek seed recorded highest total protein content (21.62%).

Ahmed *et al.* (2010) recorded highest protein content (9.75%) and soluble sugars (6.75%) in cv. Giza 30 as compared to control with application of phosphatic biofertilizer.

Mishra *et al.* (2011) concluded that the application of biofertilizers (*Azotobacter* and *Azospirillum*) either alone or in combination to fenugreek variety Pusa early bunching recorded a considerable improvement in total protein and lipid content of seeds over control.

Phenolic compounds

Phenolic compounds are widely distributed in the plant kingdom and have diverse physiological and ecological roles. These compounds occur in diversified structural classes including phenolic acids, flavonoids and tannins etc. Some of these

with their participation in redox reaction (Fig 3) are involved in resistance to oxidative stress which is associated with several oxidation linked chronic degenerative diseases such

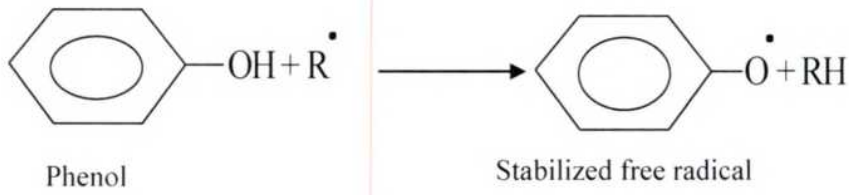


Fig. 3 Redox reaction of phenolics

The health benefit of phenolics is linked primarily to their antioxidant potential. Phenolics are effective antioxidants because the radical products of these molecules are resonance stabilized and thus relatively stable. To overcome the potential hazard from oxidative damage in the body, consumption of a diet rich in antioxidant phenolics including flavonoids and phenolic acids are considered the first line of defense to oxidative stress.

Phenol content itself is insufficient to explain the antioxidant potential which is determined by the quality of phenols which in turn depends on the contents of individual phenolic compounds and their interaction leading to either synergism or antagonism. Antioxidant potential is described by antioxidant activity which is a measure of the ability of phenol extract to scavenge radical species. In clinical studies scavenging of DPPH neutral radical by an extract is usually used as a measure of antioxidant activity.

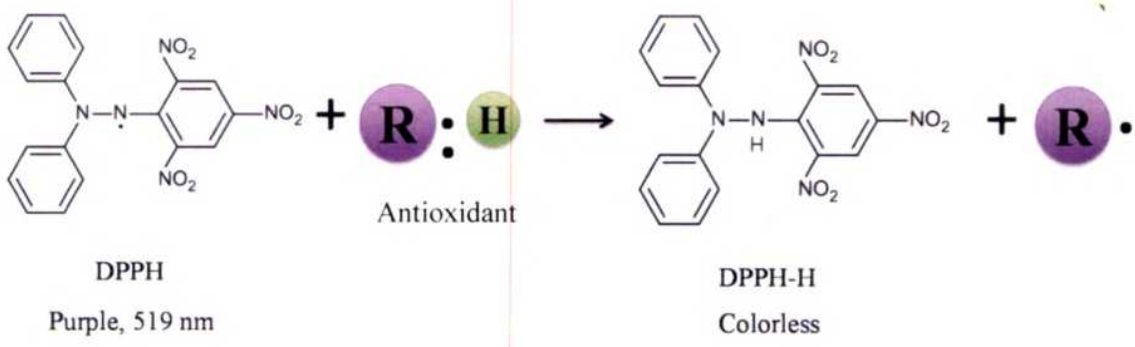


Fig. 4 The scavenging reaction between DPPH and antioxidant

Fenugreek elaborates a variety of phenolic acids and flavonoids, which are summarized below.

Table 2. Different phenolic acids and flavonoids in fenugreek

Compound	Reference
I. Phenolic acid	
i) Scopoletin	Reppel and Wagenbreth (1958)
ii) Chlorogenic acid	
iii) Caffeic acid	
iv) Coumaric acid	
v) Lignan	Wang *et al.* (1997)
II. Flavonoids	
i) Quercetin	Ganju and Puri (1959)
ii) Luteolin	Varshney and Sharma (1966)
iii)Isoorientin	Adamska and Lutomski (1971)
iv)Vitexin, Isovitexin, Vicenin	Wagner *et al.* (1973)
v) Kaempferol	Sood (1975)

The phenol content of fenugreek seed is reported by various workers was summarised in Table 3.

Table 3. Phenol content of fenugreek seed

Phenol content	Reference
i) 5.79 mg gallic acid g^{-1}	Saleh *et al.* (2017)
ii) 179 mg gallic acid g^{-1}	Rahmani *et al.* (2018)
iii) 186 mg GAE g^{-1} dry weight of methanolic extract	Seasotiya *et al.* (2014)
iv) 25.90 mg GAE g^{-1} DW of acetone extract	Mashkor *et al.* (2014)

Singh *et al.* (1994) recorded total phenol content of 11.96, 10.45 and 9.42 mg g^{-1} seed dry weight in three varieties of fenugreek namely HM 57, HM 46 and Pusa early bunching respectively. Parihar *et al.* (2011) evaluated the effect of integrated nutrient management on productivity and nutrient uptake of fenugreek, with 18 treatment combinations during winter season of 2004-05 and 2005-06 at Jaipur on sandy loam soil.

Among different treatments, integration of 50% RDN through poultry manure (PM) + 50% RDN through inorganic sources resulted phenol content of 11.27% in seed.

Diosgenin in fenugreek

Fenugreek seed is an important source of steroidal sapogenins including diosgenin, which are extensively used by both pharmaceutical and nutraceutical industries (Srichamroen *et al.*, 2005). Diosgenin is often used as a raw precursor for the production of steroidal drugs and also effective agents for the treatment of hypocholesterolemia, a disorder often associated with diabetes. The yam (*Dioscorea sp.*) tubers also contain this phytochemical and cultivation process is both time consuming and costly, requiring several years before they grow to a size where they possess a sufficient concentration of diosgenin to be used as source of commercial and pharmaceutical reagent (Rosser, 1985). Fenugreek may be a viable alternative for production of diosgenin because of its shorter growing cycle, lower production costs and consistent yield and quality (Hardman, 1969; Petropoulos, 1973).

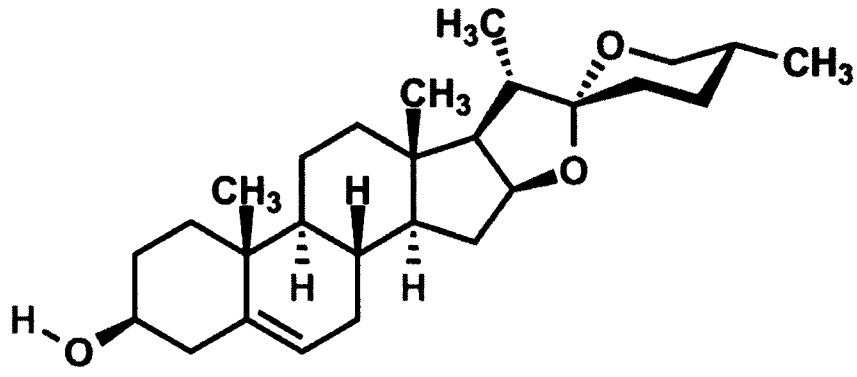


Fig 5. : Structure of diosgenin

Diosgenin content in fenugreek is reported to vary depending on genotypes and environment. Evaluation of 39 varieties of fenugreek in India (Kamal *et al.*, 1987) showed a wide variation in diosgenin content ranging between 0.07 and 0.75% on dry weight basis. A study on 31 genotypes collected from gene banks of various countries indicated diosgenin (with yamogenin) levels to vary from 1.14% to 1.64% (Provorov *et al.*, 1996). In another study, Harish *et al.* (2011) observed significant variation in diosgenin content of 10 accessions of fenugreek collected from NBPGR, New Delhi. A wide diversity in sapogenin content among fenugreek germplasms, was also observed by Singh *et al.* (2013). Taylor *et al.* (2002) reported that diosgenin levels from mature seeds

ranged from 0.28% to 0.92% among 10 accessions of fenugreek seeds produced in western Canada. Giridhar *et al.* (2016) examined the diosgenin content in the 11 promising genotypes from varied geographical locations, which also documented significant differences.

Acharya *et al.,* (2006) evaluated five fenugreek lines namely Amber, F-70, F-86, L-3314 and a Indian line in Canada and recorded the corresponding diosgenin content of 47.8±1.6, 41.0±5.1, 43.9±2.9, 44.6±2.1 and 43.8±3.2 (% w/w). Significant differences in saponin content are also observed in seeds of 46 fenugreek genotypes of NBPGR, New Delhi. Pareek and Gupta (1981) reported that indigenous fenugreek samples varied from 0.012 to 0.251 per cent. Singh *et al.* (1994) reported that 1.35%, 1.28% and 1.26% of saponin content were recorded in seeds of three varieties of fenugreek namely HM 46, HM47 and Pusa Early Bunching. Fazli and Hardman (1968) reported saponin content to vary from 0.8 to 2.2 percent in fenugreek seed from Israel, India and Ethiopia. A wide range of total steroidal saponin content in terms of diosgenin equivalent per 100 g DW ranging from 0.92 g (var. UM279) to 1.68 g (var. AM316) with the mean value of 1.34 g. Naidu *et al.* (2011) reported that feenugreek seed recorded total saponin content of 5.12 g $100\ g^{-1}$ on dry weight basis as determined by spectrophotometric assay.

All these studies were conducted in different parts of the globe with different germplasms and samples were analyzed employing different analytical techniques. Thus diosgenin content in fenugreek seed varied depending upon geographic origin, genotypes, and environmental factors.

Chapter-III

Materials and Methods

MATERIALS AND METHODS

The details of the materials used and methods adopted during the course of investigation are described below.

EXPERIMENTAL SITE

The experiments under "**Evaluation of germplasm and influence of bioinoculants on fenugreek**" were carried out during *rabi* season of two consecutive years 2013-14 and 2014-15 at the Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The research station was located at 23.5° N latitude and 89° E longitude, with an altitude of 9.75 m above the mean sea level.

SOIL

The soil of the experimental field was Gangetic alluvial (Entisol) with sandy clay loam texture, good water holding capacity, well drained with moderate soil fertility status. The physico-chemical properties of the soil (0-25 cm depth) indicating the fertility status before taking out of the experiment is presented in Table 4.

Table 4. Physico-chemical properties of the experimental soil

Particulars	Value	Methods followed
Sand	52.5%	International pipette method (Piper,1966)
Silt	30.7%	
Clay	16.8%	
Soil pH	6.8	Beckman's pH meter(Jackson,1973)
Organic carbon	0.59%	Walkey and Black (Jackson,1973)
Available nitrogen	226.45 kg ha^{-1}	Modified Kjeldahl's (Jackson,1973)
Available phosphorus	18.05 kg ha^{-1}	Modified Olsen (Jackson,1973)
Available potassium	198.46 kg ha^{-1}	Flame photometer (Jackson, 1973)

CLIMATIC CONDITION

The climatic condition of the experimental site is sub-tropical sub-humid. The details of different meteorological parameters during the experimental period of the two *rabi* seasons have been presented in Table 5.

Table 5.Meteorological data during the period of experimentation

Months	Temperature (°C)		Relative humidity (%)		Total rainfall (mm)	No. of rainy days	Sunshine hours
	Max.	Min.	Max.	Min.			
November, 2013	30.04	16.44	83.77	55.57	0.0	Nil	8.08
December	26.96	12.46	84.48	58.52	0.0	Nil	6.15
January, 2014	24.30	10.39	84.00	62.52	0.0	Nil	5.85
February	28.47	13.65	84.17	52.79	28.5	2	7.36
March	33.95	18.94	85.11	46.45	26.2	2	8.18
April	39.38	24.89	85.73	37.9	0.0	Nil	8.85
November	32.25	15.92	79.70	50.40	0.0	Nil	7.50
December	26.71	11.77	83.55	57.65	0.0	Nil	5.34
January, 2015	26.61	11.76	82.79	58.13	2.50	2	6.05
February	31.65	15.58	82.93	47.17	13.60	2	6.86
March	35.46	19.18	82.00	39.10	21.40	3	8.59
April	35.84	24.00	89.63	56.73	98.70	11	6.89

Source: Dept. of Agro-Meteorology and Physics, BCKV, Mohanpur, Nadia, W.B.

EXPERIMENTAL DETAILS

EXPERIMENT I: Evaluation of fenugreek germplasm for growth, yield and quality

Details of experiment

Location of experiment : Horticultural Research Station, Mondouri

No. of genotypes : 20

No. of replications : 3

Design : Randomised Block Design

Plot size : 2.0×1.5 m

Spacing : 30×10 cm

Date of sowing : 2nd week of November

Dose of FYM : 15 t ha^{-1}

Fertilizer dose (NPK) : 20-40-20 kg ha^{-1}

Time of application : Half of nitrogen and full phosphorous and potassium as basal and rest after 30 days as top dressing.

Time of harvesting : Last week of March

Table 6. Details of genotypes

Sl. No.	Genotypes	Source of collection
1.	Rajasthan Methi-1 (RMt-1)	SriKaran Narendra Agriculture University, Jobner, Rajasthan
2.	Rajasthan Methi-305 (RMt-305)	
3.	Rajasthan Methi-361 (RMt-361)	
4.	Hissar Sonali	Chaudhary Charan Singh Haryana Agricultural University, Hissar, Haryana
5.	Hissar Suvarna	
6.	Ajmeer Fenugreek-1 (AFg-1)	National Research Centre on Seed Spices, Ajmeer, Rajasthan
7.	Ajmeer Fenugreek-2 (AFg-2)	
8.	Ajmeer Fenugreek-3 (AFg-3)	
9.	Ajmeer Fenugreek-4 (AFg-4)	
10.	Kota Fenugreek-4 (KFGK-4)	Agricultural University, Kota, Rajasthan
11.	Kota Fenugreek-18 (KFGK-18)	
12.	Narendra Dev Methi -4 (NDM-4)	Narendra Deva University of Agriculture and Technology, Faizabad
13.	Narendra Dev Methi-8 (NDM-8)	
14.	Narendra Dev Methi-13 (NDM-13)	
15.	Narendra Dev Methi-241 (NDM-241)	
16.	Pratap Rajasthan Methi-45 (PRM-45)	MPUAT, Udaipur, Rajasthan
17.	Haryana Methi-444 (HM-444)	Rajendra Agricultural University, Dholi, Bihar
18.	Rajendra Kranti	
19.	Lam Methi-2	Dr. YSRHU, Lam Farm, Guntur, Andhra Pradesh
20.	Local	Nadia,West Bengal

The morphological characteristics of all fenugreek genotypes included in the experiment has been presented in Plate 1 (A-E)

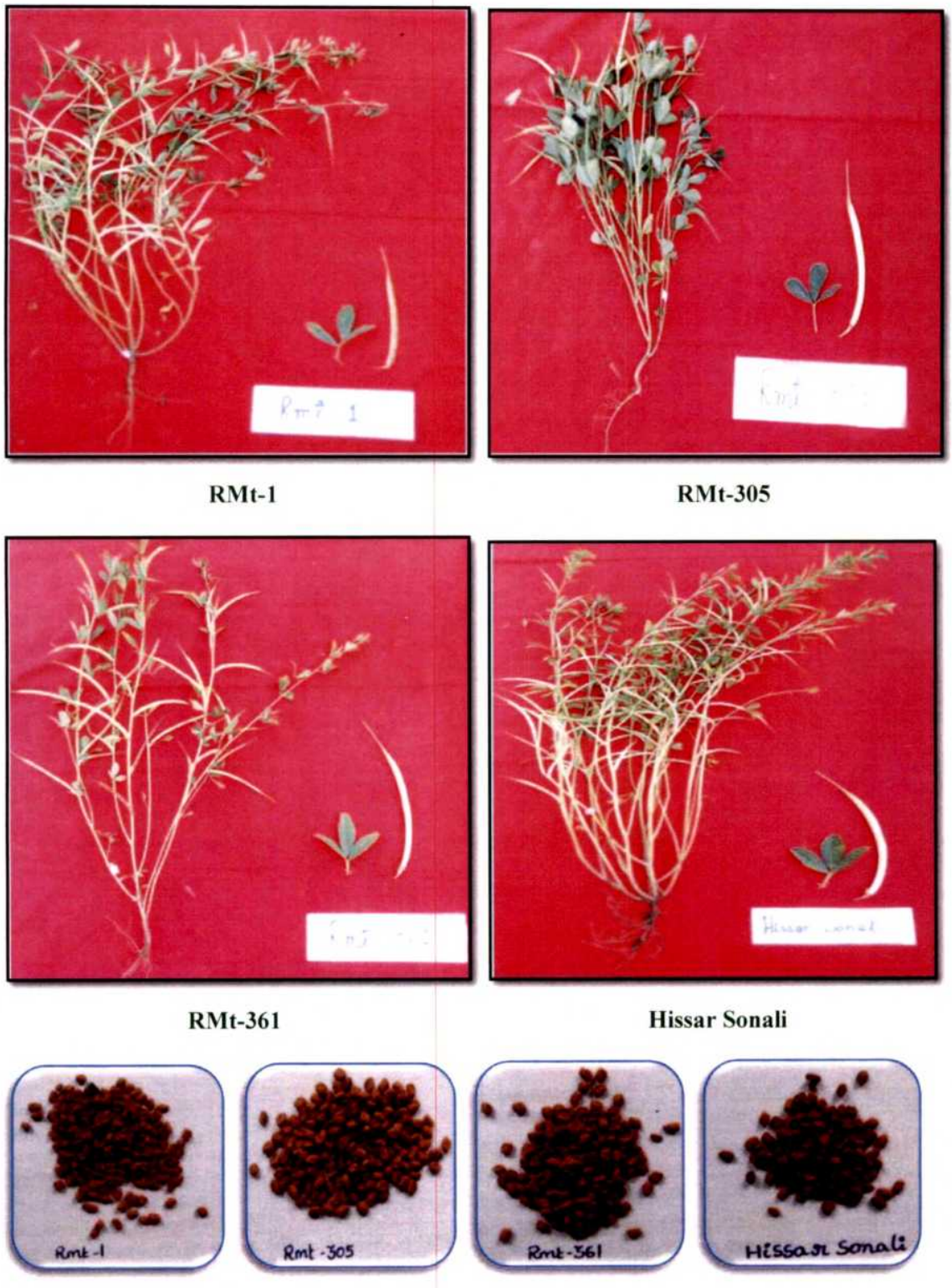


Plate 1. A) Morphological characters of fenugreek genotypes

Hissar Suvarna

AFg-1

AFg-2

AFg-3

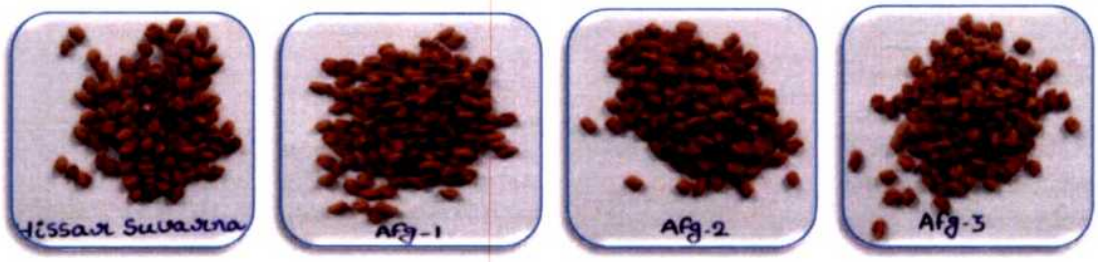


Plate 1. B) Morphological characters of fenugreek genotypes

Plate 1. C) Morphological characters of fenugreek genotypes

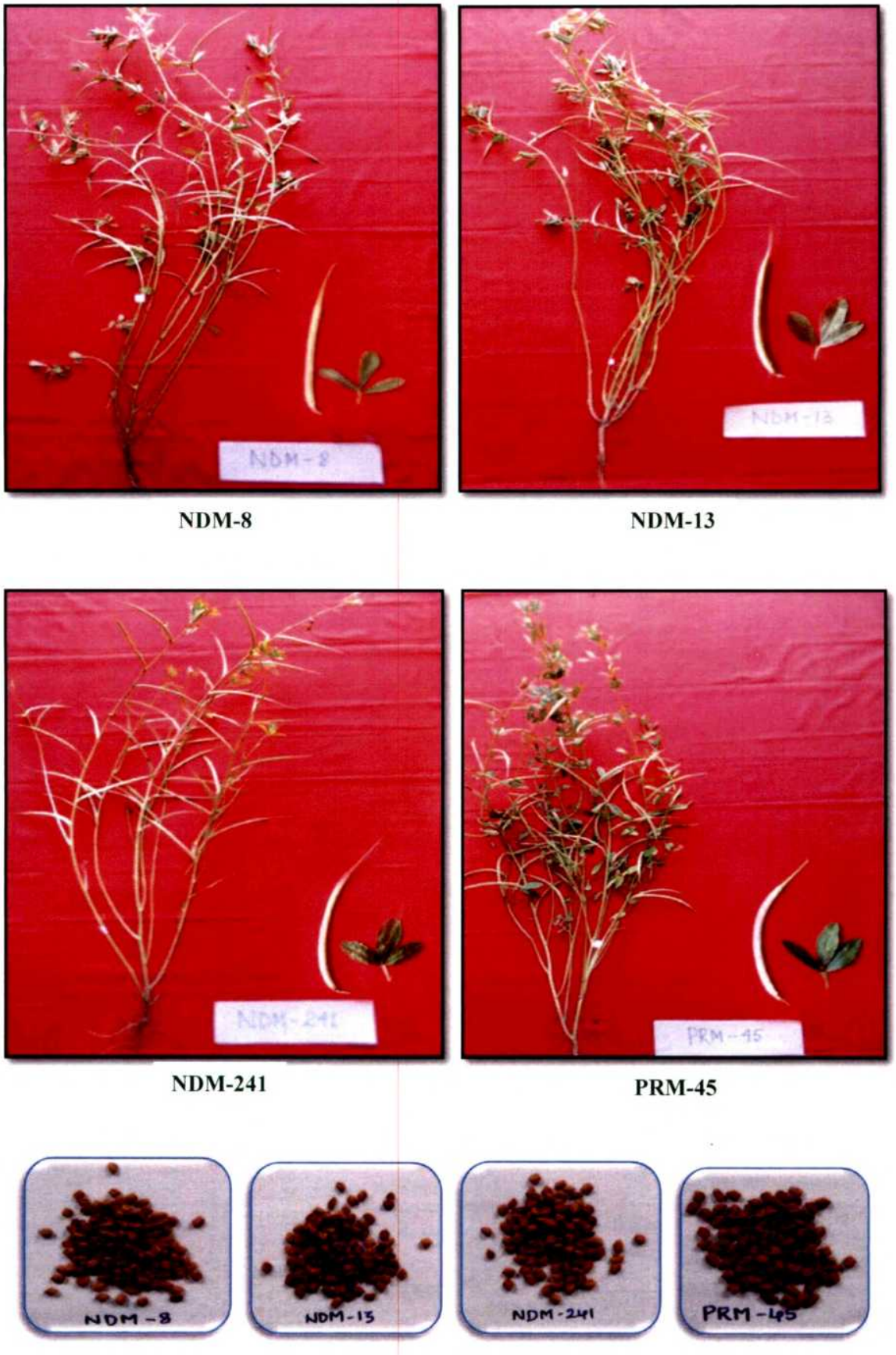


Plate 1. D) Morphological characters of fenugreek genotypes

HM-444

Rajendra Kranti

Lam Methi-2

Local

Plate 1. E) Morphological characters of fenugreek genotypes

EXPERIMENT II: Response of fenugreek to combined application of inorganic fertilizer and bioinoculants

Details of the experiment

Location of experiment : Horticultural Research Station, Mondouri

Variety : Hissar Sonali

No. of treatments : 13

No. of replications : 3

Design : Augmented Factorial RBD

Plot size : 2.0×1.5 m

Date of sowing : 2nd week of November

Spacing : 30×10 cm

Dose of FYM : 15 t ha^{-1}

Time of harvesting : Last week of March

Details of treatments

1. NPK (100%)+ *Azotobacter* + VAM + K mobiliser
2. NPK (100%)+ *Azotobacter* + PSB + K mobiliser
3. NPK (100%)+ *Azospirillum* + VAM + K mobiliser
4. NPK (100%)+ *Azospirillum* + PSB + K mobiliser
5. NPK (75%)+ *Azotobacter* + VAM + K mobiliser
6. NPK (75%)+ *Azotobacter* + PSB + K mobiliser
7. NPK (75%)+ *Azospirillum* + VAM + K mobiliser
8. NPK (75%)+ *Azospirillum* + PSB + K mobiliser
9. NPK (50%)+ *Azotobacter* + VAM + K mobiliser
10. NPK (50%)+ *Azotobacter* + PSB + K mobiliser
11. NPK (50%)+ *Azospirillum* + VAM + K mobiliser
12. NPK (50%)+ *Azospirillum* + PSB + K mobiliser
13. NPK (100%)

Different bioinoculants used

i. *Azotobacter chroococcum*

ii. *Azospirillum lipoferum*

iii. *Glomus fasciculatum* (Vesicular Arbuscular Mycorrhiza- VAM)

iv. *Bacillus polymixa* (Phosphate Solubilizing Bacteria- PSB)

v. *Frateuria aurantia* (Potassic mobilizer)

Source of bioinoculants	: Nodule Research Laboratory, BCKV
Dose of bioinoculants	: 6g plot^{-1} of each biofertilizer
Time of application of bioinoculants	: At the time of final land preparation
Dose of RDF	: 20:40:20 NPK kg ha^{-1}(Mehta *et al.*, 2012)
Time of application of fertilizers	: Half of nitrogen and full phosphorous and potassium applied 15 days after application of bioinoculants and rest nitrogen after 15 days of first application.

AGRONOMIC OPERATIONS

The experimental plots were prepared thoroughly by repeated ploughing to get a fine tilth. After levelling, beds of 2.0 x 1.5 m were prepared. Seeds were sown in lines at 30 cm apart, in the second week of November. After 15 days, seedlings were thinned to attain spacing of 10 cm within plants. Three to four hand weedings were done. Irrigation was given as per requirement.

APPLICATION OF INPUTS

The organic inputs namely farm yard manure (FYM) applied basally during final land preparation @ 15.0 t hectare^{-1}. The nitrogenous bioinoculants namely *Azotobacter chroococcum* and *Azospirillum lipoferum*, phosphorous solubilising bioinoculants namely *Glomus fasciculatum* (VAM) and *Bacillus polymixa* (PSB) and potassic mobiliser namely *Frateuria aurantia* were applied (6g plot^{-1}) directly to the soil along with FYM at the time of final land preparation. Recommended dose of inorganic fertilizers was 20:40:20 NPK kg ha^{-1} (Mehta *et al.*, 2012). The total amount of fertilizers was applied in two split doses. For the first experiment 1/2 of N and full dose of P and K were applied as basal application at the time of final land preparation. Remaining ½ of N applied

Plate 2. Mixing of biofertilizers with FYM

Plate 3. Application of biofert. in experimental plots

Plate 4. Final beds for sowing

Plate 5. Sowing of seeds in experimental plots

Azotobacter sp.

Azospirillum sp.

VAM

PSB

Plate 6. Different bioinoculants

within 30 days after sowing. For the second experiment, half dose of nitrogen and full dose of phosphorous and potassium were applied 15 days after application of bioinoculants and rest nitrogen after 15 days of first application. Urea, Single super phosphate and Muriate of potash were used as inorganic sources of N, P and K respectively.

OBSERVATIONS RECORDED

In both experiments, observations on growth parameters in ten randomly selected fenugreek plants were recorded at 30, 60, 90 and 110 (Expt I)/120 (Expt II) days after sowing (DAS). Seed yield and yield related attributes were recorded at harvest.

1. GROWTH PARAMETERS

1.1 Plant height

Plant height was measured from ground level to the growing tip of the main branch or tallest branch at 30, 60, 90, 110 DAS in case of Expt I but for Expt II, last observation was recorded at 120 DAS with the help of the meter scale. Mean plant height was worked out and expressed in centimeters.

1.2 Primary branches plant^{-1}

The branches arising from the main stem of the plant were counted at 30, 60, 90 and 110 DAS in case of Expt I but for Expt II, last observation was recorded at 120 DAS.

1.3 Secondary branches plant^{-1}

The branches arising from primary branches were counted at 60, 90 DAS and 110 DAS in case of Expt I but for Expt II, last observation was recorded at 120 DAS

1.4 Fresh and dry weight of plant

Randomly three plants were uprooted carefully at 60 and 90 DAS. At 60 DAS, after counting the nodules per plant and cleaning the root portion, the plants were weighed in digital balance. The plants were packed loosely in brown paper packet afterward and subjected to dry in hot air oven at 50° C until a constant dry weight was recorded. At 90 DAS, same procedure was followed but without nodule counting.

1.5 Nodule number

Three plants per replication were carefully dug out with roots at flowering stage (60 DAS) and number of nodules was counted and the mean number of nodules was recorded.

Plate 7. Initiation of germination of fenugreek seed

Plate 8. Completion of fenugreek seed germination

Plate 9. Thinning and weeding

Plate 10. Application of inorganic fertilizers

2. YIELD PARAMETERS

2.1 Days to first flowering

The number of days taken from sowing to appearance of first flower in a plot was recorded and expressed in number.

2.2 Days to 50 percent flowering

The number of days taken from sowing to 50 per cent flowering of the plants in a plot was recorded and expressed in number.

2.3 Days to first pod initiation

The number of days taken from sowing to appearance of first pod in the plants of each plot was recorded and expressed in number.

2.4 Days to 50 percent pod formation

The number of days taken from sowing to 50 per cent of pod formation in a plot was recorded and expressed in number.

2.5 Days to maturity (Duration of crop)

The number of days taken from sowing to attaining full maturity was recorded and expressed in number.

2.6 Number of pods plant^{-1}

The total numbers of pods from ten randomly selected plants were counted at final harvest and the average were worked out and expressed as average number of pods plant^{-1}.

2.7 Pod length

The pod length of ten randomly selected pods in each plot was measured and the average pod length expressed in centimetres.

2.8 Number of seeds pod^{-1}

The numbers of seeds present in thirty randomly selected pods were counted and the average was worked out and expressed as number of seeds pod^{-1}.

2.9 Seed yield plant^{-1}

After threshing from ten randomly selected plants the mean seed weight was calculated and expressed in grams.

Plate 11. Irrigation of experimental plots

Plate 12. Plants after 30 days after sowing

Plate 13. Plants at 50% flowering stage

Plate 14. Harvesting of fenugreek crop

Plate 15. Drying of harvested fenugreek crop

Plate 16. Threshing of dried crop

Plate 17. Winnowing of seed

Plate 18.Multi flower and pod of genotype RMt 305

2.10 Test weight

The weight of 1000 seeds from a composite sample made by mixing of the seeds obtained from ten plants was recorded and expressed in grams.

2.11 Seed yield plot^{-1}

The seed yield per plot (3 m^2) was recorded at final harvest by taking the total weight of seeds collected from the net plot area after threshing of plants and expressed in grams.

2.12 Projected seed yield ha^{-1}

The data on seed yield plot^{-1} was used to compute the seed yield ha^{-1}. The projected yield hectare^{-1} was calculated on the basis of yield plot^{-1}, considering 75% area occupied by fenugreek in the present experiment and expressed in quintals.

2.13 Straw yield plot^{-1}

The leftover straw after threshing was weighed and recorded from each plot and expressed in kg.

2.14 Straw yield

The data from plot was used to calculate straw yield hectare^{-1} expressed in tones. Same as projected seed yield, straw yield hectare^{-1} was calculated considering 75% of area occupied by crop.

2.15 Biological yield

Biological yield calculated by adding the projected yield (q ha^{-1}) and straw yield (t ha^{-1}) and expressed in t ha^{-1}.

2.16 Harvest index

The harvest index (HI) was calculated by the ratio of economic yield and biological yield which was expressed in percentage by using the following formula.

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3. QUALITY PARAMETERS

The materials used and methods employed to examine the different biochemical constituents in fenugreek seeds have been summarized in this chapter under the following heads.

Mature seeds collected from each treatment were dried and ground using mixer grinder.

3.1 Galactomannan content

The extraction of galactomannan was accomplished following the method developed by Das *et al.* (1977) with minor modification. The dried powdered fenugreek seed sample (0.1 g) was mixed with 5 ml of 0.01 M mercuric chloride solution. The resulting mixture was heated in a water bath at 80°C for 1hr and subsequently cooled. 5ml of 0.01 M mercuric chloride solution was added to the mixture and centrifuged at 5000 rpm for 15 min. After centrifugation, 1ml of supernatant was diluted with 5ml of ethyl alcohol (90%) that separated the mucilage and the samples were kept for overnight. Next day, the samples were again centrifuged at 5000 rpm for 15 min.

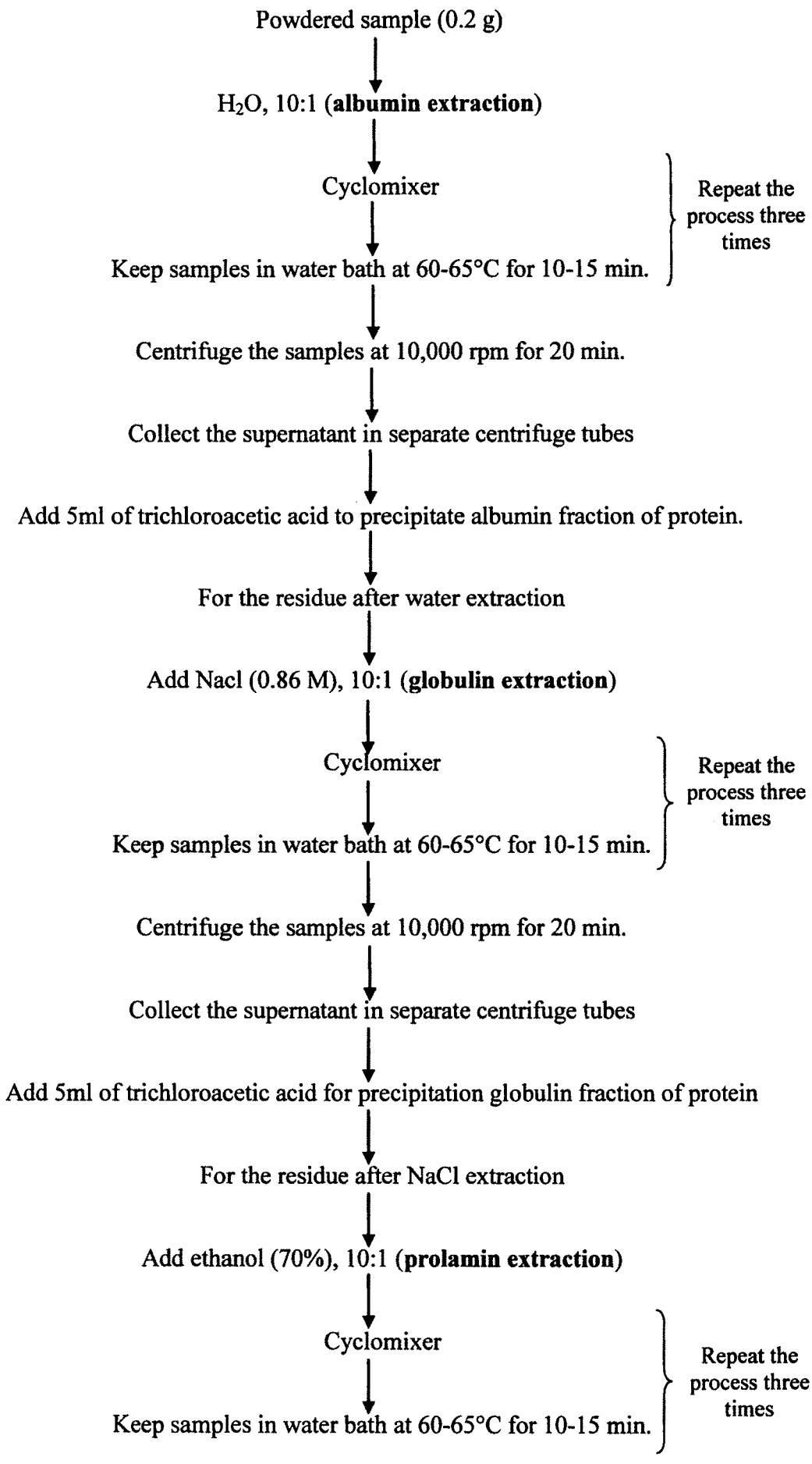
After centrifugation, the supernatant was decanted of. To it, 5 ml of distilled water was added and mixed using a cyclomixer.Samples were stored in a refrigerator for 2hrs. After extraction and solubilization of mucilage, the carbohydrate content of the mucilage was measured following phenol- sulphuric acid method adopted by Dubios *et al.*(1956) and Albalasmeh *et al.* (2013) with some modification. Briefly, 1ml of mucilage or polysaccharide solution was made to 3ml with distilled water. To it, 2ml of phenol (5%) solution was added as colouring agent. After 10 min, 5ml of conc. sulphuric acid was added. After cooling, the absorbance of the solution was recorded at 490 nm against a blank consisting of 3ml distilled water, 2ml phenol (5%) and 5ml concentrated Sulphuric acid. Finally, galactomannan content was expressed in mg $100mg^{-1}$.

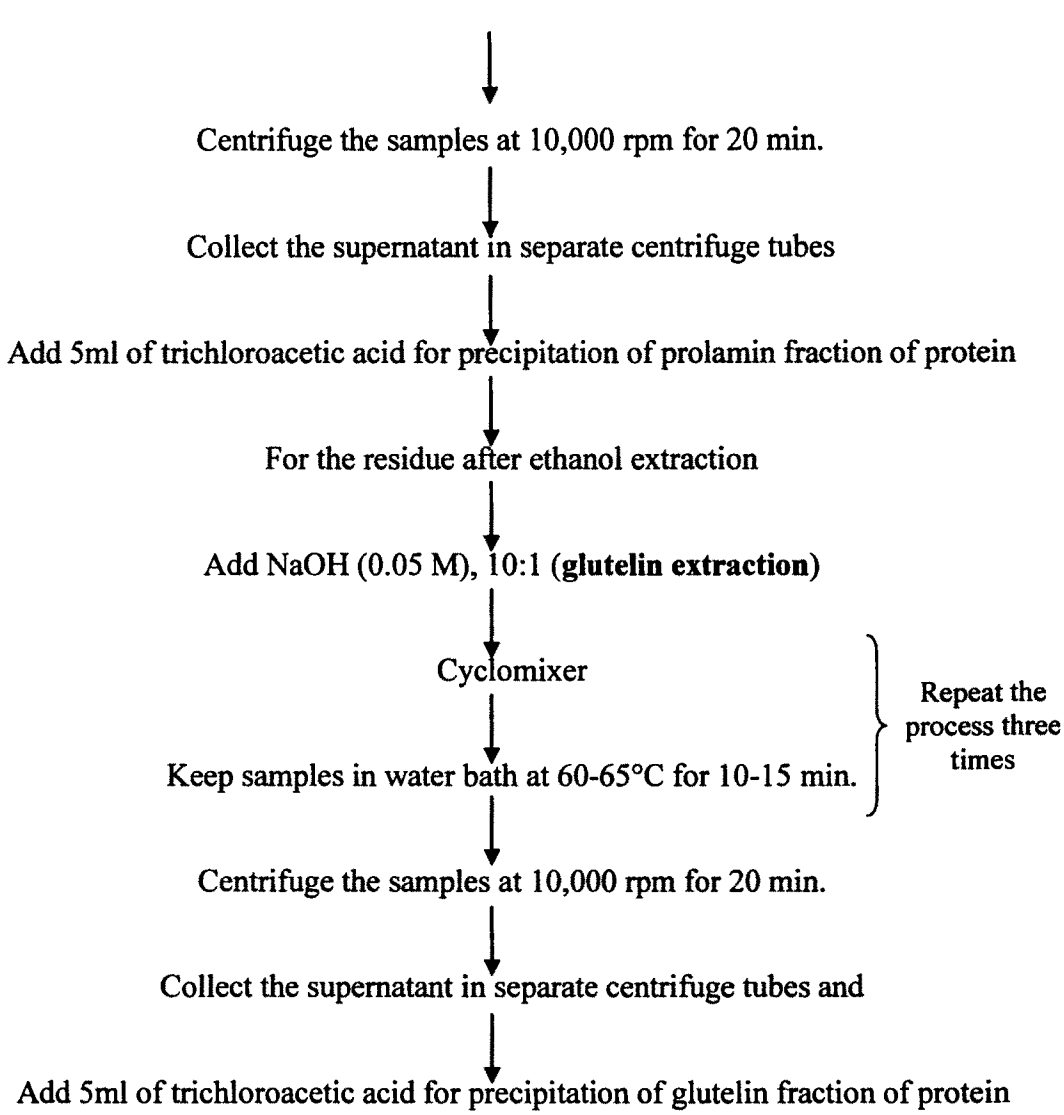
3.2 Protein fractionation

The classification of seed proteins according to their solubility was developed by Osborne (1924) that distinguishes four different fractions: albumins (water soluble), globulins (soluble in salt solution), prolamins (alcohol soluble) and glutelins (partially soluble in dilute NaOH)

3.2.1 Protein extraction

Protocol for protein fractionation was outlined in flow chart as per method described by Sauvaire *et al.* (1984) with some modification. Four different solvents, distilled water, 0.86 M NaCl, 70% ethanol and 0.05 M NaOH, were used in sequence in the solvent to meal ratio of 10:1 (ml g^{-1})


Powdered sample (0.2 g)
H_2O, 10:1 (**albumin extraction**)
Cyclomixer
Keep samples in water bath at 60-65°C for 10-15 min.
Repeat the process three times
Centrifuge the samples at 10,000 rpm for 20 min.
Collect the supernatant in separate centrifuge tubes
Add 5ml of trichloroacetic acid to precipitate albumin fraction of protein.
For the residue after water extraction
Add Nacl (0.86 M), 10:1 (**globulin extraction**)
Cyclomixer
Keep samples in water bath at 60-65°C for 10-15 min.
Repeat the process three times
Centrifuge the samples at 10,000 rpm for 20 min.
Collect the supernatant in separate centrifuge tubes
Add 5ml of trichloroacetic acid for precipitation globulin fraction of protein
For the residue after NaCl extraction
Add ethanol (70%), 10:1 (**prolamin extraction**)
Cyclomixer
Keep samples in water bath at 60-65°C for 10-15 min.
Repeat the process three times



3.2.2 Protein determination

Each protein fraction following precipitation with tricholoroacetic acid was centrifuged at 10,000 rpm for 30 minutes and the pellets obtained were dissolved in 10 ml of 1N NaOH. Protein content of the solution was determined using the method developed by Lowry *et al.* (1951) using bovine serum albumin as protein standard. 0.2 ml protein solution was made to 1ml with distilled water in test tube. To this, added 5ml of reagent C (mixture of 50ml of 0.1 N NaOH in 2g Na_2CO_3 and 1ml of 1% sodium potassium taratrate in 0.5 g $CuSO_4$). Finally 0.5 ml reagent D (FCR reagent 1:1 with distilled water) was added to make the final volume 6.5 ml. The samples were incubated in dark for 30 minutes at room temperature. The absorbance of the solution was read at 650 nm in a spectrophotometer (Systronics Visiscan 167) against a blank consisting of mixture of 1ml distilled H_2O+ 5ml reagent C+ 0.5ml reagent D. The protein content was expressed in mg $100mg^{-1}$.

3.3 Sample extraction for phenol, flavonoid and antioxidant activity determination

0.1 g of ground fenugreek seed was mixed with 15 ml of acidic (1.2 N HCl) aqueous methanol (1:1). The mixture was thereafter boiled at 80° C for 2 hr. and subsequently, after cooling, was centrifuged at 10,000 rpm for 30 minutes. Then the volume of this extract was made to 20 ml with acidic methanol in graduated tube (Chao *et al.,* 2014). This extract was used for the estimation of phenol, antioxidant activity using DPPH assay and flavonoid by using following methodologies.

3.3.1 Estimation of total phenol content

The total phenol content of fenugreek seed extracts was determined by Folin-ciocalteau method (Gul *et al.,* 2011). In brief, 0.2 ml of the extracts was mixed with 2.8 ml of distilled water, 0.5ml of FCR reagent (50% v/v). After 3 minutes of incubation, 2 ml of 10% sodium carbonate was added, thoroughly vortexed with the help of a cyclomixer and incubated at 60°C for 10 min.

The test tubes were cooled in running water and absorbance was measured at 650 nm in spectrophotometer. The total phenolic content was expressed as mg gallic acid equivalent (GAE/g) $gram^{-1}$ dry weight of sample.

3.3.2 Estimation of total flavonoid content

The total flavonoid assay was conducted according to protocol described by (Ballesteros *et al.,* 2014) using aluminium chloride as chromogenic reagent. 1 ml of extract was added with 0.3 ml of 5% of sodium nitrate. After 2 minutes, 0.3 ml of aluminium chloride (10%) was added which was kept for another 2 minutes and 3.4 ml of 4N NaOH was added. Then the mixture was incubated for 30 minutes at room temperature and the absorbance was measured at 510 nm. Total flavonoid content was expressed as mg quercetin equivalent (QE/g) $gram^{-1}$ of sample on dry weight basis.

3.3.3 Estimation of antioxidant activity (DPPH assay)

Antioxidant capacity of the phenol extract was determined using DPPH (1,1-diphenyl -2-pycrylhydrazyl) as stable radical. The method is based on the ability of phenol extract to donate a hydrogen atom to neutralize the radical which was followed by decrease in absorbance of methanolic solution of DPPH at 517 nm (Ballesteros *et al.,* 2014) in presence of extract. A reaction mixture consists of properly diluted 0.15 ml seed extract and 2.85 ml methanolic DPPH solution, after thorough shaking, mixture was

kept in dark for 30 minutes. Sample blank was prepared from 0.15 ml of distilled water and 2.85 ml methanolic DPPH solution. The absorbance of the solution was read at 517 nm. The difference in absorbance of the solution with and without extract was calculated and compared with that of with and without trolox. The antioxidant activity was expressed as mg TE/g of dried sample. (Trolox equivalent)

3.4 Diosgenin

Diosgenin was determined as per method described by Baccou *et al.* (1977) and Uematsu *et al.* (2000) with some modification. To the powdered sample (25 mg) taken in a centrifuge tube, 10 ml ethanol was added and mixed thoroughly using a cyclomixer. The mixture was centrifuged at 10,000 rpm for 30 minutes. 5ml of supernatant from each sample in a beaker was evaporated to dryness in a water bath at 60-70°C and added 2ml ethyl acetate, then 1ml of reagent A (mixture of 0.5ml anisaldehyde + 95.5 ml of ethyl acetate), followed by 1 ml of reagent C (mixture of concentrated sulphuric acid + 50 ml ethylactate). Pour the solution in graduated tube and made up the volume to 4ml. After cooling of samples for 30 minutes at room temperature, the absorbance was read at 430 nm in a spectrophotometer (Systronics Visiscan 167). 2ml ethyl acetate +1ml reagent A + 1ml reagent C served as a blank. The diosgenin content was expressed in mg $100mg^{-1}$.

4. STUDY ON TOTAL COUNT OF NITROGENOUS BACTERIA, PHOSPHOROUS SOLUBILISING BACTERIA AND POTASSIUM MOBILISER

4.1 Count of total number of viable bacteria

The microbial populations were counted before the initiation of the experiment and at 60 DAS (at 50% flowering stage). Soil samples taken from the rhizosphere were used for microbial count of *Azospirillum lipoferum*, *Azotobacter chroococcum*, phosphate solubilising microorganisms and *Frateuria aurantia* population. Serial dilution pour plate technique by using selective media for selective groups of organisms. Plating method was followed for microbial population count (Vincent, 1970). Media formulations for different bacterial population was given below

a) Count of aerobic non-symbiotic nitrogen fixing bacteria (*Azotobacter chroococcum*) using Jensens's agar media (Jensen, 1930)

	Substance	Quantity
i.	Sucrose ($C_{12}H_{12}O_{11}$)	10 g
ii.	Magnesium sulphate ($MgSO_4.7H_2O$)	0.5 g
iii.	Sodium chloride (NaCl)	0.5 g
iv.	Ferrous sulphate ($FeSO_4.7H_2O$)	0.1 g
v.	Sodium molybdate (Na_2MoO_4)	0.005 g
vi.	Calcium carbonate ($CaCO_3$)	2.0 g
vii.	Agar-agar	15.0 g
viii.	Distilled water	1000 ml

b) Count of free living bacteria (*Azospirillum lipoferum*) using nitrogen free bromo thymol blue malate semi-solid malate agar (Nfb) [Dobereiner *et al.*,1976]

	Substance	Quantity
i.	Malic acid	5.0 g
ii.	Potassium hydroxide (KOH)	4.0 g
iii.	Dipotassium hydrogen phosphate	0.5 g
iv.	Ferrous sulphate ($FeSO_4.7H_2O$)	0.1 g
v.	Manganese sulphate ($MnSO_4.7H_2O$)	0.01 g
vi.	Magesium sulphate ($MgSO_4.7H_2O$)	0.01 g
vii.	Sodium chloride (NaCl)	0.02 g
viii.	Calcium chloride ($CaCl_2$)	0.01 g
ix.	Sodium molybdate (Na_2MoO_4)	0.002 g
x.	Bromothymol blue	2.0 ml in 0.5% alcoholic solution
xi.	Agar-agar	1.75 g
xii.	Distilled water	1000 ml

pH adjusted to 6.6 to 7.0

c) Count of symbiotic nitrogen fixing bacteria (*Rhizobium sp.*) using yeast extract mannitol agar medium (YEM)

	Substance	Quantity
i.	Mannitol	10.0 g
ii.	Potassium dihydrogen phosphate (KH_2PO_4)	0.5 g
iii.	Potassium sulphate hepta hydrate ($K_2SO_4.7H_2O$)	0.2 g
iv.	Sodium chloride (NaCl)	0.1 g
v.	Yeast extract	1.0 g
vi.	Agar-agar	20.0 g
vii.	Congo red (1% aq. solution)	2.5 ml
viii.	Distilled water	1000 ml

d) Count of phosphate solubilising bacteria (Pikovaksia's, 1948)

	Substance	Quantity
i.	Calcium phosphate [$Ca_3(PO_4)_2$]	5.0 g
ii.	Sucrose ($C_{12}H_{12}O_{11}$)	10 g
iii.	Magesium sulphate ($MgSO_4.7H_2O$)	0.1 g
iv.	Ammonium sulphate [$(NH_4)_2SO_4$]	0.5 g
v.	Sodium chloride (NaCl)	0.2 g
vi.	Potassium chloride (KCl)	0.2 g
vii.	Yeast extract	0.5 g
viii.	Manganous sulphate ($MnSO_4$)	trace
ix.	Ferrous sulphate ($FeSO_4.7H_2O$)	trace
x.	Agar-agar	15.0 g
xi.	Distilled water	1000 ml

pH adjusted at 7.0 to 7.2

e) Count of potassium mobilizer using aleksandrov agar medium (Hu *et al.*, 2006)

	Substance	Quantity
i.	Glucose	10.0 g
ii.	Yeast extract	5.0 g
iii.	Magnesium sulphate ($MgSO_4.7H_2O$)	0.005 g
iv.	Ferric chloride	0.1 g
v.	Calcium carbonate	0.1 g
vi.	Calcium phosphate	2.0 g
vii.	Potassium aluminium silicate (mica)	5.0 g
viii.	Agar-agar	15.0 g
ix.	Distilled water	1000 ml

pH adjusted to 7.0 to 7.2

3.1 Preparation of growth media

The selective media of each microbial sp. was prepared in a conical flask by adding mentioned substances after weighing along with one litre distilled water and the media sterilized in a autoclave at 110-120° C depends on type of media and finally adjust the media to a required pH.

3.2 Preparation of serial dilutions

10 g of moist soil sample was added to 90 ml sterile water in 250 ml conical flask containing 20-30 of 3mm glass beads. After shaking the flask vigorously by hand, 10 ml suspension from the middle region was transferred to 90ml blank to achieve 10^{-2} dilution. The content was mixed thoroughly and continued (always using fresh pipette between subsequent dilutions) by preparing these steps until the desired dilution factor was obtained. Finally 1ml of aliquot of various dilutions were added to sterile petri dishes (triplicate for each dilution) to which were added 15 ml (approximately) of the sterile, cool, molten (45° C) specific media. The diluted soil inoculums containing microorganisms was distributed by swirling the plates three to five times in a clockwise circular motion then three to five times counter clockwise. Upon solidification, the plates were incubated, in an inverted position for 3-7 days at 28° C. The number of colonies

appearing on dilution plates was counted, averaged and multipled by the dilution factor to find the number of CFU gram^{-1} of sample.

6. BENEFIT: COST RATIO

The economic assessment for the different treatment combinations under bioinoculants with inorganics were done on the basis of cost of cultivation, gross return and net return, considering the cost of inputs and market price of the produce during the period of experimentation.

METHOD OF STATISTICAL ANALYSIS

The data collected were subjected to statistical analysis of variance following Panse and Sukhatme (1985). The mean data of two seasons was pooled and analysed using MSTAT-C to do combined analysis. Different graphical presentations have been drawn on the basis of the pooled data of the respective characters. The significance of different sources of variation was tested by Error Mean Square by Fisher and Snedecor's 'F' test at probability level of 0.05. For the determination of critical difference (C.D.) at 5% level of significance, Fisher and Yates (1979) tables were consulted. The standard error of mean [S.Em (±)] and the value of critical difference (C.D.) to compare the difference between means are provided in the tables of the results. Angular and square root transformation were utilized for statistical analysis as per requirement.

Chapter-IV

Results and Discussion

RESULTS AND DISCUSSION

EXPERIMENT 1: EVALUATION OF FENUGREEK GERMPLASM FOR GROWTH, YIELD AND QUALITY

The present experiment was undertaken to study the performance of different fenugreek germplasm in new alluvial plains of West Bengal. The results of different parameters during experimentation have been presented below.

1.1 GROWTH PARAMETERS

1.1.1 Plant height

Plant height was recorded at four different phases of growth *i.e.* 30, 60, 90 and 110 days after sowing (DAS). Significant variations were observed among the germplasm during both years and in pooled analysis (Table 7. and Fig. 6)

At 30 DAS, maximum plant height was recorded in Lam Methi-2 (16.34 cm) followed by Hissar Suvarna (11.94 cm) and NDM-8 (11.59 cm) as compared with lowest plant height in RMt-305 (8.27 cm). Both Hissar Suvarna and NDM-8 were *at par*. During the year 2014-15, plant height ranged between 9.10 cm to 16.78 cm. Maximum plant height of 16.78 cm was recorded in HM-444 followed by 15.58 cm height in NDM-8 and NDM-241 (15.33 cm). Lowest plant height of 9.10 cm was recorded in AFg-3. In pooled analysis, maximum plant height (13.58 cm) was recorded in NDM-8 and minimum height of 9.17 cm recorded in AFg-3. At 60 DAS, the range of plant height of 29.82 cm to 43.24 cm was recorded during 2013-14. Maximum plant height (43.24 cm) was recorded in HM-444 followed by 42.68 cm in PRM-45 which was *at par* and lowest height was recorded in NDM-241 (29.65 cm). During second season (2014-15), maximum plant height was recorded in NDM-8 (43.13 cm) followed by PRM-45 (41.84 cm) and Afg-2 (39.93 cm) respectively. Lowest plant height was recorded in NDM-4 (30.47 cm). As per pooled analysis, maximum plant height (42.39 cm) was recorded in NDM-8 followed by 42.25 cm in PRM-45 but both are *at par*. Lowest plant height (33.36 cm) was recorded in NDM-4.

At 90 DAS, maximum plant height (87.50 cm) was recorded in HM-444 followed by 81.02 cm in NDM-8 and 80.44 cm in Hissar Sonali. The latter two were *at par* and lowest height was recorded in AFg-3 (55.29 cm) during 2013-14. During 2014-15, maximum plant height of 93.45 cm was recorded in AFg-4 followed by AFg-2 (92.59

Table 7. Variation in plant height of different fenugreek genotypes

Genotype	Plant height (cm)											
	30 DAS			60 DAS			90 DAS			110 DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RMt-1	9.74	12.56	11.15	32.36	35.53	33.95	69.29	79.85	74.57	84.32	87.60	85.96
RMt-305	8.27	10.23	9.25	31.87	38.27	35.07	59.11	56.31	57.71	67.41	65.67	66.54
RMt-361	8.91	9.74	9.33	35.42	39.46	37.44	68.32	73.44	70.88	74.56	79.33	76.94
Hissar Sonali	10.01	12.43	11.22	39.71	34.87	37.29	80.44	85.29	82.87	83.24	97.33	90.28
Hissar Suvarna	11.94	13.33	12.64	39.15	37.63	38.39	73.69	83.03	78.36	75.64	87.07	81.36
AFg-1	9.26	14.02	11.64	41.06	38.13	39.60	72.88	77.95	75.41	76.03	89.47	82.75
AFg-2	10.51	12.75	11.63	29.82	39.93	34.87	74.66	92.59	83.63	77.24	97.80	87.52
AFg-3	9.23	9.10	9.17	36.14	32.93	34.54	55.29	84.95	70.12	67.14	86.03	76.58
AFg-4	10.63	9.55	10.09	35.46	38.45	36.95	66.01	93.45	79.73	78.42	100.56	89.49
KFGK-4	8.91	11.29	10.10	36.24	39.87	38.06	69.75	85.13	77.44	73.15	91.77	82.46
KFGK-18	9.45	13.51	11.48	34.16	37.62	35.89	70.41	86.05	78.23	76.02	94.67	85.35
NDM-4	8.47	12.79	10.63	36.24	30.47	33.36	65.86	88.91	77.34	71.45	91.57	81.51
NDM-8	11.59	15.58	13.58	41.65	43.13	42.39	81.02	86.70	83.86	84.26	94.07	89.17
NDM-13	9.87	10.28	10.08	31.72	38.83	35.28	62.46	74.68	68.57	70.45	77.17	73.81
NDM-241	9.57	15.33	12.45	29.65	37.33	33.49	66.59	89.75	78.17	74.38	100.52	87.45
PRM-45	9.01	9.49	9.25	42.68	41.84	42.25	58.52	77.73	68.13	65.17	88.47	76.82
HM-444	9.73	16.78	13.26	43.24	37.23	40.24	87.50	92.53	90.02	90.12	100.80	95.46
Rajendra Kranti	8.93	14.12	11.53	34.75	38.47	36.61	69.37	84.83	77.10	75.30	87.53	81.41
Lam Methi-2	16.34	10.22	13.28	36.14	38.32	37.23	79.63	83.74	81.68	84.12	86.93	85.53
Local	10.39	12.91	11.65	36.28	35.85	36.07	55.23	71.37	63.30	77.32	75.13	76.22
S.Em. (±)	**0.141**	**0.157**	**0.106**	**0.475**	**0.481**	**0.338**	**0.923**	**1.106**	**0.722**	**1.006**	**1.171**	**0.772**
C.D. (P=0.05)	**0.407**	**0.449**	**0.299**	**1.359**	**1.377**	**0.952**	**2.642**	**3.165**	**2.034**	**2.879**	**3.351**	**2.174**

DAS= Days after sowing

cm) and HM-444 (92.53 cm) respectively and all these three varieties are statistically *at par* and lowest plant height of 56.31 cm was recorded in RMt-305. In pooled analysis, maximum plant height (90.02 cm) was recorded in HM-444 followed by NDM-8 (83.86 cm) and AFg-2 (83.63 cm) respectively and lowest plant height (57.71 cm) was recorded in RMt-305. At 110 days, during first season maximum plant height (90.12 cm) was recorded in HM-444 followed by 84.32 cm in RMt-1 and 84.26 cm in NDM-8 but both were *at par*. The lowest plant height (65.17 cm) was observed in PRM-45. During 2014-15, maximum plant height was observed in genotype HM-444 (100.80 cm) followed by AFg-4 (100.56 cm) and NDM-241 (100.52 cm) but these three genotypes were statistically *at par*. In respect to pooled analysis, maximum plant height was recorded in HM-444 (95.46 cm) followed by Hissar Sonali (90.28 cm) and AFg-4 (89.49 cm) both are *at par*. Lowest plant height (66.54 cm) recorded in RMt-305. Extent of variation among germplasm was different in different growth phases during the both seasons of growing.

1.1.2 Number of primary branches plant^{-1}

Like plant height, observations regarding primary branches plant^{-1} were recorded at different growth phases *i.e.* at 30, 60, 90 and 110 DAS. It was observed that there was significant variations during the two growing seasons and their pooled analysis (Table 8. and Fig. 7)

At 30 DAS, maximum number of primary branches plant^{-1} (1.85) was recorded in HM-444 (1.85) followed by Hissar Suvarna (1.73) and NDM-8 (1.60) as compared to lowest (0.55) in KFGK-18 during 2013-14. During second season (2014-15), maximum number of primary branches (2.07) was recorded in Lam Methi-2 followed by 1.87 in Rajendra Kranti and 1.81 in Hissar Sonali as compared with lowest number of branches in AFg-3 (1.13). In pooled analysis, maximum number of primary branches (1.76) was recorded in HM-444 and Hissar Suvarna (1.73) which are statistically *at par*. Minimum number of branches (0.91) was observed in RMt-361.

At 60 DAS, maximum number of primary branches was noticed in NDM-8 (6.60) followed by HM-444 (6.37) and NDM-241 (6.27) and lowest in Hissar Suvarna (5.00) during 2013-14. During 2014-15, maximum number of primary branches was recorded in Hissar Sonali (5.40) followed by 4.87 in NDM-8 and 4.80 in HM-444 and minimum number of primary branches was noticed in KFGK-4 (2.53). In pooled analysis of two seasons, maximum number of primary branches was observed in NDM-8 (5.74) followed

Table 8. Variation in primary branches plant^{-1} of different fenugreek genotypes

Genotype	Number of primary branches plant^{-1}											
	30 DAS			60 DAS			90 DAS			110 DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RMt-1	0.79	1.62	1.21	5.95	4.73	5.34	6.28	6.47	6.37	7.86	7.27	7.57
RMt-305	0.92	1.23	1.07	5.70	3.80	4.75	6.38	6.05	6.22	8.24	7.33	7.79
RMt-361	0.57	1.26	0.91	5.53	3.33	4.43	6.47	5.85	6.16	7.12	6.67	6.90
Hissar Sonali	1.34	1.81	1.58	5.73	5.40	5.57	7.26	7.65	7.46	7.54	9.07	8.31
Hissar Suvarna	1.73	1.73	1.73	5.00	4.47	4.74	6.96	6.73	6.85	7.17	7.60	7.39
AFg-1	0.92	1.25	1.08	5.95	3.53	4.74	6.38	6.07	6.23	6.92	7.88	7.40
AFg-2	1.16	1.67	1.42	6.20	3.47	4.83	6.47	6.20	6.33	6.82	7.20	7.01
AFg-3	0.72	1.13	0.93	5.53	4.07	4.80	6.39	5.75	6.07	7.24	8.17	7.71
AFg-4	0.85	1.67	1.26	5.87	4.73	5.30	6.27	6.10	6.19	6.82	7.47	7.14
KFGK-4	1.08	1.67	1.38	5.80	2.53	4.17	6.81	5.87	6.34	6.94	6.13	6.53
KFGK-18	0.55	1.67	1.11	5.73	4.60	5.17	6.73	6.45	6.59	7.14	8.07	7.61
NDM-4	1.32	1.33	1.32	5.87	2.87	4.37	6.65	6.45	6.55	7.16	7.53	7.35
NDM-8	1.60	1.53	1.57	6.60	4.87	5.74	7.16	6.70	6.93	7.52	8.07	7.80
NDM-13	1.16	1.67	1.42	5.70	4.60	5.15	6.43	6.20	6.31	7.28	6.40	6.84
NDM-241	1.42	1.53	1.48	6.27	4.13	5.20	6.52	6.30	6.41	6.81	7.27	7.04
PRM-45	0.68	1.33	1.01	5.40	4.40	4.90	6.14	6.00	6.07	6.26	6.73	6.50
HM-444	1.85	1.67	1.76	6.37	4.80	5.58	6.63	8.10	7.37	7.64	8.25	7.94
Rajendra Kranti	1.41	1.87	1.64	5.65	3.73	4.69	6.38	6.20	6.29	6.56	6.82	6.69
Lam Methi-2	0.75	2.07	1.41	5.97	4.27	5.12	6.24	5.40	5.82	6.92	6.33	6.63
Local	1.35	1.76	1.55	5.70	3.60	4.65	5.96	6.27	6.11	6.72	6.67	6.70
S.Em. (±)	**0.015**	**0.021**	**0.013**	**0.077**	**0.057**	**0.048**	**0.083**	**0.083**	**0.059**	**0.092**	**0.095**	**0.066**
C.D. (P=0.05)	**0.043**	**0.060**	**0.037**	**0.220**	**0.163**	**0.135**	**0.238**	**0.238**	**0.166**	**0.263**	**0.272**	**0.186**

DAS= Days after sowing

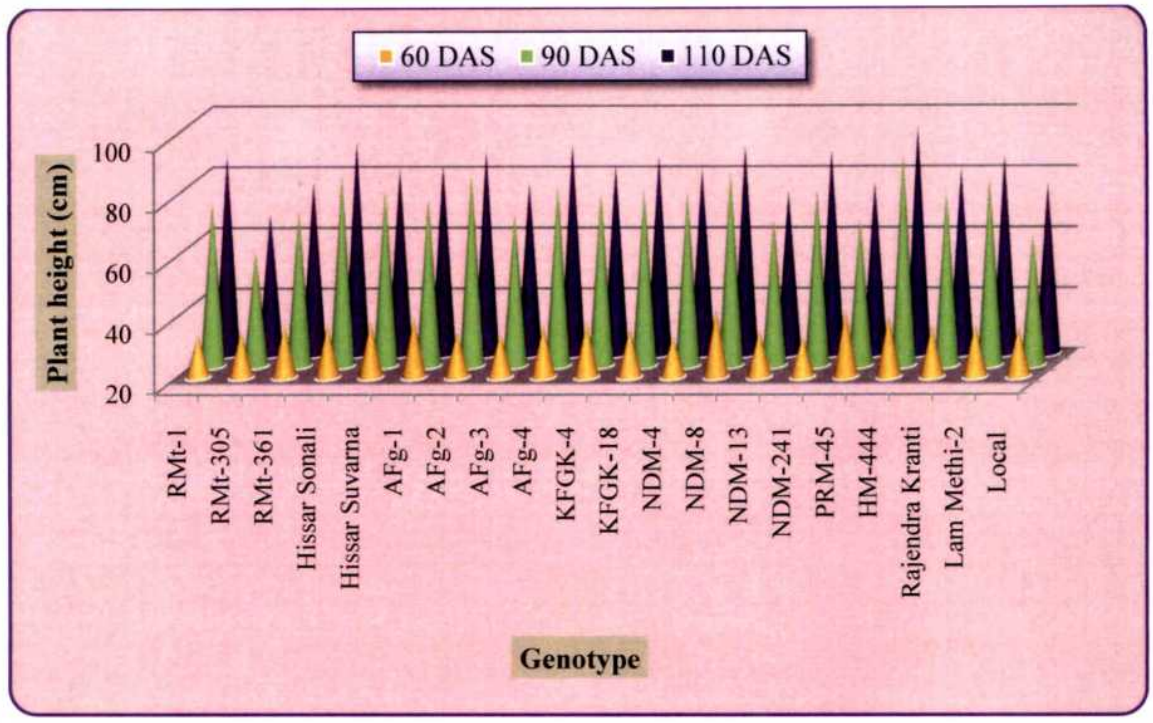


Fig. 6 Plant height of different fenugreek genotypes

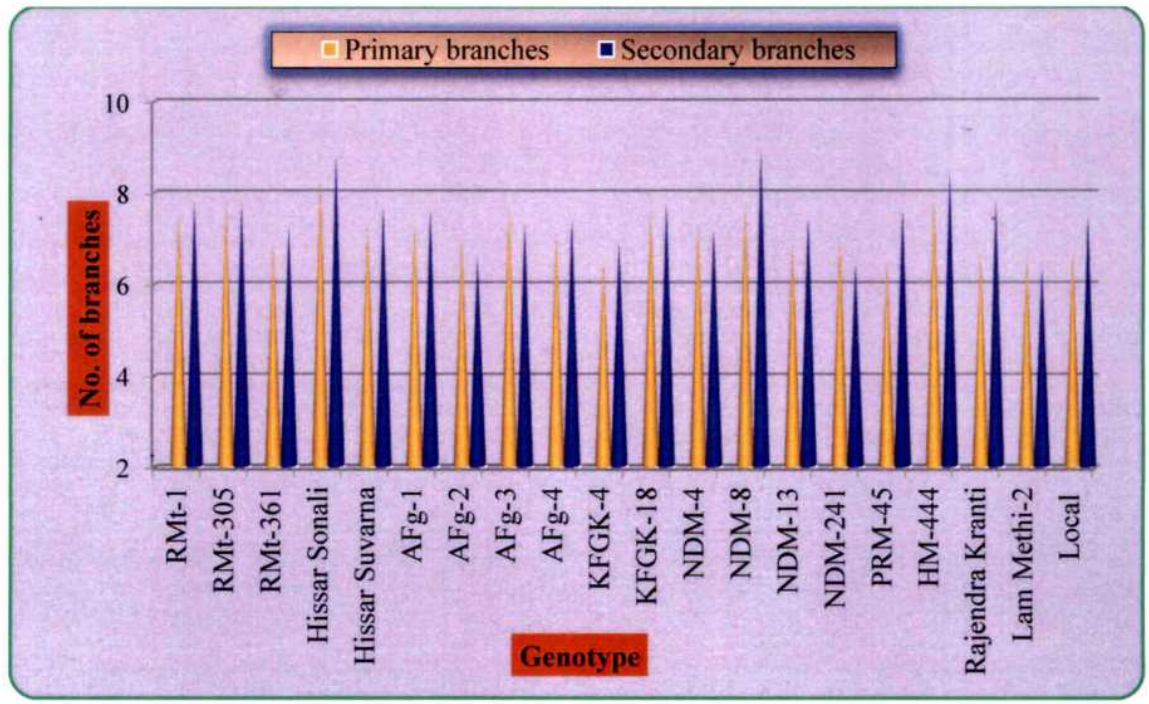


Fig. 7 Number of branches plant^{-1} of different fenugreek genotypes

at 110 DAS

by 5.58 and 5.57 in HM-444 and Hissar Sonali respectively, these two genotypes are *at par*. Lowest number of primary branches among all germplasm was observed in KFGK-4 (4.17).

During first season, at 90 DAS maximum number of primary branches was noticed in Hissar Sonali (7.26) followed by NDM-4 (7.16), both were *at par* followed by Hissar Suvarna (6.96) as compared to minimum number of branches in local (5.96) type. In 2014-15, maximum number of branches was recorded in HM-444 (8.10) followed by Hissar Sonali (7.65) and lowest number of branches observed in Lam Methi-2 (5.40). In pooled analysis, maximum number of branches was observed in Hissar Sonali and HM-444 with 7.46 and 7.37 respectively followed by NDM-8 (6.93) and minimum number of branches recorded in Lam Methi-2 (5.82).

At 110 DAS, highest number of primary branches plant^{-1} was noticed in genotype RMt-305 (8.24) followed by RMt-1 and HM-444 (7.86 and 7.64). Both genotypes are *at par* and minimum number of branches was recorded in PRM-45 (6.26). During 2014-15, maximum number of branches was observed in Hissar Sonali (9.07) followed by HM-444 (8.25) and AFg-3 (8.17). The latter two values are *at par*. Minimum number of primary branches was recorded in KFGK-4 (6.13). In pooled analysis, highest number of primary branches was noticed in Hissar Sonali (8.31) followed by HM-444 (7.94) and NDM-8 (7.80), the latter two values are *at par*. The minimum number of branches was recorded in KFGK-4 (6.53).

1.1.3 Number of secondary branches plant^{-1}

Secondary branches plant^{-1} was recorded during three growth phases i.e. 60, 90 and 110 DAS. The significant differences were observed among different germplasm during both seasons and in pooled analysis.

At 60 DAS, during 2013-14 the maximum number of secondary branches per plant was noticed in NDM-8 (3.64) followed by Hissar Sonali (3.46) and lowest number of branches was recorded in RMt-305 (2.36). Like first season, maximum number of branches (3.93) was recorded in NDM-8 during 2014-15 followed by 3.47 in RMt-361 as compared with lowest number of secondary branches (2.36) in Hissar Suvarna. In pooled analysis, maximum number of secondary branches (3.79) was recorded in NDM-8 followed by HM-444 (3.16) and Hissar Sonali (3.08) as compared to minimum number of branches (2.38) in AFg-2.

Table 9. Variation in secondary branches plant^{-1} of different fenugreek genotypes

Genotype	Number of secondary branches plant^{-1}								
	60 DAS			90 DAS			110DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RMt-1	3.24	2.53	2.89	4.65	4.73	4.69	7.16	8.40	7.78
RMt-305	2.36	2.47	2.42	5.36	6.47	5.92	7.84	7.67	7.76
RMt-361	2.63	3.47	3.05	3.82	4.07	3.95	5.96	8.53	7.25
Hissar Sonali	3.46	2.71	3.08	5.62	6.47	6.05	7.53	10.08	8.81
Hissar Suvarna	2.56	2.36	2.46	3.48	3.60	3.54	6.24	9.13	7.69
AFg-1	2.98	2.53	2.76	5.26	5.67	5.47	5.42	9.82	7.62
AFg-2	2.28	2.47	2.38	3.80	4.33	4.07	5.48	7.64	6.56
AFg-3	3.24	2.53	2.89	4.75	5.47	5.11	6.23	8.39	7.31
AFg-4	2.74	2.53	2.64	4.83	5.20	5.02	6.15	8.67	7.41
KFGK-4	2.57	2.47	2.52	3.65	3.40	3.53	6.08	7.72	6.90
KFGK-18	3.07	2.53	2.80	4.97	5.20	5.09	5.68	9.82	7.75
NDM-4	2.92	2.47	2.70	3.84	4.60	4.22	7.05	7.32	7.19
NDM-8	3.64	3.93	3.79	6.24	5.80	6.02	8.16	9.64	8.90
NDM-13	3.17	2.53	2.85	5.75	5.20	5.47	6.84	8.07	7.46
NDM-241	2.62	2.53	2.58	4.18	4.73	4.46	5.28	7.60	6.44
PRM-45	3.05	2.47	2.76	4.52	4.20	4.36	6.82	8.47	7.64
HM-444	3.25	3.07	3.16	5.70	5.53	5.61	7.28	9.53	8.41
Rajendra Kranti	3.12	2.53	2.83	5.92	5.67	5.79	6.72	8.91	7.81
Lam Methi-2	2.82	2.47	2.65	3.83	5.36	4.60	6.15	6.53	6.34
Local	2.49	2.53	2.51	3.65	4.33	3.99	5.86	9.12	7.49
S.Em. (±)	**0.038**	**0.037**	**0.030**	**0.062**	**0.064**	**0.044**	**0.083**	**0.085**	**0.059**
C.D. (P=0.05)	**0.109**	**0.106**	**0.070**	**0.177**	**0.183**	**0.124**	**0.238**	**0.243**	**0.166**

DAS= Days after sowing

At 90 DAS, maximum number of secondary branches (5.92) was noticed in Rajendra Kranti, followed by 5.75 and 5.70 in genotypes NDM-13 and HM-444 respectively and lowest number of branches was recorded in Hissar Suvarna (3.48) during 2013-14. During 2014-15, maximum number of branches (6.47) was observed in two genotypes *viz.,* Hissar Sonali and RMt-305 followed by NDM-8 (5.80) as compared to lowest number of branches (3.60) in Hissar Suvarna. In pooled analysis, highest number of secondary branches observed in Hissar Sonali (6.05) which was *at par* with NDM-8 (6.02) followed by RMt-305 (5.92) as compared with minimum number of branches (3.53) in KFGK-4.

During 2013-14, at 110 DAS, highest number of branches (8.16) was recorded in NDM-8 followed by RMt-305 (7.84) and Hissar Sonali (7.53) as compared with minimum number of branches (5.28) in NDM-241. During 2014-15, highest number of branches (10.08) was noticed in Hissar Sonali followed by 9.82 in two genotypes *viz.,* AFg-1 and KFGK-18. Minimum number of branches (6.53) was recorded in Lam Methi-2. In pooled analysis, two genotypes namely NDM-8 (8.90) and Hissar Sonali (8.81) are *at par* with respect to secondary branches as compared to lowest number of branches (6.34) in the genotype Lam Methi-2.

The positive effect was observed between number of primary and secondary branches and seed yield, might be due to lot of branches of plants with many leaves could be partitioned to reproductive organs and the results are in agreement with those of Fikreselassie *et al.* (2012)

1.1.4 Number of nodules plant^{-1}

Data pertaining to number of nodules is presented in Table 11. There was a significant difference among the genotypes for nodule number. During 2013-14, maximum number of nodules was recorded in NDM-8 (35.20) followed by NDM-4 (34.74). During 2014-15, maximum number of nodules was observed in KFGK-4 (36.20) and lowest was recorded in Hissar Suvarna (13.50). In pooled analysis, maximum number of nodules was noticed in NDM-8 (35.51) followed by HM-444 (33.20) and lowest number of nodules observed in Hissar Suvarna (13.93).

1.2 YIELD PARAMETERS

1.2.1 Number of days taken for first flowering

Significant variations were noticed among genotypes (Table 10. and Fig. 8). During 2013-14, for appearance of first flower the genotype Hissar Suvarna took

Table 10. Variation in days taken for first and 50% flowering and pod initiation of different fenugreek genotypes

Genotype	Number of days required for											
	First flowering			50% flowering			First pod initiation			50% pod initiation		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RMt-1	49.53	46.24	47.89	52.34	50.33	51.34	54.50	52.33	53.42	58.54	65.33	61.94
RMt-305	51.24	47.33	49.28	57.52	51.67	54.60	62.00	52.67	57.33	65.28	65.67	65.48
RMt-361	52.16	45.67	48.92	57.38	49.14	53.26	61.00	50.33	55.66	66.16	66.03	66.09
Hissar Sonali	50.25	46.39	48.32	54.51	51.33	52.92	58.50	50.33	54.42	62.38	65.38	63.88
Hissar Suvarna	44.24	46.28	45.26	53.35	54.33	53.84	53.00	53.67	53.34	67.35	66.19	66.77
AFg-1	50.72	45.33	48.03	53.50	50.38	51.94	59.00	49.67	54.33	62.56	65.45	64.01
AFg-2	50.56	46.14	48.35	55.50	50.67	53.08	59.00	50.67	54.83	62.92	65.62	64.27
AFg-3	51.30	46.33	48.82	56.54	51.28	53.91	57.50	52.00	54.75	64.51	67.05	65.78
AFg-4	52.42	46.67	49.55	57.52	52.33	54.93	59.50	56.33	57.91	63.28	66.25	64.77
KFGK-4	50.51	45.67	48.09	55.54	49.33	52.44	58.50	51.00	54.75	65.52	65.33	65.43
KFGK-18	50.64	46.67	48.65	53.52	51.64	52.58	58.00	52.00	55.00	64.54	67.67	66.11
NDM-4	51.32	46.67	49.00	56.32	54.67	55.50	58.50	52.67	55.59	62.52	67.33	64.92
NDM-8	51.52	46.33	48.93	56.16	51.24	53.70	58.00	50.67	54.34	62.51	60.67	61.59
NDM-13	50.28	47.33	48.81	53.52	53.33	53.42	58.00	54.00	56.00	63.42	66.33	64.88
NDM-241	51.36	45.67	48.52	55.08	49.16	52.12	59.00	50.00	54.50	65.18	65.16	65.17
PRM-45	50.52	46.67	48.60	55.52	52.33	53.93	58.50	50.67	54.58	66.20	66.33	66.27
HM-444	53.16	49.29	51.23	57.14	53.67	55.40	59.00	55.67	57.33	65.53	69.33	67.43
Rajendra Kranti	51.28	46.13	48.71	56.32	51.67	54.00	59.00	50.00	54.50	63.28	66.35	64.82
Lam Methi-2	51.38	45.33	48.36	55.87	49.45	52.66	58.50	50.00	54.25	64.16	64.67	64.42
Local	50.17	46.33	48.25	56.35	50.33	53.34	61.50	52.00	56.75	65.52	65.33	65.43
S.Em. (±)	**0.662**	**0.602**	**0.448**	**0.722**	**0.668**	**0.492**	**0.759**	**0.672**	**0.507**	**0.826**	**0.823**	**0.584**
C.D. (P=0.05)	**1.895**	**1.723**	**1.262**	**2.066**	**1.912**	**1.386**	**2.170**	**1.923**	**1.428**	**2.364**	**2.355**	**1.645**

DAS= Days after sowing

NDM-8 HM-444 NDM-13

NDM-4 Hissar Sonali KFGK-4

Plate 19. Variation in nodule formation in fenugreek genotypes

minimum duration (44.24 days) followed by RMt-1 (49.53 days). Maximum number of days (53.16) taken for first flower appearance was observed in HM-444 followed by AFg-4 (52.42 days) but they were *at par*. During 2014-15, Lam Methi-2 and AFg-1 took only 45.33 days for appearance of first flower. Genotype HM-444 took more number of days (49.29) for appearance of first flower. In pooled analysis, it was observed that Hissar Suvarna took minimum number of days (45.26) for appearance of first flower. But HM-444 took maximum number of days (51.23) for appearance of first flower.

1.2.2 Number of days taken for 50% flowering

For flower initiation of 50% of plants RMt-1 took minimum number of days (52.34) followed by Hissar Suvarna (53.35 days) but these two were statistically *at par*. RMt-305 and AFg-4 took more number of days (57.52) to reach 50% flowering stage during 2013-14. During 2014-15, genotypes RMt-361 and NDM-241 reached 50% flowering stage within 49.14 and 49.16 days respectively. Genotype Hissar Suvarna and NDM-4 took 54.33 and 54.67 days respectively to reach 50% flowering stage. In pooled analysis, it was observed that RMt-1 and AFg-1 took 51.34 and 51.94 days respectively to reach 50% flowering stage. Maximum number of days of 55.50 and 55.40 required to reach 50% flowering stage in two genotypes *viz.* NDM-4 and HM-444 respectively (Table 10.)

1.2.3 Number of days taken for first pod initiation

During 2013-14, days taken for appearance of first pod was noticed in Hissar Suvarna (53.00 days) followed by RMt-1 (54.50 days) but both values are statistically *at par*. More number of days (62.00 and 61.50) taken for appearance of pod in two genotypes *viz.*, RMt-305 and Local respectively. During 2014-15, two genotypes *viz.*, AFg-1, Lam Methi-2 and Rajendra Kranti took 49.67 and 50.00 days respectively for appearance of pod. But, genotype AFg-4 took maximum number days (56.33) from date of sowing to appearance of first pod. In pooled analysis, it was observed that Hissar Suvarna and RMt-1 recorded lesser number of days for appearance of first pod as compared to other genotypes. AFg-4 and Rmt-305 recorded more number of days for the initiation pod *i.e* 57.91 and 57.33 days respectively (Table 10.)

1.2.4 Number of days taken for 50% pod initiation

To reach 50% pod initiation stage, Hissar Suvarna took maximum number of days (67.35) followed by PRM-45 (66.20 days) and RMt-361 (66.16 days) but all these

three .. statistically *at par*. The genotype RMt-1 reached early to 50% pod initiation stage within 58.54 days compared to other genotypes during 2013-14. During 2014-15, NDM-8 recorded minimum number of days (60.67) to reach 50% pod initiation stage and genotype HM-444 recorded maximum number of days (69.33) followed by KFGK-18 (67.67 days) but these two values are statistically *at par*. In pooled analysis, it was observed that two genotypes *viz.*, NDM-8 and RMt-1 recorded minimum number of days (61.59 and 61.94 days) and two other genotypes *viz.*, HM-444 and Hissar Suvarna recorded maximum number of days (67.43 and 66.77 days) as compared to other genotypes and both of them are statistically *at par* (Table 10. and Fig. 8)

1.2.5 Number of days taken for crop to reach maturity

Number of days taken to reach maturity varied significantly among the genotypes. The shortest duration of 111.19 days was noticed in Hissar Suvarna followed by KFGK-18 (120.64 days). The maximum duration (145.53 days) in NDM-241 followed by RMt-361 (144.54 days), NDM-4 (143.53 days) and NDM-8 (143.17 days) but all these are statistically *at par*. During 2014-15, AFg-2 recorded minimum crop duration of (112.33 days) followed by Hissar Suvarna (113.67) to reach the harvest in comparison to other genotypes. Genotype AFg-3 recorded maximum crop duration (139.46 days) followed by Local (138.92 days) and AFg-1 (138.02 days) all these three are statistically *at par*. In accordance with pooled analysis, Hissar Suvarna was observed as early maturing variety (112.43 days) followed by AFg-2 (115.50 days) and three genotypes recorded as late maturing varieties *viz.*, Local (140.72 days) followed by NDM-241 (139.43 days) and AFg-3 (139.00 days) these three are statistically *at par*. Significant variation in flowering and maturity was also reported by Rao (2001)

1.2.6 Number of pods plant^{-1}

There is a significant variation among genotypes for number pods plant^{-1} (Table 12. and Fig. 10). During 2013-14, highest number of pods plant^{-1} was recorded in Local (85.58) and followed by Hissar Suvarna (85.27) but both were statistically *at par* as compared to lowest number of pods recorded in RMt-361 (33.78). During 2014-15, highest number of pods (87.64) was observed in RMt-1 followed by NDM-8 (77.34) and Hissar Sonali (70.85). The minimum number of pods plant^{-1} was recorded in Hissar Suvarna (38.80). In pooled analysis, it was observed that NDM-8 recorded more number of pods plant^{-1} (80.28) followed by KFGK-18 (65.72), PRM-45 (65.46) and Hissar

Table 11. Variation in days to maturity and number of nodules of different fenugreek genotypes

Genotype	Days to maturity			Number of nodules plant^{-1}		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RMt-1	135.35	131.68	133.52	23.52 (4.90)	22.16 (4.76)	22.84 (4.83)
RMt-305	136.72	130.33	133.53	27.15 (5.26)	27.38 (5.28)	27.27 (5.27)
RMt-361	144.54	129.63	137.09	24.45 (4.99)	20.50 (4.58)	22.48 (4.79)
Hissar Sonali	126.05	132.71	129.38	31.62 (5.67)	25.15 (5.06)	28.39 (5.37)
Hissar Suvarna	111.19	113.67	112.43	14.36 (3.85)	13.50 (3.74)	13.93 (3.80)
AFg-1	125.50	138.02	131.76	18.49 (4.36)	19.28 (4.45)	18.88 (4.40)
AFg-2	118.67	112.33	115.50	15.12 (3.95)	22.12 (4.76)	18.62 (4.35)
AFg-3	138.52	139.46	139.00	18.54 (4.36)	14.86 (3.92)	16.70 (4.14)
AFg-4	134.84	136.67	135.76	19.16 (4.43)	18.57 (4.37)	18.87 (4.40)
KFGK-4	139.12	132.49	135.81	20.13 (4.54)	36.20 (6.06)	28.17 (5.30)
KFGK-18	120.64	131.16	125.90	26.02 (5.15)	27.45 (5.29)	26.74 (5.22)
NDM-4	143.53	132.67	138.10	34.74 (5.94)	24.50 (5.00)	29.62 (5.47)
NDM-8	143.17	129.84	136.51	35.20 (5.97)	35.83 (6.03)	35.51 (6.00)
NDM-13	141.06	117.67	129.36	29.16 (5.45)	34.17 (5.89)	31.67 (5.67)
NDM-241	145.53	133.33	139.43	26.35 (5.18)	25.83 (5.13)	26.09 (5.16)
PRM-45	141.82	130.67	136.25	30.62 (5.58)	20.83 (4.62)	25.73 (5.10)
HM-444	138.51	128.62	133.57	31.24 (5.63)	35.17 (5.97)	33.20 (5.80)
Rajendra Kranti	137.56	128.27	132.92	21.16 (4.65)	19.17 (4.43)	20.16 (4.54)
Lam Methi-2	139.04	127.65	133.34	16.28 (4.10)	14.67 (3.89)	15.48 (4.00)
Local	142.52	138.92	140.72	16.12 (4.08)	15.33 (3.98)	15.73 (4.03)
S.Em. (±)	**1.786**	**1.706**	**1.235**	**0.032**	**0.031**	**0.022**
C.D. (P=0.05)	**5.111**	**4.882**	**3.479**	**0.092**	**0.088**	**0.063**

*Values in the parenthesis are the square root transformed values utilized for statistical analysis.

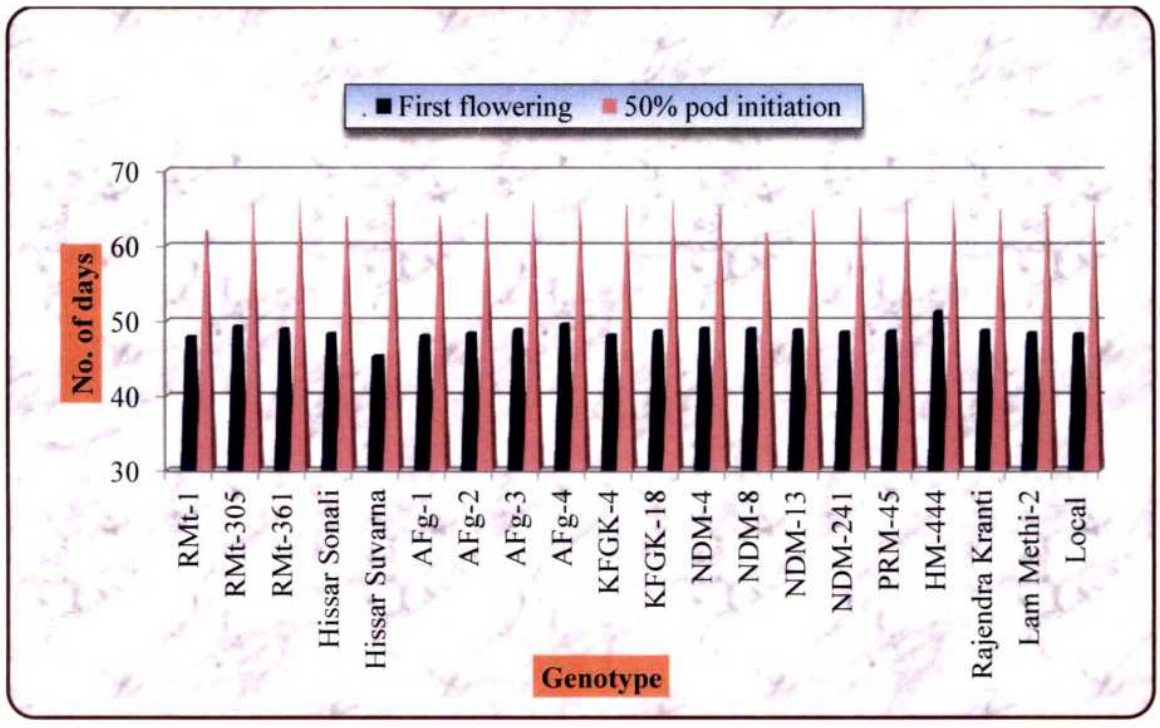


Fig. 8 Days taken for flowering and pod initiation of different genotypes

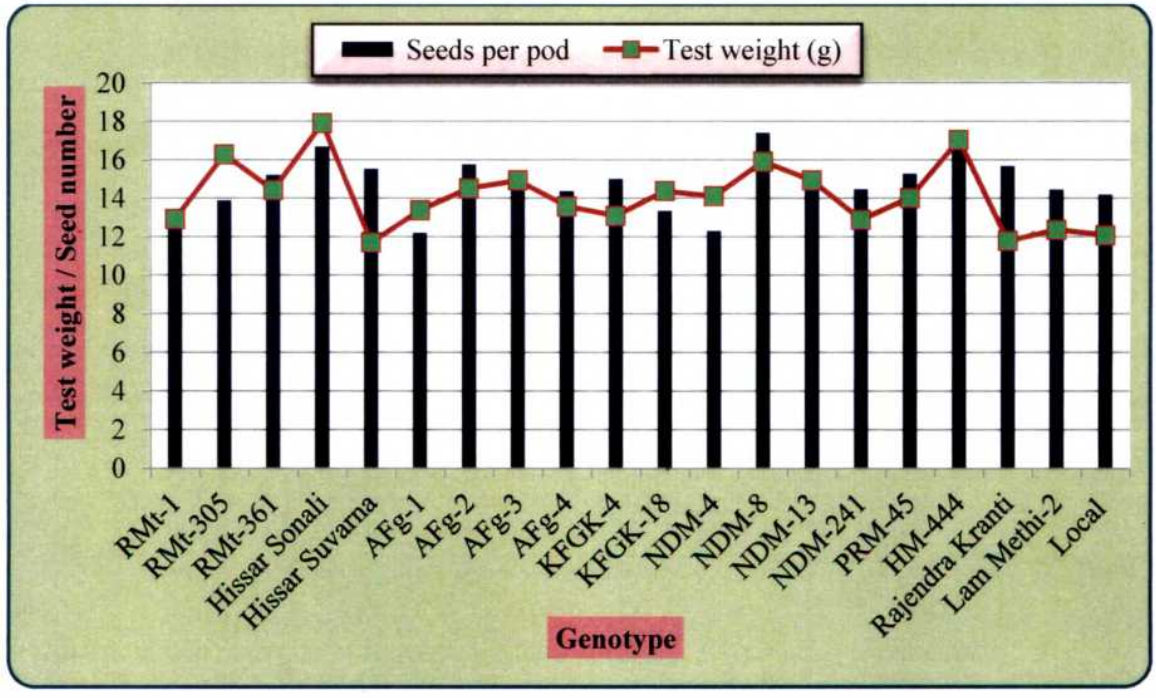


Fig. 9 Variation in number of Seeds pod $^{-1}$ and test weight of different fenugreek genotypes

Sonali (65.26). Lowest number of pods plant^{-1} was noticed in NDM-13 (38.41) as compared to the other genotypes. The results are in good agreement with Chandra *et al.* (2000), Koli and Sri (2002) and Singh *et al.* (2015)

1.2.7 Pod length

Data related to length of pod was presented in Table 12. The significant difference in genotypes for length of pod was observed in both seasons and their pooled analysis. During the first season, more length of pod was observed in four genotypes without any significant differences viz., Hissar Sonali (9.56 cm), Lam Methi-2 (9.56 cm), AFg-2 (9.39 cm) and Hissar Suvarna (9.35 cm) as compared to minimum pod length (8.03 cm) recorded in Rajendra Kranti. During 2014-15, highest pod length (10.90 cm) was recorded in Hissar Suvarna followed by NDM-8 (10.75 cm) but both values were *at par* followed by PRM-45 (10.39 cm). Length of pod was lowest in NDM-4 (7.21 cm). In pooled analysis, highest pod length (10.13 cm) was recorded in Hissar Suvarna followed by Hissar Sonali (9.85 cm) and RMt-305 (9.78 cm) the latter two values being *at par* as compared to the lowest pod length (7.99 cm) recorded in AFg-1. The above findings are in good conformity with those of Gangopadhyay *et al.* (2009).

1.2.8 Number of seeds pod^{-1}

Data pertaining to the number of seeds pod^{-1} is presented in Table 12. and Fig. 9 significant difference was noticed among the germplasm in both the years and their pooled analysis. During 2013-14, highest number of seeds pod^{-1} (18.67) was recorded in HM-444 followed by 16.90 in NDM-8 and 16.56 in PRM-45 but the latter two values were *at par* and the lowest number of seeds pod^{-1} was recorded in NDM-4 (10.04). During 2014-15, highest number of seeds pod^{-1} (17.87) was recorded in NDM-8 followed by Hissar Sonali (17.09), AFg-2 (16.90) and NDM-13 (16.71) and all the three genotypes are *at par* for seed number pod^{-1}. In comparison to other genotypes, lowest number of seeds pod^{-1} recorded in KFGK-4 (13.97). In pooled analysis two genotypes namely NDM-8 and HM-444 recorded more seed number pod^{-1} *i.e.* 17.39 and 17.24 respectively followed by Hissar Sonali (16.67) as compared to that lowest number of seeds pod^{-1} in AFg-1 (12.19).

1.2.9 Test weight

Data in respect of test weight was presented in Table12. and Fig. 9 and it clearly indicated that there was a significant difference among the genotypes in both the years

Table 12. Variation in pod characters of different fenugreek genotypes

Genotype	Number of pods plant^{-1}			Pod length (cm)			Number of seeds pod^{-1}			Test weight (g)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RMt-1	40.37	87.64	64.01	8.67	9.97	9.32	12.47	14.16	13.31	12.46	13.33	12.90
RMt-305	47.90	57.82	52.86	9.21	10.34	9.78	12.29	15.43	13.86	17.52	15.03	16.27
RMt-361	33.78	52.20	42.99	8.45	7.55	8.00	14.60	15.77	15.19	14.15	14.67	14.41
Hissar Sonali	59.67	70.85	65.26	9.56	10.13	9.85	16.25	17.09	16.67	18.54	17.26	17.90
Hissar Suvarna	85.27	38.80	62.04	9.35	10.90	10.13	14.77	16.24	15.51	12.62	10.73	11.68
AFg-1	47.08	50.34	48.71	8.71	7.26	7.99	10.09	14.30	12.19	14.25	12.47	13.36
AFg-2	60.92	66.28	63.60	9.39	8.76	9.08	14.60	16.90	15.75	15.13	13.87	14.50
AFg-3	48.26	59.20	53.73	9.11	9.21	9.16	14.82	15.62	15.22	15.26	14.56	14.91
AFg-4	55.09	74.61	64.85	8.42	9.78	9.10	14.20	14.49	14.35	13.95	13.17	13.56
KFGK-4	56.52	61.38	58.95	8.96	8.47	8.72	16.02	13.97	15.00	12.82	13.33	13.07
KFGK-18	59.64	71.80	65.72	8.61	9.55	9.08	11.41	15.23	13.32	14.75	13.96	14.36
NDM-4	45.25	60.27	52.76	9.28	7.21	8.25	10.04	14.54	12.29	14.35	13.83	14.09
NDM-8	83.22	77.34	80.28	8.64	10.75	9.70	16.90	17.87	17.39	16.15	15.64	15.90
NDM-13	41.65	35.16	38.41	9.28	7.91	8.60	12.38	16.71	14.55	16.25	13.57	14.91
NDM-241	55.15	42.80	48.97	9.13	9.19	9.16	14.56	14.38	14.45	12.36	13.37	12.87
PRM-45	68.58	62.34	65.46	9.03	10.39	9.71	16.56	13.98	15.27	15.46	12.53	14.00
HM-444	50.46	59.45	54.95	9.15	10.26	9.71	18.67	15.82	17.24	17.32	16.72	17.02
Rajendra Kranti	56.73	43.21	49.97	8.03	9.68	8.86	15.94	15.41	15.67	11.28	12.25	11.77
Lam Methi-2	66.23	47.96	57.10	9.56	9.48	9.52	14.77	14.11	14.44	12.21	12.49	12.35
Local	85.58	39.60	62.59	8.15	8.08	8.12	13.93	14.40	14.17	12.47	11.64	12.06
S.Em. (±)	**0.778**	**0.812**	**0.562**	**0.117**	**0.119**	**0.083**	**0.181**	**0.198**	**0.134**	**0.190**	**0.178**	**0.130**
C.D. (P=0.05)	**2.227**	**2.324**	**1.583**	**0.335**	**0.341**	**0.234**	**0.518**	**0.567**	**0.377**	**0.544**	**0.509**	**0.366**

DAS= Days after sowing

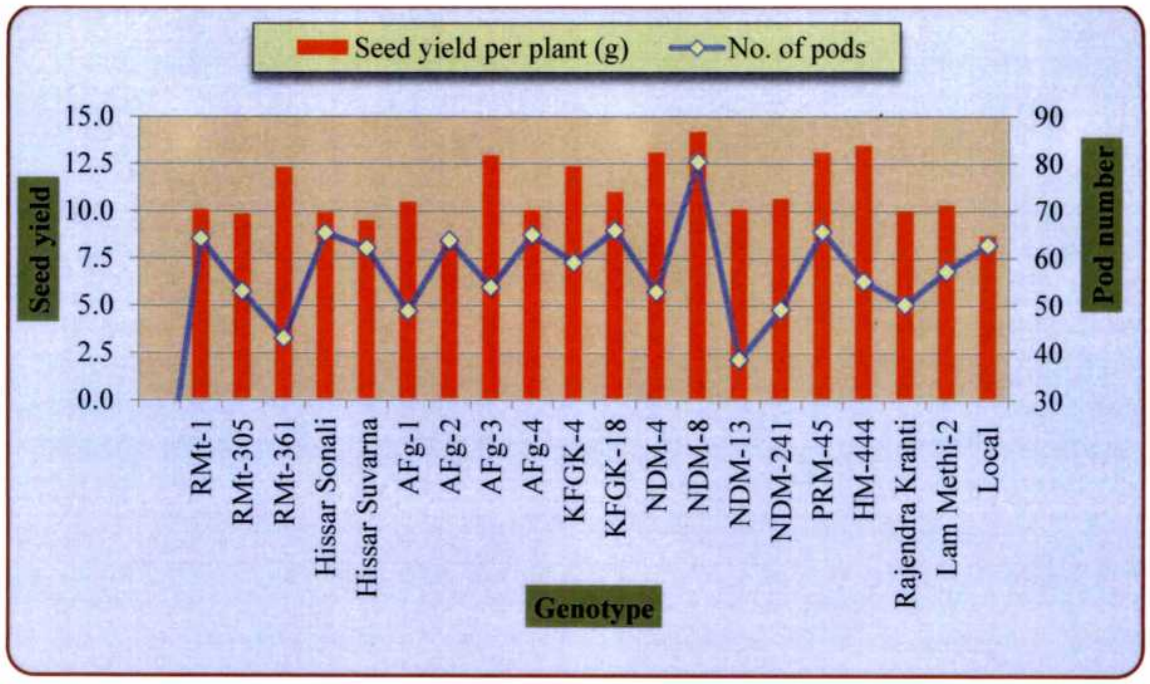


Fig. 10 Variation in number of pods and seed yield plant^{-1} in different fenugreek genotypes

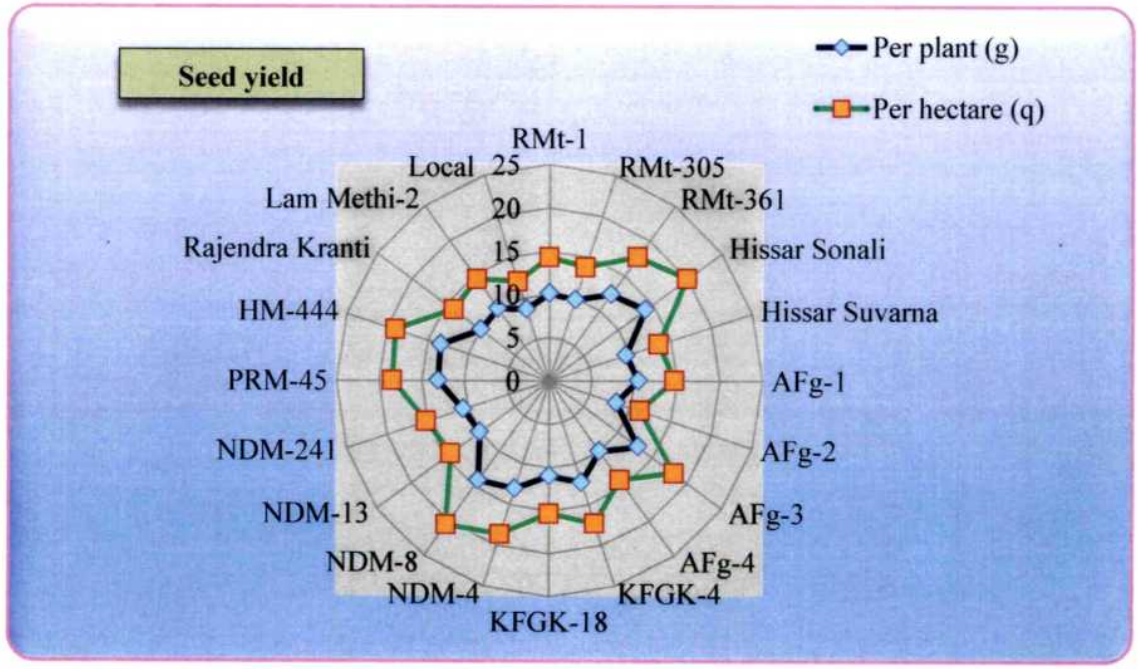


Fig. 11Variation in seed yield of different fenugreek genotypes

and in pooled analysis. During 2013-14, maximum test weight (18.54 g) was observed in Hissar Sonali followed by 17.52 g in RMt-305 and 17.32 g in HM-444 but the latter two were *at par*. The lowest test weight (11.28 g) was recorded in Rajendra Kranti. During 2014-15, highest test weight was recorded in Hissar Sonali (17.26 g) followed by HM-444 (16.72) g and NDM-8 (15.64 g) as compared to lowest test weight in Hissar Suvarna (10.73 g). In pooled analysis, it was noticed that highest test weight (17.90 g) in Hissar Sonali followed by HM-444 (17.02 g) and RMt-305 (16.27 g) as compared to lowest test weight (11.68 g) in Hissar Suvarna.

1.2.10 Seed yield plant^{-1}

The significant variations among different genotypes were noticed in respect of seed yield plant^{-1} during both the years and in pooled analysis (Table 13. and Fig. 10 &11). During 2013-14, the maximum seed yield plant^{-1} (13.82 g) was recorded in two genotypes *viz.*, HM-444 and NDM-8 followed by PRM-45 (13.46 g) in comparison to lowest seed yield plant^{-1} in AFg-2 (7.98 g). During 2014-15, maximum seed yield plant^{-1} was noticed in NDM-8 (14.52 g) followed by NDM-4 (13.31 g) and HM-444 (13.03 g) as compared to lowest seed yield in KFGK-18 (10.7 g). In pooled analysis, the genotype NDM-8 recorded highest seed yield plant^{-1} (14.17 g) followed by HM-444 (13.43 g) and NDM-4 (13.08 g). Lowest seed yield plant^{-1} was recorded in AFg-2 (8.27 g).

1.2.11 Seed yield plot^{-1}

Like seed yield per plant, significant variations were noticed during both the years and pooled analysis (Table 13). Seed yield plot^{-1} was highest in genotype NDM-4 (802.87 g 3m^{-2}) followed by HM-444 (790.53 g 3m^{-2}) and AFg-3 (762.67 g 3m^{-2}) as compared to lowest seed yield (437.47 g 3m^{-2}) in AFg-2 during first season. During 2014-15, genotype NDM-8 recorded highest seed yield plot^{-1} (843.20 g 3m^{-2}) followed by NDM-4 (764.60 g 3m^{-2}) and Hissar Sonali (749.60 g 3m^{-2}) against lowest seed yield in AFg-2 (457.27 g 3m^{-2}). In pooled analysis, NDM-8 recorded highest seed yield (823.03 g 3m^{-2}) followed by HM-444 (759.50 g 3m^{-2}) as compared to lowest seed yield (447.37 g 3m^{-2}) observed in AFg-2.

1.2.12 Projected seed yield hectare^{-1}

In respect of projected seed yield, there were significant differences among genotypes in two growing seasons and their pooled analysis (Table 13 and Fig. 12). During 2013-14, maximum seed yield (20.07q ha^{-1}) was recorded in NDM-8 followed by

Table 13. Variation in seed yield of different fenugreek genotypes

Genotype	Yield plant^{-1} (g)			Yield plot^{-1} (g 3m^{-2})			Projected yield (q ha^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RMt-1	9.58	10.52	10.05	543.80	592.53	568.17	13.60	14.81	14.20
RMt-305	9.67	9.92	9.80	551.53	547.87	549.70	13.79	13.70	13.74
RMt-361	12.13	12.43	12.28	689.80	718.80	704.30	17.25	17.97	17.61
Hissar Sonali	9.26	10.54	9.90	686.40	749.60	718.36	17.16	18.74	17.95
Hissar Suvarna	9.26	9.68	9.47	522.93	555.47	539.20	13.07	13.89	13.48
AFg-1	10.58	10.31	10.45	591.47	582.93	587.20	14.79	14.57	14.68
AFg-2	7.98	8.56	8.27	437.47	457.27	447.37	10.94	11.43	11.19
AFg-3	13.15	12.23	12.69	762.67	685.13	723.90	19.07	17.13	18.10
AFg-4	10.26	9.78	10.02	582.93	547.13	565.04	14.57	13.68	14.13
KFGK-4	11.92	12.73	12.33	659.53	728.47	694.00	16.49	18.21	17.35
KFGK-18	11.25	10.70	10.98	630.67	598.00	614.33	15.77	14.95	15.36
NDM-4	12.85	13.31	13.08	728.67	764.60	746.63	18.22	19.12	18.67
NDM-8	13.82	14.52	14.17	802.87	843.20	823.03	20.07	21.08	20.58
NDM-13	10.38	9.73	10.06	592.47	550.13	571.30	14.81	13.75	14.28
NDM-241	10.25	10.98	10.62	581.33	631.80	606.57	14.53	15.80	15.17
PRM-45	13.46	12.68	13.07	751.93	722.80	737.37	18.80	18.07	18.43
HM-444	13.82	13.03	13.43	790.53	728.47	759.50	19.76	18.21	18.99
Rajendra Kranti	9.27	10.64	9.96	509.87	600.40	555.13	12.75	15.01	13.88
Lam Methi-2	10.62	9.93	10.27	596.20	558.80	577.50	14.91	13.97	14.44
Local	8.94	8.36	8.65	492.40	467.60	480.00	12.31	11.69	12.00
S.Em. (±)	**0.152**	**0.155**	**0.108**	**9.330**	**9.298**	**6.585**	**0.234**	**0.232**	**0.165**
C.D. (P=0.05)	**0.435**	**0.444**	**0.304**	**26.702**	**26.610**	**18.548**	**0.670**	**0.664**	**0.465**

in HM-444 (19.76 q ha^{-1}) but both were statistically *at par* followed by AFg-3 (19.07 q ha^{-1}) and PRM-45 (18.80 q ha^{-1}). Lowest seed yield (10.94 q ha^{-1}) was recorded in AFg-2. During 2014-15 genotype NDM-8 also recorded highest seed yield (21.08 q ha^{-1}) followed by NDM-4 (19.12 q ha^{-1}) and Hissar Sonali (18.74 q ha^{-1}). In pooled analysis, it was noticed that NDM-8 recorded highest projected yield (20.58 q ha^{-1}) followed by HM-444 (18.99 q ha^{-1}) and NDM-4 (18.67 q ha^{-1}) the latter two genotypes were statistically *at par*. The lowest seed yield was recorded in AFg-2 (11.19 q ha^{-1}). Yield is quantitative character, obtained by the complex polygenetic character largely affected by environmental conditions and the results are consistent with those of Chandra *et al.* (2000) and Kaushik *et al.* (2001).

Pods plant $^{-1}$ exhibited a positive association with seed yield per plant. This means that plants bearing more number of pods $plant^{-1}$ produce more seed yield. Numbers of primary and secondary branches were found to be positively correlated with yield $plot^{-1}$ (Wojo *et al.,* 2016). Similar results were reported by McCormick (2004) and Fikreselassie *et al.* (2012).

1.2.13 Straw yield $plot^{-1}$

Data pertaining to straw yield are presented in Table 14. Highest straw yield (1.57 kg $3m^{-2}$) was recorded in NDM-8 and lowest (1.16 kg $3m^{-2}$) was recorded in AFg-2 during 2013-14. During 2014-15, NDM-8 also recorded highest straw yield (1.59 kg $3m^{-2}$) followed by NDM-4 (1.55 kg $3m^{-2}$) as compared to lowest in AFg-2 (1.22 kg $3m^{-2}$). In pooled analysis, NDM-8 recorded highest straw yield (1.58 kg $3m^{-2}$) followed by NDM-4 (1.54 kg $3m^{-2}$) and lowest straw yield $plot^{-1}$ was recorded in AFg-2 (1.19 kg $3m^{-2}$).

1.2.14 Straw yield $hectare^{-1}$

The maximum per hectare straw yield was highest in NDM-8 (3.93 t ha^{-1}) followed by NDM-4 (3.80 t ha^{-1}) and AFg-3 (3.78 t ha^{-1}) but the latter two were statistically *at par* as compared to lowest in Afg-2 (2.90 t ha^{-1}) during 2013-14. During second growing season, NDM-8 recorded highest straw yield (3.97 t ha^{-1}) followed by NDM-4 (3.89 t ha^{-1}). In pooled analysis, NDM-8 also recorded highest straw yield (3.95 t ha^{-1}) and lowest was recorded in AFg-2 (2.98 t ha^{-1}).

Table 14. Variation in straw yield, biological yield and harvest index of different fenugreek genotypes

Genotype	Straw yield plot^{-1} (kg 3m^{-2})			Straw yield hectare^{-1} (t)			Biological yield (t ha^{-1})			Harvest Index (%)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RMt-1	1.34	1.43	1.39	3.36	3.57	3.46	4.72	5.05	4.89	28.67	29.00	28.67
RMt-305	1.23	1.24	1.23	3.07	3.10	3.08	4.45	4.47	4.45	31.00	30.67	31.00
RMt-361	1.44	1.47	1.45	3.59	3.67	3.63	5.31	5.46	5.39	32.00	33.00	32.00
Hissar Sonali	1.50	1.54	1.52	3.76	3.85	3.80	5.47	5.72	5.60	31.37	32.76	32.05
Hissar Suvarna	1.32	1.33	1.33	3.30	3.32	3.31	4.61	4.71	4.66	28.00	29.67	28.00
AFg-1	1.35	1.34	1.35	3.38	3.36	3.37	4.86	4.82	4.84	30.33	30.33	30.33
AFg-2	1.16	1.22	1.19	2.90	3.05	2.98	3.99	4.20	4.10	27.33	27.00	27.33
AFg-3	1.51	1.48	1.50	3.78	3.71	3.74	5.69	5.42	5.55	33.67	31.67	33.67
AFg-4	1.31	1.30	1.30	3.29	3.24	3.26	4.74	4.61	4.68	30.67	29.67	30.67
KFGK-4	1.48	1.51	1.49	3.70	3.78	3.74	5.35	5.60	5.48	31.00	32.33	31.00
KFGK-18	1.43	1.40	1.41	3.56	3.50	3.53	5.14	5.00	5.07	30.67	30.00	30.67
NDM-4	1.52	1.55	1.54	3.80	3.89	3.84	5.62	5.80	5.71	32.33	33.00	32.33
NDM-8	1.57	1.59	1.58	3.93	3.97	3.95	5.94	6.07	6.01	34.00	35.00	34.00
NDM-13	1.34	1.34	1.34	3.35	3.35	3.35	4.83	4.72	4.78	30.67	29.00	30.67
NDM-241	1.35	1.36	1.35	3.36	3.41	3.39	4.82	4.99	4.90	30.33	31.67	30.33
PRM-45	1.51	1.49	1.50	3.78	3.72	3.75	5.66	5.52	5.59	33.33	32.67	33.33
HM-444	1.48	1.44	1.46	3.70	3.60	3.65	5.67	5.42	5.55	34.67	33.33	34.67
Rajendra Kranti	1.31	1.31	1.31	3.27	3.28	3.28	4.54	4.78	4.66	28.33	31.33	28.33
Lam Methi-2	1.33	1.33	1.33	3.33	3.32	3.32	4.82	4.71	4.77	31.00	29.67	31.00
Local	1.30	1.31	1.31	3.26	3.27	3.26	4.49	4.44	4.46	27.33	26.33	27.33
S.Em. (±)	**0.008**	**0.009**	**0.006**	**0.020**	**0.020**	**0.015**	**0.039**	**0.038**	**0.027**			
C.D. (P=0.05)	**0.023**	**0.026**	**0.017**	**0.057**	**0.063**	**0.042**	**0.112**	**0.109**	**0.076**			

1.2.15 Biological yield hectare^{-1}

During 2013-14, highest biological yield was recorded in NDM-8 (5.94 t ha^{-1}) followed by AFg-3 (5.69 t ha^{-1}) and HM-444 (5.67 t ha^{-1}). During 2014-15, NDM-8 recorded highest biological yield (6.07 t ha^{-1}) followed by NDM-4 (5.80 t ha^{-1}) and lowest was recorded in Local (4.44 t ha^{-1}). In pooled analysis, NDM-8 recorded highest biological yield (6.01t ha^{-1}) followed by NDM-4 (5.71 t ha^{-1}). The lowest biological yield recorded in AFg-2 (4.10 t ha^{-1}) among all genotypes.

1.2.16 Harvest Index

During 2013-14, HM-444 recorded maximum harvest index (34.67%) followed by NDM-8 (34%). During 2014-15, NDM-8 recorded maximum harvest index (35%) followed by HM-444 (33.33%). In pooled analysis, it was observed that HM-444 recorded highest harvest index (34.67%) followed by NDM-8 (34%) and the lowest recorded in local and AFg-2 (27.33%).

1.3 QUALITY PARAMETERS

Fenugreek is a rich source of protein that provides basic nutrition. In addition, it encompasses a wide variety of secondary phytochemicals including galactomanan, diosgenin and phenolic compounds, which are known for their pharmacological significance. The development of trait-specific varieties of fenugreek relies on the characterization of their genetic resources. In the present study, 20 genotypes of fenugreek were grown during the period 2013-14 and 2014-15 and seeds were evaluated for the contents of protein and some selected phytochemicals of medicinal importance.

1.3.1 Galactomannan content

The analytical data pertaining to glactomannan content in fenugreek seed in two different seasons along with pooled was presented in Table 15. and Fig. 12 Galactomannan content in seeds of fenugreek varied between 5.623 and 33.177 mg 100 mg^{-1} with a mean value of 19.4 mg 100 mg^{-1} during 2013-14, while the corresponding value during 2014-15 was between 10.957 and 31.873 mg 100 mg^{-1} with a mean value of 21.415 mg 100 mg^{-1} indicating 5 and 3 fold variation respectively in a particular growing season. The genotype HM-444 registered highest galactomannan content (33.177 mg 100 mg^{-1}) followed by Hissar suvarna (25.737 mg 100 mg^{-1}) and KFGK-18 (25.770 mg 100 mg^{-1}) during 2013-14 while that was lowest in KFGK-4 (5.623 mg 100 mg^{-1}). In

Table 15. Variation in galactomannan and soluble protein content of seed in different fenugreek genotypes

Genotype	Galactomannan (mg 100mg^{-1})			Total soluble protein (mg 100mg^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RMt-1	10.000	24.723	17.362	18.417	16.687	17.552
RMt-305	8.827	31.873	20.350	24.520	16.687	20.603
RMt-361	14.933	17.538	16.236	18.830	17.007	17.918
Hissar Sonali	11.992	23.184	17.588	13.473	14.562	14.018
Hissar Suvarna	25.737	15.713	20.725	13.863	22.830	18.347
AFg-1	17.720	22.355	20.038	28.777	25.277	27.027
AFg-2	17.413	23.165	20.289	21.637	19.203	20.420
AFg-3	18.897	10.957	14.927	22.753	20.937	21.845
AFg-4	11.847	26.805	19.326	28.027	25.620	26.823
KFGK-4	5.623	13.027	9.325	23.890	22.970	23.430
KFGK-18	25.770	13.385	19.577	22.707	21.730	22.218
NDM-4	15.537	25.762	20.649	24.533	23.637	24.085
NDM-8	15.237	26.140	20.688	21.820	21.333	21.577
NDM-13	16.233	17.063	16.648	25.887	22.297	24.092
NDM-241	21.240	14.998	18.119	27.763	25.947	26.810
PRM-45	7.713	17.272	12.493	32.060	28.953	30.507
HM-444	33.177	15.872	24.524	22.467	19.380	20.923
Rajendra Kranti	22.117	16.815	19.466	23.830	21.847	22.838
Lam Methi-2	12.301	14.705	13.503	18.687	15.533	17.110
Local	19.570	27.697	23.633	25.940	21.727	23.834
S.Em. (±)	**0.057**	**0.131**	**0.071**	**0.225**	**0.167**	**0.140**
C.D. (P=0.05)	**0.163**	**0.375**	**0.200**	**0.644**	**0.478**	**0.394**

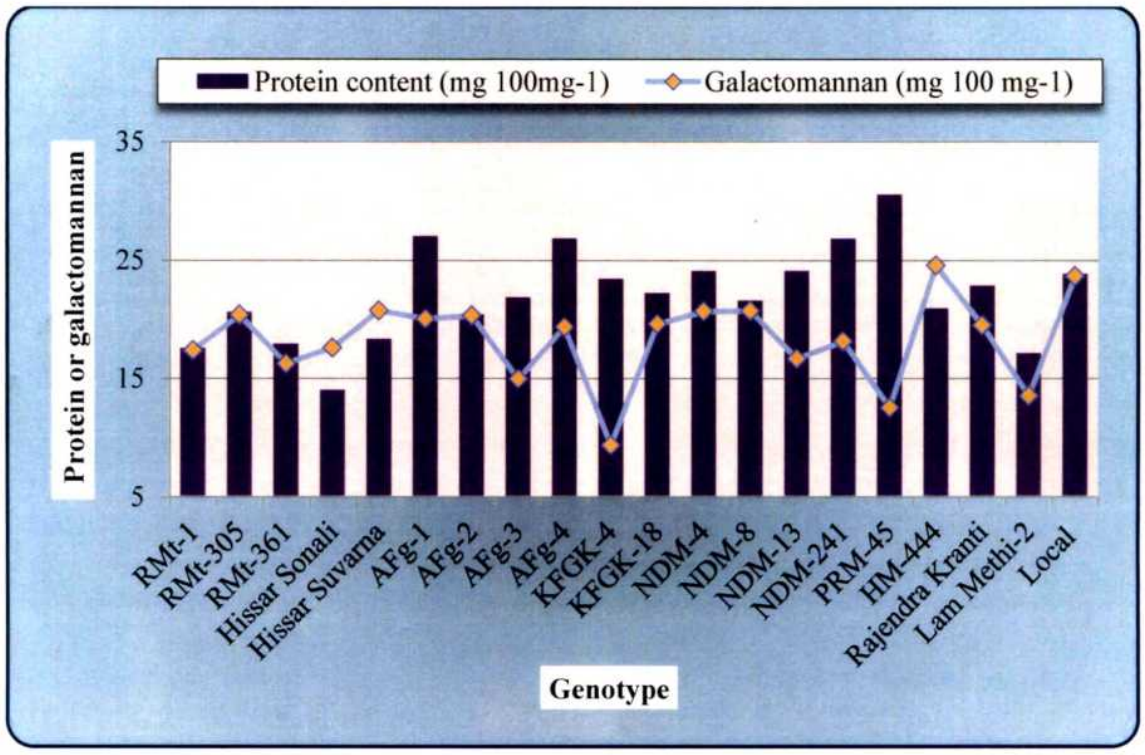


Fig. 12 Variation in protein and galactomannan content of fenugreek seed

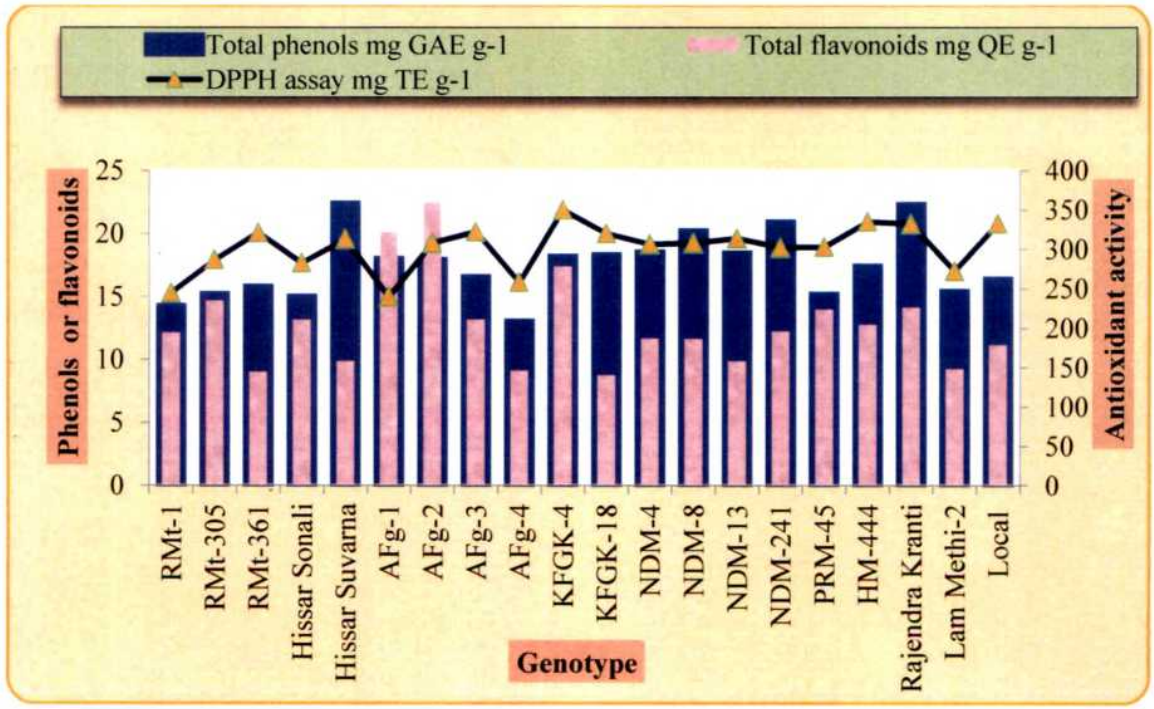


Fig. 13 Variation in phenols, flavonoids and DPPH assay of fenugreek seed

contrast, highest galactomannan content was recorded in genotype RMt-305 (31.873 mg 100 mg^{-1}) followed by local (27.697 mg 100 mg^{-1}) and least in genotype AFg-3 (10.957 mg 100 mg^{-1}) during 2014-15. Significant differences in galactomannan content among the genotypes in both the growing seasons indicated that genotypes vary considerably in their potential to accumulate galactomannan, which supports the observation of Rathore *et al.* (2013). Moreover, most of the genotypes with few exceptions accumulate higher galatomannan during the second season as compared to the first season. Furthermore, the rank order of genotypes with their galactomannan content differed between seasons indicating the influence of environmental factors such as temperature, sunshine hours through their effect on photosynthetic pathway that primarily control the flux of metabolites to the formation of galactomannan.

There are no significant differences in mean minimum temperature and sunshine hours during both the growing seasons but those differed significantly during the first four months. On the other hand, mean maximum temperature differed between both the seasons. Thus, it appears that temperature between 11°C and 30°C is favourable for photosynthesis to occur more efficiently with subsequent greater accumulation of galactomannan. Galactomannan content of seeds of fenugreek grown under different seasons when pooled indicated that HM-444 with a value of 24.524 mg 100mg^{-1} ranked first similar to that observed during 2013-14. Local variety (23.633 mg 100 mg^{-1}) ranked distinct second while KFGK-4 registered the lowest (9.325 mg 100 mg^{-1}) galactomannan. The galactomannan content observed in the present study is similar to that reported by earlier workers (Brummer *et al.*, 2003 and Rathore *et al.*, 2013.).

1.3.2 Total soluble protein and its fractions

Total soluble protein content with their fractions was presented in Table 15 and Fig. 12. During 2013-14, the genotype PRM-45 (32.060 mg 100 mg^{-1}) registered highest total soluble protein followed by AFg-1 (28.777 mg 100 mg^{-1}) and AFg-4 (28.027 mg 100 mg^{-1}). During 2014-15, the highest total soluble protein (28.953 mg 100 mg^{-1}) was recorded in PRM-45 followed by NDM-241 (25.947 mg 100 mg^{-1}) and AFg-4 (25.620 mg 100 mg^{-1}). Lowest amount of total soluble protein was recorded in Hissar Sonali (14.562 mg 100 mg^{-1}). Total soluble protein content varied 2.38 fold between 13.473 and 32.060 mg 100 mg^{-1} during 2013-14 and 2 fold between 14.562 and 28.953 mg 100 mg^{-1} during 2014-15. In contrast to galactomanan content, the mean total soluble protein in fenugreek seed is higher (22.767 mg 100 mg^{-1}) in first as compared to second season

Table 16. Variation in different fractions of seed protein in different fenugreek genotypes

Genotype	Protein fractions (mg 100 mg^{-1})											
	Albumin			Globulin			Prolamin			Glutellin		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RMt-1	9.073	8.150	8.612	5.153	3.737	4.445	0.627	0.413	0.520	3.563	4.387	3.975
RMt-305	13.620	9.260	11.440	5.650	7.757	6.703	1.130	0.860	0.995	4.120	6.000	5.060
RMt-361	9.700	7.507	8.603	4.840	7.060	5.950	0.573	0.450	0.512	3.717	1.990	2.853
Hissar Sonali	6.205	6.765	6.485	4.207	5.970	5.088	0.765	0.155	0.460	2.297	1.672	1.984
Hissar Suvarna	12.010	10.010	11.010	7.533	6.533	7.033	0.277	0.203	0.240	6.053	6.083	6.068
AFg-1	13.783	12.833	13.308	9.983	9.447	9.715	0.220	0.197	0.208	4.790	2.800	3.795
AFg-2	14.290	13.450	13.870	4.603	2.813	3.708	0.107	0.117	0.112	2.637	2.823	2.730
AFg-3	9.607	7.940	8.773	7.150	7.377	7.263	0.367	0.403	0.385	5.630	5.217	5.423
AFg-4	16.283	14.830	15.557	5.817	6.447	6.132	0.843	0.460	0.652	5.083	3.883	4.483
KFGK-4	14.967	11.200	13.083	5.620	7.157	6.388	0.227	0.287	0.257	3.077	4.327	3.702
KFGK-18	12.703	10.087	11.395	5.937	6.540	6.238	0.400	0.920	0.660	3.667	4.183	3.925
NDM-4	9.710	7.263	8.487	6.880	6.600	6.740	0.100	1.243	0.672	7.843	8.530	8.187
NDM-8	9.157	7.073	8.115	5.663	6.773	6.218	0.173	1.153	0.663	6.827	6.333	6.580
NDM-13	14.687	6.027	10.357	7.400	5.000	6.200	0.853	0.187	0.520	2.947	11.083	7.015
NDM-241	15.767	13.787	14.777	6.743	4.290	5.517	0.247	0.700	0.473	5.007	7.170	6.088
PRM-45	12.580	12.927	12.753	8.843	7.180	8.012	2.053	0.990	1.522	8.583	7.857	8.220
HM-444	10.497	9.217	9.857	5.613	5.467	5.540	1.403	0.660	1.032	4.953	4.037	4.495
Rajendra Kranti	12.303	8.953	10.628	6.373	8.793	7.583	1.343	0.700	1.022	3.810	3.400	3.605
Lam Methi-2	8.013	7.013	7.513	5.747	4.747	5.247	0.343	0.190	0.267	4.583	3.583	4.083
Local	13.500	10.383	11.942	7.260	5.817	6.538	0.930	0.493	0.712	4.250	5.033	4.642
S.Em. (±)	**0.154**	**0.108**	**0.094**	**0.073**	**0.086**	**0.057**	**0.051**	**0.043**	**0.033**	**0.092**	**0.083**	**0.062**
C.D. (P=0.05)	**0.441**	**0.309**	**0.265**	**0.209**	**0.246**	**0.161**	**0.146**	**0.123**	**0.093**	**0.263**	**0.238**	**0.175**

(21.757 mg 100 mg^{-1}). The pooled analysis of both growing seasons indicated that highest total soluble protein (30.507 mg 100mg^{-1}) was observed in PRM-45 and least in Hissar Sonali (14.02 mg 100 mg^{-1}). The present study further suggested that genotypes vary in their total soluble protein content depending not only by genetic factors but also by growing season.

Total soluble protein consists of different soluble fractions such as albumin (water soluble), globulin (salt soluble), prolamin (ethanol soluble) and glutellin (alkali soluble). The contents of each of these fractions across different genotypes and growing season are presented in Table16. Albumin content ranged from 8.013-16.283 and 6.027-14.830 mg 100 mg^{-1} with an average of 12.148 mg 100 mg^{-1} and 10.429 mg 100 mg^{-1} during the first and second growing season respectively. Albumin constitutes and 53% and 48% of total soluble protein depending on genotype and growing season. The genotype AFg-4 registered highest albumin content in both seasons. Hissar Sonali registered lowest albumin in first growing season as well as when pooled. On the other hand, salt soluble protein, globulin differed significantly among the genotypes. During 2013-14 and 2014-15, maximum globulin content was recorded in genotype AFg-1 (9.983 and 9.447 mg 100 mg^{-1}). Hissar Sonali with 4.207 and AFg-2 with 2.813 mg 100 mg^{-1} registered lowest globulin in different growing season. Globulin represented 31% and 28% depending on genotype and season respectively. Pooled data of both the seasons established AFg-1 with 9.72 mg 100 mg^{-1} globulin content as a superior genotype followed by PRM-45 (8.01 mg 100 mg^{-1}). Likewise, prolamin also varied significantly between genotypes ranging from 0.100-2.053 and 0.117-1.153 mg 100 mg^{-1} in consecutive growing seasons and constitutes only a small fraction of total protein. Among twenty genotypes, maximum prolamin content was observed with PRM-45 (2.05 mg 100 mg^{-1}) in 2013-14 while NDM-8 with 1.153 mg 100 mg^{-1} ranked first during 2014-15. In pooled analysis, genotype PRM-45 showed highest prolamin followed by HM-444 (1.032 mg 100 mg^{-1}) and Rajendra Kranti (1.022 mg 100 mg^{-1}) and AFg-2 with prolamin content of 0.11 mg 100 mg^{-1}, ranked at the bottom. During the first season, highest glutellin content was observed in genotype PRM-45 (8.583 mg 100 mg^{-1}) followed by NDM-4 (7.843 mg 100 mg^{-1}) and least in Hissar Sonali (2.297 mg 100 mg^{-1}). It was further evident that there was a significant difference among the genotypes. During 2014-15, NDM-13 registered highest glutellin (11.083 mg 100 mg^{-1}) and Hissar Sonali (1.672 mg 100 mg^{-1}) ranked lowest. In pooled analysis, glutellin content ranged

between 1.984 mg to 8.220 mg 100 mg^{-1} with an average of that constitutes 23% of total soluble protein.

1.3.3 Total phenols, flavonoids and antioxidant activity

The results of phenol, flavonoid and antioxidant activity of fenugreek seeds in different genotypes and season have been summarized in Table 17. and Fig. 13 Variation in amount of total phenols was noticed during both growing seasons and their pooled analysis. During 2013-14, total phenol content ranged between 24.733 mg GAE g^{-1} observed in the genotype Rajendra Kranti to 14.833 mg GAE g^{-1} in AFg-4 with a mean value of 19.783 mg GAE g^{-1}. The other genotypes that showed higher phenol include NDM-241 (23.157 mg GAE g^{-1}) and Hissar Suvarna (23.048 mg GAE g^{-1}). During 2014-15, highest total phenol content was recorded in Hissar Suvarna (21.065 mg GAE g^{-1}) and lowest in AFg-4 (10.578 mg GAE g^{-1}). In pooled analysis, phenol content ranged from 12.706 to 22.056 mg GAE g^{-1} with the highest amount occurring in Hissar Suvarna followed by Rajendra Kranti (21.964 mg GAE g^{-1}) and NDM-241 (20.580 mg GAE g^{-1}). Thus phenol, a widely distributed secondary compound varied significantly depending on genotype that supports the observation of earlier workers (Rahmani *et al.,* 2018). Moreover, environmental factors such as temperature and sunshine hours appear to control phenol accumulation as evidenced by the greater accumulation of total phenol in 2013-14 as compared to 2014-15.

Flavonoid content during the first season varied significantly depending on genotype with the highest found in genotype AFg-2 (35.903 mg QE g^{-1}) followed by AFg-1 (30.077 mg QE g^{-1}) and least in RMt-361 (9.290 mg QE g^{-1}). During 2014-15, highest and lowest total flavonoids was recorded in Hissar Sonali (12.882 mg QE g^{-1}) and KFGK-18 (5.010 mg QE g^{-1}) respectively. In pooled analysis of both seasons, total flavonoid content ranged between 8.725 and 22.440 mg QE g^{-1} with the highest amount recorded in AFg-2 followed by AFg-1 (20.115 mg QE g^{-1}) while RMt-36 registered lowest total flavonoids (8.998 mg QE g^{-1}). Significant variation is also observed in both the growing seasons with greater accumulation in 2013-14.

Antioxidant activity, a measure of phenol quality, was highest in genotype KFGK-4 (318.800 mg TE g^{-1}) and lowest in RMt-1 (135.633 mg TE g^{-1}) with an average value of 227.216 mg TE g^{-1} during 2013-14. However, during 2014-15, highest (380.40 mg TE g^{-1}) antioxidant activity was recorded in KFGK-4 followed by NDM-4 (377.00

Table 17. Variation in phenols, flavonoid, antioxidant activity and diosgenin content of seed in different fenugreek genotypes

Genotype	Total phenols (mg GAE g^{-1})			Total flavonoids (mg QE g^{-1})			DPPH assay (mg TE g^{-1})			Diosgenin (mg $100mg^{-1}$)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
RMt-1	16.090	11.752	13.914	13.497	10.700	12.098	135.633	353.000	244.317	0.080	0.166	0.123
RMt-305	18.043	11.715	14.879	18.897	10.357	14.627	244.267	328.600	286.267	0.077	0.276	0.176
RMt-361	18.050	12.870	15.460	9.290	8.707	8.998	317.367	323.733	320.550	0.137	0.243	0.190
Hissar Sonali	17.578	11.744	14.661	13.340	12.882	13.111	244.883	319.367	282.125	0.185	0.280	0.233
Hissar Suvarna	23.048	21.065	22.056	11.960	7.693	9.827	290.233	335.000	312.617	0.142	0.445	0.294
AFg-1	20.507	14.813	17.660	30.077	10.153	20.115	150.033	328.000	239.017	0.139	0.234	0.186
AFg-2	21.720	13.457	17.588	35.903	8.977	22.440	290.600	324.200	307.400	0.093	0.349	0.221
AFg-3	20.880	11.605	16.242	17.587	8.713	13.150	310.733	332.800	321.767	0.127	0.480	0.303
AFg-4	14.833	10.578	12.706	9.677	8.507	9.092	187.567	327.600	257.583	0.110	0.288	0.199
KFGK-4	21.690	13.988	17.839	28.433	6.310	17.372	318.800	380.400	349.600	0.133	0.489	0.311
KFGK-18	20.387	15.583	17.985	12.440	5.010	8.725	277.033	362.000	319.517	0.130	0.411	0.271
NDM-4	21.220	15.125	18.172	17.377	5.903	11.640	234.867	377.000	305.933	0.097	0.508	0.302
NDM-8	22.397	17.343	19.870	17.103	6.107	11.605	244.000	370.867	307.433	0.080	0.523	0.302
NDM-13	18.330	17.857	18.093	13.650	6.040	9.845	258.233	368.000	313.117	0.083	0.396	0.240
NDM-241	23.157	18.003	20.580	17.440	6.930	12.185	244.533	358.600	301.667	0.083	0.270	0.177
PRM-45	14.913	14.777	14.845	21.573	6.297	13.935	248.467	356.000	302.233	0.133	0.302	0.218
HM-444	17.213	16.958	17.086	16.917	8.580	12.748	312.700	356.000	334.350	0.093	0.309	0.201
Rajendra Kranti	24.733	19.195	21.964	18.800	9.397	14.098	309.400	353.933	331.667	0.093	0.236	0.165
Lam Methi-2	16.390	13.750	15.070	11.973	6.447	9.210	254.917	288.600	271.758	0.068	0.124	0.096
Local	15.647	16.463	16.055	11.897	10.360	11.128	311.267	352.533	331.900	0.090	0.244	0.167
S.Em. (±)	**0.171**	**0.200**	**0.131**	**0.171**	**0.050**	**0.089**	**1.880**	**1.091**	**1.087**	**0.001**	**0.050**	**0.003**
C.D. (P=0.05)	**0.489**	**0.572**	**0.369**	**0.489**	**0.143**	**0.251**	**5.380**	**3.122**	**3.062**	**0.003**	**0.143**	**0.008**

mg TE g^{-1}). Lam Methi-2 with a value of 288.60 mg TE g^{-1} showed lowest antioxidant activity. Thus antioxidant activity varied not only by genotype but also by growing season. In pooled analysis, highest antioxidant activity was recorded in KFGK-4 (349.600 mg TE g^{-1}) followed by HM-444 (334.350 mg TE g^{-1}) and the lowest in RMt-1 (244.317 mg TE g^{-1}). Comparison of data relating to total phenol, total flavonoid and antioxidant activity suggested that antioxidant activity is not determined by quantity of phenol and flavonoid rather it is governed by complex mixture of phenolic compounds including flavonoids.

1.3.4 Diosgenin

It was noticed that significant variation was present in both years and their pooled analysis among the 20 genotypes presented in Table 17. and Fig. 13 During 2013-14, maximum diosgenin was observed in genotype Hissar Sonali (0.185 mg 100mg^{-1}) as compared to minimum diosgenin (0.068 mg 100 mg^{-1}) was recorded in Lam Methi-2. During 2014-15, highest diosgenin (0.523 mg 100 mg^{-1}) was recorded in NDM-8 followed by NDM-4 (0.508 mg 100 mg^{-1}) but both genotypes are *at par*. Diosgenin content was lowest in Lam Methi-2 (0.124 mg 100 mg^{-1}). In pooled analysis, highest diosgenin (0.311 mg 100 mg^{-1}) was recorded in KFGK-4 followed by 0.303 mg 100 mg^{-1} in AFg-3, 0.302 mg 100 mg^{-1} in both NDM-4 and NDM-8 but KFGK-4 and AFG-3 are *at par* and the lowest diosgenin (0.096 mg 100 mg^{-1}) was recorded in Lam Methi-2. Present investigation confirmed the wide variability of diosgenin content within genotypes. The observed data is consistent with the reports of Acharya *et al.*, 2006; Thomas *et al.*, 2006 and Giridhar *et al.*, 2016. Factors like geographic origin, type of genotype, environment, and interaction of genotype and environment and management practices influence the amount of diosgenin (Taylor *et al.*, 2002; Acharya *et al.*, 2006 and Giridhar *et al.*, 2016).

Experimental results revealed a number of interesting features of growth yield and quality parameters of fenugreek with different genotypes. Among different genotypes, NDM-8 exhibited maximum number of secondary branches $plant^{-1}$ (8.90) minimum number of days required for 50% pod initiation (61.59 days), maximum number of pods $plant^{-1}$ (80.28), number of seeds pod^{-1} (17.39), nodule $plant^{-1}$ (35.51) seed yield $plant^{-1}$ (14.17 g), yield $plot^{-1}$ (823.13 g) and projected yield (20.58 q ha^{-1}) and straw yield ha^{-1} (3.95 t). Maximum plant height (95.46 cm), number of primary branches $plant^{-1}$ (7.94), maximum days required for first flowering (51.23 days) and 50% pod

initiation (67.43 days) and highest galactomannan content (24.52 mg 100 mg^{-1}) was noticed in HM-444. The maximum pod length (10.13 cm) and maximum total phenols (22.056 mg GAE g^{-1}) and early flower initiation (46.26 days) and pod initiation (53.34 days) were noticed in Hissar Suvarna. Maximum test weight was recorded in Hissar Sonali (17.90 g). Minimum and maximum days for 50% flower initiation were recorded in RMt-1 (51.34 days) and AFg-4 (57.91 days) respectively. The genotype AFg-2 recorded maximum total flavonoids (22.44 mg QE g^{-1}) and minimum days to reach crop maturity (115.50 days). The longest duration (140.72 days) of crop was noticed in local type. The maximum albumin content (15.55 mg 100mg^{-1}) was recorded in AFg-4 which also recorded maximum number of days (57.91 days) to reach first pod initiation. Maximum globulin (8.012 mg 100mg^{-1}), prolamin (1.522 mg 100 mg^{-1}) and glutellin (8.22 mg 100mg^{-1}) were observed in genotype PRM-45. The highest antioxidant activity (349.600 mg TE g^{-1}) and maximum diosgenin (0.311 mg 100mg^{-1}) were noticed in genotype KFGK-4.

For any crop improvement programme presence of genetic variability in the population is very important as it provides the chance to pick the genotype having desirable trait for improvement and it also gives a range of options to improve the trait of interest. From the study we can draw a conclusion that the mean performance of thirty characters under study revealed a great range of mean values, which indicates that there is a wide genetic variability among the genotypes for the traits like plant height, number of pods per $plant^{-1}$, number of seed pod^{-1}, test weight, yield, protein fractions, phenol content and diosgenin content.

Therefore, there is a scope for selection of genotypes with desirable traits to evolve variety and for combining desirable component characters in cross breeding programme. Similar results were reported by earlier workers (Verma *et al.*, 2003 , Banerjee and Kole,2004, Gangopadhyay *et al.*, 2009, Prajapati *et al.*,2010, Singh *et al.*, 2015 and Mamatha *et al.*, 2017).

The improvement in growth and yield attributes resulted in significant improvement in seed yield of genotype NDM-8 which out yielded other genotypes. Variation among the genotypes in respect of yield and yield attributes might be due to genetic differences in genotype. Straw yield also followed the same trend. Increased vegetative growth provided more sites for transportation of photosynthesis and ultimately resulted in improvement of yield attributes and yield. Jat *et al.* (2003) and Bhunia *et al.* (2006) also reported the same results.

The seed yield depends upon the number of pods plant^{-1}, length of pod, number of seeds pod^{-1} and test weight (Singh *et al.*, 2012; Datta and Chatterjee, 2014). Significant variation among the genotypes might be due to genetic characters (Banafar and Nair, 1992; Malik and Tehlan, 2009) and also through better expression of associated physiological traits (Banafar, 2000). Among all attributing characters, number of pods plant^{-1} was superior in NDM-8 as compared to other genotypes and ultimately seed yield hectare^{-1} was maximum followed by HM-444.

The mean differences due to genotypes were highly significant for all the characters which indicate the presence of substantial genetic diversity in the material studied. These findings are in good agreement with the findings of Santosha *et al.* (2014) and Singh *et al.* (2015). Variation in plant height was due to the inherent genetic makeup of the genotypes and their interaction with the environment, which in some way influence the morphological expression through the activity of endogenous hormonal level and apical dominance. These findings are quite similar to those reported by Kaushik *et al.* (2001), Raje (2004) and Gangopadhyay *et al.* (2009).

Yield attributing characters like seeds pod^{-1}, test weight, number of pods plant^{-1} and vegetative characters like plant height and branches plant^{-1} having a direct effect on seed yield (Sharma and Sastry, 2008; Giridhar and Sarada, 2009; Pushpa *et al.*, 2012; Singh *et al.*, 2013 and Giridhar *et al.*, 2016).

Among the twenty genotypes, the performance of NDM-8 (20.58 q ha^{-1}) was best followed by HM-444 (18.99 q ha^{-1}) and it was lowest in AFg-2 (11.19 q ha^{-1}). The grain yield is a quantitative character associated with characters like number of branches, pods plant^{-1}, seeds pod^{-1} and test weight of seed. The results are in good conformity with Pathak *et al.* (2014) and Giridhar *et al.* (2016). The specific ability of genotype having high yield is that adaptability and response of that genotype to that growing situation coupled with efficient source sink metabolism during critical stages of growth *i.e.* flowering to maturity period which solely depends on genetic architecture and inherent genetic potential. This confirms the superiority in important yield traits is crucial for the improvement of a genotype.

The knowledge of genetic variation is important for selection in crop improvement programme. Mc Cormick *et al.* (2009) found a significant variation for flowering time and duration, growth habit and seed yield. Yield is a complex character

governed by several other yield attributing characters are quantitatively inherited and highly affected by environment, it is difficult to judge whether the observed variability is heritable or not. A successful selection programme depends upon the information on genetic variability and association of yield components with seed yield. Information on variability in a population owing to genetic and non-genetic causes is a pre-requisite for initiating a crop improvement programme.

From yield maximization point of view, the genotype NDM-8 is the most promising, followed by HM-444 and NDM-4 for cultivation under alluvial plains of West Bengal.

EXPERIMENT 2: RESPONSE OF FENUGREEK TO COMBINED APPLICATION OF INORGANIC FERTILIZERS AND BIOINOCULANTS

The response of different levels of inorganic fertilizer, nitrogenous and phosphatic biofertilizers and their interactions on various growth, yield and quality parameters of fenugreek are presented here under and discussed on the basis of pooled analysis.

2.1 GROWTH PARAMETERS

Different vegetative parameters like plant height, number of primary and secondary branches, fresh and dry weight of plants were recorded. Plant height and number of primary branches were recorded at 30, 60, 90 and 120 days after sowing (DAS) but number of secondary branches was counted at 60, 90 and 120 DAS.

2.1.1 Plant height

Pooled analysis of data presented in Table 18. and Fig. 14 clearly indicated that plant height varied significantly in sole effect of three components *i.e.* inorganic fertilizer (N), nitrogenous bioinoculants (N) and phosphatic bioinoculants (P) and their interactions F×N, F×P, N×P and F×N×P. The non-significant variation was observed in F×N×P interaction during both the years at 90 DAS and during 2014-15 at 120 DAS and in some F×P and N×P interactions.

At 30 DAS, in respect of sole effects among different fertilizer levels, maximum plant height of 16.79 cm was observed in treatment NPK (75%) followed by NPK (50%). Between two nitrogenous bioinoculants, higher plant height (16.77 cm) was noticed in *Azospirillum* as compared to *Azotobacter* (16.27 cm). In case of phospahtic bio-inoculatns, higher plant height (17.33 cm) was observed in VAM.

In between the interactions of F×N, the increasing trend (15.62-16.87 cm) in plant height was noticed in case of *Azotobacter* with the reduction of fertilizer level. But in case of *Azospirillum*, the maxiumum plant height (17.25 cm) was noticed with 75% inorganic fertilizer. In F×P interaction, maximum plant height (17.89 cm) was observed in case of VAM with 75% level of inorganic fertilizer but increasing trend in plant height (14.92-16.53 cm) was recorded in PSB along with decreasing level of inorganic fertilizer (100% to 50%). In N×P interaction, *Azotobacter* ×VAM interaction showed higher plant height of 17.40 cm followed by *Azospirillum* ×VAM (17.26 cm). The role of VAM is

better than PSB at this stage. In F×N×P interaction, maximum plant height was noticed in 100% NPK+ *Azosprillum* +VAM (18.23 cm) followed by 75% NPK+ *Azosprillum* +VAM (18.00 cm) but variation was not significant. Plant height under combination of 50% NPK+ *Azotobacter* +VAM was 17.83 cm which was *at par* with the above treatment combinations. The plant height under 100% NPK (control) was 15.22 cm.

At 60 DAS, the similar trend was noticed. In sole effect of inorganic fertilizer, the increasing trend in plant height (35.29 to 35.74 cm) was recorded with decreasing level of fertilizer up to 75% NPK. Between two nitrogenous bioinoculants *Azospirillum* recorded higher plant height (36.03 cm) as compared to *Azotobacter* (33.85 cm) and in phosphatic bioinoculants higher palnt height (35.87 cm) was recorded in VAM than PSB (34.00 cm).

In respect to F×N interaction, the response of *Azospirillum* was better as compared to *Azotobacter*. The decreasing trend of plant height (34.55 to 32.79 cm) was observed with decreasing level of inorganic fertilizer (100% to 50% NPK) in combination with *Azotobacter* but just reverse trend was in case of *Azospirillum* up to medium level of fertilizer (100% to 75% NPK) *i.e.* maximum plant height of 37.29 cm in 75% NPK followed by 36.03 cm in 100% NPK in combination with *Azospirillum*. In respect of F×P interaction, non- significant variation was observed in the year 2014-15 and in pooled analysis. Both phosphatic bioinoculants showed better response at this stage with 75% NPK and performance of VAM is better than PSB. The maximum plant height of 36.80 cm was recorded in combination of 75% NPK + VAM as compared to 34.69 cm in 75% NPK+PSB. In case of N×P interaction, combination of *Azospirillum* +VAM is more pronounced (37.33 cm) as compared to *Azotobacter* +VAM (34.42 cm). The plant height under *Azotobacter*+ PSB and *Azospirillum*+ PSB were 33.28 and 34.72 cm respectively.

In case of F×N×P interactions, the combination of bioinoculants with 75% NPK was more effective as compared to 100% or 50% NPK. The role of *Azospirillum* and VAM was better as compared to *Azotobacter* and PSB combination. The maximum plant height of 38.62 cm was noticed in 75% NPK+ *Azospirillum*+ VAM followed by 38.17 cm in 100% NPK+ *Azospirillum*+ VAM which was *at par*. The plant height under 100% NPK (control) is 27.64 cm.

At 90 DAS, significant variation was noticed in both sole effect and all types of interaction during both the years and in pooled analysis except F×N×P interaction in both

Table 18. Plant height of fenugreek as influenced by inorganic fertilizers and bioinoculants

Treatments	Plant height (cm)											
	30 DAS			60 DAS			90 DAS			120 DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer												
100% NPK (F_1)	13.62	18.70	16.16	34.50	36.09	35.29	67.39	74.92	71.15	76.71	83.54	80.12
75% NPK (F_2)	13.83	19.75	16.79	34.95	36.54	35.74	65.79	90.65	78.22	73.83	93.51	83.67
50% NPK (F_3)	13.84	19.39	16.61	31.61	35.94	33.78	69.50	73.16	71.33	76.51	80.08	78.30
S.Em. (±)	**0.087**	**0.125**	**0.075**	**0.215**	**0.237**	**0.158**	**0.450**	**0.522**	**0.341**	**0.499**	**0.561**	**0.371**
C.D. (P=0.05)	**NS**	**0.364**	**0.214**	**0.627**	**NS**	**0.450**	**1.313**	**1.523**	**0.969**	**1.457**	**1.636**	**1.056**
Nitrogenous bioinoculants												
Azotobacter (N_1)	14.12	18.42	16.27	33.73	33.97	33.85	64.40	77.84	71.12	72.94	81.15	77.05
Azospirillum (N_2)	13.40	20.14	16.77	33.64	38.41	36.03	70.71	81.31	76.01	78.42	90.27	84.34
S.Em. (±)	**0.071**	**0.102**	**0.061**	**0.175**	**0.193**	**0.129**	**0.367**	**0.426**	**0.278**	**0.408**	**0.458**	**0.303**
C.D. (P=0.05)	**0.207**	**0.297**	**0.174**	**NS**	**0.565**	**0.367**	**1.072**	**1.244**	**0.791**	**1.190**	**1.336**	**0.862**
Phosphatic bioinoculants												
VAM (P_1)	14.23	20.43	17.33	34.41	37.34	35.87	68.90	81.85	75.37	77.24	87.32	82.28
PSB (P_2)	13.29	18.13	15.71	32.96	35.04	34.00	66.22	77.30	71.76	74.12	84.10	79.11
S.Em. (±)	**0.071**	**0.102**	**0.061**	**0.175**	**0.193**	**0.129**	**0.367**	**0.426**	**0.278**	**0.408**	**0.458**	**0.303**
C.D. (P=0.05)	**0.207**	**0.297**	**0.174**	**0.512**	**0.565**	**0.367**	**1.072**	**1.244**	**0.791**	**1.190**	**1.336**	**0.862**

Contd....

VAM= Vesicular arbuscular mycorrhiza PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=Days after sowing; NS= Non siginificant,
N_1=*Azotobacter chroococcum*; N_2=*Azospirillum lipoferum*; P_1= *Glomus fasciculatum*; P_2=*Bacillus polymixa*

Contd.....

Treatments	Plant height (cm)											
	30 DAS			60 DAS			90 DAS			120 DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)												
F_1N_1	13.64	17.61	15.62	35.85	33.26	34.55	63.30	71.45	67.37	75.62	78.17	76.89
F_1N_2	13.60	19.80	16.70	33.15	38.92	36.03	71.48	78.39	74.93	77.80	88.90	83.35
F_2N_1	13.93	18.72	16.32	34.32	34.08	34.20	62.73	86.06	74.39	68.92	86.95	77.94
F_2N_2	13.73	20.77	17.25	35.57	39.00	37.29	68.85	95.24	82.05	78.74	100.07	89.40
F_3N_1	14.81	18.93	16.87	31.02	34.56	32.79	67.18	76.02	71.60	74.29	78.34	76.31
F_3N_2	12.87	19.86	16.36	32.20	37.33	34.76	71.81	70.31	71.06	78.74	81.83	80.28
S.Em. (±)	**0.123**	**0.176**	**0.106**	**0.304**	**0.335**	**0.224**	**0.636**	**0.738**	**0.482**	**0.706**	**0.793**	**0.525**
C.D. (P=0.05)	**0.358**	**0.515**	**0.302**	**0.886**	**0.978**	**0.636**	**1.857**	**2.154**	**1.370**	**2.061**	**2.314**	**1.493**
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)												
F_1P_1	14.89	19.90	17.40	35.07	37.39	36.23	69.81	78.00	73.91	77.70	87.64	82.67
F_1P_2	12.35	17.50	14.92	33.93	34.78	34.36	64.97	71.83	68.40	75.72	79.44	77.58
F_2P_1	14.23	21.56	17.89	36.12	37.48	36.80	66.75	91.22	78.98	77.67	92.85	85.26
F_2P2	13.42	17.94	15.68	33.77	35.61	34.69	64.83	90.08	77.46	69.99	94.17	82.08
F_3P_1	13.57	19.82	16.70	32.04	37.15	34.59	70.14	76.34	73.24	76.35	81.47	78.91
F_3P_2	14.10	18.97	16.53	31.18	34.74	32.96	68.85	69.99	69.42	76.67	78.70	77.69
S.Em. (±)	**0.123**	**0.176**	**0.106**	**0.304**	**0.335**	**0.224**	**0.636**	**0.738**	**0.482**	**0.706**	**0.793**	**0.525**
C.D. (P=0.05)	**0.358**	**0.515**	**0.302**	**0.886**	**NS**	**NS**	**1.857**	**2.154**	**1.370**	**2.061**	**2.314**	**1.493**
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
N_1P_1	14.71	20.08	17.40	34.05	34.78	34.42	65.29	78.37	71.83	75.13	82.08	78.61
N_1P_2	13.53	16.76	15.14	33.41	33.15	33.28	63.52	77.31	70.41	70.75	80.22	75.49
N_2P_1	13.75	20.77	17.26	34.77	39.89	37.33	72.51	85.33	78.92	79.35	92.55	85.95
N_2P_2	13.05	19.51	16.28	32.51	36.93	34.72	68.91	77.29	73.10	77.50	87.98	82.74
S.Em. (±)	**0.100**	**0.144**	**0.087**	**0.248**	**0.274**	**0.183**	**0.519**	**0.603**	**0.394**	**0.577**	**0.647**	**0.429**
C.D. (P=0.05)	**0.292**	**0.420**	**0.247**	**0.724**	**0.799**	**0.519**	**NS**	**1.759**	**1.119**	**1.683**	**1.889**	**NS**

Contd....

Contd....

Treatments	Plant height (cm)											
	30 DAS			60 DAS			90 DAS			120 DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
$F_1N_1P_1$	14.81	18.32	16.57	35.37	33.20	34.29	65.21	72.05	68.63	78.03	80.87	79.45
$F_1N_1P_2$	12.46	16.89	14.68	36.33	33.31	34.82	61.39	70.84	66.12	73.20	75.47	74.34
$F_1N_2P_1$	14.97	21.48	18.23	34.76	41.58	38.17	74.41	83.95	79.18	77.37	94.40	85.89
$F_1N_2P_2$	12.23	18.11	15.17	31.53	36.25	33.89	68.54	72.82	70.68	78.23	83.40	80.82
$F_2N_1P_1$	14.44	21.14	17.79	34.07	35.88	34.98	62.47	85.87	74.17	74.57	86.17	80.37
$F_2N_1P_2$	13.41	16.30	14.86	34.57	32.28	33.43	62.98	86.24	74.61	63.27	87.73	75.50
$F_2N_2P_1$	14.02	21.97	18.00	38.17	39.07	38.62	71.02	96.56	83.79	80.77	99.53	90.15
$F_2N_2P_2$	13.43	19.57	16.50	32.97	38.93	35.95	66.68	93.92	80.30	76.70	100.60	88.65
$F_3N_1P_1$	14.89	20.77	17.83	32.70	35.27	33.99	68.18	77.19	72.69	72.80	79.20	76.00
$F_3N_1P_2$	14.72	17.08	15.90	29.33	33.85	31.59	66.18	74.84	70.51	75.77	77.47	76.62
$F_3N_2P_1$	12.25	18.87	15.56	31.37	39.03	35.20	72.10	75.48	73.79	79.90	83.73	81.82
$F_3N_2P_2$	13.48	20.85	17.17	33.03	35.62	34.33	71.52	65.13	68.33	77.57	79.93	78.75
Control (100% NPK)	12.03	18.40	15.22	28.52	26.76	27.64	65.21	71.83	68.52	69.73	73.80	71.77
Without control												
S.Em. (±)	**0.173**	**0.249**	**0.150**	**0.429**	**0.474**	**0.316**	**0.900**	**1.044**	**0.682**	**0.999**	**1.121**	**0.743**
C.D. (P=0.05)	**0.506**	**0.728**	**0.427**	**1.253**	**1.383**	**0.899**	**NS**	**NS**	**1.938**	**2.915**	**NS**	**2.112**
With control												
S.Em. (±)	**0.128**	**0.184**	**0.111**	**0.097**	**0.172**	**0.077**	**0.662**	**0.768**	**0.502**	**0.735**	**0.825**	**0.547**
C.D. (P=0.05)	**0.372**	**0.536**	**0.314**	**0.282**	**0.502**	**0.218**	**1.933**	**2.242**	**1.426**	**2.145**	**2.408**	**1.554**

years. In sole effect of inorganic fertilizers, maximum plant height (78.22 cm) was recorded in 75% NPK. As regards to nitrogenous bioinoculants, plant height of 76.01 and 71.12 cm were recorded in *Azospirillum* and *Azotobacter* respectively. The plant height of 75.37 cm and 71.76 cm were recorded in sole effects of phosphatic bioinoculants *viz.*, VAM and PSB respectively.

In F×N interaction, nitrogenous bioinoculants with 75% NPK combination proved better as compared to others. The maximum plant height (82.05 cm) was noticed with 75% NPK+ *Azospirillum* followed by 100% NPK+ *Azospirillum* (74.93 cm). In F×P interaction, also similar trend was noticed *i.e.* at 75% NPK. Maximum plant height (78.98 cm) was recorded in 75% NPK+ VAM combination followed by 100% NPK+VAM (73.94 cm). The role of VAM is better than PSB. In N×P interaction, combination of *Azospirillum* and VAM is better than other. Plant height of 78.92 and 71.83 cm were recorded in *Azospirillum*+ VAM and *Azotobacter* +VAM combination.

In F×N×P interaction, both categories of bioinoculants acts in a better way with medium level of inorganic fertilizer *i.e.* at 75% NPK. Maximum plant height (83.79 cm) was recorded in 75% NPK+ *Azospirillum* + VAM followed by 80.30 cm in 75% NPK+ *Azospirillum* + PSB as compared to 68.33 cm under 50% NPK+ *Azospirillum*+ PSB.

At 120 DAS, the significant variation was observed in sole and interaction effects except in pooled analysis of N×P combination and during the year 2014-15 with F×N×P interaction. In case of sole effect of fertilizer level, maximum plant height of 83.67 cm was noticed in 75% NPK as compared to 80.12 cm and 78.30 cm in 100% and 50% NPK respectively. Higher plant height of 84.34 cm was noticed in *Azospirillum* as compared to 77.05 cm in *Azotobacter*. Plant height of 82.28 and 79.11 cm were observed in VAM and PSB respectively. In F×N interaction, maximum plant height (89.40 cm) was recorded in 75% NPK+ *Azospirillum* followed by 83.35 and 80.28 cm in *Azospirillum* with 100% NPK and 50% NPK respectively. Better response noticed in *Azospirillum* as compared to *Azotobacter*. In F×P interaction, VAM also responded better at 75% NPK (85.26 cm) as compared to 100% (82.67 cm) and 50% NPK (78.91 cm) respectively. In N×P combination, *Azospirillum* +VAM recorded maximum plant height (85.95 cm) as compared to *Azotobacter* +PSB (78.61 cm).

In F×N×P interaction, increasing trend was noticed with bioinoculants up to 75% NPK. Maximum plant height of 90.15 cm was observed in 75% NPK+ *Azospirillum* + VAM followed by 75% NPK+ *Azospirillum*+ PSB (88.65 cm) and 100% NPK +

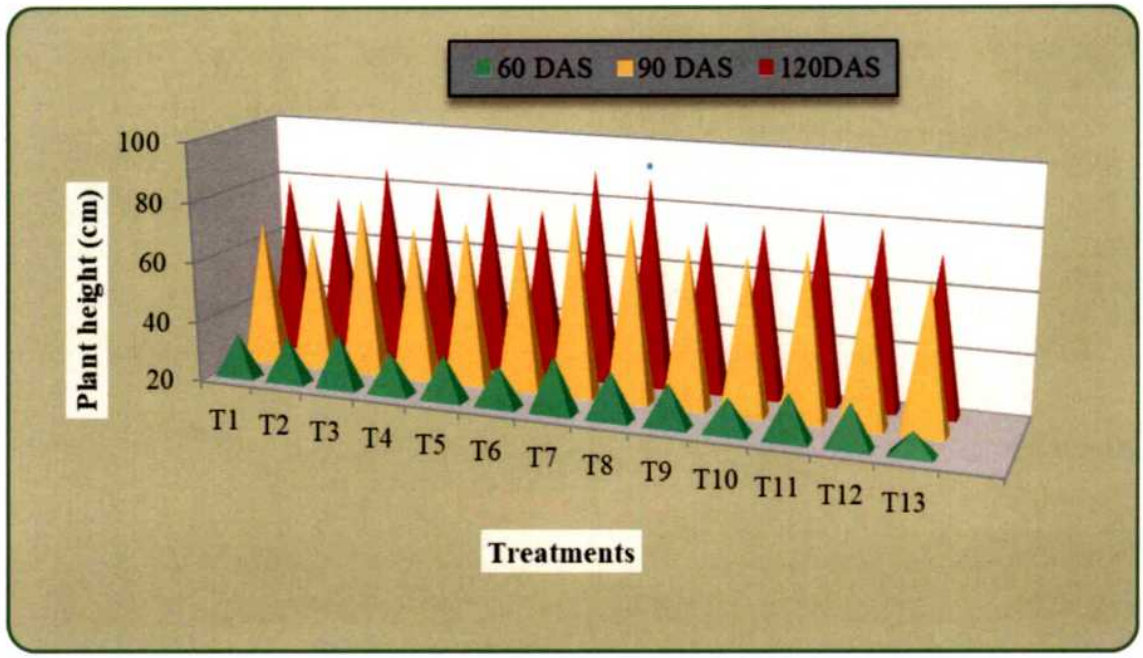


Fig. 14 Plant height under different inorganic and biofertilizer combinations

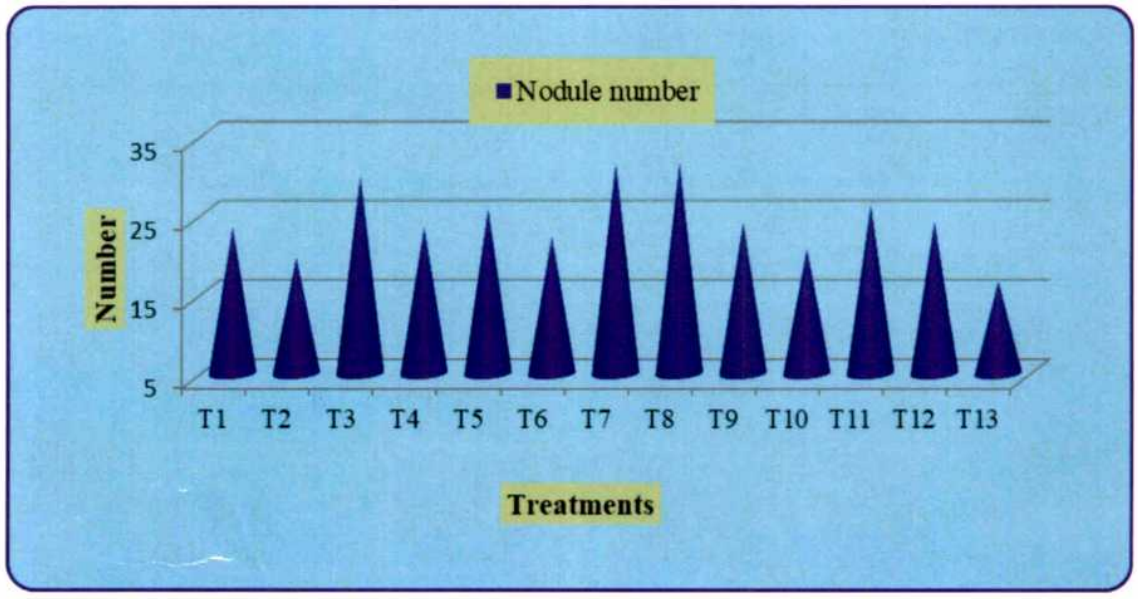


Fig. 15 Number of nodules at 60 DAS under different inorganic and biofertilzer combinations

T_1: NPK 100% + *Azotobacter* + VAM + KM
T_2: NPK 100% + *Azotobacter* + PSB + KM
T_3: NPK 100% + *Azospirillum* + VAM + KM
T_4: NPK 100% + *Azospirillum* + PSB+ KM
T_5: NPK 75% + *Azotobacter* + VAM + KM
T_6: NPK 75% + *Azotobacter* + PSB + KM
T_7: NPK 75% + *Azospirillum*+ VAM+ KM
T_8: NPK 75% + *Azospirillum* + PSB+ KM
T_9: NPK 50% + *Azotobacter* + VAM+ KM
T_{10}: NPK 50% + *Azotobacter* + PSB+ KM
T_{11}: NPK 50% + *Azospirillum*+ VAM+ KM
T_{12}: NPK 50% + *Azospirillum*+ PSB+ KM
T_{13}: Recommended NPK - 20:40:20 kg ha^{-1}

Azospirillum +VAM (85.89 cm) as compared to lowest plant height (71.77 cm) under control (only 100% NPK)

2.1.2 Number of primary branches plant^{-1}

Investigation concerning the number of branches plant^{-1} showed a significant variation in most of the cases both in sole effect and interactions. Non-significant variation noticed in sole effect of nitrogenous bioinoculants during 2014-15, phosphatic bioinoculants during 2013-14 at 60 DAS, F×N interaction during 2013-14 at 30 DAS, F×P interaction in both years and in pooled analysis at 60 DAS and N×P interaction in pooled analysis at 60 DAS and also during 2013-14 at 120 DAS and F×N×P during 2014-15 at 120 DAS (Table 19. and Fig). In sole effect of inorganic fertilizers, increasing trend in number of primary branches was noticed with decreasing level of fertilizer (100% to 75% NPK) up to medium level at all four growth stages. In case of nitrogenous and phosphatic bioinoculants the role of *Azospirillum* and VAM is more as compared to *Azotobacter* and PSB.

At 30 DAS, in respect of fertilizer level the maximum number of primary branches (2.41) was observed with 75% NPK followed by 100% NPK (1.92). The number of branches was 2.20 in *Azospirillum* as compared to 1.94 in *Azotobacter*. In respect of phosphatic bioinoculants the number of primary branches was 2.26 as against 1.87 in case of PSB. In case of F×N interaction, maximum branches of 2.56 was noticed with 75% NPK+ *Azospirillum* combination followed by 75% NPK+ *Azotobacter* (2.26). In case of F×P interaction, the efficacy of bio-inoculant was more with 75% NPK as compared to 100% NPK. The maximum number of branches (2.73) was recorded with 75% NPK+ VAM followed by 100% NPK+ VAM (2.13) combination. In N×P interaction maximum number of branches (2.49) was observed in *Azospirillum*+ VAM combination.

In F×N×P interaction, maximum number of branches (2.99) was observed with 75% NPK+ *Azospirillum* +VAM followed by 100% NPK+*Azospirillum*+ VAM (2.36) as compared to 1.20 in control (100% NPK)

At 60 DAS, in sole effect of fertilizer levels, the highest number of branches was noticed with 75% NPK (4.61). In the sole effect of two types of bioinoculants, higher number of branches with *Azospirillum* (4.46) and VAM (4.43) respectively as compared with *Azotobacter* (4.08) and PSB (4.21). In F×N, highest number of branches (5.02) was

Table 19. Number of primary branches of fenugreek as influenced by inorganic fertilizers and bioinoculants

Treatments	Number of primary branches											
	30 DAS			60 DAS			90 DAS			120 DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer												
100% NPK (F_1)	1.48	2.36	1.92	3.61	5.24	4.42	4.73	5.83	5.28	6.69	7.45	7.07
75% NPK (F_2)	2.11	2.71	2.41	3.80	5.42	4.61	5.43	6.74	6.09	6.69	7.75	7.22
50% NPK (F_3)	1.72	2.02	1.87	3.28	4.26	3.77	4.49	6.09	5.29	5.41	6.58	5.99
S.Em. (±)	**0.011**	**0.022**	**0.012**	**0.028**	**0.032**	**0.021**	**0.032**	**0.041**	**0.026**	**0.041**	**0.047**	**0.031**
C.D. (P=0.05)	**0.032**	**0.064**	**0.035**	**0.082**	**0.094**	**0.060**	**0.094**	**0.120**	**0.074**	**0.120**	**0.138**	**0.088**
Nitrogenous bioinoculants												
Azotobacter (N_1)	1.77	2.11	1.94	3.21	4.94	4.08	4.66	5.89	5.27	5.95	7.16	6.55
Azospirillum (N_2)	1.77	2.62	2.20	3.91	5.00	4.46	5.10	6.55	5.82	6.57	7.37	6.97
S.Em. (±)	**0.009**	**0.018**	**0.010**	**0.023**	**0.026**	**0.017**	**0.026**	**0.034**	**0.021**	**0.033**	**0.039**	**0.025**
C.D. (P=0.05)	**NS**	**0.053**	**0.028**	**0.067**	**NS**	**0.049**	**0.077**	**0.098**	**0.060**	**0.098**	**0.112**	**0.072**
Phosphatic bioinoculants												
VAM (P_1)	1.95	2.57	2.26	3.54	5.12	4.33	5.04	6.40	5.72	6.37	7.42	6.89
PSB (P_2)	1.59	2.16	1.87	3.59	4.83	4.21	4.73	6.04	5.38	6.15	7.11	6.63
S.Em. (±)	**0.009**	**0.018**	**0.010**	**0.023**	**0.026**	**0.017**	**0.026**	**0.034**	**0.021**	**0.033**	**0.039**	**0.025**
C.D. (P=0.05)	**0.026**	**0.053**	**0.028**	**NS**	**0.077**	**0.049**	**0.077**	**0.098**	**0.060**	**0.098**	**0.112**	**0.072**

Contd.....

VAM= Vesicular arbuscular mycorrhiza PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=Days after sowing; NS= Non siginificant,
N_1=*Azotobacter chroococcum*; N_2=*Azospirillum lipoferum*; P_1= *Glomus fasciculatum*; P_2 = *Bacillus polymixa*

Contd.....

Treatments	Number of primary branches											
	30 DAS			60 DAS			90 DAS			120 DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)												
F_1N_1	1.48	2.40	1.94	3.12	5.17	4.15	4.69	5.75	5.22	6.40	7.55	6.98
F_1N_2	1.48	2.32	1.90	4.10	5.30	4.70	4.77	5.91	5.34	6.97	7.35	7.16
F_2N_1	2.09	2.42	2.26	3.22	5.17	4.20	4.77	5.86	5.31	5.87	7.29	6.58
F_2N_2	2.13	3.00	2.56	4.38	5.67	5.02	6.10	7.62	6.86	7.50	8.22	7.86
F_3N_1	1.74	1.49	1.61	3.30	4.49	3.89	4.54	6.05	5.29	5.57	6.64	6.10
F_3N_2	1.71	2.55	2.13	3.26	4.03	3.65	4.44	6.12	5.28	5.24	6.53	5.89
S.Em. (±)	**0.015**	**0.031**	**0.017**	**0.040**	**0.046**	**0.030**	**0.046**	**0.058**	**0.037**	**0.058**	**0.067**	**0.044**
C.D. (P=0.05)	**NS**	**0.091**	**0.049**	**0.116**	**0.133**	**0.085**	**0.133**	**0.170**	**0.104**	**0.169**	**0.195**	**0.124**
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)												
F_1P_1	1.59	2.66	2.13	3.60	5.40	4.50	5.07	6.04	5.56	7.00	8.04	7.52
F_1P_2	1.37	2.06	1.71	3.62	5.07	4.35	4.39	5.61	5.00	6.37	6.87	6.62
F_2P_1	2.53	2.93	2.73	3.78	5.57	4.67	5.60	6.99	6.30	6.64	7.55	7.09
F_2P2	1.69	2.49	2.09	3.82	5.27	4.55	5.27	6.49	5.88	6.74	7.95	7.34
F_3P_1	1.73	2.12	1.92	3.24	4.38	3.81	4.44	6.16	5.30	5.48	6.67	6.07
F_3P_2	1.72	1.93	1.82	3.32	4.14	3.73	4.54	6.01	5.27	5.34	6.50	5.92
S.Em. (±)	**0.015**	**0.031**	**0.017**	**0.040**	**0.046**	**0.030**	**0.046**	**0.058**	**0.037**	**0.058**	**0.067**	**0.044**
C.D. (P=0.05)	**0.045**	**0.091**	**0.049**	**NS**	**NS**	**NS**	**0.133**	**0.170**	**0.104**	**0.169**	**0.195**	**0.124**
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
N_1P_1	1.87	2.20	2.03	3.12	5.14	4.13	4.52	5.91	5.22	6.02	7.12	6.57
N_1P_2	1.67	2.01	1.84	3.30	4.74	4.02	4.80	5.86	5.33	5.87	7.19	6.53
N_2P_1	2.03	2.94	2.49	3.95	5.09	4.52	5.55	6.88	6.21	6.72	7.71	7.21
N_2P_2	1.51	2.30	1.91	3.87	4.91	4.39	4.66	6.21	5.44	6.42	7.02	6.72
S.Em. (±)	**0.013**	**0.025**	**0.014**	**0.032**	**0.037**	**0.024**	**0.037**	**0.048**	**0.030**	**0.047**	**0.054**	**0.036**
C.D. (P=0.05)	**0.037**	**0.074**	**0.040**	**0.095**	**0.109**	**NS**	**0.109**	**0.139**	**0.085**	**NS**	**0.159**	**0.102**

Contd....

Contd....

Treatments	Number of Primary branches											
	30 DAS			60 DAS			90 DAS			120 DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
$F_1N_1P_1$	1.34	2.45	1.90	3.07	5.43	4.25	4.77	5.60	5.19	6.73	7.90	7.32
$F_1N_1P_2$	1.61	2.35	1.98	3.17	4.91	4.04	4.60	5.89	5.25	6.07	7.20	6.64
$F_1N_2P_1$	1.84	2.87	2.36	4.12	5.37	4.75	5.37	6.48	5.93	7.27	8.17	7.72
$F_1N_2P_2$	1.12	1.76	1.44	4.07	5.23	4.65	4.17	5.33	4.75	6.67	6.53	6.60
$F_2N_1P_1$	2.53	2.42	2.47	3.07	5.27	4.17	4.33	6.13	5.23	5.67	6.87	6.27
$F_2N_1P_2$	1.65	2.43	2.04	3.37	5.07	4.22	5.20	5.59	5.40	6.07	7.70	6.89
$F_2N_2P_1$	2.53	3.45	2.99	4.48	5.87	5.18	6.87	7.85	7.36	7.60	8.23	7.92
$F_2N_2P_2$	1.73	2.55	2.14	4.27	5.47	4.87	5.33	7.38	6.36	7.40	8.20	7.80
$F_3N_1P_1$	1.73	1.74	1.73	3.23	4.73	3.98	4.47	6.01	5.24	5.67	6.60	6.14
$F_3N_1P_2$	1.74	1.25	1.50	3.36	4.24	3.80	4.60	6.09	5.35	5.47	6.67	6.07
$F_3N_2P_1$	1.72	2.50	2.11	3.25	4.03	3.64	4.40	6.31	5.36	5.28	6.73	6.01
$F_3N_2P_2$	1.69	2.60	2.15	3.27	4.03	3.65	4.47	5.93	5.20	5.20	6.33	5.77
Control (100% NPK)	0.95	1.45	1.20	2.53	3.90	3.21	4.42	6.12	5.27	5.67	6.27	5.97
Without control												
S.Em. (±)	**0.022**	**0.044**	**0.024**	**0.056**	**0.065**	**0.042**	**0.065**	**0.082**	**0.052**	**0.082**	**0.094**	**0.062**
C.D. (P=0.05)	**0.063**	**0.129**	**0.069**	**0.164**	**0.189**	**0.120**	**0.189**	**0.241**	**0.147**	**0.239**	**NS**	**0.176**
With control												
S.Em. (±)	**0.016**	**0.032**	**0.018**	**0.041**	**0.048**	**0.031**	**0.048**	**0.061**	**0.038**	**0.060**	**0.069**	**0.046**
C.D. (P=0.05)	**0.047**	**0.095**	**0.051**	**0.170**	**0.139**	**0.089**	**0.139**	**0.177**	**0.108**	**0.176**	**0.203**	**0.129**

recorded with F_2N_2 followed by F_1N_2 (4.70). In F×P interaction highest number of primary branches was recorded with 75% NPK+ VAM (4.67). Maximum number of branches (4.52) was observed in *Azospirillum*+ VAM combination. In F×N×P interaction, the highest number of branches (5.18) was recorded with 75% NPK+ *Azospirillum*+ VAM followed by 75% NPK+ *Azospirillum*+ PSB (4.87) against minimum number of branches (3.21) under control (only 100% NPK).

At 90 DAS, maximum primary branches of 6.09, 5.82, and 5.72 were recorded in 75% NPK, *Azospirillum* and VAM respectively *i.e.* sole effects of fertilizers, nitrogenous and phosphatic bioinoculants. In F×N interaction, 75% NPK+ *Azospirillum* recorded maximum number of branches (6.86) followed by 100% NPK+ *Azospirillum* (5.34). In F×P interaction, maximum number of branches (6.30) was recorded with 75% NPK+ VAM followed by 75% NPK+PSB (5.88). In N×P interaction higher number of branches was observed with *Azospirillum*+VAM (6.21) followed by *Azospirillum* +PSB (5.44). In respect to F×N×P interaction, maximum number of branches (7.36) was recorded with 75% NPK +*Azospirillum*+ VAM followed by 75% NPK+ *Azospirillum*+ PSB (6.36). The number of branches were minimum (5.19) in 100% NPK + *Azotobacter*+ VAM.

At 120 DAS, among sole effect of fertilizers, nitrogenous and phosphatic bioinoculants recorded maximum number of primary branches (7.22, 6.97 and 6.89) with respect of 75% NPK, *Azospirillum* and VAM respectively. In F×N interaction, combination of 75% NPK+ *Azospirillum* recorded maximum number of primary branches (7.86) followed by 100% NPK+*Azospirillum* (7.16). In F×P interaction, 100% NPK+ VAM recorded maximum number of primary branches (7.52) followed by 75% NPK+ PSB (7.34). In N×P interaction, maximum number of primary branches (7.21) was recorded in *Azospirillum*+ VAM. In case of F×N×P interaction, maximum number of primary branches (7.92) was recorded with the combination of 75% NPK+*Azospirillum*+VAM followed by 75% NPK+*Azospirillum*+PSB (7.80) and 100% NPK+ *Azospirillum*+ VAM (7.72) but all of them were *at par*. The number of branches in control (100% NPK) plots was 5.97.

2.1.3 Number of secondary branches plant^{-1}

Results presented in Table 20, showed the significant variation in respect of both sole and interaction at 60 DAS except in sole effect of fertilizers during 2014-15, F×N interaction both in the year 2014-15 and pooled analysis and in F×N×P interaction during

Table 20.Number of secondary branches of fenugreek as influenced by inorganic fertilizers and bioinoculants

Treatments	Number of secondary branches								
	60 DAS			90 DAS			120 DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizers									
100% NPK (F_1)	4.53	4.50	4.52	5.70	8.16	6.93	7.74	12.25	10.00
75% NPK (F_2)	4.76	4.37	4.56	6.04	8.78	7.41	7.91	13.53	10.72
50% NPK (F_3)	4.52	4.33	4.42	5.24	6.17	5.70	7.34	13.12	10.23
S.Em. (±)	**0.030**	**0.050**	**0.029**	**0.036**	**0.066**	**0.037**	**0.052**	**0.087**	**0.050**
C.D. (P=0.05)	**0.087**	**NS**	**0.082**	**0.105**	**0.193**	**0.106**	**0.151**	**0.253**	**0.142**
Nitrogenous bioinoculants									
Azotobacter (N_1)	4.47	3.99	4.23	5.50	6.81	6.16	7.15	12.06	9.61
Azospirillum (N_2)	4.74	4.80	4.77	5.82	8.59	7.20	8.18	13.87	11.02
S.Em. (±)	**0.024**	**0.041**	**0.024**	**0.029**	**0.054**	**0.030**	**0.042**	**0.071**	**0.041**
C.D. (P=0.05)	**0.071**	**0.120**	**0.067**	**0.086**	**0.157**	**0.086**	**0.124**	**0.207**	**0.116**
Phosphatic bioinoculants									
VAM (P_1)	4.72	4.72	4.72	5.91	7.98	6.94	7.94	13.50	10.72
PSB (P_2)	4.49	4.08	4.28	5.40	7.43	6.42	7.39	12.43	9.91
S.Em. (±)	**0.024**	**0.041**	**0.024**	**0.029**	**0.054**	**0.030**	**0.042**	**0.071**	**0.041**
C.D. (P=0.05)	**0.071**	**0.120**	**0.067**	**0.086**	**0.157**	**0.086**	**0.124**	**0.207**	**0.116**

Contd.....

VAM= Vesicular arbuscular mycorrhiza PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=Days after sowing; NS= Non siginificant,
N_1=*Azotobacter chroococcum*; N_2=*Azospirillum lipoferum*; P_1= *Glomus fasciculatum*; P_2= *Bacillus polymixa*

Contd.....

Treatments	Number of secondary branches								
	60 DAS			90 DAS			120 days		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)× Nitrogenous bioinoculants (N)									
F_1N_1	4.37	4.14	4.25	5.40	7.17	6.28	7.25	11.60	9.42
F_1N_2	4.70	4.87	4.78	6.00	9.15	7.57	8.24	12.90	10.57
F_2N_1	4.57	4.00	4.28	5.70	7.37	6.53	7.30	11.39	9.34
F_2N_2	4.95	4.73	4.84	6.38	10.20	8.29	8.53	15.67	12.10
F_3N_1	4.47	3.84	4.15	5.40	5.91	5.65	6.91	13.20	10.06
F_3N_2	4.57	4.82	4.69	5.08	6.43	5.75	7.77	13.04	10.40
S.Em. (±)	**0.042**	**0.071**	**0.041**	**0.051**	**0.093**	**0.053**	**0.073**	**0.123**	**0.071**
C.D. (P=0.05)	**0.123**	**NS**	**NS**	**0.149**	**0.273**	**0.150**	**NS**	**0.358**	**0.201**
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)									
F_1P_1	4.50	4.70	4.60	6.17	7.70	6.93	8.24	13.20	10.72
F_1P_2	4.57	4.30	4.43	5.24	8.61	6.92	7.25	11.30	9.27
F_2P_1	4.85	4.50	4.68	6.50	9.44	7.97	8.00	14.22	11.11
F_2P2	4.67	4.23	4.45	5.58	8.13	6.85	7.83	12.83	10.33
F_3P_1	4.80	4.95	4.88	5.07	6.80	5.93	7.60	13.08	10.34
F_3P_2	4.24	3.70	3.97	5.40	5.54	5.47	7.08	13.16	10.12
S.Em. (±)	**0.042**	**0.071**	**0.041**	**0.051**	**0.093**	**0.053**	**0.073**	**0.123**	**0.071**
C.D. (P=0.05)	**0.123**	**0.208**	**0.117**	**0.149**	**0.273**	**0.150**	**0.214**	**0.358**	**0.201**
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)									
N_1P_1	4.44	4.14	4.29	5.58	7.06	6.32	7.47	12.57	10.02
N_1P_2	4.49	3.84	4.17	5.41	6.56	5.99	6.83	11.56	9.19
N_2P_1	4.99	5.30	5.14	6.24	8.89	7.56	8.42	14.43	11.42
N_2P_2	4.49	4.31	4.40	5.39	8.30	6.85	7.94	13.30	10.62
S.Em. (±)	**0.034**	**0.058**	**0.033**	**0.042**	**0.076**	**0.043**	**0.060**	**0.100**	**0.058**
C.D. (P=0.05)	**0.101**	**0.170**	**0.095**	**0.121**	**NS**	**0.122**	**NS**	**NS**	**NS**

Contd....

Contd....

Treatments	Number of secondary branches								
	60 DAS			90 DAS			120 days		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)× Nitrogenous bio inoculnats (N)× Phosphatic bioinoculants (P)									
$F_1N_1P_1$	3.93	4.20	4.07	5.43	6.46	5.95	7.82	12.13	9.98
$F_1N_1P_2$	4.80	4.07	4.44	5.37	7.87	6.62	6.67	11.07	8.87
$F_1N_2P_1$	5.07	5.20	5.14	6.90	8.93	7.92	8.65	14.27	11.46
$F_1N_2P_2$	4.33	4.53	4.43	5.10	9.36	7.23	7.82	11.53	9.68
$F_2N_1P_1$	4.53	3.87	4.20	6.10	8.27	7.19	7.46	11.84	9.65
$F_2N_1P_2$	4.60	4.13	4.36	5.30	6.46	5.88	7.13	10.93	9.03
$F_2N_2P_1$	5.17	5.13	5.15	6.90	10.60	8.75	8.53	16.60	12.57
$F_2N_2P_2$	4.73	4.33	4.53	5.85	9.80	7.83	8.53	14.73	11.63
$F_3N_1P_1$	4.87	4.34	4.61	5.22	6.46	5.84	7.13	13.73	10.43
$F_3N_1P_2$	4.07	3.33	3.70	5.57	5.35	5.46	6.69	12.67	9.68
$F_3N_2P_1$	4.73	5.56	5.15	4.92	7.13	6.03	8.07	12.42	10.25
$F_3N_2P_2$	4.40	4.07	4.24	5.23	5.73	5.48	7.47	13.65	10.56
Control (100% NPK)	3.93	4.15	4.04	4.42	5.80	5.11	7.53	11.95	9.74
Without control									
S.Em. (±)	**0.060**	**0.101**	**0.058**	**0.072**	**0.132**	**0.074**	**0.104**	**0.174**	**0.100**
C.D. (P=0.05)	**0.174**	**NS**	**0.165**	**0.210**	**0.386**	**0.212**	**NS**	**0.507**	**0.284**
With control									
S.Em. (±)	**0.044**	**0.074**	**0.043**	**0.053**	**0.097**	**0.055**	**0.076**	**0.128**	**0.074**
C.D. (P=0.05)	**0.128**	**0.217**	**0.121**	**0.155**	**0.284**	**0.156**	**0.223**	**0.373**	**0.209**

2014-15. Like primary branches, the similar trend was also noticed in number of secondary branches. In respect of sole effect of fertilizers, maximum number of branches (4.56) was noticed at 75% NPK. In nitrogenous bioinoculants, *Azospirillum* recorded 4.77 branches as compared to 4.23 in *Azotobacter*. In phosphatic bioinoculants, 4.72 numbers of secondary branches was noticed in VAM as compared to PSB. In F×N interaction, maximum number of branches (4.84) was observed in 75% NPK+ *Azospirillum* followed by 100% NPK+ *Azospirillum* (4.78). In F×P interaction, maximum number of branches (4.88) was noticed in 50% NPK+ VAM followed by 75% NPK+ VAM (4.68). As regard to N×P interaction, *Azospirillum*+ VAM combination was more effective than others. In F×N×P interaction, the combination of 75% NPK+ *Azospirillum*+ VAM (5.15), 50% NPK+ *Azospirillum*+ VAM (5.15) and 100% NPK+ *Azospirillum*+ VAM (5.14) were similar but they proved better as compared to other. The number of branches under control was 4.04.

At 90 DAS, in sole effect of fertilizers, 75% NPK recorded highest number of secondary branches (7.41) as compared to 100% NPK (6.93) and 50% NPK (5.70). In respect of nitrogenous bioinoculants, 7.20 numbers of branches were recorded under *Azospirillum* against 6.16 in *Azotobacter*. Regarding phosphatic bioinoculants, VAM is more efficient (6.94) as against PSB (6.42). In case of F×N interaction, increasing trend in number of branches was noticed with decreasing trend of fertilizers level from 100% to 75% NPK. Maximum number of branches 8.29 was recorded in 75% NPK+ *Azospirillum* followed by 100% NPK+ *Azospirillum* (7.57). In F×P combination, the highest number of branches (7.97) was recorded with 75% NPK+ *Azospirillum* followed by 100% NPK+ *Azospirillum* (6.93). Both F×N and F×P interactions indicated that reduced level of inorganic fertilizer up to 75% is more congenial for the activity of bioinoculants. In case of N×P highest number of branches (7.56) was noticed with *Azospirillum*+ VAM combination. In F×N×P interaction, maximum number of branches (8.75) was recorded in 75% NPK+ *Azosprillum*+ VAM followed by 100% NPK+ *Azosprillum*+ VAM (7.92) against lowest number of branches under control (5.11).

At 120 days, in respect of sole effect of fertilizers, maximum number (10.72) was recorded in 75% NPK followed by 50% NPK (10.23) and 100% NPK (10.00). Regarding nitrogenous bioinoculants the number of branches under *Azospirillum* and *Azotobacter* were 11.02 and 9.61 respectively. Sole effect of VAM exhibited 10.72 numbers of branches as compared to 9.91 in PSB. In respect of F×N interaction, maximum number of branches (12.10) was recorded in 75% NPK+ *Azospirillum* followed by 100% NPK

+*Azospirillum* (10.57). In case of F×P, maximum number of branches (11.11) was recorded in 75% NPK+VAM followed by 100% NPK + VAM (10.72). As per N×P interaction, 11.42 numbers of branches was recorded in *Azospirillum*+ VAM followed by *Azospirillum* + PSB (10.62). In F×N×P combination, 75% NPK+ *Azospirillum*+ VAM proved best (12.57) followed by 75% NPK+ *Azospirillum*+ PSB (11.63) as compared to lowest number of secondary branches (8.87) in 100% NPK+ *Azotobacter*+ PSB

2.1.4 Fresh weight of plant

Results presented in Table 21 showed significant variations in respect of individual and interaction at both 60 and 90 DAS except in F×P interaction in 2013-14 at 90 DAS and N×P interaction during 2013-14 at 60 DAS and F×N×P interaction during 2013-14 at 90 DAS. Maximum fresh weight of 26.50 g was recorded with 75% NPK followed by 100% NPK (24.31 g) and 50% NPK (21.28 g). In the sole effect of nitrogenous bioinoculants, *Azospirillum* and *Azotobacter* recorded 25.90 and 22.16 g fresh weight. In between VAM and PSB, higher fresh weight (25.62 g) was recorded in VAM as against 22.44 g with PSB. In respect of F×N interaction, the role of nitrogenous bioinoculants was more pronounced at medium level of inorganic fertilizer and maximum fresh weight was obtained with combination of 75% NPK+ *Azospirillum* (29.30 g) followed by 100% NPK+ *Azospirillum* (25.81 g). In F×P interaction, highest fresh weight was noticed in 75% NPK + VAM combination (27.80 g) followed by 100% NPK+ VAM (26.53 g). In N×P interaction, 27.65 g fresh weight was recorded with *Azospirillum*+ VAM followed by *Azospirillum*+ PSB. In F×N×P interaction, highest fresh weight of 30.77 g was observed at 75% NPK+ *Azospirillum*+ VAM followed by 100% NPK+ *Azospirillum*+ VAM (28.45 g) and 75% NPK+ *Azosppirillum* + PSB (27.83 g) as compared to 19.42 g in control (100% NPK).

At 90 DAS, in respect of sole effect of fertilizers, maximum fresh weight (60.14 g) of plant was recorded with 75% NPK followed by 100% NPK (56.99 g) and 50% NPK (52.52 g). Regarding nitrogenous bioinoculants, *Azospirillum* recorded fresh weight of 58.47 g as compared to *Azotobacter* (54.62 g). Between VAM and PSB, higher fresh weight (57.67 g) was noticed in VAM as compared to 55.43 g under PSB. In F×N interaction, a positive response in increasing the fresh weight was noticed with decreasing the fertilizer level up to 75% NPK. The maximum fresh weight (63.26 g) was observed in 75% NPK+ *Azospirillum* followed by 100% NPK+ *Azospirillum* (58.85 g). In respect of F×P interaction, maximum fresh weight (61.84 g) was recorded in

Table 21. Fresh and dry weight plant^{-1} of fenugreek as influenced by inorganic fertilizers and bioinoculants

Treatments	Fresh weight (g)						Dry weight (g)					
	60 DAS			90 DAS			60 DAS			90 DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer												
100% NPK (F_1)	21.40	27.23	24.31	53.96	60.02	56.99	4.57	5.71	5.14	11.52	12.81	12.16
75% NPK (F_2)	25.16	27.84	26.50	57.59	62.68	60.14	5.42	5.89	5.65	12.26	13.34	12.80
50% NPK (F_3)	20.63	21.94	21.28	48.97	56.07	52.52	4.24	4.31	4.28	10.11	11.76	10.94
S.Em. (±)	**0.149**	**0.170**	**0.112**	**0.354**	**0.396**	**0.263**	**0.032**	**0.036**	**0.024**	**0.076**	**0.084**	**0.056**
C.D. (P=0.05)	**0.435**	**0.495**	**0.318**	**1.033**	**1.155**	**0.747**	**0.093**	**0.105**	**0.068**	**0.221**	**0.247**	**0.160**
Nitrogenous bioinoculants												
Azotobacter (N_1)	21.06	23.27	22.16	51.93	57.32	54.62	4.35	4.72	4.53	10.70	11.95	11.32
Azospirillum (N_2)	23.72	28.07	25.90	55.08	61.86	58.47	5.13	5.88	5.51	11.90	13.32	12.61
S.Em. (±)	**0.122**	**0.139**	**0.091**	**0.289**	**0.323**	**0.215**	**0.026**	**0.029**	**0.019**	**0.062**	**0.069**	**0.046**
C.D. (P=0.05)	**0.355**	**0.404**	**0.259**	**0.843**	**0.943**	**0.610**	**0.076**	**0.086**	**0.055**	**0.180**	**0.201**	**0.130**
Phosphatic bioinoculants												
VAM (P_1)	24.07	27.17	25.62	55.26	60.08	57.67	5.15	5.61	5.38	11.76	12.77	12.26
PSB (P_2)	20.71	24.17	22.44	51.76	59.10	55.43	4.34	4.99	4.66	10.83	12.51	11.67
S.Em. (±)	**0.122**	**0.139**	**0.091**	**0.289**	**0.323**	**0.215**	**0.026**	**0.029**	**0.019**	**0.062**	**0.069**	**0.046**
C.D. (P=0.05)	**0.355**	**0.404**	**0.259**	**0.843**	**0.943**	**0.610**	**0.076**	**0.086**	**0.055**	**0.180**	**0.201**	**0.130**

Contd.....

VAM= Vesicular arbuscular mycorrhiza PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=days after sowing; NS= Non siginificant,
N_1=*Azotobacter chroococcum*; N_2=*Azospirillum lipoferum*; P_1= *Glomus fasciculatum*; P_2 =*Bacillus polymixa*

Contd.....

Treatments	Fresh weight (g)						Dry weight (g)					
	60 DAS			90 DAS			60 DAS			90 DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)												
F_1N_1	20.51	25.13	22.82	52.89	57.37	55.13	4.35	5.21	4.78	11.21	12.22	11.71
F_1N_2	22.29	29.33	25.81	55.04	62.66	58.85	4.79	6.21	5.50	11.83	13.41	12.62
F_2N_1	23.26	24.14	23.70	55.23	58.79	57.01	4.82	4.88	4.85	11.27	12.03	11.65
F_2N_2	27.05	31.55	29.30	59.95	66.58	63.26	6.02	6.90	6.46	13.25	14.66	13.96
F_3N_1	19.42	20.54	19.98	47.69	55.79	51.74	3.89	4.07	3.98	9.62	11.62	10.62
F_3N_2	21.84	23.35	22.59	50.25	56.36	53.30	4.60	4.55	4.57	10.61	11.91	11.26
S.Em. (±)	**0.211**	**0.240**	**0.158**	**0.500**	**0.560**	**0.372**	**0.045**	**0.051**	**0.034**	**0.107**	**0.119**	**0.079**
C.D. (P=0.05)	**0.615**	**0.700**	**0.449**	**1.461**	**1.634**	**1.056**	**0.132**	**0.148**	**0.096**	**0.312**	**0.349**	**0.226**
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)												
F_1P_1	23.47	29.59	26.53	55.53	60.83	58.18	5.03	6.32	5.68	11.91	13.02	12.46
F_1P_2	19.32	24.86	22.09	52.40	59.20	55.80	4.10	5.09	4.60	11.13	12.61	11.87
F_2P_1	26.69	28.91	27.80	59.43	64.24	61.84	5.84	6.16	6.00	12.75	13.82	13.28
F_2P2	23.63	26.78	25.20	55.75	61.13	58.44	5.00	5.61	5.30	11.77	12.87	12.32
F_3P_1	22.07	23.00	22.53	50.81	55.17	52.99	4.58	4.36	4.47	10.63	11.46	11.04
F_3P_2	19.19	20.88	20.04	47.13	56.98	52.05	3.91	4.26	4.08	9.60	12.06	10.83
S.Em. (±)	**0.211**	**0.240**	**0.158**	**0.500**	**0.560**	**0.372**	**0.045**	**0.051**	**0.034**	**0.107**	**0.119**	**0.079**
C.D. (P=0.05)	**0.615**	**0.700**	**0.449**	**NS**	**1.634**	**1.056**	**0.132**	**0.148**	**0.096**	**NS**	**0.349**	**0.226**
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
N_1P_1	22.73	24.45	23.59	53.24	55.96	54.60	4.76	5.05	4.91	11.09	11.69	11.39
N_1P_2	19.39	22.08	20.74	50.62	58.67	54.65	3.94	4.38	4.16	10.30	12.22	11.26
N_2P_1	25.41	29.88	27.65	57.27	64.20	60.73	5.54	6.17	5.86	12.42	13.84	13.13
N_2P_2	22.03	26.27	24.15	52.89	59.53	56.21	4.73	5.59	5.16	11.37	12.80	12.09
S.Em. (±)	**0.172**	**0.196**	**0.129**	**0.409**	**0.457**	**0.303**	**0.037**	**0.042**	**0.027**	**0.087**	**0.098**	**0.065**
C.D. (P=0.05)	**NS**	**0.572**	**0.367**	**1.193**	**1.334**	**0.862**	**NS**	**NS**	**NS**	**NS**	**0.285**	**0.184**

Contd....

Contd....

Treatments	Fresh weight (g)						Dry weight (g)					
	60 DAS			90 DAS			60 DAS			90 DAS		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
$F_1N_1P_1$	22.51	26.72	24.62	54.13	57.15	55.64	4.79	5.71	5.25	11.52	12.23	11.88
$F_1N_1P_2$	18.50	23.53	21.02	51.64	57.59	54.62	3.90	4.70	4.30	10.89	12.20	11.55
$F_1N_2P_1$	24.43	32.46	28.45	56.92	64.51	60.72	5.27	6.93	6.10	12.29	13.80	13.05
$F_1N_2P_2$	20.14	26.19	23.17	53.15	60.81	56.98	4.30	5.48	4.89	11.37	13.01	12.19
$F_2N_1P_1$	24.35	25.29	24.82	56.32	60.44	58.38	5.16	5.16	5.16	11.60	12.51	12.06
$F_2N_1P_2$	22.17	22.99	22.58	54.13	57.14	55.64	4.47	4.59	4.53	10.93	11.54	11.24
$F_2N_2P_1$	29.02	32.52	30.77	62.54	68.04	65.29	6.51	7.16	6.84	13.89	15.13	14.51
$F_2N_2P_2$	25.08	30.57	27.83	57.36	65.11	61.24	5.52	6.63	6.08	12.61	14.19	13.40
$F_3N_1P_1$	21.34	21.35	21.35	49.28	50.29	49.79	4.32	4.29	4.31	10.16	10.32	10.24
$F_3N_1P_2$	17.50	19.72	18.61	46.10	61.28	53.69	3.46	3.84	3.65	9.08	12.91	11.00
$F_3N_2P_1$	22.79	24.65	23.72	52.34	60.04	56.19	4.83	4.43	4.63	11.09	12.60	11.85
$F_3N_2P_2$	20.88	22.04	21.46	48.16	52.67	50.42	4.36	4.67	4.52	10.12	11.21	10.67
Control (100% NPK)	19.70	19.13	19.42	46.15	55.27	50.71	3.90	3.74	3.82	9.13	10.77	9.95
Without control												
S.Em. (±)	**0.298**	**0.339**	**0.224**	**0.708**	**0.792**	**0.526**	**0.064**	**0.072**	**0.048**	**0.151**	**0.169**	**0.112**
C.D. (P=0.05)	**0.870**	**0.991**	**0.635**	**NS**	**2.311**	**1.494**	**0.187**	**0.210**	**0.135**	**NS**	**0.493**	**0.319**
With control												
S.Em. (±)	**0.219**	**0.250**	**0.165**	**0.521**	**0.583**	**0.387**	**0.047**	**0.053**	**0.035**	**0.111**	**0.124**	**0.083**
C.D. (P=0.05)	**0.640**	**0.729**	**0.468**	**1.520**	**1.701**	**1.099**	**0.137**	**0.154**	**0.100**	**0.325**	**0.363**	**0.235**

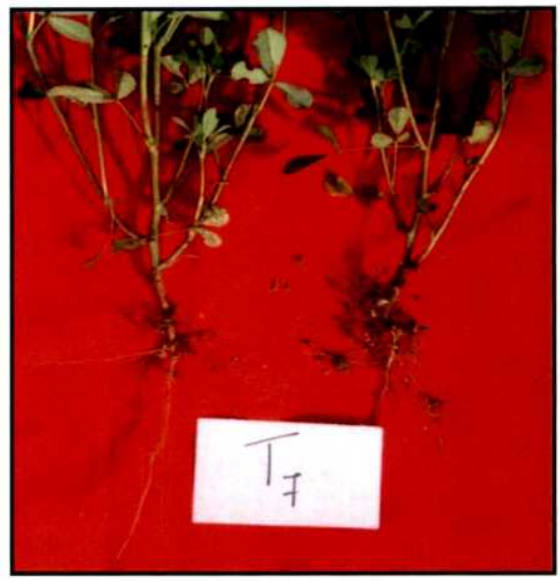
combination of 75% NPK+ VAM followed by 75% NPK+ PSB (58.44 g). In N×P interaction, fresh weight ranged from 54.60 g to 60.73 g. Maximum fresh weight (60.73 g) was recorded in *Azospirillum*+ VAM followed by *Azospirillum*+ PSB (56.21 g). In F×N×P combination, maximum fresh weight (65.29 g) recorded in 75% NPK+ *Azospirillum*+ VAM followed by 75% NPK+ *Azospirillum*+ PSB (61.24 g) as compared to 50.71 g under control (100% NPK).

2.1.5 Dry weight of the plant

Perusal of data presented in Table 21, clearly demonstrated that dry weight varied significantly in individual factors and their interactions during both the years of experimental data and also in pooled analysis. The non-significant variation observed in F×P combination during 2013-14 at 90 DAS and for N×P interaction at 60 DAS during both years and their pooled analysis and also at 90 DAS during 2013-14. In respect to the sole effect of inorganic fertilizers, maximum dry weight (5.65 g) was recorded at 60 DAS with the effect of 75% NPK. Among bioinoculants, maximum dry weight 5.51 g and 5.38 g were recorded with *Azospirillum* and VAM respectively. As regard to F×N interaction, maximum dry weight (6.46 g) was noticed with 75% NPK+ *Azospirillum* followed by 100% NPK+ *Azospirillum* (5.50 g). In F×P interaction, 75% NPK+ VAM recorded maximum dry weight (6.00 g) followed by 100% NPK+ VAM (5.68 g). In N×P combination, *Azospirillum* and VAM combination was more pronounced (5.86 g) as compared to other. In F×N×P interaction, combination of 75% NPK+ *Azospirillum*+ VAM recorded maximum dry weight (6.84 g) as compared to lowest dry weight (3.65 g) recorded in 50% NPK+ *Azotobacter*+ PSB.

At 90 DAS, in respect of sole effect of inorganic fertilizers, nitrogenous and phosphatic bioinoculanats, maximum dry weight of 12.80 g, 12.61 g and 12.26 g were observed in 75% NPK, *Azospirillum* and VAM respectively. In F×N interaction, dry weight ranged from 10.62 to 13.96 g. Maximum dry weight was recorded with 75% NPK+ *Azospirillum*. But in F×P interaction, highest dry weight (13.28 g) was observed with 75% NPK+ VAM followed by 100% NPK+ VAM (12.46 g). In N×P interaction, maximum dry weight (13.13 g) was noticed in *Azospirillum*+ VAM followed by *Azospirillum* +PSB (12.09 g). In F×N×P combination, maximum dry weight (14.51 g) was recorded in 75% NPK+ *Azospirillum*+ VAM followed by 75% NPK+ *Azospirillum*+ PSB (13.40 g) as compared to lowest dry weight (9.95 g) under control (100% NPK). These findings clearly indicated that bioinoculants may acts properly in combination

100% NPK+ *Azos.*+ VAM+K-mobiliser



75% NPK+ *Azos.*+ VAM+K-mobiliser

75% NPK+ *Azos.*+ PSB+K-mobiliser

100% NPK

Plate 20. Nodules under different treatment combinations

with medium level of fertilizers (75% NPK) as compared to higher (100%) and lower (50%) level.

2.1.6 Nodule number plant^{-1}

Data presented in Table 25. and Fig. 15 clearly indicated the significant variation in the sole and interaction effects during both the years and in pooled analysis. In respect of individual effect of different fertilizer level the maximum nodule number of 27.82 was noticed with 75% NPK followed by 100% NPK (24.12) and 50% NPK (23.84) and later two were *at par*. Between two nitrogenous bioinoculants wide variation was noticed. The nodule number was 27.85 and 22.67 under *Azospirillum* and *Azotobacter* respectively. The sole effect of VAM and PSB exhibited the nodule number of 26.86 and 23.66 respectively. In F×N interaction, combination of *Azospirillum* with different levels of inorganic NPK showed formation of more number of nodules as compare to *Azotobacter*. Maximum nodules of 31.59 was noticed in 75% NPK+ *Azospirillum* followed by 100% NPK + *Azospirillum* (26.71) and 50% NPK + *Azospirillum* (25.25) whereas in *Azotobacter* with different levels of inorganic fertilizer the nodule number ranged between 21.53 to 24.06. As regard to F×P interaction, maximum number of nodules observed in 75% NPK+ VAM (28.67) followed by 75% NPK+ PSB (26.97). In case of N×P interaction, highest number of nodules was recorded in combination of *Azospirillum* + VAM (29.27) and lowest recorded in *Azotobacter* + PSB (20.90). In F×N×P interaction, the number of nodules in the range of 16.61 to 31.61 was recorded. Highest nodule was recorded in combination of 75% RDF+ *Azospirillum*+ PSB (31.61) followed by 31.56 number of nodules in 75% RDF+ *Azospirillum*+ VAM (31.56) as compared to lowest number of nodules (16.61) was recorded in control (100% NPK).

2.2 YIELD PARAMETERS

Different yield parameters like days required for flower initiation, 50% flowering, pod initiation, 50% pod initiation, pod length, number of seeds pod^{-1}, number of pods plant^{-1}, test weight and seed yield showed variation in different treatment combinations.

2.2.1 Days required for first flower initiation

As per pooled analysis, significant variations were observed in sole effect of inorganic fertilizer treatment. Delayed initiation takes place in case of 50% NPK. In F×N interaction, the significant variations noticed during 2014-15 and in pooled analysis.

Table 22.Number of days taken for flowering to pod initiation in fenugreek as influenced by inorganic fertilizers and bioinoculants

Treatments	Number of days required for											
	First flowering			50% flowering			First pod initiation			50% pod initiation		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer												
100% NPK (F_1)	39.70	46.76	43.23	42.87	54.92	48.90	44.02	52.95	48.48	50.37	67.85	59.11
75% NPK (F_2)	39.70	46.13	42.92	42.05	55.37	48.71	43.20	52.26	47.73	50.20	67.40	58.80
50% NPK (F_3)	41.22	46.73	43.97	43.49	57.29	50.39	43.71	53.15	48.43	51.25	68.05	59.65
S.Em. (±)	**0.264**	**0.306**	**0.200**	**0.280**	**0.369**	**0.229**	**0.290**	**0.347**	**0.224**	**0.332**	**0.443**	**0.274**
C.D. (p=0.05)	**0.770**	**NS**	**0.568**	**0.818**	**1.077**	**0.652**	**NS**	**NS**	**0.636**	**NS**	**NS**	**NS**
Nitrogenous bioinoculants												
Azotobacter (N_1)	40.11	46.53	43.32	43.08	55.59	49.34	43.66	52.71	48.18	50.60	67.79	59.19
Azospirillum (N_2)	40.31	46.55	43.43	42.52	56.13	49.33	43.62	52.86	48.24	50.61	67.74	59.17
S.Em. (±)	**0.215**	**0.249**	**0.163**	**0.229**	**0.301**	**0.187**	**0.237**	**0.283**	**0.183**	**0.271**	**0.362**	**0.224**
C.D. (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Phosphatic bioinoculants												
VAM (P_1)	39.76	46.92	43.34	42.63	55.89	49.26	43.52	53.07	48.30	50.72	68.07	59.39
PSB (P_2)	40.66	46.16	43.41	42.98	55.83	49.40	43.76	52.50	48.13	50.49	67.46	58.97
S.Em. (±)	**0.215**	**0.249**	**0.163**	**0.229**	**0.301**	**0.187**	**0.237**	**0.283**	**0.183**	**0.271**	**0.362**	**0.224**
C.D. (p=0.05)	**0.629**	**0.728**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Contd.....

VAM= Vesicular arbuscular mycorrhiza PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=Days after sowing; NS= Non siginificant,
N_1=*Azotobacter chroococcum*; N_2=*Azospirillum lipoferum*; P_1= *Glomus fasciculatum*; P_2= *Bacillus polymixa*

Contd.....

Treatments	Number of days required for											
	First flowering			50% flowering			First pod initiation			50% pod initiation		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)												
F_1N_1	39.58	46.34	42.96	43.06	54.60	48.83	44.29	52.72	48.50	50.40	67.82	59.11
F_1N_2	39.82	47.17	43.50	42.68	55.25	48.96	43.75	53.17	48.46	50.34	67.89	59.12
F_2N_1	39.35	47.26	43.30	42.23	55.50	48.87	42.86	53.00	47.93	50.36	68.16	59.26
F_2N_2	40.06	45.00	42.53	41.88	55.25	48.56	43.55	51.51	47.53	50.04	66.63	58.33
F_3N_1	41.39	46.00	43.69	43.96	56.67	50.31	43.85	52.40	48.12	51.04	67.40	59.22
F_3N_2	41.05	47.47	44.26	43.02	57.90	50.46	43.57	53.90	48.73	51.45	68.70	60.07
S.Em. (±)	**0.373**	**0.432**	**0.283**	**0.396**	**0.522**	**0.324**	**0.410**	**0.490**	**0.316**	**0.47**	**0.63**	**0.39**
C.D. (P=0.05)	**NS**	**1.261**	**0.803**	**NS**	**NS**	**NS**	**NS**	**1.432**	**NS**	**NS**	**NS**	**NS**
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)												
F_1P_1	39.00	47.01	43.01	42.59	53.84	48.22	43.52	52.92	48.22	50.21	68.15	59.18
F_1P_2	40.40	46.50	43.45	43.15	56.00	49.58	44.52	52.98	48.75	50.53	67.56	59.04
F_2P_1	39.87	46.59	43.23	42.26	55.17	48.71	43.58	52.50	48.04	50.97	67.81	59.39
F_2P2	39.54	45.67	42.60	41.85	55.58	48.71	42.82	52.01	47.42	49.43	66.99	58.21
F_3P_1	40.40	47.17	43.78	43.04	58.66	50.85	43.47	53.79	48.63	50.98	68.25	59.62
F_3P_2	42.04	46.30	44.17	43.93	55.92	49.92	43.95	52.50	48.23	51.51	67.84	59.68
S.Em. (±)	**0.373**	**0.432**	**0.283**	**0.396**	**0.522**	**0.324**	**0.410**	**0.490**	**0.316**	**0.470**	**0.627**	**0.388**
C.D. (P=0.05)	**1.089**	**NS**	**NS**	**NS**	**1.524**	**0.922**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
N_1P_1	40.02	46.62	43.32	43.35	55.62	49.48	43.96	52.65	48.31	51.09	67.97	59.53
N_1P_2	40.19	46.44	43.32	42.82	55.56	49.19	43.36	52.76	48.06	50.10	67.61	58.86
N_2P_1	39.49	47.22	43.36	41.91	56.16	49.03	43.08	53.49	48.29	50.35	68.17	59.26
N_2P_2	41.13	45.87	43.50	43.14	56.10	49.62	44.16	52.23	48.20	50.87	67.31	59.09
S.Em. (±)	**0.305**	**0.353**	**0.231**	**0.323**	**0.426**	**0.265**	**0.334**	**0.400**	**0.258**	**0.384**	**0.512**	**0.317**
C.D. (P=0.05)	**0.889**	**NS**	**NS**	**0.944**	**NS**	**NS**	**0.976**	**NS**	**NS**	**NS**	**NS**	**NS**

Contd....

Contd....

Treatments	Number of days required for											
	First flowering			50% flowering			First pod initiation			50% pod initiation		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
$F_1N_1P_1$	39.64	46.35	43.00	43.56	53.52	48.54	44.92	52.16	48.54	51.26	67.96	59.61
$F_1N_1P_2$	39.52	46.33	42.93	42.56	55.67	49.12	43.65	53.28	48.47	49.53	67.67	58.60
$F_1N_2P_1$	38.36	47.67	43.02	41.62	54.16	47.89	42.12	53.67	47.90	49.16	68.33	58.75
$F_1N_2P_2$	41.28	46.67	43.98	43.74	56.33	50.04	45.38	52.67	49.03	51.52	67.45	59.49
$F_2N_1P_1$	40.17	47.84	44.01	42.92	54.67	48.80	43.59	53.33	48.46	51.43	68.68	60.06
$F_2N_1P_2$	38.53	46.67	42.60	41.54	56.33	48.94	42.12	52.67	47.40	49.28	67.64	58.46
$F_2N_2P_1$	39.57	45.33	42.45	41.59	55.67	48.63	43.57	51.67	47.62	50.50	66.93	58.72
$F_2N_2P_2$	40.54	44.67	42.61	42.16	54.82	48.49	43.52	51.35	47.44	49.57	66.33	57.95
$F_3N_1P_1$	40.26	45.67	42.97	43.56	58.67	51.12	43.38	52.46	47.92	50.58	67.26	58.92
$F_3N_1P_2$	42.51	46.33	44.42	44.35	54.67	49.51	44.32	52.33	48.33	51.50	67.53	59.52
$F_3N_2P_1$	40.53	48.67	44.60	42.52	58.64	50.58	43.56	55.12	49.34	51.38	69.24	60.31
$F_3N_2P_2$	41.56	46.26	43.91	43.51	57.16	50.34	43.58	52.67	48.13	51.52	68.15	59.84
Control (100% NPK)	41.52	49.34	45.43	43.56	59.33	51.45	50.52	55.67	53.10	51.54	69.83	60.69
Without control												
S.Em. (±)	**0.528**	**0.611**	**0.400**	**0.560**	**0.738**	**0.459**	**0.579**	**0.694**	**0.447**	**0.664**	**0.887**	**0.548**
C.D. (P=0.05)	**1.540**	**NS**	**1.136**	**NS**	**NS**	**1.303**	**1.691**	**NS**	**1.271**	**NS**	**NS**	**1.558**
With control												
S.Em. (±)	**0.388**	**0.450**	**0.294**	**0.412**	**0.543**	**0.338**	**0.426**	**0.511**	**0.302**	**0.489**	**0.653**	**0.404**
C.D. (P=0.05)	**1.134**	**1.313**	**0.836**	**1.203**	**1.586**	**0.959**	**1.244**	**1.490**	**0.857**	**1.427**	**1.905**	**1.147**

Duration for flower initiation ranged between 42.53 days (75% NPK+ *Azospirillum*) to 44.26 days (50% NPK+ *Azospirillum*). The non-significant variation was noticed in case of F×P and N×P interactions. In F×N×P interaction, minimum (42.45 days) and maximum (44.60) days for flower initiation were recorded in treatment combination of 75% NPK+ *Azospirillum*+VAM and 50% NPK+ *Azospirillum*+ VAM (Table 22.). Most delayed initiation takes place in control (100% NPK)

2.2.2 Days required for 50% flowering

Results presented in Table 22. showed significant variations in the sole effect of inorganic fertilizers only. The non-significant variation was noticed in the sole effect of bioinoculants during both the years and in pooled analysis. Days required for 50% flowering initiation ranged from 48.71 days (75% NPK) to 50.39 days (50% NPK). In F×N and N×P interaction the variations were non-significant. However significant variation was observed in F×P interaction. The minimum (48.22 days) and maximum (50.85 days) days required for 50% flowering initiation were noticed in 100% NPK+ VAM and 50% NPK+ PSB combination. In F×N×P interaction, though significant variations were observed in pooled analysis but it was non-significant during both the years. However, minimum (47.89 days) and maximum (51.12 days) required for 50% flower initiation were recorded in 100% NPK+ *Azospirillum* +VAM and 50% NPK+ *Azotobacter*+ PSB respectively. The duration required in control was 51.45 days.

2.2.3 Days required for first pod initiation

Results presented in Table 22. showed non-significant variation in most of the cases both in individual and interaction effects. In sole effect of fertilizers, maximum days required for first pod initiation was 48.48 days in 100% NPK. In F×N, F×P and N×P interactions days required for first pod initiation ranged from 47.42 to 48.75 days. In F×N×P interaction, minimum days required for first pod initiation was recorded in combination of 75% NPK+ *Azotobacter* + PSB (47.40 days) and longest time required for first pod initiation was 49.34 days which was observed in 50% NPK+ *Azospirillum*+ VAM. In control, time required for same was 53.10 days.

2.2.4 Days required for 50% pod initiation

Findings obtained from Table 22. indicated the non-significant variation among the different observations in respect of sole and two factor interaction except in pooled analysis of three factor interaction *i.e.* F×N×P. In the sole effect of inorganic fertilizers,

nitrogenous and phosphatic bioinoculants the days required for 50% pod initiation varied from 58.80 days (75% NPK) to 59.65 days (50% NPK). In F×N, F×P and N×P interactions the duration ranged from 58.21 days (75% NPK+ PSB) to 60.07 days (50% NPK+ *Azospirillum*). In the interaction of F×N×P, duration ranged between 57.95 days (75% NPK+ *Azospirillum*+ PSB) to 60.31 days (50% NPK+ *Azotobacter*+ VAM). In control, 60.69 days are required for 50% pod initiation.

2.2.5 Pod length

The findings obtained from Table 23 indicated the significant variations in most of the cases, *i.e.* in respect of both sole effects and interactions during both the years and in pooled analysis. The non-significant variations were observed in case of sole effect of inorganic fertilizers during the year 2014-15, in N×P during 2013-14 and in F×N×P during 2014-15. In sole effect of fertilizers, maximum (9.25 cm) and minimum (8.99 cm) pod length were observed in 75% NPK and 50% NPK respectively. The pod lengths under *Azotobacter* and *Azospirillum* were 8.99 and 9.32 cm respectively. In the individual effect of phosphatic bioinoculants pod length under VAM and PSB were 9.30 and 9.01 cm respectively. In respect to F×N interaction, maximum pod length was observed with 75% NPK+ *Azospirillum* (9.59 cm) followed by 50% NPK+ *Azotobacter* (8.89 cm) respectively. In F×P interaction, maximum (9.44 cm) and minimum (8.95 cm) pod lengths were recorded in 75% NPK+ VAM and 50% NPK+PSB respectively. In respect to N×P combination the longest pod (9.52 cm) was associated with *Azospirillum* + VAM and minimum pod length (8.90 cm) was observed in *Azotobacter*+ PSB. In F×N×P interaction, maximum pod length (9.79 cm) was recorded in 75% NPK+ *Azospirillum*+ VAM followed by 100% NPK+ *Azospirillum*+ VAM (9.52 cm).

2.2.6 Number of seeds pod^{-1}

Results presented in Table 23 and Fig. 16 showed significant variation in respect of both individual and interaction effects except in N×P and F×N×P interaction during the year 2014-15. In the sole effect of inorganic fertilizers, the maximum number of seeds (17.02) was noticed in 75% NPK. In the sole effect of bioinoculants, more number of seeds (16.96) was recorded in *Azospirillum* and VAM (16.89) respectively. In F×N interaction, the number of seedsranges from 14.94 (100% NPK+ *Azospirillum*) to 17.56 (75% NPK+ *Azospirillum*). In respect of F×P interaction seed ranges from 14.91 (100% NPK+ PSB) to 17.23 (75% NPK+ VAM). In case of N×P interaction, maximum (17.29)

Table 23. Different pod characters of fenugreek as influenced by inorganic fertilizers and bioinoculants

Treatments	Pod length (cm)			Number of seeds pod^{-1}			Number of pods plant^{-1}			Test weight (g)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer												
100% NPK (F_1)	9.66	8.80	9.23	17.71	14.21	15.96	52.61	79.67	66.14	16.46	13.70	15.08
75% NPK (F_2)	9.61	8.89	9.25	18.02	16.02	17.02	51.19	91.74	71.47	15.13	14.09	14.61
50% NPK (F_3)	9.31	8.68	8.99	18.20	14.85	16.53	48.95	81.38	65.17	15.16	13.48	14.32
S.Em. (±)	**0.061**	**0.058**	**0.042**	**0.117**	**0.098**	**0.076**	**0.349**	**0.588**	**0.338**	**0.105**	**0.078**	**0.065**
C.D. (P=0.05)	**0.179**	**NS**	**0.119**	**0.341**	**0.286**	**0.215**	**1.018**	**1.717**	**0.962**	**0.306**	**0.227**	**0.184**
Nitrogenous bioinoculants												
Azotobacter (N_1)	9.45	8.54	8.99	17.37	14.73	16.05	48.15	78.70	63.43	14.68	13.68	14.18
Azospirillum (N_2)	9.60	9.04	9.32	18.58	15.33	16.96	53.69	89.83	71.76	16.48	13.84	15.16
S.Em. (±)	**0.050**	**0.047**	**0.034**	**0.096**	**0.080**	**0.062**	**0.285**	**0.480**	**0.276**	**0.086**	**0.063**	**0.053**
C.D. (P=0.05)	**0.146**	**0.139**	**0.097**	**0.279**	**0.234**	**0.175**	**0.831**	**1.402**	**0.785**	**0.250**	**NS**	**0.150**
Phosphatic bioinoculants												
VAM (P_1)	9.63	8.97	9.30	18.48	15.29	16.89	52.14	93.11	72.62	15.82	13.97	14.90
PSB (P_2)	9.42	8.61	9.01	17.47	14.77	16.12	49.70	75.42	62.56	15.35	13.54	14.44
S.Em. (±)	**0.050**	**0.047**	**0.034**	**0.096**	**0.080**	**0.062**	**0.285**	**0.480**	**0.276**	**0.086**	**0.063**	**0.053**
C.D. (P=0.05)	**0.146**	**0.139**	**0.097**	**0.279**	**0.234**	**0.175**	**0.831**	**1.402**	**0.785**	**0.250**	**0.185**	**0.150**

Contd.....

VAM= Vesicular arbuscular mycorrhiza PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=Days after sowing; NS= Non siginificant,
N_1=*Azotobacter chroococcum*; N_2=*Azospirillum lipoferum*; P_1= *Glomus fasciculatum*; P_2= *Bacillus polymixa*

Contd.....

Treatments	Pod length (cm)			Number of seeds pod^{-1}			Number of pods plant^{-1}			Test weight (g)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)												
F_1N_1	9.69	8.67	9.18	16.40	13.48	14.94	49.06	80.51	64.79	15.96	13.18	14.57
F_1N_2	9.64	8.92	9.28	19.01	14.95	16.98	56.17	78.83	67.50	16.95	14.22	15.59
F_2N_1	9.34	8.49	8.91	17.45	15.53	16.49	46.50	75.09	60.79	13.33	14.18	13.76
F_2N_2	9.88	9.30	9.59	18.60	16.52	17.56	55.89	108.39	82.14	16.94	14.01	15.47
F_3N_1	9.32	8.47	8.89	18.26	15.18	16.72	48.90	80.51	64.70	14.76	13.67	14.22
F_3N_2	9.30	8.90	9.10	18.14	14.53	16.34	49.00	82.26	65.63	15.57	13.28	14.42
S.Em. (±)	0.087	0.082	0.059	0.165	0.139	0.107	0.493	0.832	0.479	0.148	0.110	0.091
C.D. (P=0.05)	0.253	0.240	0.168	0.483	0.405	0.304	1.440	2.428	1.360	0.433	0.321	0.260
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)												
F_1P_1	9.76	9.09	9.42	18.88	15.13	17.01	54.17	94.71	74.44	16.91	13.95	15.43
F_1P_2	9.57	8.51	9.04	16.53	13.29	14.91	51.06	64.63	57.84	16.01	13.45	14.73
F_2P_1	9.95	8.94	9.44	18.30	16.17	17.23	50.49	96.95	73.72	15.04	14.15	14.59
F_2P2	9.26	8.85	9.06	17.75	15.88	16.81	51.90	86.53	69.21	15.23	14.04	14.63
F_3P_1	9.19	8.90	9.04	18.27	14.58	16.42	51.77	87.66	69.72	15.51	13.82	14.67
F_3P_2	9.43	8.47	8.95	18.13	15.13	16.63	46.13	75.11	60.62	14.82	13.13	13.97
S.Em. (±)	**0.087**	**0.082**	**0.059**	**0.165**	**0.139**	**0.107**	**0.493**	**0.832**	**0.479**	**0.148**	**0.110**	**0.091**
C.D. (P=0.05)	**0.253**	**0.240**	**0.168**	**0.483**	**0.405**	**0.304**	**1.440**	**2.428**	**1.360**	**0.433**	**0.321**	**0.260**
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
N_1P_1	9.55	8.63	9.09	17.94	15.03	16.48	48.13	84.91	66.52	14.65	13.79	14.22
N_1P_2	9.35	8.45	8.90	16.80	14.42	15.61	48.17	72.49	60.33	14.72	13.56	14.14
N_2P_1	9.72	9.32	9.52	19.03	15.56	17.29	56.15	101.30	78.73	16.98	14.16	15.57
N_2P_2	9.49	8.76	9.12	18.14	15.11	16.62	51.22	78.35	64.79	15.98	13.51	14.75
S.Em. (±)	**0.071**	**0.067**	**0.048**	**0.135**	**0.113**	**0.087**	**0.403**	**0.679**	**0.391**	**0.121**	**0.090**	**0.075**
C.D. (P=0.05)	**NS**	**0.196**	**0.137**	**NS**	**NS**	**NS**	**1.176**	**1.982**	**1.111**	**0.353**	**0.262**	**0.212**

Contd....

Contd....

Treatments	Pod length (cm)			Number of seeds pod^{-1}			Number of pods plant^{-1}			Test weight (g)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
$F_1N_1P_1$	9.83	8.82	9.33	17.41	14.39	15.90	49.40	84.25	66.83	15.96	13.73	14.85
$F_1N_1P_2$	9.55	8.52	9.04	15.39	12.56	13.98	48.72	76.77	62.75	15.96	12.63	14.30
$F_1N_2P_1$	9.69	9.35	9.52	20.35	15.87	18.11	58.93	105.17	82.05	17.85	14.17	16.01
$F_1N_2P_2$	9.58	8.49	9.04	17.67	14.02	15.85	53.40	52.48	52.94	16.05	14.27	15.16
$F_2N_1P_1$	9.78	8.41	9.10	18.01	15.57	16.79	44.53	75.34	59.94	13.45	14.03	13.74
$F_2N_1P_2$	8.89	8.56	8.73	16.88	15.48	16.18	48.46	74.84	61.65	13.21	14.33	13.77
$F_2N_2P_1$	10.12	9.46	9.79	18.58	16.77	17.68	56.45	118.56	87.51	16.62	14.27	15.45
$F_2N_2P_2$	9.63	9.14	9.39	18.61	16.27	17.44	55.33	98.22	76.78	17.25	13.74	15.50
$F_3N_1P_1$	9.03	8.65	8.84	18.39	15.12	16.76	50.47	95.15	72.81	14.54	13.62	14.08
$F_3N_1P_2$	9.61	8.28	8.94	18.13	15.23	16.68	47.33	65.86	56.60	14.98	13.73	14.36
$F_3N_2P_1$	9.35	9.14	9.25	18.15	14.04	16.09	53.07	80.17	66.62	16.48	14.03	15.26
$F_3N_2P_2$	9.25	8.65	8.95	18.13	15.03	16.58	44.93	84.35	64.64	14.65	12.53	13.59
Control (100% NPK)	7.92	8.78	8.35	18.43	14.08	16.26	43.48	71.24	57.36	13.52	13.15	13.34
Without control												
S.Em. (±)	**0.123**	**0.116**	**0.084**	**0.234**	**0.196**	**0.151**	**0.698**	**1.176**	**0.677**	**0.210**	**0.155**	**0.129**
C.D. (P=0.05)	**0.358**	**NS**	**0.238**	**0.683**	**NS**	**0.429**	**NS**	**3.434**	**1.924**	**0.612**	**0.453**	**0.367**
With control												
S.Em. (±)	**0.090**	**0.086**	**0.062**	**0.172**	**0.144**	**0.111**	**0.514**	**0.866**	**0.498**	**0.154**	**0.114**	**0.095**
C.D. (P=0.05)	**0.264**	**0.250**	**0.175**	**0.503**	**0.422**	**0.316**	**1.499**	**2.527**	**1.416**	**0.450**	**0.334**	**0.270**

and minimum (15.61) seed number w.. noticed in *Azospirillum*+ VAM and *Azotobacter* + PSB respectively. In F×N×P interaction, the maximum number of seed per pod (18.11) was recorded in 100% NPK+ *Azospirillum*+ VAM followed by 75% NPK+*Azospirillum* + VAM (17.68). The seed number under control was 16.26.

2.2.7 Number of pods plant^{-1}

The number of pods per plant is .. important criterion for determining the yield of fenugreek. Perusal of data presented in Table 23 and Fig. 16 clearly demonstrated that pod number varied from 65.17 (50% NPK) to 71.47 (75% NPK). As regard to nitrogenous bioinoculants, the pod number in *Azotobacter* and *Azospirillum* were 63.43 and 71.76 respectively. In sole effect of phosphatic bioinoculants, maximum (72.62) and minimum (62.56) pod number were noticed in VAM and PSB respectively. In F×N interaction, pod number varied from 60.79 (75% NPK+ *Azotobacter*) to 82.14 (75% NPK + *Azospirillum*). But in F×P interaction, pod number ranged from 57.84 (100% NPK+PSB) to 74.44 (100% NPK+VAM). Wide variation (60.33-78.73) was observed in N×P interaction. Maximum and minimum pod number were associated with *Azospirillum*+ VAM (78.73) and *Azotobacter*+ PSB (60.33) respectively. In F×N×P interaction, maximum number of pods (87.51) plant^{-1} was noticed in 75% NPK+ *Azospirillum*+ VAM followed by 100% NPK+ *Azospirillum*+ VAM (82.05). Lowest number of pods plant^{-1} recorded in combination of 100% NPK+ *Azospirillum*+ PSB (52.94) as compared to 100% NPK (57.36).

2.2.8 Test weight

Perusal of data presented in Table 23 clearly demonstrated that test weight varied significantly in individual effects and interaction during both the year and in pooled analysis. The decreasing trend (15.08 g to 14.32 g) was noticed with decreasing level of inorganic fertilizers (100% NPK to 50% NPK). Between nitrogenous bioinoculants, higher test weight was noticed in *Azospirillum* (15.16 g). In phosphatic bioinoculants higher test weight was associated with VAM (14.90 g). In F×N interaction, maximum test weight (15.59 g) was noticed in 100% NPK+ *Azospirillum* followed by 75% NPK+*Azospirillum* (15.47 g) against the least test weight in 75% NPK+ *Azotobacter* (13.76 g). In respect to F×P interaction, the test weight ranged from 13.97 g (50% NPK+ PSB) to 15.43 g (100% NPK+ *Azospirillum*). In N×P interaction, the maximum (15.57 g) and minimum test weight (14.14 g) were associated with *Azospirillum*+ VAM and

Azotobacter+ PSB. In F×N×P interaction, maximum test weight of 16.01 g was recorded in 100% NPK+ *Azospirillum* + VAM followed by 75% NPK+ *Azosirillum*+ PSB (15.50 g) as compared to 13.59 g in 50% NPK+ *Azospirillum*+ PSB. Minimum test weight of 13.34 g was recorded in control (only 100% NPK).

2.2.9 Seed yield plant^{-1}

Results presented in Table 24 and Fig. 17 showed significant variations in respect of both sole and interaction effects in most of the cases except in sole effect of phosphatic bioinoculants during the year 2014-15, in F×P and N×P during the year 2013-14 and 2014-15 respectively. In sole effect of inorganic fertilizer, the maximum (8.50 g) and minimum (7.60 g) yield plant^{-1} were noticed with 75% NPK and 50% NPK respectively. In the nitrogenous bioinoculants the higher yield of 8.57 g was recorded in *Azospirillum* as compared to 7.71 g in *Azotobacter*. As regard to phosphatic bioinoculants, yield was 8.25 and 8.03 g in VAM and PSB respectively. In F×N×P interaction, yield plant^{-1} ranged from 7.44 g (50% NPK+ *Azotobacter*) to 9.15 g (75% NPK+*Azospirillum*). In respect of F×P interaction, maximum seed yield (8.75 g) was recorded in 75% NPK+ VAM. In N×P interaction maximum seed yield was noticed in *Azospirillum*+ VAM (8.72 g). In F×N×P interaction, maximum seed yield of 9.24 g was recorded in 75% NPK+ *Azospirillum* + VAM followed by 75% NPK+ *Azospirillum*+ PSB (9.06 g) and 7.56 g plant^{-1} in control (100% NPK).

2.2.10 Seed yield plot^{-1}

Perusal data presented in Table 24 clearly demonstrated that plot yield varied significantly in individual effects and interactions except the sole effect of nitrogenous and phosphatic bioinoculants during the year 2013-14 and 2014-15. In the individual effect of inorganic fertilizers, the maximum plot yield (791.61 g 3m^{-2}) was recorded in 75% NPK as compared to minimum yield (708.83 g 3m^{-2}) with 50% NPK. Between nitrogenous bioinoculants, the yield was 771.42 g 3m^{-2} in *Azospirillum* against 715.03 g 3m^{-2} in *Azotobacter*. But in phosphatic bioinoculants, VAM recorded the yield of 748.67 g 3m^{-2} against 737.78 g 3m^{-2} in PSB. In F×N interaction, yield plot^{-1} ranged from 671.45 g 3m^{-2} (50% NPK+ *Azotobacter*) to 814.79 g 3m^{-2} (75% NPK+ *Azospirillum*). In case of F×P interaction, the yield ranged from 708.77 g 3m^{-2} (50% NPK+ PSB) to 794.39 g 3m^{-2} (75% NPK+ VAM). As regards N×P interaction, highest (784.14 g 3m^{-2}) and lowest (713.20 g 3m^{-2}) yield were recorded in *Azospirillum* + VAM and *Azotobacter* + VAM

Table 24 .Yield of fenugreek as influenced by inorganic fertilizers and bioinoculants

Treatments	Seed yield									Biological yield (q ha^{-1})		
	Yield $plant^{-1}$ (g)			Yield $plot^{-1}$ (g $3m^{-2}$)			Projected yield (q ha^{-1})					
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer												
100% NPK (F_1)	7.09	9.56	8.33	675.07	783.40	729.23	16.88	19.59	18.23	53.77	58.20	55.99
75% NPK (F_2)	7.40	9.60	8.50	678.60	904.62	791.61	16.97	22.61	19.79	53.92	62.71	58.31
50% NPK (F_3)	5.86	9.34	7.60	640.40	777.27	708.83	16.01	19.43	17.72	52.01	57.56	54.79
S.Em. (±)	**0.046**	**0.062**	**0.038**	**3.469**	**5.560**	**3.243**	**0.087**	**0.139**	**0.081**	**0.150**	**0.186**	**0.118**
C.D. (P=0.05)	**0.134**	**0.182**	**0.109**	**10.126**	**16.228**	**9.217**	**0.253**	**0.406**	**0.230**	**0.438**	**0.543**	**0.336**
Nitrogenous bioinoculants												
Azotobacter (N_1)	6.21	9.21	7.71	667.40	762.66	715.03	16.69	19.07	17.88	53.44	57.22	55.33
Azospirillum (N_2)	7.35	9.79	8.57	661.98	880.86	771.42	16.55	22.02	19.29	53.03	61.77	57.40
S.Em. (±)	**0.037**	**0.051**	**0.031**	**2.833**	**4.539**	**2.648**	**0.071**	**0.113**	**0.066**	**0.123**	**0.152**	**0.097**
C.D. (P=0.05)	**0.109**	**0.148**	**0.089**	**NS**	**13.250**	**7.525**	**NS**	**0.331**	**0.188**	**0.358**	**0.444**	**0.275**
Phosphatic bioinoculants												
VAM (P_1)	6.97	9.54	8.25	680.89	816.45	748.67	17.02	20.41	18.72	53.97	59.34	56.66
PSB (P_2)	6.59	9.47	8.03	648.49	827.07	737.78	16.21	20.68	18.44	52.49	59.64	56.07
S.Em. (±)	**0.037**	**0.051**	**0.031**	**2.833**	**4.539**	**2.648**	**0.071**	**0.113**	**0.066**	**0.123**	**0.152**	**0.097**
C.D. (P=0.05)	**0.109**	**NS**	**0.089**	**8.268**	**NS**	**7.525**	**0.207**	**NS**	**0.188**	**0.358**	**NS**	**0.275**

Contd.....

VAM= Vesicular arbuscular mycorrhiza PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=Days after sowing; NS= Non siginificant,
N_1=*Azotobacter chroococcum*; N_2=*Azospirillum lipoferum*; P_1= *Glomus fasciculatum*; P_2= *Bacillus polymixa*

Contd.....

Treatments	Seed yield									Biological yield (q ha^{-1})		
	Yield $plant^{-1}$(g)			Yield $plot^{-1}$ (g $3m^{-2}$)			Projected yield (q ha^{-1})					
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)												
F_1N_1	6.34	9.34	7.84	648.40	762.02	705.21	16.21	19.05	17.63	52.51	57.47	54.99
F_1N_2	7.85	9.79	8.82	701.73	804.78	753.26	17.54	20.12	18.83	55.03	58.94	56.98
F_2N_1	6.89	8.82	7.85	679.67	857.21	768.44	16.99	21.43	19.21	54.11	60.88	57.49
F_2N_2	7.90	10.39	9.15	677.53	952.04	814.79	16.94	23.80	20.37	53.72	64.55	59.14
F_3N_1	5.40	9.48	7.44	674.13	668.77	671.45	16.85	16.72	16.79	53.69	53.32	53.50
F_3N_2	6.32	9.21	7.76	606.67	885.77	746.22	15.17	22.14	18.66	50.33	61.81	56.07
S.Em. (±)	**0.065**	**0.088**	**0.054**	**4.906**	**7.863**	**4.586**	**0.123**	**0.196**	**0.115**	**0.212**	**0.263**	**0.167**
C.D. (P=0.05)	**0.189**	**0.257**	**0.154**	**14.320**	**22.949**	**13.034**	**0.358**	**0.573**	**0.326**	**0.620**	**0.769**	**0.476**
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)												
F_1P_1	7.27	9.63	8.45	715.07	770.39	742.73	17.88	19.26	18.57	55.68	57.78	56.73
F_1P_2	6.92	9.50	8.21	635.07	796.41	715.74	15.88	19.91	17.89	51.86	58.63	55.24
F_2P_1	7.64	9.87	8.75	695.93	892.86	794.39	17.40	22.32	19.86	54.83	62.30	58.57
F_2P2	7.15	9.34	8.25	661.27	916.39	788.83	16.53	22.91	19.72	53.00	63.13	58.06
F_3P_1	6.01	9.12	7.56	631.67	786.12	708.89	15.79	19.65	17.72	51.41	57.95	54.68
F_3P_2	5.71	9.57	7.64	649.13	768.42	708.77	16.23	19.21	17.72	52.61	57.18	54.89
S.Em. (±)	**0.065**	**0.088**	**0.054**	**4.906**	**7.863**	**4.586**	**0.123**	**0.196**	**0.115**	**0.212**	**0.263**	**0.167**
C.D. (P=0.05)	**NS**	**0.257**	**0.154**	**14.320**	**22.949**	**13.034**	**0.358**	**0.573**	**0.326**	**0.620**	**0.769**	**0.476**
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
N_1P_1	6.34	9.23	7.79	676.13	750.27	713.20	16.90	18.76	17.83	53.77	56.78	55.27
N_1P_2	6.07	9.19	7.63	658.67	775.05	716.86	16.47	19.38	17.92	53.10	57.66	55.38
N_2P_1	7.60	9.85	8.72	685.64	882.63	784.14	17.14	22.07	19.60	54.17	61.91	58.04
N_2P_2	7.11	9.74	8.43	638.31	879.09	758.70	15.96	21.98	18.97	51.88	61.62	56.75
S.Em. (±)	**0.053**	**0.072**	**0.044**	**4.006**	**6.420**	**3.745**	**0.100**	**0.160**	**0.094**	**0.173**	**0.215**	**0.137**
C.D. (P=0.05)	**0.155**	**NS**	**NS**	**11.692**	**18.738**	**10.642**	**0.292**	**0.468**	**0.266**	**0.506**	**0.628**	**0.389**

Contd....

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Treatments	Seed yield									Biological yield (q ha^{-1})		
	Yield $plant^{-1}$ (g)			Yield $plot^{-1}$ (g $3m^{-2}$)			Projected yield (q ha^{-1})					
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
$F_1N_1P_1$	6.51	9.25	7.88	678.40	715.35	696.88	16.96	17.88	17.42	53.99	55.78	54.89
$F_1N_1P_2$	6.17	9.43	7.80	618.40	808.68	713.54	15.46	20.22	17.84	51.03	59.15	55.09
$F_1N_2P_1$	8.03	10.01	9.02	751.73	825.42	788.58	18.79	20.64	19.72	57.36	59.77	58.57
$F_1N_2P_2$	7.66	9.56	8.61	651.73	784.14	717.94	16.29	19.60	17.95	52.69	58.10	55.40
$F_2N_1P_1$	7.16	9.38	8.27	688.40	855.35	771.88	17.21	21.38	19.30	54.54	60.68	57.61
$F_2N_1P_2$	6.62	8.25	7.44	670.93	859.06	765.00	16.77	21.48	19.13	53.67	61.08	57.38
$F_2N_2P_1$	8.12	10.35	9.24	703.47	930.36	816.91	17.59	23.26	20.42	55.12	63.92	59.52
$F_2N_2P_2$	7.68	10.43	9.06	651.60	973.71	812.66	16.29	24.34	20.32	52.32	65.17	58.75
$F_3N_1P_1$	5.36	9.06	7.21	661.60	680.12	670.86	16.54	17.00	16.77	52.77	53.87	53.32
$F_3N_1P_2$	5.43	9.89	7.66	686.67	657.41	672.04	17.17	16.43	16.80	54.60	52.77	53.68
$F_3N_2P_1$	6.65	9.18	7.91	601.73	892.12	746.93	15.04	22.30	18.67	50.04	62.04	56.04
$F_3N_2P_2$	5.98	9.24	7.61	611.60	879.42	745.51	15.29	21.98	18.64	50.62	61.58	56.10
Control (100% NPK)	6.95	8.16	7.56	644.12	665.82	654.97	16.10	16.65	16.37	51.50	51.75	51.62
Without control												
S.Em. (±)	**0.092**	**0.124**	**0.076**	**6.938**	**11.119**	**6.486**	**0.173**	**0.278**	**0.162**	**0.300**	**0.372**	**0.237**
C.D. (P=0.05)	**0.268**	**0.363**	**0.217**	**NS**	**32.455**	**18.433**	**NS**	**0.811**	**0.461**	**NS**	**1.087**	**0.673**
With control												
S.Em. (±)	**0.068**	**0.092**	**0.056**	**5.107**	**8.185**	**4.774**	**0.128**	**0.205**	**0.119**	**0.221**	**0.274**	**0.174**
C.D. (P=0.05)	**0.197**	**0.267**	**0.160**	**14.905**	**23.886**	**13.566**	**0.373**	**0.597**	**0.339**	**0.645**	**0.800**	**0.495**

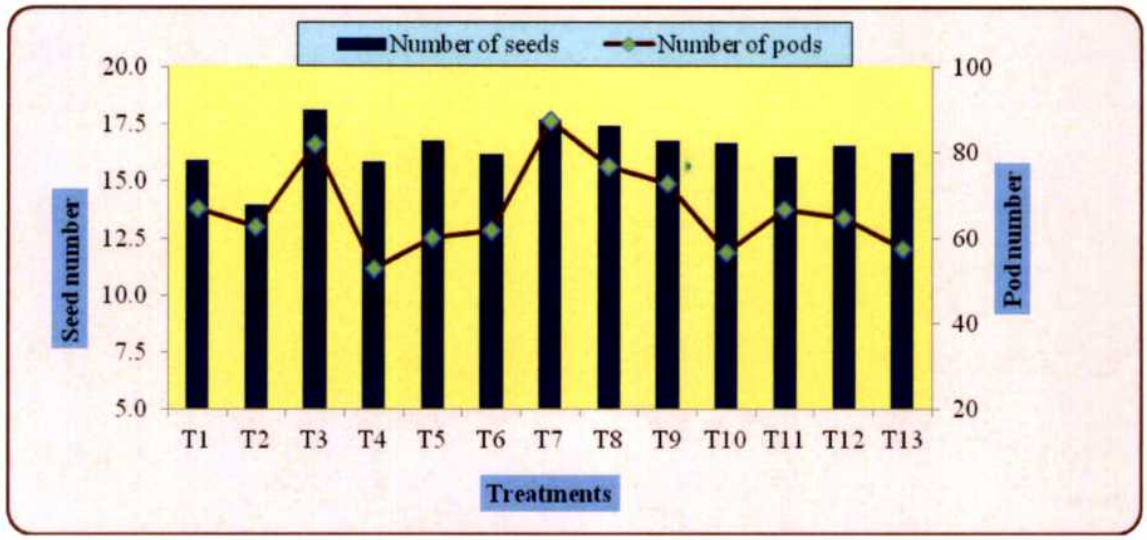


Fig. 16 No. of pods plant^{-1} and seeds pod^{-1} under different inorganic and biofertilzer combinations

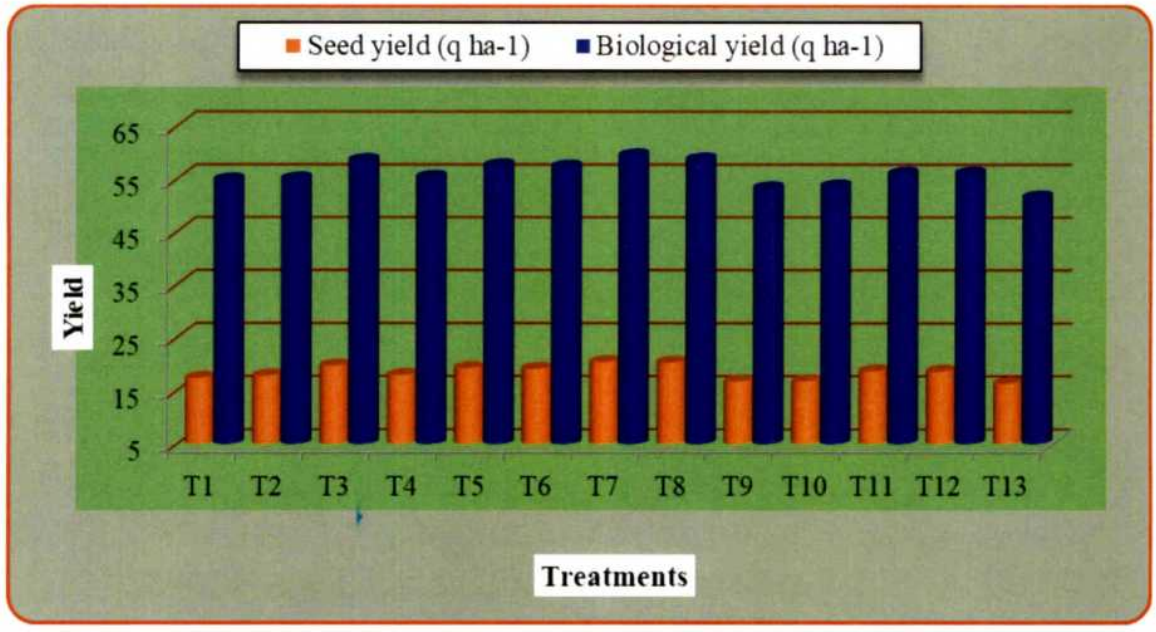


Fig. 17 Seed yield and biological yield under different inorganic and biofertilzer combinations

T_1: NPK 100% + *Azotobacter* + VAM+ KM
T_2: NPK 100% + *Azotobacter* + PSB+ KM
T_3: NPK 100% + *Azospirillum*+ VAM+ KM
T_4: NPK 100% + *Azospirillum* + PSB+ KM
T_5: NPK 75% + *Azotobacter* + VAM+ KM
T_6: NPK 75% + *Azotobacter* + PSB+ KM
T_7: NPK 75% + *Azospirillum*+ VAM+ KM
T_8: NPK 75% + *Azospirillum* + PSB+ KM
T_9: NPK 50% + *Azotobacter* + VAM+ KM
T_{10}: NPK 50% + *Azotobacter* + PSB+ KM
T_{11}: NPK 50% + *Azospirillum*+ VAM+ KM
T_{12}: NPK 50% + *Azospirillum* + PSB+ KM
T_{13}: Recommended NPK - 20:40:20 kg ha^{-1}

respectively. In case of F×N×P interaction, maximum yield of 816.91g $3m^{-2}$ was observed in 75% NPK+ *Azospirillum*+ VAM followed by 75% NPK+ *Azospirillum*+ PSB (812.66 g $3m^{-2}$) as compared to 670.86 g $3m^{-2}$ in 50% NPK+ *Azotobacter* + VAM but the lowest yield (654.97 g $3m^{-2}$) was noticed in 100% NPK only (control).

2.2.11 Projected seed yield hectare^{-1}

Results presented in a Table 24 showed significant difference in respect of both individual and interaction effect except F×P and N×P interactions during 2013-14 and 2014-15 respectively and F×N×P interaction during 2013-14. Similar trend of effect as in plot yield was reflected in projected yield also. In the sole effect of three components, maximum yield was recorded in 75% NPK (19.79 q ha^{-1}) as compared to minimum yield (17.72 q ha^{-1}) with 50% NPK. In F×N interaction, the yield ranged from 16.79 q ha^{-1} to 20.37 q ha^{-1} (75% NPK+ *Azospirillum*). In respect of F×P and N×P interaction, maximum yield of 19.86 and 19.60 q ha^{-1} was observed in 75% NPK+ VAM and *Azospirillum*+ VAM respectively. In F×N×P interaction, the highest yield (20.42 q ha^{-1}) recorded in 75% NPK+ *Azospirillum* + VAM followed by 75% NPK+ *Azospirillum*+ PSB (20.32 q ha^{-1}). The lowest projected yield of 16.37 q ha^{-1} was recorded in control (only 100% NPK).

2.2.12 Biological yield hectare^{-1}

Investigation concerning the biological yield showed the significant variation in respect of both individual effect and interaction during both years and pooled analysis. In case of individual effect of inorganic fertilizer, the biological yield increased up to medium level of NPK *i.e.* maximum biological yield (58.31 q ha^{-1}) was recorded with 75% NPK followed by 100% NPK (55.99 q ha^{-1}). Between nitrogenous inoculants, the effect of *Azospirillum* (57.40 q ha^{-1}) is more pronounced as compared to *Azotobacter* (Table 24 and Fig. 17). In F×P interaction, the maximum yield of 58.57 q ha^{-1} was recorded with 75% NPK + VAM followed by 75% NPK+ PSB. In N×P combination comparatively high yield of 58.04 q ha^{-1} was recorded in *Azospirillum* +VAM followed by *Azospirillum* + PSB (56.75 q ha^{-1}). In F×N×P interaction, the maximum yield of 59.52 q ha^{-1} was recorded in 75% NPK + *Azospirillum*+ VAM followed by 75% NPK+ *Azospirillum*+ PSB as compared to biological yield under 50% NPK + *Azotobacter*+ VAM (53.32 q ha^{-1}). The minimum biological yield of 51.62 q ha^{-1} was recorded in control (only 100% NPK)

Table 25. Nodule number and harvest index of fenugreek as influenced by inorganic fertilizers and bioinoculants

Treatments	Nodule number			Harvest index (%)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer						
100% NPK (F_1)	18.61 (4.31)	29.63 (5.49)	24.12 (4.90)	31.00	34.00	32.50
75% NPK (F_2)	24.53 (4.99)	31.11 (5.61)	27.82 (5.30)	31.00	36.00	33.50
50% NPK (F_3)	18.62 (4.36)	29.06 (5.43)	23.84 (4.90)	31.00	34.00	32.50
S.Em. (±)	**0.015**	**0.018**	**0.011**			
C.D. (P=0.05)	**0.043**	**0.052**	**0.033**			
Nitrogenous bioinoculants						
Azotobacter (N_1)	17.21 (4.18)	28.13 (5.35)	22.67 (4.77)	31.00	33.00	32.00
Azospirillum (N_2)	23.96 (4.92)	31.74 (5.67)	27.85 (5.30)	31.00	36.00	33.50
S.Em. (±)	**0.115**	**0.018**	**0.009**			
C.D. (P=0.05)	**0.443**	**0.052**	**0.027**			
Phosphatic bioinoculants						
VAM (P_1)	22.94 (4.82)	30.78 (5.59)	26.86 (5.20)	32.00	34.00	33.00
PSB (P_2)	18.23 (4.29)	29.09 (5.43)	23.66 (4.86)	31.00	35.00	33.00
S.Em. (±)	**0.012**	**0.015**	**0.009**			
C.D. (P=0.05)	**0.035**	**0.042**	**0.027**			

Contd.....

VAM= Vesicular arbuscular mycorrhiza PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=Days after sowing; NS= Non siginificant,
N_1=*Azotobacter chroococcum*; N_2=*Azospirillum lipoferum*; P_1= *Glomus fasciculatum*; P_2= *Bacillus polymixa*
Values in the parenthesis are the square root transformed values utilized for statistical analysis

Contd.....

Treatments	Nodule number			Harvest index (%)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)						
F_1N_1	13.68 (3.74)	29.39 (5.47)	21.53 (4.60)	31.00	33.00	32.00
F_1N_2	23.54 (4.89)	29.88 (5.51)	26.71 (5.20)	32.00	34.00	33.00
F_2N_1	20.56 (4.59)	27.56 (5.29)	24.06 (4.94)	31.00	35.00	33.00
F_2N_2	28.51 (5.38)	34.67 (5.93)	31.59 (5.66)	32.00	37.00	34.50
F_3N_1	17.40 (4.23)	27.45 (5.28)	22.42 (4.75)	31.00	31.00	31.00
F_3N_2	19.83 (4.49)	30.67 (5.58)	25.25 (5.04)	30.00	36.00	33.00
S.Em. (±)	**0.021**	**0.025**	**0.016**			
C.D. (P=0.05)	**0.061**	**0.074**	**0.046**			
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)						
F_1P_1	22.15 (4.73)	31.22 (5.63)	26.69 (5.18)	32.00	33.00	32.50
F_1P_2	15.07 (3.90)	28.05 (5.34)	21.56 (4.62)	31.00	34.00	32.50
F_2P_1	25.62 (5.10)	31.73 (5.67)	28.67 (5.39)	32.00	36.00	34.00
F_2P2	23.45 (4.87)	30.50 (5.55)	26.97 (5.21)	31.00	36.00	33.50
F_3P_1	21.05 (4.64)	29.39 (5.47)	25.22 (5.05)	31.00	34.00	32.50
F_3P_2	16.18 (4.08)	28.73 (5.40)	22.45 (4.74)	31.00	33.00	32.00
S.Em. (±)	**0.021**	**0.025**	**0.016**			
C.D. (P=0.05)	**0.061**	**0.074**	**0.046**			
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)						
N_1P_1	19.22 (4.43)	29.67 (5.49)	24.44 (4.96)	31.00	33.00	32.00
N_1P_2	15.20 (3.94)	26.59 (5.20)	20.90 (4.57)	31.00	33.00	32.00
N_2P_1	26.66 (5.20)	31.89 (5.69)	29.27 (5.45)	32.00	36.00	34.00
N_2P_2	21.26 (4.64)	31.58 (5.66)	26.42 (5.15)	31.00	36.00	33.50
S.Em. (±)	**0.017**	**0.021**	**0.013**			
C.D. (P=0.05)	**NS**	**0.060**	**0.038**			

Contd....

Contd.....

Treatments	Nodule number			Harvest index(%)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)						
$F_1N_1P_1$	16.78 (4.16)	30.11 (5.53)	23.45 (4.84)	31.37	32.06	31.71
$F_1N_1P_2$	10.57 (3.33)	28.67 (5.40)	19.62 (4.36)	30.30	34.18	32.24
$F_1N_2P_1$	27.52 (5.29)	32.33 (5.73)	29.93 (5.51)	32.76	34.52	33.64
$F_1N_2P_2$	19.56 (4.48)	27.42 (5.28)	23.49 (4.88)	30.91	33.73	32.32
$F_2N_1P_1$	21.89 (4.73)	29.67 (5.49)	25.78 (5.11)	31.55	35.24	33.40
$F_2N_1P_2$	19.22 (4.44)	25.44 (5.09)	22.33 (4.77)	31.25	35.16	33.21
$F_2N_2P_1$	29.34 (5.46)	33.78 (5.85)	31.56 (5.66)	31.90	36.38	34.14
$F_2N_2P_2$	27.67 (5.31)	35.55 (6.00)	31.61 (5.66)	31.13	37.33	34.23
$F_3N_1P_1$	18.99 (4.41)	29.22 (5.45)	24.11 (4.93)	31.34	31.56	31.45
$F_3N_1P_2$	15.81 (4.04)	25.67 (5.12)	20.74 (4.58)	31.44	31.14	31.29
$F_3N_2P_1$	23.11 (4.86)	29.56 (5.48)	26.34 (5.17)	30.06	35.95	33.01
$F_3N_2P_2$	16.55 (4.13)	31.78 (5.68)	24.17 (4.91)	30.20	35.69	32.95
Control (100% NPK)	10.33(3.29)	22.89 (4.84)	16.61 (4.14)	31.26	32.17	31.71
Without control						
S.Em. (±)	**0.030**	**0.036**	**0.023**			
C.D. (P=0.05)	**0.086**	**0.104**	**0.065**			
With control						
S.Em. (±)	**0.022**	**0.026**	**0.015**			
C.D. (P=0.05)	**0.063**	**0.077**	**0.044**			

2.2.13 Harvest index

Results presented in Table 25 showed significant variations in both sole and interaction effects of three components. In respect to sole effect of inorganic fertilizers, nitrogenous and phosphatic bioinoculants the harvest index ranged from 32 to 34%. The maximum harvest index noticed in medium level of inorganic fertilizer (75% NPK). In F×N interaction the maximum harvest index (34%) was noticed in 75% NPK+ *Azospirillum* and minimum with 50% NPK + *Azotobacter*. In respect of F×P interaction the highest value of harvest index (34%) was noticed with 75% NPK in combination with both VAM and PSB. Lowest harvest index was noticed both in higher and lower level of inorganic fertilizer. In respect of N×P interaction the highest value was associated with *Azospirillum*+ VAM (34%). In F×N×P combination, the harvest index ranged from 31.29 to 34.23%. The maximum harvest index was associated with 75% NPK+ *Azospirillum* + PSB followed by 75% NPK+ *Azospirillum* + VAM. The lowest harvest index (31.29%) was recorded in 75% NPK+ *Azotobacter*+ PSB. Control (100% NPK only) noticed with 31.71% of harvest index.

2.3 QUALITY PARAMETERS

2.3.1 Galactomannan content

Data pertaining to galactomannan content in the sole effects and their interactions was presented in Table 26, and Fig. 18 Among the different levels of inorganic fertilizers, 100% NPK recorded highest (7.927 mg 100 mg^{-1}). In respect to nitrogenous bioinoculants, maximum galactomannan content was recorded in *Azotobacter* (7.716 mg 100 mg^{-1}) as compared to *Azospirillum* (7.297 mg 100 mg^{-1}). In phosphatic bioinoculants highest value was recorded in PSB (8.218 mg 100 mg^{-1}) as compare to VAM (6.599 mg 100 mg^{-1}). In two factors interaction of inorganic fertilizer × nitrogenous bioinoculants, the highest value was recorded in 100% NPK+ *Azotobacter* (8.903 mg 100 mg^{-1}) followed by 50% NPK+ *Azospirillum* (7.691 mg 100 mg^{-1}) and the lowest value (6.683 mg 100 mg^{-1}) was recorded in 75% NPK+ *Azospirillum* . In inorganic fertilizer (F)×phosphatic bio inoculants (P) interaction the highest value was recorded in 100% NPK+ PSB (8.636 mg 100 mg^{-1}) and the lowest value was recorded in 75% NPK+ VAM (5.495). In this interaction PSB was better than VAM. In nitrogenous × phosphatic bioinoculants interaction, the highest value was recorded in combination of *Azotobacter*+ PSB (8.713 mg 100 mg^{-1}) and the lowest was recorded in *Azospirillum*+ VAM (6.494 mg

Table 26. Galactomannan and total soluble protein content of fenugreek seed as influenced by inorganic fertilizers and bioinoculants

Treatments	Galactomannan (mg 100 mg^{-1})			Total soluble protein (mg 100 mg^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer						
100% NPK (F_1)	6.506	9.348	7.927	12.648	11.779	12.213
75% NPK (F_2)	7.242	6.260	6.751	15.616	14.117	14.866
50% NPK (F_3)	7.651	7.465	7.558	14.228	13.850	14.039
S.Em. (±)	**0.002**	**0.018**	**0.009**	**0.018**	**0.023**	**0.015**
C.D. (P=0.05)	**0.006**	**0.051**	**0.025**	**0.054**	**0.068**	**0.042**
Nitrogenous bioinoculants						
Azotobacter (N_1)	7.346	8.085	7.716	14.074	13.148	13.611
Azospirillum (N_2)	6.919	7.297	7.108	14.254	13.349	13.802
S.Em. (±)	**0.002**	**0.014**	**0.007**	**0.015**	**0.019**	**0.012**
C.D. (P=0.05)	**0.005**	**0.042**	**0.020**	**0.044**	**0.056**	**0.034**
Phosphatic bioinoculants						
VAM (P_1)	6.613	6.599	6.606	14.299	13.583	13.941
PSB (P_2)	7.652	8.783	8.218	14.029	12.914	13.472
S.Em. (±)	**0.002**	**0.014**	**0.007**	**0.015**	**0.019**	**0.012**
C.D. (P=0.05)	**0.005**	**0.042**	**0.020**	**0.044**	**0.056**	**0.034**

Contd.....

VAM= Vesicular arbuscular mycorrhiza, PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=Days after sowing; NS= Non siginificant,
N_1=*Azotobacter chroococcum*; N_2=*Azospirillum lipoferum*; P_1= *Glomus fasciculatum*; P_2 = *Bacillus polymixa*

Contd.....

Treatments	Galactomannan (mg 100 mg^{-1})			Total soluble protein (mg 100 mg^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)						
F_1N_1	7.157	10.650	8.903	12.935	12.165	12.550
F_1N_2	5.855	8.047	6.951	12.360	11.393	11.877
F_2N_1	7.412	6.225	6.818	15.237	14.542	14.889
F_2N_2	7.072	6.295	6.683	15.995	13.692	14.843
F_3N_1	7.470	7.380	7.425	14.050	12.737	13.394
F_3N_2	7.832	7.550	7.691	14.407	14.963	14.685
S.Em. (±)	**0.003**	**0.025**	**0.012**	**0.026**	**0.033**	**0.021**
C.D. (P=0.05)	**0.009**	**0.072**	**0.035**	**0.076**	**0.097**	**0.059**
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)						
F_1P_1	6.682	7.755	7.218	13.500	12.802	13.151
F_1P_2	6.330	10.942	8.636	11.795	10.757	11.276
F_2P_1	5.743	5.247	5.495	17.052	15.202	16.127
F_2P2	8.740	7.273	8.007	14.180	13.032	13.606
F_3P_1	7.415	6.797	7.106	12.345	12.745	12.545
F_3P_2	7.887	8.133	8.010	16.112	14.954	15.533
S.Em. (±)	**0.003**	**0.025**	**0.012**	**0.026**	**0.033**	**0.021**
C.D. (P=0.05)	**0.009**	**0.072**	**0.035**	**0.076**	**0.097**	**0.059**
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)						
N_1P_1	6.922	6.514	6.718	14.212	13.308	13.760
N_1P_2	7.770	9.656	8.713	13.936	12.988	13.462
N_2P_1	6.304	6.684	6.494	14.386	13.858	14.122
N_2P_2	7.534	7.910	7.722	14.122	12.841	13.481
S.Em. (±)	**0.002**	**0.020**	**0.010**	**0.021**	**0.027**	**0.017**
C.D. (P=0.05)	**0.007**	**0.059**	**0.029**	**NS**	**0.079**	**0.048**

Contd....

Contd.....

Treatments	Galactomannan (mg 100 mg^{-1})			Total soluble protein (mg 100 mg^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)						
$F_1N_1P_1$	6.810	9.760	8.285	13.780	12.980	13.380
$F_1N_1P_2$	7.503	11.540	9.522	12.090	11.350	11.720
$F_1N_2P_1$	6.553	5.750	6.152	13.220	12.623	12.922
$F_1N_2P_2$	5.157	10.343	7.750	11.500	10.163	10.832
$F_2N_1P_1$	6.943	3.713	5.328	17.396	16.410	16.903
$F_2N_1P_2$	7.880	8.737	8.308	13.077	12.673	12.875
$F_2N_2P_1$	4.543	6.780	5.662	16.707	13.993	15.350
$F_2N_2P_2$	9.600	5.810	7.705	15.283	13.390	14.337
$F_3N_1P_1$	7.013	6.070	6.542	11.460	10.534	10.997
$F_3N_1P_2$	7.927	8.690	8.308	16.640	14.940	15.790
$F_3N_2P_1$	7.817	7.523	7.670	13.230	14.957	14.093
$F_3N_2P_2$	7.847	7.577	7.712	15.583	14.969	15.276
Control (100% NPK)	11.992	23.184	17.588	13.473	14.562	14.018
Without control						
S.Em. (±)	**0.004**	**0.035**	**0.018**	**0.037**	**0.047**	**0.029**
C.D. (P=0.05)	**0.012**	**0.103**	**0.050**	**0.107**	**0.137**	**0.084**
With control						
S.Em. (±)	**0.003**	**0.026**	**0.013**	**0.027**	**0.035**	**0.022**
C.D. (P=0.05)	**0.009**	**0.075**	**0.037**	**0.079**	**0.101**	**0.062**

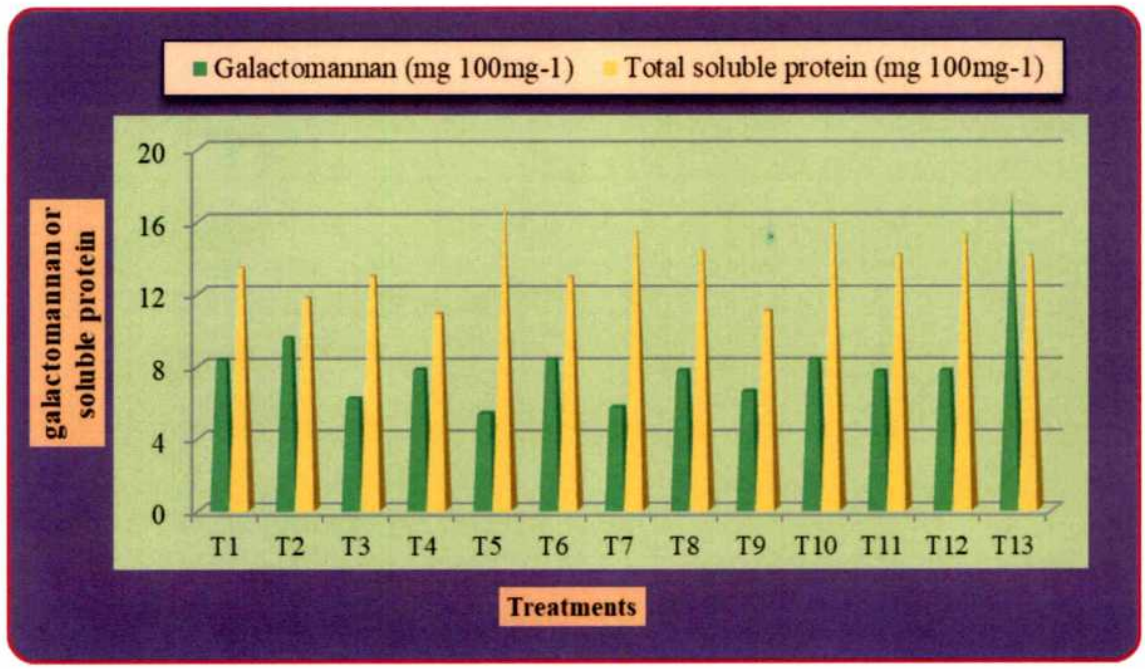


Fig. 18 Total soluble protein and galactomannan in fenugreek seed under different inorganic and biofertilizer combinations

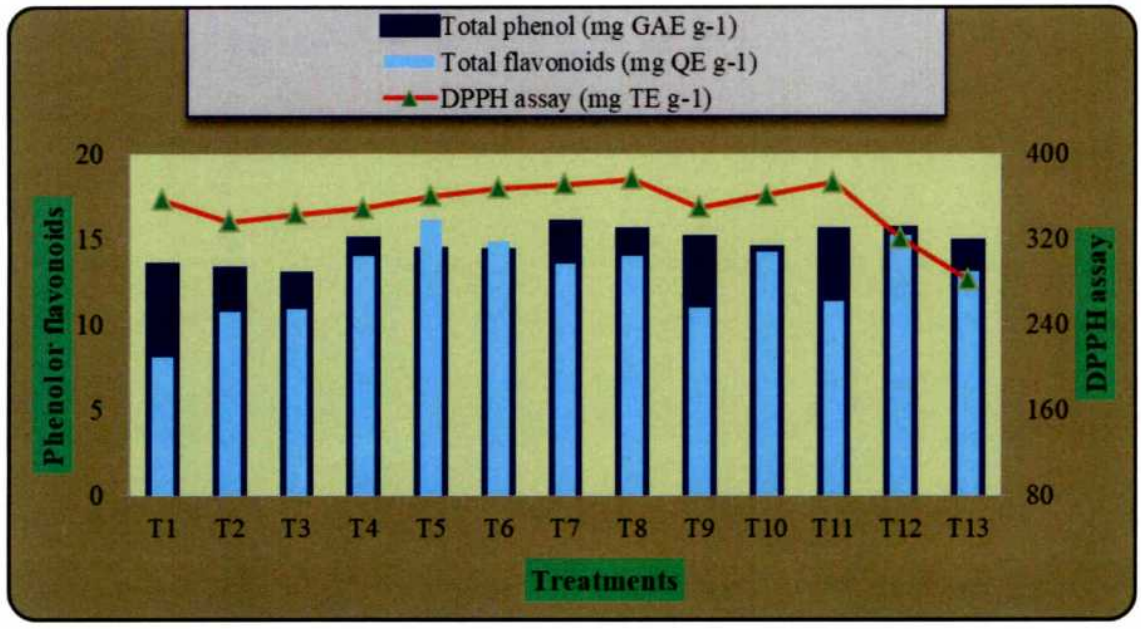


Fig. 19 Phenols, flavonoids and DPPH assay in fenugreek seed under different inorganic and biofertilizer combinations

T_1: NPK 100% + *Azotobacter* + VAM+ KM
T_2: NPK 100% + *Azotobacter* + PSB+ KM
T_3: NPK 100% + *Azospirillum*+ VAM+ KM
T_4: NPK 100% + *Azospirillum* + PSB+ KM
T_5: NPK 75% + *Azotobacter* + VAM+ KM
T_6: NPK 75% + *Azotobacter* + PSB+ KM
T_7: NPK 75% + *Azospirillum*+ VAM+ KM
T_8: NPK 75% + *Azospirillum* + PSB+ KM
T_9: NPK 50% + *Azotobacter*+ VAM+ KM
T_{10}: NPK 50% + *Azotobacter* + PSB+ KM
T_{11}: NPK 50% + *Azospirillum*+ VAM+ KM
T_{12}: NPK 50% + *Azospirillum*+ PSB+ KM
T_{13}: Recommended NPK - 20:40:20 kg ha^{-1}

100 mg^{-1}). In three way interaction inorganic F × N × P the highest galactomannan content (17.588 mg 100 mg^{-1}) was recorded in 100% NPK (control) followed by 100% NPK+ *Azotobacter*+ PSB (9.522 mg 100 mg^{-1}) and the lowest galactomannan content was recorded in 75% NPK+ *Azotobacter*+ VAM (5.328 mg 100 mg^{-1}).

2.3.2 Total soluble protein and their fractions

Total soluble protein content in respect of sole treatments, maximum value (14.866 mg 100 mg^{-1}) was noticed in medium level of inorganic fertilizers *i.e.* 75% NPK. Highest total soluble protein content (13.802 mg 100 mg^{-1}) was recorded in *Azospirillum* in respect of nitrogenous bio inoculants. In phosphatic bioinoculants the highest total soluble protein content was recorded in VAM (13.941 mg 100 mg^{-1}). In two way interaction of inorganic fertilizer levels and nitrogenous bioinoculants, the highest total soluble protein content was recorded in combination of 75% NPK+ *Azotobacter* (14.889 mg 100 mg^{-1}) followed by 75% NPK+ *Azospirillum* (14.843 mg 100 mg^{-1}) and the lowest was recorded in 100% NPK+ *Azospirillum* (11.877 mg 100 mg^{-1}). In inorganic fertilizer (F)×phosphatic bio inoculants (P) interaction, the highest total soluble protein content was recorded in 75% NPK+ VAM (16.127 mg 100 mg^{-1}) and the lowest total soluble protein was recorded in 100% NPK+PSB combination (11.276 mg 100 mg^{-1}). In both interactions, 75% NPK was better as compared to other levels of inorganic fertilizers. In nitrogenous × phosphatic bioinoculants interaction, the highest total soluble protein content was recorded in *Azospirillum* + VAM (14.122 mg 100 mg^{-1}) and the lowest total soluble protein content was recorded in *Azotobacter* + VAM (13.462 mg 100 mg^{-1}). In three way interaction of F × N × P the highest total soluble protein content was recorded in combination of 75% NPK+ *Azotobacter*+ VAM (16.903 mg 100 mg^{-1}) followed by 50% NPK+ *Azotobacter*+ PSB (15.790 mg 100 mg^{-1}) and the lowest was recorded in 100% NPK+ *Azospirillum*+ PSB (10.832 mg 100 mg^{-1}). In 100% NPK (control), the amount of total soluble protein recorded was 14.018 mg 100 mg^{-1}. Different fractions of protein based on solubility are presented in Table 27. and Fig. 18

i) Albumin content

In the sole effect of inorganic fertilizers the maximum albumin content (5.370 mg 100 mg^{-1}) was recorded in lowest level of fertilizer *i.e.* 50% NPK. Highest albumin content recorded in *Azospirillum* (5.306 mg 100 mg^{-1}) as compared to *Azotobacter*. In phosphatic bioinoculants, the highest albumin content was recorded in VAM (5.368 mg

100 mg^{-1}). In interaction of F×N, the highest albumin content was recorded in combination of 50% NPK+ *Azospirillum* (5.747 mg 100 mg^{-1}) and the lowest albumin content was recorded in 75% NPK+ *Azotobacter* (4.759 mg 100 mg^{-1}). In inorganic fertilizer × phosphatic bioinoculants interaction, the highest albumin content was recorded in 50% NPK+PSB (5.430 mg 100 mg^{-1}) and the lowest albumin content was recorded in 75% NPK+ PSB (4.365 mg 100 mg^{-1}). In N×P interaction the highest albumin content was recorded in *Azospirillum* + VAM (5.489 mg 100 mg^{-1}) and the lowest albumin content was recorded in *Azotobacter* + PSB (4.789 mg 100 mg^{-1}). In three factor interaction inorganic fertilizer × nitrogenous bioinoculants × phosphatic bio inoculants the highest albumin content was recorded in 100% NPK (control) as 6.485 mg 100 mg^{-1} followed by 50% NPK+ *Azospirillum*+ PSB (6.037 mg 100 mg^{-1}) and the lowest albumin content was recorded in combination of 75% NPK+ *Azotobacter*+ PSB (4.210 mg 100 mg^{-1}).

ii) Globulin content

In the sole effects of different factors, highest content of globulin was recorded with medium level of inorganic fertilizers *i.e.* in 75% NPK (5.268 mg 100 mg^{-1}), *Azospirillum* (5.130 mg 100 mg^{-1}) and PSB (5.006 mg 100 mg^{-1}) respectively and lowest was recorded in 100% NPK (4.671 mg 100 mg^{-1}), *Azotobacter* (4.238 mg 100 mg^{-1}) and VAM (5.299 mg 100 mg^{-1}) respectively. In two way interaction of inorganic fertilizer and nitrogenous bioinoculants, the highest globulin content was recorded in 75% NPK+ *Azospirillum* (5.510 mg 100 mg^{-1}) followed by 50% NPK+ *Azospirillum* (5.192 mg 100 mg^{-1}) and lowest was recorded in 100% NPK+ *Azotobacter* (4.654 mg 100 mg^{-1}). In inorganic fertilizer (F) × phosphatic bioinoculants (P) interaction the highest globulin content was recorded in 50% NPK+ PSB (5.908 mg 100 mg^{-1}) and the lowest globulin content was recorded in 50% NPK+ VAM (4.159 mg 100 mg^{-1}). In nitrogenous boinoculants × phosphatic bioinoculants interaction, the highest globulin content was recorded in *Azospirillum* + PSB (5.196 mg 100 mg^{-1}) and the lowest globulin content was recorded in *Azotobacter*+ PSB (4.816 mg 100 mg^{-1}). In this interaction, it was also observed that in combination with PSB, *Azospirillum* was proved better than *Azotobacter*. In three way interaction of inorganic fertilizer level × nitrogenous bioinoculants × phosphatic bioinoculants, the globulin content range in between 3.309 to 6.442 mg 100 mg^{-1}. Highest value was recorded in combination of 50% NPK + *Azotobacter* + PSB followed by 75% NPK+ *Azotobacter* + VAM (6.263 mg 100 mg^{-1}) as compared to 100% NPK recorded 5.088 mg 100 mg^{-1}.

Table 27. Soluble protein fractions of fenugreek seed as influenced by inorganic fertilizers and bioinoculants

Treatments	Albumin (mg 100mg^{-1})			Globulin (mg 100mg^{-1})			Prolamin (mg 100mg^{-1})			Glutellin (mg 100mg^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer												
100% NPK (F_1)	5.271	5.203	5.237	5.023	4.320	4.671	0.313	0.740	0.527	2.041	1.517	1.779
75% NPK (F_2)	4.691	5.068	4.880	5.881	4.655	5.268	0.722	0.678	0.700	4.322	3.716	4.019
50% NPK (F_3)	4.913	5.828	5.370	5.540	4.527	5.034	0.740	1.467	1.103	3.036	2.028	2.532
S.Em. (±)	**0.008**	**0.008**	**0.006**	**0.009**	**0.015**	**0.008**	**0.007**	**0.009**	**0.006**	**0.008**	**0.007**	**0.005**
C.D. (P=0.05)	**0.024**	**0.024**	**0.016**	**0.026**	**0.043**	**0.024**	**0.020**	**0.027**	**0.016**	**0.023**	**0.021**	**0.015**
Nitrogenous bioinoculants												
Azotobacter (N_1)	4.863	5.174	5.018	5.466	4.238	4.852	0.512	0.913	0.712	3.233	2.823	3.028
Azospirillum (N_2)	5.053	5.559	5.306	5.497	4.764	5.130	0.672	1.010	0.841	3.032	2.017	2.524
S.Em. (±)	**0.007**	**0.007**	**0.005**	**0.007**	**0.012**	**0.007**	**0.005**	**0.008**	**0.005**	**0.006**	**0.006**	**0.004**
C.D. (P=0.05)	**0.019**	**0.019**	**0.013**	**0.021**	**0.035**	**0.020**	**0.016**	**0.022**	**0.013**	**0.019**	**0.017**	**0.012**
Phosphatic bioinoculants												
VAM (P_1)	5.257	5.479	5.368	5.299	4.653	4.976	0.609	0.876	0.743	3.133	2.574	2.854
PSB (P_2)	4.659	5.253	4.956	5.663	4.349	5.006	0.574	1.047	0.811	3.132	2.266	2.699
S.Em. (±)	0.007	0.007	0.005	0.007	0.012	0.007	0.005	0.008	0.005	0.006	0.006	0.004
C.D. (P=0.05)	0.019	0.019	0.013	0.021	0.035	0.020	0.016	0.022	0.013	NS	0.017	0.012

Contd.....

VAM= Vesicular arbuscular mycorrhiza PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=Days after sowing; NS= Non siginificant,
N_1=*Azotobacter chroococcum*; N_2=*Azospirillum lipoferum*; P_1 = *Glomus fasciculatum*; P_2= *Bacillus polymixa*

Contd.....

Treatments	Albumin (mg 100mg^{-1})			Globulin (mg 100mg^{-1})			Prolamin (mg 100mg^{-1})			Glutellin (mg 100mg^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)												
F_1N_1	5.498	5.105	5.302	4.937	4.372	4.654	0.390	0.798	0.594	2.110	1.890	2.000
F_1N_2	5.043	5.300	5.172	5.108	4.268	4.688	0.237	0.682	0.459	1.972	1.143	1.558
F_2N_1	4.567	4.952	4.759	5.560	4.492	5.026	0.338	0.742	0.540	4.772	4.357	4.564
F_2N_2	4.815	5.185	5.000	6.202	4.818	5.510	1.107	0.613	0.860	3.872	3.075	3.473
F_3N_1	4.523	5.465	4.994	5.900	3.850	4.875	0.808	1.198	1.003	2.818	2.223	2.521
F_3N_2	5.302	6.192	5.747	5.180	5.204	5.192	0.672	1.735	1.203	3.253	1.832	2.543
S.Em. (±)	**0.011**	**0.011**	**0.008**	**0.013**	**0.021**	**0.012**	**0.010**	**0.013**	**0.008**	**0.011**	**0.010**	**0.008**
C.D. (P=0.05)	**0.033**	**0.033**	**0.023**	**0.037**	**0.060**	**0.034**	**0.028**	**0.039**	**0.023**	**0.033**	**0.030**	**0.021**
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)												
F_1P_1	5.450	5.350	5.400	5.407	4.810	5.108	0.388	0.750	0.569	2.255	1.892	2.073
F_1P_2	5.092	5.055	5.073	4.638	3.830	4.234	0.238	0.730	0.484	1.827	1.142	1.484
F_2P_1	5.285	5.503	5.394	6.420	4.900	5.660	0.662	0.690	0.676	4.685	4.108	4.397
F_2P2	4.097	4.633	4.365	5.342	4.410	4.876	0.783	0.665	0.724	3.958	3.323	3.641
F_3P_1	5.037	5.585	5.311	4.070	4.249	4.159	0.778	1.188	0.983	2.460	1.723	2.092
F_3P_2	4.788	6.072	5.430	7.010	4.806	5.908	0.702	1.745	1.223	3.612	2.332	2.972
S.Em. (±)	**0.011**	**0.011**	**0.008**	**0.013**	**0.021**	**0.012**	**0.010**	**0.013**	**0.008**	**0.011**	**0.010**	**0.008**
C.D. (P=0.05)	**0.033**	**0.033**	**0.023**	**0.037**	**0.060**	**0.034**	**0.028**	**0.039**	**0.023**	**0.033**	**0.030**	**0.021**
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
N_1P_1	5.249	5.246	5.247	5.246	4.529	4.887	0.561	0.671	0.616	3.157	2.862	3.009
N_1P_2	4.477	5.102	4.789	5.686	3.947	4.816	0.463	1.154	0.809	3.310	2.784	3.047
N_2P_1	5.266	5.713	5.489	5.352	4.777	5.064	0.658	1.081	0.869	3.110	2.287	2.698
N_2P_2	4.841	5.404	5.123	5.641	4.751	5.196	0.686	0.939	0.812	2.954	1.747	2.351
S.Em. (±)	**0.009**	**0.009**	**0.007**	**0.010**	**0.017**	**0.010**	**0.008**	**0.011**	**0.007**	**0.009**	**0.008**	**0.006**
C.D. (P=0.05)	**5.249**	**5.246**	**5.247**	**0.030**	**0.049**	**0.028**	**0.023**	**0.032**	**0.019**	**0.027**	**0.025**	**0.018**

Contd.....

Contd....

Treatments	Albumin (mg 100mg^{-1})			Globulin (mg 100mg^{-1})			Prolamin (mg 100mg^{-1})			Glutellin (mg 100mg^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
$F_1N_1P_1$	5.533	5.003	5.268	5.247	4.933	5.090	0.527	0.657	0.592	2.473	2.387	2.430
$F_1N_1P_2$	5.463	5.207	5.335	4.627	3.810	4.218	0.253	0.940	0.597	1.747	1.393	1.570
$F_1N_2P_1$	5.367	5.697	5.532	5.567	4.687	5.127	0.250	0.843	0.547	2.037	1.397	1.717
$F_1N_2P_2$	4.720	4.903	4.812	4.650	3.850	4.250	0.223	0.520	0.372	1.907	0.890	1.398
$F_2N_1P_1$	5.080	5.537	5.308	6.953	5.573	6.263	0.190	0.707	0.448	5.173	4.593	4.883
$F_2N_1P_2$	4.053	4.367	4.210	4.167	3.410	3.788	0.487	0.777	0.632	4.370	4.120	4.245
$F_2N_2P_1$	5.490	5.470	5.480	5.887	4.227	5.057	1.133	0.673	0.903	4.197	3.623	3.910
$F_2N_2P_2$	4.140	4.900	4.520	6.517	5.410	5.963	1.080	0.553	0.817	3.547	2.527	3.037
$F_3N_1P_1$	5.133	5.197	5.165	3.537	3.081	3.309	0.967	0.650	0.808	1.823	1.607	1.715
$F_3N_1P_2$	3.913	5.733	4.823	8.263	4.620	6.442	0.650	1.747	1.198	3.813	2.840	3.327
$F_3N_2P_1$	4.940	5.973	5.457	4.603	5.417	5.010	0.590	1.727	1.158	3.097	1.840	2.468
$F_3N_2P_2$	5.663	6.410	6.037	5.757	4.992	5.374	0.753	1.743	1.248	3.410	1.823	2.617
Control (100% NPK)	6.205	6.765	6.485	4.207	5.970	5.088	0.765	0.155	0.460	2.297	1.672	1.984
Without control												
S.Em. (±)	**0.016**	**0.016**	**0.011**	**0.018**	**0.029**	**0.017**	**0.013**	**0.019**	**0.011**	**0.016**	**0.015**	**0.011**
C.D. (P=0.05)	**0.047**	**0.047**	**0.032**	**0.052**	**0.085**	**0.048**	**0.039**	**0.055**	**0.033**	**0.046**	**0.043**	**0.030**
With control												
S.Em. (±)	**0.012**	**0.012**	**0.008**	**0.013**	**0.022**	**0.013**	**0.010**	**0.014**	**0.008**	**0.012**	**0.011**	**0.008**
C.D. (P=0.05)	**0.035**	**0.035**	**0.024**	**0.039**	**0.063**	**0.036**	**0.029**	**0.040**	**0.024**	**0.034**	**0.032**	**0.022**

iii) Prolamin content

In the sole effect of three factors (inorganic fertilizer, nitrogenous and phosphatic bioinoculants) highest values were noticed in 50% NPK (1.103 mg 100 mg^{-1}), *Azospirillum* (0.841 mg 100 mg^{-1}) and in PSB (0.811 mg 100 mg^{-1}). In interaction of F×N the highest prolamin content was recorded in combination of 50% NPK+ *Azospirillum* (1.203 mg 100 mg^{-1}) followed by 50% NPK+ *Azotobacter* (1.003 mg 100 mg^{-1}) and the lowest prolamin content was recorded in 100% NPK+ *Azospirillum* (0.459 mg 100 mg^{-1}). In F× P interaction, the highest prolamin content was recorded in 50% NPK + PSB (1.223 mg 100 mg^{-1}) and the lowest prolamin content was recorded in 100% NPK+ PSB (0.484 mg 100 mg^{-1}). In N× P interaction, the highest prolamin content was recorded in combination of *Azospirillum*+ VAM (0.869 mg 100 mg^{-1}) and the lowest prolamin content was recorded in *Azotobacter*+ VAM (0.616 mg 100 mg^{-1}). In three way interaction, the highest prolamin content was recorded in combination of 50% NPK+ *Azospirillum*+ PSB (1.248 mg 100 mg^{-1}), and the lowest prolamin content was recorded in 100% NPK+ *Azospirillum*+ PSB (0.372 mg 100 mg^{-1}). Through this interaction, it was noticed that in combination with *Azospirillum*+ PSB, 50% NPK was proved better than other levels.

iv) Glutellin content

In the sole effect of inorganic fertilizer, nitrogenous and phosphatic bioinoculants the maximum values of 4.019, 3.028 and 2.854 mg 100 mg^{-1} were recorded in treatments of 75% NPK, *Azotobacter* and VAM respectively. In two way interaction of F×N, the highest glutellin content was recorded in combination of 75% NPK+ *Azotobacter* (4.564 mg 100 mg^{-1}) and the lowest glutellin content was recorded in 100% NPK+ *Azospirillum* (1.558 mg 100 mg^{-1}) .

In F× P interaction, the highest glutellin content was recorded in 75% NPK+ VAM (4.397 mg 100 mg^{-1}) and the lowest glutellin content was recorded in 100% NPK+ PSB (1.484 mg 100 mg^{-1}). In both interactions, 75% NPK was proved better than other level fertilizers. In N× P interaction the highest glutellin content was recorded in *Azotobacter*+ VAM (3.009 mg 100 mg^{-1}) and the lowest glutellin content was recorded in combination of *Azospirillum*+ PSB (2.351 mg 100 mg^{-1}). In three way interaction F×N×P, the highest glutellin content was recorded in combination of 75% NPK+ *Azotobacter*+ VAM (4.883 mg 100 mg^{-1}), and the lowest glutellin was recorded in 100% NPK+ *Azospirillum*+ PSB (1.398 mg 100 mg^{-1}). 100% NPK recorded 1.984 mg 100 mg^{-1} of glutellin.

2.3.3 Total phenols, flavonoids and antioxidant activity

The data pertaining to total phenol content of sole effects of different components (levels of inorganic fertilizers, nitrogenous bioinoculants and phosphatic bioinoculants) and their interactions were presented in Table 28. and Fig. 19. As regards the sole effects of fertilizers, highest total phenol was recorded in 50% NPK (14.985 mg GAE g^{-1}). In case of bioinoculants, highest total phenol content was recorded in *Azospirillum* (14.907 mg GAE g^{-1}) and PSB (14.514 mg GAE g^{-1}) respectively as compared to other levels of fertilizers and bioinoculants. In two way interaction of inorganic fertilizer and nitrogenous bioinoculants, the highest total phenol content was recorded in 75% NPK+ *Azospirillum* (15.553 mg GAE g^{-1}) followed by 50% NPK+ *Azospirillum* (15.383 mg GAE g^{-1}) and the lowest total phenol content was recorded in 100% NPK+ *Azotobacter* (13.173 mg GAE g^{-1}). In inorganic fertilizer × phosphatic bioinoculants interaction, the highest total phenol content was recorded in 50% NPK+VAM (15.104 mg GAE g^{-1}) followed by 75% NPK+ VAM (15.745 mg GAE g^{-1}) and the lowest total phenol content was recorded in 100% NPK+ VAM (13.017 mg GAE g^{-1}). In nitrogenous bioinoculants × phosphatic bioinoculants interaction the highest total phenol content was recorded in *Azospirillum*+ PSB (15.202 mg GAE g^{-1}) and the lowest total phenol content was recorded in *Azotobacter*+ PSB (13.826 mg GAE g^{-1}). In F×N×P interaction, the highest total phenol content was recorded in the combination of 75% NPK+ *Azospirillum*+ VAM (15.753 mg GAE g^{-1}) as compared to lowest (11.744 mg GAE g^{-1}) in 100% NPK (control)

There was significant variation with respect to the sole effects of different levels (100, 75 and 50%) of inorganic fertilizers, nitrogenous bioinoculants (*Azotobacter* and *Azospirillum*) and phosphatic bioinoculants (VAM and PSB) and also their interactions. The data presented in Table 28. and Fig. 19 in respect to the sole effects, maximum flavonoid content recorded were14.670, 13.213 and 13.881 mg QE g^{-1} in 75% NPK, *Azospirillum* and PSB respectively as compared to lowest as 10.971, 12.549 and 11.881 in 100% NPK, *Azotobacter* and VAM respectively. In two way interaction of F×N, the maximum total flavonoids content was recorded in 75% NPK+ *Azotobacter* (15.519 mg QE g^{-1}) and the lowest total flavonoids content was recorded in 100% NPK+ *Azotobacter* (9.465 mg QE g^{-1}). In F × P interaction, the highest total flavonoids content was recorded in 75% NPK+ VAM (14.901 mg QE g^{-1}) and the lowest was recorded in 100% RDF+ VAM (9.536 mg QE g^{-1}). In N×P interaction, the highest total flavonoids content was

Table 28. Total phenols, flavonoids, antioxidant activity and diosgenin content of fenugreek seed as influenced by inorganic fertilizers and bioinoculants

Treatments	Total phenol (mg GAE g^{-1})			Total flavonoids (mg QE g^{-1})			Antioxidant activity (DPPH assay) [mg TE g^{-1}]			Diosgenin (mg 100mg^{-})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer												
100% NPK (F_1)	13.502	13.456	13.479	9.768	12.174	10.971	351.667	341.733	346.700	0.204	0.382	0.293
75% NPK (F_2)	15.413	14.291	14.852	16.556	12.784	14.670	376.233	362.250	369.242	0.261	0.399	0.330
50% NPK (F_3)	17.333	12.637	14.985	13.416	12.588	13.002	347.900	355.233	351.567	0.373	0.207	0.290
S.Em. (±)	**0.007**	**0.019**	**0.010**	**0.006**	**0.002**	**0.003**	**0.274**	**0.213**	**0.172**	**0.0002**	**0.0002**	**0.0002**
C.D. (P=0.05)	**0.019**	**0.054**	**0.028**	**0.016**	**0.005**	**0.008**	**0.800**	**0.620**	**0.488**	**0.0007**	**0.0007**	**0.0005**
Nitrogenous bioinoculants												
Azotobacter (N_1)	15.138	12.803	13.971	14.014	11.083	12.549	355.778	355.600	355.689	0.264	0.290	0.277
Azospirillum (N_2)	15.694	14.119	14.907	12.479	13.947	13.213	361.422	350.544	355.983	0.295	0.369	0.332
S.Em. (±)	**0.005**	**0.015**	**0.008**	**0.005**	**0.001**	**0.002**	**0.224**	**0.174**	**0.140**	**0.0002**	**0.0002**	**0.0001**
C.D. (P=0.05)	**0.016**	**0.044**	**0.023**	**0.013**	**0.004**	**0.007**	**0.654**	**0.507**	**NS**	**0.0006**	**0.0005**	**0.0004**
Phosphatic bioinoculants												
VAM (P_1)	15.746	12.980	14.363	12.049	11.712	11.881	363.278	355.933	359.606	0.254	0.316	0.285
PSB (P_2)	15.086	13.943	14.514	14.444	13.318	13.881	353.922	350.211	352.067	0.305	0.344	0.324
S.Em. (±)	**0.005**	**0.015**	**0.008**	**0.005**	**0.001**	**0.002**	**0.224**	**0.174**	**0.140**	**0.0002**	**0.0002**	**0.0001**
C.D. (P=0.05)	**0.016**	**0.044**	**0.023**	**0.013**	**0.004**	**0.007**	**0.654**	**0.507**	**0.398**	**0.0006**	**0.0005**	**0.0004**

Contd.....

VAM= Vesicular arbuscular mycorrhiza PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=Days after sowing; NS= Non siginificant,
N_1=*Azotobacter chroococcum*; N_2=*Azospirillum lipoferum*; P_1 = *Glomus fasciculatum*; P_2 = *Bacillus polymixa*
GAE= Gallic acid equivalents; QE= Quercetin equivalents; TE= Trolox equivalent; DPPH= 2,2-diphenyl-1-picrylhydrazyl.

Contd.....

Treatments	Total phenol content (mg GAE g^{-1})			Total flavonoids content (mg QE g^{-1})			Antioxidant activity (DPPH assay) [mg TE g^{-1}]			Diosgenin content (mg $100mg^{-1}$)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)												
F_1N_1	13.973	12.373	13.173	9.465	9.465	9.465	343.633	349.900	346.767	0.186	0.338	0.262
F_1N_2	13.030	14.538	13.784	10.072	14.883	12.478	359.700	333.567	346.633	0.222	0.427	0.324
F_2N_1	14.827	13.478	14.152	18.265	12.773	15.519	377.000	351.900	364.450	0.251	0.330	0.291
F_2N_2	16.000	15.105	15.553	14.847	12.795	13.821	375.467	372.600	374.033	0.271	0.468	0.369
F_3N_1	16.615	12.559	14.587	14.313	11.012	12.663	346.700	365.000	355.850	0.354	0.203	0.279
F_3N_2	18.052	12.715	15.383	12.518	14.163	13.341	349.100	345.467	347.283	0.393	0.211	0.302
S.Em. (±)	**0.009**	**0.026**	**0.014**	**0.008**	**0.003**	**0.004**	**0.388**	**0.301**	**0.243**	**0.0004**	**0.0003**	**0.0002**
C.D. (P=0.05)	**0.027**	**0.077**	**0.039**	**0.023**	**0.008**	**0.012**	**1.132**	**0.877**	**0.690**	**0.0010**	**0.0009**	**0.0007**
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)												
F_1P_1	13.625	12.408	13.017	7.548	11.523	9.536	361.233	340.100	350.667	0.188	0.371	0.280
F_1P_2	13.378	14.503	13.941	11.988	12.825	12.407	342.100	343.367	342.733	0.220	0.393	0.307
F_2P_1	15.745	14.193	14.969	17.610	12.192	14.901	376.600	355.800	366.200	0.229	0.361	0.295
F_2P2	15.082	14.389	14.735	15.502	13.377	14.439	375.867	368.700	372.283	0.293	0.437	0.365
F_3P_1	17.868	12.339	15.104	10.990	11.422	11.206	352.000	371.900	361.950	0.345	0.214	0.279
F_3P_2	16.798	12.935	14.867	15.842	13.753	14.798	343.800	338.567	341.183	0.402	0.200	0.301
S.Em. (±)	**0.009**	**0.026**	**0.014**	**0.008**	**0.003**	**0.004**	**0.388**	**0.301**	**0.243**	**0.0004**	**0.0003**	**0.0002**
C.D. (P=0.05)	**0.027**	**0.077**	**0.039**	**0.023**	**0.008**	**0.012**	**1.132**	**0.877**	**0.690**	**0.0010**	**0.0009**	**0.0007**
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
N_1P_1	15.440	12.791	14.115	12.781	10.803	11.792	363.289	348.733	356.011	0.251	0.297	0.274
N_1P_2	14.837	12.816	13.826	15.248	11.363	13.306	348.267	362.467	355.367	0.276	0.283	0.280
N_2P_1	16.052	13.170	14.611	11.318	12.621	11.969	363.267	363.133	363.200	0.256	0.334	0.295
N_2P_2	15.336	15.069	15.202	13.640	15.273	14.457	359.578	337.956	348.767	0.334	0.404	0.369
S.Em. (±)	**0.008**	**0.021**	**0.011**	**0.006**	**0.002**	**0.003**	**0.317**	**0.245**	**0.198**	**0.0003**	**0.0003**	**0.0002**
C.D. (P=0.05)	**0.022**	**0.063**	**0.032**	**0.019**	**0.006**	**0.009**	**0.924**	**0.716**	**0.563**	**0.0008**	**0.0008**	**0.0005**

Contd.....

Contd....

Treatments	Total phenol content (mg GAE g^{-1})			Total flavonoids content (mg QE g^{-1})			Antioxidant activity (DPPH assay) [mg TE g^{-1}]			Diosgenin content (mg $100mg^{-1}$)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)												
$F_1N_1P_1$	14.797	11.787	13.292	7.890	8.437	8.163	365.667	348.800	357.233	0.242	0.334	0.288
$F_1N_1P_2$	13.150	12.960	13.055	11.040	10.493	10.767	321.600	351.000	336.300	0.130	0.341	0.235
$F_1N_2P_1$	12.453	13.030	12.742	7.207	14.610	10.908	356.800	331.400	344.100	0.133	0.408	0.271
$F_1N_2P_2$	13.607	16.047	14.827	12.937	15.157	14.047	362.600	335.733	349.167	0.311	0.445	0.378
$F_2N_1P_1$	14.270	14.100	14.185	20.683	11.693	16.188	373.400	348.000	360.700	0.188	0.360	0.274
$F_2N_1P_2$	15.383	12.855	14.119	15.847	13.853	14.850	380.600	355.800	368.200	0.314	0.300	0.307
$F_2N_2P_1$	17.220	14.287	15.753	14.537	12.690	13.613	379.800	363.600	371.700	0.269	0.362	0.316
$F_2N_2P_2$	14.780	15.923	15.352	15.157	12.900	14.028	371.133	381.600	376.367	0.272	0.574	0.423
$F_3N_1P_1$	17.253	12.485	14.869	9.770	12.280	11.025	350.800	349.400	350.100	0.323	0.198	0.261
$F_3N_1P_2$	15.977	12.633	14.305	18.857	9.743	14.300	342.600	380.600	361.600	0.385	0.208	0.297
$F_3N_2P_1$	18.483	12.193	15.338	12.210	10.563	11.387	353.200	394.400	373.800	0.366	0.230	0.298
$F_3N_2P_2$	17.620	13.237	15.428	12.827	17.763	15.295	345.000	296.533	320.767	0.419	0.192	0.306
Control (100% NPK)	17.578	11.744	14.661	13.340	12.882	13.111	244.883	319.367	282.125	0.185	0.280	0.233
Without control												
S.Em. (±)	**0.013**	**0.037**	**0.020**	**0.011**	**0.004**	**0.006**	**0.548**	**0.425**	**0.343**	**0.0005**	**0.0005**	**0.0003**
C.D. (P=0.05)	**0.038**	**0.108**	**0.055**	**0.032**	**0.011**	**0.016**	**1.601**	**1.241**	**0.976**	**0.0015**	**0.0013**	**0.0009**
With control												
S.Em. (±)	**0.010**	**0.027**	**0.014**	**0.008**	**0.003**	**0.004**	**0.404**	**0.313**	**0.253**	**0.0004**	**0.0003**	**0.0002**
C.D. (P=0.05)	**0.028**	**0.080**	**0.041**	**0.024**	**0.008**	**0.012**	**1.178**	**0.913**	**0.718**	**0.0011**	**0.0010**	**0.0007**

recorded in *Azospirillum*+ PSB (14.457 mg QE g^{-1}) as compared to other combinations. In three way interaction of F×N×P, the highest total flavonoids content was recorded in 75% NPK+ *Azotobacter*+ VAM (16.188 mg QE g^{-1}) and the lowest total flavonoids content was recorded in 100% NPK+ *Azotobacter*+ VAM (8.163 mg QE g^{-1}). 100% NPK (control) recorded total flavonoid content of 13.111 mg QE g^{-1} of seed.

The data pertaining to antioxidant activity presented in Table 28. and Fig.19 revealed that among the sole effects of three factors there was significant difference in inorganic fertilizer level and phosphatic bioinoculants but non-significant difference was observed in nitrogenous bioinoculants. Highest antioxidant activity (369.242 mg TE g^{-1}) was recorded in 75% NPK with regard to sole effect of inorganic fertilizer. *Azospirillum* recorded highest antioxidant activity (355.983 mg TE g^{-1}). Between phosphatic bioinoculants the highest antioxidant activity was recorded in VAM (359.606 mg TE g^{-1}). In two way interaction of F×N, *Azospirillum* was better than *Azotobacter* and 75% NPK was better than other levels. The highest antioxidant activity was recorded in combination of 75% NPK+ *Azospirillum* (374.033 mg TE g^{-1}) and the lowest antioxidant activity was recorded in 100% NPK+ *Azospirillum* (346.633 mg TE g^{-1}). In F × P interaction, the highest antioxidant activity was recorded in combination of 75% NPK+ PSB (372.283 mg TE g^{-1}) and the lowest antioxidant activity was recorded in 50% NPK+PSB (341.183 mg TE g^{-1}). In N×P interaction, the highest antioxidant activity was recorded in *Azospirillum*+ VAM (363.200 mg TE g^{-1}) and the lowest antioxidant activity was recorded in *Azospirillum* + PSB (348.767 mg TE g^{-1}). In three way interaction of inorganic fertilizer × nitrogenous bioinoculants × phosphatic bioinoculants the highest antioxidant activity was recorded in 75% NPK+ *Azospirillum*+ PSB (376.367 mg TE g^{-1}) and the lowest antioxidant activity was recorded in 50% NPK+ *Azospirillum*+ PSB (320.767 mg TE g^{-1}). The antioxidant activity of 282.125 mg TE g^{-1} was noticed in 100% NPK (control).

2.3.4 Diosgenin content

The data pertaining to diosgenin content in the sole effects and their interactions were presented in Table 28. In respect of sole effect of inorganic fertilizer highest diosgenin was recorded in 75% NPK (0.330 mg $100mg^{-1}$). Between nitrogenous bioinoculants, highest diosgenin content was recorded in *Azospirillum* (0.332 mg $100mg^{-1}$) but with respect to phosphatic bioinoculants the highest diosgenin content was recorded in PSB (0.324 mg $100mg^{-1}$). In interaction of F×N, the maximum diosgenin content was

recorded in combination of 75% NPK+ *Azospirillum* (0.369 mg $100mg^{-1}$) and the lowest diosgenin content was recorded in 100% NPK+ *Azotobacter* (0.262 mg $100mg^{-1}$). In combination of F×P, 75% NPK+PSB proved better than other combinations. Among nitrogenous and phosphatic bioinoculants, *Azospirillum*+ PSB combination recorded highest diosgenin (0.369 mg $100mg^{-1}$) and in *Azotobacter*+ VAM (0.274 mg $100mg^{-1}$) recorded the lowest. In three way interaction F×N×P, the highest diosgenin content was recorded in combination of 75% NPK+ *Azospirillum*+ PSB (0.423 mg $100mg^{-1}$) followed by 100% NPK+ *Azospirillum*+ PSB (0.378 mg $100mg^{-1}$) and the lowest diosgenin content (0.233 mg $100mg^{-1}$) was recorded in control (100% NPK).

2.4 TOTAL COUNT OF MICROBIAL POPULATION

The populations of three types of nitrogenous bioinoculants i.e. *Azotobacter*, *Azospirillum* and *Rhizobium* and phosphorous solubilizing microorganisms and potassic mobilize were counted and varied response of the different treatment combinations were observed.

2.4.1 Population of *Azotobacter sp.*

Results presented in Table 29 and Fig. 20. showed significant variation in respect of both individual and interaction effects. In case of sole effect of inorganic fertilizers increasing trend (50.37×10^5 to 57.60×10^5 CFU g^{-1} of soil) in the *Azotobacter* population was observed with the decreasing level of inorganic fertilizer (100% NPK to 50% NPK) clearly indicating that antagonistic effect of higher level of fertilizers on the buildup of the microbial population. In case of individual effect of nitrogenous bioinoculants, *Azotobacter* population was higher in sole effect of *Azospirillum* but VAM recorded more population as compared to *Azotobacter*. In respect of F×N interaction, maximum population (60.03×10^5 CFU g^{-1} of soil) observed with75% NPK + *Azospirillum* followed by 50% NPK+ *Azospirillum* (59.74×10^5 CFU g^{-1} of soil) but they were *at par*. The results again indicate that microbial population was higher at lower level of inorganic fertilizer. In case of F×P interaction maximum *Azotobacter* population (59.20×10^5 CFU g^{-1} of soil) was recorded in 50% NPK+ PSB combination. In N×P interaction, the combination of *Azospirillum*+ VAM recorded maximum (60.70×10^5 CFU g^{-1} of soil) *Azotobacter* population. In F×N×P interaction, maximum population (62.43×10^5 CFU g^{-1} of soil) was noticed in 50% NPK + *Azospirillum*+ VAM followed by 75% NPK + *Azospirillum*+ VAM (61.54×10^5 CFU g^{-1} of soil) but both were *at par*. The minimum population was noticed under control (27.84×10^5 CFU g^{-1} of soil)

Table 29. Population of nitrogenous bioinoculants in soil of fenugreek as influenced by inorganic fertilizers and bioinoculants

Treatments	Nitrogenous bioinoculants								
	Azotobacter sp. (x10^5 CFU g of soil^{-1})			*Azospirillum sp.* (x10^5 CFU g of soil^{-1})			*Rhizobium sp.* (x10^3 CFU g of soil^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Initial soil population	36.68	40.62	38.65	34.84	38.16	36.5	43.08	47.38	45.23
Inorganic fertilizer									
100% NPK (F_1)	48.95	51.80	50.37	40.64	36.39	38.52	71.59	74.06	72.82
75% NPK (F_2)	52.05	54.30	53.18	38.16	41.09	39.63	77.09	78.34	77.71
50% NPK (F_3)	58.19	57.00	57.60	43.96	41.09	42.52	76.91	74.03	75.47
S.Em. (±)	**0.358**	**0.358**	**0.250**	**0.287**	**0.275**	**0.197**	**0.497**	**0.498**	**0.348**
C.D. (P=0.05)	**1.044**	**1.044**	**0.711**	**0.838**	**0.803**	**0.559**	**1.449**	**1.453**	**0.989**
Nitrogenous bioinoculants									
Azotobacter (N_1)	48.60	50.58	49.59	34.63	33.44	34.04	72.42	74.77	73.59
Azospirillum (N_2)	57.52	58.16	57.84	47.21	45.61	46.41	77.97	76.18	77.08
S.Em. (±)	**0.292**	**0.292**	**0.204**	**0.234**	**0.225**	**0.161**	**0.405**	**0.406**	**0.284**
C.D. (P=0.05)	**0.852**	**0.852**	**0.581**	**0.684**	**0.655**	**0.457**	**1.183**	**1.186**	**0.807**
Phosphatic bioinoculants									
VAM (P_1)	54.54	56.02	55.28	41.05	38.32	39.68	76.89	75.21	76.05
PSB (P_2)	51.58	52.72	52.15	40.79	40.73	40.76	73.50	75.74	74.62
S.Em. (±)	**0.292**	**0.292**	**0.204**	**0.234**	**0.225**	**0.161**	**0.405**	**0.406**	**0.284**
C.D. (P=0.05)	**0.852**	**0.852**	**0.581**	**NS**	**0.655**	**0.457**	**1.183**	**NS**	**0.807**

Contd.....

VAM= Vesicular arbuscular mycorrhiza PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=days after sowing; NS= non siginificant,
N_1=*Azotobacter chlorococcum*; N_2=*Azospirillum lipoferum*; P_1 = *Glomus fasciculatum*; P_2 = *Bacillus polymixa*

Contd.....

Treatments	Nitrogenous bioinoculants								
	Azotobacter sp. ($x10^5$ CFU g of $soil^{-1}$)			*Azospirillum sp.* ($x10^5$ CFU g of $soil^{-1}$)			*Rhizobium sp.* ($x10^3$ CFU g of $soil^{-1}$)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)									
F_1N_1	45.67	48.31	46.99	33.00	30.05	31.53	69.62	75.19	72.40
F_1N_2	52.22	55.28	53.75	48.28	42.73	45.51	73.56	72.94	73.25
F_2N_1	45.38	47.27	46.32	31.92	31.87	31.89	73.89	75.90	74.90
F_2N_2	58.72	61.34	60.03	44.40	50.32	47.36	80.28	80.77	80.53
F_3N_1	54.75	56.15	55.45	38.98	38.41	38.69	73.74	73.21	73.48
F_3N_2	61.63	57.86	59.74	48.94	43.77	46.36	80.08	74.85	77.46
S.Em. (±)	**0.506**	**0.506**	**0.354**	**0.406**	**0.389**	**0.278**	**0.702**	**0.704**	**0.492**
C.D. (P=0.05)	**1.476**	**1.476**	**1.006**	**1.185**	**1.135**	**0.791**	**NS**	**2.054**	**1.398**
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)									
F_1P_1	53.94	55.82	54.88	39.86	35.16	37.51	71.75	71.90	71.83
F_1P_2	43.95	47.77	45.86	41.42	37.62	39.52	71.42	76.22	73.82
F_2P_1	52.10	57.82	54.96	40.06	41.91	40.98	78.96	78.86	78.91
F_2P2	52.00	50.79	51.39	36.26	40.28	38.27	75.21	77.81	76.51
F_3P_1	57.58	54.42	56.00	43.24	37.89	40.56	79.96	74.87	77.42
F_3P_2	58.80	59.59	59.20	44.68	44.29	44.49	73.86	73.19	73.52
S.Em. (±)	**0.506**	**0.506**	**0.354**	**0.406**	**0.389**	**0.278**	**0.702**	**0.704**	**0.492**
C.D. (P=0.05)	**1.476**	**1.476**	**1.006**	**1.185**	**1.135**	**0.791**	**2.050**	**2.054**	**1.398**
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)									
N_1P_1	50.01	49.70	49.85	32.41	28.74	30.57	72.91	75.13	74.02
N_1P_2	47.19	51.45	49.32	36.85	38.14	37.50	71.92	74.40	73.16
N_2P_1	59.07	62.34	60.70	49.69	47.89	48.79	80.87	75.29	78.08
N_2P_2	55.97	53.98	54.98	44.72	43.32	44.02	75.07	77.08	76.08
S.Em. (±)	**0.413**	**0.413**	**0.289**	**0.332**	**0.318**	**0.227**	**0.573**	**0.575**	**0.402**
C.D. (P=0.05)	**NS**	**1.205**	**0.821**	**0.968**	**0.927**	**0.646**	**1.674**	**1.677**	**NS**

Contd.....

Contd....

Treatments	Nitrogenous bioinoculants								
	Azotobacter sp. ($x10^5$ CFU g of $soil^{-1}$)			*Azospirillum sp.* ($x10^5$ CFU g of $soil^{-1}$)			*Rhizobium sp.* ($x10^3$ CFU g of $soil^{-1}$)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)									
$F_1N_1P_1$	53.90	49.34	51.62	29.92	27.16	28.54	68.48	74.56	71.52
$F_1N_1P_2$	37.44	47.28	42.36	36.08	32.94	34.51	70.75	75.81	73.28
$F_1N_2P_1$	53.98	62.30	58.14	49.80	43.16	46.48	75.02	69.24	72.13
$F_1N_2P_2$	50.46	48.26	49.36	46.76	42.30	44.53	72.09	76.63	74.36
$F_2N_1P_1$	44.38	52.38	48.38	33.79	29.45	31.62	73.16	79.34	76.25
$F_2N_1P_2$	46.37	42.15	44.26	30.04	34.28	32.16	74.62	72.46	73.54
$F_2N_2P_1$	59.82	63.26	61.54	46.32	54.36	50.34	84.76	78.38	81.57
$F_2N_2P_2$	57.62	59.42	58.52	42.48	46.28	44.38	75.80	83.16	79.48
$F_3N_1P_1$	51.74	47.38	49.56	33.51	29.61	31.56	77.10	71.50	74.30
$F_3N_1P_2$	57.76	64.92	61.34	44.44	47.20	45.82	70.38	74.92	72.65
$F_3N_2P_1$	63.41	61.45	62.43	52.96	46.16	49.56	82.82	78.24	80.53
$F_3N_2P_2$	59.84	54.26	57.05	44.92	41.38	43.15	77.33	71.45	74.39
Control (100% NPK)	26.33	29.35	27.84	34.46	27.06	30.76	55.54	49.38	52.46
Without control									
S.Em. (±)	**0.715**	**0.715**	**0.500**	**0.574**	**0.550**	**0.394**	**0.993**	**0.995**	**0.696**
C.D. (P=0.05)	**2.088**	**2.087**	**1.422**	**1.676**	**1.606**	**1.118**	**2.899**	**2.905**	**1.978**
With control									
S.Em. (±)	**0.526**	**0.526**	**0.368**	**0.423**	**0.405**	**0.290**	**0.731**	**0.733**	**0.512**
C.D. (P=0.05)	**1.536**	**1.536**	**1.047**	**1.234**	**1.182**	**0.823**	**2.134**	**2.138**	**1.455**

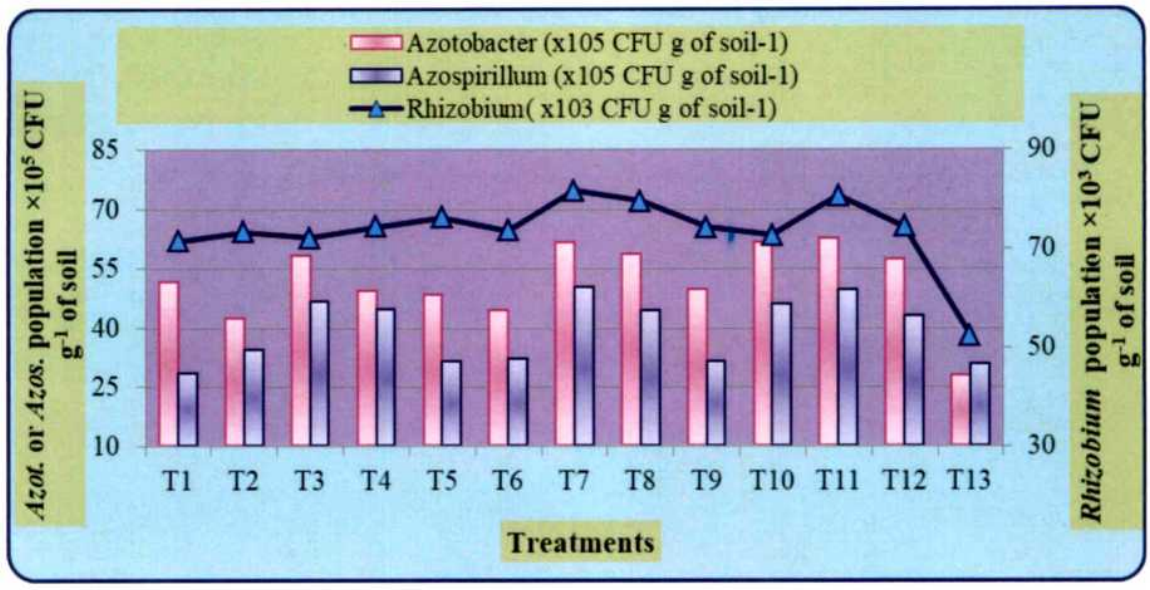


Fig. 20 Population of nitrogenous bioinoculants under different inorganic and biofertilizer

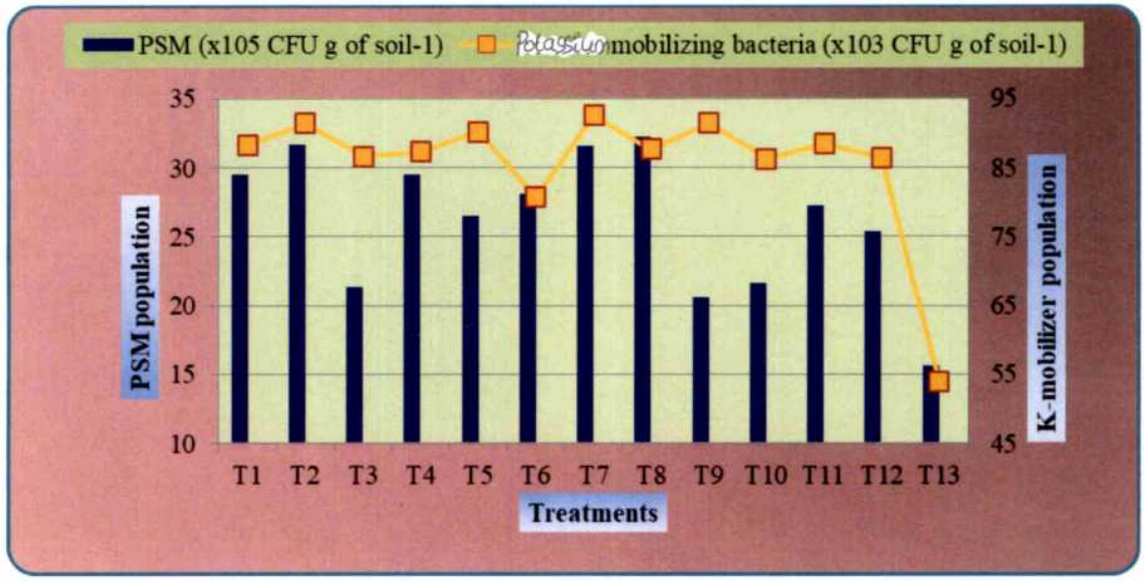


Fig. 21 Population of phoshphate solubilizing microorganism and Potassium mobilizing bacteria under different inorganic and biofertilizer combinations

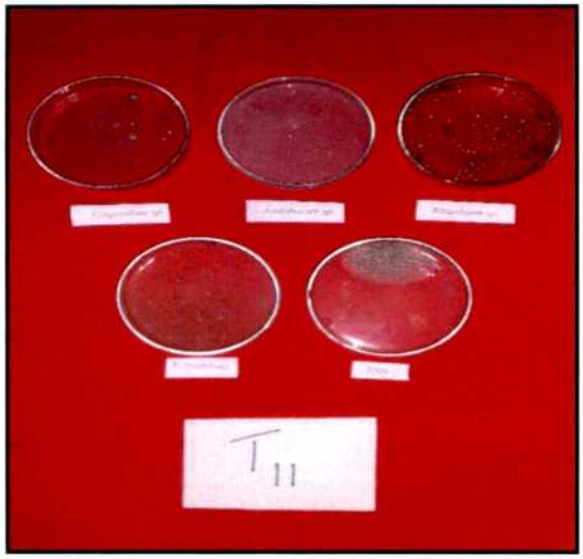
T_1: NPK 100% + *Azotobacter*+ VAM+ KM
T_2: NPK 100% + *Azotobacter* + PSB+ KM
T_3: NPK 100% + *Azospirillum* + VAM+ KM
T_4: NPK 100% + *Azospirillum* + PSB+ KM
T_5: NPK 75% + *Azotobacter* + VAM+ KM
T_6: NPK 75% + *Azotobacter* + PSB+ KM
T_7: NPK 75% + *Azospirillum*+ VAM+ KM
T_8: NPK 75% + *Azospirillum* + PSB+ KM
T_9: NPK 50% + *Azotobacter* + VAM+ KM
T_{10}: NPK 50% + *Azotobacter* + PSB+ KM
T_{11}: NPK 50% + *Azospirillum*+ VAM+ KM
T_{12}: NPK 50% + *Azospirillum*+ PSB+ KM
T_{13}: Recommended NPK - 20:40:20 kg ha^{-1}

2.4.2 Population of *Azospirillum sp.*

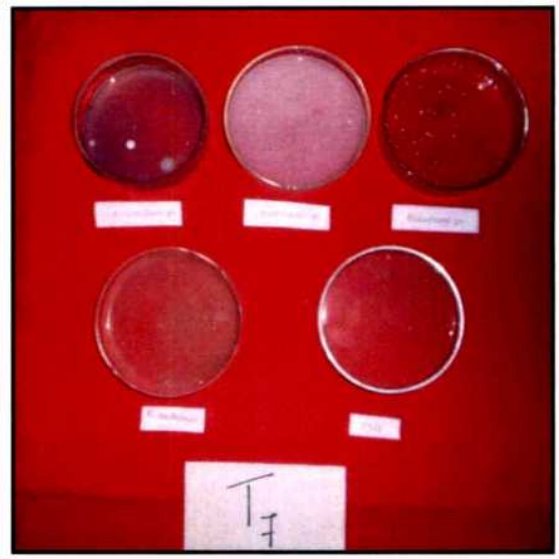
Significant variation in respect of the population of *Azospirillum sp.* was noticed both in sole and interaction effect during both the years and in pooled analysis except in case of sole effect of phosphatic bioinoculant during the year 2013-14 (Table 29 and Fig. 20). The same trend like *Azotobacter* sp. was observed *i.e.* maximum population (42.52× 10^5 CFU g^{-1} of soil) recorded with lower level of inorganic fertilizer. In nitrogenous bioinoculants, higher population of *Azospirillum* (46.41× 10^5 CFU g^{-1} of soil) but between VAM and PSB not much variation was observed. In respect of F×N interaction, maximum population (47.36× 10^5 CFU g^{-1} of soil) was noticed in 75% NPK+ *Azospirillum* followed by 50% NPK+ *Azospirillum* (46.36× 10^5 CFU g^{-1} of soil). Between VAM and PSB, higher population noticed with 50% NPK+PSB. In respect of N×P interaction, higher value was recorded with *Azospirillum*+ VAM combination. The population range recorded in between 30.57 to 48.79× 10^5 CFU g^{-1} of soil with *Azotobacter* +VAM and *Azospirillum*+ VAM combination. In F×N×P interaction, highest population was recorded in combination of 75% NPK+ *Azospirillum* + VAM (50.34× 10^5 CFU g^{-1} of soil) followed by 50% NPK+ *Azospirillum* + VAM (49.56× 10^5 CFU g^{-1} of soil). But both the treatments were statistically *at par*. 100% NPK (control) recorded population of 30.76× 10^5 CFU g^{-1} of soil.

2.4.3 Population of *Rhizobium sp.*

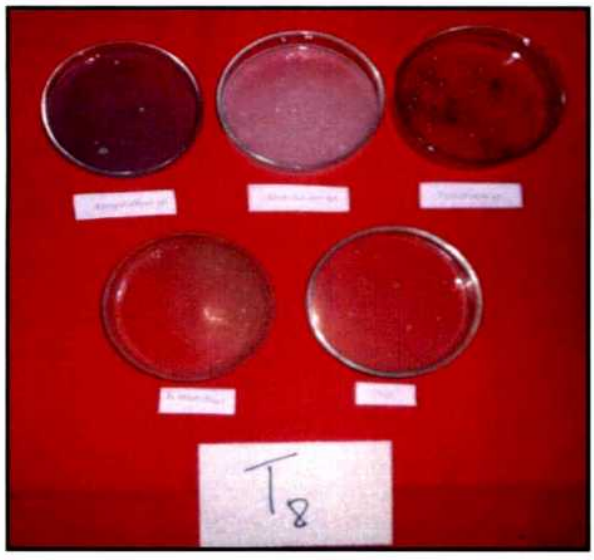
Investigation concerning the population of *Rhizobium sp.*, significant variation was observed in both sole and interaction effects during both the years and pooled analysis excepting sole effect of phosphatic bioinoculants during 2014-15, F×N interaction during 2013-14 and N×P interaction in pooled analysis (Table 29 and Fig. 20). In sole effect of inorganic fertilizers, the maximum (77.71× 10^3 CFU g^{-1} of soil) and minimum (72.82× 10^3 CFU g^{-1} of soil) population were observed in 75% and 100% NPK respectively. The *Rhizobium* population was higher in sole effect of *Azospirillum* and VAM as compared to other. In F×N interaction, the population of *Rhizobium sp.* ranged from 72.40 to 80.53 × 10^3 CFU g^{-1} of soil which was observed in 100% NPK+ *Azotobacter* and 75% NPK+ *Azospirillum* respectively. In case of F×P combination, maximum population was observed with 75% NPK+VAM. In N×P interaction, highest and lowest population was recorded in *Azospirillum*+ VAM and *Azotobacter*+ PSB respectively. In F×N×P interaction, maximum population of *Rhizobium sp.* was noticed in 75% NPK+ *Azospirillum*+ VAM (81.57 × 10^3 CFU g^{-1} of soil) followed by 50% NPK+



50% NPK+ *Azos.* + VAM+ K-mobiliser



75% NPK+ *Azos.* + VAM+ K-mobiliser



75% NPK+ *Azos.*+ PSB+K-mobiliser

100% NPK

Plate 21. Bioinoculants under different treatment combinations

Azospirillum+ VAM (80.53× 10^3 CFU g^{-1} of soil) but they were *at par*. The minimum population (52.46× 10^3 CFU g^{-1} of soil) was recorded in control (100% NPK).

2.4.4 Phosphorous solubilizing microorganisms (PSM)

Results presented in Table 30. showed significant variations in respect of both individual and interaction effect during both the years and pooled analysis but non-significant variation observed only in N×P interaction during 2014-15. Like *Rhizobium* the population of PSM increased with the decrease of fertilizer level up to medium level (75% NPK). Maximum population of 29.61 × 10^5 CFU g^{-1} of soil was observed in 75% NPK. In nitrogenous bioinoculants, the *Azospirillum* recorded higher population (27.87×10^5 CFU g^{-1} of soil) but in phosphatic bioinoculants, higher population of PSM (28.07× 10^5 CFU g^{-1} of soil) was noticed in PSB. In F×N interaction, maximum (31.90× 10^5 CFU per g of soil) and minimum (21.07× 10^5 CFU g^{-1} of soil) population of PSM were recorded in 75% NPK+ *Azospirillum* and 50% NPK+ *Azotobacter* respectively. In F×P interaction, maximum (30.55× 10^5 CFU g^{-1} of soil) population was recorded in 100% NPK+ PSB followed by 75% NPK+PSB (30.19× 10^5 CFU g^{-1} of soil) but both of them were *at par*. In N×P interaction, maximum value (29.02× 10^5 CFU g^{-1} of soil) was observed in PSB. In F×N×P interaction, maximum (32.24× 10^5 CFU g^{-1} of soil) population was recorded in 75% NPK+ *Azospirillum*+ PSB followed by 100% NPK+ *Azotobacter*+ PSB (31.64× 10^5 CFU g^{-1} of soil). Minimum population (15.64× 10^5 CFU per g of soil) was observed in control (100% NPK).

2.4.5 Potash mobilizing bacteria

The findings obtained from Table 30 and Fig. 21 indicated the significant variation was present in the sole effect of phosphotic bioinoculants only. Among the two way interaction, non-significant variation was observed in pooled analysis of N×P and three way interaction non significant variation during 2013-14. In respect of inorganic fertilizers, maximum population recorded in 100% NPK (88.36 × 10^3 CFU g^{-1} of soil). *Azospirillum* recorded more population as compared to *Azotobacter*. In the individual effect of phosphatic bioinoculants, population was higher in VAM. In F×N interaction, maximum population of potash mobilizing bacteria noticed in 75% NPK+ *Azospirillum* (90.01 × 10^3 CFU g^{-1} of soil) followed by 100% NPK+ *Azotobacter* but they were *at par*. In respect of F×P interaction, maximum population (91.30× 10^3 CFU g^{-1} of soil) was noticed under 75% NPK+VAM followed by 50% NPK+ VAM (89.85× 10^3 CFU g^{-1} of

Table 30. Population of phosphorous solubilising microorganisms and Potassium mobilizing bacteria in the soil of fenugreek as influenced by inorganic fertilizers and bioinoculants

Treatments	Potassium mobilizing bacteria (x10^3 CFU g of soil^{-1})			Phosphorous solubilizing micro organisms (x10^5 CFU g of soil^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Initial soil population	62.47	66.17	64.32	37.3	41.74	39.52
Inorganic fertilizer						
100% NPK (F_1)	88.40	88.31	88.36	26.61	29.38	27.99
75% NPK (F_2)	86.86	88.53	87.70	29.79	29.44	29.61
50% NPK (F_3)	86.70	89.43	88.06	22.82	24.56	23.69
S.Em. (±)	**0.572**	**0.574**	**0.401**	**0.185**	**0.189**	**0.131**
C.D. (P=0.05)	**NS**	**NS**	**NS**	**0.540**	**0.551**	**0.372**
Nitrogenous bioinoculants						
Azotobacter (N_1)	87.43	88.54	87.99	26.02	26.63	26.33
Azospirillum (N_2)	87.20	88.98	88.09	26.79	28.95	27.87
S.Em. (±)	**0.467**	**0.469**	**0.327**	**0.151**	**0.154**	**0.107**
C.D. (p=0.05)	**NS**	**NS**	**NS**	**0.441**	**0.450**	**0.303**
Phosphatic bioinoculants						
VAM (P_1)	88.79	90.24	89.51	25.39	26.87	26.13
PSB (P_2)	85.85	87.28	86.56	27.42	28.71	28.07
S.Em. (±)	**0.467**	**0.469**	**0.327**	**0.151**	**0.154**	**0.107**
C.D. (P=0.05)	**1.363**	**1.368**	**0.931**	**0.441**	**0.450**	**0.303**

Contd.....

VAM= Vesicular arbuscular mycorrhiza PSB= Phosphate solubilizing bacteria
F_1 = 100% NPK, F_2= 75% NPK, F_3= 50% NPK; DAS=Days after sowing; NS= Non siginificant,
N_1=*Azotobacter chroococcum*; N_2=*Azospirillum lipoferum*; P_1 = *Glomus fasciculatum*; P_2 = *Bacillus polymixa*

Contd.....

Treatments	Potassium mobilizing bacteria (x10^3 CFU g of soil^{-1})			Phosphorous solubilizing micro organisms (x10^5 CFU g of soil^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)						
F_1N_1	90.38	89.24	89.81	28.92	32.24	30.58
F_1N_2	86.42	87.39	86.90	24.30	26.52	25.41
F_2N_1	83.46	87.31	85.39	27.38	27.27	27.33
F_2N_2	90.26	89.75	90.01	32.20	31.61	31.90
F_3N_1	88.46	89.07	88.77	21.76	20.39	21.07
F_3N_2	84.93	89.79	87.36	23.89	28.73	26.31
S.Em. (±)	**0.809**	**0.812**	**0.567**	**0.262**	**0.267**	**0.185**
C.D. (P=0.05)	**2.360**	**2.370**	**1.612**	**0.763**	**0.779**	**0.526**
Inorganic fertilizer (F)×Phosphatic bioinoculants (P)						
F_1P_1	87.40	87.39	87.39	22.59	28.30	25.44
F_1P_2	89.40	89.24	89.32	30.63	30.46	30.55
F_2P_1	89.71	92.89	91.30	31.13	26.95	29.04
F_2P2	84.01	84.17	84.09	28.45	31.93	30.19
F_3P_1	89.26	90.45	89.85	22.45	25.37	23.91
F_3P_2	84.14	88.42	86.28	23.20	23.75	23.47
S.Em. (±)	**0.809**	**0.812**	**0.567**	**0.262**	**0.267**	**0.185**
C.D. (P=0.05)	**2.360**	**2.370**	**1.612**	**0.763**	**0.779**	**0.526**
Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)						
N_1P_1	91.02	88.82	89.92	25.43	25.65	25.54
N_1P_2	83.84	88.26	86.05	26.61	27.61	27.11
N_2P_1	86.55	91.66	89.10	25.35	28.09	26.72
N_2P_2	87.85	86.29	87.07	28.24	29.81	29.02
S.Em. (±)	**0.660**	**0.663**	**0.463**	**0.214**	**0.218**	**0.151**
C.D. (P=0.05)	**1.927**	**1.935**	**NS**	**0.623**	**NS**	**0.429**

Contd....

Contd.....

Treatments	Potassium mobilizing bacteria (x10^3 CFU g of soil^{-1})			Phosphorous solubilizing micro organisms (x10^5 CFU g of soil^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Inorganic fertilizer (F)×Nitrogenous bioinoculants (N)× Phosphatic bioinoculants (P)						
$F_1N_1P_1$	91.16	85.32	88.24	27.98	31.06	29.52
$F_1N_1P_2$	89.60	93.16	91.38	29.86	33.42	31.64
$F_1N_2P_1$	83.63	89.45	86.54	17.19	25.53	21.36
$F_1N_2P_2$	89.20	85.32	87.26	31.40	27.50	29.45
$F_2N_1P_1$	88.78	91.52	90.15	28.78	24.26	26.52
$F_2N_1P_2$	78.14	83.10	80.62	25.98	30.28	28.13
$F_2N_2P_1$	90.64	94.26	92.45	33.48	29.64	31.56
$F_2N_2P_2$	89.88	85.24	87.56	30.91	33.57	32.24
$F_3N_1P_1$	93.13	89.63	91.38	19.52	21.64	20.58
$F_3N_1P_2$	83.79	88.51	86.15	23.99	19.13	21.56
$F_3N_2P_1$	85.38	91.26	88.32	25.38	29.10	27.24
$F_3N_2P_2$	84.48	88.32	86.40	22.40	28.36	25.38
Control (100% NPK)	51.47	56.05	53.76	15.02	16.26	15.64
Without control						
S.Em. (±)	**1.144**	**1.148**	**0.802**	**0.370**	**0.377**	**0.262**
C.D. (P=0.05)	**NS**	**3.352**	**2.279**	**1.080**	**1.102**	**0.743**
With control						
S.Em. (±)	**0.842**	**0.845**	**0.590**	**0.272**	**0.278**	**0.193**
C.D. (P=0.05)	**2.456**	**2.467**	**1.678**	**0.795**	**0.811**	**0.547**

soil). In N×P interaction, maximum population was recorded in *Azotobacter*+ VAM (89.92× 10^3 CFU g^{-1} of soil). In respect of F×N×P interaction, maximum population of potash mobilizing bacteria was noticed with 75% NPK+ *Azospirillum*+ VAM (92.45× 10^3 CFU g^{-1} of soil) followed by 50% NPK+ *Azotobacter* + VAM (91.38× 10^3 CFU g^{-1} of soil) as compared to minimum population (53.76× 10^3 CFU g^{-1} of soil) under control (only 100% NPK).

2.5 EFFECT OF INORGANIC FERTILIZERS AND BIOINOCULANTS ON ECONOMICS OF FENUGREEK PRODUCTION

The perusal data presented in Table 31 and Fig. 22 revealed the marked variations among the treatments in respect of cost of production, gross returns, net returns and B:C ratio during both years and in mean data.

The maximum cost of production was observed in four treatment combinations of 100% NPK with both nitrogenous and phosphatic bioinoculants (₹ 44,633) as compared to lowest cost of production in 100% NPK (₹ 36,683).

In case of gross returns, maximum gross return obtained in combination of 75% NPK+ *Azospirillum*+ VAM (₹ 1,22,550) followed by 75% NPK+ *Azospirillum*+ PSB (₹ 1,21,890) as compared to minimum returns (₹ 98250) noticed in control (100% NPK).

In case of net returns, maximum net return was recorded in combination of 75% NPK+ *Azospirillum*+ VAM (₹ 78,578) followed by 75% NPK+ *Azospirillum*+ PSB (₹ 77,918) as compared to lowest net returns (₹ 59, 887) in 100% NPK+ *Azotobacter*+ VAM.

Highest B:C ratio was observed in 75% NPK+ *Azospirillum*+ VAM (1.79) followed by 75% NPK+ *Azospirillum*+ PSB (1.77) as compared to lowest in the combination of 50% NPK+ *Azotobacter*+ VAM (1.32).

Experimental results revealed a number of interesting features of growth, yield and quality parameters of fenugreek with various treatment combinations. The combination of biofertilizer along with graded levels of inorganic fertilizers performed better over cent percent inorganic. Among different combinations, maximum plant height (90.15 cm), number of primary branches per $plant^{-1}$ (7.92), secondary branches $plant^{-1}$ (12.57), fresh weight of plant (65.29 g) and dry weight of plant (14.51 g), maximum pod length (9.79 cm), number of pods $plant^{-1}$ (87.51) and yield $plant^{-1}$(9.24 g) yield $plot^{-1}$ (816.91 g $3m^{-2}$), projected yield (20.42 q ha^{-1}), minimum days required for

Table 31. Economics of fenugreek seed production as influenced by inorganic fertilizers and bioinoculants

Treatments	Cost of production (₹ha^{-1})			Gross returns (₹ha^{-1})			Net returns (₹ha^{-1})			Benefit: cost ratio		
	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean
$F_1N_1P_1$	44713	44553	44633	101760	107280	104520	57047	62727	59887	1.28	1.41	1.34
$F_1N_1P_2$	44713	44553	44633	92760	121320	107040	48047	76767	62407	1.07	1.72	1.40
$F_1N_2P_1$	44713	44553	44633	112740	123840	118290	68027	79287	73657	1.52	1.78	1.65
$F_1N_2P_2$	44713	44553	44633	97740	117600	107670	53027	73047	63037	1.19	1.64	1.41
$F_2N_1P_1$	44032	43912	43972	103260	128280	115770	59228	84368	71798	1.35	1.92	1.63
$F_2N_1P_2$	44032	43912	43972	100620	128880	114750	56588	84968	70778	1.29	1.93	1.61
$F_2N_2P_1$	44032	43912	43972	105540	139560	122550	61508	95648	78578	1.40	2.18	1.79
$F_2N_2P_2$	44032	43912	43972	97740	146040	121890	53708	102128	77918	1.22	2.33	1.77
$F_3N_1P_1$	43351	43272	43312	99240	102000	100620	55889	58728	57309	1.29	1.36	1.32
$F_3N_1P_2$	43351	43272	43312	103020	98580	100800	59669	55308	57489	1.38	1.28	1.33
$F_3N_2P_1$	43351	43272	43312	90240	133800	112020	46889	90528	68709	1.08	2.09	1.59
$F_3N_2P_2$	43351	43272	43312	91740	131880	111810	48389	88608	68499	1.12	2.05	1.58
Control (100% NPK)	36763	36603	36683	96600	99900	98250	59837	63297	61567	1.63	1.73	1.68

Cost of inputs

Seed	: ₹ 100 kg^{-1}	Urea	: ₹4.44 kg^{-1} (2013); ₹5.90 kg^{-1} (2014)	*Azotobacter /Azospirillum*	: ₹150 kg^{-1}
FYM	: ₹ 800 t^{-1}	SSP	: ₹ 8 .00kg^{-1} (2013); ₹7.20 kg^{-1}(2014)	VAM/PSB	: ₹190 kg^{-1}
Man days	: ₹ 193 day^{-1}	MOP	: ₹17.00 kg^{-1} (2013); ₹16.20 kg^{-1} (2014)	Potasic mobililiser	: ₹190 kg^{-1}

Sale **price of fenugreek seed: ₹ 60 kg^{-1}**

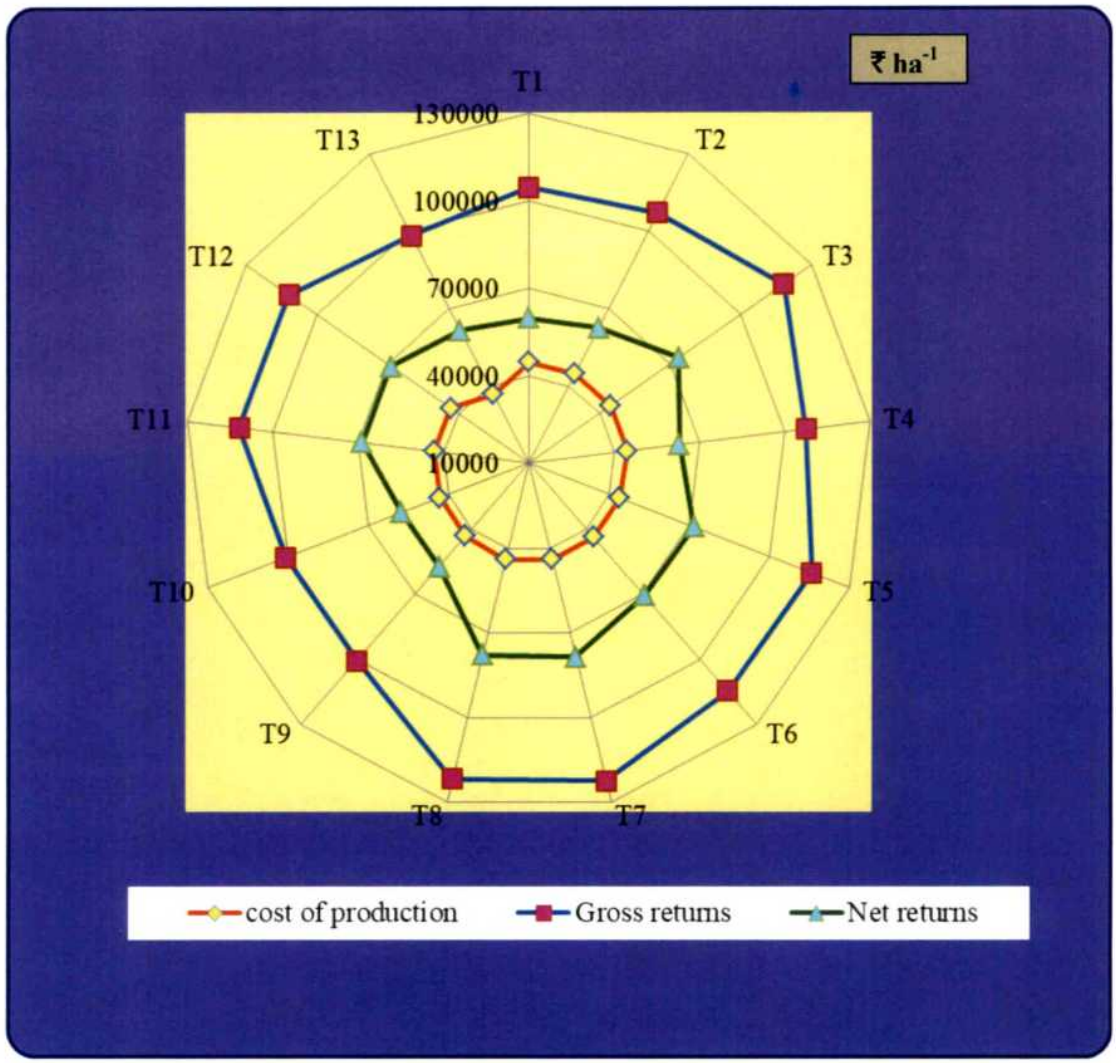


Fig. 22 Economics of fenugreek seed production under different inorganic and biofertilizer combinations

T_1: NPK 100% + *Azotobacter* + VAM+ KM
T_2: NPK 100% + *Azotobacter* + PSB+ KM
T_3: NPK 100% + *Azospirillum*+ VAM+ KM
T_4: NPK 100% + *Azospirillum* + PSB+ KM
T_5: NPK 75% + *Azotobacter* + VAM+ KM
T_6: NPK 75% + *Azotobacter* + PSB+ KM
T_7: NPK 75% + *Azospirillum*+ VAM+ KM
T_8: NPK 75% + *Azospirillum* + PSB+ KM
T_9: NPK 50% + *Azotobacter*+ VAM+ KM
T_{10}: NPK 50% + *Azotobacter* + PSB+ KM
T_{11}: NPK 50% + *Azospirillum*+ VAM+ KM
T_{12}: NPK 50% + *Azospirillum*+ PSB+ KM
T_{13}: Recommended NPK - 20:40:20 kg ha^{-1}

flower initiation (42.45 days), maximum population of *Azospirillum* (50.34 × 10^5 CFU g^{-1} of soil), *Rhizobium* (81.57× 10^3 CFU g^{-1} of soil) and potash mobilizing bacteria (92.45× 10^3 CFU g^{-1} of soil) were observed in plants raised with NPK (75%) + *Azospirillum*+ VAM combination. The same treatment combination was also recorded the maximum gross return (₹1,22,500), net return (₹78,578) and B:C ratio (1.79). The plants raised with NPK (100%) + *Azospirillum*+ VAM produced highest test weight (16.01 g) and recorded minimum duration (47.89 days) for 50% flower initiation. Maximum days for first flower initiation (45.43 days), 50% flower initiation (51.45 days), first pod initiation (53.10 days) and 50% pod initiation (60.69 days) and also maximum galactomannan (17.588 mg 100 mg^{-1}) and albumin (6.485 mg 100 mg^{-1}) content in seed were recorded in plants raised from control (100% NPK). The plants raised under NPK (75%) + *Azospirillum*+ PSB combination recorded maximum phosphate solublising microorganisms (32.24 × 10^5 CFU g^{-1} of soil), antioxidant activity (376.26 mg TE g^{-1}) and diosgenin (0.423 mg 100 mg^{-1}). Maximum population of *Azotobacter* (62.43× 10^5 CFU g^{-1} of soil) was noticed in 50% NPK + *Azospirillum*+ VAM combination. Maximum globulin (6.44 mg 100 mg^{-1}) and prolamin (1.248 mg 100 mg^{-1}) content were recorded in treatment combination of 50% NPK+ *Azotobacter*+PSB and 50% NPK+ *Azospirillum*+ PSB respectively. Maximum glutellin (4.88 mg 100 mg^{-1}) and total protein (16.90 mg 100 mg^{-1}) were noticed in plants raised under treatment combination of 75% NPK +*Azotobacter*+ VAM. The plants under 75% NPK+ *Azotobacter*+ PSB recorded minimum days for first pod initiation (51.45 days).

Combined application of biofertilizer and inorganic fertilizers had beneficial effect on growth, yield and yield attributing characters. The increase in yield was largely as consequence of the cumulative effect of plant growth characters. These findings are in good agreement with the observations of the earlier workers on fenugreek (Mehta *et al.*, 2010, Mehta and Patel, 2011; Sunanda *et al.*, 2014; Dadrashan *et al.*, 2015).

Nitrogen and phosphorous are major nutrients that limit plant growth and development worldwide (Blaise *et al.*, 2005). Increase in growth might be due to the combined effect of both nitrogen and phosphate solubilizing bacteria which enhances the nitrogen and phosphate availability and its uptake in the soil.

The positive effect of fertilizers on growth and yield of fenugreek has been reported by others (Mavai *et al.*, 2000; Khan *et al.*, 2005 and Kumar *et al.*, 2015). In the recent years, application of biological fertilizers has drawn researcher's attention due to

their successful performance in crop production and their less ecological foot print compared with chemical fertilizers. The application of these microorganisms has resulted in higher yield and quality in different crops (Vessey, 2003).

The present findings are in good agreement with the observations of Dadrashan *et al.* (2015) who observed that both forage and seed yield were best with biofertilizer+ 50% chemical fertilizer. The advantage of integrated fertilizer over chemical fertilizer even more pronounced when deficit irrigation was practiced. They also reported that forage yield difference between biofertilizers+75% inorganic and biofertilizer+ 50% inorganic was not statistically significant. They also noticed that length and weight of roots of fenugreek considerably higher with biofertilizer as compared to unfertilized control and plants those received sole chemical fertilizers.

The present findings corroborate the results of some earlier workers such as Sunanda *et al.* (2014) who obtained highest fresh herb yield, dry herb yield, number of pods per plant, pod length, seed yield, total protein content in seed with treatment consisting of 75% N+ RD PK+ FYM (7.5 t ha^{-1}) + *Rhizobium* (1.5 kg ha^{-1}) + *Azospirillum* (5 kg ha^{-1}) + PSB (5 kg ha^{-1}). INM provided basic source for yield attributes and seed yield is an output of sequential metamorphosis from the chain of source to sink relationship. Microorganisms are important attributes in agriculture to promote the circulation of plant nutrients and reduce the cost of chemical fertilizers. Application of mycorrhiza and non-symbiotic nitrogen fixing bacteria has been shown to enhance soil fertility and availability of nutrients for plants (Cardaso *et al.*, 2006). Positive effects of biofertilizers on improving crop growth might be due to increase in nitrogenase activity and synthesis of growth promoting substances by phosphate solubilising bacteria play a strong role in phosphorous nutrition by enhancing its availability to plants through release from inorganic and organic soil phosphorous pools through solubilisation and mineralization processes (De *et al.*, 2012).

Khiriya and Singh (2003) reported that biofertilizer application on potash uptake is mainly positive and therefore with increase in crop growth there has been improvement in potassium uptake by fenugreek. Application of integrated biofertilizers (combination of different bacteria) showed the highest biological yield. 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.

It seems that most of the sole and integrated biofertilizers like *Azospirillum* + VAM had positive effect on yield components of fenugreek. These results support the findings of Ghosh and Mohluddin (2000) and Chaichi *et al.* (2015). Phosphate solubilising organisms are reported to solubilise inorganic fixed form of P by excreting organic acids that directly dissolves fixed phosphatic materials of soil (Balachandran and Nagarajan, 2002) and these bacteria also has the ability of secreting growth promoting compounds like auxins, gibberellins, vitamins *etc.* considered to be important for proper growth and development of plant (Whitelaw, 2000). The effect of combined application of nitrogenous and phosphatic bioinoculants enhanced the availability of N and P which might be utilized by plants for synthesis of protein, carbohydrates and it's partitioning towards the formation of flowers and increases in sink capacity results in increased number of pods consequently the yield of crop (Jat, 2002)

The better efficiency of *Azospirillum* as compared to *Azotobacter* was reported by Mohan *et al.* (2004). The good response of VAM in turmeric cv. Suguna also reported by Reddy *et al.* (2003). The present findings are in good agreement with the observations of Gowda *et al.* (2002) observed a improved growth, yield and quality of chilli with 75% per cent nitrogen, phosphorous plus 100 per cent potassium in addition to the inoculation of *Azotobacter*, *Azospirillum*, PSB and VAM. Application of biofertilizers along with reduced levels of chemical fertilizers has beneficial effects compared to application of recommended NPK.

Dhanpal *et al.* (1978) reported that *Azospirillum* produced bio-active substances having similar effect as that of growth regulators besides N-fixation. Higher efficiency of *Azospirillum*+ VAM as compared to other biofertilizer combinations was also reported by Tilak (1995).

The positive influence of biofertilizers on the various growth and yield parameters observed in the present study were due to enhanced uptake of nutrients by the plants (Barea, 1991). *Azotobacter* and *Azospirillum* aid in increased plant growth due to their nitrogen fixing capacity and also they are known to help in the synthesis of growth promoting substances like IAA and GA (Jackson and Brown, 1966). PSB enhances P availability, it is known to produce aminoacids, vitamins and growth promoting substances like IAA and GA helps in improving growth of plants.

Considering the projected yield ha^{-1}, net return and B:C ratio, the most effective treatment combination was 75% NPK+ *Azospirillum*+ VAM followed by 75% NPK+ *Azospirillum*+ PSB, clearly indicating the chance of saving 25% inorganic fertilizers for seed production of fenugreek under alluvial plains of West Bengal.

Chapter-V

Summary and Conclusion

SUMMARY AND CONCLUSION

The experiments on **"Evaluation of germplasm and influence of bioinoculants on fenugreek"** were carried out at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal during *rabi* (winter) season of 2013-14 and 2014-15. Experiment I and II were undertaken separately to evaluate the suitable genotype of fenugreek and to study the efficacy of different bioinoculants along with graded levels of inorganic nutrition in fenugreek.

The seeds were sown during second week of November in 2.0 x 1.5 m plots and harvested during last week of March in both the years. After thinning the population was maintained at a spacing of 30 x 10 cm. The dose of farmyard manure was 15 tonnes hectare^{-1}. The recommended fertilizer dose was 20: 40: 20 kg NPK ha^{-1}. Total amount of phosphate and potash and half of nitrogen were applied as basal for Expt. I but 15 days later after application of bioinoculants in Expt. II. The rest amount of nitrogenous fertilizers was applied within 30 days after sowing in Expt. I and fifteen days after first application in case of Expt. II. Ten plants were selected from each plot for taking different observations on growth and yield parameters. Three plants were uprooted randomly at 60 and 90 days after sowing for counting nodule and both fresh and dry weight.

The observations on growth and yield parameters are plant height, number of primary and secondary branches at different phases of growth, number of days taken for first and 50% flowering and similarly first pod formation and 50% pod formation, number of nodules plant^{-1}, both fresh and dry weight plant^{-1}, number of pods plant^{-1}, number of seeds plant^{-1}, pod length, seed yield and straw yield.

In respect of quality parameters the galactomannan, total soluble protein and their fractions- albumin, globulin, prolamin, glutellin; total phenols and flavonoids, antioxidant activity and diosgenin content were estimated for both the experiments. In case of Experiment-II, microbial populations (*Azotobacter*, *Azospirillum*, *Rhizobium*, phosphate solubilizing microorganisms and potassic mobilizing bacteria) were counted and benefit: cost ratio also calculated. The facilities of the laboratories of Agricultural Biochemistry and Nodule Research Laboratory were exclusively utilized for carrying out this research programme.

Experiment I. Evaluation of fenugreek germplasm for growth, yield and quality.

The experiment was laid out in Randomized Block Design with three replications and twenty germplasm were included, collected from different research station/ university. The germplasm are RMt-1, RMt-305 and RMt-361 (SKNU, Jobner, Rajasthan), Hissar Sonali and Hissar Suvarna (CCHAU, Haryana), AFg-1, AFg-2, AFg-3 and AFg-4 (NRCSS, Ajmeer), KFGK-4 and KFGK-18 (Kota, Rajasthan), NDM-4, NDM-8, NDM-13 and NDM-241 (NDUAT, Faizabad, Uttar Pradesh), PRM-45 (Udaipur), HM-444 and Rajendra Kranti (RAU, Dholi, Bihar), Lam Methi-2 (DR YSRHU, Andhra Pradesh) and Local (Nadia, West Bengal). Experimental results revealed a number of interesting features of growth, yield and quality parameters of fenugreek with different genotypes. Among different genotypes, NDM-8 exhibited maximum number of secondary branches plant^{-1} (8.90), minimum number of days required for 50% pod initiation (61.59 days), maximum number of pods plant^{-1} (80.28), number of seeds pod^{-1} (17.39), number of nodule plant^{-1} (35.51), seed yield plant^{-1} (14.17 g), seed yield plot^{-1} (823.13 g) and projected yield (20.58 q ha^{-1}) and straw yield ha^{-1}(3.95 t). Maximum plant height (95.46 cm), number of primary branches plant^{-1} (7.94), maximum days required for first flowering (51.23 days) and 50% pod initiation (67.43 days) and highest galactomannan content (24.524 mg 100 mg^{-1}) were noticed in HM-444. The maximum pod length (10.13 cm) and maximum total phenols (22.056 mg GAE g^{-1}) and early flower initiation (46.26 days) and pod initiation (53.34 days) were noticed in Hissar Suvarna. Maximum test weight was recorded in Hissar Sonali (17.90 g). Minimum and maximum days for 50% flower initiation were recorded in RMt-1 (51.34 days) and AFg-4 (57.91 days) respectively. The genotype AFg-2 recorded maximum total flavonoids (22.440 mg QE g^{-1}) and minimum days to reach crop maturity (115.50 days). The longest duration (140.72 days) of crop was noticed in local type. The maximum albumin content (15.557 mg 100mg^{-1}) was recorded in AFg-4 which also required maximum number of days (57.91 days) to reach first pod initiation. Maximum globulin (8.012 mg 100mg^{-1}), prolamin (1.522 mg 100 mg^{-1}) and glutellin (8.22 mg 100mg^{-1}) were observed in genotype PRM-45. The highest antioxidant activity (349.600 mg TE g^{-1}) and maximum diosgenin (0.311 mg 100mg^{-1}) were noticed in genotype KFGK-4.

From yield maximization point of view, the genotype NDM-8 may be considered as best genotype followed by HM-444 and NDM-4.

Experiment II. Response of fenugreek to combined application of inorganic fertilizers and bioinoculants

Three levels of inorganic fertilizers *i.e.* 100%, 75% and 50% of recommended NPK (20:40:20 kg ha^{-1}) along with five bioinoculants namely *Azotobacter chroococcum*, *Azopirillum lipoferum*, *Glomus fasiculatum* (vesicular arbuscular mycorrhiza), *Bacillus polymixa* (phosphate solubilising bacteria) and *Frateuria aurantia* (potassic mobilizer) were included altogether 13 treatments and 3 replications designed in Augmented Factorial RBD. Experimental results revealed a number of interesting features of growth, yield and quality parameters of fenugreek with various treatment combinations. The combination of biofertilizer along with graded levels of inorganic fertilizers performed better over cent percent inorganic. Among different treatments, maximum plant height (90.15 cm), number of primary branches per $plant^{-1}$ (7.92), secondary branches $plant^{-1}$ (12.57), fresh weight of plant (65.29 g), dry weight of plant (14.51 g), maximum pod length (9.79 cm), number of pods $plant^{-1}$ (87.51), yield $plant^{-1}$(9.24 g), yield $plot^{-1}$ (816.91 g $3m^{-2}$), projected yield (20.42 q ha^{-1}), minimum days required for flower initiation (42.45 days), maximum population of *Azospirillum* (50.34 × 10^5 CFU g^{-1} of soil), *Rhizobium* (81.57× 10^3 CFU g^{-1} of soil) and potash mobilizing bacteria (92.45× 10^3 CFU g^{-1} of soil) were observed in plants raised with NPK (75%) + *Azospirillum*+ VAM combination. This combination also recorded maximum net returns ₹ 78, 578 and B:C ratio of 1.79. The plants raised with NPK (100%) + *Azospirillum*+ VAM produced highest test weight (16.01 g) and recorded minimum duration (47.89 days) for 50% flower initiation. Maximum days for first flower initiation (45.43 days), 50% flower initiation (51.45 days), first pod initiation (53.10 days), 50% pod initiation (60.69 days) and also maximum galactomannan (17.588 mg 100 mg^{-1}) and albumin (6.485 mg 100 mg^{-1}) content in seed were recorded in plants raised from control (100% NPK). The plants raised under NPK (75%) + *Azospirillum*+ PSB combination recorded maximum phosphate solublising microorganisms (32.24 × 10^5 CFU g^{-1} of soil), antioxidant activity (376.26 mg TE g^{-1}) and diosgenin (0.423 mg 100 mg^{-1}). Maximum population of *Azotobacter* (62.43× 10^5 CFU g^{-1} of soil) was noticed in 50% NPK + *Azospirillum*+ VAM combination. Maximum globulin (6.44 mg 100 mg^{-1}) and prolamin (1.248 mg 100 mg^{-1}) content were recorded in treatment combination of 50% NPK+ *Azotobacter*+PSB and 50% NPK+ *Azospirillum*+ PSB respectively. Maximum glutellin (4.88 mg 100 mg^{-1}) and total protein (16.90 mg 100 mg^{-1}) were noticed in plants raised under treatment combination of 75% NPK + *Azotobacter* + VAM. The plants under 75% NPK+ *Azotobacter*+ PSB recorded minimum days for first pod initiation (51.45 days).

Considering the projected yield ha^{-1}, net return and B:C ratio the effective treatment combination was 75% NPK+ *Azospirillum*+ VAM followed by 75% NPK+ *Azospirillum*+ PSB clearly indicating the chance of saving 25% inorganic fertilizers for fenugreek production.

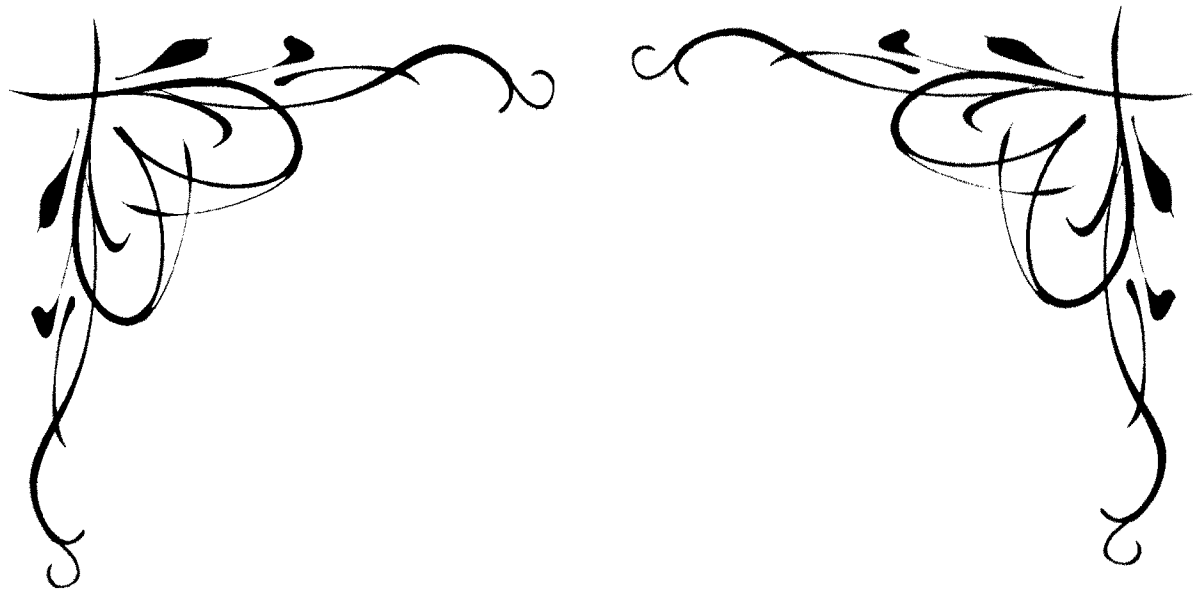
Chapter-VI

Future Scope of Research

FUTURE SCOPE OF RESEARCH

In the present study **"Evaluation of germplasm and influence of bioinoculants on fenugreek"** was investigated. There is, however immense scope of future research in the same line and further research may be undertaken on the following aspects.

1. Detailed study on nutrient recycling in bio-organically managed crops
2. Effect of integrated management on various qualitative parameters.
3. Inclusion of fenugreek in different cropping sequence for higher income generation and maintainance of soil health.
4. To find out the breeding strategies for development of new genotypes suitable for different agro-climatic zones.
5. Effect of pinching and growth regulators on fenugreek need to be studied.
6. Investigation may be undertaken to find out the effect of micronutrients on growth, yield and quality of fenugreek.
7. Combination of best treatments should also be tried to find out the additive/ synergistic effect.
8. Combined application of growth substance with bio-inoculants may be tried for yield maximisation.
9. Framing of agro-techniques for mass seed production programme for the promising genotypes.
10. Effect of deficit irrigation on seed production and quality aspects of fenugreek seed may be studied.



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